XVI Congreso Internacional de Interacción Persona-Ordenador

7 al 9 de Septiembre de 2015

Vilanova i la Geltrú. Barcelona. España

Actas del XVI Congreso Internacional de Interacción Persona-Ordenador. Interacción 2015

EDITORES

Pere Ponsa, José Antonio Román, Daniel Guasch

AIPO

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Pere Ponsa

José Antonio Román

Daniel Guasch

Escola Politècnica Superior d'Enginyeria Vilanova i la Geltrú

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PRESENTATION

En el siglo XXI, el ordenador de sobremesa está siendo desplazado por tecnología que se mueve con nosotros. El cambio en la forma de interactuar supone revisar los paradigmas clásicos existentes y avanzar en una interacción natural entre la persona, la interfaz y el entorno. Interacción 2015 es un congreso internacional fomentado por la Asociación de Interacción Persona-Ordenador (AIPO) que tiene como objetivo principal promover y difundir los avances recientes en el área de la Interacción Persona-Ordenador (IPO), tanto a nivel académico como empresarial. Este congreso es punto de encuentro de profesionales y académicos en accesibilidad, usabilidad, ergonomía, robótica, experiencia de usuario, realidad aumentada, etc. La IPO abarca un espectro multidisciplinar como por ejemplo el diseño de productos-servicios, la sociología, comunicación audiovisual, ciencias empresariales, bellas artes, psicología, ingeniería industrial, etc.

La organización de Interacción 2015, XVI edición del congreso, está a cargo de la Escuela Politécnica Superior de Ingeniería de Vilanova i la Geltrú y cuenta con la colaboración de la Cátedra de Accesibilidad de la Universidad Politécnica de Catalunya y el Centro de Estudios Tecnológicos para la Dependencia y la Vida Autónoma (CETpD) y el apoyo de diversas entidades.

La presente edición del congreso ha recibido un total de 105 trabajos. En concreto, 94 contribuciones científicas procedentes de 22 países, de las cuales se han seleccionado 66 en forma de 41 artículos largos, 21 artículos cortos y 4 trabajos para el coloquio doctoral. A estas contribuciones se suman los envíos de 9 propuestas para el Concurso AIPO TFG/TFM 2015 (los finalistas (2) y vencedores (2)) y las propuestas recibidas (2) del Student Design Challenge. A partir de los tópicos iniciales del congreso, los trabajos seleccionados se han agrupado en las sesiones: natural user interfaces, methodologies and models, enGendering Technology, child computer interaction, interface design, interaction devices, interacton for people with disability, games, usability and user experience, software-architecture and interaction, accessibility and semantic web.

El congreso cuenta con la presencia de conferencias plenarias de Panos Markopoulos (Interaction Design for Rehabilitation), Els Rommes (Including Gender in the Interaction) y José Antonio Plaza (Towards Intracellular Computer-Human Interaction: a microelectronic perspective), la conferencia de Manel Garrido (Robots Sensitivos) y el tutorial de Antonio Miguel Baena (Desarrollo de aplicaciones de realidad aumentada para tabletas y smartphones). Finalmente el panel de discusión sobre el presente y futuro de IPO a cargo de José Antonio Macías (AIPO) y Marina Talavera (Hewlett Packard).

En esta edición del congreso se presenta dos concursos en su primera edición: Concurso AIPO al mejor Trabajo Fin de Grado y Trabajo Fin de Màster TFG/TFM en el ámbito de la interacción y el Concurso de Diseño Student Design Challenge para estudiantes de diseño y con el reto de interacción entre ciudadanos y ciudad mediante productos digitales interactivos.

En Interacción 2015 se ha querido establecer un equilibrio entre el programa científico y el social, en este sentido la colaboración del Ayuntamiento de Vilanova i la Geltrú ha estado clave para mostrar aspectos de la vida de la ciudad, el patrimonio cultural presente en el Museo del Ferrocarril de Catalunya y el Museo Víctor Balaguer. Otra muestra es la de torres humanas castelleras a cargo de LLunàtics UPC Vilanova.

El programa científico y el programa social se complementan con exposición de producto en el hall de la Escuela. Un agradecimiento a todas aquellas entidades que han patrocinado y dado soporte al congreso: KUKA Robots Ibérica, UPF Barcelona School of Management, Tobii, grupo investigación Automatización y Sistemas Avanzados de Control ASAC[1] UAB, Hewlett Packard.

El congreso agradece a todas las personas que han colaborado en las diversas actividades programadas. Gracias a José Antonio Macías, presidente de AIPO el soporte para la confección del Congreso, así como a Víctor M. Penichet, CHISPA, y a todo el equipo del capítulo español de ACM SIGCHI, por la suma de esfuerzos entre el congreso y Association for Computing Machinery ACM. Finalmente, in Memoriam Jesús Lorés por sus esfuerzos en la fundación de AIPO y el impulso de la disciplina IPO desde el grupo de investigación GRIHO de la Universitat de Lleida.

Pere Ponsa Conference Chair
José Antonio Román, Conference Co-Chair
Daniel Guasch Program Chair

[1] Grupo con el que se colabora en programa CiCYT DPI2013-47825-C3-1-R.

Interacción 2015 is the International Conference promoted by the Spanish Human Computer Association (In Spanish: Asociación para la Interacción Persona-Ordenador, AIPO), whose main objective is to promote and disseminate the recent advances in the field of Human-Computer Interaction. This conference provides a forum for discussion and exchange of ideas on design and application of techniques and methodologies with a multidisciplinary approach (from engineering to human factors, human-robot interaction, accessibility, interface design, usability, natural interaction, etc.),

The 16th International Conference Interacción 2015 is organized by the Technical School of Vilanova I la Geltrú (Universitat Politècnica Catalunya Barcelona Tech) and has the support of the Accessibility Chair, the Interactive Systems Design Lab and the Technical Research Center of Dependency Care and Autonomous Living.

This edition has received 105 contributions: 94 scientific contributions from 22 countries, 9 papers into the AIPO Challenge best final project (degree, master) and 2 papers into the Student Design Challenge. In the 94 scientific contributions, the 66 accepted papers in these categories: 41 full papers, 21 short papers and 4 papers for the Doctoral Colloquium. The sessions in this conference are classified in: natural user interfaces, methodologies and models, EnGendering Technology, child computer interaction, interface design, interaction devices, interacton for people with disability, games, usability and user experience, software-architecture and interaction, accessibility and semantic web.

The conference structure is a set of sessions and a set of social and scientific activities. In example, the plenary conferences of Panos Markopoulos (Interaction Design for Rehabilitation), Els Rommes (Including Gender in the Interaction) and José Antonio Plaza (Towards Intracellular Computer-Human Interaction: a microelectronic perspective), the Spanish Conference of Manel Garrido (Robots Sensitivos and the

Spanish tutorial de Antonio Miguel Baena (Desarrollo de aplicaciones de realidad aumentada para tabletas y smartphones). Finally, a discussion about the present and future of HCI with José Antonio Macias and Marina Talavera (Hewlett Packard).

Thank you for the support of all the people, local committee, chairs, entities (Víctor Penichet CHISPA, Spanish local Chapter of ACM SIGCHI), (José Antonio Macías, AIPO) and sponsors: KUKA Robots Ibérica, UPF Barcelona School of Management, Tobii, research group ASAC UAB, Hewlett Packard and Llunàtics UPC Vilanova (Human Towers).

In memoriam Jesús Lorés for the effort and support of HCI activities through the GRIHO Research Group from the Universitat de Lleida.

Pere Ponsa Conference Chair
José Antonio Román, Conference Co-Chair
Daniel Guasch Program Chair

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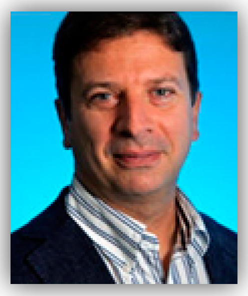


Panos Markopoulos

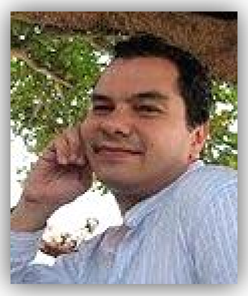
Department of Industrial Design, TU/e Eindhoven University of Technology, Eindhoven. The Netherlands

p.markopoulos@tue.nl

ABSTRACT

There is a growing demand for rehabilitation and this necessitates the development of rehabilitation technology. Further, such technologies can not only improve the quantity of rehabilitation that can be offered but also its quality. For a long time, this challenge has been considered as a purely engineering and technical challenge. The prolific growth of such technologies and the increasing relevance of tele-rehabilitation scenarios, mean have drawn the attention of industry and academia to the challenge of designing such technologies to motivate patients, to ensure compliance, good ergonomics and product design to support the correct execution of training exercises, and of course the potential of generating immense amounts of data that can help monitor and provide feedback regarding patient progress. This talk presents a few cases of such technologies and discusses some general challenges such as designing appropriate feedback, including patients in participatory design processes, acceptance of technologies, evaluation in the field, and interaction design issues relating to the implementation of innovations in healthcare.

Tutorial: Desarrollo de Aplicaciones de Realidad Aumentada para Tabletas y Smartphones



Antonio Miguel Baena

AMB Piensa
amb@ambpiensa.com

RESUMEN

Este tutorial se centra en la realidad aumentada y en cómo puede ser utilizada para coeditar y desarrollar aplicaciones para tabletas y smartphones. El tutorial contempla estudio de casos como los llevados a cabo recientemente en el Museo Thyssen Bortnemisza y la Central Nuclear José Cabrera.

Conferencia: Kuka – Robots sensitivos

Manel Garrido

KUKA Robots Ibérica

RESUMEN

La nueva era en la robótica pasa por transferir a los robots capacidades sensitivas. KUKA ha conseguido que su robot LBR iiwa sienta y gestione con gran precisión los esfuerzos que se generan en su entorno de acción. Por lo tanto nos permite automatizar procesos tanto industriales como fuera de ese entorno, donde la sensibilidad de las personas es imprescindible para conseguir el objetivo de la acción. Como consecuencia de esa virtud sensitiva, además, este robot permite trabajar de forma segura en entornos colaborativos.

Plenary Conference: Including Gender in the Interaction

Els Rommes

Institute for Gender Studies, Radboud University Nijmegen
The Netherlands

ABSTRACT

What does it mean to pay attention to gender in the design of computer systems? Should everything be pink, or all content be about fashion? In this lecture, Rommes will discuss various notions of what ‘inclusion of gender’ can mean, and which advantages and disadvantages the various way of ‘including gender’ may have. In addition, she will discuss why it could be relevant to pay attention gender and how this can be done through the use of various design methodologies.

Plenary Conference: Towards Intracellular Computer-Human Interaction: a micro-electronic perspective

José Antonio Plaza

Micro and Nano-tools research group
Institute of Microelectronics of Barcelona
IMB-CNM (CSIC)
joseantonio.plaza@imb-cnm.csic.es

ABSTRACT

Success of the semiconductor industry has been driven in part by the miniaturization process, as approximately every three years we see a new generation of memory chips and microprocessors, in which the size of their fundamental elements, the transistors, is reduced 33%. The sizes of these transistors are several orders of magnitude smaller in relation typical human body cell (tens of microns of diameter). The microfabrication techniques of the electronics industry are being also routinely adapted to fabricate systems which are able to integrate mechanical, thermal, optical, magnetic, chemical, or even fluidics components in the same silicon chip, in addition to combining them with electronic components. These silicon chips inside human living cells could provide endless possibilities, beyond the scope of our imagination. In this talk, we present our research in the bases of this incipient future field. We believe that the study of this field will open a new line of research based on Human-Computer Interactions to investigate the relationship between chips and human living cells, human organs or human actors.

Panel de discusión: Reflexiones sobre la Interacción Persona-Ordenador

José Antonio Macías

Presidente Asociación Interacción Persona-Ordenador
Universidad Autónoma de Madrid
j.macias@uam.es

Marina Talavera

Experience Design Strategist
Hewlett Packard Española
talavera@hp.com

OBJETIVO

En el siglo XXI, el ordenador de sobremesa está siendo desplazado por tecnología que se mueve con nosotros. El cambio en la forma de interactuar supone revisar los paradigmas clásicos existentes y avanzar en una interacción natural entre la persona, la interfaz y el entorno. Interacción 2015 es un congreso internacional fomentado por la Asociación de Interacción Persona-Ordenador (AIPO) que tiene como objetivo principal promover y difundir los avances recientes en el área de la Interacción Persona-Ordenador (IPO), tanto a nivel académico como empresarial. Este panel de discusión es un punto de encuentro de profesionales y académicos para reflexionar conjuntamente sobre el presente de la interacción persona-ordenador y tendencias de futuro. El panel lanza las siguientes preguntas, ¿Hacía donde avanza el diseño de la interfaz de usuario?, ¿Cómo mejorar la experiencia de usuario?, ¿Cuáles serán los siguientes paradigmas clásicos?, ¿Qué retos deben afrontarse en la sociedad ante los cambios tecnológicos? , ¿Cómo potenciar la sinergia entre profesionales y académicos?

NATURAL USER INTERFACES (I)

Diseño de actividades de mejora de capacidades cognitivas para tabletops tangibles

Clara Bonillo
GIGA Affective Lab
Dep. Informática e Ingeniería de Sistemas,
Universidad de Zaragoza, España.
clarabonfdez@hotmail.com

Javier Marco
GIGA Affective Lab
Dep. Informática e Ingeniería de Sistemas,
Universidad de Zaragoza, España.
javi.marco@unizar.es

Eva Cerezo,
Sandra Baldassarri
GIGA Affective Lab
Dep. Informática e Ingeniería de Sistemas, Instituto de Investigación en Ingeniería de Aragón (I3A)
Universidad de Zaragoza, España.
{ecerezo, sandra}@unizar.es

ABSTRACT
El objetivo de este trabajo es explorar la potencialidad del uso de tabletops tangibles en el desarrollo de actividades terapéuticas de mejora o mantenimiento de capacidades cognitivas deterioradas por la edad, enfermedades o tratamientos. Para ello se ha llevado a cabo un análisis de las áreas cognitivas y de las actividades más habituales utilizadas por los terapeutas en el trabajo de dichas áreas. Ello ha llevado a la definición de un lenguaje de marcas basado en XML destinado a la definición de las actividades, y de un reproductor que permite la ejecución de dichas actividades sobre el tabletop tangible NIKVision del grupo GIGA Affective Lab de la Universidad de Zaragoza. Nueve actividades han sido desarrolladas con dichas herramientas y evaluadas por una terapeuta y su grupo de pacientes, pertenecientes a una asociación local de adultos con enfermedad mental. Los resultados de la evaluación son muy prometedores y animan a continuar trabajando en la línea.

Categorías and Términos Descriptores
H.5.2. Interfaces de usuario: estilos de interacción, prototipado. D.2.2 Herramientas de diseño y técnicas. Interfaces de Usuario.

Términos Generales
Diseño, Lenguajes.

Palabras clave
Interacción tangible, interacción natural, estimulación cognitiva, mesa interactiva, tabletop, lenguaje de marcas.

1. INTRODUCCIÓN
El envejecimiento de la población en los últimos años ha supuesto una revolución demográfica: se estima que actualmente hay unos 600 millones de personas mayores de 60 años y parece que esta cifra va a ir aumentando. Este hecho supone un reto para el resto de la sociedad, puesto que hay que considerar el declive tanto físico como cognitivo que se produce a medida que una persona envejece. Por otra parte, se estima que el 14% de la carga global de las enfermedades a nivel mundial puede ser atribuida a trastornos neuropsiquiátricos [10], los cuáles también producen un declive en las capacidades cognitivas ya sea por la propia enfermedad o por efectos secundarios de la medicación que dichas enfermedades conllevan. Una forma de ayudar a estas personas a mejorar dichas capacidades, o por lo menos evitar su deterioro, es a través de actividades que potencien el uso de dichas capacidades [9].

Además de las actividades tradicionales de mejora o mantenimiento, durante los últimos años se ha empezado a explorar el uso de dispositivos tabletop para trabajar la estimulación cognitiva, centrándose principalmente en ancianos [2] [7]. Un tabletop es un dispositivo, con un aspecto más o menos cercano al de una mesa convencional, cuya superficie está aumentada mediante la proyección de imagen y sonido procedente de una aplicación informática y en el que la interacción con dicha aplicación se lleva a cabo mediante movimientos de los dedos en contacto con la superficie de la mesa (multitáctil). Esta forma de interacción presenta muchas ventajas, ya que la superficie del tabletop supone un espacio amplio para las capacidades visuales y motrices de los usuarios. La estimulación audiovisual les resulta motivante y se les ofrece un mayor rango de actividades que pueden abarcar uno o más aspectos de la estimulación cognitiva. Sin embargo, este tipo de interacción presenta una importante desventaja y es que la complejidad y precisión de muchos gestos táctiles puede hacerla dificultosa y frustrante para usuarios con problemas de motricidad, como los ancianos o personas con trastornos mentales graves. Por ello, otros modelos de Interacción Natural, como la Interacción Tangible, pueden ofrecer una alternativa más adaptada a las características de dichos usuarios [4]. La Interacción Tangible plantea que la interacción entre el usuario y la aplicación informática sea a través de objetos físicos de uso cotidiano. Técnicamente, un dispositivo tabletop tangible es capaz de identificar distintos objetos colocados en su superficie, así como seguir las distintas manipulaciones que los usuarios realizan con ellos, mostrando información proyectada sobre la misma superficie donde se manipulan los objetos.

El grupo GIGA Affective Lab cuenta con NIKVision [8], un tabletop Tangible en el que la interacción se lleva a cabo mediante objetos colocados sobre la superficie de una mesa. El objetivo de este trabajo ha sido explorar las potencialidades de la Interacción Tangible en un dispositivo tabletop como NIKVision en la estimulación cognitiva.

El artículo está organizado de la forma siguiente: en la sección 2 se realiza un estado del arte en el que se estudian tabletops destinados a la estimulación cognitiva; en la sección 3 se realiza un estudio de las áreas cognitivas que más se suelen trabajar y del tipo de actividades más frecuentes en cada una de ellas; así mismo, se presentan las herramientas generadas para la definición y ejecución de actividades: el lenguaje de marcas y el reproductor. En la sección 4 se presentan las actividades desarrolladas y en la sección 5 su evaluación con usuarios. Finalmente en la sección 6 se presentan conclusiones y trabajo futuro.

2. ESTADO DEL ARTE

A continuación se va a hacer un repaso del estado del arte en cuanto a experiencias de trabajo de capacidades cognitivas haciendo énfasis en aquellas que hacen uso de tabletops.

En Kown et al. 2013 [5] se presenta el sistema E-CoRe para la mejora de la capacidad cognitiva a través de un dispositivo tabletop. La una aplicación llamada "Making Cookies" utiliza distintos objetos para simular que se hacen galletas y su objetivo es mejorar tres áreas cognitivas: la memoria, el razonamiento y la atención.

En Gamberini et al. 2006 [2] se ha desarrollado un tabletop con una aplicación similar al juego de encontrar parejas. La interacción se lleva a cabo con unos lápices especiales en lugar de con el dedo a través de diversos minijuegos, en los que se busca mejorar funciones cognitivas como la memoria, el razonamiento, la atención selectiva y dividida, y la clasificación.

En Leitnet et al. 2007 [6] se ha desarrollado un tabletop Tangible para la rehabilitación física y cognitiva. En él se plantea trabajar con distintas actividades tipo puzle manipulando cubos con distintos patrones dibujados sobre ellos, siendo el objetivo de la tarea alinearlos para que coincidan con el patrón que se muestra en la mesa.

Por último, Sociable [11] es un proyecto europeo para el entrenamiento cognitivo de personas mayores. Para ello se hace uso de un tabletop táctil para ejecutar actividades organizadas en diversas categorías: memoria, atención, razonamiento, lenguaje y orientación.

Del estudio de los ejemplos anteriores se puede concluir que tanto el tabletop como las actividades desarrolladas para éste acercan a las personas con dificultades cognitivas a las nuevas tecnologías y les permiten seguir trabajando sus capacidades para evitar (o por lo menos disminuir) su deterioro. Sin embargo, no se está aprovechando todo lo que se podría las ventajas que ofrecen la combinación de la Interacción Tangible con los tabletop.

Por ejemplo, a pesar de que Gamberini et al. 2006 [2] trabaja diferentes áreas cognitivas, los lápices que se utilizan simplemente como sustitutos de los dedos, por lo tanto no se tendría que considerar como Interacción Tangible.

Con los cubos de Leiner et al. 2007 [6], o los objetos para hacer galletas de Kown et al. 2013 [5], sí que se está utilizando la Interacción Tangible. Sin embargo, ambos se han centrado en el desarrollo de una única actividad con juguetes ya predefinidos, por lo que es muy limitada en los aspectos cognitivos cubiertos.

Por último, en el proyecto Sociable [11] se menciona un tabletop con una gran variedad de actividades cognitivas pero todas ellas están basadas en la interacción táctil y por lo tanto no aprovecha las ventajas que tendrían esas actividades usando Interacción Tangible. Basándonos en la variedad de actividades de proyecto Sociable el presente trabajo pretende explorar las potencialidades que ofrecen los dispositivos tabletop y la Interacción Tangible en el tratamiento de problemas cognitivos.

A continuación se presenta el estudio que se ha realizado de las distintas actividades y juegos que se utilizan habitualmente para el tratamiento de problemas cognitivos.

3. ESTUDIO DE ACTIVIDADES COGNITIVAS

Nuestro objetivo es llevar a cabo una selección de actividades que cubran el máximo número de áreas cognitivas y que además aprovechen al máximo el uso del tabletop y de la Interacción Tangible.

3.1 Áreas cognitivas

Antes de realizar la selección de actividades se explicará en qué consiste cada una de las áreas cognitivas que suelen trabajarse [9], junto con ejemplos de actividades que se suelen desarrollar para potenciar dichas áreas.

- **Memoria**: es una de las funciones cerebrales cuyo deterioro es más patente con la edad. Un ejemplo típico de juego de memoria es el juego de encontrar las parejas.
- **Atención**: dentro de la atención podemos distinguir a su vez tres subtipos [1]: selectiva (aquella que se basa en reaccionar ante estímulos concretos de entre todos los que se presentan), dividida (aquella en la que hay que centrarse en varios estímulos a la vez, perteneciendo generalmente estos estímulos a sentidos diferentes como por ejemplo la vista y el oído), y sostenida (aquella que requiere concentración continua). Un ejemplo de actividad de atención es el juego de encontrar las diferencias o los puzles, que se utilizan para trabajar la atención sostenida.
- **Cálculo**: esta área cognitiva se refiere a la capacidad de una persona de realizar cálculos matemáticos sin instrumentos adicionales. Ejemplos de actividades de este tipo se pueden encontrar en juegos de mesa como el Parchís (hay que ir contando los puntos cuando te comes una ficha), o el Dominó (se tienen que estar contando constantemente los puntos que se llevan).
- **Lenguaje**: capacidad de los seres humanos para comunicarse por medio de signos. Actividades que potencian esta área pueden ser emparejar sinónimos y antónimos, u ordenar frases desordenadas.
- **Orientación espacio-temporal**: es la toma de conciencia de los movimientos en el espacio y el tiempo de forma coordinada. Se relaciona con el conocimiento que tiene cada persona del tiempo en el que está (fecha y hora) y del lugar en el que está. Para trabajar la orientación se suelen utilizar preguntas del tipo: ¿qué hora es?, ¿en qué momento del día estamos?, ¿dónde estamos?
- **Razonamiento**: facultad que permite resolver problemas, extraer conclusiones y aprender de manera consciente de los hechos, estableciendo conexiones causales y lógicas necesarias entre ellos. Un ejemplo claro de juego de razonamiento es el Sudoku.

Una vez detectadas la áreas y actividades más habituales, se llevó a cabo un análisis de requisitos que se explican en la siguiente sección.

3.2 Análisis de requisitos

Se llevó a cabo un análisis exhaustivo de las diferentes actividades cognitivas expuestas en el anterior apartado, con objeto de extraer los elementos comunes a todas ellas y poder elaborar un conjunto de requisitos (Tabla 1) a cumplir por una aplicación informática capaz de ejecutar cualquiera de estas actividades en un dispositivo tabletop.

Tabla 1. Requisitos de la herramienta

	Requisito	Actividad
R 1	Se han de tener **áreas** interactivas en las que poder poner uno o más objetos.	Todas
R 2	En algunas actividades se ha de tener en cuenta la orientación de los objetos colocados sobre el área	Atención
R 3	Las áreas tienen una lista de **objetos** correctos y una lista de objetos incorrectos	Todas
R 4	La imagen de **fondo** mostrada en pantalla podrá cambiar pasado un cierto tiempo que será configurable	Memoria
R 5	Las áreas interactivas pueden estar fijas en una posición en pantalla o ir asociadas a objetos	Todas
R 6	Se tiene que poder ofrecer algún tipo de **realimentación** cuando se coloquen objetos en las áreas dependiendo de si están bien o mal	Todas
R 7	Se tiene que poder definir **tareas** dentro de una misma actividad de modo que cuando se complete una tarea de la misma, se pase a la siguiente	Todas
R 8	Las actividades pueden requerir objetos concretos diferenciados o fichas del mismo tipo	Todas

En el análisis se vio que en realidad los elementos comunes eran coincidentes con los de otros juegos puramente lúdicos que se pueden jugar sobre la superficie de una mesa. Así, un juego típico de tablero está compuesto por un conjunto de áreas fijas en la superficie (R1 de la Tabla 1), un conjunto de piezas de juego (R8 de la Tabla 1) y un conjunto de reglas que definen el significado de colocar piezas en cada área (R3 de la Tabla 1) y su efecto asociado (R6 de la Tabla 1). Además de la colocación de la ficha dentro del área, la orientación puede también tener un significado concreto (R2 de la Tabla 1), por ejemplo, en el juego del Tangram. Juegos de tablero clásicos como el parchís (ver fig. 1 izquierda) pueden describirse como un tablero dividido en varias celdas en las que se colocan las piezas de juego siguiendo unas determinadas reglas.

Por otro lado, hay muchos juegos populares de mesa que no usan tablero y por tanto no tienen áreas predefinidas en la superficie de la mesa; p.e. Dominó (ver fig. 1 derecha) o juegos de cartas. En este tipo de juegos cada pieza de juego se relaciona con las otras piezas por “proximidad”, la orientación puede tener un significado (R2 de la Tabla 1) y las reglas de juego se aplican cuando un pieza de juego está al lado de otra; en otras palabras, cada pieza juego tiene un área asociada a ella (R5 de la tabla 1), y cuando otras piezas entran en dicha área se produce un efecto en el juego (R6 de la Tabla 1).

En los juegos de memoria, es necesario mostrar inicialmente al jugador una información que se oculta tras un tiempo determinado, durante el cual el jugador debe memorizarlo (R4 de la Tabla 1), por ejemplo, en el juego Simon™.

A menudo, las actividades y juegos cognitivos se juegan como una secuencia de tareas (R7 de la Tabla 1) con un nivel de dificultad variable, o gradual. Conforme el jugador completa tareas fáciles, se vuelve a plantear la misma actividad con un grado de dificultad mayor. Por ejemplo, de nuevo el juego Simon™, se juega como una sucesión de tareas en el que la secuencia a memorizar va aumentando gradualmente.

Una vez recopilados los requisitos comunes a las actividades cognitivas y juegos de mesa, se ha creado una herramienta informática que permite definir y ejecutar actividades basadas en Interacción Tangible en un dispositivo tabletop. Para ello, primero ha sido necesario crear un lenguaje de definición de actividades y juegos que cubra todos los requisitos anteriormente expuestos usando una sintaxis entendible por una aplicación informática.

Figura 1: Diferentes juegos de mesa. Izquierda: tablero de Parchís. Derecha: Dominó, un juego de mesa sin tablero

3.3 Lenguaje de modelado de actividades cognitivas

Partiendo del análisis de requisitos previo se ha extraído un vocabulario o conjunto de términos que siempre aparecen en los juegos y actividades cognitivas. Un juego de tabletop es modelado como una secuencia de tareas (ver fig. 2). Cada tarea es un objetivo que el jugador ha de alcanzar para poder avanzar en el juego. Cada tarea está compuesta por:

- Un **fondo**: el tablero.
- Varias **áreas**: zonas del tablero o de una pieza de juego en las que posicionar unas determinadas piezas de juego tiene un significado.
- Varias **piezas de juego**: objetos utilizados en el juego. Se colocan en las áreas; fuera de ellas la pieza no tiene ningún significado para el juego.
- **Retroalimentación**: elementos gráficos o sonoros que muestran las consecuencias de las acciones del jugador.

Siguiendo el R3 de la Tabla 1, cada área lleva asociada una lista de piezas de juego correctas e incorrectas o, por defecto, todas las piezas no correctas son consideradas incorrectas. Cuando una pieza de juego se sitúa dentro de un área, esta acción es interpretada en el juego como correcta o incorrecta dependiendo de la lista en la que esté contenida la pieza de juego. El componente de retroalimentación informará al jugador de si la acción es correcta o incorrecta a través de una imagen, una animación y/o un sonido. Para completar una tarea del juego, todas las áreas definidas en esa tarea han de contener todas las piezas de juego correctas (y sólo las correctas). En ese caso, el componente de retroalimentación informará también de que la tarea está completa y el juego avanzará a la siguiente tarea.

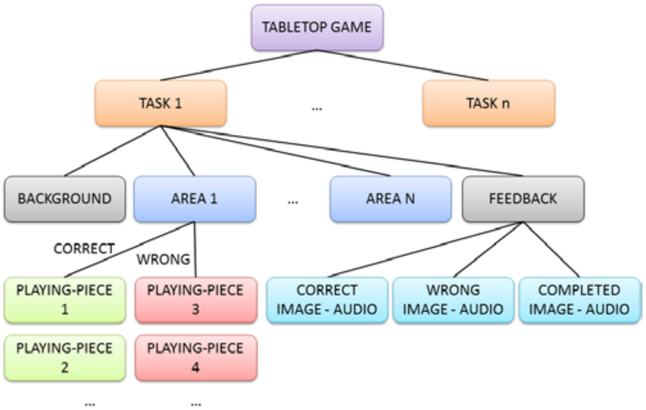


Figura 2: Jerarquía de los elementos

La estructura jerárquica de los diferentes elementos hace que la forma más adecuada de modelar las actividades y juegos sea mediante un lenguaje de marcas como el XML, ya que este tipo de lenguajes son muy adecuados para representar jerarquías. La figura 3 muestra la especificación en sintaxis XML del lenguaje de modelado.

```
<game>
 <task>
  <background>
   <color rgb="0xrrggbb"/>
    <image path="path/filename"/>
    <audio path="path/filename”/>
  </background>
  <area[associated_fid=”id”][orient=”yes/no”]>
   <pos x="n" y="n" width="n" height="n"/>
   <image path="path/filename"/>
   <imageCorrect path="path/filename"/>
   <imageWrong path="path/filename"/>
   <fid id="1,2,…" correct="yes/no"
    sound="path/filename" orient="n"/>
   <fid id="*” correct="yes/no"
    sound="path/filename" orient="n"/>
  </area>
  …
  <feedback>
   <pos x="n" y="n" width="n" height="n"/>
   <imageCompleted path="path/filename"/>
   <soundCompleted path="path/filename"/>
   <imageCorrect path="path/filename"/>
   <soundCorrect path="path/filename"/>
   <imageWrong path="path/filename"/>
   <soundWrong path="path/filename"/>
  </feedback>
 </task>
…
</game>
```

Figura 3: Sintaxis XML del lenguaje de modelado

Una vez definido el lenguaje de marcas, se ha implementado una aplicación informática capaz de interpretar ficheros XML que siguen la sintaxis previamente expuesta para modelar los juegos, y ejecutarlos en un dispositivo tabletop.

3.4 Intérprete del lenguaje de modelado de actividades cognitivas

El intérprete es la aplicación encargada de cargar y ejecutar los juegos en el dispositivo tabletop.

Cuando se ejecuta, el intérprete lee todos los ficheros XML almacenados en una carpeta específica del sistema informático del tabletop. Cada fichero XML contiene un juego modelado con la sintaxis detallada en la sección anterior. El reproductor muestra en la superficie del tabletop una pantalla de menú con todos los juegos de la carpeta (ver fig. 4 izquierda). De esta manera, el jugador puede ejecutar un juego tocando su icono correspondiente

Cuando un juego ha sido elegido, el intérprete carga e interpreta el fichero XML, y recupera todos los gráficos y ficheros de audio requeridos para renderizar el juego sobre el tabletop. El intérprete es capaz de cargar los formatos de imagen (BMP, GIF, JPG, PNG…), y de audio (WAV, MP3…) más comunes. En caso de los recursos de animación, el intérprete acepta ficheros SWF. Finalmente, el tablero se muestra en el tabletop y el jugador puede jugar situando las diferentes piezas de juego sobre la superficie (ver fig. 4 derecha).

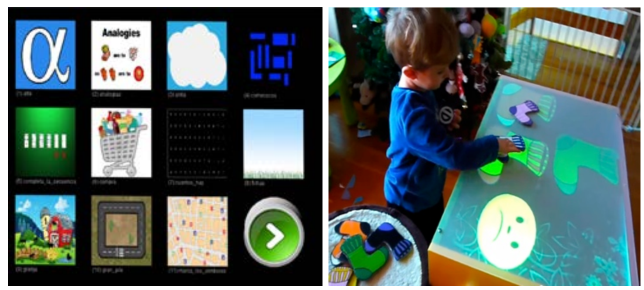


Figura 4: Intérprete del lenguaje de marcas. Izquierda: Pantalla de menú del intérprete. Derecha: Intérprete ejecutando un juego

4. ACTIVIDADES DESARROLLADAS

Se decidió comenzar con actividades de memoria, atención y razonamiento, en las que las potencialidades del uso de objetos eran más palpables. A continuación se detallan las actividades agrupadas por área de trabajo cognitivo.

4.1 Actividades de memoria

Como actividades de memoria se desarrollaron las actividades “Lista de la compra”, “Viajes” y “Kraken”.

En “Lista de la compra” se muestra en pantalla una imagen con una lista de la compra con alimentos durante cinco segundos. Pasado ese tiempo, se quita la imagen de la lista poniéndose una imagen con una bolsa de la compra y el usuario ha de seleccionar los alimentos correctos y situarlos en la bolsa. Los objetos que se utilizan en esta actividad son doce juguetes de comidas y bebidas: agua, cebolla, guisantes, huevo, leche, manzana, naranja, pimiento, tomate, zanahoria, zumo de naranja y zumo de uva (ver fig 5 arriba). La retroalimentación de esta actividad consiste en una carita que se pone sonriente cuando se coloca un alimento correcto, y triste si el alimento colocado no estaba en la lista.

En la actividad “Viajes”, al usuario se le muestra un mapa de Europa y se reproduce una grabación con un itinerario a seguir con distintos medios de transporte. El usuario ha de recordar el itinerario y situar los transportes correspondientes en los países correctos. Los objetos que se utilizan en esta actividad son tres juguetes de medios de transporte: tren, avión y barco (ver fig 5 abajo-izquierda). La retroalimentación de esta actividad consiste en una carita que se pone sonriente cuando se pone el medio de tranporte en su correspondiente país, o triste en caso contrario.

En la actividad "Kraken", al usuario se le muestra una imagen de un mar dividido en casillas. Durante unos segundos, el usuario puede ver en qué casillas están varios monstruos justo antes de que la imagen inicial se oculte y sólo queden las casillas mostrando mar. El objetivo del juego es que el usuario (que empieza en la casilla de la esquina inferior derecha) llegue a la isla del tesoro (situada en la esquina superior izquierda) evitando las casillas en las que había monstruos. El objeto que se utiliza en esta actividad es un juguete de un barco (ver fig 5 abajo-derecha). La retroalimentación de esta actividad consiste en la animación del monstruo que aparece cuando el jugador pisa una casilla incorrecta.

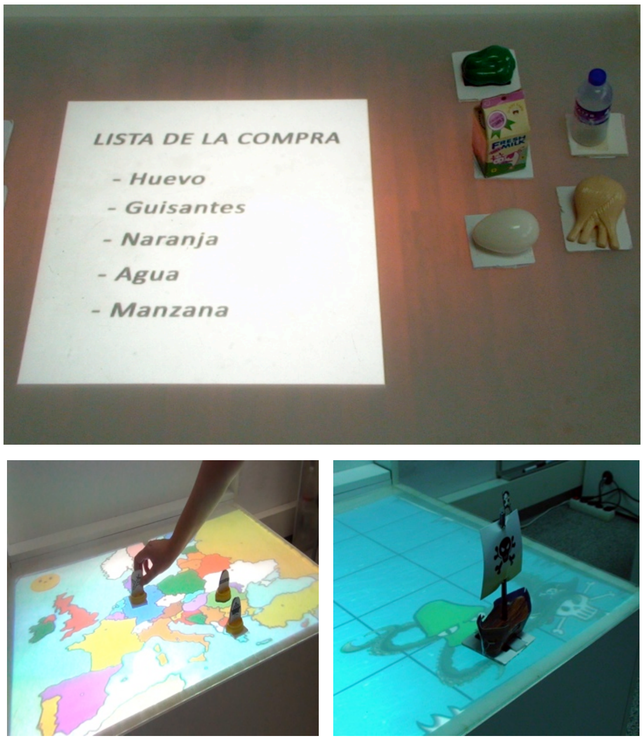


Figura 5: Actividades de memoria. Arriba: Lista de la compra Abajo-Izquierda: Viajes. Abajo-Derecha: Kraken

4.2 Actividades de atención

Como actividades de atención, se desarrollaron las siguientes: "¿Cuántos hay?" (atención dividida), "Marca los símbolos" (atención selectiva), y "Tangram" (atención sostenida).

En "¿Cuántos hay?" al usuario se le muestra una imagen con números entre el 0 y el 9. Nada más empezar la actividad suena una grabación que le dice al usuario qué número ha de buscar. El usuario tendrá que ir situando fichas sobre todos los números que encuentre de ese tipo, mientras que a la vez se estará reproduciendo una grabación con una secuencia de golpes: por ejemplo, sonarán cuatro golpes, habrá una pausa, sonarán ocho golpes, habrá una pausa... de modo que el usuario, a la vez que marca los números, durante la pausa tendrá que decir cuántos golpes han sonado. Los objetos que se utilizan en esta actividad son fichas que el usuario tendrá que colocar en los números correspondientes (ver fig 6 arriba). La retroalimentación de esta actividad consiste en la aparición de un tick verde o de una cruz roja encima del número dependiendo de si este es correcto o incorrecto.

En "Marca los símbolos" se presenta un mapa con símbolos de gasolineras, restaurantes, hoteles, farmacias...y se pide al usuario que marque todos los que sean de un tipo concreto. Los objetos que se utilizan en esta actividad son fichas que el usuario tendrá que colocar en los símbolos correspondientes (ver fig 6 abajo-izquierda). La retroalimentación de esta actividad consiste en la aparición de un tick verde o de una cruz roja encima del símbolo dependiendo de si este es correcto o incorrecto.

La actividad "Tangram" tiene dos modos: el fácil, en el que se ve en qué posición está cada una las piezas que conforman la figura, y el difícil, en el que solo se muestra el contorno de la figura. En la modalidad difícil también se trabaja el razonamiento, al tener que deducir dónde va cada pieza. Los objetos con los que trabajamos en esta actividad son las siete piezas del Tangram (ver fig 6 abajo-derecha). La retroalimentación de esta actividad consiste en una carita que se pone sonriente cuando una pieza se coloca de forma correcta, o triste si se coloca una pieza del puzle en un lugar que no le corresponde.

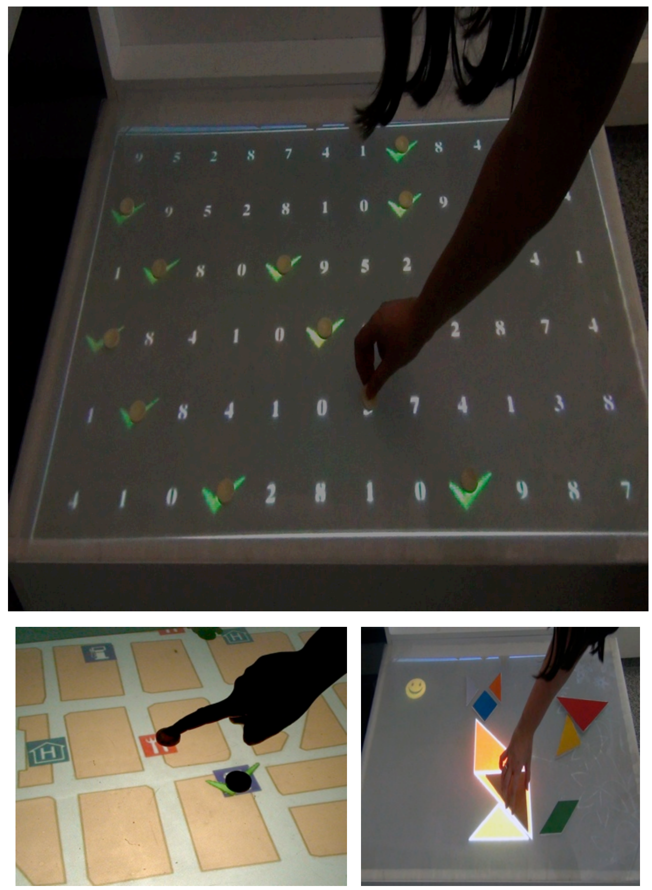


Figura 6: Actividades de atención. Arriba: ¿Cuántos hay? Abajo-Izquierda: Marca los símbolos. Abajo-Derecha: Tangram

4.3 Actividades de razonamiento

Como actividades de memoria, se desarrollaron las actividades "Relaciones sintagmáticas", "Analogías", y "Completa la secuencia".

En “Relaciones sintagmáticas”, el usuario ha de seguir unas instrucciones que guardan relaciones entre sí para rellenar una composición de figuras geométricas con las figuras de la forma y color adecuados. Esta actividad tiene dos modos: el fácil, con una composición de cuatro figuras geométricas (dos cuadrados y dos círculos) y el difícil, con una composición de seis figuras geométricas (dos cuadrados, dos círculos y dos triángulos). Los objetos que se utilizan son cuadrados, círculos y triángulos de colores rojo, azul, verde o amarillo (ver fig 7 arriba). La retroalimentación de esta actividad consiste en una carita que se pone sonriente o triste dependiendo de si la acción del jugador es correcta o incorrecta.

En “Analogías” se dispone de un conjunto de fichas con dos imágenes cada una. A cada imagen le corresponde una pareja, que estará en otra ficha diferente. El objetivo de la actividad es que todas las fichas formen una cadena de modo que todos los extremos de las fichas estén con su correspondiente pareja. Los objetos que se utilizan en esta actividad son las diferentes fichas (ver fig 7 abajo-izquierda). La retroalimentación de esta actividad es únicamente sonora, diferenciando cuando dos fichas están bien unidas y cuando no.

En “Completa la secuencia” se usan fichas de dominó para mostrar una secuencia en la que faltan algunas piezas. El usuario ha de seleccionar la pieza que falta para completar la secuencia. Los objetos que se utilizan en esta actividad son las fichas de dominó (ver fig 7 abajo-derecha). La retroalimentación de esta actividad consiste en una carita que se pone sonriente cuando se coloca una pieza en su lugar correcto, o triste en caso contrario.

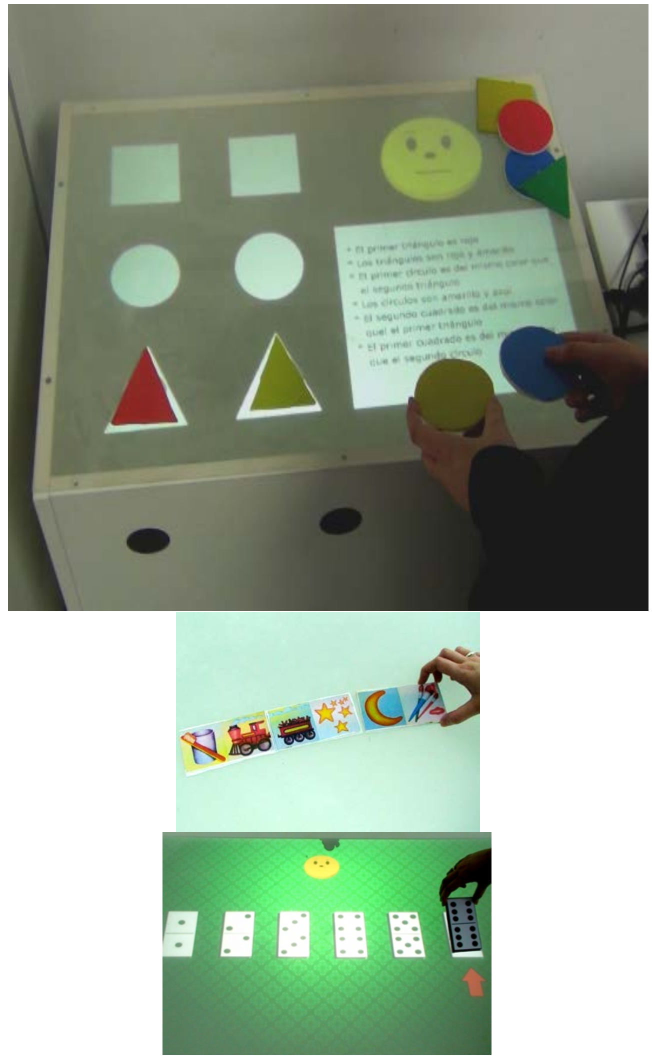


Figura 7: Actividades de razonamiento. Arriba: Relaciones sintagmáticas. Abajo-Izquierda: Analogías. Abajo-Derecha: Completa la secuencia

5. EVALUACIÓN DE LAS ACTIVIDADES

Nuestro objetivo al plantear la evaluación fue responder a la pregunta: ¿Cómo perciben los pacientes las nuevas actividades en un tabletop Tangible?

La evaluación se llevó a cabo como resultado de la colaboración con ASAPME, una asociación local que trabaja con adultos con enfermedades mentales. La terapeuta de esta asociación usa juegos tradicionales (sin ordenador) con sus pacientes para trabajar y mejorar sus habilidades cognitivas, que pueden estar afectadas como resultado de su enfermedad o como efecto secundario de su medicación. Las áreas cognitivas que trabajan son: atención, concentración, memoria, percepción, lenguaje, cálculo, razonamiento y pensamiento lógico, y motivación entre otras. El grupo de terapia estaba compuesto por cuatro adultos de edades entre los 25 y 65 años con diferentes enfermedades mentales: esquizofrenia, esquizofrenia y retraso mental, síndrome frontal, psicosis maniaco depresiva, trastorno mental orgánico con descontrol de impulsos y retraso mental, trastorno de ansiedad y trastornos físicos.

5.1 Metodología

Después de enseñarle a la terapeuta las actividades expuestas en la sección 4, ella mostró gran interés en aplicarlas con sus pacientes en sus sesiones de trabajo. Además, la actividad de razonamiento "Relaciones sintagmáticas" es una actividad que la terapeuta aplica habitualmente con sus pacientes sin uso de ordenador (ver fig 8).

Se planearon dos sesiones de evaluación. Durante la primera sesión, los pacientes probaron las actividades desarrolladas exceptuando "Relaciones Sintagmáticas". Con esta evaluación se quería valorar la experiencia del usuario a la hora de probar las actividades en la mesa. Para ello se utilizó el cuestionario AttrakDiff [3], el cual es ampliamente usado para evaluar la percepción de la usabilidad que los usuarios tienen al utilizar un dispositivo o aplicación. El cuestionario AttralDiff considera tanto dimensiones pragmáticas como hedónicas de usabilidad.

Durante la segunda sesión de evaluación, los pacientes probaron la actividad "Relaciones Sintagmáticas". El objetivo de esta sesión era comparar la preferencia de los pacientes entre la actividad con tabletop y sin tabletop.

Durante ambas sesiones estaban presentes la terapeuta, que ayudaba a los pacientes mientras estos probaban las actividades, y dos evaluadores, que eran los encargados de tomar nota de los comentarios de los participantes. Ambas sesiones duraron dos horas cada una y se llevaron a cabo en la sala donde los pacientes realizaban normalmente sus actividades. Fue en esa misma aula donde se instaló un tabletop NIKVision para que los pacientes probaran las actividades.

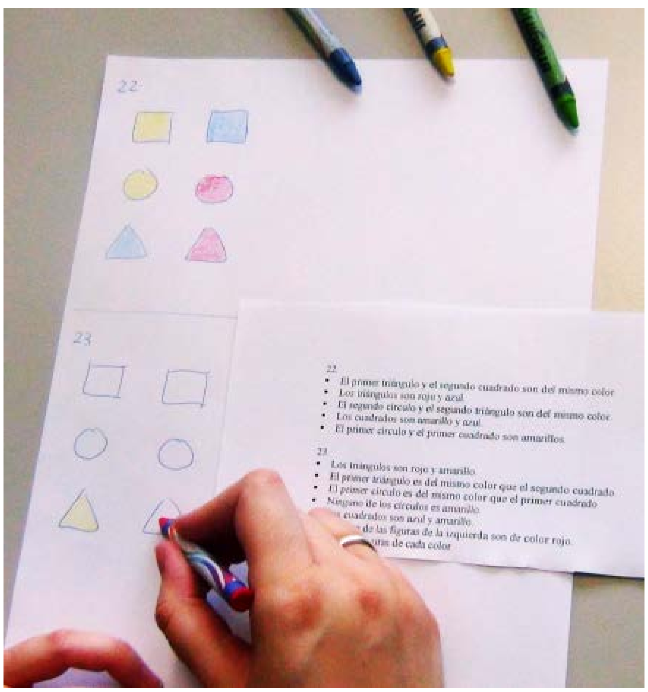


Figura 8: Versión no tecnológica de la actividad "Relaciones sintagmáticas"

5.2 Sesión 1: Uso de actividades por los pacientes

Previamente a la sesión, la terapeuta decidió qué actividades iba a realizar cada uno de los pacientes, así como el grado de dificultad. Además, en relación con el cuestionario AttrakDiff, la terapeuta nos dijo que este tipo de cuestionario resultaría difícil de rellenar para los pacientes, así que se realizó una simplificación del mismo: en primer lugar se eliminó la pregunta "predecible – impredecible" por considerar la terapeuta que sus pacientes no iban a comprender a qué se refería este par de adjetivos; en segundo lugar, en vez de tener que puntuar utilizando dos adjetivos antónimos como indica el cuestionario AttrakDiff original, la terapeuta eligió de entre los dos adjetivos contrapuestos el más comprensible (por ejemplo, entre el par de adjetivos "aislante" e "integrador" se eligió el segundo) de modo que el paciente sólo tuviera que calificar dicho adjetivo entre 1 y 7, significando el 1 "totalmente en descuerdo" y el 7 "totalmente de acuerdo" (ver fig. 9).

Tecnológico	☐☐☐☐☐☐☐	Engorroso	☐☐☐☐☐☐☐	Claro	☐☐☐☐☐☐☐
Separatista	☐☐☐☐☐☐☐	Elegante	☐☐☐☐☐☐☐	Atrayente	☐☐☐☐☐☐☐
Agradable	☐☐☐☐☐☐☐	Común	☐☐☐☐☐☐☐	Atrevido	☐☐☐☐☐☐☐
Ingenioso	☐☐☐☐☐☐☐	Integrador	☐☐☐☐☐☐☐	Innovador	☐☐☐☐☐☐☐
Complejo	☐☐☐☐☐☐☐	Me acerca a la gente	☐☐☐☐☐☐☐	Soso	☐☐☐☐☐☐☐
Profesional	☐☐☐☐☐☐☐	Desaliñado	☐☐☐☐☐☐☐	Exigente	☐☐☐☐☐☐☐
Atractivo	☐☐☐☐☐☐☐	Tentador	☐☐☐☐☐☐☐	Motivante	☐☐☐☐☐☐☐
Práctico	☐☐☐☐☐☐☐	Original	☐☐☐☐☐☐☐	Corriente	☐☐☐☐☐☐☐
Simpático	☐☐☐☐☐☐☐	Bueno	☐☐☐☐☐☐☐	Razonable	☐☐☐☐☐☐☐

Figura 9: Cuestionario AttrakDiff adaptado que rellenaron los pacientes

Durante esta sesión los participantes probaron por turnos algunas de las actividades de memoria, atención y razonamiento desarrolladas en el tabletop. Uno de los pacientes se negó a jugar con el tabletop ya que comentó que no le gustaba el dispositivo. Los demás completaron las actividades sin problemas aunque los tiempos de completitud de las actividades variaron dependiendo de la enfermedad mental del paciente, en un rango de quince minutos y media hora.

Finalmente, los usuarios rellenaron su cuestionario AttrackDiff. Uno de los pacientes necesitó para ello la ayuda de la terapeuta porque no acababa de entender lo que había que hacer.

5.3 Sesión 2: Comparativa de la actividad con tabletop y sin tabletop

Durante esta sesión, todos los participantes trabajaban en papel con la versión no tecnológica de la actividad (ver fig. 8) y por turnos también jugaban con la versión de tabletop.

El mismo paciente que se había negado a jugar con el tabletop durante la sesión anterior tampoco quiso en esta sesión probar la versión de tabletop de la actividad, pero el resto de pacientes completaron el juego sin problemas, aunque necesitaron diferente tiempo: los pacientes más afectados cognitivamente requirieron media hora mientras que los menos afectados completaron el juego en diez minutos.

Al finalizar todos los usuarios sus actividades de "Relaciones Sintagmáticas", se realizó una discusión en común de la opinión y percepción que tienen sobre cada una de las versiones. Todos (menos el que no jugó), participaron en dicha discusión, durante 15 minutos.

5.4 Resultados

En cuanto a los resultados de la primera sesión, en el cuestionario AttrakDiff cada adjetivo se engloba dentro de una de las cuatro dimensiones siguientes:

- Cualidades pragmáticas (PQ): mide el producto como herramienta utilizada para realizar una tarea.
- Cualidades Hedónicas-Estimulantes (HQ-S): mide en qué medida el producto apoya la estimulación.
- Cualidades Hedónicas-Identificación (HQ-I): mide en qué medida el producto permite al usuario identificarse con él.
- Escala de atractivo global (ATT): mide el valor global del producto basado en la percepción de sus cualidades hedónicas y pragmáticas.

A pesar de haber hecho una simplificación del cuestionario, analizando las respuestas dadas por los pacientes se han observado contradicciones a la hora de responder, puesto que un paciente calificó el adjetivo "Integrador" con un 0 pero después calificó "Me acerca a la gente" con un 5, otro paciente calificó "Ingenioso" con un 4 y "Soso" con un 6, y otro paciente calificó "Engorroso" con un 6 y "Claro" con otro 6. Por lo tanto, se puede llegar a la conclusión de que para este tipo de pacientes sería recomendable cambiar algunos de los adjetivos por otros más sencillos para que les resulten más fáciles de comprender y los resultados sean más fiables. A la hora de calcular los resultados, los adjetivos contradictorios previamente mencionados no se tuvieron en cuenta en ningún caso.

En la figura 10 se pueden ver las medias de los resultados de los tres usuarios que participaron en la sesión agrupados en las cuatro dimensiones. Aunque todas las notas superan el 50%, se aprecia que la nota más baja es la pragmática (PQ), indicando que los pacientes no consideran que la herramienta destaque por su utilidad en la realización de actividades. Sin embargo, las notas de las dos dimensiones hedónicas (HQ-S y HQ-I) son mayores, indicando que los usuarios destacan más del tabletop su capacidad motivadora y atrayente. Por último, se puede ver que la dimensión con mejores resultados es la última (ATT), con un valor de casi el 75%, lo cual indica que el valor global del producto es bastante satisfactorio. Por tanto, se puede extraer como conclusión que los usuarios están satisfechos con el uso de las actividades sobre el tabletop, ya que aunque no consideran que éstas les aporten mucho más que el hacer sus actividades tradicionales, sí que se sienten atraídos y motivados a la hora de realizarlas.

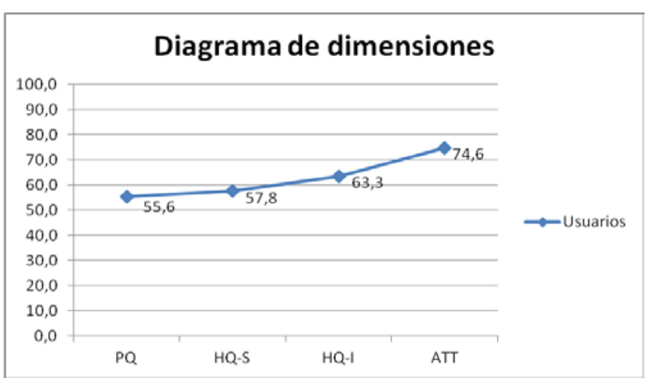


Figura 10: Resultados del cuestionario AttrakDiff adaptado

Respecto a las notas que se tomaron, pudimos extraer algunas conclusiones para mejorar las actividades, como se comenta a continuación:

Casi todos los participantes encontraron las últimas tareas de la actividad de razonamiento "Completa la secuencia" demasiado difíciles, lo cual indica que es necesario bajar la dificultad de dicha actividad.

También nos dimos cuenta de que en la actividad "Lista de la compra" el dibujo de la bolsa que aparecía en el área destinada a poner los alimentos podría no ser el más adecuado, ya que uno de los pacientes interpretó que al ser una bolsa, los alimentos tenían que meterse por la parte de arriba y por lo tanto concentraba todos los alimentos únicamente en la parte del arriba del área en vez de en toda la zona de la bolsa. En esa misma actividad también descubrimos que el tiempo que se muestra la lista con los alimentos al principio de la actividad era demasiado corto para uno de los pacientes.

Por último, observamos que la posición de la retroalimentación visual en determinadas actividades tenía que mejorarse, ya que en actividades como la de "Viajes" o "Tangram" la retroalimentación (carita que se pone triste o contenta) está situada demasiado alejada de las áreas interactivas, lo que provoca que muchas veces el paciente no la perciba. En otras actividades, como "Busca los símbolos", la retroalimentación sí que era adecuada ya que ésta aparecía directamente sobre el área en la que jugaba el paciente y, por tanto, éste siempre lo veía.

En cuanto a los resultados de la segunda sesión, el grupo discutió durante 15 minutos con los evaluadores su valoración del juego de tabletop. La discusión empezó preguntándoles qué actividad les gustaba más: la no tecnológica o la versión del tabletop. La actividad de tabletop fue, en general, bien recibida por los pacientes que jugaron en el dispositivo tabletop, y todos ellos eligieron la versión de tabletop de la actividad en vez de la de papel. Sin embargo, también expresaron algunas matizaciones personales. Uno de los participantes apuntó que, aunque era más divertido hacer la actividad en el tabletop, prefería leer las instrucciones en papel en vez de en el tabletop ya que mirar a la pantalla de tabletop por mucho tiempo le cansaba la vista. Otro paciente dijo inicialmente que prefería hacer la actividad en papel porque cuando jugaba con la versión del tabletop, a veces le daba retroalimentación errónea diciendo que la pieza de juego estaba mal puesta e inmediatamente después decía que estaba bien (este suceso era debido a un problema técnico que fue posteriormente solucionado). Cuando se le preguntó al paciente qué elegiría en caso de que el problema estuviera solucionado, dijo que elegiría la actividad de tabletop en vez de la de papel porque era más divertida y porque era más fácil saber si habías elegido la figura correcta gracias al sonido, mientras que en la de papel tenía que preguntar a la terapeuta además de borrar y colorear de nuevo cuando fallaba. Finalmente, otro paciente nos dijo que prefería la actividad de tabletop pero que no le gustaban los sonidos incorrectos: él prefería que un sonido sólo se reprodujera cuando hacía algo bien y que nada sonara cuando hacía algo mal. La terapeuta nos dijo después que algunos pacientes se motivan con retroalimentación positiva pero que se frustran fácilmente con la retroalimentación negativa; por lo tanto, es un aspecto importante a considerar en el futuro a la hora de diseñar actividades de tabletop personalizadas según las preferencias de los pacientes.

6. CONCLUSIONES Y TRABAJO FUTURO

Tras analizar las áreas cognitivas más tratadas por los terapeutas en pacientes mayores o con enfermedad mental se han desarrollado las herramientas necesarias para el diseño y ejecución de actividades de ese tipo en tabletops Tangibles basados en visión como NIKVision: un lenguaje de marcas flexible basado en XML y un intérprete de dicho lenguaje. Ambas han sido utilizadas en el desarrollo de nueve actividades que han sido probadas por una terapeuta y su grupo de pacientes adultos con enfermedad mental. La evaluación ha servido para reafirmar las potencialidades de este tipo de actividades desarrolladas sobre un tabletop Tangible y también para encontrar algunos problemas de usabilidad y de la propia metodología de evaluación con ese tipo de pacientes. Así, se ha detectado la importancia de diseñar una correcta y adaptada retroalimentación de las actividades, así como la necesidad de una mayor adaptación de los cuestionarios de evaluación con objeto de obtener resultados más fiables de los mismos.

Como trabajo futuro, se está trabajando en el desarrollo de una interfaz gráfica que permita el desarrollo de actividades por parte de los propios terapeutas.

7. AGRADECIMIENTOS

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Analyzing Learnability of Common Mobile Gestures used by Down Syndrome Users

Alfredo Mendoza G.
Universidad Juarez Autónoma de Tabasco
Av. Universidad S/N, Magisterial, Villahermosa, Tab.
(52) 993 312 4680
amendoza@correo.uaa.mx

Francisco J. Alvarez R.
Universidad Autónoma de Aguascalientes
Av. Universidad 940, Cd. Universitaria, Aguascalientes, Ags.
(52) 449 910 7400
fjalvar@correo.uaa.mx

Ricardo Mendoza G.
Instituto Tecnológico de Aguascalientes
Av. A. López Mateos Ote. No. 1801, Bona Gens, Aguascalientes, Ags
(52) 449 910 5002
mendozagric@mail.ita.mx.

Francisco Acosta E.
Universidad Juarez Autónoma de Tabasco
Av. Universidad S/N, Magisterial, Villahermosa, Tab.
(52) 993 312 4680
francisco.acosta@ujat.mx

Jaime Muñoz A.
Universidad Autónoma de Aguascalientes
Av. Universidad 940, Cd. Universitaria, Aguascalientes, Ags.
(52) 449 910 7400
jmauaa@gmail.com

ABSTRACT
The objective of this research was to analyze the learnability of the 8 most common mobile gestures used by first-timers Down Syndrome (DS) users. The study was performed by testing mobile gestures usage by 10 DS teenagers that had never interacted with a mobile/gestural interface. They developed 18 tasks over a tablet computer. Results were measured by the *Task Performance Learnability Metric* which focuses in factors such as success, optimality, and error decreasing. Although gestural interaction was thought to be intuitive by design, DS users face limitations in fine-motor and visual skills, so as in eye-hand coordination, which difficult manipulation of particular mobile gestures. This vein, findings of this research helped to determine the most adequate interactions for mobile gestural interfaces used by DS users.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Representation**]: User Interfaces - *Graphical user interfaces, Input devices and strategies*

General Terms
Documentation, Performance, Design, Human Factors

Keywords
UX, Learnability, Usability, Interaction, Disabilities

1. INTRODUCTION
Down Syndrome (DS) is caused by a genetic anomaly where subjects have an extra copy of chromosome 21; such genetic condition brings particular characteristics in learning, communicating and perceiving skills. Worldwide, the estimated incidence of DS is between 1 in 1,000 to 1 in 1,100 live births. About 6,000 babies are born in the United States with DS each year (Parker et al, 2010). The prevalence of Down syndrome is about 8 people with DS per each 10,000 people in the United States (Presson, 2013), 7 per 10,000 in England and Wales (Wu & Morris, 2013), and 8 per 10,000 in Spain (FESD, 2010), to quote some data. The particular characteristics of DS people might be considered in the design of any user interface in order to be friendly-used, since these limitations may affect the use of any computational application when it has not been well designed. The quality and mount of knowledge, which designers had considered to the final product about users, will benefit the user experience. Understanding people, their characteristics, capabilities, commonalities and differences allow designers to create more effective, safer, efficient, and enjoyable systems (Ritter et al., 2014).

This study focuses in the *learnability* of the most common mobile gestures used by DS users. Learnability is one of the five components of Usability (Learnability, Efficiency, Memorability, Errors and Satisfaction) and is defined as how easy for users is to complete basic tasks the first time they encounter with some design (Nielsen, 2012). This means that the main goal of this study is to analyze how easy to learn are the most common mobile gestures by the DS users in the very first encounter with mobile devices.

2. BACKGROUND
There are significant characteristics of DS individuals that may affect their performance as computers users. Based on the complete list of characteristics found in (Champman & Hesketh, 2000, Lauteslager, 2000), the most related with mobile gestures are shown next:

- Short hands and broad fingers.
- Difficulties in fine and gross motor skills.
- Low muscle tone
- Difficulties in vision capacities
- Poor eye- hand coordination
- Anxiety
- Difficulties in comprehension of abstract concepts

Drs. Jinjuan Feng and Jonathan Lazar of Towson University had leaded some important researches on Human-Computer Interaction that involved DS users. In (Lazar, 2010), they applied a survey about general usage of Computers to 561 DS children. Among their most important findings, they show that 93% of the children use mouse without much difficulty, they also remark that they applied the survey only to children that already use computers, but it is a remarkable finding because their expectations based on the clinical information was overcome. Dr. Lazar also analyzed the work-place related skills of adult expert users with DS; he found that many of the participants were able to efficiently use different programs, systems and devices at work (Lazar et al, 2011). These papers leave an open question about how easy to use were input techniques for DS users. In (Hu, et al, 2011), through an empirical study that involves eight users with DS, the efficacy of keyboard-mouse, word prediction, and speech recognition, where examined. All of them already were familiar with the keyboard-mouse input technique, and seven of the eight participants completed all the tasks, although none of them where used neither word prediction nor speech recognition.

Within their findings, they confirm the fact that Dr. Lazar and their team visualized previously: One design is unlikely to fit the needs of all DS users, instead, offering different design options targeting for specific user profiles might be a more effective solution (Hu, et al, 2011). They mention two factors that influence the user's performance level: the computer experience (number of years using computers) and number of hours per week of computer usage.

In 2012, the research team of Towson University made an empirical study about how usable were the tablets computers used by expert adults with DS (Kumin et al, 2012). They found that adults with DS are able to use multi-touch devices when already had received formal computer training. Involving 10 participants, Social networking, Email, Calendar, Price comparison, and Text entry/note-taking activities made in a tablet computer were tested. It is important to remark that all users were experts and use computers in their everyday work activities.

One interesting finding in this study was that some users had problems with the sensitive nature of the device, mixing and confusing gestures, this gives the idea that mobile gestures are not as self-evident as it was thought.

One of the main advantages of the gestural interfaces used by mobile devices over traditional keyboard-mouse interfaces is the direct relationship with ordinary-living gestures; this implies that users must not necessarily pass through a capacitation program for learning the manipulation of such devices; being *natural*, last generation of mobile devices interfaces, allows an intuitive learning. Thus, the question discussed in this study is how *natural* are the mobile interfaces gestures for DS novice users?

3. COMMON MOBILE GESTURES

This section describes the 8 most commonly used mobile gestures. It is important to mention that, with the exception of figure 5, all gestures representations are based on (Villamor et al., 2010).

3.1 Tap

Tap gesture is the most basic one; it consists in pressing briefly the surface of the device with one fingertip. The result could be just the selection of an item of the screen or the trigger of a predefined action. (Apple, 2014; Android, 2015), the typical symbol to express this gesture is shown in figure 1.

Figure 1. Tap gesture

3.2 Double Tap

The double tap (figure 2), also known as double touch, consists in rapidly touching twice the surface of the device with one fingertip in the same point (Apple, 2014; Android, 2015). The most common functionality of this gesture is to zoom in (or out when is already zoomed) a picture.

Figure 2. Double tap gesture

3.3 Swipe

Swiping is the action of pressing, moving and lifting at some point of the screen. One particular characteristic of this gesture, in order to avoid misunderstandings with others, is that the fingertip that triggers the gesture will never lose contact with the surface until the gesture is done. Figure 3 presents the graphic representation of swipe gesture.

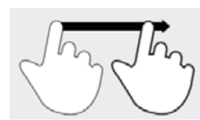

Figure 3. Swipe gesture

3.4 Flick

Flick is defined as quickly brush the surface of the device with one fingertip (Villamor et al., 2010). The gesture finishes with the fingertip away from the surface, that and the speed of doing it, are the main differences between *flick* and *swipe*. Figure 4 is the most common graphical representation of *flick* gesture. The most known action of this gesture is to advance (forwards or backwards) rapidly in a list of elements.

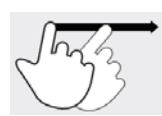

Figure 4. Flick gesture

3.5 Hold and drag

This gesture is composed of two elements: long touch and swipe. By holding the touch with one fingertip over a specific element of the screen, the user can drag it to another position. Commonly, by holding and dragging an object of the screen, user may change its position, send it to trash or close it. In order to represent the *hold and drag* gesture, authors has develop the figure 5, based on those shown in (Villamor et al., 2010).

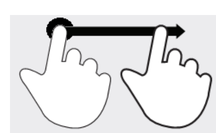

Figure 5. Hold and Drag gesture

3.6 Pinch

The pinch gesture consists in pressing the surface of the device with two fingers, move them inwards and lifting (Google, 2015). The graphical representation shown in figure 6, presents the *pinch* gesture made with thumb and index fingers.

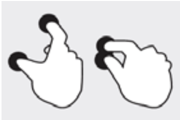

Figure 6. Pinch gesture

3.7 Spread

Spread gesture implies the inverse movement of *pinch* gesture; i. e. the gesture begins with pressing the device's surface with the two fingers close-together, spreading and lifting. Figure 7 presents a graphical representation.

Figure 7. Spread gesture

3.8 Rotate

The *rotate* gesture consists in touching the device's surface with two fingers and move them in a clockwise or counterclockwise direction (Villamor, et al., 2010). A graphical representation is shown in figure 8.

Figure 8. Rotate gesture

4. EMPIRICAL STUDY

4.1 Participants

The study involves 10 DS teenagers between 15 and 20 years old; all of them enrolled in a special education center where no computational instruction is given to them. All 10 participants had no experience with mobile devices, touchscreens or smartphones. It is worth mentioning that all parents of the 10 users involved in this research gave their consent by signing the institutional consent document based on the *Informed Parental Consent for Research Involving Children* of the World Health Organization.

4.2 Instruments

The device selected for this study was the Samsung Galaxy Tab 10.1; specifications are shown in table1.

Table1. Specs of device

Characteristic	Samsun Galaxy
Display size	10.1''
Screen resolution	1280x800
Internal memory	16GB
Processor	1.2 GHz Qd-Core
Platform	Android™ 4.4

4.3 Metrics

In (Grossman et al., 2009) a taxonomy of learnability evaluation metrics was presented; there, six different categories group the metrics according with their objective. For this study, the next points, taken form *task performance metric,* was chosen:

- Percentage of users who completed the task optimally
- Percentage of users who completed the task without any help
- Ability to complete task optimally after certain time frame
- Decrease in task errors made over certain time interval
- Time until user completes a certain task successfully

In order to clarify the way the metrics will be measured, an explanation for the key terms is presented next:

- A task is considered as optimally completed when the user completes all the instructions at the first try, without any help.
- A task is considered as completed without help when the user completes the task successfully, regardless the number of tries.
- A task is considered as completed successfully when the user triggers the current gesture action without errors.
- An error occurs when the actions of the users do not trigger the current gesture's actions. A hesitation is not considered as error.
- All the time measured starts when the first explanation is completed, and stops when the activity is successfully completed.

Thus, data were computed as next:

- Percentage of users who completed the task optimally
- Percentage of users who completed the task without any help
- Percentage of users that acquired the ability to complete task optimally after certain time frame
- Percentage of users that decrease in task errors made over certain time interval
- Average time until user completes a certain task successfully

4.4 Experiment design

28 users' tasks were developed in order to test all 8 gestures. The main premise was to define tasks where the cognitive load would not affect the user performance of any gesture. From this fact, the next rules where followed by each user task:

- Use the minimum number of colors as possible
- Use simple images without too many realism
- Avoid abstract images
- Avoid ambiguity

- Avoid words inside the images.
- Use white background when possible.
- Use the most typical forms of all objects.

Figure 9 shows an example of the application of the rules, both images represent a house; left side picture is overloaded with graphical information (trees, ground, fence, bench, etc.), right picture is a simple representation of a house with minimum colors.

a) b)

Figure 9. a) Overloaded Picture b) Simple picture

Every gesture was tested in three levels: basic, intermediate, and advanced; basic level implies the simplest tasks where the user only makes the gesture. Levels intermediate and advanced involve more complicated tasks that involve repetitions, combinations, or specified conditions of gestures. Next are shown the tasks defined for each gesture:

1. *Tap*: In a grill given to user, he/she must tap the indicated cell. The size of each cell is decreasing with each success. The three levels are tested with the cell size.

2. *Double* tap: In a grill given to user, he/she must tap the indicated cell. The size of each cell is decreasing with each success. The levels of difficulty are evaluated same way as the first task.

3. *Hold and drag*: For all levels of difficulty, a group of left-aligned elements is given to users; they must drag all of them to their final position, the difference between levels is the way the user must follow with the object.
   Basic: Objects must be moved in a straight line.
   Intermediate level: Objects must be moved in an "L" line.
   Advanced:
   a) Objects must be moved in a straight line, in certain time.
   b) Objects must be moved in an "L" line, in certain time.

4. *Swipe*: All the next tasks will be done by side to side swipe.
   Basic:
   (a) Being in certain picture, user goes to the next one.
   (b) Being in certain picture, user goes to the previous one.
   Intermediate: Users must go forward in a document, sheet by sheet until reach some pre-established page, then they must return to the first one.
   Advanced: Users must reach the final page of a document as fast as they can, then they must return to the first one as the same way.

5. *Flick*
   Basic: Use flick forward and backwards.
   Intermediate: Use flick and stop it.
   Advanced
   (a) Use flick forwards and stop it to reach certain page.
   (b) Use flick backwards and stop it to reach certain page.

6. *Rotate*:
   Basic: Rotate image
   Intermediate: Rotate and resize an image
   Advanced: Rotate 180° and zoom in an image.

7. *Pinch*:
   Basic: Zoom out a picture
   Intermediate: Users must reach the minimum zoom of a picture as fast as they can.
   Advanced: Users must zoom-out a picture and rotate it 180° in clockwise at the same time.

8. *Spread*: All tasks will be developed using only one hand.
   Basic: Zoon in a picture
   Intermediate: Users must reach the maximum zoom of a picture as fast as they can.
   Advanced: Users must zoom-in a picture and rotate it 180° in clockwise at the same time.

Next table shows an overview of all the 28 tasks:

Table2. Overview of user tasks

Gesture	Level	Task
Tap	Basic	Tap the indicated cell, cell sizes:7''and 4''
	Intermediate	Tap the indicated cell, cell size: 2''and 1''
	Advanced	Tap the indicated cell, cell size: .5'' and .25''
Double Tap	Basic	Double-tap the indicated cell, cell size: 7'' and 4''
	Intermediate	Double-tap the indicated cell, cell size: 2''and 1''
	Advanced	Double-tap the indicated cell, cell size: .5''and .25''
Hold and drag	Basic	Move objects in a straight line.
	Intermediate	Move objects in an "L" line.
	Advanced	Move objects in an "S" line.
Swipe	Basic	Go to the next picture Go to the previous one
	Intermediate	Use swipe continuously.
	Advanced	Use swipe with speed.
Flick	Basic	Flick forward Flick backwards
	Intermediate	Use flick and stop it.
	Advanced	Use flick and stop it to reach certain page.
Rotate	Basic	Rotate image
	Intermediate	Rotate and resize an image
	Advanced	Rotate 180° and zoom in an image
Pinch	Basic	Zoom out a picture

	Intermediate	Reach the minimum zoom
	Advanced	Zoom-out a and rotate 180°
Spread	Basic	Zoom in a picture
	Intermediate	Reach the maximum zoom
	Advanced	Zoom-in a and rotate 180°

4.5 Study development

Although, all activities were planed and designed with a multi-disciplinary team involving psychologists, clinicians and experts in special education, all tests were made with the presence of the psychologist in order to supervise that users understand the instructions and the activities procedure.

All 10 individual tests were videotaped in order to be analyzed and data were tabulated. All results obtained in the study are presented arranged by gesture. A table presents the corresponding value involving all 10 users' information using the metric presented in 4.3. Some data were note as N. M. (Not Measured) due to the low significance of measuring that factor.

4.5.1 *Tap*

The goal of all activities for *tap* gesture was tapping the indicated (in green color) cell of a table. The size of all cells reduces at each success, whilst the number of cells increases; thus, the difficulty also increases.

For *tap* gesture, since this is a very easy task, the time was not measured in basic and intermediate level, due to users tap the corresponding cell almost instantly. In advance level, the time was taken until user complete the tasks, and involves time for locating the cell and time expended in all tries. The results for *tap* are shown in table 3.

As it is shown in the table, some users fail to complete tasks where more precision were required; errors involved accidental activation of swipe and double tap, keep holding and too much force applied to make the tap (resulting in not detection of the gesture by the device).

Table 3. Results for single tap

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	100%	60%	30%
Percentage of users who completed the task without any help	100%	80%	30%
Percentage of users that acquired the ability to complete task successfully after certain time frame	100%	100%	80%
Percentage of users that decrease in task errors made over certain time interval	100%	100%	100%
Average time until user completes a certain task successfully (secs.)	N. M.	N. M.	1.5

4.5.2 *Double tap*

Double tapping involves the same windows and cells of single *tap*, but users have to touch twice the surface in order to advance in the activity.

Common mistakes involved accidental activation of other gestures (such as swipe), multiple tapping. For some users were difficult to make only two taps in the tiny cells.

The same consideration for time measurement made with single tapping, were done for double tapping: only advance level were measured. Corresponding results are shown in table 4.

Table 4. Results for double tap

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	90%	60%	30%
Percentage of users who completed the task without any help	100%	60%	30%
Percentage of users that acquired the ability to complete task successfully after certain time frame	100%	90%	80%
Percentage of users that decrease in task errors made over certain time interval	100%	100%	90%
Average time until user completes a certain task successfully (secs.)	N. M.	N. M.	2.5

4.5.3 *Swipe*

A document with several pages, each of them presenting only one single basic image of fruits, vegetables, animals and other simple objects, was shown to the users; after a brief explanation of the functionality to advance forward and backwards through the pages of the document, user was ask to advance to the next, previous and certain image. Next, user was asked to go to certain previously located image, so he/she must do the *swipe* gesture ten times. Once user was familiar with this gesture, for advanced level, he/she was asked to go to certain object (10 pages away to the current) as fast as he/she can. Single *swiping* did not represent a challenge to any user, but when multiple *swiping* was required, users tend to make some mistakes. Among the most common were: undetected swipe, due to incomplete or short gestures, diagonal swipe, that sometimes results in undetected gestures, and opposite swipe, due to no-lifting finger from the device's surface when swiping. All errors were most presented in advance level activities (See Table 5).

4.5.4 *Flick*

For *flick* gesture, the same document with simple images was used, after a brief explanation of its functionality users were asked to do the activities. First, users made the *flick* to advance forwards and backwards, in a preview-slide of the all document pages. Then he/she was asked to stop the slide before stops itself. Once user understands the gesture and its actions, he/she was asked to stop the slide in a certain page. For this activity, the objective page was the only one in colors, the rest of all pages were in gray scale. The most common behavior of users was trying to accelerate the slide by doing multiple slides. The result of this action was commonly to stop the slide.

Table5. Results for swipe

Factor \ Level	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	90%	90%	70%
Percentage of users who completed the task without any help	100%	90%	70%
Percentage of users that acquired the ability to complete task successfully after certain time frame	100%	100%	100%
Percentage of users that decrease in task errors made over certain time interval	100%	100%	100%
Average time until user completes a certain task successfully (secs.)	N. M.	12.25	7.4

The advanced level activity was very hard to achieve by all users. At first, researchers thought it was caused of vision problems, but after a brief analysis of the visual capacities of users it was discarded. Researchers and experts support that the difficulty was due to a coordination problem that in general affects DS individuals.

Table 6 shows the information tabulated that involve all 10 users' tests for *flick* gesture.

Table 6. Results for flick

Factor \ Level	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally.	20%	10%	10%
Percentage of users who completed the task without any help	40%	60%	10%
Percentage of users that acquired the ability to complete task successfully after certain time frame	80%	80%	20%
Percentage of users that decrease in task errors made over certain time interval	80%	80%	20%
Average time until user completes a certain task successfully (secs.)	4.6	8.6	13

4.5.5 *Hold and drag*

This activity involves two steps: tap over one object of the screen and hold it, and then, move the object to another place. It was especially difficult to user to understand the moment when he/she can move the object; that is why none of them complete the activity optimally. Once the user hold the tap over one object, it takes less than a second to presented a colored-transparent square that covers the object, then it is enabled to be moved. At first, users were asked to move certain object in a straight line and place in a previously located square. In general, all three levels of difficulty involve moving an object to a predefined place by following the indicated trajectory. The most common mistakes made in *hold and drag* gesture were trying to move the object without *hold*, and stop holding in the way to the final position. Sometimes, users lift the finger in the middle of the trajectory; they were asked to do it again but without releasing the object. Only those users that did not make this mistake were tabulated as *optimally* completed. All results are shown in table 7.

Table 7. Results for hold and drag

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	0%	0%	0%
Percentage of users who completed the task without any help	0%	0%	0%
Percentage of users that acquired the ability to complete task successfully after certain time frame	50%	50%	40%
Percentage of users that decrease in task errors made over certain time interval	50%	50%	40%
Average time until user completes a certain task successfully (secs.)	10.5	33.6	15.6

4.5.6 *Rotate*

In general, users can do *pinch*, *spread*, and *rotate* with two fingers of one hand or with one finger of each hand. Both ways of doing these gestures was shown to users, when users seem to have troubles with one way; then were asked to do it in the other way. Optimally data was record when users made it with one of the two options, even if fail with the first one. Users were asked to rotate a picture with no restrictions, and then were asked to rotate 90° and 180° a picture. Pictures involve single images of simple objects, animals and fruits that were easy understandable not only their contents but their position, this was verified by experts. The application used for these activities restricts the exact position of the picture, no help is on positioning. Sometimes users achieve the goal of the activities but taking various steps, first rotating the picture 90°, stopping, replacing hands and rotating another 90°; these users were not taken into account as *optimally completed*. All results for this gesture are shown in next table:

Table 8. Results for Rotate

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	80%	60%	40%
Percentage of users who completed the task without any help	80%	80%	90%
Percentage of users that acquired the ability to complete task successfully after certain time frame	100%	100%	100%
Percentage of users that decrease in task errors made over certain time interval	100%	100%	100%
Average time until user completes a certain task successfully (secs.)	N. M.	4.5	5.6

4.5.7 *Pinch*

After a brief explanation of making the *pinch* and the *spread* gestures over a picture, user was asked to do it. Once he/she understand both gestures in general, particular activities to each were asked to be done. Users were asked to zoom-out a picture as it can be done in order to test the continuous *pinching* over one point, and then were asked to increase the speed: next picture, more speed. Once the gesture was understood, it was easy for users to make multiple gestures slowly; but when speed factor entered, mistakes begin to happen. Common mistakes when users tried to do multiple *pinch* rapidly were: undetected gesture, undecireble *swipe*, *spread*, and *rotate* gestures. Results are shown in table 9.

Table 9. Results for Pinch

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	60%	20%	0%
Percentage of users who completed the task without any help	70%	60%	40%
Percentage of users that acquired the ability to complete task successfully after certain time frame	90%	80%	80%
Percentage of users that decrease in task errors made over certain time interval	90%	80%	80%
Average time until user completes a certain task successfully (secs.)	N. M.	15.5	5.4

4.5.8 *Spread*

Pinch and *spread* gestures cannot be explain to users in separated activities, since they involves related movements of fingers and produce very similar results in the test application. Nevertheless, activities for each gesture were applied separately. Activities involved *zooming-in* basic pictures, reach the maximum size of it by making continuous *spread* gestures, and do it with speed. Results shown in table 10 denote that it is a little more difficult to DS users to make, rapidly and continuously, the *spread* gesture than the *pinch* gesture, probably because *pinch* movement is more commonly used in real life than it is *spread.* Users have the same errors at advanced level as they have in pinch: undetected gestures and mistake gestures.

Table 10. Results for Spread

Level / Factor	Basic	Intermediate	Advanced
Percentage of users who completed the task optimally	70%	20%	0%
Percentage of users who completed the task without any help	70%	60%	20%
Percentage of users that acquired the ability to complete task successfully after certain time frame	90%	80%	40%
Percentage of users that decrease in task errors made over certain time interval	90%	80%	40%
Average time until user completes a certain task successfully (secs.)	N. M.	17.6	6

By calculating the joint probability between the three levels of difficulty of all the first four factors, the probability that one individual succeed in at least one factor (independently of the level) is shown in Figure 10. With this graphic, it is easy to identify which gestures are difficult and which are not.

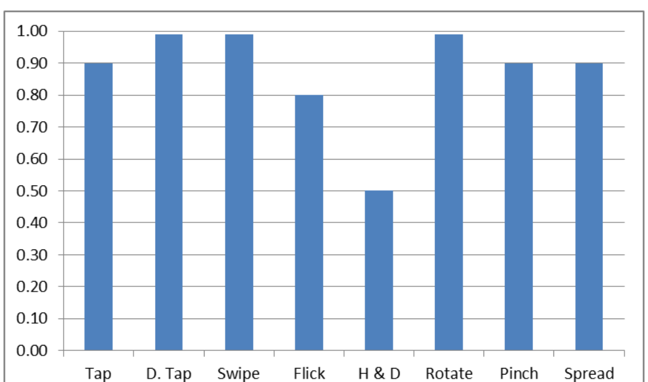

Figure 10. Probability of success on each gesture

5. Conclusions

People with DS commonly have problems with fine motor skills (coordination, manipulation), skills required to interact with any mobile/gestural interface. It was found that there are some gestures that are simple and very understandable by DS users, but others are still hard to discover, learn and apply. Interfaces where this fact is not considered on their design will diminish the user's performance.

Tap gesture, for example, is the most basic and simple gesture; for DS users it was evident how to make a *tap* over an interface object with great performance and almost no trouble; but due to the common visual problems in DS users, plus the characteristics of hands and fingers (see part 2) it turns to be difficult for them to make *tap* gesture over the tiny ones. These factors affect the same way the development of *double-tap* gesture.

It was also evident the usage of *swipe* gesture when used in a normal way. When DS users were asked to *swipe* continuously and rapidly, they tend to make mistakes.

It turned out that *flick* is one of the most difficult gestures to make, especially when users were asked to stop the slide. It requires great eye- hand coordination that becomes a real challenge to them.

There were some troubles with *Hold and drag* gesture, but only when the required time for hold was too long. The default time of new systems such as Android 5.0.1 works just fine.

The last three gestures, *rotate*, *pinch* and *spread*, did not present greatest troubles in the basic actions. Errors appeared when users start to mix them and repeat them continuously. Along with *flick* gesture, they required a more extended explanation than the first four, to be completely understood by users.

Based on these findings, the next recommendations are proposed:

- For very-first-timers users, require only simple gestures that involve one simple movement, trigger only one evident and distinguishable action, and that go according to real life, not only for their movement but also for their action that trigger.
- Add a flexible error handling rule for gestures considering that users may accidentally make undesirable gestures.
- Avoid, as much as possible, gestures that involves great eye-hand coordination such as *flick*, especially for novice users.
- Avoid little tiny selectable objects even for expert users.

These recommendations do not tend to asseverate that DS users could not be able to use some robust mobile interfaces; with the proper capacitation plan, users can understand, use, and even master almost any activity, in fact, throughout the study, all users increase their performance as they use the mobile devices.

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Multi-touch Technology in Early Childhood: Current Trends and Future Challenges

Vicente Nacher, Javier Jaen
ISSI Group, Dpto. Sistemas Informáticos y Computación
Universitat Politècnica de València.
vnacher@dsic.upv.es fjaen@upv.es

ABSTRACT
The advantages of the direct manipulation style make the multi-touch technology an ideal mechanism to support learning activities for children. Moreover, although pre-kindergarten children are becoming frequent users of the technology little work has been done in the area to assess their actual abilities. This paper goes over the state of the art of multi-touch technology targeting pre-kindergarten children and its use for educational purposes. In addition, in this work we present future challenges that should be faced in the area in the near future to establish the basis on which designers will develop educational applications for children that fully exploit the multi-touch technology according to the actual abilities of pre-kindergarten children.

Categories and Subject Descriptors
H.5.2. [Information interfaces and presentation]: User Interfaces - Interaction Styles.

General Terms
Performance, Design, Experimentation, Human Factors, Standardization.

Keywords
Multi-touch interaction; pre-kindergarten children; gestures; future challenges

1. INTRODUCTION
Multi-touch technology has rapidly evolved in recent decades and nowadays it has widespread acceptance [5] because it provides users with a more natural and intuitive way to interact [23]. As pointed out in [7] children between zero and eight years old are frequent users of digital media in the USA and they meet with touch technology often before they can even speak. Supporting these ideas the Horizon report [12] places mobile devices, such as tablets and smartphones, as one of the two emerging technologies suitable for children aged under 2 years.

The three basic ideas behind the direct manipulation concept were listed by Shneiderman and Plaisant [21]: (1) the visibility of objects and actions of interest; (2) the replacement of typed commands by pointing-actions on objects of interest; and (3) the rapid, reversible and incremental actions that help children to keep engaged, giving them control over the technology and avoiding complex instructions.

A detailed analysis of applications in the Apple store made by Shuler [22] reveals the growing use of educational applications for children based on touch devices. This is specially the case for preschool children (Figure 11) who were the target users of nearly 60% of these applications by 2011.

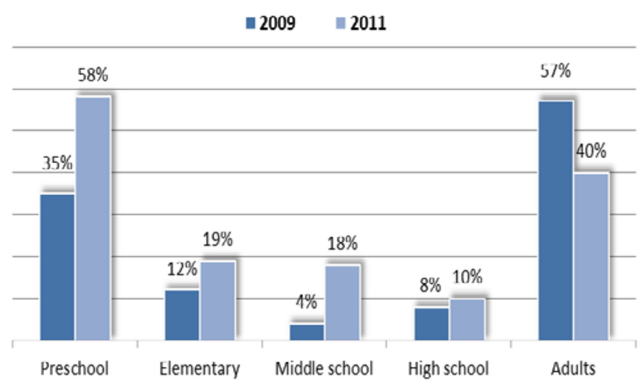

Figure 11. Target age 2009 vs 2011 for Education cat. in the Apple Store [22].

However, the increasing interest in multi-touch technology has not given rise to studies on the design of multi-touch systems for the youngest age range [10]. Moreover, the lack of standardized and universally accepted interactions for these challenging users makes the design of well-designed multi-touch interactions even more crucial [11].

According to these facts, in this paper we carry out a review of the current state of the literature of multi-touch technology with pre-kindergarten children and provide a set of future challenges to be addressed in the future. The end goal is to define a research agenda to make this technology usable by pre-kindergarten children and give application designers the necessary guidelines to develop touch applications according to the actual skills of pre-kindergarten children.

2. STATE OF THE ART
Until very recently, there have been no research efforts addressing multi-touch interaction with pre-kindergarten children (aged less than three years). Possibly this has been the case because age is a limiting factor for experimental studies; young children do not have the verbal and cognitive skills to express their likes and preferences [15] and, they are not able to carry out tasks for long periods or are easily distracted [8]. However, according to Piaget [19], children are in a preoperational stage from 2 years old onwards, i.e., they begin to think in terms of images and symbols, and develop symbolic play with imaginary objects, which means they could be candidates for multi-touch technology. In addition, being aware of children developmental abilities is critical when designing software for the very young [26].

This has motivated recent studies that assess the abilities of pre-kindergarten children to perform basic touch gestures. The work by Nacher et al [18] reveals that the advantages and features of multi-touch technology is not being fully exploited in existing commercial applications since only the drag and tap gestures are being used and no support for collaboration is given. Hence, the work evaluates a set of basic touch gestures with children aged from two to three years (Figure 12) concluding that even these young users are able to perform a set of basic touch gestures such as tap, drag, scale (up & down) and one finger rotation. In addition, in this work a set of design guidelines is proposed to deal with complex gestures such as double tap and long pressed. These assisted strategies were evaluated later in [16] and results show that even these more complex gestures can be successfully performed by pre-kindergarten children with basic assistance.

Figure 12. Examples of scale up and drag tests (extracted from[18]**).**

In the experimental studies in [1, 2] four applications are considered and the interaction needed to play with them is evaluated. The gestures under test are the tap, drag, rotate, drag and drop, pinch, spread and flick and the experiment involves children aged 2 to 4 years. According to the results, the authors conclude that children aged four are able to perform all the evaluated gestures. Those aged three only find problematic the spread task. Finally, those aged two are able to perform the tap and drag gestures properly, learn quickly the flick gesture but they are less effective with the more complex gestures such as drag and drop and pinch.

Another interesting study is the work of Vatavu et al [24] who evaluate touch gestures with children between 3 and 6 years using tablets and mobile devices. They conclude that despite there is a significant performance growth with age, in general, children have good performance with the tap, double tap and single hand drag and drop gestures. However, in the case of the double hand drag and drop gesture (see Figure 13) they do not reach these good results and the success rate drops to 53.7%. In addition, authors correlate the results with a sensorimotor evaluation based on children's finger dexterity and their graphomotor and visuospatial processing abilities. The correlation shows that children with higher visuospatial skills (i.e. having better skills for understanding relationships between objects, as location and directionality) perform better in the drag and drop tasks. Furthermore, the study also reveals that children with more developed visuospatial skills tap closer to the center of targets in the tap and double tap tasks since they have a better understanding of the targets' geometries.

Figure 13. Child performing double drag gestures (extracted from [24]**).**

Usability is not the only dimension that has been addressed by recent studies in the field. Another topic of interest is that of communicability when pre-kindergarten children are considered. The work in [17] report a first approach to evaluate mechanisms for applications to communicate pre-kindergarten children the expected multi-touch gestures at a given moment. In this study, the authors present and evaluate two visual approaches (iconic and animated) to communicate touch gestures (see Figure 14). Three touch gestures are considered: the tap representing in-place gestures (i.e. those in which the hand does not actually describe a trajectory but taps at a very specific pace or in a specific way); the drag representing one-contact point gestures that require a movement following a specific trajectory; and the scale up gesture representing two-contact point gestures that require movement. The results show, firstly, that none of the evaluated languages is effective to communicate in-place gestures and, secondly, that the animated approach overcomes the iconic one for gestures that require movement of contacts reaching success rates above 85%. This fact suggests that even pre-kindergarten children are able to interpret the direct mapping between the visual stimuli (i.e. a hand sliding on the surface) and the gesture to be performed. Therefore, this work suggests that visual languages could be an effective way to enable pre-kindergarten children autonomous interaction.

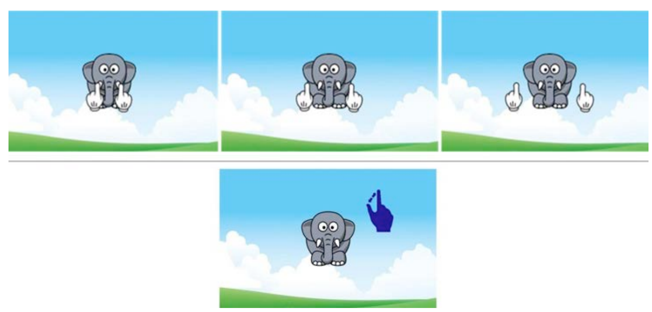

Figure 14. Description of the animated visual (top) and the iconic (bottom) language for the scale up gesture (extracted from [17]**).**

Exploring the educational dimension and the suitability of multi-touch surfaces to support educational activities there are several works that strengthen the idea that this technology provides benefits for pre-kindergarten children education. For example, the work by Bebell et al [4] shows a nine week study comparing the improvement of kindergarten children taking early literacy lessons when using tablets for learning or using a traditional non-technological method. Their results show that the group that learned with tablets scored higher on early literacy assessments, particularly these higher scores are present in the ability to recognize sounds and represent sounds and letters. Following the same line, Chiong and Shuler [6] conduct an experiment involving touch devices and audiovisual material adapted to children aged three to seven years and their results show that children obtain remarkable gains in vocabulary and phonological awareness. Moreover, Knoche et al [14] point out that the interaction of children aged between 16 and 33 months with interactive elements in a tablet does not reduce their comments in dialogic reading activities. Another example is provided by Zaranis et al [27] who conduct an experiment to study the effectiveness of digital activities on smart mobile devices (tablets) to teach mathematical concepts such as general knowledge of numbers, efficient counting, sorting and matching with kindergarten children. Their results show that the tablet-aided learning provided better learning outcomes for the students than the traditional teaching method. Kammer et al [13] present three applications to foster the development of cognitive and motor skills on a multi-touch tabletop with children aged from four to six years. The conducted experiment shows that even preschool children are able to use this technology and they enjoy the task and collaborate in the multi-user activity.

The results of these works suggest that pre-kindergarten children are prepared to use multi-touch technology and the intuitive and natural interaction of direct manipulation style of the multi-touch technology makes it ideal to support pre-kindergarten children interaction and, hence, educational activities targeted to them. Moreover, these works conclude that these particular users are able to perform a set of touch gestures successfully and future applications designed for them do not need to be restricted to only basic interactions such as the drag and tap gestures. However, these works reveal that there is no consensus or standardization of the multi-touch interaction style for users in these early ages.

3. FUTURE CHALLENGES

In this section we present a compilation of future works that we consider interesting and necessary to complete the literature and shed light on the specific needs of pre-kindergarten children when using multi-touch technology.

On the one hand, according to Hinrichs and Carpendale [9] who point out that there is evidence that some events are affected by previous and subsequent ones and given that all the analyzed studies consider and evaluate the gestures in isolation, an interesting strand of future work would be to evaluate these same gestures that pre-kindergarten can do in isolation but when several interactive elements are shown simultaneously. Users should perform different preset sequences of these gestures in order to determine whether the cluttering of elements in the interaction or the task chaining affect their performance. These results will help to develop more complex applications which are not restricted to only one possible interaction in each phase of the game.

Another interesting issue that remains to be addressed is the processing of the unexpected touch events when children are holding the tablet with a finger resting on the display or when part of the palm also touches the surface. This issue is difficult to address because children may not be aware of such unintentional contacts with other parts of their body when their fingers approach the screen resulting in an unexpected effect. It would therefore be interesting to explore potential improvements in multi-touch usability, for instance by determining and filtering out unexpected blob contacts wherever applicable.

Addressing the topic of the definition of effective mechanisms to communicate which actions are expected from the user; and taking as a starting point the work in [17], there is still a great deal of work to do to assess the best approaches. This preliminary study points out that animated languages can be effective to communicate touch gestures to pre-kindergarten children and help them to be autonomous when using the multi-touch devices. However, as pointed out by the authors, only three gestures were evaluated, hence, it remains to be evaluated whether the inclusion of additional gestures has an impact on the overall performance and effectiveness of the languages. Moreover, the gestures were tested in isolation; therefore, languages should be studied when the interaction area is cluttered with many touchable elements and their corresponding visual cues or with elements that may be manipulated with several different gestures. With respect to communicability of touch gestures, another possible future work can be the evaluation of other languages both iconic and animated in order to find out which type of language fits better to communicate touch gestures to infants. In addition, an interesting future work could be to design and evaluate a similar approach to the method used by Balonian et al [3] for children between five and six years old. In this work, each gesture was associated to a specific character in a way that the gestures were "recallable". Metaphors such as a walking ladybug for a drag gesture or a jumping grasshopper for a double tap were used. Finding suitable metaphors that pre-kindergarten children can understand could be very useful to develop autonomous educational applications.

The studies in the literature point out that pre-kindergarten children have the necessary skills to make use of multi-touch technology. However, these works implement assistive techniques to deal with precision issues during the initiation and termination phases of gestures since they assume that pre-kindergarten children are no able to perform the gestures with high accuracy. This causes that the implemented interaction styles do not allow children to have the control over the termination of the gestures despite they are in the process of developing their motor skills and some of them may have already the proper cognitive abilities to perform the gestures with higher levels of precision. As a result, existing applications designed under these assumptions do not benefit from the use of multi-touch technology to help children to develop their precision-related cognitive and motor skills. According to this observation it would be interesting to evaluate dynamic gestures (those that require movement of contacts over the surface) demanding high levels of accuracy to users, specifically, it would be interesting to evaluate how accurately they can rotate an object, how close they can drag an object to a target and whether they are able to perform scaling gestures (up and down) with enough accuracy to stop the stroke of the gesture in a specific moment to reach a desired size. This would certainly help in understanding the limitations on accuracy that should be fulfilled in applications targeting pre-kindergarten children. In addition, the data collected during the experimentation could be used to develop assistive strategies to deal with precision issues in an adaptive way for the users that actually need it and not in an exhaustive way for every child as current systems do.

Finally, once known the actual capabilities and abilities of pre-kindergarten children, the gestures that they can perform, the accuracy that they can achieve and evaluated the communicative strategies suitable for them; interesting future works could be developed for the definition, construction and evaluation of environments based on multi-touch technology that foster creativity and allow collaboration between peers. These environments could be integrated into classrooms and be used with educational purposes to allow children to develop their creativity skills and allow educators to monitor the progress of their students and create appropriate content for them. As Rushton [20] points out, the creation of classroom environments that enhance students expression and selection opportunities provides a proper atmosphere towards helping children to learn at their own pace. A starting point could be taking advance of (1) the portability of tablets that allow children and teachers to use various locations in the classroom enabling the creativity and collaboration of small groups of children; and (2) the more sophisticated interface of tablets that allows both individual and mutual interaction between two or more users [25].

4. CONCLUSIONS

The contributions of this paper are twofold; firstly, a review of the state of the art of multi-touch technology for pre-kindergarten children was made. The literature suggests that the use of this technology is an ideal way to develop applications for these very young users. In addition, the presented studies show that pre-kindergarten children are able to perform more touch gestures than could be expected when analyzing existing commercial applications. On the other hand, pre-kindergarten children are developing their motor skills and, hence, in order to use the multi-touch technology, designers should be aware of the actual capabilities of children when developing interfaces for them. The second contribution is a collection of future challenges to be faced in the near future when building multi-touch technology for preschool children. These challenges are related to communicability, adaptability and usability of multi-touch applications designed for these challenging users. We hope that the usability studies and design guidelines compiled from these works and the future challenges discussed in this paper will allow designers of future applications for pre-kindergarten children to fully exploit the potential of multi-touch technology to support their cognitive and motor development.

5. ACKNOWLEDGMENTS

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Vibrotactile Vest and *The Humming Wall*: “I like the hand down my spine”

Ann Morrison
Department of Architecture, Design and Media Technology,
Aalborg University
Rendsburggade 14,
9000, Aalborg, DENMARK
morrison@create.aau.dk

Cristina Manresa-Yee
Department of Mathematics and Computer Science
Universitat de les Illes Balears
Crta. Valldemossa km 7.5
07122, Palma, SPAIN
cristina.manresa@uib.es

Hendrik Knoche
Department of Architecture, Design and Media Technology,
Aalborg University
Rendsburggade 14,
9000, Aalborg, DENMARK
hk@create.aau.dk

ABSTRACT
Vibrotactile information can be used to elicit sensations and encourage particular user body movements. We designed a vibrotactile vest with physiological monitoring that interacts with a vibroacoustic urban environment, *The Humming Wall*. In this paper, we describe the first field trial with the system held over a 5-week period in an urban park. We depict the participants' experience, engagement and impressions while wearing the vibrotactile vest and interacting with the wall. We contribute with positive responses to novel interactions between the responsive environment and the vibrotactile vest, with a system designed to calm, activate, guide and warn the participants.

Categories and Subject Descriptors
H.5.2. Information interfaces and presentation: User interfaces.

General Terms
Design, Human Factors, Measurement

Keywords
Wearable computing; Vibrotactile; The Humming Wall; Audio vibrations; Haptic patterns; Sensations; Vibroacoustics

1. INTRODUCTION
Touch is highly connected to our emotions [1] and vibrotactile cues can cause different sensations (e.g. calming, pain) depending on factors such as frequency or rhythm [2, 3]. Further, touch is a powerful communication channel that is not used as frequently as sight or hearing. By structuring vibrotactile patterns, we can build a vibrotactile language to convey information for different applications such as enhancing communication [4] or helping to perceive the interlocutor's facial expression [5]. We are especially interested in those works using vibrotactile cues working with whole body navigational cues and instigating body motion as well as vibrations used for activation/calming purposes.

Working with a kinesiologist-neurophysiologist, we designed novel placement and patterns for vibrotactile actuators on the body to activate, guide, warn and to emulate natural touch sensations such as stroking up or down the back to relax a person—'there, there, it's okay'.

In order to enrich and yield a positive experience for the vest wearer, we built a responsive urban environment *The Humming Wall*, designed to enrich participants experience with the environment and invite open-ended, embodied and playful interactions [6-8]. *The Humming Wall* is a 12 x 3.5 x 2.7 meter (long x wide x high) vibroacoustic wall (see Fig.1) with a calming low-level hum. The curving wall is designed for general public use and is placed in Utzon Park (Aalborg, Denmark), with seating at each end on both sides (that also act as wind protection).

For the vest wearer though, the interactive experience is unique. Several actions performed on the wall (knocks, a swipe action downwards, upwards; sideways left to right, right to left) are replicated in actuators vibrating in the vest. Further, people feel, see and hear their own heartbeat in one zone of the wall and feel and hear their own breath in another.

The aim of this work is to describe participant experience and engagement with the paired tactile interaction between vest and wall, evaluated in field trials held over a 5-week period in an urban park with 39 people. As this was the first execution of these paired vibro-tactile-acoustic systems, we kept the interaction paradigms relatively simple.

The paper is structured as follows: Section 2 compiles works on vibrotactile interfaces related to activation, navigation and calming purposes as well as responsive environments. Section 3 describes the design of the vest and *The Humming Wall*. Section 4 presents the evaluation and section 5, the results of the field trial. Finally, we summarise the findings and discuss their implications.

Figure 1. General public at the wall, hearing and feeling the vibration and playing with the wall

2. RELATED WORK
Work related to the vibrotactile vest and *The Humming Wall* includes (i) vibrotactile languages working with whole body navigational cues and instigating body motion, (ii) vibrotactile interfaces initiating activating/calming sensations and (iii) responsive vibroacoustic environments in public spaces where visual is not the privileged sense. As we cannot cover all of these in detail here, we cover an abridged version.

In order to motivate and improve motor skills, Spelmezan et al. [9] developed a tactile language to assist athletes to improve their motor skills in snowboarding. In this line of work, McDaniel et al. [10] proposed a framework, MOVeMENT (Mapping Of Vibrations to moveMENT), that used vibrotactile stimulation to teach motor skills and to motivate fundamental movements (flexion, extension, abduction, adduction and rotation). Further, Rosenthal et al. [11] presented a belt to provide vibrotactile spatio-temporal patterns to teach choreographed dance. Morelli et al [12] and Yuan and Folmer [13] also used vibrotactile cues to inform users with sight loss or blindness to carry out certain movements to play videogames.

Several research projects use vibrotactile cues for navigation. Tsukada et al. [14] designed a belt that transmits directional information. Van Erp et al. [15] also tested a directional belt but with different distance-coding schemes. Other wearable supports have been used, such as the Vibrotactile Glove [16] that offered users with disabilities information by indicating warning signals, spatial representation, and directional guidance using a glove.

Vibrations have been used for therapies to generate soothing and calming sensations to users. Vaucelle et al. [17] presented Touch Me, a flexible vibrotactile motor array in a soft enclosure that can be applied to large areas of the body and remotely actuated by a care-giver through a remote switch array to provide soothing touch simulation over an entire part of the body. Paredes and Chan [18] employed two vibrotactile motors in a bracelet that stimulates acupressure points in the wrists and the chest (when the wrist is held to the sternum) to reduce stress. And using the same bracelet, they coached participants to breathe according to well-known deep-breathing techniques. Arafsha et al [19] designed a haptic jacket to enhance comfort with 6 affective haptic components: chest and neck vibration, neck warmth, heartbeat simulation, arms vibration and shivering.

Prior work on responsive vibroacoustic environments in public spaces for developing embodied, multi-user interactive experiences include works such as MEDIATE, an environment that uses real time visual, aural and vibrotactile stimuli both for sensing and giving feedback for education with autistic children [20] or ListenTree, an audio-haptic display embedded in a tree in a natural environment. A visitor notices a faint sound that appears to emerge from a tree, and feels a slight vibration under their feet as they approach. Future versions will add touch input to achieve a more responsive installation [21].

3. THE SYSTEMS

There are two systems. First, a vibrotactile vest which produces vest-to-human interactions as felt sensations for the wearer. Second, *The Humming Wall* produces two types of human-to-Wall-to-human interactions, one type between the vest wearer and the wall and the other enables interaction between non-vest wearers-to-vest wearers via the wall and also interactions for non-vest wearers with the wall itself.

3.1 Vibrotactile vest

The vest is made of two layers, an inner layer consisting of one-size-fits all adjustable harness (see Fig. 2a, 2b) and an outer layer consisting of an enclosing vest (See Fig. 2c). The harness houses 32 actuators, moveable to ensure they are placed exactly on each different shaped body. The lower harness fits around the legs, to safeguard that the harness stays pulled down and keeps the actuators in place while the participants move around. The actuators are operated in overlapping patterns to provide different haptic synesthesia sensations such as sense of movement, shiver and states of activation and/or calming as well as providing navigational cues. We explored the positioning and combinations of the actuators with a kinesiologist trained in neurophysiology.

Figure 2. The vibrotactile vest: adjustable harness (a) front and (b) back and (c) outer shell and skirt-apron.

For the initial patterns, 29 actuators were used (see Fig. 3). These patterns try to emulate the hands on work that a kinesiologist-neurophysiologist does in activating sequential points of the body. In addition, we emulated the natural touching we give each other for calming-comforting (e.g. stroking the back to calm or comfort a person), guidance-navigation (e.g. placing hands on nape of back and shoulder as if to support and guide an elder) or information-instruction (e.g. stopping the body with pulses to the solar plexus). The reader is directed to [22] for a more detailed description of the patterns.

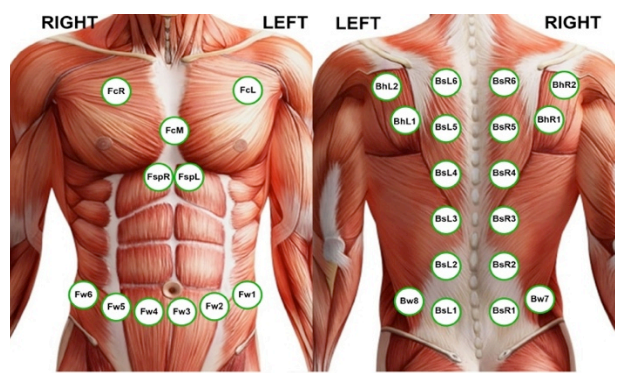

Figure 3. Placement of actuators

In Table 1, examples of patterns are described. Ten patterns were designed:

- Calming: *Up, Down,*
- FeelGood: *WaistLeftToRight, WaistRightToLeft, MidFrontToBack*
- Activation: S*hiver, Tarzan*
- Navigation: T*urnLeft, TurnRight*

- Warning: *Stop*

The Zephyr BioHarness 3 [23] is integrated into the harness and vest system to read the physiological state of the wearer in real-time, specifically their heartbeat and breath rate. Two custom-made electronic boards are also included in the wearable system: one controls communication and the other powers and controls the actuators.

Table 1. Examples of patterns

Actions	Pattern
Activating: Tarzan	4x(FcL, FcR), pause, FcM
Calming: down	(BsL6, BsR6), (BsL5, BsR5), (BsL4, BsR4), (BsL3, BsR3), (BsL2, BsR2), (BsL1, BsR1)
Navigating: turn left	Bw7, (BhR1, BhR2), (Fw3, Fw2), (Fw2, Fw1), (Fw1, Bw8)
Alert: Stop	(FspL, FspR)

The outer shell, made in 3 adjustable sizes, is a padded layered stretchable vest designed to keep the actuators tightly in place against the bowed areas of the body, especially the lower back and chest, so the vibrations are evenly felt in all areas. We offered an adjustable skirt-apron for the sake of modesty and/or aesthetics, particularly for those wearing dresses.

3.2 The Humming Wall

A 12m long, 3.5m wide and 2.7m high was cut from EPS150 foam blocks with a hot wire and glued together to form 11 segments. Each segment is coated with a PolyUrea coating for strength and durability. The wall is fitted with an array of 2-channel DMX controlled warm and cold white lights. These lights are used for ambient and indicative visual effects on the wall. An array of tactile transducers placed in the wall generates different haptic sensations, audio cues and haptic feedback. Each segment has an 80W Bass-Shaker mounted with a frequency range suitable for haptic and audio feedback, and amplified so that each segment functions as a vibrating speaker. *The Humming Wall* has its own baseline vibration and audible hum. A combination of piezo- and capacitive electronics to read and analyse touches, enables the differentiation of knocking (or tapping) and swiping gestures.

The wall is divided into five zones that interact with different input from the data registered in the vest or from gestures done on the wall and trigger different output in the wall and on the vest simultaneously. In the two seating areas, the physiological data from the vest is relayed to the wall:

a) *Heartbeat*—displayed as audio, vibration and light (at the same beat) in the wall (Fig. 4a).

b) *Breath rate*—displayed as audio and vibration in the wall (Fig. 4e).

Then, there are three zones where sensations relayed at the wall are transferred to the vest:

c) *Knock*—3 panels respond to knocking with audio and vibration in the wall and knocks are felt in individual actuators of the vest. Right panel knocks are transferred to the right side of the body—front and waist; middle panel transferred to the back; and Left panel transferred to left side of the body—front and waist (Fig. 4c).

d) *Swipe*—3 panels that respond to up, down, left and right gestures. These played as audio and vibration at the wall with a corresponding gesture played on the vest—e.g. swiped up or down the back and swiped across the waist—left to right or right to left—depending on direction of gesture (Fig. 4d).

e) *Knock & Swipe*—5 panels that respond to knock and swipe at the wall and on the vest. The swipe gestures run along the 5 sections with audio, vibration and lights. The knocks are relayed alternatively to all actuators and felt all over the body. Knocking on two panels activated two actuators at once, knocking on three activated three actuators (Fig. 4b).

The wall was placed in an outside environment at Utzon Park (Aalborg, Denmark) between two of Utzon's architectural structures, the Utzon Center and Utzon student housing, and encompasses Utzon's aesthetics and design principles. The design includes harmonious modular repeating segments with internal voids large enough for arms to access electronics and cables to enable interactivity, serving both the aesthetics and pragmatics.

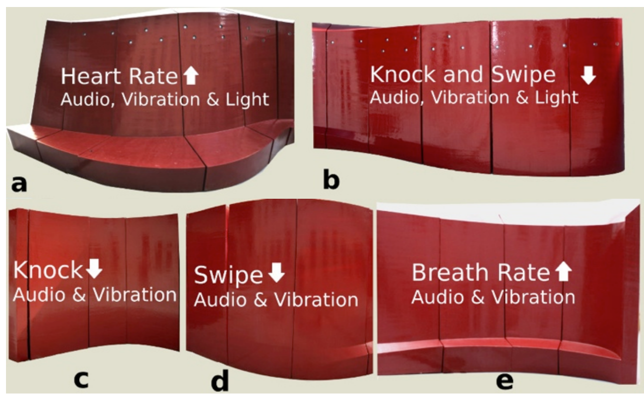

Figure 4. a) Heartbeat: Vest transmits to Wall; Audio, Vibration and Light emulate vest wearers heartbeat at wall. (b) Knock and Swipe: Wall transmits to Vest; Audio, Vibration and Light respond to knock and swipe. (c) Knock: Wall to Vest (d) Swipe: Wall to Vest (e) Breath Rate: Vest to wall

4. EVALUATION

To evaluate the tactile interaction, people were invited to participate in pairs asking a familiar, friend or partner to take part with them, as early tests proved the interaction was best done in pairs and personal. The trial was held over an extended period of 5 weeks from June 23-July 25, 2014. The duration of the trials per pair took between 1.5 to 4 hours, averaging 2.5 hours per pair. The initial programmed 3-week period proved too short given emergent circumstances and the programmed 2 hours for each set of paired participants was not enough time as we constantly had to push-rush the participants to move onto the next zone. Subsequently, from participant 16 onwards, participants were told there were 7 activities and they could either choose their own timing or we could prompt. All chose to set their own timing.

4.1 The Participants

We enlisted 39 volunteers with ages from 12 to 65 years (average age 39), 20 females and 19 males. 19 participated in mixed gender groups, 11 in female/female and 9 in male/male groups (uneven numbers are due to only one participant from a pair wearing the vest). Most people took part with close or good friends (11), their partners (10), colleagues (10), family members (5), or social friends or acquaintances (3). 22 self reported basic or average IT skills with 17 advanced or above. 28 spent on average more than 20 hours on a computer each week and 12 enjoyed playing a musical instrument regularly. 31 had tertiary level qualifications with 14 knowledgeable about wearable technology.

4.2 Procedure and venues

Each pair of participants was accompanied throughout the trial by two researchers and all sessions were videoed. The trial was divided in 4 steps:

(1) Utzon Library Fitting: fitting was done in a side room of the Utzon Library with a change screen for privacy. Demographic info was collected and the BioHarness, harness and vest was fitted and tested to place correctly actuators on the body (15-35 mins).

(2) Utzon Park Patterns: participants were guided by a researcher and introduced to the ten vibration patterns 3 times while asked to talk aloud their responses to the sensations. Then participants and researchers stopped, each vibration pattern was played again and responses discussed again (10-15 mins).

(3) *The Humming Wall* Interaction: participants interacted with 5 zones of activity (with 2 of the zones repeat visits = 7 total activities) at *The Humming Wall*. The participants moved clockwise around the wall from one zone to the next. The activities were: (1) heartbeat, (2) knock, (3) breath rate, (4) swipe (5) 2nd visit to breath, (6) knock & swipe and (7) 2nd visit to heartbeat (20-90 mins).

(4) Utzon Library Evaluation: participants took off the vest, filled in questionnaires and undertook semi-structured interviews (15-40 mins).

4.3 Data Collection and Processing

Data was gathered using quantitative and qualitative methods. Before the trial, the participants filled in informed consent forms and a demographic questionnaire with questions on fitness levels, their general IT level and experience with vibrotactile technology, embodied interaction, large public displays and playing musical instruments. Activity data was logged for each participant from the actuators and from the BioHarness, the heartbeat and breath rate. The actions done on the wall were also registered, knocking and swiping, together with the segment and direction and the time spent in each zone.

After walking around the wall, participants completed shortened adapted versions of questions from MEC Spatial Presence Questionnaire (MEC-SPQ) [24], Flow State Scale (FSS) [25] and Intrinsic Motivation Inventory (IMI) [26], to gauge reactions to the sensations in the vest and the interaction with *The Humming Wall*. The questionnaires comprised 21 Likert-type items to analyse and cross-check users' perceptions. For Presence, we measured concentration, errors, activated thinking, and imagining space. For IMI, we measured interest/enjoyment, perceived competence, pressure/tension, and effort/importance. For Flow, we measured challenge-skills balance, goals, concentration on task, and sense of control. The overall experience was measured through 10 semantic differential scale items (See Table 2). Lastly, each participant described their experience, highlighting chosen aspects in semi-structured recorded interviews.

Data post-processing tasks included transcribing user interviews and translating them into English for further analysis. Videos were cut into manageable chunks and coded focusing on where activities and interactions occurred. We transcribed the talk aloud responses of the participants to each vibration and coded them numerically. For each zone we measured the amount of time the participants spent, coded to what degree they explored the interrelation of knocking and swiping on the wall and corresponding sensations for the vest wearer.

We used 5 level Likert-type scales (from completely disagree to completely agree) to measure items adopted from IMI, FSS and MEC-SPQ. The levels of agreement were mapped to values from 1 to 5. The semantic differential scale items featured 5 numerical levels with the differential labels at the extreme values (e.g. Impersonal 1,2,3,4,5 Personal).

5. RESULTS

In this section we report on findings from questionnaires, vest activity logging, video footage analysis, time spent at each section of the wall and semi-structured interviews.

5.1 Questionnaires

In Table 2 we find a summary of the results for a subset of the questions. Most responses show that users enjoyed interacting with *The Humming Wall*. Participants were relaxed when carrying out the tasks (Q19) and they found it pleasant to complete the different activities at the wall (Q2, Q16). They did not report discomfort associated with the vibrations from the wall (Q4), and most users felt that they lost track of time during the trial (Q15). When responding to the items regarding the vest, they did not feel much discomfort associated with the vibrations in the vest (Q4), they felt it was possible to be active in the surroundings (Q6) and the vest vibrations made it easier to understand the tasks and responses (Q17). In general users stated that they were concentrating on the sensations in the vest (Q1) and thought whether these sensations could be useful for other activities (Q7). Most participants found that some sensations held greater meaning than others (Q3).

Results summarising the overall experience with the vest and the wall are shown in Fig. 5. Participants reported to be relaxed and calmed even though they reported to be active as well. Further, users felt that it was a personal experience, but at the same time, they felt sociable at the installation.

When crossing results of the questionnaires with the demographic data using non-parametric Mann-Whitney tests we found the following statistically significant differences. Males agreed significantly more than females that some sensations made more sense than others but enjoyed less learning how to do the tasks suggested by the sensations. They felt less warm and personal than the women. Participants who exercised 2 or more times per week reported significantly warmer and more relaxed experiences than those exercising less. Participants with average and lower IT knowledge found the experience significantly: easier to respond to vibrations, found their understanding of the sensations improving more as the trial progressed and felt warmer and more sociable than the participants with high IT knowledge. Those participants with more experience at large displays agreed significantly more that some of the vest vibrations were uncomfortable when compared to the less experienced. Musical participants who enjoyed playing an instrument reported a different experience from participants who did not. Non-instrument players had a significantly more sociable and open experience. We found no significant differences between those with experience with embodied games, e.g. Wii, compared to those with little or none. Those less knowledgeable with vibrotactile technology enjoyed learning how to do the tasks suggested by the sensation significantly more and had a more personal experience than the savvy ones. Those knowledgeable in wearable technology reported a significantly more relaxed experience compared to those with little or no knowledge in this area.

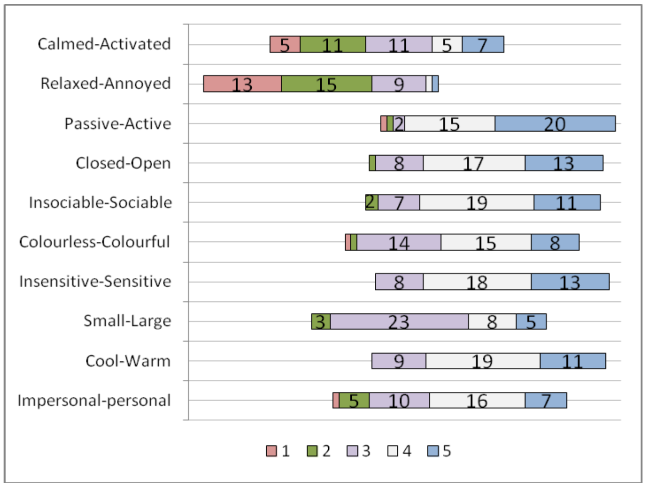

Figure 5: Overall experience results for 39 participants. Semantic differential items

5.2 Logging of wall activity at zones

As commented before, from participant 16 onwards, participants could choose their own pace. As a consequence, all interaction durations from that point at the wall lengthened with an average of 9.8 extra minutes per participant when interacting at the wall. In Fig. 6, the time spent at each zone is shown. The larger differences can be seen at Heartbeat zone 1st visit, Breath rate zone 1st visit and Knock zone when participants could decide on their timings. Participants spent more time in the physiology zones when they decided their own pace (54.8%) than in the Knocking and Swiping zones (45.2%) (Fig. 7). On average, participants deciding on their own timings stayed almost 6 extra minutes in the physiology zones and around 4 minutes more in the action zones comparing with participants that were guided.

In addition and regardless of this impact, there were two significant predictors of the time spent in the knocking and swiping zones: participants spent more there, the stronger their relationship was with their pair and if they tried to find out the mapping of the knocking to the vest. Together these factors accounted for 32% of the variance in time spent in these zones.

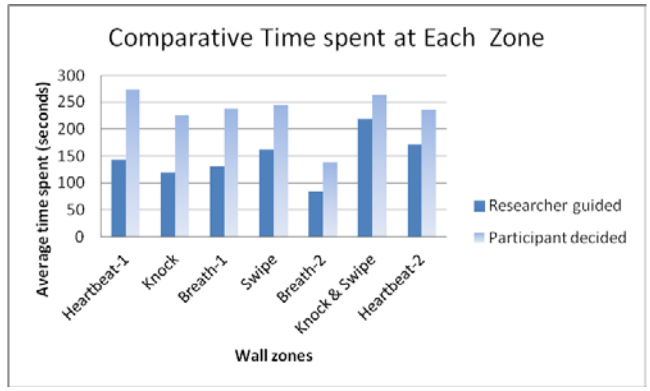

Figure 6: Comparative Times (guided or not) for Wall

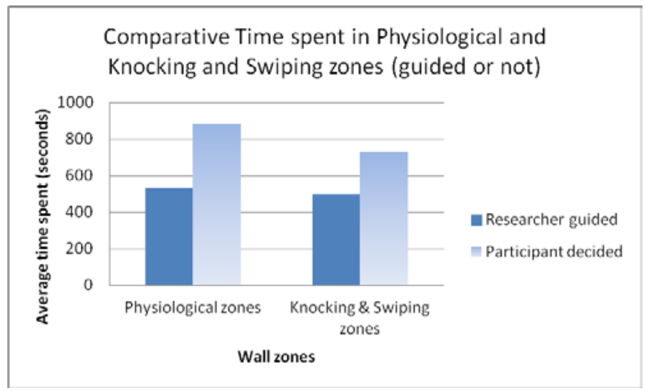

Figure 7: Comparative Time spent in Physiological and Knocking and Swiping zones (guided or not)

The total time spent in the physiology zones was significantly predicted by the following three factors in the regression analysis: participants spent more time in those zones when they could advance at their own pace, were less knowledgeable about vibrotactile technology and if they had tried to find out the mapping of the knocking to the vest. These three factors accounted for 58% of the variance in time spent in the physiology zones.

5.2.1 *Knocking*

56% of the participants tried to map knocking to the vest wearer's body. That is, they assumed a direct mapping between body and wall, e.g. that knocking higher would map closer to the head, knocking in the middle section would trigger actuators around the waist and lower would be felt in the lower back (see Fig. 8).

5.2.2 *Swiping*

The main swipe movements were up, down, left and right. However, participants also experimented with other swiping directions. 64% of the participants made waving-swipe-circular movements with one or two hands, as if massaging a back when swiping at the wall (See Fig. 9).

Figure 8. (a) Knocking at lower wall, (b) at mid wall. (c) at high wall and looking at partner to see response.

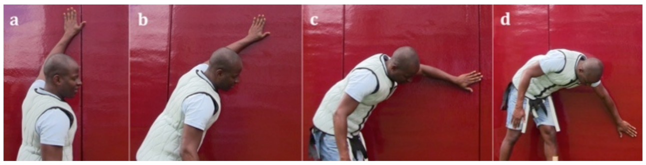

Figure 9: Participant is making circular wave style swipes

5.3 Vibration Patterns

The talk aloud responses to the 10 patterns that were registered in the Utzon Park Patterns stage were coded numerically, i.e. a response to each individual pattern was judged as either negative (-1), neutral (0) or positive (1) - see Fig. 10. We used the numerically coded responses to the 10 patterns in a non-parametric Friedman test rendering a Chi-square value of 51.9, which was significant (p<.001). Post-hoc pairwise comparisons showed that *Up*, *Down*, and *WaistRightToLeft* all were significantly more positively evaluated than all other patterns, whereas the *Tarzan*-activation pattern was significantly evaluated more negatively than all others (see Fig. 10).

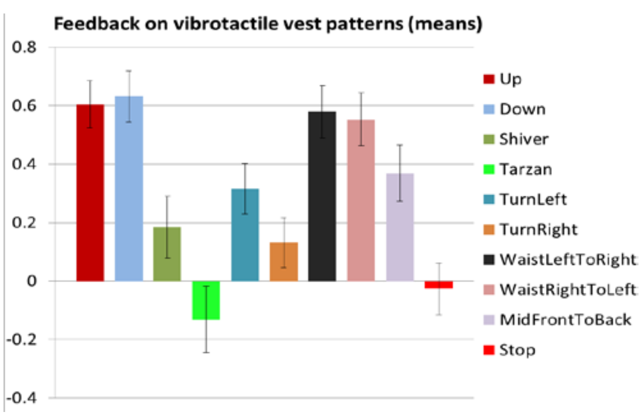

Figure 10: Means of coded responses to the vibration patterns with error bars (standard error of the mean)

5.4 Semi-structured interviews

In the semi-structured interviews we asked a series of questions, for example ‘How did you find the sensations in the vest?’ ‘Were any unpleasant?’ in order to engage and to get participants talking about their experience and express their views in their own terms. People were generally very forthcoming and the interviews lively.

Participants often describe the interactions as interesting, fun, unusual or new and different. For example, participants described the experience as ‘*Funny - different –a new experience*’; ‘*I like to try new things, so it was new to me*’. Others took some time to adjust before they felt comfortable: ‘*In the beginning it was a new feeling and it was stressful… Later I got used to it*’ and ‘*a bit scary, intimidating at start, but then more natural when I understood how it felt*’. Some tried to compare to other experiences: ‘*front vibrations felt like standing in room with loud music, connection vibrations going one side to another like being in the ocean, and then stroking hand down back*’. Others were uncertain how to discuss it, especially the whole body sensation: ‘*haven’t felt before… single vibrations from mobile… but, not all over body and flowing… not sure how to describe… is new*’. And discussed: ‘*all immersed, when all over body—could feel like me vibrating all over, especially ones on stomach*’. Others talked about it acting like a real touch: ‘*Putting up the same emotion as touch—bringing out the same sense of well-being or happiness as when somebody touches or pats or hugs you… the hug* [Shiver, Activating] *was very surprising’*.

Some of the patterns made people ticklish, especially around the waist [Waist, FeelGood], and at the sides: ‘*It was like somebody was tickling me’*. And ‘*I like the hand down my spine’* [Back, Calming] or ‘*The tickling on the side* [Waist, FeelGood]*… gave me goosebumps from the outside—like you didn't have the sensation but got the goosebumps anyway’*. For most, the waist and the back sensations were the most pleasant: ‘*I liked the ones around the waist the most’*. And ‘*the waist was very pleasant and it tickles a bit’* [Waist, FeelGood] or ‘*Those on the back were pleasant… nothing was uncomfortable… it was all very gentle’* [Back, Calming] and ‘*Preferred up and down—lifting you up with up swipe…Up more than down, felt more natural for me*’. Yet there was differences in interpretations and preferences between elements of the patterns: ‘*Solar plexus* [Front, Warning], *not so bad once got used to it—at first didn’t like it—was heavier—then saw it is a warning of don't do that’*, whereas for another ‘*Front—not as pleasant—not as natural—vibrating there’*. But others preferred a different set of patterns again: ‘*The feeling in the chest was best, feel it better also at lower back---very nice’* and different intensities ‘*All could be stronger’* and **‘***Tarzan* [Front, Activating], *was pleasant. Just as pleasant for waist etc…* Some also suggested certain movements took longer to learn: ‘*turn left or right, took time to get more used to them–needed to do again a few times at first—and was harder to figure out at the beginning, but become almost normal quickly’*.

The Humming Wall also provided new sensations with responses such as: ‘*Knew touching wall, but no idea how it would feel, exciting to know how it felt—big difference to having the feeling of it all over body and not just on fingers or one part.’* Many participants explored mapping the body to the wall: ‘*I thought I was able to knock high and feel high in body, middle to middle and once or twice—there was a specific connection between the two… it became difficult to find the good spots like you do with massage*’. Sensations felt better in certain spots, so participants kept seeking a logic, often ordering a partner to repeat or go back to find a sensation again.

Many found the wall helped them relax with participants often referring to the wall as: ‘*therapeutic’* or ‘*good to help take care of health’* and ‘*Love the wall, soothing and relaxing listening to humming sounds and feeling vibrations---also to play it when sat there—calming humming sound—like it in my couch’*. The wall appeared to be a safe place where people felt protected and even though in a public space, somehow private. ‘*Did not mind to hear my physiology in a public space… Enjoyed to sit in each others* [physiology]*…. tried to breathe in the same rhythm and heart* *beats also'*. Most participants seemed to relax well on the wall (see Fig. 11).

Figure 11. Participants relaxing and listening to their heartbeat at the end of the interaction sequence.

5.5 Observations

The participants enjoyed exploring and playing with the paired vibrotactile interaction. In the *Breath rate* zone, they played around with their breathing by holding their breath or doing deep slow breathing. In the *Heartbeat* zone, they followed the suggestion of jumping to increase their heartbeat and then sitting down to 'feel-hear' the heartbeat rhythm slowing down. In the *Swipe* and *Knock* zones, participants played their own little musical rhythms, running up and down, or trying to touch 4 panels at once and/or generally experimenting with what was possible and playing together at the wall.

When interviewing the participants, we noted that for many of them, it was difficult to describe the sensation experienced. Additionally, sensations in more than just one area of the body at the same time generally confused people.

6. SUMMARY OF FINDINGS

The results of the first field trial with participants wearing the vibrotactile vest and interacting with *The Humming Wall* were very positive. Answers to the questionnaires denoted that participants found the experience enjoyable and pleasant. They were highly engaged and concentrated with this novel interaction with the vest and the environment, as they did not notice the passing of time. In addition, they were activated, motivated but relaxed and understood what was required of them. As well, participants found this a personal, warm, sensitive, sociable, active and open experience.

Crossing demographic information with the questionnaires, we observed that women reported to have a more personal and warm experience than men. Fitter people and particularly those with average or lower IT knowledge had the best experiences—the latter even understanding the sensations better as the trial progressed. Further, participants less familiar with vibrotactile technology had a more personal experience and enjoyed learning how to do the tasks suggested by the sensations more than experts in this domain.

Regarding the patterns and the sensations they elicited from the vest wearer, we found, particularly for males, that some sensations made more sense than others, and this was confirmed across genders in the video logging and semi-structured interviews. Participants responded more positively to *Up*, *Down*, *WaistLeftToRight*, *WaistRightToLeft*, (calming patterns) than to e.g. *Shiver*, *Tarzan* (activating) or *Turn Left* (navigation) and *Stop* (warning).

For the participants' relation to *The Humming Wall* interaction, most participants experimented with mapping the knocking to the vest wearer's body and with different types of swipes—emulating massaging a body. The time spent in the physiology zones was longer when we offered participants to walk around the wall at their own pace; they were less knowledgeable with vibrotactile technology and if they had explored the mapping of the actions done in the wall to the vest.

From the interviews we found that people had very diverse reactions to the patterns: some requested more activating (*Tarzan* or *Shiver*) but most preferred the calming sensations (waist and back). Overall, for many participants this was a new experience, for some daunting at the beginning, others uncertain how to 'name it', but a whole body experience and for most an activating and enjoyable one. There was an obvious connection to the wall as a whole body and playful experience and one that had put their inside body available to the wall in a public space.

7. DISCUSSION AND CONCLUSIONS

We designed a vibrotactile vest with physiological monitoring that interacts with a vibroacoustic urban environment, *The Humming Wall*. Different vibrotactile patterns were designed together with a kinesiologist-neurophysiologist for the vest to emulate calming and activating sensations and to guide or warn the vest wearer. Further, actions on the wall are replicated on the vest, and in two areas of the wall the participants 'feel' (viboracoustically) and hear their heartbeat and breath rate. We conducted a field trial held over a 5-week period in Utzon Park, a public space in Aalborg, Denmark. In this work we described the experience of 39 participants interacting with the vest and the responsive environment and their engagement with the system.

The participants had a novel, unusual and generally activating, yet calming experience. It was very physical, tangible, embodied—not that they did particularly use those words—but they talked about feelings of well-being, hunger, goose bumps on the skin and touch as if it was real enough—'*I like the hand down my spine*'. Overall, they had a very personal experience and people were 'touched' and often moved by it.

Allowing participants to control their own timing increased the time spent and potentially the quality of ownership of the experience. Participants built proprietorship from their speculative play and experimentation—despite their personal heartbeat and breath rate being made publicly available in the public space.

For this first implementation, delays and unforeseen factors meant we pared back and simplified many of our initial planned interactions in the interests of robustness. Our concerns then were that the experience would hold a short novelty factor and that there would be 'not enough to do'—breath rate, heartbeat, swipe, knock—people would be finished in 5 minutes! In addition, we had deliberately worked without the visual, (beyond minimal responsive lighting—which many did not notice) in order to investigate the potential of vibrotactile interaction. Given the newness for many of our participants, their warm, social responses, and that they wanted to stay much longer than we had envisaged—or even allowed time for—anything more complicated could have undermined this initial investigation.

We found the nature of the relationships—the intimacy—that the wall enabled was surprising. Pairs who play well generally found a good place to play and discover at the wall. The experience was abstract, there were no real tasks, no game as such, rather a place to explore—which people did and made their own fun.

As future work, we will redevelop some of the internal electronics and place *The Humming Wall* in a public environment to conduct a longitudinal study including general use. We found a wide array of personal preferences and responses to the sensations in the vibrotactile patterns and we need to address these. Calming sensations were clearly more popular and easily understood than the activating, warning or guiding ones—but understandably the later would not necessarily be designed to be as pleasant. People were easily confused by sensations in more than one area of the body, so we have work to do on uncovering best placements of actuators for guiding sensations on e.g. the shoulder and nape of the back that are more easily understood—yet this is something we see and use in everyday life when guiding elders or children. Further, it would be interesting to evaluate the system with blind (or blindfolded) users to analyse their perceived sensations when using the system.

This work demonstrates potential for responsive urban environments that are nurturing for and assistive to the physiological states of their inhabitants.

8. ACKNOWLEDGMENTS

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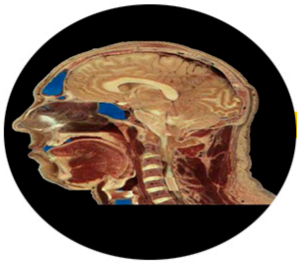

NATURAL USER INTERFACES (II)

Exploración del busto humano en tiempo real mediante interacción natural con fines educativos

Roi Méndez
CITIUS
Universidade de Santiago de Compostela
roi.mendez@usc.es

Julián Flores
CITIUS
Universidade de Santiago de Compostela
julian.flores@usc.es

Rubén Arenas
CITIUS
Universidade de Santiago de Compostela
ruben.arenas@usc.es

ABSTRACT
En este trabajo se presenta el desarrollo de un sistema interactivo de visualización del interior del cráneo humano para La Domus (Casa del Hombre de A Coruña). La interacción del usuario con el mismo se realiza a través de una interfaz natural e intuitiva (desarrollada ad-hoc) basada en sensores de movimiento Prime Sense. Se presentan el ciclo de vida del desarrollo del proyecto basado en prototipos y por tanto los diferentes prototipos implementados así como las pruebas realizadas sobre los mismos hasta llegar a la implementación final que, a día de hoy, se encuentra operativa en el museo.

Categories and Subject Descriptors
I.3.6 [**Computer Graphics**]: Methodology and Techniques – *Interaction Techniques*

General Terms
Design, Human Factors.

Keywords
Interacción, Kinect, Prime Sense, museo interactivo, anatomía humana, interacción natural.

1. INTRODUCCIÓN
En los últimos años los museos, en especial los científicos, han sufrido una gran evolución pasando de meras salas de exposición a espacios donde el usuario puede interactuar con los elementos que se muestran. Incluso museos clásicos como el Louvre han incorporado elementos como la Nintendo 3DS o el sensor Kinect para crear una experiencia más interactiva con el visitante. En este tipo de entornos tiene una importancia capital el hecho de mantener la atención del visitante y transmitirle conocimientos de una forma clara, amena y entretenida, promoviendo un aprendizaje por experimentación que haga más atractiva la información que se desea transmitir. Si, por otra parte, los potenciales visitantes son niños debemos desarrollar paradigmas educativos que permitan difuminar, en la medida de lo posible, la frontera entre el aprendizaje y el juego.

El caso de estudio se centra en el diseño e implementación de un contenido interactivo para la Domus, Casa del Hombre de A Coruña [2], museo interactivo, encuadrado en el conjunto de museos científicos de la ciudad, que centra su actividad en diferentes aspectos del ser humano como especie, proporcionando, entre otras cosas, un recorrido completo a través de su anatomía. Se trata de un museo orientado principalmente a un público infantil y familiar, por lo que ha de tenerse en cuenta el aspecto lúdico a la hora de desarrollar la instalación. Esta instalación se enmarca dentro de una nueva exposición denominada Chispas compuesta por 13 módulos interactivos, que recorren cada una de las 8 inteligencias descritas por Gardner [4] y algunos aspectos de la anatomía y fisiología del cerebro. Se plantea crear un contenido interactivo que permita al visitante observar las características anatómicas del cerebro, explorarlo y visualizar las diferentes partes del mismo, así como los elementos orgánicos del busto humano. Por lo tanto, este módulo cubre la parte de la exposición centrada en la anatomía del cerebro.

2. OBJETIVOS
El objetivo principal de este proyecto es desarrollar un sistema que permita la exploración anatómica del cerebro humano mediante una interacción natural por parte del usuario.

Para lograr este objetivo se plantearon dos requisitos funcionales principales:

- Implementar una herramienta de visualización de imagen médica (TAC, RMI o similar) que permita explorar el modelo mediante un plano de corte en los tres ejes cartesianos del espacio, pudiendo seleccionar la posición del plano y el eje de corte del mismo en cada momento. De esta forma se podrá visualizar el interior del cráneo desde una perspectiva cenital, frontal o lateral permitiéndole al usuario la exploración del modelo desde diferentes ángulos y puntos de vista.
- Implementar un sistema de interacción intuitivo, natural y atractivo del usuario con el sistema, evitando el uso de periféricos clásicos como teclados, ratones y, cada vez más, pantallas táctiles. Este sistema debe permitir que el usuario defina en todo momento el plano de corte deseado y su posición en el espacio. Igualmente debe de definirse la posición física del usuario respecto al sistema así como las acciones que este debe realizar para un correcto funcionamiento del mismo.

3. DISEÑO DEL CONTENIDO
El paradigma utilizado para el diseño del sistema se basa en la arquitectura clásica de un expositor de museo. Estos expositores son urnas en cuyo interior se expone el elemento de interés. En nuestro caso se sustituye la urna por un monitor y se introduce un componente de interacción del usuario con el contenido que permita incrementar el valor expositivo y docente del mismo. De esta forma, el diseño debe tener una arquitectura similar, tal como se muestra en la Figura 1. Está formado por una pantalla en la que realiza la visualización de las imágenes del cráneo y uno o varios sensores para permitir la interacción natural del usuario con el sistema.

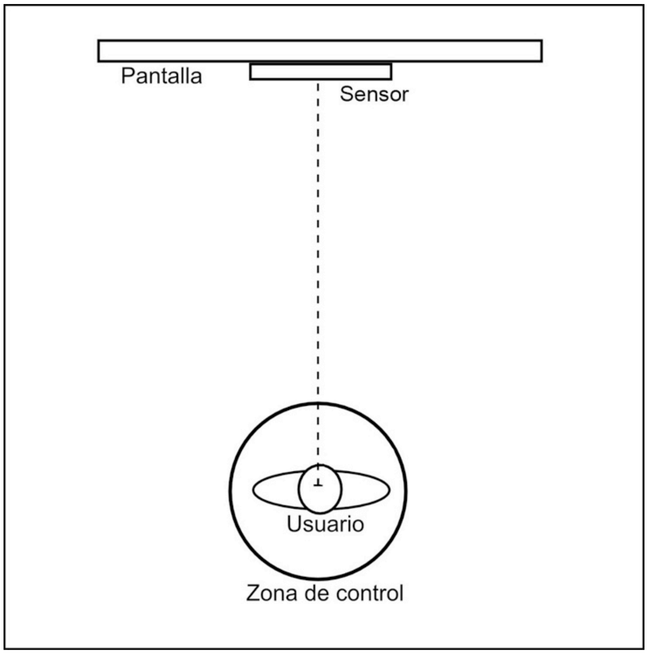

Figura 1. Esquema de diseño del módulo

Puesto que se trata de un contenido interactivo se define una zona de control en la que el usuario puede moverse manteniendo el control del sistema, fuera de la cual el usuario perderá el control del mismo. Esto es necesario debido a que, al estar situado el módulo en una zona con tránsito de visitantes se debe de discernir cual de los posibles usuarios en la zona cercana al quiosco tiene el control. Esta diferenciación se realizará mediante la restricción del funcionamiento del sistema a la zona de control especificada.

4. TECNOLOGÍAS EMPLEADAS Y DISEÑO HARDWARE

Se realizó un estudio previo de cuáles eran las mejores alternativas para llevar el proyecto a cumplir sus objetivos de forma eficiente y satisfactoria. Siguiendo las necesidades básicas planteadas se realizó un estudio de las diferentes herramientas de software libre tanto para la visualización como para la interacción del usuario con el sistema. Como fue comentado con anterioridad el sistema consta de dos partes: un entorno gráfico que permite la visualización del modelo y un sistema de interacción para controlar dicha visualización.

4.1 Sistema de Visualización

Se ha de construir una imagen tridimensional a partir de la información contenida en 275 imágenes con una resolución de 512x512 pixels pertenecientes al Visible Human Project [12]. Para realizar este proceso se planteó el uso de un motor gráfico especializado en esta tarea: VTK (The Visualizaton Toolkit)[7]. No obstante, los resultados de rendimiento con las imágenes del dataset desaconsejaron su uso, ya que los frame rates obtenidos no eran estables y caían en ocasiones por debajo del tiempo real necesario para toda aplicación interactiva. Asimismo, la propia implementación del visor de VTK realiza una simplificación del modelo cuando está siendo manipulado (cuando la imagen visualizada no es fija) para evitar caídas en el frame rate, lo que deriva en una visualización poco precisa y en un efecto de popping cuando se deja de manipular el modelo y se muestra el render sin simplificar. Teniendo esto en cuenta se optó por un motor gráfico orientado al render en tiempo real, decantándonos por OSG (Open Scene Graph) [11] por tratarse de uno de los más extendidos y potentes, así como por la posibilidad de integración que ofrecía tanto con ITK (Insight Segmentation and Registration Toolkit) [6] como con DCMTK (DICOM Toolkit) [10], herramientas que permiten leer e interpretar variados formatos de imagen médica y en especial DICOM, formato que se ha convertido en un estándar en este campo y que presenta grandes dificultades de lectura, interpretación y generación debido a su complejidad interna [1]. Con esta herramienta se obtuvo una visualización en tiempo real (sin variaciones en la calidad del renderizado) y con un frame rate estable, condiciones indispensables para el sistema planteado.

En este punto se planteó la substitución de las imágenes iniciales en formato DICOM (en escala de grises) por unas equivalentes en formato png (en color) ya que la información cromática permite una mejor percepción de los diferentes tejidos y estructuras presentes en el modelo además de aumentar la espectacularidad de la visualización. Al disponer del dataset completo del Visible Human Project [12] (incluidas las imágenes reales en color de los cortes realizados) y utilizar OSG como motor de render el cambio fue directo, ya que este motor gráfico permite la importación de volúmenes como conjuntos de imágenes en diferentes formatos. Este cambio permitió, además, aumentar la resolución de la visualización al tener las imágenes en color un mayor detalle que su equivalente DICOM. Se hubo de ajustar el tamaño del volumen de entrada para mantener el frame rate dentro de los parámetros del tiempo real ejecutando la aplicación sobre una tarjeta gráfica Nvidia Geforce 9600GT.

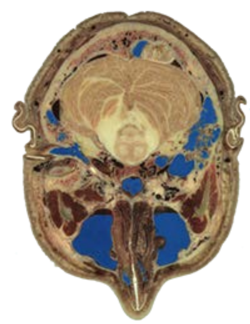

Figura 2. Imagen de un corte procesado.

Las imágenes en color precisaron de un preprocesado ya que la zona exterior al cráneo estaba completamente cubierta por la mezcla de gelatina y agua empleada para la congelación del sujeto. A efectos prácticos esto supone que al realizar la visualización exterior lo que observa el usuario es un bloque azul. Para su procesado se definió una zona de interés (en la que estaba contenido el busto) y descartar todos los elementos exteriores a esta zona. Una vez realizado este proceso se procedió a la eliminación de la región exterior azul mediante un proceso de umbralización. Al ser la parte anatómica de la imagen una región cerrada y al tener los tejidos de la misma una pigmentación bien diferenciada de la región a eliminar bastó con seleccionar el color azul y aplicarle una serie de umbrales. El resultado puede verse en la Figura 2. En cuanto a las zonas que contienen mucosas en el interior del cráneo (aparecen también azules debido a la penetración del líquido de congelación en su interior) se decidió no procesarlas ya que la pigmentación resultado de la congelación permite a un usuario no experto detectarlas con mayor facilidad. El conjunto de datos final está formado por 275 imágenes con una resolución de 1024x608 pixels.

El proceso seguido a la hora de construir un modelo 3D a partir de una serie de cortes 2D es el siguiente: Primero se cargan las imágenes en memoria. Una vez cargadas se construye una textura 3D que se visualizará a través de un proceso de Raycasting. Para realizar los cortes requeridos en los tres ejes cartesianos se hace uso de tres planos de clipping (uno por cada eje) que, combinados con la textura 3D y el raycasting permiten renderizar todos los detalles tanto exteriores como interiores del volumen visualizado.

4.2 Sistema de Interacción

Al tratarse de un museo principalmente dirigido a público infantil y familiar el diseño de una interacción intuitiva y al mismo tiempo atractiva resulta indispensable.

En los últimos años han aparecido una serie de sensores avanzados que permiten enriquecer, a través una captura de movimiento de bajo coste, la interacción del usuario con el ordenador, creando nuevas interfaces naturales y metáforas de acción que añaden una tercera dimensión además de aumentar la implicación física del usuario en la interacción con la máquina [3]. Persiguiendo un control más natural del sistema se plantea la utilización de estos sensores con el fin de evitar el uso de periféricos tradicionales como el ratón y el teclado buscando simplificar la realización de una serie de tareas por parte del usuario. Los tipos de sensorización planteados fueron los siguientes:

- Sensorizaciones mediante cámaras de infrarrojos: Se planteó el uso de sistemas de cámaras de infrarrojos para sensorizar al usuario. El usuario tendría una herramienta que manejaría en el aire y a través de la cual podría interactuar con el sistema. Esta herramienta sería seguida por el sistema y el renderizado de las imágenes 3D se realizaría consecuentemente a esta interacción. Los principales inconvenientes que llevaron a decartar este tipo de sensorización fue, por un lado, la ausencia de librerías libres y fiables para el tipo de hardware disponible y, por otro, la necesidad de que el usuario manejase una herramienta, con las posibilidades de hurto y rotura que esto implica.

- Sensorizaciones mediante cámaras RGB y marcadores: El extenso uso que el grupo de investigación ha hecho de sensorizaciones con webcams empleando marcadores llevó a que se planteara una interacción basada en esta tecnología. El problema planteado era la dificultad de, con un usuario manipulando un objeto en el aire, evitar oclusiones en los patrones, así como obtener la configuración óptima de iluminación de la sala sin, con ello afectar al resto de la exposición o, al igual que en el caso de la sensorización con cámaras de infrarrojos la presencia del elemento físico manipulable que puede ser hurtado o que se puede deteriorar con el uso.

- Sensorización mediante el uso de sensores PrimeSense: Se planteó el uso de sensores PrimeSense como Kinect o Asus Xtion debido a las grandes posibilidades que ofrecen y lo novedoso de la interacción que plantean. La ventaja principal de esta tecnología es que trabaja sin la necesidad de usar patrones ni marcadores de ningún tipo. Emplea cámaras de color e infrarrojos para detectar usuarios en su zona de acción y reconstruye automáticamente un esqueleto del mismo, siguiendo sus movimientos en el espacio.

Teniendo en cuenta que las condiciones lumínicas del museo no podían ser controladas sin afectar a toda la exposición se descartó el uso de cámaras RGB por los problemas que presentan ante cambios de iluminación. Se descartó la manipulación de un objeto como interfaz de control (un mando de consola o elemento manipulable con captura de movimiento) por los problemas de mantenimiento que este podría presentar así como por la posibilidad de hurto del mismo. Se descartó, por tanto, el uso de cámaras de infrarrojos o mandos de control. Se decidió, por tanto emplear sensores PrimeSense para crear una interacción natural entre el usuario y el sistema a través de los movimientos de su cuerpo.

El esquema de interacción es el siguiente: El visitante del museo llega al módulo, se sitúa de pie, en una posición indicada mediante un gráfico en el suelo, de forma frontal a la instalación y el sensor lo detecta y obtiene de sus gestos la información necesaria para manipular el sistema. Finalmente, la imagen que se muestra en pantalla varía siguiendo los gestos realizados por el usuario. Para la detección de gestos se decidió optar por un desarrollo ad-hoc en lugar de emplear gestos estándar ya que se entendió que estos se adecuarían mucho mejor a una interacción natural y efectiva [9].

5. IMPLEMENTACIÓN

La implementación del sistema se planteó como un desarrollo por prototipos, se crearon diferentes prototipos y se probaron en sujetos experimentales, hasta obtener una implementación intuitiva del sistema, de modo que este a penas necesitase de instrucciones de uso y la interacción con el mismo surgiese de forma natural. También se tuvieron en cuenta diversos factores para evitar la fatiga del usuario [5] como una posición natural y relajada del mismo durante la interacción, la no necesidad de mantener una tensión postural innecesaria en manos o cabeza para tener una interacción efectiva, etc.

5.1 Prototipo 1

La exploración tradicional de modelos 3D se basa en el zoom, la rotación y la traslación [8] convirtiendo la interacción del usuario con el sistema (generalmente a través de interfaces 2D) en algo complejo y que requiere de un aprendizaje. Sin embargo, el paradigma planteado reduce éste al desplazamiento de planos a través de los ejes cartesianos, lo que simplifica la interacción al no ser dependientes las transformaciones en unos de las realizadas en otros. Por ser tres los planos de corte planteados, se definieron tres zonas de acción distintas que permiten al usuario operar en cada una sobre un plano de corte distinto.

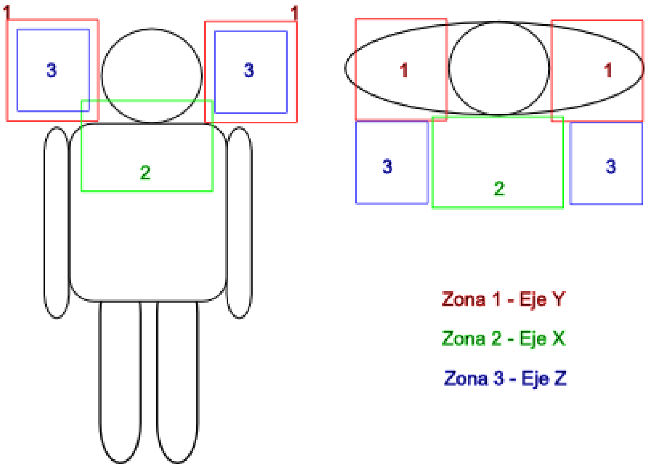

Figura 3. Zonas de acción del prototipo 1.

Se definieron las zonas de interacción que pueden verse en la Figura 3 y cada una de ellas se asoció con un eje. Este primer prototipo restringe las zonas de acción al entorno de la cabeza del usuario asumiendo una metáfora exploratoria basada en que si se explora el busto, la forma más simple de interacción para el usuario era asumir que lo que está visualizando es su propio cráneo y que, al desplazar las manos en torno a él, puede explorar su interior. La zona 1 se situó frente al pecho (para evitar poner las manos delante de los ojos y entorpecer la visión) y permite realizar cortes en el modelo en el sentido horizontal (eje X). La zona 2, a la derecha o izquierda de la cabeza, permite realizar cortes en sentido vertical (eje Y) y la zona 3, situada delante de la zona 2 permite explorar el interior del busto en profundidad (eje Z).

El prototipo se probó con 6 usuarios experimentales (entre los que se encontraban los organizadores de la exposición) que utilizaron el sistema en base a objetivos (detectar el nervio óptico, visualizar el cerebelo, etc.). A pesar de las ventajas que presentaba esta propuesta, como el ser válida tanto para zurdos como para diestros (las zonas de interacción estaban situadas a ambos lados de la cabeza) o lo acertado de la metáfora de interacción que facilitaba la comprensión del funcionamiento al usuario, empíricamente se pudieron detectar una serie de problemas operativos:

- Problemas derivados del poco recorrido que tiene el movimiento de la mano entorno a la cabeza: Ya que el modelo 3D se construye a partir de 275 cortes y el desplazamiento de la mano para mover el plano a través del mismo se reducía a 25 centímetros, lo que dificultaba la visualización de pequeños detalles al avanzar el plano de corte una gran distancia con un movimiento sutil de la mano (11 imágenes por centímetro de recorrido de la mano).

- El ruido en la señal producida por el sensor: El sensor introducía una gran cantidad de ruido, lo que derivaba en un movimiento continuo de los planos de corte, impidiendo una visualización clara de los mismos. Este ruido se veía incrementado, además, por la cercanía de las manos al cuerpo derivada del tipo de interacción propuesta, que dificultaba la labor de seguimiento del sensor.

- La indefinición entre zonas de acción: Cuando la mano pasa de una zona de acción a otra la perspectiva del modelo que visualiza el usuario cambia al modificar el plano de corte sobre el que actúa, produciendo confusión al no ser capaz de identificar los límites de las diferentes zonas de acción, situación a la que contribuye el tamaño reducido de las mismas.

5.2 Prototipo 2

Dados los problemas que planteaba el prototipo 1 se decidió implementar dos cambios básicos en la concepción del sistema.

Por un lado se decidió aumentar el recorrido de la mano ampliando las zonas de acción que pasaron del entorno de la cabeza a ocupar todo el entorno del tronco (de 25 cm a 50 cm de recorrido) para permitir al usuario tener un mayor control del detalle que deseaba ver en cada momento (5,5 imágenes por cada centímetro de recorrido de la mano). Al ser más grande el rango de movimiento de la mano el plano se moverá más lentamente respecto al movimiento de la misma permitiendo observar detalles que, de otra forma, serían imposibles de visualizar y reduciendo, de esta forma, la intensidad de los temblores en la imagen debidos al ruido de la señal del sensor.

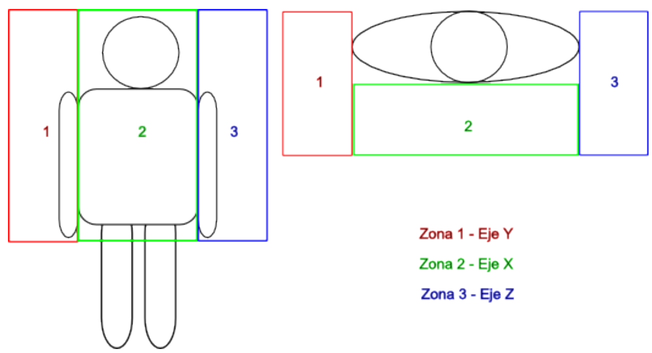

Figura 4. Zonas de acción del prototipo 2.

Por otro lado, se decidió también hacer una mayor diferenciación de zonas de trabajo, para que en cada zona espacial sucediese sólo una cosa, buscando simplificar, de esta forma, la comprensión de qué se manipulaba en cada zona. Se definieron las tres zonas como se muestra en la Figura 4. A la derecha del hombro derecho se permitía al usuario interactuar con el eje vertical de corte desplazando su mano en sentido vertical, en la zona delantera del torso y cabeza se interactuaba con el eje horizontal de corte desplazando la mano en sentido horizontal y a la izquierda del hombro izquierdo, acercando y alejando la mano del mismo, se realizaba la interacción del usuario con el eje de profundidad de corte.

Para probar el funcionamiento de este prototipo se realizaron pruebas a 7 usuarios no expertos. Estas pruebas estaban compuestas por 9 tareas cronometradas (localizar el nervio óptico, localizar el bulbo raquídeo, etc.) y un breve cuestionario para evaluar el nivel de frustración del usuario así como la usabilidad del sistema. Las tareas fueron realizadas con éxito por la totalidad de los usuarios, que invirtieron un tiempo medio de 13 segundos en realizar cada una de ellas. De las respuestas al cuestionario se dedujo que los usuarios consideraban el prototipo atractivo, así como intuitivo una vez habían interiorizado la mecánica de funcionamiento del mismo. Sin embargo, en los momentos iniciales, se sentían perdidos al no saber qué dirección exploraban con cada mano, lo que les producía frustración al pasar de una tarea a otra. También salió a relucir la dificultad de algún usuario diestro para manejar el plano de profundidad (Z) con la mano izquierda, ralentizando de manera notable su desempeño en las tareas que requerían el uso de esta vista.

Al ser la primera impresión y el manejo intuitivo del sistema de capital importancia en un museo interactivo, así como la accesibilidad y que la aplicación sea usable para el usuario independientemente de su pericia con su mano menos hábil, se decidió cambiar radicalmente el enfoque que se estaba dando a la interacción, eliminando por completo las zonas de actuación diferenciadas.

5.3 Prototipo 3

Ante los problemas planteados por las zonas diferenciadas de interacción (frustración en el usuario al no saber que tarea realiza en cada zona, dificultades de manejo de la aplicación con la mano menos hábil, etc.) se cambió el enfoque de la interacción planteada, centrando la misma en la dirección principal de movimiento de la mano. Esta solución consiste en que la visualización es modificada y el objeto explorado en la dirección del eje en que la mano del usuario presente un mayor desplazamiento. Esta solución plantea tres ventajas principales respecto a las dos anteriores:

- Permite una diferenciación más intuitiva del eje de corte que se está utilizando en cada momento y de por qué es ese el eje sobre el que se actúa al no importar en que parte del espacio se encuentre la mano, sino la dirección en la que se mueve.
- Permite la utilización de ambas manos indiferentemente, solo hay que seleccionar cual tiene preferencia en caso de que ambas estén interactuando.
- Ofrece la posibilidad de tener un mayor rango de movimiento en los tres ejes, al no estar este limitado por su correspondiente zona acción.

Se repitieron las pruebas que se habían realizado en el prototipo anterior sobre los mismos 7 usuarios. De nuevo las 9 tareas fueron completadas con éxito por todos los participantes no observándose diferencias notables en los tiempos empleados en uno y otro caso (entorno a los 13 segundos de media) para completarlas. Sin embargo si se apreciaron diferencias en las respuestas al cuestionario. Se subrayaba la facilidad para el manejo del mismo, lo intuitivo que resultaba y lo preciso que era en el movimiento. Se señalaba también alguna dificultad a la hora de cambiar de tipo de vista, pero la valoración general, tanto de usabilidad como de atractivo, fue muy positiva eliminando la frustración inicial que si habían sentido en la utilización del anterior prototipo.

Se determinó, por tanto que este sería el prototipo final y se pasó a su implementación final para ser probado con una muestra poblacional más representativa de los futuros usuarios que el sistema tendría en el museo.

En esta implementación final se determinó que el sistema reaccionaría a movimientos de las manos de los usuarios cuando estas estuviesen por encima de la cintura y que, en caso de no ser así, el sistema permanecería en reposo. Asimismo se decidió que en caso de interacción de las dos manos al mismo tiempo se le daría preferencia a la derecha por ser la de mayor frecuencia poblacional. También se definieron las medidas y posicionamiento de los diferentes elementos del sistema (Figura 5).

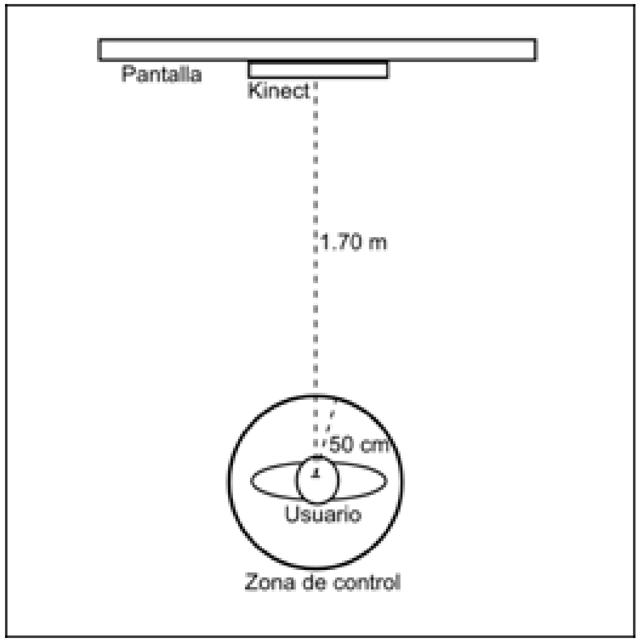

Figura 5. Diseño final del sistema con medidas.

6. PRUEBAS

En la fase de prototipado también se observó la necesidad de dar un punto visual de referencia para que el usuario supiese en todo momento que plano de corte estaba visualizando y en qué posición respecto al busto se encontraba. Para esto, en una primera aproximación se optó por replicar el modelo en perspectiva y situarlo en el interior de un cubo transparente a través del cual se desplazaban los planos de corte de forma visual y solidaria con el plano de corte real. Esta visualización, a pesar de lo vistoso no resultó efectiva para conocer la posición exacta del plano respecto al modelo (por motivos de perspectiva) por lo que se decidió optar por una solución más esquemática y que transmitiera la información de una forma más simple y directa. Se emplearon dos siluetas (una de frente y otra de perfil) que se visualizan en paralelo a la imagen del modelo 3D. Según el plano de corte que se esté explorando en cada momento varía la silueta que se está visualizando y, dependiendo de la posición del plano que actúa sobre el modelo, se desplaza una línea a través de la silueta indicándole al usuario qué zona del busto está visualizando. Dos flechas indican la dirección en la que se está desplazando el plano en cada momento simplificando el control por parte del usuario así como la comprensión del funcionamiento del sistema (Figura 6).

Aprovechando una serie de visitas de escolares al centro de investigación y dado el enfoque familiar del museo se realizaron una serie de pruebas de uso del sistema en las que participaron 41 estudiantes de entre 8 y 9 años. La prueba consistió en dejarlos manipular libremente el sistema sin ponerles límite de actuación o tiempo y una puesta en común posterior de la experiencia. Se debe de subrayar que el tiempo de utilización no fue totalmente libre al encontrarse la prueba en medio de una visita que debía de cumplir unos tiempos aunque sí que es un escenario que se puede asemejar a una visita de escolares en grupo al museo en la que hay un tiempo limitado y numerosas instalaciones para visitar.

El tiempo medio que estuvieron interactuando con el sistema fue de 61 segundos de los cuales un 75% del tiempo lo hicieron utilizando la mano derecha, el 11% la mano izquierda y un 14% no realizando ninguna actividad. Estos datos confirmaron que ante la utilización del sistema los usuarios se mantenían activos y probando sus funcionalidades. Destaca en este aspecto el uso de la mano izquierda ya que solo un usuario era zurdo. El porcentaje del 11% se explica a través del intento de los escolares de probar todas las posibilidades del sistema "retándolo" a funcionar con las dos manos.

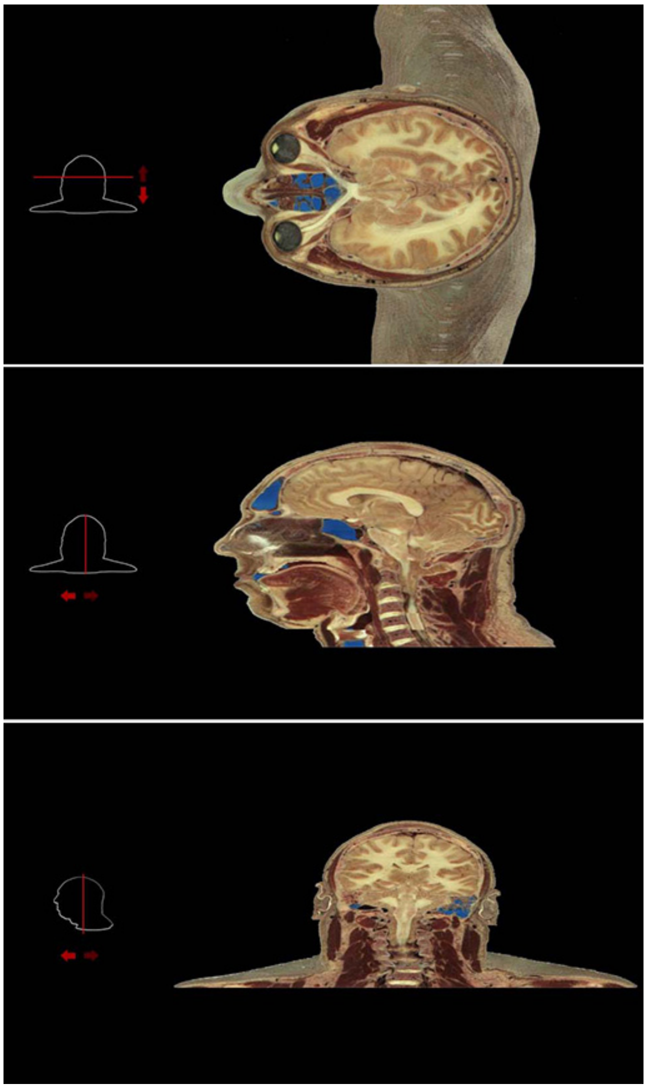

Figura 6. Diferentes visualizaciones presentes en la aplicación final.

Dentro de la fase de actividad (ya sea con la mano derecha o la izquierda) los usuarios interactuaron con la vista frontal (eje Z) un 29% del tiempo, con la vista superior (eje Y) un 40% del tiempo y con la vista lateral (eje X) un 31% (Figura 7). Destaca ligeramente la vista superior al ser la que posee una mayor resolución, al tratarse de los cortes originales a partir de los cuales se realizó la reconstrucción del modelo 3D. Esta mayor nitidez se refleja en un mayor interés de los usuarios por los pequeños detalles visibles en ese eje.

Más allá de los datos obtenidos, los escolares afirmaron sentir una mayor curiosidad por el sistema que si hubiese sido manejado a través de un periférico clásico y que la interacción les había resultado más amena. Insistiendo repetidamente en que les habría gustado probar un sistema similar a través del que se pudiese observar el cuerpo humano al completo.

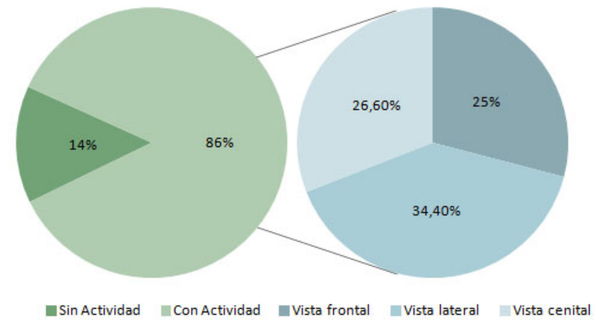

Figura 7. Resultados del proceso de pruebas en porcentajes de tiempo.

Desde el punto de vista de una supervisión visual exterior se puede afirmar que, en general, este tipo de interacción atraía la atención de los usuarios pero, en ciertos momentos esta interacción se convertía más en una finalidad que en un medio, ocupando el juego de "retar" a la máquina con movimientos rápidos o ondulantes una mayor parte de la atención del niño que la visualización propiamente dicha.

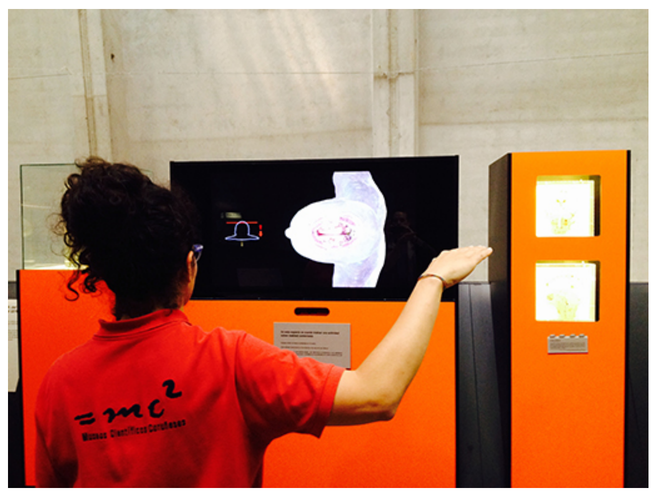

Figura 8: Instalación final en el museo

7. CONCLUSIONES Y TRABAJO FUTURO

Se ha desarrollado un sistema de visualización y exploración del cerebro humano a partir de una visualización basada en texturas 3D, controlado de una manera natural e intuitiva a través de una interfaz natural para su exhibición en el museo de divulgación científica Casa Domus. El funcionamiento del sistema se ha ido probando a lo largo de su desarrollo por prototipos y se ha validado en una prueba final con usuarios potenciales del mismo.

El sistema ha sido instalado en el museo, con gran aceptación por parte de los organizadores y visitantes de la exposición.

Como trabajo futuro se plantea la mejora del cambio de plano de corte utilizado en cada momento, ya que, debido al ruido de la señal del sensor se descartan los pequeños cambios en la dirección del movimiento para esta finalidad, dificultando, en ocasiones, la interacción del usuario con el sistema.

También se plantea la necesidad de introducir información visual y auditiva sobre los diferentes órganos y tejidos que se encuentran en el busto, indicando su nombre, una breve explicación de su funcionalidad etc. Esto incrementaría, tanto el valor divulgativo de la instalación, como el interés del usuario.

8. AGRADECIMIENTOS

Domus, Casa del Hombre de A coruña.

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Performance evaluation of gesture-based interaction between different age groups using Fitts' Law

Diana Carvalho
INESC TEC and UTAD
4200-465 Porto, Portugal and
5000-801 Vila Real, Portugal
+351 {222094000, 259350000}
dianac@utad.pt

Maximino Bessa
INESC TEC and UTAD
4200-465 Porto, Portugal and
5000-801 Vila Real, Portugal
+351 {222094000, 259350000}
maxbessa@utad.pt

Luís Magalhães
Centro ALGORITMI, UMinho
4800-058 Guimarães, Portugal
+351 253510180
lmagalhaes@dsi.uminho.pt

Eurico Carrapatoso
INESC TEC and FEUP
4200-465 Porto, Portugal
+351 222094000
emc@fe.up.pt

ABSTRACT

The recent advances made in human-computer interaction have allowed us to manipulate digital contents exploiting recognition-based technologies. However, no work has been reported that evaluates how these interfaces influence the performance of different user groups. With the appearance of multiple sensors and controllers for hand gesture recognition, it becomes important to understand if these groups have similar performance levels concerning gestural interaction, and if some sensors could induce better results than others when dealing with users of different age brackets. In this respect, it could also be important to realize if the device's sensor accuracy in terms of hand / full body recognition influences interaction performance. We compare two gesture-sensing devices (Microsoft Kinect and Leap Motion) using Fitts' law to evaluate target acquisition performances, with relation to users' age differences. In this article, we present the results of an experiment implemented to compare the groups' performance using each of the devices and also realize which one could yield better results. 60 subjects took part in this study and they were asked to select 50 targets on the screen as quickly and accurately as possible using one of the devices. Overall, there was a statistically significant difference in terms of performance between the groups in the selection task. On the other hand, users' performance showed to be rather consistent when comparing both devices side by side in each group of users, which may imply that the device itself does not influence performance but actually the type of group does.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – *evaluation/methodology, input devices and strategies (e.g., mouse, touchscreen).*

General Terms

Performance, Design, Human Factors.

Keywords

HCI, natural user interfaces, gestural interaction, performance, Fitts' law, Microsoft Kinect, Leap Motion, target acquisition, selection tasks.

1. INTRODUCTION

For many years, the traditional mode of interaction with computers was based on a WIMP interface (Windows, Icons, Menus, Pointing device), which allowed us to interact with the machine via specific pointing devices, usually a computer mouse. With the paradigm shift to Post-WIMP interfaces [5], we have turned towards a user-oriented and task-oriented approach that attempts to simplify the usability of the interface [17], giving preference to the users innate skills [16] and allowing us to take advantage of recognition-based technologies that understand human behaviors, such as gestures or touch. However, there seems to be a constant addition of new modes of interaction without the proper awareness as to which could be the most adequate for different user profiles (e.g., children, elderly users, people with different levels of digital literacy, people with disabilities) and also regarding which types of tasks (selection, insertion, manipulation).

A previous study of ours [3] presented insights on how users interact using different input modalities and which interface holds the best results in terms of usability testing regarding three user groups with different age brackets. Our preliminary findings indicated that the gestural interface presented worse results than the other ones, and we thus acknowledged that the device itself used for the gesture-recognition – the Kinect – could be negatively influencing the user due to the accuracy required by the task. Different optical sensors, which allow human body acquisition with respected accuracy, have been released and comparable controllers in the same price range include the Kinect and Leap Motion, a sensor with declared sub-millimeter precision that claims to obtain higher levels of accuracy than the Kinect [24]. Therefore we think that it may be important to understand if another device could perform better than the one used in the previous experiment. After all, when it comes to gestural interfaces the precision of the sensor is said to be vital.

In this context, this study aims at throwing some light on the indices of performance of three groups of users with different age-brackets concerning the use of two different gestural sensors. We intended to understand: (1) if the gestural interaction presents significantly better results on specific groups opposed to others with regards to their age; (2) if the devices used and their declared precision influence or not the reaction times and indices of performance in each group.

2. SCIENTIFIC BACKGROUND

2.1 Natural Interfaces

Active and passive input modes of interaction [19] have been implemented in countless fields. However, published studies have not yet provided an understanding of how different user groups perceive distinct tasks and if their performance is directly influenced by the interaction modality.

Little is known about how the different interfaces affect one's performance when it comes to age-related issues. There are no transversal comparisons of different age groups in one same study where more than one natural interface is evaluated. Work has been developed in this area, but not as a systematic approach. Sambrooks and Wilkinson compare gestural, touch and mouse interaction with 15 participants aged between 22 and 34 years old [21]. They reached the conclusion that touch and mouse presented better results, but this interaction performance was not compared between other groups of users and thus it just clarified that the gestural performance was indeed worse than the other interfaces regarding that specific niche of participants. Other studies, as [2, 6, 9], compared the interaction performance when using traditional mouse inputs or touchscreens, but not between other natural recognition-based interfaces as a hole, and they only compare at the most two groups.

Concerning the gestural controllers, tests have been performed in order to understand the accuracy of any given device [20, 24], but they have not been compared amongst different user profiles, such as distinct age groups.

2.2 Fitts' Law: An Overview

Fitts' law is a human performance model that has been widely applied to describe the relationship between movement time, distance and accuracy within specific pointing tasks, as a way to formally evaluate pointing devices [15] and compare their efficiency [23]. The original experimental paradigm Fitts' Law [7] measures the rate of transmission in "bits per second" of a pre-established movement with different indices of difficulty. Also, ISO 9241-9 "Ergonomic requirements for office work with visual display terminals (VDTs) -- Part 9: Requirements for non-keyboard input devices" [10, 11] provides a standard approach for input device evaluation based on Fitts' law. Fitts' performance model can also be applied when comparing and evaluating pointing devices. Task differences, selection techniques, response irregularity and test conditions applied may influence experimental variations. Understanding these variables increases the validity of across-studies comparisons regarding input techniques [15]. In this sense, researchers use this model to measure multiple movement times and then determine how the different conditions or devices affect the coefficients of the equation, that is, performance.

3. CASE STUDY

The aim of this work is to compare two different gestural input devices in order to understand if different age groups display similar indices of performance between them, and which device could lead to better target acquisition performance rates for different user groups, using Fitts' law.

To accomplish this, we compared the use of Microsoft Kinect and Leap Motion Controller for motion and gesture control with users from three distinct age groups: children, young adults and older-adults. A total of 60 participants who were naïve to the purpose of the experiment took part in this case study, and were grouped by age and device: (1) 20 children from 9 - 12 years old (10 for each device); (2) 20 young adults from 20 - 35 years old (10 for each device); (3) 20 older-adults from 45 - 60 years old (10 for each device).

We intended to emphasize the distinct age groups and work with users that had noticeable differences concerning cognitive performance levels and dexterity and, as such, we tried to select distinct groups. First, we did not consider users younger than 9 years old because: (1) they are not so used to the computer and do not use it on a daily basis, and also they do not have the dexterity capabilities as improved as older children; and (2) these ages are encompassed by the fifth and sixth year of primary school, being these school years the ones that show greater variance in terms of reasoning by the children [12]. As this variance tends to significantly fade towards high school, we selected graduate students, being these users already at a different stage concerning cognitive performance when compared with the group of children. Finally, the group of older-adults consisted of active workers of a secretariat department. This group could present worse dexterity or consider gestures to be more challenging.

Also, we ascertained that all of the participants had the same level of computer proficiency and used the computer on a daily basis. However, when it comes to gestural interaction, this modality was not familiar to the participants, who were conscious of this gesture-based interface mainly due to having seen gaming consoles with support to this modality. In fact, only seven users had already tried gestural interaction once.

The majority of participants were right-handed (right-handed: 58; left-handed: 2), and the setup was calibrated to accommodate each arm as needed: the left-handed participants used the left arm to perform the tests, and the right-handed used the right arm.

3.1 Apparatus

We conducted the experiment in a closed room with artificial light and the tests were performed in a specific setup assembled for the purpose of this research. The system consisted on a 22'' screen placed on a desk in front of the user, with a resolution of 1280x800 pixels; a Microsoft Kinect sensor mounted on a tripod behind the screen, about 25 cm above it and facing the user; a Leap Motion sensor placed on top of the desk, between the user and the screen, and facing upwards. The distance between the user and the Kinect sensor was about 75 cm, and was calibrated to see the user's upper body only. The user was seated facing the setup at all times, and this setup was not altered throughout the different trials. Also, a purpose-built application based on Fitts' law was developed in Python with the support of: the Kivy Framework, TuioKinect and the Leap Motion Python API.

3.2 Experiment Design

The experiment made use of an independent-measures design and the tasks were performed in a controlled environment. Aside from the discrete data collected during the tests, we also gathered qualitative observational analysis on the participants' behavior. At the beginning of each phase of this study, we performed a questionnaire regarding the participants' previous experience with gestural interfaces. Also, at the end of each test we proposed a questionnaire with qualitative Likert Scales [13], in order to understand the users' preferences and their views regarding: ease of use of the device in question, fatigue effect, level of user comfort / frustration, and users' degree of concentration.

The tests were performed on different days and with different users. As such, the participants only tried one of the devices, and not both of them, as we did not intend for the use of one device to influence the movement times recorded on the other due to performance improvement over trials.

In order to understand the users' index of performance when considering target acquisition tasks using gestural interaction with the Kinect sensor versus Leap Motion, we resorted to Fitts' law evaluation paradigm, a frequently used model for measuring movement performance. Fitts quantifies the movement tasks' difficulty, also known as Index of Difficulty (ID), by the metric "bits" and calculates it by using the value of the distance, or amplitude (A), between two specific targets and their width (W) or tolerance area:

$$ID = log2(A/W + 1). \quad (1)$$

Although not in its original form, this formulation is a more stable model for the Fitts' Law suggested by Mackenzie [15], since it is resilient to negative values. The Index of Difficulty can be obtained by varying the values of the width of the targets and their distance, thus providing a range of task difficulties. We used six different amplitudes: A = 200, 460, 750, 770, 930, 940 pixels; and five different target widths: W = 16, 26, 50, 120, 200 pixels. These choices attain seven levels of Fitts' Law's index of difficulty, from 1.72 bits to 5.20 bits. The order of appearance of the seven indices of difficulty was randomized. We also included two target directions (left, right) in the study because it could be relevant to understand if the contactless motion was influenced by different directions [4, 8].

In summary, the target acquisition data consisted of: 60 participants divided in three groups; two input devices (Microsoft Kinect; Leap Motion); two target directions (left, right); 25 repetitions per index of difficulty; and seven indices of difficulty (1.72, 2.25, 3.12, 3.14, 4.04, 4.89, and 5.20 bits). Thereby, altogether there were 28 experimental conditions and an overall of 42 000 trials.

The gestural-based cursor illustration was a target badge (Figure 15) grounded on the validated "point and wait" strategy [22] for selection. This cursor was shown on the screen when a pointing gesture was interpreted by the system. The center of the target badge represented the point from which the selection coordinates were referenced by the application. When the system detected the gesture to be motionless, a visual feedback was triggered to make the user aware of the selection progress: a green circle started growing inside the cursor representation until it reached the whole target and thus the selection was made. Here, the user had to point and wait for 0.8 seconds for the system to recognize the intention.

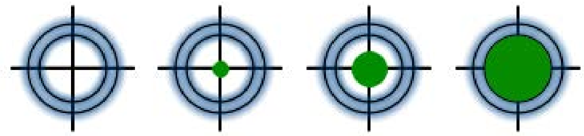

Figure 1. Feedback for the selection strategy.

3.3 Procedure

We analyzed the users' performance considering only movements along the "x" axis and used a reciprocal one-dimensional pointing task based on Fitts' original experiments [7]. This consisted on a horizontal movement between two vertical bars displayed on the screen, representing an initial location and a target (as shown on Figure 2). According to MacKenzie [15], three-dimensional movements may follow the same predictive model as a one-directional task, as a possible substitute for target width when the angle of the approach varies can be the distance through the targets along the approach vector. However, we only intend to understand the one-dimensional movement with homogeneous shapes.

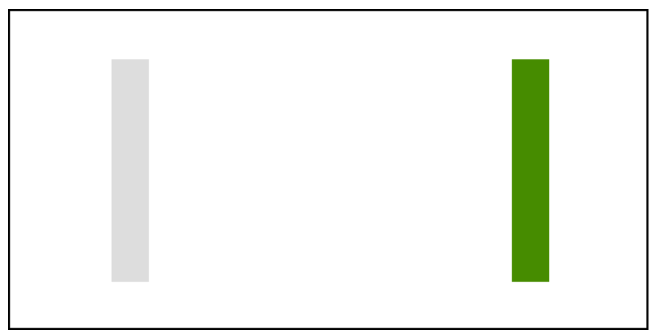

Figure 2. Layout of the targets displayed on the screen

Each test proceeded as follows. At the beginning of the test, the participant would be required to select a "start" button shown on the screen, therefore maintaining a consistent original position. Afterwards, two vertical bars would be revealed: a grey bar representing the initial position, and the green bar being the intended target to be selected. Participants then selected the target bar in each successive trial, which was at all times organized in the opposite direction (from left to right and from right to left). Also, there was a visual feedback to indicate the gesture position was on top of the target object: the bar changed its color to blue. The start time was recorded from each target bar to the next and stopped when the next target was selected. At the end of all of the trials, the bars disappeared and a "successfully completed task" message appeared on the screen.

Participants were given a practice attempt before starting the test. This period consisted in completing a continuous task [15] with 10 consecutive trials, in order for the participant to feel at ease with the interaction device.

3.4 RESULTS AND DISCUSSION

In this section, we present the results of this case study. We believe that we may be able to throw some light on how or if: (1) the different user groups exhibit significant differences in terms of interaction performance when compared between each other; (2) the accuracy of the devices influences gestural interaction when it comes to target acquisition tasks, concerning users of different age brackets.

3.5 Movement Times and Errors

We present the movement times recorded during each trial of the experimental tests with the Kinect and Leap Motion devices (Figure 17). A boxplot analysis of the data revealed a presence of outliers from standardization failure [18] on some of the movement times regarding the calibration of the equipment, and thus these results were removed in order to prevent distortion of estimates.

In terms of movement times recorded, the device that registered the fastest mean results throughout all the three groups was the Leap Motion: children (1.94 s); young adults (1.76 s); and older-adults (2.24 s). On the other hand, the Kinect sensor registered higher mean movement times: children (2.46 s); young adults (2.03 s); and older-adults (2.64 s).

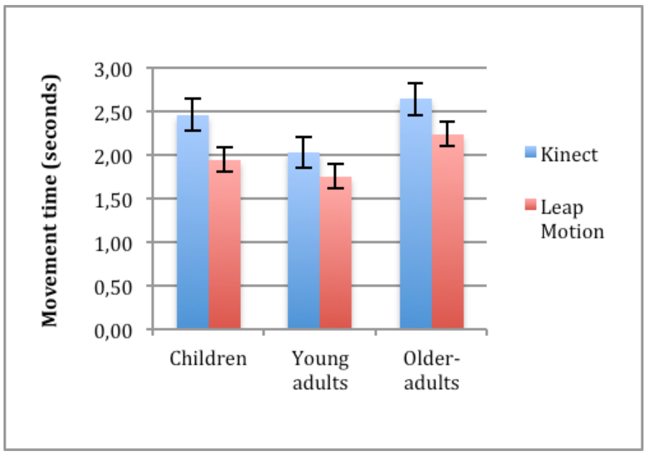

Figure 3. Mean movement times of each group with both devices

We assessed the normality of data with the Shapiro-Wilk Test in order to understand if the data were normally distributed and could thus be considered for statistical analysis. We elected this test over the Kolmogorov-Smirnov due to our narrow sample. As we found that the data were not normally distributed across all of the groups and since we were working with small samples, we performed a non-parametric Mann-Whitney U test to understand if the devices presented significantly different results for each group in terms of movement time. Indeed, every group presented a statistically significant difference between the use of each device. In this regard, the group of children revealed slower movement times using the Kinect sensor, with an average rank of 13.80, while the Leap Motion had an average rank of 7.20, being this difference significant ($U = 17$, $p = .013$). Concerning the group of the young adults, there was also a statistically significant difference between the devices ($U = 23$, $p = .041$), but not as pronounced as the children, being the Kinect the one with the highest movement times (Kinect, average rank of 13.20; Leap Motion, average rank of 7.80). Also, we determined a statistically significant difference when comparing the older-adults' interaction using both sensors ($U = 21$, $p = .028$), where the Leap Motion remains faster (Kinect, average rank of 13.40; Leap Motion, average rank of 7.60). This may indicate that according to the movement times all the groups display lower results when interacting with the Leap Motion sensor than with the Kinect, which may imply that for gestural interaction concerning selection tasks, the Leap Motion could induce quicker reaction times regardless of the users' age.

Overall, considering a comparison between the three groups, the young adults presented the lowest mean time with both devices, which may indicate that when it comes to gestural interaction the young adults are quicker in completing target acquisition tasks than the other groups. Since our group sample was limited to 10 participants for each group and each device and some data were not normally distributed, a non-parametric independent-samples Kruskal-Wallis 1-way ANOVA was run to determine whether this difference in terms of mean times throughout the groups was indeed significant. The distribution of the times of all the groups using the Leap Motion was considered the same and thus not statistically different ($\chi^2(2) = 5.635$, $p =.060$), presenting a mean rank time of 15 for the group of children, 11.10 for young adults, and 20.40 for older-adults. On the other hand, considering the use of the Kinect, the Kruskal-Wallis test showed that except for the children and older-adults ($p = .875$), there was a statistically significant difference in mean times between the different groups ($\chi^2(2) = 12.742$, $p =.002$), with a mean rank time of 17.30 for the group of children, 7.75 for young adults, and 21.45 for older-adults. Hence, the difference of movement times using of the Kinect was statically significant between the group of children versus young adults ($p = .046$), and the group of young adults versus older-adults ($p = .002$).

In this sense, when using the Leap Motion, the groups did not present statistically different results concerning movement times, which may suggest that their reaction times are not that disparate. However, when using the Kinect sensor the groups show inconsistency with regard to movement times.

Another aspect that we looked at was error rate. We assumed a speed–accuracy tradeoff approach [25] when dealing with errors, as the selection rested on the "point and wait" strategy and thus did not trigger false selections caused by user mistakes. The more precisely the task was performed, the longer it took to be completed, and vice-versa. Here, the selection would only be triggered when the system detected the gesture to be motionless and precisely on top of the target bar. Otherwise, no selection was made.

3.6 Indices of Performance

Figure 18 shows the Index of Performance achieved by the three groups for each interaction device. The chart clearly shows the children as having the worst performance of all the groups, either with the Kinect (IP = 1.64 bits/s) or with the Leap Motion (IP = 2.03 bits/s); followed by the young adults with an IP of 2.98 bits/s with the Kinect, and 2.47 bits/s with the Leap Motion. The group of older-adults presented the highest throughput regarding gestural interaction for target acquisition tasks with both devices: the Kinect with an IP of 3.03 bits/s and the Leap Motion with 3.25 bits/s.

A Shapiro-Wilk Test showed us that the data were not normally distributed and, as such, we performed a Mann-Whitney U test to understand if there were significant differences between each group's performance concerning the device used. None of the groups presented a significant difference between the performance using each device: children (U = 34, p = .226); young adults (U = 38.50, p = .384); older-adults (U = 44, p = .650).

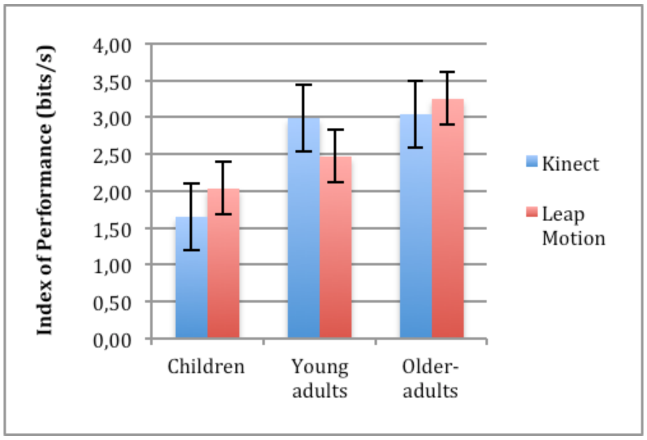

Figure 4. Groups' Index of Performance concerning both devices

An independent-samples Kruskal-Wallis 1-way ANOVA test was also run to determine if there was a statistically significant difference in terms of performance between the groups. Considering the Kinect, the performance of the children versus young adults (p = .031) as well as versus older-adults (p = .013) was significantly different. Contrarily, the group of young adults and older-adults did not register significant differences (p = 1.000). On the other hand, considering the Leap Motion sensor, the only significant difference presented was between the groups of children versus older-adults (p = .034), and not between children and young adults (p = .824) or young adults versus older-adults (p = .453).

We might reach the conclusion that, in terms of performance, neither the Kinect nor the Leap Motion sensor directly influences gestural interaction. However, they appear to have different results regarding users of different age brackets, which implies that these sensors could affect accuracy of interaction depending on the user's age. The group that revealed the best performance results was the older-adults' one, which has already shown to have worse results when it came to reaction times during selection tasks. Here, we may infer that since other pointing devices like the mouse or even touch inputs may request more accuracy than gestural commands, these allow older-adults to overcome some problems of dexterity that may exist in this age bracket, and thus demonstrate improved performances over other groups of users. However, we will not further explore this assumption on the course of this paper. In contrast, children may need more time practicing to overcome the learning curve to better understand the relation between the physical environment of the gesture itself and its visual feedback.

3.7 Participants' Behavior and Feedback

During the experiment, participants shared the same behavior concerning both devices. They were attentive to the task: trying to maintain a certain pattern with the arm's motion and trying to avoid any sudden movements. The most perceptible behavior we noticed was that some of the participants would push the arm foreword in order to try to elevate the target badge on the screen, instead of lifting it upwards. This situation would lead the participants to a higher level of frustration with either device because the badge would not go up unless the arm was raised.

Also, at the end of the experiment the participants answered a questionnaire about their preferences. We discuss below the responses with the majority of the preferences. In terms of ease of use, 50% of the children focused their choice in that the Kinect was relatively difficult to use, being the other answers scattered throughout the Likert scale. In contrast, the Leap Motion had 37% of the children saying it was relatively easy. The older-adults also shared this opinion (40% signed the Kinect as relatively difficult; and 45% said the Leap Motion was very easy). Although the results do not show this tendency, some participants felt that the Leap Motion sensor seemed easier to use than the Kinect. The young adults stated that both devices were very easy to use (50% of the responses regarding each device).

On the other hand, in terms of ease of learning and improvement, both children and young adults thought both devices were relatively easy, but the older-adults argued that the Leap Motion was easier to learn than the Kinect. Regarding fatigue, all of the groups thought both devices were relatively demanding except the older-adults' group that considered the Leap Motion less challenging than the Kinect. Finally, all groups considered the Kinect as a device that requires further concentration to complete the trials, as opposed to the Leap Motion that was simpler in terms of attention to the task.

4. CONCLUSIONS AND FUTURE WORK

This investigation was intended to understand (1) if there are age-related differences regarding gestural selection tasks when using one device to the detriment of the other; (2) if two different gestural sensors, the Kinect and the Leap Motion, could differently influence the users' interaction performance and target acquisition times.

We are aware that conducting further tests may help ascertain whether the devices do truly influence the participant's movement times and respective index of performance. Also, it is possible that by continuing the experiment the groups' index of performance would increase, and we therefore need to understand if practice could be considered as a way to attenuate the learning curve, and consider running more tests to set aside potential hardware problems on detection that could be negatively affecting accuracy.

Nevertheless, we acknowledge it appears to be evidence that for selection and target acquisition tasks a gestural interface may not be the best approach, as it shows low indices of performance throughout the three groups. We may presume that for selection tasks that require a higher level of precision neither device displayed proof that it influenced the user to complete the trials with better performance. In fact, the devices' accuracy did not appear to have a direct relation to improved performance.

As stated earlier, mean movement times should not be considered the only variable when exploring the users' performance, and here we can relate to why: for example, when comparing the movement times and respective index of performance, children exhibited mean times similar to the other groups, but not nearly as good performance as the others. Children have as good response times as other groups, but they do not present a consistent interaction, which may reveal that they are faster but not as precise when interacting with gesture-based interfaces. On the other hand, the group of older-adults was indeed the one that exhibited the best results concerning performance with both devices. However, it was also the one group to present higher movement times, which may indicate that they have a consistent interaction. Regardless of their movement times being not as fast as the other groups, they tend to be more precise throughout the several levels of difficulty of each set of trials.

This is a work in progress, and more tests will be conducted to further attest these findings, but we may suggest that: (1) in terms of index of performance the groups displayed statistically different results: the group of older-adults held the best gestural performance results, and the children the worst, when compared between each other; (2) both devices behave in a similar manner for selection tasks and there are no statistically significant differences concerning their accuracy when comparing each of the three groups individually. However, in terms of user preference, some participants felt that the Leap Motion sensor was easier to use and less demanding in terms of concentration than the Kinect.

Aside from more tests to be conducted, in the future we also intend to broaden our research to other elemental tasks (as insertion and manipulation) using gestural interfaces and observe performance considering our targeted age groups. Also, we intend to follow other evaluation methods and test the 7 measurements of McKenzie [14] and Steering Law [1] for tracking performance evaluation for these pointing devices.

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Including multi-stroke gesture-based interaction in user interfaces using a model-driven method

Otto Parra González [1]
Universidad de Cuenca
Av. 12 de Abril s/n y A. Cueva
01.01.168, Cuenca, Ecuador
+593 07 405 1000
otto.parra@ucuenca.edu.ec

Sergio España
[1]Universitat Politècnica de València
Camino de Vera s/n
46022, Valencia, Spain
+34 96 387 7000
sergio.espana@dsic.upv.es

Oscar Pastor
Universitat Politècnica de València
Camino de Vera s/n
46022, Valencia, Spain
+34 96 387 7000
opastor@dsic.upv.es

ABSTRACT

Technological advances in touch-based devices now allow users to interact with information systems in new ways, being gesture-based interaction a popular new kid on the block. Many daily tasks can be performed on mobile devices and desktop computers by applying multi-stroke gestures. Scaling up this type of interaction to bigger information systems and software tools entails difficulties, such as the fact that gesture definitions are platform-specific and this interaction is often hard-coded in the source code and hinders their analysis, validation and reuse. In an attempt to solve this problem, we here propose gestUI, a model-driven approach to the multi-stroke gesture-based user interface development. This system allows modelling gestures, automatically generating gesture catalogues for different gesture-recognition platforms, and user-testing the gestures. A model transformation automatically generates the user interface components that support this type of interaction for desktop applications (further transformations are under development). We applied our proposal to two cases: a form-based information system and a CASE tool. We include details of the underlying software technology in order to pave the way for other research endeavours in this area.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User interfaces. – Graphical User Interfaces, Interaction Styles, Input devices and strategies.

General Terms

Design, Experimentation, Human Factors, Verification.

Keywords

Customised gesture, model-driven engineering, user interface, gesture-based interaction.

1. INTRODUCTION

Natural user interface (NUI) considers the use of many different interaction modalities, including multi-touch, motion tracking, voice, and stylus [1]. Users interact with computers employing intuitive action such as touching, gesturing and speaking.

Several issues may hinder the wide adoption of gesture-based interaction in complex information systems engineering. Currently, gesture-based interaction is limited to its specification in the implementation stage in the software development lifecycle (SDLC) using tools to write source code. Gesture-based interfaces have been reported to be more difficult to implement and test than traditional mouse and pointer interfaces [2], yet the development of gesture-based capabilities has to be done entirely in the source code by programmers with specific technical skills [3].

With the aim of overcoming this situation, this paper introduces a Model-Driven Development (MDD) approach to gesture-based information systems interface development. The method is intended to allow software engineers to focus on the key aspects of gesture-based information system interfaces; namely, defining gestures and specifying gesture-based interaction. Coding and portability efforts are alleviated by means of model-to-text (M2T) transformations. We focus on multi-stroke gestures as they are expressive and currently wide-spread.

Our proposal has the following benefits: (a) the solution is integrated with the existing source code of user interfaces; (b) the solution can be used on any target platform (platform-independence).

We also implemented a tool prototype to support our approach that defines multi-strokes gestures and includes them in a user interface. This tool prototype is coded in Java and Eclipse Modelling Framework.

The contributions of this paper are the following:

- We present gestUI, an MDD method for gesture-based IS interface development consisting of: (i) a modelling language to represent multi-stroke gestures, and (ii) a set of multi-platform model transformations.
- We provide a tool support for the method that captures multi-stroke gestures sketched by the users, transforms them into a model, and automatically generates (i) the gesture catalogue and (ii) the source code of the gesture-based IS interface.
- We validate our approach by applying it to two cases in different types of information systems for desktop-computing.

This paper is organized as follows: Section 2 includes the definitions of items contained in the proposal. Section 3 reviews related work. Section 4 describes our proposal. Section 5 introduces the tool prototype designed to apply this approach. Section 6 describes its application in two cases and Section 70 contains our conclusions and projected future work.

2. BACKGROUND

2.1 Stroke gestures

Nacenta et al. [4] demonstrate that users prefer user-defined gestures rather than stock and pre-defined gestures. Although user-defined gestures offer better memorability, efficiency and accessibility than pre-defined gestures, they have received little attention in the literature [5]. According to the taxonomy of gestures in [6], semaphoric gestures refer to strokes or marks made with a mouse, pen or finger. This type of gesture is further classified as single-stroke and multi-stroke, according to the number of strokes required to sketch them (see Fig. 1).

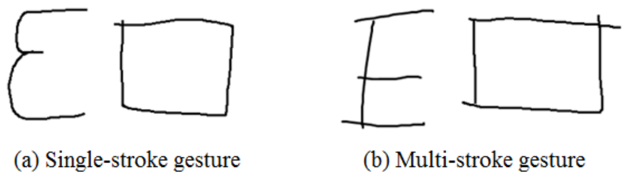


Figure 1. Types of semaphoric gestures

According to [7] a stroke gesture is commonly encoded as a time-ordered sequence of two-dimensional points with coordinates (x, y). Optionally, stroke gestures can also have time stamps as the third dimension so the sampling points are encoded as (x, y, t) if the temporal aspect of a gesture is to be preserved and used. In this work, stroke gestures are used to issue commands, which are the names of the executable computing functions issued by the user.

2.2 Model related definitions

A model is a description of a system or part of a system written in a well-defined language. A well-defined language is a language with well-defined form (syntax), and meaning (semantics), which is suitable for automated interpretation by a computer [8]. A model, both source and target, is expressed in a language [9], for example, XML.

Model-Driven Architecture® (MDA®) is an architectural framework for software development. One of its fundamental aspects is its ability to address the complete development lifecycle, covering analysis and design, programming, testing, component assembly as well as deployment and maintenance. MDA specifies three default viewpoints on a system: computation independent, platform independent and platform specific. MDA specifies three default models of a system corresponding to these three viewpoints: computation independent model (CIM), platform independent model (PIM) and a platform specific model (PSM) [10].

Model-Driven Engineering (MDE) describes software development approaches in which abstract models of software are created and systematically transformed into concrete implementations [11]. Model-driven development (MDD) automates the transformation of models from one form to another.

Model-driven describes an approach to software development whereby models are used as the primary source for documenting, analysing, designing, constructing, deploying and maintaining a system [10].

Model-to-Text (M2T) transformation is a model management operation that involves generating text (e.g., source code, documentation, configuration files) from models [12].

3. RELATED WORK

This section briefly reviews the role of model-driven engineering (MDE) in HCI in which models are used to create a user interface that includes user interaction. Several studies have reported on the use of model-driven engineering in HCI to design user interfaces with this type of interaction.

Aquino et al. [13] emphasize the importance of interaction modelling on the same level of expressiveness as any other model involved in the development life cycle of an interactive application. They define the presentation model of the OO-Method as an abstract model from which the model compiler can automatically generate a user interface for different interaction modalities and platforms, although they do not include an explicit reference to a type of interaction modality (e. g., graphical, vocal, tactile, haptic, and multimodal).

Deshayes et al. [14] propose the use of MDE and model execution in the context of human-computer interaction (HCI) by means of heterogeneous models obtained with the ModHel'X modelling environment for developing a simple HCI application for gesture-based interaction. Their application makes it possible to browse a virtual book using gestures (e.g., swiping, moving) in Microsoft Kinect.

Vanderdonckt [15] describes a set of variables related to the development of user interfaces, one of which considers interaction devices and styles. Interaction styles include the gesture recognition. However, he point out that an abstract user interface is independent of any interaction modality [16] so that an explicit reference to a specific type of interaction style is not considered.

[17] includes a report regarding user interface plasticity and MDE, in which three information spaces are defined: the user model, environment model, and platform model. The platform model considers the possible interactions that can be included in a user interface. This report also includes a description of models that have been defined with the aim of creating user interfaces. It also mentions the variety of interaction modalities currently available thanks to the diversity of technological spaces that can be included in the definition of concrete user interfaces.

Calvary et al. in [18] describe the relation between MDE and HCI in implementing user interfaces. In this context, they introduce the models contained in a number of frameworks (e g., UsiXML, CTTe), one being the interaction model considered in the process of defining user interfaces. However, the interaction modality is not considered.

In [19], the authors propose the Abstract Interaction Model that is added to the Presentation Model in the OO-Method. Two sub-models are considered to define the Interaction Model: the user model and abstract interface model. A set of interaction components is defined in the abstract interface model that define its interface with the software system. These components are conceptual modelling elements that describe the interaction behaviour expected by the user but not how it is implemented, so that this system does not include the interaction modality in the process of user interface generation.

All the works cited above mention the importance of using MDE and HCI to obtain user interfaces in a short time at a low cost. Although they also point out the need for a specification of an interaction modality, they do not include gestures in their proposals. We considered gesture-based interaction in this proposal in order to obtain a complete definition of user interfaces using MDE and HCI.

4. OUR PROPOSAL

This section describes gestUI [20], a user-driven iterative method based on the MDD paradigm. The system defines multi-strokes gestures, creates a gesture catalogue model and using model transformations to obtain the interface source code, including gesture-based interaction. gestUI is expected to be integrated into a full interface development method (shown in Fig. 2 by generic activities and artefacts in grey). The method can either be model-driven or code-centric. gestUI is user-driven because the users participate in all non-automated activities and is iterative because it aims to discover the necessary gestures incrementally and provides several loopbacks.

Our proposal is based on Model-driven Architecture (MDA) considering three layers: the platform-independent layer, platform-specific layer and code layer. gestUI consists of five activities and their products which are distributed in the three layers, as shown in Fig. 2.

In the platform-independent layer, during the A1 activity, "Define gestures", the stakeholders and developers have meetings to discuss gesture definition for the user interface. The stakeholders try the gestures in the interface implemented in the tool to verify that these gestures are suitable for the tasks in their information system. Finally, a gesture catalogue model is obtained conforms to the gesture catalogue metamodel (Fig. 3). In the gesture catalogue each gesture is formed by one or more strokes defined by postures, described by means of coordinates (X, Y). The sequence of strokes in the gesture is specified by means of precedence order. Each posture in a gesture is related to a figure (line, circle, etc.) with an orientation (up, down, left, right), and is qualified by a state (initial, executing, final).

In the platform-specific layer there are two activities: (i) Activity A2, "Design gesture-based interaction" which consists of a process to define the relationship between a gesture and an action (command) to be executed in an information system. This activity produces the gesture-based interaction model. If the stakeholders consider that the definition of gestures is incomplete or inadequate the process can return to Activity 1 to be redefined. (ii) Activity A3, "Generate gesture specification", employs an M2T transformation to generate a platform-specific gestures catalogue specification.

There are two activities in the code layer: (i) Activity A4, "Generate gesture-based interface", which employs the gesture-based interaction model and the platform-specific gestures catalogue specification to obtain the source code of the gesture-based user interface by applying a model transformation. (ii) Activity 5, "Test gestures", tests the gestures defined by the stakeholders and included in the information system. This is an iterative process because it is possible to redefine the gestures if the users are not satisfied with their definition.

If the gesture catalogue is complete and the users agree with the definition of the correspondence gesture-action in the information system (IS), then the process is finished. The IS then contains gesture-based interaction as a complementary interaction modality to the traditional interaction.

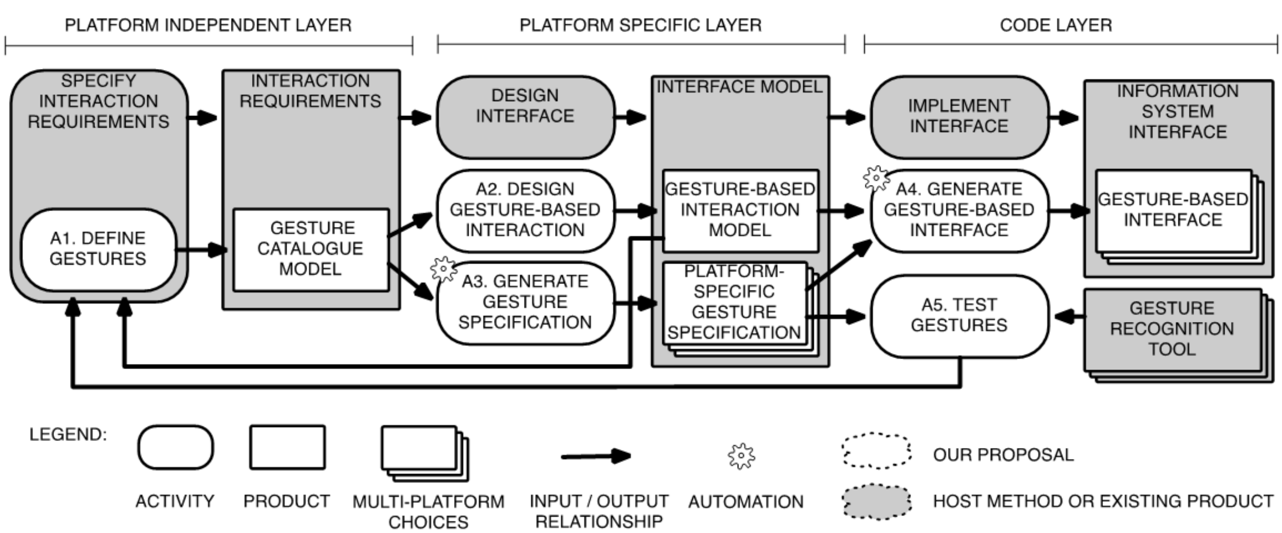


Figure 2. gestUI method overview

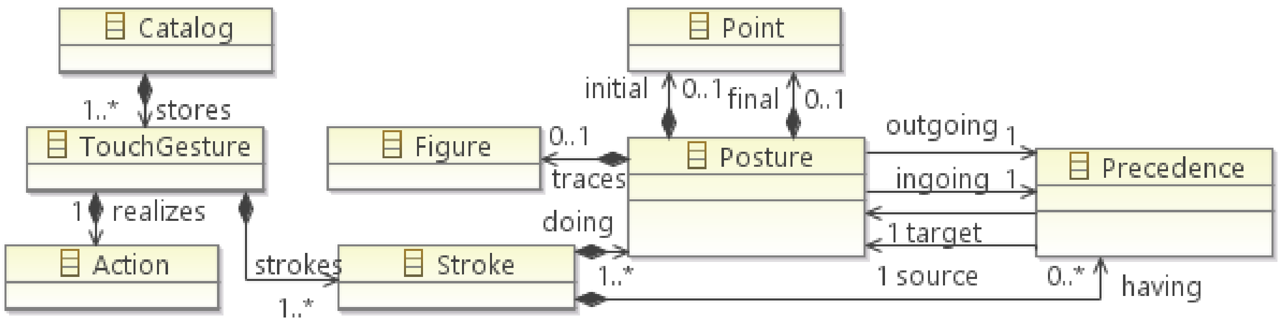


Figure 3. Gesture catalogue metamodel

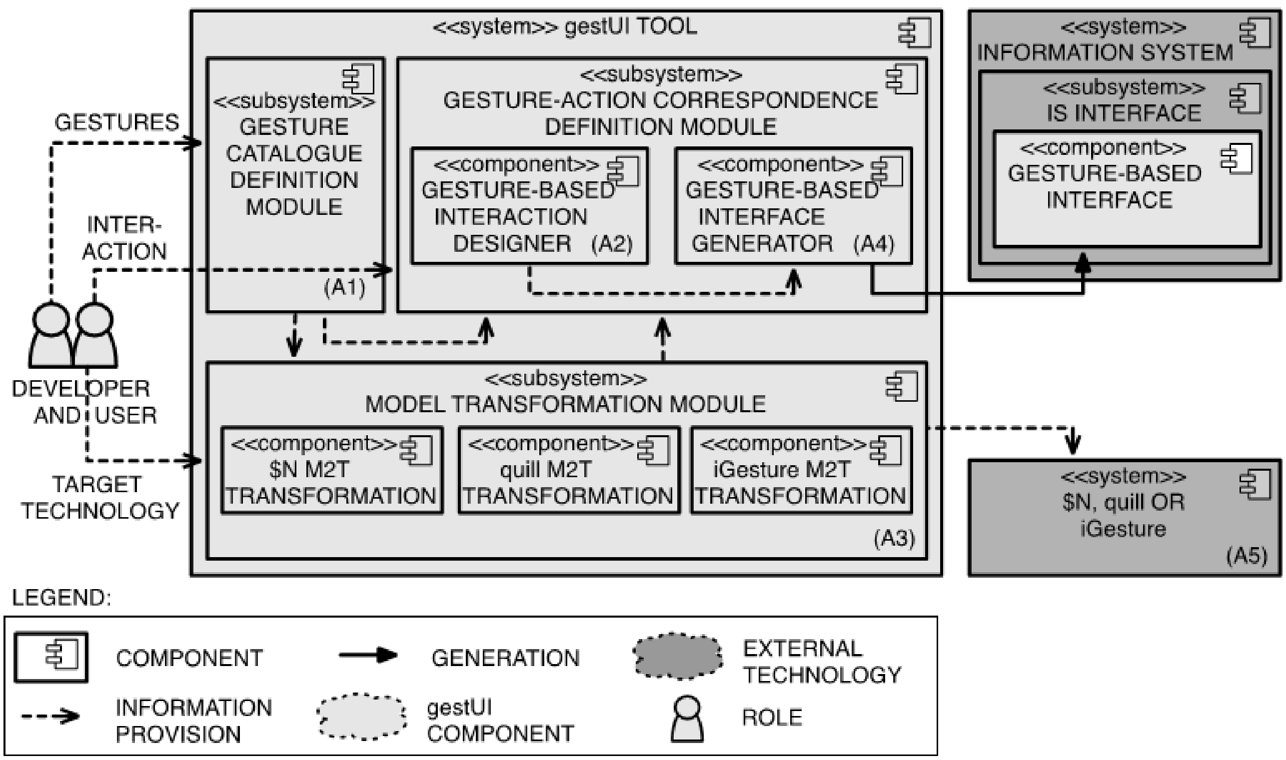


Figure 4. gestUI tool overview

5. TOOL

This section describes the tool that implements our proposal. This tool is structured in three modules as shown in Fig. 4. The number in brackets indicates the method activity each component supports. The method's internal products are not shown. The relationship with the external gesture recogniser is represented.

The first module "Gesture catalogue definition" contains a process that obtains the gesture catalogue model from the users' gesture definition made by the users. Activity A1 is included in this module.

The second module "Gesture-Action correspondence definition" includes a process to specify the correspondence between gestures and actions (commands) available in the IS. Activities A2 and A4 are included in this module.

The third module "Model transformation" contains the definition of the M2T transformations for some platforms as targets for gesture-based interaction in the user interface. Activity A3 is included in this module.

The tool prototype is developed in Java and Eclipse and permits the proposal to be applied by means of its modules: (i) to define multi-strokes gestures, (ii) to obtain a gesture catalogue model using model transformations, (iii) to define gesture-action correspondence and, (iv) to generate source code to include gesture-based interaction in user interfaces. At present, the tool generates Java source code embedded into the IS interface source code.

6. DEMONSTRATING THE PROPOSAL

This section describes an application of the method with the implemented tool to include gesture-based interaction in existing information systems (IS). gestUI is integrated into a code-centric interface development method considering two legacy desktop-computing IS: forms-based IS and case tools.

The process of obtaining a user interface with gesture-based interaction involves the following steps:

a) Define the gestures according to the users' requirements, and then obtain the gesture catalogue model.

b) Obtain the platform-specific gesture catalogue by means of model transformation using the gesture catalogue model and the target platform as source for the transformation.

c) Specify the user interface to which we will add the gesture-based interaction by definition of gesture-action correspondence. The user interface source code which includes the gesture-based interaction is generated.

d) Add the generated source code to the existing user interface source code and recompile the system.

6.1 Form-based Information System

In the first case, we consider a form-based IS to manage information for the computing department of a business company, formed by departmental offices that have offices. In each department there are employees who use computers with one or more operating systems and printers.

The IS manages the information of: (i) the company, (ii) departments, (iii) devices (computers, printers), (iv) the operating systems installed in the computers, (v) the operation status of the devices, (vi) the employee that uses the devices. For the sake of brevity, we will only consider the option to manage information of operating systems in the process of inclusion of gesture-based interaction. Fig. 5 shows the domain class diagram of this IS.

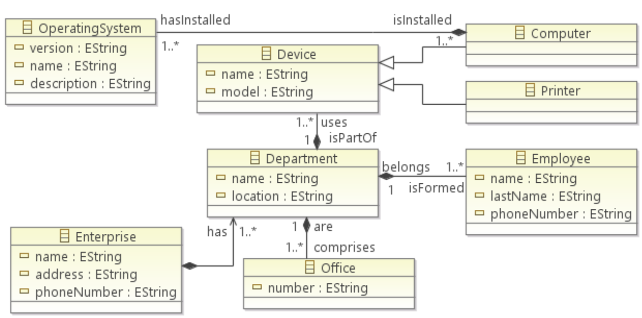


Figure 5. Domain class diagram of the form-based IS

This software, written in Java using Swing in Eclipse, employs a three-tier architecture: data access logic, business logic, and presentation logic [20]. The set of operations that can be executed in each component are called CRUD operations (create, read, update, and delete). In this case we need to define gestures in order to execute these operations in each option (component) of the IS.

The first step is the creation of new gestures using the interface implemented for this task, (see in Fig. 6). The users define gestures according to their preferences in order to execute actions in an information system. For instance, in a database (a) C, to create a new record to enter in the IS, (b) U, to update the information of a record, (c) D, to delete a record, and (d) R, to read the information of a record. Using these gestures, we obtain the gesture catalogue model by means of a model transformation.

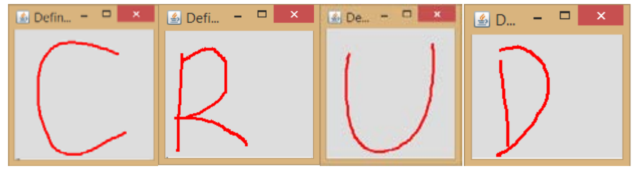


Figure 6. Gestures defined for form-based IS

Therefore, in order to define the gesture catalogue model the user selects gestures from a gesture repository containing all the gestures that the user has defined. This catalogue contains the description of each gesture, but does not contain the action (command) definition to execute it (in Fig. 7 the action is assigned to "null") because this feature (to assign an action) is platform-specific must be specified in the next step.

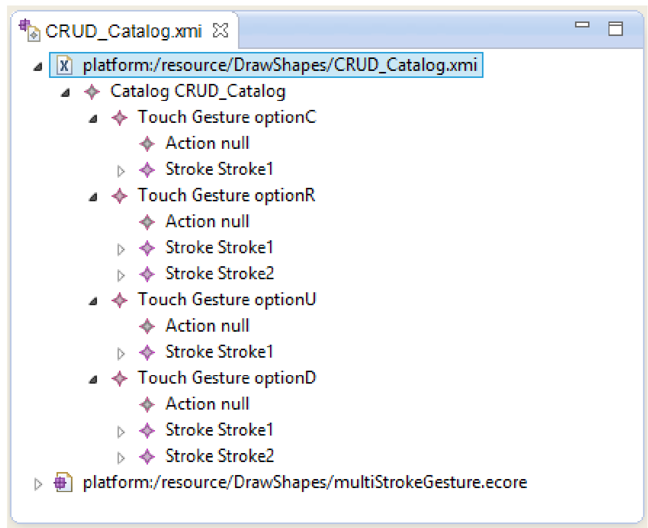


Figure 7. Gesture catalogue model

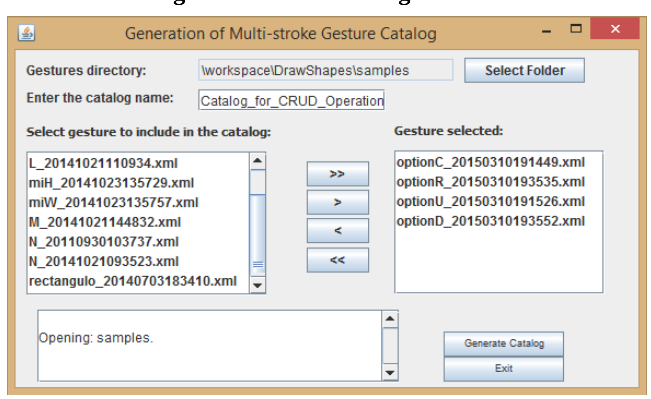


Figure 8. Obtaining platform-specific gesture specification

The next step is the generation of platform-specific gesture specification by choosing the gestures that are used in the IS (Fig. 8). Using this specification and entering the target platform ($N) and the target language (XML) as input data we apply a model transformation to obtain the gestures to be used in the gesture recognition process using $N [21].

Fig. 9 shows an excerpt from a gesture definition generated in XML to be used with $N. In this case, the gesture which represents the letter "D" is formed by two strokes (shown in Fig. 6), each of which contains points with coordinates (X, Y) and a timestamp (T).

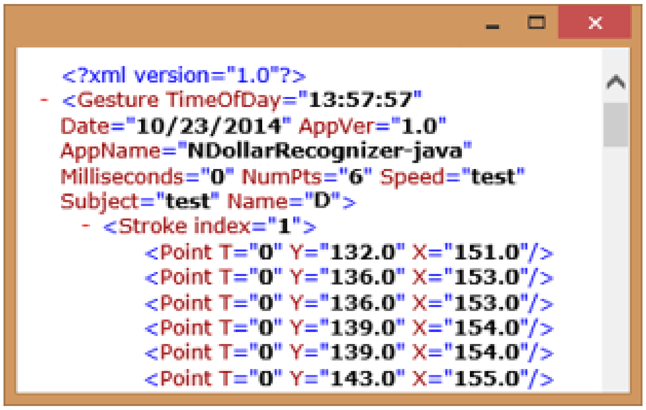


Figure. 9. An excerpt from a gesture written in XML

The next step concerns with the definition of the gesture-action correspondence in order to complete the gesture definition. In this case, the process consists of the selection of a user interface source code to apply a parsing process and determine the actions to be included in this source code. We consider code which contains methods in Java containing "action perform" structures (Fig. 10), which typically define the actions to be executed by selecting buttons or options in the menu in a form-based IS.

```
class BotonListener implements ActionListener {

    public void actionPerformed(ActionEvent e){
        JButton o = (JButton) e.getSource();
        String label = o.getText();

        if (label.equalsIgnoreCase("Create"))
        {
            AltaSistOP ventanaAltaSistOP=new AltaSistOP(modelo,1);
            ventanaAltaSistOP.setVisible(true);
        }
        if (label.equalsIgnoreCase("Update"))
        {
            if (jTable.getSelectedRow()!=-1)
            {
              try {
                controladorSistOP.GetSistOPs();
```

Figure 10. An excerpt of source code of user interface

The developer assign the gesture-action correspondence in collaboration with the user, supported by the Gesture-action correspondence definition module. The process consist in select one gesture (Fig. 11, left) for each action specified in the user interface (Fig. 11, centre). The correspondence gesture-action is defined (Fig. 11, right). The next step is the source code generation by selecting button "Generate" in the interface shown in Fig. 11. In this case, we obtain Java source code to include gesture-based interaction in the user interface source code

Figure 11. Gesture-Action correspondence definition

When generating the user interface Java source code, many references are included: (i) references to libraries to manage gestures (e.g. listeners to manage mouse events such as move, down, up, release, drag), (ii) references to the libraries of the gesture-recognition technology (e.g. $N), (iii) references to the method of executing the gesture-action correspondence (i.e. executingActions in Fig. 12), (iv) references to the methods of capturing gestures (i.e. mouseDragged, mouseReleased), and (v) references to the method of loading the multi-stroke gesture catalogue.

```
void executeActions(String gesture){

    if (gesture.equals("C")) {
        AltaSistOP ventanaAltaSistOP=new AltaSistOP(modelo,1);
        ventanaAltaSistOP.setVisible(true);
    }
    else
        if (gesture.equals("U")) {
            ActualizaSistOP ventanaActualizaSistOP=
                                new ActualizaSistOP(modelo,1);
            ventanaActualizaSistOP.setVisible(true);
        }
```

Figure 12. An excerpt of source code to execute actions

Additionally, the definition of some classes have been changed in order to implement mouseListener and mouseMotionListener to detect mouse events.

Finally, when we execute the form-based IS (Fig. 13), we use the gestures included in the source code to execute the actions specified in the process. In this case, we can use traditional interaction and gesture-based interaction.

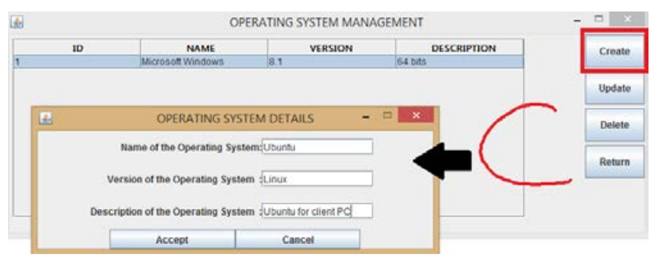


Figure 13. Form-based IS with gesture-based interaction

In the form-based IS shown in Fig. 13, the user draws the gesture "C" with the aim of creating a new operating system record. When the gesture recognizer analyses the gesture sketched by the user as correct, then a new window for the user to fill in the form related to the operating system details.

6.2 Case tool

Now, we describe the application to the second type of IS: in this case, we consider Graphical Editing Framework (GEF), an Eclipse project which provides a development framework for graphical representation of information. The GEF project is developed in JFace and Standard Widget Toolkit (SWT) with Eclipse Modelling Framework. GEF is designed with a Model-View-Controller (MVC) architecture. Briefly, the function of each component is [22]:

- Model: holds the information (underlying objects being represented graphically) to be displayed and is persisted across sessions.
- View: renders information on the screen and provides basic user interaction, in this case, a canvas containing a collection of figures.
- Controller: coordinates the activities of the model and the view, passing information between them as necessary. The controller has a collection of GEF edit parts.

According to [22], the GEF project is formed by three subsections:

- Draw2D, a lightweight framework layered on top of SWT for rendering graphical information.
- GEF Framework, an MVC framework layered on top of Draw2D to facilitate user interaction with graphical information.
- Zest, a graphing framework layered on top of Draw2D for graphing.

In this work, we employ the example called Shapes, included in GEF project, to apply the method. Considering that GEF has a plug-in structure, then the Shapes source code is comprised by two components: (i) source code of GEF which provides the functionality of an editor (to display and draw elements in a diagram), and, (ii) source code of the example, which define the canvas and the palette of the tool and employs the methods defined in the plug-in to use the editor. The palette defined in Shapes permits rectangles and ellipses to be drawn. Therefore, we need to modify the View component both in the source code of GEF and the example Shapes, in order to define the finger gestures for drawing ellipses and rectangles.

We describe below the process applied to the GEF framework in order to include gesture-based interaction in this case tool.

Table 2. Gestures and elements related

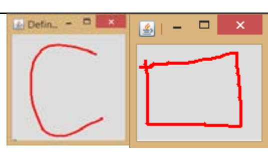
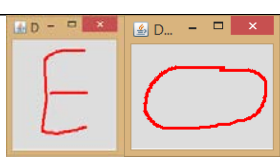
Gestures	Element related
	Rectangle
	Ellipse

Table 13 shows the gestures used to draw the elements defined in the Shapes palette. In the process of defining gestures, in some cases it is possible to "reuse" gestures that the users have sketched previously, for instance, we use the gesture "C" to execute different actions: (i) in the form-based IS to create a record, and (ii) in the case tool to draw a rectangle.

Using the process described in this paper, we obtain the gesture catalogue model, then in the next step we get the platform-specific gesture specification and finally, the definition of gestures using XML to use in the $N gesture recognizer.

The gesture-action correspondence definition is executed in the source code of Shapes. Fig. 14 includes an excerpt from the source code that contains the reference to the aforementioned actions: draw rectangles and ellipses.

```
/**
 * Return a IFigure depending on the instance of the current model element.
 * This allows this EditPart to be used for both subclasses of Shape.
 */
private IFigure createFigureForModel() {
      if (getModel() instanceof EllipticalShape) {
            return new Ellipse();
      } else if (getModel() instanceof RectangularShape) {
            return new RectangleFigure();
```

Figure 14. An excerpt of source code of Shapes

We apply the process of parsing in this source code to determine the actions defined to draw the elements contained in the palette. The user selects the gestures in the catalogue (Fig. 15, left), and defines the relation with the actions that were found in the parsing process (Fig. 15, centre). Finally, the gesture-action correspondence is obtained (Fig. 15, right).

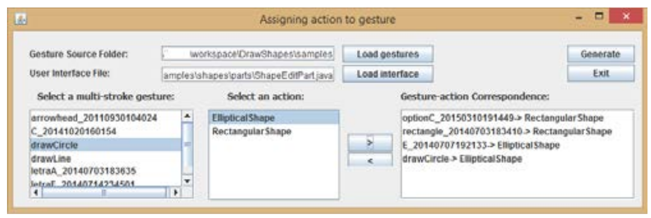


Figure 15. Gesture-action correspondence definition

When generating the user interface Java source code, many references are included; for instance, in the GEF source code we add references to gesture management libraries (e.g. listeners to manage mouse events such as mouseUp and mouseDrag), to the gesture-recognition technology libraries (e.g. $N) and the method of executing the gesture-action correspondence (Fig. 16).

Also, in the methods for managing mouse events we add source code to capture gestures (i.e. mouseDrag (Fig. 17), mouseUp), and the method of loading the multi-stroke gesture catalogue is added.

```
private IFigure createFigureForModel() {
    if (getModel() instanceof EllipticalShape) {
        return new Ellipse();
    } else if (getModel() instanceof RectangularShape) {
        return new RectangleFigure();
    } else if (getModel() instanceof GestureShape) {
        if (gestureType.equalsIgnoreCase("1"))      // (C o rectangle)
            return new RectangleFigure();
        else if (gestureType.equalsIgnoreCase("2")) // circle or E
            return new Ellipse();
        else
            throw new IllegalArgumentException();
```

Figure 16. An excerpt of source code to execute actions

```
public void mouseDrag(MouseEvent mouseEvent, EditPartViewer viewer) {
    Tool tool = getActiveTool();
    if (tool != null) {
        if (isGesture == 1)
            ManagingGestureAndMouse.detectingMouseDrag(mouseEvent);
        tool.mouseDrag(mouseEvent, viewer);
    }
}
```

Figure 17. An excerpt of the source code of GEF

We then consider the source code of the example in order to add the option of including gesture-based interaction in the palette. In the source code containing the definition of the palette we add the source code shown in Fig. 18. The option added is shown in a red circle in Fig. 19. The users thus have two styles of interaction in GEF: (i) traditional interaction (using mouse and keyboard) and (ii) gesture-based interaction (using fingers to sketch gestures).

```
*ShapesEdito... | GestureShape... | LightweightS... | AbstractGrap... | DiagramEditP...
        tool = new GestureTemplateCreationEntry("Gesture",
                "Create a shape with gestures", GestureShape.class,
                new SimpleFactory(GestureShape.class),
                ImageDescriptor.createFromFile(ShapesPlugin.class,
                        "icons/gesture16.png"), ImageDescriptor.createFromFile(
                        ShapesPlugin.class, "icons/gesture24.png"));
        toolbar.add(tool);
        palette.setDefaultEntry(tool);
```

Figure 18. An excerpt from the source code to modify the palette

Obviously, then the source code should be compiled to obtain the case tool with gesture-based interaction included.

When the user employs the gestures defined in this case tool to draw an ellipse/rectangle on the canvas using his/her finger, the gesture recognizer analyses the sketch. If it is correct, then the system draws an ellipse/rectangle defined in the GEF palette.

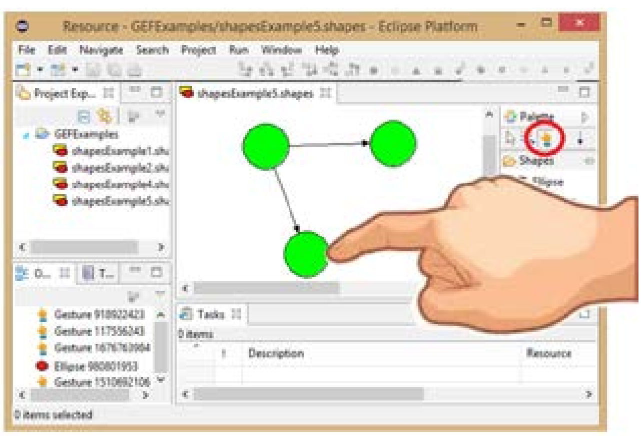


Figure 19. Case tool with gesture interaction

7. CONCLUSIONS AND FUTURE WORK

gestUI is a model-driven method for developing multi-stroke gesture-based user interfaces. We validated the method and supporting tools by applying them to two types of applications: a form-based application and a CASE tool built using GEF (an Eclipse framework with the structure of a plug-in) that can be used to draw simple diagrams. We generated the 'Platform-specific gesture specification' for the two types of applications to illustrate the multiplatform capability of the approach. The gestures were successfully recognised by the corresponding tools. We then automatically generated the final gesture-based interface components and integrated them into the application interfaces.

The advantages of the gestUI proposal are: its platform independence enabled by the model-driven development paradigm, the convenience of including user-defined symbols and its iterative and user driven approach.

Future work will be developed along the following lines: (i) a user study to determine user preferences in defining gestures according to the task to be executed, (ii) applying this method to extending the Capability Design Tool (CDT) of the "Capability as a Service" Project (CaaS project) in order to incorporate gesture-based interaction into this framework.

8. ACKNOWLEDGMENTS

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Interfaces de Usuario Tangibles como Mecanismo de Interacción en Entornos Multi-dispositivos

Elena de la Guía, María D. Lozano, Víctor Penichet, Luis Orozco, Vicente López
Computer Science Research Institute
University of Castilla-La Mancha
Campus Universitario, Albacete - SPAIN
{mariaelena.guia, maria.lozano, victor.penichet, luis.orozco, vicente.lcamacho}@uclm.es

ABSTRACT
En los últimos años la tecnología ha crecido exponencialmente nos encontramos escenarios donde se trabaja con múltiples dispositivos, como son móviles, Tablet PC, portátiles, wereables, etc. interactuando entre sí para ofrecer servicios fácilmente. Hoy en día encontramos mecanismos de interacción tangible y natural que permiten fusionar el mundo real y digital simulando entornos reales y familiares a los usuarios. Sin embargo, la diversidad de usuarios finales se ha incrementado, es decir, nos encontramos usuarios con diferentes habilidades cognitivas, conocimientos, discapacidades, etc. Actualmente, el primer desafío es como diseñar y distribuir las interfaces/información alrededor del entorno sin saturar al usuario. El siguiente desafío es como motivar y guiar al usuario alrededor de entornos MDE sin distraerlo de su tarea u objetivo principal. Teniendo en cuenta que la interacción tangible es más familiar y fácil de aprender para los usuarios que no tienen experiencia con la tecnología se han desarrollado y evaluado cuatro prototipos. Son juegos MDE basados en interfaces de usuario distribuidas y tangibles. Después de evaluar los prototipos, analizar los datos y basándonos en las lecciones aprendidas se han propuesto 8 directrices iniciales. El objetivo principal es servir de guía para diseñar e investigar dichos entornos. Las 8 directrices se han basado en los siguientes elementos (espacio físico/ múltiples usuarios/ motivación).

Categories and Subject Descriptors
H5.2. Information interfaces and presentation: User Interfaces. – Graphical user interfaces.

General Terms
Design, Experimentation, Human Factors,

Keywords
Interfaces de Usuario Distribuidas, Interacción Tangible

1. INTRODUCCIÓN
Hace años la interacción persona ordenador se basaba en interfaces de usuario controladas a través de un ratón y un teclado conectados al ordenador.

Hoy en día nos encontramos con escenarios dotados de múltiples dispositivos donde las interfaces de usuario tradiciones se quedan limitadas y surge la necesidad de estudiar e investigar nuevos mecanismos de interacción e interfaces que se adapten al entorno y al usuario. Durante estos últimos años ha surgido un nuevo concepto denominado DUIs (Distributed User Interfaces o Interfaces de Usuario Distribuidas) su objetivo principal es distribuir las interfaces en distintos dispositivos. Pero todavía existen aspectos a abordar, ¿Cómo interactuamos con las interfaces de usuario?, los estudios en este campo han evolucionado desde la manipulación directa que proponía Sheiderman[1] a la manipulación táctil que permite digitalizar objetos y entornos reales, mezclando la parte digital con la real. Actualmente se están insertado las interfaces de usuario tangibles como mecanismo de interacción. Cuando hablamos de interfaces de usuario tangibles (TUI o Tangible User Interface en inglés) [2] nos referimos a objetos físicos utilizados como representaciones y controles de la información digital. De esta forma conseguimos combinar dispositivos digitales con objetos reales creando escenarios más familiares e intuitivos para el usuario.

Ahora que tenemos entornos físicos reales surgen las siguientes preguntas. ¿Qué directrices son recomendables seguir para distribuir interfaces de usuario en los diferentes dispositivos/objetos/usuarios de la manera más eficaz posible?

La organización del artículo está definida de la siguiente manera: Primero se presenta un breve repaso sobre las interfaces de usuario distribuidas y las técnicas de interacción tangible utilizadas en entornos multi-dispositivo. A continuación se describen los prototipos realizados basados en interfaces de usuario distribuidas e interacción tangible. Por último, se presentan las recomendaciones y directrices obtenidas gracias a las evaluaciones y lecciones aprendidas de los prototipos desarrollados.

2. TRABAJOS RELACIONADOS
La rápida evolución de la tecnología ha cambiado la forma en que interactuamos con sistemas interactivos. En los últimos años han surgido entornos dotados de múltiples dispositivos, también denominados MDE (Multi-Device Environment). Estos escenarios soportan interfaces de usuario distribuidas. Esta se define como una interfaz de usuario donde sus componentes pueden ser distribuidos a través de una o más dimensiones como puede ser entrada, salida, plataforma, espacio y tiempo [3]. Según González en [4], las interfaces de usuario Distribuidas (DUI) se pueden clasificar en función de las características de la interfaz en un MDE. Las interfaces pueden ser divididas o distribuidas en el entorno físico de acuerdo a sus propiedades. El objetivo principal de una DUI es facilitar las tareas a los usuarios en el sistema de software, poniendo a su disposición una configuración óptima de interfaz de usuario que están disponibles en el entorno de trabajo de los usuarios. Según Vandervelpen y Coninx en [6] los elementos que forman parte de un entorno de distribución de interfaces son los siguientes: *Recursos de interacción* (RIs) son canales de I/O disponibles para que el usuario ejecute una tarea. Incluye recursos de I/O como teclados, pantallas, micrófonos, etc. Hablamos de canales limitados a una dirección y una simple modalidad. *Dispositivos de interacción* (DIs) son sistemas que integran computación y son capaces de controlar la entrada o envían la salida a los RIs individuales a los que se encuentran conectados. Un DI es una colección de RIs junto con la unidad de computo. Los DIs en este escenario serían ordenadores, dispositivos móviles, etc. Sin embargo, la distribución de las

interfaces en el espacio es complejo, el desafío principal es: ¿Cómo configurar y distribuir las Interfaces de Usuario entre IR, ID para conseguir un sistema usable y atractivo al usuario? Hay estudios al respecto [5], sin embargo, no hacen hincapié sobre las técnicas de interacción que sería más apropiada dependiendo del sistema. Tampoco tienen en cuenta la psicología cognitiva humana innata en los usuarios.

Con el fin de proporcionar diferentes técnicas de interacción tangible nos hemos centrado en el gesto de acercar y alejar también llamado "*Approche&Remove*" [7][8][9] en este caso distinguimos del recurso interactivo que utilicemos como entrada, este puede ser el dispositivo móvil, un objeto o los dedos. Estos tipos de interacción permiten al usuario interactuar con interfaces de usuario distribuidas fácilmente. De esta forma se ofrece un estilo natural y fácil de interacción que resulta intuitiva y motivadora para las personas que no tienen experiencia con la tecnología. Han sido desarrollados con la tecnología NFC (Near Field Communication).

3. CARACTERÍSTICAS DE LOS MDE DESARROLLADOS

Se han desarrollado cuatro prototipos funcionales basados en juegos de aprendizaje y estimulación cognitiva. Teniendo en cuenta la diversidad de los usuarios, se han enfocado en usuarios con necesidades especiales. Los cuatro son colaborativos, interactivos y distribuyen interfaces de usuario en el entorno. Cada uno de ellos implementa una técnica de interacción tangible diferente.

3.1 Distribución de interfaces de Usuario

Para diseñar la distribución de las interfaces de usuario se ha tenido en cuenta la cognición distribuida innata en los usuarios. Como dice Hutchins [10] la cognición distribuida propone que la cognición y el conocimiento no se limitan a un individuo, sino que se distribuye a través de objetos, personas y herramientas en el entorno. Se ha hecho uso del modelo presentado en [15] donde se distribuye el contenido del juego teniendo en cuenta los modelos mentales. Para el diseño de entornos MDE, hemos seguido los siguientes criterios. La memoria a largo plazo se asocia con las interfaces de usuario tangibles, es decir, los objetos digitalizados que permiten al usuario interactuar con el sistema. De esta manera, el proceso que seguiría la mente de los usuarios al utilizar el sistema es el siguiente: en primer lugar, la interfaz del juego es visualizada utilizando la memoria sensorial, a continuación, mediante la memoria a corto plazo el usuario interioriza las interfaces tangibles, finalmente, cuando se entiende la imagen almacenada, se guarda en la memoria a largo plazo, resultando intuitivo el uso del sistema. (Ver Figura 1).

Figura 1. Distribución de una interfaz de usuario común en interfaces distribuidas y tangibles

3.2 Tipos de Interacción Tangible

Con el fin de interactuar con entornos multi-dispositivo donde la interfaz de usuario principal está distribuida en un computador, tablet, smartphone, o proyección en la pared. Se han digitalizado objetos comunes como pueden monedas, tarjetas, juguetes, paneles, etc. ahora llamadas interfaces de usuario tangibles.

Se describen tres tipos diferentes de técnicas de interacción, donde se utilizan diferentes recursos de interacción (RI). La operación interna del sistema es la misma.

Input: Objeto inteligente

Esta técnica es llamada "*Approach&Remove Object*", consiste en interactuar con el sistema acercando y alejando la interfaz de usuario tangible (objeto digitalizado) a un dispositivo de interacción (DI) en este caso cualquier dispositivo móvil (smartphone o tablet) que incorpore el lector NFC en su interior. El dispositivo móvil (DI) es el encargado de conectarse con el sistema y enviarle la información requerida, posteriormente el sistema mostrará la información de salida solicitad (Ver figura 2.a).

Input: Dispositivo móvil

Esta técnica de interacción también se denomina "*Approach&Remove Device*" debido a que el gesto que realiza el usuario para interactuar con el Sistema es el mismo, acercar y alejar el dispositivo móvil al panel digitalizado (Interfaz de usuario tangible) (Ver figura 2.b).

Input: Dispositivo móvil & Objeto digitalizado

Esta técnica de interacción es tangible pero combina dos tipos de interacción; tangible, es decir, el usuario interactúa con objetos comunes y otra técnica basada en tocar una superficie digital con los dedos (touch). El usuario interactúa con la Tablet y puede utilizar tantos los dedos como los objetos (Ver figura 2.c).

Output: Dispositivo móvil y Pantalla

Para mostrar los resultados, tenemos multi-dispositivos que nos muestran mensajes e información multi-modal (audio, visual, textual y gráfica).

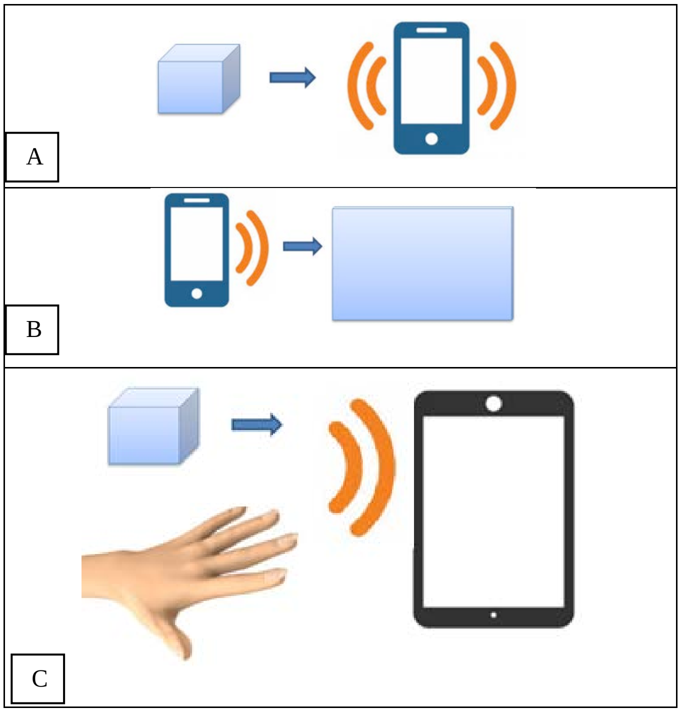

Figura 2. Inputs en entornos MDE a) (IR) es el objeto inteligente; b) (IR) es el dispositivo móvil; c) (IR) puede ser un objeto inteligente o los dedos (touch)

3.3 Diseño del contenido

Para diseñar el contenido de los prototipos se ha buscado activar la motivación por parte del usuario. La motivación es un factor interno que incita a una acción, activa, dirige y mantiene la conducta. Es decir, es el factor que va animar al usuario a utilizar e interactuar con los sistemas propuestos. Existen dos tipos de motivación: Intrínseca y Extrínseca: Las personas que tienen motivación intrínseca realizan acciones porque encuentran satisfacción en el mismo hecho de hacerlas, así como la auto superación, la sensación de éxito, etc. Por otra parte, la motivación extrínseca aparece cuando lo que atrae al individuo no es la acción que se realiza en sí, sino lo que se recibe a cambio de la actividad realizada (por ejemplo, premios, recompensa, puntos, etc.

Teniendo en cuenta que los prototipos son juegos se ha seguido una serie de criterios basados en la teoría de flujo propuesta por Sweetser y Wyeth [19].

Los puntos más importantes que se han tenido en cuenta para diseñar e implementar el contenido y distribución de las interfaces de usuario han sido los siguientes.

Concentración: El objetivo de la aplicación es mantener la atención y concentración del usuario enfocada en la aplicación. Para conseguir que la interfaz sea limpia y el usuario no se distraiga con otro tipo de información se distribuye la interfaz de la aplicación siguiendo la cognición distribuida descrita anteriormente. Por un lado el espacio de trabajo principal y por otro lado los controles y dispositivos de navegación.

Desafío o Reto: Según Malone [17] cualquier juego tiene que proporcionar un reto, es decir, debe despertar la curiosidad de los usuarios. En los prototipos se incluyen tareas para que exploren el entorno, recompensas, puntos, niveles para que mejoren las capacidades cognitivas y sientan un desafío mientras utilizan el sistema.

Control: Lepper y Malone [16] aconsejan que los juegos ofrezcan el control al usuario. En este caso los usuarios tienen sus propias interfaces de usuarios tangibles y dispositivos móviles privados con el fin de ofrecerles la confianza de que utilizan sus propios recursos.

Feedback: La aplicación a través de audio, imágenes y texto ofrece información relevante para guiar en todo momento al usuario.

Inmersión: La inmersión es la característica del juego que provoca al jugador para que se vea envuelto en el mundo virtual, volviéndose parte de éste e interactuando con él. En este caso el mundo es real y combinamos el factor real (interacción y búsqueda de objetos) con el factor virtual (tablet, Smartphone, pantallas, etc. que nos ofrecen los juegos).

Interacción social: El factor real nos ofrece un espacio físico que al mismo tiempo permite a los usuarios interactuar entre ellos con para conseguir un objetivo común.

4. DESCRIPCIÓN DE LOS PROTOTIPOS

A continuación se describen los entornos que soportan múltiples dispositivos, interfaces de usuario distribuidas e interacción basadas en interfaces de usuario tangibles. Se han enfocados para tareas/juegos colaborativos que soportan múltiples usuarios interactuando simultáneamente.

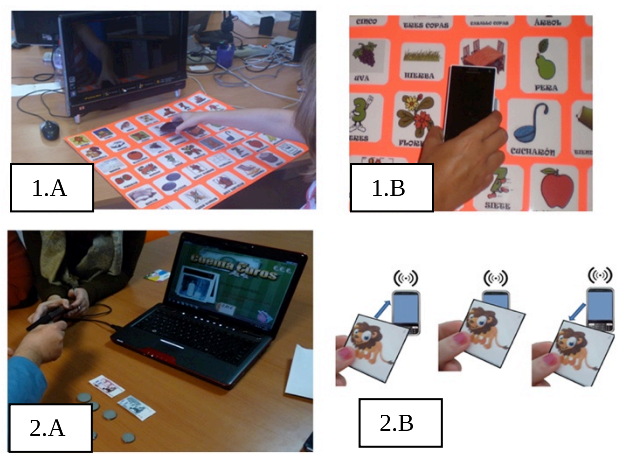

Figura 3.-Sistemas a-) Co-Brain Training , b) TraInAb

Co-Brain Training (Collaborative Brain Training) [13] **(**Ver Figura 3 1.a**)** es un juego interactivo y colaborativo diseñado para estimular habilidades cognitivas como son la memoria, atención y lenguaje en personas que tienen Alzheimer. Su funcionamiento es el siguiente: la interfaz principal del juego se proyecta en una pared permitiendo que puedan jugar múltiples usuarios. Los usuarios interactúan con el sistema acercando el dispositivo móvil que incorpora el lector NFC(como un apuntador) a un panel interactivo (Ver Figura 3 1.b) donde se muestran las opciones posibles del juego.

TraInAb (Training Intellectual Abilities)[12] (Ver Figura 3 2.a).es un juego interactivo y colaborativo diseñado para terapias de estimulación cognitiva en usuarios que tienen discapacidad intelectual. El sistema integra una nueva forma de interacción a través de objetos comunes de la vida cotidiana como pueden ser cartas, juguetes, monedas. Su funcionamiento es el siguiente: la interfaz principal del juego se proyecta en una pared con el fin de aumentar su visibilidad y permitir que puedan jugar múltiples usuarios. Los usuarios interactúan con el sistema acercando los objetos (interfaces tangibles), identificados mediante tecnología NFC (Near Field Communication), al dispositivo móvil que incorpora el lector NFC (Ver Figura 3 2.b).

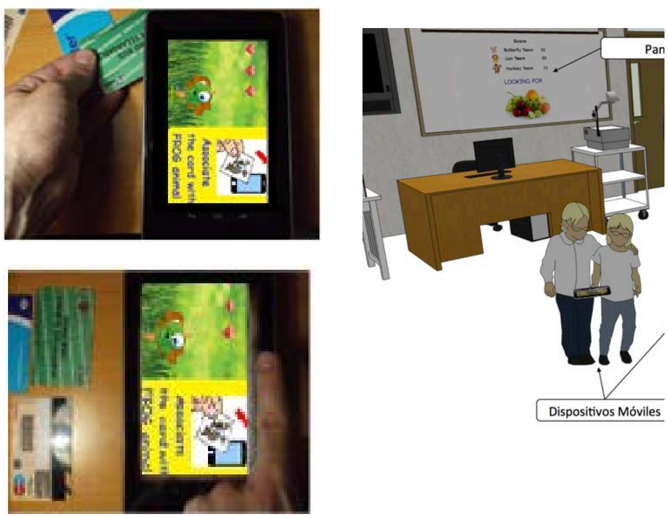

Figure 4. a) Sistema NFCBook b) Sistema Real Game

NFCBook [14] es un libro-juego, es decir, una obra literaria donde se involucra al lector en el seno de la historia permitiéndole decidir sobre el curso de la misma. Su contenido se ha basado en la colección de libros-juegos denominada "*Elige tu propia aventura*". El objetivo principal de la aplicación es motivar a los usuarios para que adquieran el hábito de lectura ayudándoles de esta forma a desarrollar habilidades cognitivas tales como agilidad mental, concentración, activación del sistema visual, etc. Para incentivar al usuario se ha tenido en cuenta factores lúdicos que pretenden convertir una actividad a priori aburrida en una actividad que motive al usuario a participar en ella (Figura 3.a).
El libro que antes era físico se ha convertido en formato digital para ser leído y consultado desde un dispositivo móvil (tablet, smartphone, etc.). Para interactuar con el libro-juego se utilizan objetos físicos que integran NFC en su interior. De esta forma antes de comenzar a jugar es necesaria una fase de búsqueda y selección de tarjetas comunes que integren NFC, después el usuario tendrá el control para configurarlas y posteriormente disfrutar del libro-juego a través del dispositivo móvil y las interfaces tangibles o tarjetas.
La aplicación interactiva distribuye interfaces de usuario en dispositivos móviles y objetos comunes. El funcionamiento es el siguiente, el usuario a través de tarjetas físicas casuales que puede encontrar en cualquier lugar, como son tickets de transportes públicos, entradas a espacios públicos, museos, cines, etc. personaliza sus objetos y su propio juego. La aplicación ha sido implementada en Android e internamente utiliza tecnología NFC para dar un valor a las tarjetas físicas que posteriormente pasaran a ser interfaces tangibles a través de las que se interactuará con el juego.
Real Game es un juego ejecutado en el entorno real donde los usuarios interactúan con el entorno y entre ellos a través de dispositivos móviles/objetos. Los usuarios exploran el entorno, el sistema detecta donde se encuentran y en función de esto les plantea retos a través de los dispositivos móviles que portan. Los retos se resuelven colaborativamente interactuando con los objetos que se encuentran en una determinada zona del entorno, acercan el objeto a otro objeto/dispositivo móvil. Una pantalla principal se muestra las puntaciones, recompensas, retos logrados, etc. (Ver Figura 4.b)

5. LECCIONES APRENDIDAS

La obtención de datos nos permite definir directrices que ayuden a futuros diseñadores e investigadores a tomar decisiones a la hora de desarrollar entornos MDE que soporten interfaces de usuario distribuidas y tangibles. Después de realizar iterativas evaluaciones de los prototipos se han recogido los tiempos medios dependiendo de la interacción, el número medio de errores, la tangibilidad, affordance, número de interacciones verbales entre los usuarios, el coste y la infraestructura de los sistemas. A continuación se describen brevemente algunos de los resultados obtenidos.
Teniendo en cuenta que los sistemas se diseñan para un un **espacio físico real**, es necesario que sea usable, es decir, la interacción debería ser fácil de aprender, sencilla, atractiva al usuario y familiar, con el fin de romper la brecha digital que existen entre varios grupos de usuarios. Por ese motivo, se ha decidido diseñar entornos que simulen el modo real de trabajar que tienen los usuarios en su vida cotidiana. La distribución de interfaces de usuario se realiza siguiendo la psicología cognitiva distribuida, es decir, teniendo en cuenta los procesos mentales del usuario.

Usabilidad y fácil aprendizaje.

La *tangibilidad* es el atributo que define a los dispositivos/objetos que son fácilmente detectables con los sentidos. En este caso los objetos son más comunes y familiares teniendo un grado de tangibillidad más alto. La técnica de interacción tangible basada en acercar los objetos a otros objetos o dispositivos comunes camuflados en objetos ofrecen una alta tangibilidad proporcionando entornos más familiares y fáciles de utilizar para usuarios que no tengan experiencia previa utilizando las nuevas tecnologías *Affordance* es la cualidad de un objeto o ambiente que permite a un individuo realizar una acción, en este caso, los objetos tienen un grado de affordance más alto. Se asemejan a los entornos reales.

Distribución de Interfaces de Usuario en RI/DI

El *tiempo medio* que tardaban los usuarios en buscar la solución correcta en el juego dependía del orden en el que se habían distribuido las interfaces de usuario. Un ejemplo se dio en el juego de deletrear, teníamos 27 opciones correspondientes al abecedario, buscar la letra correcta entre 27 objetos era muy tedioso y los usuarios tardaban más tiempo, sin embargo cuando las letras estaban organizadas en el panel interactivo los usuarios accedían automáticamente a la opción correcta en cada momento, necesitaban menos tiempo para buscar la opción, en tareas donde las opciones siguen un orden como son los números, letras, etc.. es más intuitivo utilizar paneles interactivos con la técnica de interacción consistente en acercar y alejar el dispositivo móvil a la interfaz de usuario tangible. Es decir, los paneles interactivos son más aconsejables cuando podemos agrupar opciones. En el caso en el que tengamos que distribuir la información o necesitas tenerlo más organizado, el panel es preferible como interfaz de usuario tangible. De esta manera, los paneles pueden distribuir menús y atajos para utilizar el sistema.

El número de errores debido a la técnica de interacción se ocasionaban por los siguientes motivos:

1º. El usuario acercaba el dispositivo móvil al panel pero no apuntaba de forma precisa la opción que deseaba seleccionar y el lector recogía el valor de la opción más cercana.

2º. El usuario acercaba la interfaz de usuario tangible al dispositivo móvil, pero no en el área donde se encuentra el lector NFC, por lo que tenían que buscar el área primero y acercar la tarjeta. Este error se dio cuando comenzaron el juego y más en el caso de la Tablet que el móvil, debido al tamaño del dispositivo. Cuando el usuario acercaba la interfaz tangible al dispositivo móvil había menos errores, el dispositivo era más pequeño y la lectura de la tarjeta NFC (que se encontraba en el interior del objeto) era más precisa.

El número de errores fue mayor al acercar el dispositivo móvil a la interfaz de usuario tangible. En cambio la técnica de interacción consistente en acercar la interfaz de usuario tangible al dispositivo móvil eran más precisas por lo que el número de errores fue muy reducido.

El coste es mayor cuando se utiliza la técnica de interacción basada en acercar el dispositivo móvil al panel interactivo, todos los usuarios deben tener su propio móvil. Sin embargo, acercar los objetos a un único dispositivo conlleva un coste muy bajo.

Motivación- Múltiples Usuarios

La interacción social se facilitaba con las técnicas de interacción basada en acercar los objetos a un dispositivo móvil. Se mejoraba la comunicación, comentaban entre ellos las posibles soluciones, y se obtuvieron más interacciones verbales entre los usuarios. Les resultaba más atractivo y novedoso. Cuando interactuaban acercando el dispositivo móvil al panel que compartían entre todos, cobraba importancia los turnos para que puedan interactuar todos, el número de interacciones verbales entre ellos fue menor.

Tabla 1. Comparación de las propiedades de las técnicas de interacción tangible

Alto, medio y bajo	**Approach &Remove el dispositivo móvil**	**Approach& Remove el objeto**	**Approach& Remove el objeto combinado con 'touch'**
% Errores	Medio	Bajo	Medio
Coste de la Infraestructura	Medio(un dispositivo móvil cada usuario)	Bajo	Bajo
Tangibilidad	Bajo	Alto	Alto
Affordance	Medio	Alto	Alto
Agrupamiento	Alto	Medio	Medio
Interacción Social	Medio	Alto	Medio

6. RECOMENDACIONES DE DISEÑO

Después de analizar los datos se han definido ocho directrices iniciales para el diseño de sistemas MDE que soportan interfaces de usuario distribuidas y tangibles.

Directriz 1. Se debe organizar los objetos de una forma ordenada y consistente. Esta es una de las reglas más comunes que se siguen diseñando GUI (Interfaces de usuario gráficas) y siguiendo las teorías de la escuela psicológica de la Gestalt [11], donde describen que las personas percibimos los objetos como patrones bien organizados más que como partes discretas. La mente configura, a través de ciertas leyes, los elementos que llegan a ella a través de los canales sensoriales (percepción) o de la memoria (pensamiento, inteligencia y resolución de problemas).

Teniendo en cuenta la percepción visual del usuario y las lecciones aprendidas. Se deben agrupar objetos de la misma naturaleza en un panel, tabla, surface, etc. como por ejemplo (Abecedario, números, opciones gestionar ficheros: abrir, guardar, etc.). Los paneles se van a utilizar como atajos para realizar acciones en el sistema que se llevan a cabo repetidas veces.

Directriz 2. Se deben dividir los espacios de trabajo en dos tipos diferente. Por un lado el privado donde el usuario tiene el control de su información, dispositivos, objetos, etc. Por otro lado el espacio de trabajo colaborativo donde el usuario puede ver los datos de los demás usuarios, enviar información a todos los demás componentes del grupo, etc. De esta forma conseguimos que el usuario tenga el control de su información dándole confianza [18].

Directriz 3. Añadir el componente "Espacio físico" donde el entorno ofrece información al usuario permitiéndole explorar e interactuar, reduce la carga cognitiva. En este caso, las interfaces de usuario visuales deben ser sencillas e intuitivas con el fin de no despistar al usuario. Además los mensajes auditivos, sensoriales, etc. Son preferibles para no saturar al usuario con la información visual.

Directriz 4. Añadir señales, pistas, etc. Cuando el usuario necesite explorar a través del entorno. De esta forma se consigue que el usuario no se sienta perdido y sepa en cada momento donde se encuentra.

Directriz 5. Se debe reducir la distancia de los usuarios respecto a los objetos que se utilizan repetidas veces mientras se usa el sistema. Estos objetos deben estar cerca.

Directriz 6. El Sistema debe avisar al usuario a través de alertas/notificaciones/pistas donde se está mostrando la información importante en cada momento de forma que el usuario preste atención a la información relevante.

Directriz 7. Añadir componentes motivacionales es recomendable con el objetivo de que el usuario disfrute y se sienta inmerso en la tarea. Se pueden añadir de dos tipos diferentes: *Motivación intrínseca:* El usuario debe sentir que tienen el control del juego, añadirle la posibilidad de comunicación con otros usuarios, la facilidad de explorar en el entorno y crearle desafíos. *Extrínseca.* Añadir mecanismos lúdicos, es decir puntos, ranking, premios, refuerzo positivo, etc.

Directriz 8. Se debe tener en cuenta el awareness, es decir, el usuario debe ser capaz de percibir, sentir, o ser consciente de los acontecimientos, objetos, acciones, etc tanto del entorno como de los demás usuarios. Es decir, cuando el usuario trabaje con grupos de usuarios debe ser consciente de los demás usuarios y a la vez ser capaz de comunicarse con ellos y compartir información fácilmente. La comunicación entre los usuarios debe evitar que sea a través de mensajes escritos en dispositivos con reducida pantallas, es preferible que sea a través de botones, gestos, etc. Estas deberían ser mostradas a los demás a través de notificaciones, sonidos, mensajes sensoriales, imágenes, etc.

7. CONCLUSIONES

Actualmente nos encontramos con escenarios que distribuyen interfaces en entornos con múltiples dispositivos. Interactuar con diferentes interfaces no es una tarea trivial, por ese motivo hemos propuestos la interacción tangible como mecanismo de interacción, esta resulta intuitiva y permite que la mayoría de los usuarios se sientan familiarizados con objetos comunes, resultando más agradable su uso. Las interfaces de usuario se han distribuido siguiendo la psicología distribuida y se han añadido componentes para motivar a los usuarios a usar los sistemas. Después de analizar las evaluaciones realizadas de cuatro prototipos se han obtenido ocho directrices de diseño iniciales. Estos resultados son preliminares, como trabajo futuro se pretende realizar una evaluación más exhaustiva con el fin de obtener criterios y patrones que ayuden a futuros diseñadores e investigadores a construir sistemas de esta naturaleza.

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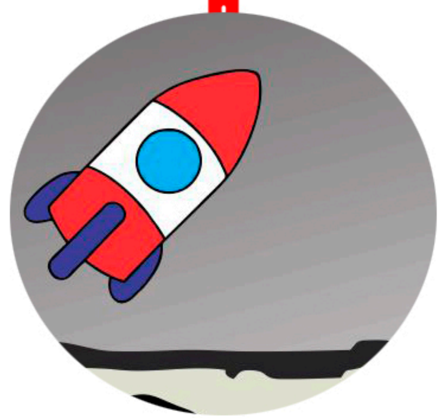
METHODOLOGIES AND MODELS



Limitaciones del Modelo de Tareas del W3C para aplicaciones Post-WIMP

Miguel A. Teruel, Arturo C. Rodríguez, Francisco Montero,
Elena Navarro, Víctor López-Jaquero and Pascual González
Grupo de Investigación LoUISE
Instituto de Investigación en Informática de Albacete
02071 – Albacete (España)
miguel@dsi.uclm.es, arturo.rodriguez@uclm.es, fmontero@dsi.uclm.es,
elena.navarro@uclm.es, victor@dsi.uclm.es, pgonzalez@dsi.uclm.es

RESUMEN
La evolución tecnológica y la aparición de nuevos dispositivos que ésta conlleva está provocando grandes cambios en el modo en que las personas interaccionan con los sistemas software. Cada vez son más los sistemas cuyas técnicas de interacción están basados en realidad virtual, reconocimientos de gestos, dispositivos corporales y muchos otros, que se alejan notablemente de la interacción clásica de los sistemas denominados WIMP (Windows, Icons, Menus, Pointers). Estos nuevos sistemas, a los que se denomina sistemas Post-WIMP, necesitan, por lo tanto, que los lenguajes para la especificación de sistemas evolucionen de igual forma para poder hacer frente al incremento de la complejidad y a los nuevos conceptos inherentes a sus formas de interacción. En este artículo se presenta un lenguaje de modelado de tareas de sistemas Post-WIMP, basado a su vez en CSRML, como alternativa al actual meta-modelo de tareas propuesto por el W3C. Este nuevo lenguaje tiene como finalidad especificar las tareas que serán realizadas por el usuario a través de la interfaz de sistemas Post-WIMP con la expresividad de la que carece el actual meta-modelo de tareas del W3C. Cabe destacar principalmente dos ventajas de esta nueva propuesta respecto a la del W3C. Por un lado, se han incluido varios elementos y relaciones para enriquecer el nuevo meta-modelo con la expresividad necesaria para llevar a cabo la especificación de la colaboración de forma detallada. Por otro lado, nuestra propuesta permite representar la información de awareness que los usuarios Post-WIMP deberían tener durante la interacción con el sistema. Para mostrar la utilización de este nuevo meta-modelo, presentamos un ejemplo de modelado basado en un juego “first person shooter” Post-WIMP con una interfaz de realidad virtual.

Categorías y descriptores de tema
H.5.2 [User Interfaces]: Interaction styles., I.3.6. [Methodology and Techniques]. Interaction techniques.

Términos Generales
Modelado, Interacción, Experimentación, Lenguajes.

Palabras clave
Post-WIMP; CSRML; W3C task model; collaboration; awareness.

1. INTRODUCCIÓN
Durante las últimas dos décadas, investigadores en Interacción Persona-Ordenador (HCI) han desarrollado una amplia gama de nuevas interfaces que se alejan de las tradicionales WIMP (Window, Icon, Menu, Pointing). Estas interfaces WIMP presentan carencias para llevar a cabo tareas complejas como el diseño asistido por ordenador, la manipulación simultanea de una gran cantidad de datos o los juegos altamente interactivos. También tienen deficiencias en aplicaciones que requieren una monitorización continua de señales de entrada, representación de modelos 3D o simplemente en interacciones para las que no hay widgets estándar. Por esta razón, las interfaces de usuario personalizadas se han convertido en la mejor alternativa a la hora de realizar tareas complejas.

Post-WIMP es un término usado para describir interfaces que van más allá de los paradigmas habituales (ventanas, iconos, menús y punteros) [1]. Esta nueva generación de interfaces ha sido impulsada tanto por los avances en tecnología como por un mejor entendimiento de la psicología humana. Definidas por van Dam [1] como interfaces “*que contienen al menos una técnica de interacción no dependiente de los clásicos widgets 2D, como menús o iconos*”, algunos ejemplos de interacciones Post-WIMP son: (i) realidad virtual, aumentada o mixta, (ii) interacción tangible, (iii) computación ubicua, (iv) computación sensible al contexto, (v) interacción con dispositivos móviles, (vi) computación perceptual, e (vii) interacción ligera, tácita o pasiva. Aunque algunas personas podrían clasificar estos estilos de interacción como innovaciones dispares, futuristas y heterogéneas, comparten importantes características como una considerable demanda de información de contexto que ayude a entender, conectar y analizar el trabajo que se lleva a cabo.

Esta evolución de las interfaces requiere que los lenguajes para el análisis de requisitos y la especificación de sistemas sean adaptados de forma adecuada, pudiendo así recoger las necesidades de información de estos nuevos paradigmas de interacción. El análisis de tareas no es una excepción y, a pesar de que los meta-modelos actuales han supuesto una herramienta eficaz en el desarrollo de sistemas WIMP, las nuevas interfaces Post-WIMP introducen la necesidad de revisarlos. Además, el análisis de tareas está estrechamente relacionado con la interacción, puesto que, como afirman Gea y Gutiérrez [2], *cubre diferentes técnicas orientadas a describir las interacciones entre las personas y los entornos de una manera sistemática* y tiene como objetivo obtener una descripción formal del conjunto de acciones que debe realizar el usuario para lograr un fin; acciones que pueden ser tanto cognitivas como interacciones con la interfaz.

En este artículo, proponemos una alternativa al actual meta-modelo de tareas del W3C [3] considerando dos de los principales aspectos clave de los sistemas Post-WIMP: *awareness* (habilidad del usuario de ser consciente de lo que le rodea) y *colaboración* entre usuarios. La necesidad de incorporar dichos conceptos surge, no sólo del estudio de la literatura relacionada, sino también de la amplia experiencia acumulada en nuestro grupo de investigación a lo largo de los últimos quince años en el desarrollo de interfaces post-WIMP, que se inició con sistemas de interacción 3D [4].

Como base para esta propuesta, se ha elegido el lenguaje CSRML (Collaborative Systems Requirements Modelling Language, [5][6]) ya que dispone de capacidad expresiva para especificar las necesidades de colaboración y awareness. Además, otra razón para escoger este lenguaje es que ha sido evaluado para tratar con diferentes dominios, como la edición colaborativa de documentos [5] o la inteligencia de negocio [7]. No obstante, el modelo de tareas CSRML ha sido ampliado y modificado para conseguir dos objetivos. En primer lugar para hacerlo compatible con el modelo W3C y en segundo lugar, para enriquecerlo con elementos de awareness ligados a sistemas Post-WIMP, ya que CSRML estaba diseñado para atender básicamente a las necesidades de los sistemas colaborativos .

Este artículo está organizado de la siguiente manera. La Sección 2 presenta el estado de la cuestión relacionada con el actual meta-modelo de tareas propuesto por la W3C. En base a las deficiencias detectadas en la propuesta de la W3C, en la Sección 3 se presenta el meta-modelo de tareas para interfaces Post-WIMP. Para que puedan apreciarse más claramente las diferencias de la propuesta de la W3C y la nuestra, en la Sección 4 se presenta un ejemplo de modelado basado en un juego Post-WIMP que se ha modelado usando ambos meta-modelos de tareas. Finalmente, en la Sección 5 se presentarán algunas conclusiones.

2. META-MODELO DE TAREAS DEL W3C

Gea y Gutiérrez [2] definen el análisis de tareas como *el estudio de lo que un usuario tiene que realizar en términos de acciones y/o procesos cognitivos para conseguir un objetivo*. Este análisis se traduce en modelos de tareas que tradicionalmente, han proporcionado una descripción eficaz de sistemas interactivos WIMP. Representan información estática de las tareas de aplicación y de usuario a dos niveles: *estructural* (descomposición de tareas) y *temporal* (relaciones temporales). Cada tarea especificada en el modelo de tareas es una actividad o proceso cuya realización es necesaria para conseguir los objetivos del usuario. Además, los analistas pueden representar tareas en diferentes niveles de abstracción, por lo que pueden considerar una actividad como una tarea atómica o descomponerla en sub-tareas, con el objetivo de proporcionar una especificación con mayor detalle, y después, establecer relaciones temporales entre ellas. Sin embargo, esta descripción no tiene en cuenta detalles sobre cómo se llevan a cabo los procesos e interacciones, ambos necesarios para el correcto diseño del diseño del sistema.

El modelo de tareas del W3C está basado en la notación ConcurTaskTrees (CTT), ampliamente aceptada [8] y tiene como objetivo definir un estándar para el modelado de tareas. El meta-modelo de tareas del W3C proporciona una estructura jerárquica entre tareas y ofrece varios operadores, usados también en CTT, para definir las relaciones temporales entre tareas. Además, proporciona una taxonomía de tipos de tareas. Los elementos del meta-modelo de tareas (**¡Error! No se encuentra el origen de la referencia.**) son los siguientes:

- *Task*: acción que se realiza desde la perspectiva del usuario. Desde el punto de vista estructural, hay dos tipos de tareas: Tareas atómicas (acciones indivisibles) y tareas compuestas (divisibles en subtareras). Además, pueden definirse cuatro tipo de tareas: (i) *User*, o tareas de usuario: actividad cognitiva que no se realiza directamente a través de la interfaz. (ii) *System*, o tarea de sistema: acción realizada por la aplicación. (iii) *Interaction*: acciones realizadas por los usuarios que dan lugar a respuestas instantáneas del sistema y (iv) *Abstract*: tareas que se descomponen en subtareas de distintas categorías.

- *Domain Object*: un objeto del modelo de dominio relacionado con una tarea.

- *Condition Group*: operación lógica que puede ser usada para especificar una precondición y/o una post-condición de una tarea.

- *Logic Operator*: operador que conecta los operandos del Condition Group y especifica el tipo de operación lógica.

- *Condition Literal*: valor u objeto del modelo del dominio usado como operando en una operación lógica.

- *N-ary Operator*: operador que establece una restricción temporal entre subtareas.

- *1-ary Operator*: operador que establece si una tarea es opcional y/o iterativa.

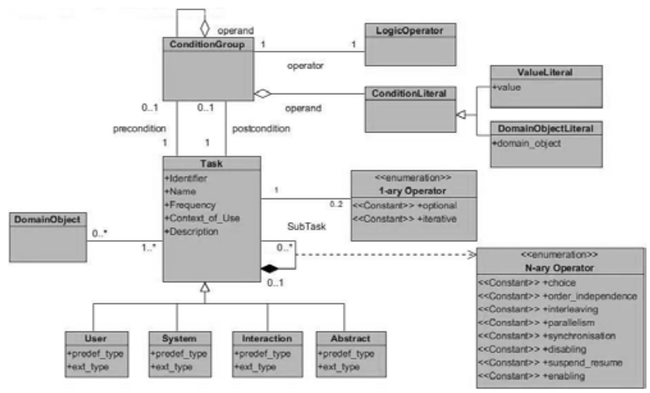


Figura 1. Meta-modelo actual del W3C [3]

El meta-modelo mostrado en la Fig. 1 permite al analista describir modelos de tareas de sistemas WIMP de forma eficaz. Este meta-modelo usa las relaciones de composición para especificar estructuras jerárquicas de tareas y asocia los operadores temporales a estas relaciones. Aunque estos operadores son suficientemente expresivos para describir dichas relaciones, sería razonable incluir una nueva meta-clase específica para establecer relaciones temporales entre tareas, asociando el operador a dicha clase, permitiendo así desligar las relaciones estructurales de las temporales y estableciendo un único operador para cada relación temporal.

Las aplicaciones actuales tienden claramente a ser colaborativas (por ejemplo, juegos, editores de texto, redes sociales, IDEs, etc.) con un considerable número de usuarios interactuando concurrentemente. Además, las interfaces de usuario de dichas aplicaciones han evolucionado enormemente hacía el paradigma Post-WIMP. Así, Jacob et al. [9] identificaron los siguientes cuatro aspectos del mundo real que una aplicación Post-WIMP debería soportar:

- *Naïve Physics*: las personas tienen conocimiento general del mundo físico.
- *Body Awareness & Skills*: las personas tienen conciencia/conocimiento de sus propios cuerpos y poseen habilidades para controlar y coordinar sus cuerpos.
- *Enviroment Awareness & Skills*: las personas son conscientes de lo que les rodea y poseen habilidades para negociar, manipular y moverse por el entorno.
- *Social Awareness & Skills*: las personas son generalmente conscientes de otras personas en su entorno y tienen habilidades para interactuar con ellos.

Como se puede ver, todos estos aspectos están principalmente relacionados con el concepto de awareness [10]. Por ejemplo, la propiocepción del usuario en el entorno físico juega un papel fundamental en entornos de realidad virtual en los que puede existir una interacción con cualquier parte del cuerpo. Una representación virtual del cuerpo y otras informaciones, como la localización virtual pueden mejorar la experiencia de usuario al interactuar con sistemas Post-WIMP. El conocimiento de los grupos o equipos a los que pertenecen los usuarios es un ejemplo de Social Awareness. Otro ejemplo de awareness lo encontramos en sistemas en los que varios usuarios están editando un documento al mismo tiempo, necesitan saber con quién están colaborando y qué cambios están haciendo en el documento. Esta necesidad ha sido ampliamente analizada en Computer Supported Collaborative Work (CSCW). Ellis et al. [11] identificaron las fuertes relaciones entre awareness y colaboración en el modelo de colaboración 3C. Debido a que awareness y colaboración están muy extendidos en las aplicaciones contemporáneas, especialmente en entornos virtuales colaborativos (Collaborative Virtual Environments CVE) [12], un meta-modelo de tareas debería permitir especificar tales características. Por lo tanto, puesto que la especificación actual del W3C fue originalmente diseñada para especificar entornos WIMP, en este artículo presentamos un meta-modelo de tareas extendido para entornos Post-WIMP basado en CSRML con el fin de especificar estos innovadores sistemas.

3. UN LENGUAJE DE MODELADO DE TAREAS PARA ENTORNOS POST-WIMP

Una vez se han identificado los problemas y limitaciones del meta-modelo de tareas del W3C para especificar sistemas Post-WIMP, presentamos en esta sección el meta-modelo de tareas CSRML [5] adaptado para la especificación de tareas Post-WIMP. Se ha escogido este lenguaje porque soporta la especificación de requisitos de sistemas colaborativos, uno de los elementos principales de los sistemas Post-WIMP. CSRML es un lenguaje de modelado de requisitos orientado a objetivos para la especificación de sistemas colaborativos respaldado por una herramienta empíricamente validada [13]. Los elementos usados para el modelado de tareas se describen a continuación (ilustrados en Fig. 3 y Fig. 4). Además, la representación gráfica de dichos elementos se puede ver en la Fig. 2.

- *Task*: El concepto de tarea del W3C ha sido extendido para incluir la importancia usando un código de colores (verde, amarillo, naranja y rojo) siendo el color verde el de menor importancia y el rojo el de mayor importancia. Además, se han identificado cuatro tipos de tareas: (i) *Abstract Task*: Abstracción de un conjunto de tareas concretas, (ii) *User Task*: Tarea realizada por un usuario sin necesidad de interactuar con la interfaz e (iii) *Interaction Task*: Tarea que implica una interacción con la interfaz o respuestas del sistema. Hay cuatro tipos de tareas de interacción: *Individual Task* es una tarea que no conlleva colaboración (puede ser realizada por un participante). Estas tareas contemplan también las tareas de sistema, ya que éste es considerado como un actor más dentro del modelo. *Collaboration/ Communication/Coordination* tasks son tareas que requieren al menos dos participantes para poder ser realizadas, con el objetivo de llevar a cabo algún tipo de colaboración / comunicación / coordinación entre ellos.
- *Legacy Elements*: Con el fin de hacer este modelo de tareas compatible con el del W3C, varios elementos han sido añadidos a su meta-modelo.
- *Role*: Establece el comportamiento de un actor para un conjunto de tareas relacionadas. Un actor que desempeña un rol puede participar en una tarea individual o colectiva (mediante las relaciones de participación). Cabe señalar que la relación entre un actor y un rol es especificada en el modelo de usuario, no en el modelo de tareas.
- *Goal*: Contesta a la pregunta “¿por qué?”. Describe un estado del mundo que el usuario querría alcanzar. Sin embargo, un *Goal* (objetivo) no describe cómo debería alcanzarse dicho estado.

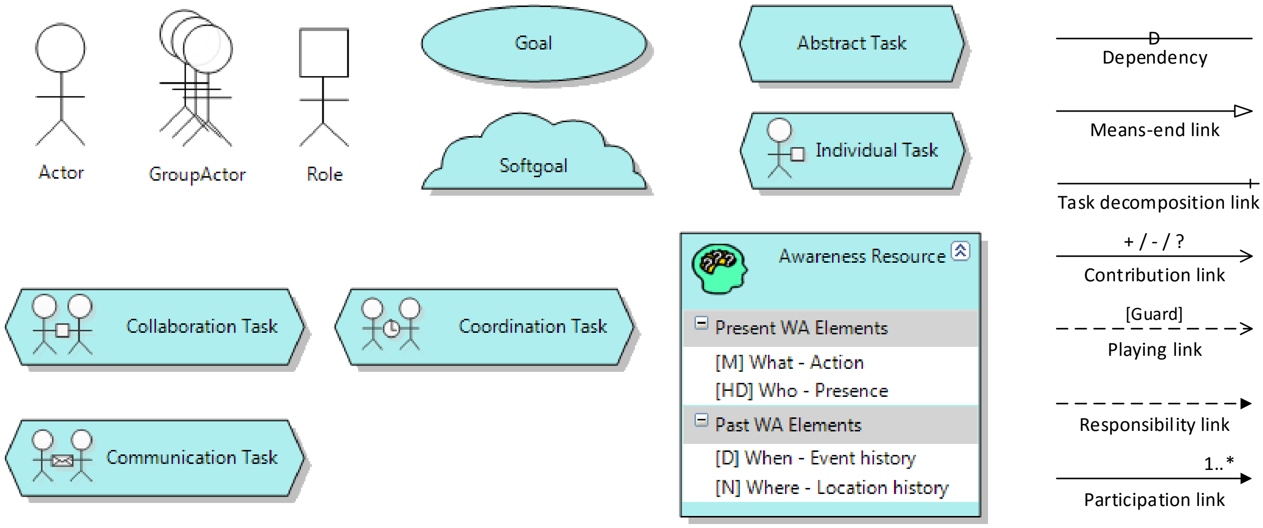


Figura 2. Representación gráfica de los elementos del meta-modelo de tareas para sistemas Post-WIMP

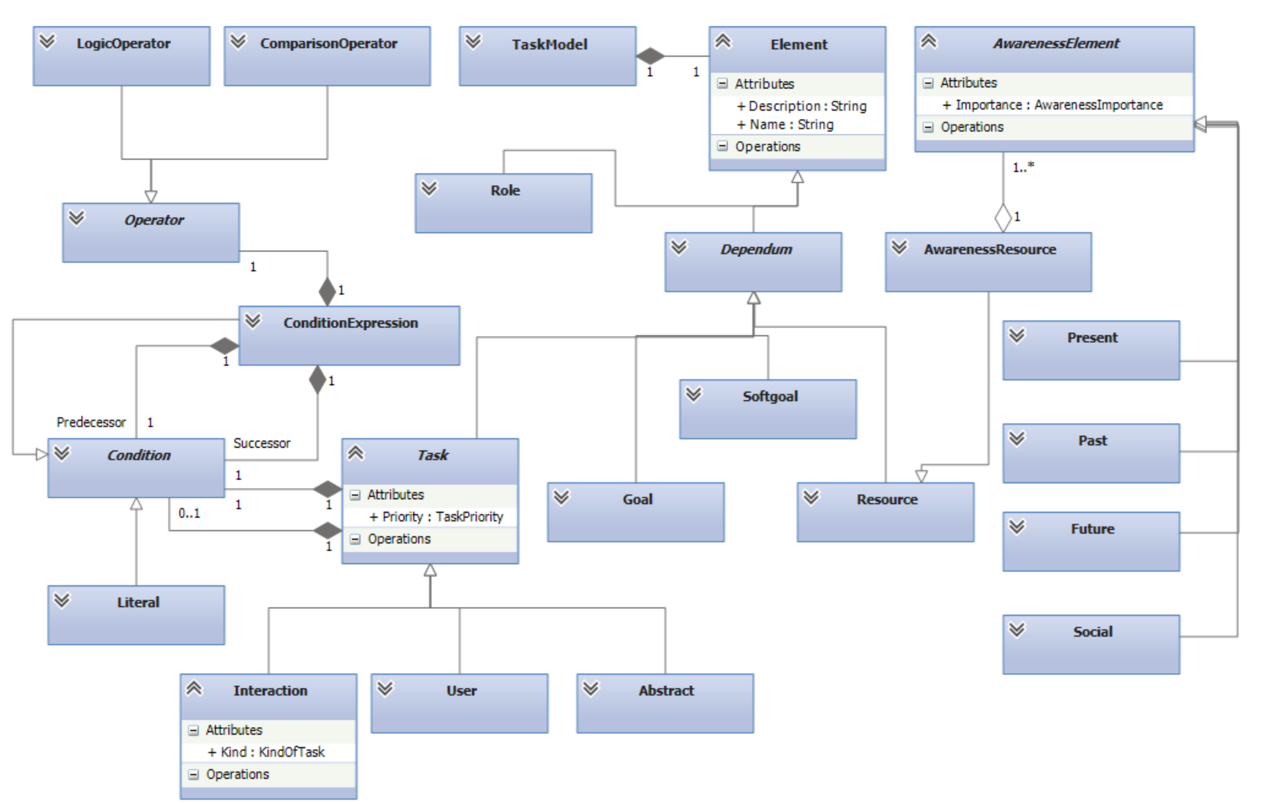


Figura 3. Meta-modelo de tareas para sistemas Post-WIMP (Elementos)

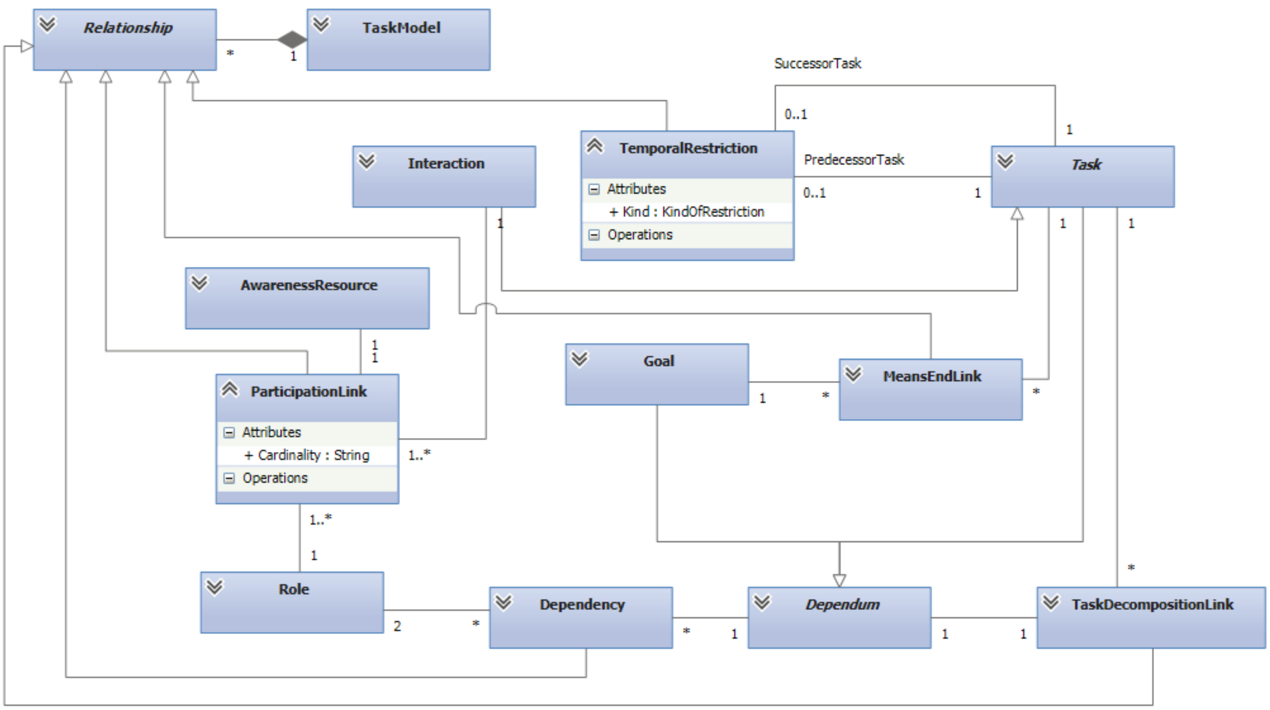


Figura 4. Meta-modelo de tareas para sistemas Post-WIMP (Relaciones)

- *Softgoal*: Es una condición del mundo que el usuario quiere alcanzar, pero a diferencia del concepto *Goal*, esta condición no está claramente definida. Un *Softgoal* es normalmente un atributo cualitativo que restringe otros elementos, como un objetivo, una tarea o un recurso.
- *Resource*: Es una entidad que el usuario necesita para alcanzar un objetivo o realizar una tarea. El principal interés de un recurso es saber si está disponible y de quién.
- *Awareness Resource*: Este elemento representa información de *awareness* que un usuario necesita para completar una tarea. Este elemento es representado como un conjunto de elementos de *Awareness* (*Awareness Elements)* ligados a una relación de participación entre un rol y una tarea.
- *Awareness Element*: Un *Awareness Resource* muestra todos los *Awareness Elements* disponibles (si son necesarios) e indica su importancia en función de la contribución a la realización de la tarea. Estos elementos de awareness son una extensión de los identificados por Gutwin y Greenberg [14] para entornos Post-WIMP con el propósito de ser compatibles con los diferentes elementos de awareness identificados por Jacob et al. [9]. Por ejemplo, el elemento *Presence – Where – Reach* está relacionado con el elemento de Jacob *Body awareness*; el elemento *Future – Where – Next Position* está relacionado con el *conocimiento del entorno*; y *Social & group dynamics – What – Group goal* es un ejemplo de *Social Awareness*. Además, estos elementos de awareness están clasificados en cuatro categorías relacionadas con el presente, el pasado, el futuro y aspectos sociales. Por último, su importancia puede ser establecida como *nice to have* (N), *desirable* (D), *highly desirable* (HD) o *mandatory* (M).
- Participation Link: denota quién está involucrado en una tarea. Esta relación tiene un atributo para especificar su cardinalidad, es decir, el número de usuarios que pueden involucrarse en la tarea. Opcionalmente puede tener un *Awareness Resource* ligado que representa que el *Role* tiene una necesidad especial de percepción para participar en la tarea. Sin esta percepción, la realización de la tarea se vería afectada negativamente o incuso el *Role* podría ver impedida su participación en la tarea.
- Task Decomposition Link: Describe elementos esenciales de una tarea. Un *Task Decomposition Link* relaciona una tarea con subtareas a realizar, *subgoals* a conseguir, *Resources* necesarios y *softgoals* que normalmente definen la calidad de los objetivos para la tarea.
- Means-end Link: documenta qué *softgoal*, *task* o *resource* contribuyen a alcanzar un objetivo.
- Dependency: Es una relación ente un *depender* y un *dependee* para un *dependum*. El *depender* y el *dependee* son actores y el *dependum* puede ser un *goal*, una tarea (*task*), un *resource* o un *softgoal*. El *depender* depende del *dependee* para alcanzar un objetivo, realizar una

tarea o usar un recurso. Si el *dependee* no puede proporcionar un *dependum* al *depender* la realización de la tarea, alcanzar el objetivo o usar el recurso se vuelve difícil o imposible.

4. MODELADO DE UN SISTEMA POST-WIMP

Para analizar el meta-modelo propuesto, presentamos un ejemplo de modelado que consiste en un juego *First Person Shooter* (FPS) multi-dispositivo de realidad virtual. Este sistema hará uso de diferentes dispositivos para facilitar la interacción entre el usuario y el sistema. En primer lugar utilizará un dispositivo de visualización inmersivo para proporcionar al usuario los gráficos 3D así como para capturar los movimientos de cabeza del usuario para controlar la dirección de la visión de la representación virtual del usuario (personaje). Para proporcionar al usuario sonido posicional, permitiéndole saber la dirección de los disparos y los pasos de otros personajes, se dispone de auriculares de sonido envolvente, los cuales incorporan un micrófono para comunicarse con otros usuarios. Por otra parte para incorporar sensaciones hápticas se situarán varios actuadores vibrotáctites sobre el cuerpo del usuario para permitir que éste sienta en qué lugar del cuerpo y cuándo el personaje es alcanzado. Se situarán 7 dispositivos colocados en cabeza, brazos, pecho y espalda. Para controlar la posición de la mano dominante del usuario que simula el arma, se utilizará un tracker que recoja la posición de la mano. Por lo tanto, la dirección y el disparador/gatillo del arma del personaje serán controlados con este dispositivo. Finalmente, en su mano no dominante, el usuario dispondrá de un mando para controlar los movimientos del personaje (adelante, atrás y a los lados).

Por otra parte, las tareas que un usuario realizará durante el juego son: *DefeatEnemy* (tarea principal), *Move*, *Communicate* (dependerá de la distancia entre los jugadores), *Revive Player* (dos jugadores pueden devolver la vida a otro jugador del mismo equipo), *Shoot*, *Aim*, *Pull The Trigger*, *Get Power-ups*, *Deploy Power-up* (tarea de sistema), *Show End* (tarea de sistema). Además, puesto que el juego a implementar es tanto colaborativo como Post-WIMP, puede proporcionarse a los usuarios información de *awareness* sobre el entorno del juego (por ejemplo, estado del jugador, posición de otros personajes, terreno de juego, etc.). Concretamente, la información de *awareness* que será proporcionada por el sistema se describe en la Tabla 1.

Una vez explicadas las tareas del juego y las necesidades de *awareness*, todo ello será modelado usando tanto el actual meta-modelo de tareas de la W3C (en adelante W3CTM) como nuestra propuesta PWTM (Post-WIMP Task Meta-model).

Tabla 1. Información de awareness del FPS

Tipo de Awareness	Descripción
Own status	Información sobre el estado de salud del personaje y los *power-ups* activos
Connected players	Lista que mostrará tanto los jugadores conectados como sus equipos.
Allies location	Localización de los usuarios miembros del mismo equipo es mostrada en un mini-mapa
Power-ups position	Las nuevas mejoras del arma y del personaje que se han desplegado en el juego se muestran en el mini-mapa.
Received Damage	Cuando el personaje de un usuario es alcanzado por una bala, el usuario sentirá una vibración en su propio cuerpo, obteniendo así información de *awareness* de la dirección del disparo (por ejemplo si el personaje es alcanzado desde atrás, el usuario sentirá una vibración en su espalda).
Caused Damage	Cuando un personaje es alcanzado por un disparo se proporciona información auditiva.
Steps and Shooting sound	Las armas y los pasos de los personajes producirán sonidos que pueden dar información de *awareness* sobre su localización.

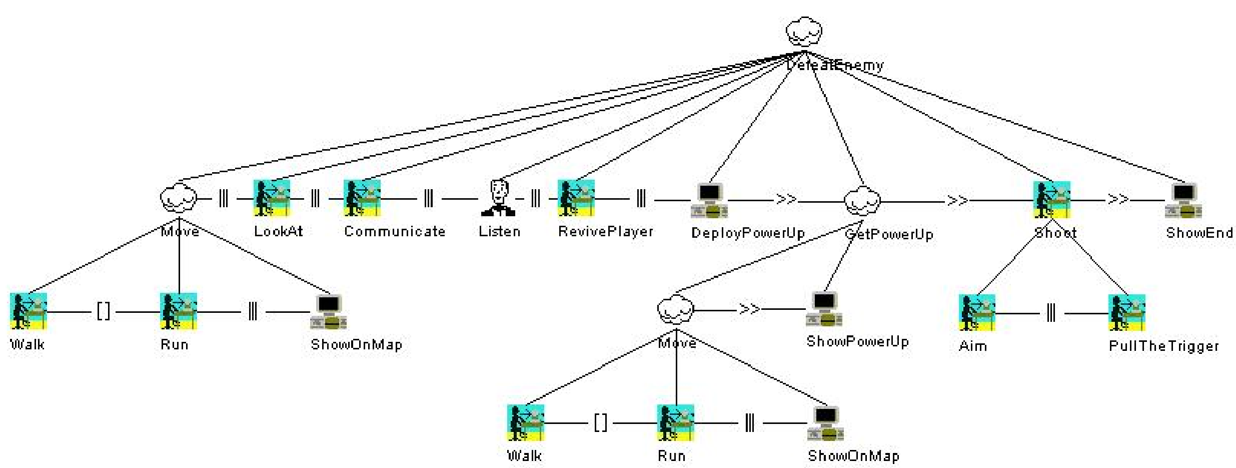


Figura 5. Especificación de tareas usando el meta-modelo del W3C

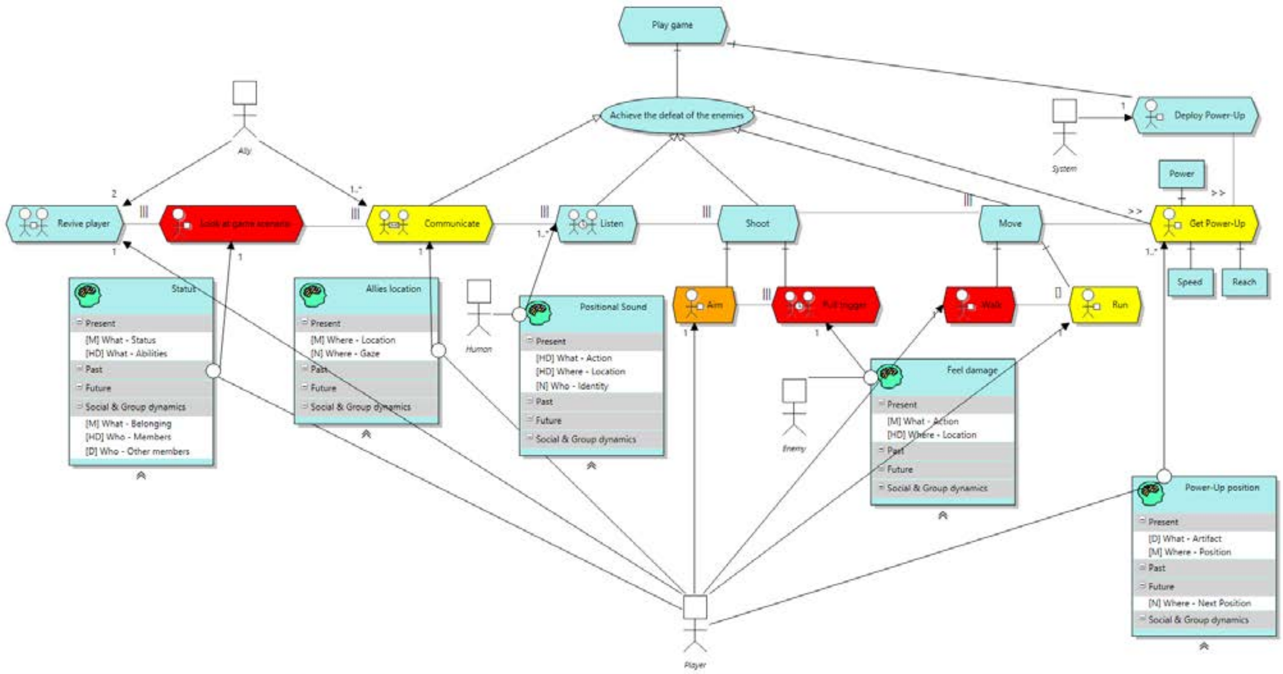


Figura 6. Especificación de tareas usando el meta-modelo Post-WIMP

4.1 USANDO W3CTM PARA ESPECIFICAR LAS TAREAS DEL JUEGO

La Fig. 5 muestra una instancia del modelo obtenido usando el meta-modelo de la W3C para nuestro ejemplo de modelado. Como puede observarse, la tarea *DefeatEnemy* es la raíz del árbol de tareas. Esta tarea se descompone en otras subtareas. *Move*, *LookAt*, *RevivePlayer*, *Communicate*, *Listen* y *DeployPowerUp* que pueden ser realizadas de forma concurrente. *DeployPowerUp* habilita la tarea *GetPowerUp* puesto que ésta no puede ser realizada si no hay *power-ups* en el escenario. *GetPowerUp* habilita la tarea *Shoot* y ésta, *ShowEnd*. La tarea *Move* puede ser realizada de dos formas diferentes, por lo que se descompone *Walk* y *Run* y el operador *N-Ary* entre estas tareas será el operador *Choice*. Además, el sistema muestra el movimiento sobre el mapa de forma concurrente. Para conseguir *power-ups*, el usuario debe moverse a través del escenario virtual. Cuando el personaje pasa a través de un ítem virtual que representa el *power-up*, el sistema informa al usuario mediante la tarea *ShowPowerUp*. La tarea *Shot* se descompone en dos subtareas: *Aim* y *PullTheTrigger*. Ambas tareas pueden ser realizadas de forma concurrente. Cuando un equipo gana un juego, el sistema informa a los usuarios del final.

El modelo, mostrado en la Fig. 5, presenta varias deficiencias de cara a posteriores fases del proceso de desarrollo. En primer lugar, no aparecen los participantes de las tareas ni el concepto de rol, lo que impide describir quiénes intervienen en tareas como *Communicate* o *RevivePlayer* y el papel que juegan en las mismas. Por otro lado, este modelo no nos permite definir la información de awareness necesaria para la realización de algunas tareas. Por ejemplo, la tarea Communicate, según la propia especificación del ejemplo, sólo puede llevarse a cabo cuando la posición de los participantes hace que estén lo suficientemente cerca, por lo que esta información es relevante para el desarrollo del sistema. Por último, en un entorno virtual de inmersión completa, la tarea de dirigir la mirada hacia distintas zonas del escenario requiere de información de awareness que está relacionada con la propiocepción del usuario y de las dinámicas sociales y de grupo.

4.2 Post-WIMP Task Meta-model PARA ESPECIFICAR LAS TAREAS DEL JUEGO

Tras especificar las tareas del ejemplo de modelado usando el meta-modelo de la W3C, se procederá al modelado del mismo sistema usando nuestra propuesta. Como puede observarse en la Fig. 6, esta especificación enriquece la mostrada anteriormente (Fig. 5) añadiendo nuevos elementos y relaciones que aportan características de colaboración y *awareness* al modelado. Puesto que este nuevo modelo está basado en un lenguaje de requisitos orientado a objetivos [15], se ha añadido el objetivo *Achieve the defeat of enemies* al modelo de tareas, ya que es el principal objetivo de los usuarios que realizan la tarea *Play Game*. Además, tres recursos llamados *Speed*, *Reach* y *Power*, correspondientes a tres diferentes *power-ups* han sido incluidos en el modelo de tareas. Otra diferencia es que las tareas de interacción han sido detalladas definiendo su tipo y prioridad. Como ejemplo, la tarea *Communicate* es considerada una *Communication Task*, ya que permite a los usuarios de un mismo equipo comunicarse entre ellos. Las tareas *Listen* y *Pull Trigger* son consideradas *Coordination Tasks*. Estas tareas de coordinación son un tipo especial de tareas colaborativas en las que distintas informaciones (ruido y salud en nuestro caso) permiten coordinarse a varios jugadores. Además, la tarea *Revive Player*, es una *Collaborative Task* ya que dos diferentes personajes tienen que aproximarse a un tercero que ha muerto para poder revivirlo. Finalmente, otras tareas como *Look At Game Scenario* o *Walk* son tareas individuales que pueden ser realizadas por un solo usuario. Estas dos tareas han sido asignadas con la prioridad más alta (color rojo) ya que deben ser implementadas en primer lugar para obtener un prototipo de la aplicación lo antes posible. Por esta misma razón, *Aim* también ha sido considerada una tarea de alta prioridad, mientras que *Listen* y *Deploy Power-Up* han sido consideradas con una prioridad normal porque en nuestro primer prototipo no es absolutamente necesario tener el sonido o el sistema de *power-ups* totalmente desarrollado.

Como se muestra en la Fig. 6, la especificación Post-WIMP no tiene tareas de sistema. Cuando una tarea es realizada por el sistema, se indicará con la participación del *Role* "System" en dicha tarea (por ejemplo la tarea *Deploy Power-Up* es realizada por el sistema). Además, otros cuatro roles toman parte en esta especificación: *Player*, *Allies*, *Enemies* y *Human*, que es el "super-role" de los tres primeros. Sin embargo, hay que señalar que la asociación del usuario con los roles que puede jugar se especifica en el modelo de usuario, no en el modelo de tareas, que no se presenta aquí por problemas de espacio.

Los *Participation Links* son usados para especificar qué usuarios están involucrados en tareas de interacción. Por ejemplo, dos diferentes *Participation Links* están relacionados con la tarea *Communicate*, porque cuando se realiza esta tarea un jugador (1) habla con uno o más (1..*) de sus aliados.

Finalmente, cinco diferentes recursos de *awareness* se han adjuntado a los *Participation Links* para representar la información de *awarenes* requerida para realizar las tareas. Primero, el jugador debe ([M]) tener el recurso de *Awareness Allies location* para proporcionarle la localización de sus aliados a la hora de realizar la tarea *Communicate*, ya que la comunicación sólo puede llevarse a cabo si los miembros del equipo están cerca. Adicionalmente, sería deseable ([N]) tener información sobre dónde miran otros jugadores para coordinar ataques conjuntos. Además, cuando se realiza la tarea *Look At Game Scenario*, los jugadores necesitan información de *Awareness* sobre su propio estatus, algo que es altamente deseable ([HD]), para ser conscientes de sus propias habilidades (*power-ups*). Finalmente, es necesario que cada usuario sepa a qué grupo pertenece así como los miembros que posee ese grupo. Por último, es deseable ([D]) saber quiénes son los miembros de los equipos. Como se ha mostrado, la especificación Post-WIMP permite especificar la colaboración y el *awareness* de forma adecuada, siendo estos dos aspectos primordiales para el desarrollo de sistemas Post-WIMP contemporáneos. Esta especificación de la información de awareness solventa los problemas especificados en la sub-sección anterior.

5. CONCLUSIONES Y TRABAJOS FUTUROS

A lo largo de los últimos años, no sólo la apariencia visual de las interfaces de usuario ha cambiado, sino también la forma en la que las personas interactúan con los ordenadores. De hecho, las clásicas interfaces WIMP están dando paso a nuevos sistemas Post-WIMP que van más allá de ventanas, iconos, ratón y punteros. La interacción con estos nuevos sistemas está basada en reconocimiento de gestos, realidad virtual, dispositivos corporales, etc. Debido a la evolución de los sistemas de interacción, los mecanismos necesarios para especificarlos deben hacerlo también. Este hecho supone la principal motivación para la realización de este trabajo, que propone el desarrollo de un modelo de tareas alternativo a la actual revisión del modelo del W3C, para adecuar el modelado de tareas a la especificación de requisitos de sistemas Post-WIMP. La colaboración es uno de los aspectos clave en dichos sistemas, por lo que nuestra propuesta se basa en el modelo de tareas Collaborative Systems Requirements Modelling Language (CSRML) [5], que implementa el ampliamente aceptado modelo de colaboración 3C [10]. Con el objetivo de hacer que este modelo tenga la capacidad de especificar las necesidades de *awareness* de sistemas Post-WIMP identificadas por Jacob [9], el modelo de *awareness* de CSRML, llamado Gutwin's Workspace Awareness [14] ha sido enriquecido con características especiales como *Context Awareness* o *Social Awareness*. Además, se ha presentado un ejemplo de modelado en el que se ha modelado un juego Post-WIMP tanto con la actual propuesta del W3C como con el lenguaje presentado en este trabajo. Esto nos ha permitido ilustrar que las características Post-WIMP relacionadas con el *awareness* y la colaboración sólo pueden ser especificadas con éste último.

A pesar de que este modelo ha mostrado ser más adecuado para sistemas Post-WIMP, es necesario profundizar más en este sentido. Con el objetivo de mejorar la especificación de requisitos de sistemas Post-WIMP, nuestros siguientes trabajos se centrarán en un modelo de contexto que complemente el modelo de tareas. Así, mediante el uso de dicho modelo, será posible especificar cómo las aplicaciones Post-WIMP pueden adaptarse al contexto de uso (es decir, hardware disponible, capacidades del usuario, características del entorno físico como luz y ruido, etc.). Al mismo tiempo, la implementación del caso de uso presentado en este trabajo ya ha comenzado. Ya está disponible un prototipo jugable basado en la especificación de tareas creada mediante la propuesta de meta-modelo de tareas post-WIMP recogida en este artículo.

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An Ontology-Driven Approach to Model & Support Mobility and GeoLocation Based Campus Interactions

Maha Khemaja
PRINCE, ISITC, H Sousse
University of Sousse, Tunisia
+216 23501625
maha_khemaja@yahoo.fr

Félix Buendía
Computer Engineering Dept.
Universitat Politècnica Valencia
+34 963877000 (ext. 75734)
fbuendia@disca.upv.es

ABSTRACT

University campuses are increasingly becoming places where different interactions take place including those related to instructional and learning tasks. Most of these interactions require gathering contextual information from the campus facilities, platforms, services or people that are part of this environment. The current work aims at providing an ontology-based proposal, which can enable to model most of these context features that can be useful to support multiple kinds of interactions in Campus settings. This proposal permits to reason and make inferences on contextual information and features in such a way to provide users with mobile geolocated services such as path finding, small group meetings planning or personalized information about campus facilities. The proposed ontology has been applied in a University campus with the purpose of guiding users to improve their personal experiences.

Author Keywords

Ontology proposal; Campus interactions; context modeling; mobile apps; geolocation services.

ACM Classification Keywords

H.5. Human computer interaction (HCI). Ubiquitous and mobile computing, mobile devices.

1. INTRODUCTION

University campuses are today organized as small or medium-size towns where different types of interactions take place. They usually involve common services such as resident accommodation, catering, or social meetings but, obviously, the most demanded services deal with learning activities or student life in the campus. Even in this type of learning services, there is a wide range of possibilities that are based on indoor/outdoor scenarios, lecture vs. lab or seminar sessions, presential or online activities, individual or collaborative tasks as well as the diversity of disciplines and domains that are taught in higher education.

Moreover, campuses increasingly provide spaces for exhibiting artistic masterpieces or historical work and seek to attract and inform new comers about them. Most of these campus facilities are generally supported by information systems (internal data bases, web portals, intranet sites) allowing users to query for specific information as lecture schedules, labs availability, tutorial sessions or specific artistic show location. However, these information systems do not take into account one's user context and act only on a reactive manner to user's explicit requests.

Therefore, there is a need to incorporate this kind of context information based on the user's profile and preferences, the user's location, the status or the scheduling of an activity that is occurring at the present time. This idea was advanced by authors such as Weiser [[1]] or Crook & Barrowcliff [[2]] who believed in the potential of ubiquitous computing to offer new tools and patterns of student's interactions. Such potential was analyzed in 13 institutions that provided "ubiquitous computing" in very different ways [[3]]. DeGagne and Wolk [[4]] examined how college students used technology in their everyday life on a campus with ubiquitous computing and communication. Currently, many universities have platforms and apps like iStanford[1] or UCC[2] that provide generic coarse-grain contextual information useful for their students' lifetime. Nevertheless, the support of specific context-aware interactions usually requires a more fine-grain approach that represents context concepts and their relationships in a more detailed way. Several initiatives have been promoted for applying ubiquitous computing technologies for campus environments in specific cases.

For example, Aware Campus [[5]] or Active Campus [[6]] explore location-aware applications addressed to guide users and allow them to annotate or share location information with others. MyCampus [[7]] is another application that was conceived to enhance everyday campus life at Carnegie Mellon University introducing context-aware agents, recommender services and case-based reasoning. Moreover, Scott & Benlamri [[8]] describe several initiatives to move traditional learning spaces into smart ones by using ubiquitous context-aware services.

The current work focuses on the modeling of contextual information that can be useful to support Campus interactions. It is practically impossible to cope with every potential interaction in this type of settings but a possible subset or interaction patterns can be defined. For example, outdoor activities can be performed in several disciplines from architecture; agricultural studies to arts either for collaborative or individual tasks. These activities may require a certain support beyond the academic works to be developed within them. Therefore, models have to be provided to both represent information items about the context surrounding the target learning activity and reason and infer related knowledge and information. From these models, context aware mobile and geolocation apps addressed to campus settings can be further developed.

[1] https://itservices.stanford.edu/service/mobile

[2] http://www.usca.edu/ucc/index2.html

The rest of the paper is organized as follows. Section II presents some works related to the proposed approach. Section III describes the main features of the overall approach with the ontology proposal and the development process fundamentals. Section IV illustrates the application of the presented approach, and, finally, Section V gives some concluding remarks.

2. RELATED WORKS

Along last years, several ways to model context issues have been proposed. Strang [[9]] established that a well designed model is a key element in any context-aware system and identified several approaches from the more simple based on key-value data structures to mark-up scheme, graphical, object oriented, logic-based or ontology models. Ontology notations represent a powerful semantic mechanism that enable not only to reason or infer new information but also to share it in different ways. In this sense, we can differentiate generic ontology proposals that have been applied to campus samples from other specifically addressed to this environment. CoBrA-ONT [[10]] is an example of ontology for context-aware pervasive computing environments that was applied in campus context. The CoCA (Collaborative Context-Aware) service platform [[11]] is based on a hybrid context management model and it was used to build a Pervasive Campus-Aware Smart Onlooker (PiCASO) scenario. The SeCOM model [[12]] was used to develop a Geomobile system at the FUV (Federal University of Viçosa) that contained information about the structure and activities carried out in the campus. Its context model was based on ontological concepts such as *Actor*, *Activity*, *SpatialEvent* and *Temporal Event*. This Geomobile system was developed using the C#NET language and addressed to PocketPC emulators though the conceptual ideas are similar to those proposed in the current paper. Moreover, the SeCOM model was used to develop the iCas system [[13]] based on a Java+XHMTL framework to support students and teachers in their campus life using OWL services. Otherwise, Geo-Wiki [[14]] provided a semantic geographical knowledge based on Google Maps technologies but it is addressed to specific wiki services.

3. OVERALL APPROACH

The main idea in the current work aims at providing an ontology-based proposal which can enable, first, to model most of those context features that can be useful to represent Campus interactions, and, second, to support a development process, which helps with the elaboration of mobile geolocated applications in this context.

3.1 Context ontology

A methodology addressed to model the ontological context has been applied. First, the category of the ontology to develop is identified. Secondly, a development process inspired from several ontology construction methodologies is applied [[15]], [[16]]. Ontology construction methodologies promote the following basic phases: (1) Ontology Specification which specifies the ontology purpose, domain and scope and it requires to decide whether or not to reuse existing ontologies, (2) Ontology Conceptualization in which the important terms of the ontology are enumerated, taxonomies i.e. classes and classes hierarchies are defined, binary relationships, class and instance attributes or properties, formal axioms and rules and finally, instances are built and described. (3) Ontology Formalization (in a formal or semi-formal) model (4) Ontology Implementation and validation using an Ontology development framework or a programming environment. In order to define the domain and scope of the ontology, a list of competency questions that a knowledge base should be able to answer are gathered [[17]]:

- What are the elements that compose the user's context in a campus setting?
- What kind of contextual information could enable a proactive decision making about user's interactions as, for example, indoor or outdoor activities?
- What kind of activities could engage a given user?
- What kind of scenarios and activities could be carried out by campus actors accordingly to their preferences and profiles?
- Which kind of information will allow users to plan meetings and through which campus facilities?

How could new campus users locate buildings, sculptures, other persons or different objects in the campus?

To answer these competency questions, several taxonomies are identified. For instance, a context element taxonomy illustrated in Figure 1 constitutes as explained in [[18]] a first layer of elements or primary context types for characterizing the situation of a particular entity. These context types act as access points into other sources of contextual information called secondary context (e.g. the email address of a given user) for the entity as well as the primary context for other related entities (e.g. other people in the same location).

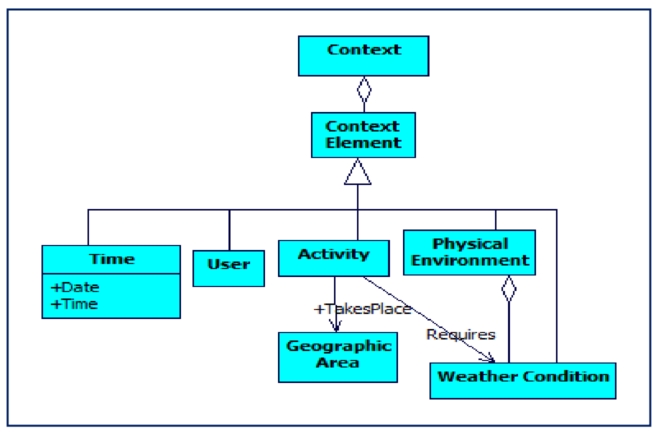

Figure 1. Context Ontology model.

Figure 2 shows part of the Context Ontology that models different types of activities and their related interactions. The *Activity* taxonomy illustrates possible activities that could engage users in Campus settings where the *Learning Activity* concept is distinguished from *Recreational Activity Concept* while the *Facility* taxonomy represents items and elements provided by the campus infrastructure that link them to the corresponding activities. Figure 3 shows part of the ontology model that represents the *Geographic area* entity where a specific *Activity* is developed.

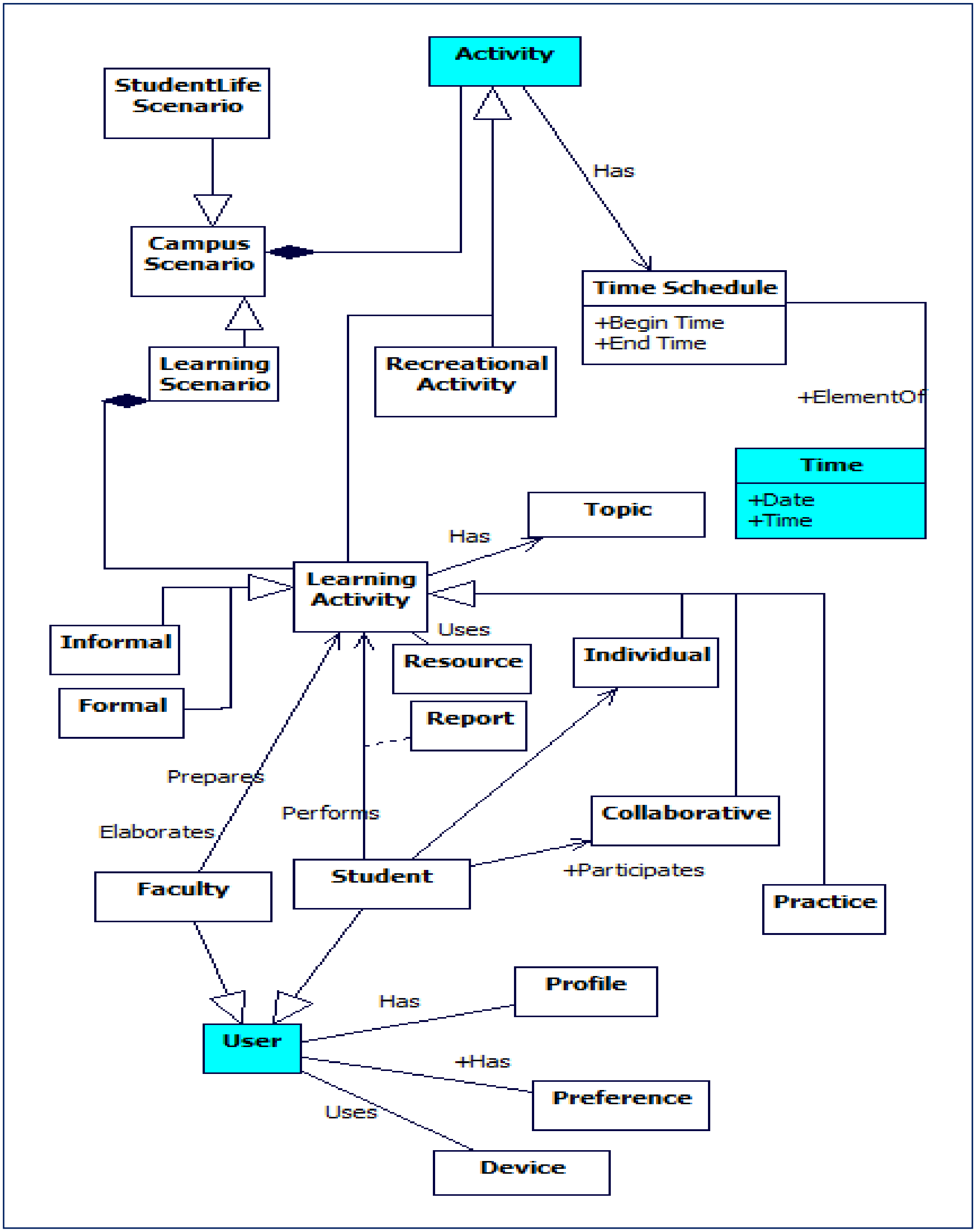

Figure 2. Campus Activity Ontology model

The *Geographic Area* considered in Campus settings deals with physical elements that can be found in a Campus together with their organizational aspects. The concept of *POI* (Point of Interest), for example, is described as a *GeoLocation* point having a certain textual description. It is located in a certain *Location Area* and may be part of a *Path* that could be followed by a Campus user.

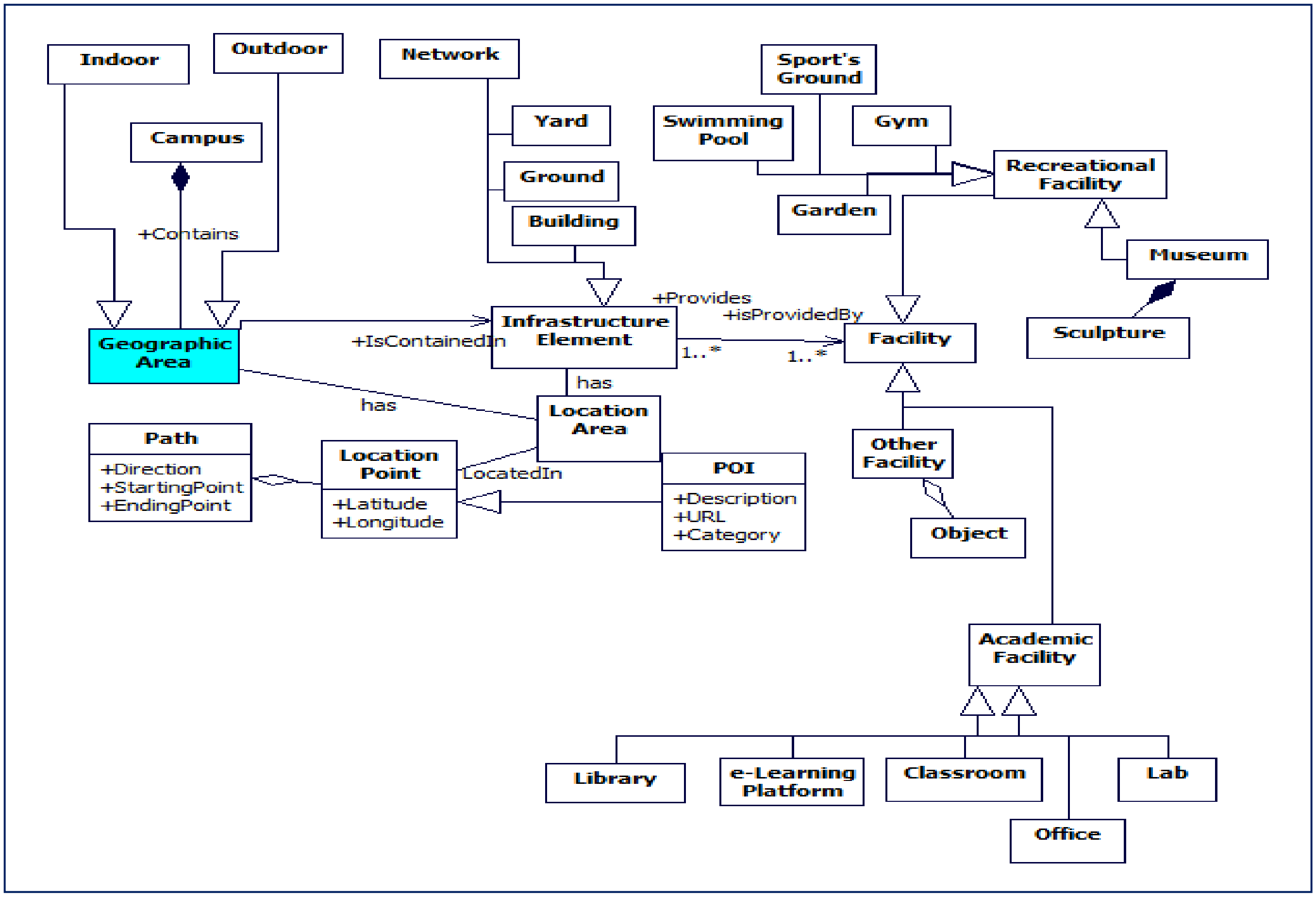

Figure 3. Campus GeoLocation Ontology Model.

All concepts, their properties and types are defined clearly in a Glossary as well as in a dictionary. Table 1 contains main ontology terms representing classes or entities such as *User*, *Activity*, and *POI* concepts. This latter is specifically interesting because it represents a specific location in a campus that could attract new comers or students and which could be useful for them either for recreational, learning or cultural related activities.

Table 3. Ontology elements.

Name	***Description***
Context	The set of circumstances or facts that surroun d a particular event, situation, etc
Context element	A kind of circumstance or fact composing context
User/End User	The person or the organization that is part of the campus environment and to which the software/applications are intended.
Activity	A thing that a person (user) or a group does or has done
Environment	The surroundings or conditions in which a person lives or operates. The setting or conditions in which a particular activity is carried on
Campus	The grounds and buildings of a university
Scenario	The way in which a situation may develop.
Geographical area	An area, especially part of a country or the world having definable characteristics an d boundaries
Location	A particular place or position
Point of Interest	A specific point location that someone may find useful or interesting
Path	A road, way, or track made for a particular pu rpose. The route or course along which a person moves
Campus Facility	Something (such as a building or large piece of equipment) that is built for a specific purpose. It makes an action, operation, or

	activity easier.

Moreover, constraints on concepts and relations between them are identified and expressed as axioms or domain/range constraints. The ontology expressivity power is enhanced by a set of logical rules. These rules are defined and used to enable inferences and reasoning in the context of the proposed ontology. Table 2 shows an excerpt of such axioms and logical rules.

Table 2. Ontology Constraints and Rules.

Constraint	***Example***
Disjoint classes	An object or instance of student for example could not be an instance of faculty. An individual activity cannot be at the same time a collaborative activity. If Student(?S) and Faculty(?F) →isDifferent(?S,?F) If Activity(?A) and isCollaborative(?A) →
Existential restriction	A Path with POI is a path that fulfils the constraint at least one POI exists and pertains to the path isPath_With_POI(?P) → ∃ POI(?po) and isLocatedIn(?po,?P)
Rule	***Example***
Add_GUI_ Component	A user U who's GUI interface is a Map m and who have visited a POI p1 at Time t1 and who's next planned Activity A at Time t2 is to visit another POI p2 is informed about the next POI location by adding a Marker to his interface: If IsLocated (U, p1,t1) and Next_InPath(p1,p2) and Activity(A,t2)="Visit POI" → set_Up_GUI_Component(Marker(Map m,p2))
Draw_Direction_Path	A user U who's current Location l is far from form the POI p2 to be visited is informed about the next POI location by drawing Direction path on his interface: If IsLocated(U,l,t1) and IsFarFrom(l,p2) → Draw_Direction_Path(p1,p2)
Apply_Zoom	When the distance between two POIs is small it is better to ZoomUp the Map: If Distance (p1, p2) < 2 Km →Apply_Zoom(m, 13)

3.2 Development process

Modern software development is increasingly requiring separation of concerns. Therefore, each component to be developed should individually address a different purpose and brings itself contribution to achieve the global application goal. Separation between the user's interface, the interaction mode and the business logic should also be taken into account as illustrated by Figure 4. This architecture model based on *MVC* (*Model View Controller*) enables a development process which could be carried out by a development team with different roles and skills.

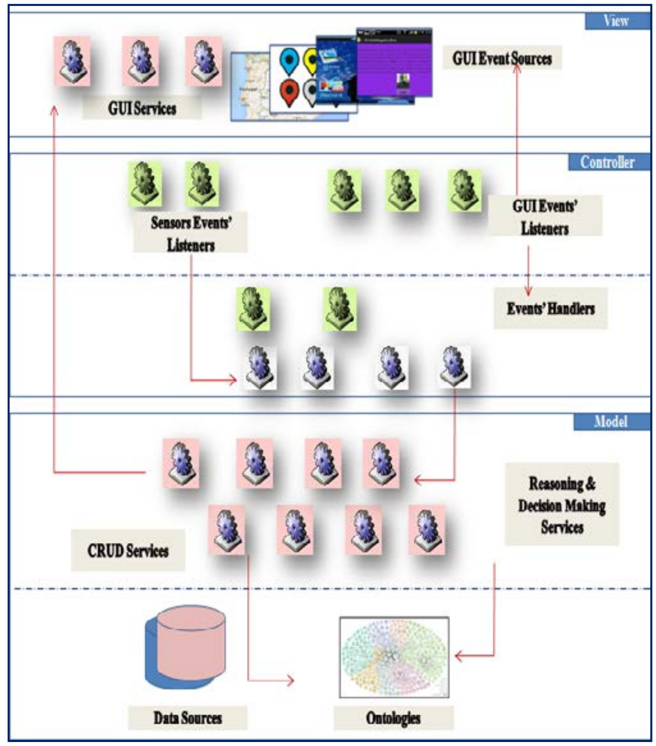

Figure 4. Application architectural model.

In order to grant a best user experience, the interaction model as well as the user interface should be intuitive, ergonomic and compliant to the user's habits and preferences. It should also avoid her/him having an overloaded view. User inputs are requested only when they are strictly necessary. The user's interactions are, therefore, driven by a set of components that are able to detect her/his context and provide her/him consequently and seamlessly with the best fitted services.

Taking into account all these considerations, the core application process structure addresses these actions (1) initialize the first application's *State*, (2) sense and analyze *Context* info, (3) update the application *State*, (4) display the next *State*. The process continues at point (2) until the user explicitly stops the application.

The development process targeting this kind of application is incremental. It also follows a "bottom-up" approach through the next steps:

- Identify possible users' needs and interaction rules that drive the application behavior.
- Identify and develop information sources and data structures (Ontology sources and Databases).
- Identify existent components that could be reused and/or reassembled as for instance, third party services such as those provided by *Google Play* services, *Weather Forecast* services or also transportation and traffic services.

- Identify issues such as *User Interface* structure, components, *GUI* services and attributes.
- Develop context sensing and *Events Listeners* components.
- Develop *Events handlers* and implement their interactions with business services.
- Develop business services that firstly, reason and request ontology sources and databases and, secondly, act on the user's interface components accordingly to interaction rules by triggering GUI services.

In the context of the present work, point (1) and (2) are represented by developed ontologies as well as their associated rules.

The point (4) considers *Widgets* and *Graphical User Interface* components provided by mobile devices.

The point (5) relies on sensor modules (e.g. GPS) present on the user's devices, on remote services (e.g. *Weather* services) as well as on the user's interaction with the app GUI components. Each detected event (e.g. Location changed) will trigger the relevant *Event handler*. Mappings between *Event Handlers* and capabilities provided by services developed in point (6) are inferred automatically which constitute the core of the interaction logic provided to the user. As illustrated by Figures 4 and 5, service categories vary from *Decision Making* to *GUI Services*. Moreover, these services collaborate to detect the user's context and decide on the action to be realized as, for example, to add one *GUI* component or to update one another.

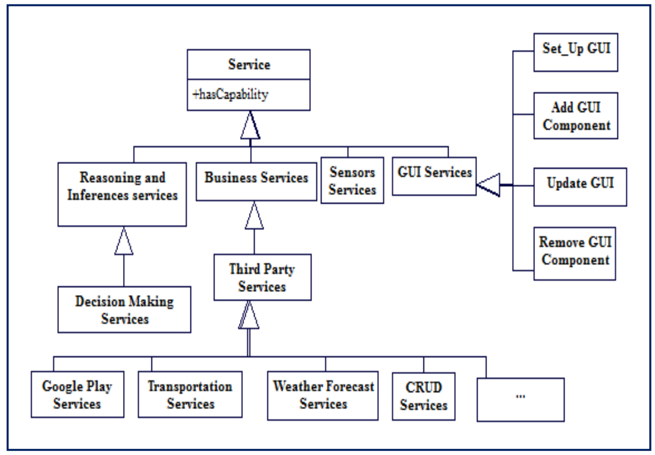

Figure 5. Services taxonomy.

4. SAMPLE APPLICATION

As a proof of concept, a sample application is provided that deals with specific interactions within a University Campus. These interactions can be addressed to educational purposes for Campus students but also to allow other users to take advantage of its services or visit its patrimony facilities. First, the geographical campus environment is described. Thereafter, technical details of the mobile application used within this environment are provided.

Figure 6. University Campus map.

4.1 Environment description

The context of the sample application is based on an existing University Campus. Figure 6 shows a map of the target campus, which represents the geographical areas that integrate it. Each area is identified by a sector label (e.g. sector 2C) and it includes a set of buildings, objects and other campus facilities such as sport arenas or yards. Additionally, this map displays some numbered blue little squares that represent "Meeting points" for each campus sector.

Figure 7 shows a detailed view of one of the sectors represented in the map. It is located close to the main street and there are two campus entries labeled as L and M. There are also two near bus stops and a tram station. The selected sector is composed by several buildings (6A-G), sports courts (green areas), two Meeting Points (P6A and P6B), and a set of numbered red spots.

Figure 7. Campus sector map.

These spots are signaling special artistic points (e.g. sculptures that are part of the Patrimony campus) which can be interesting for Art students or an occasional visitor for cultural exhibitions at the campus. Figure 8 shows a group of students observing a sculpture called "Cactus" and listening to the tutor explanations. These students are in a course of Sculpture Conservation and they want to know those technical issues that can be harmful for sculpture materials. This situation could be a sample scenario where interactions can take advantage of geolocation services.

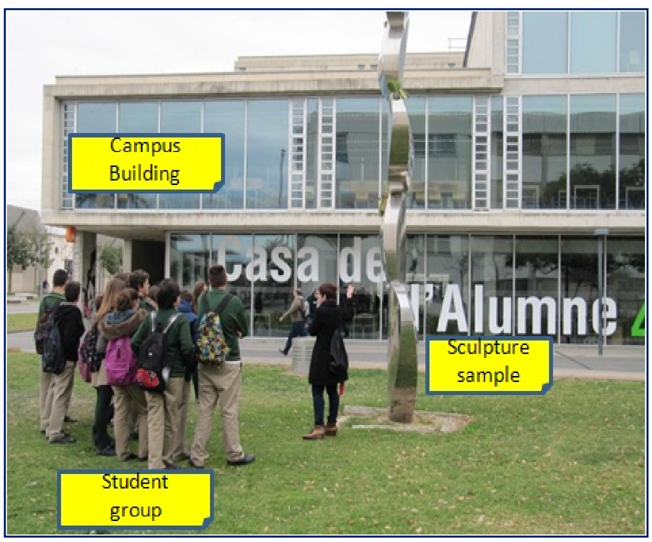

Figure 8. Campus Sculpture exhibition.

4.2 Technical solution

The sample application called *OntoMapAndro* has been developed through an Android framework and deployed using a mobile device. It tracks the user's location and allows her/him to interact with a main GUI component which is a *Map* representation of the campus space, interesting *POIs* and paths (see Figure 9) within the previously introduced campus environment.

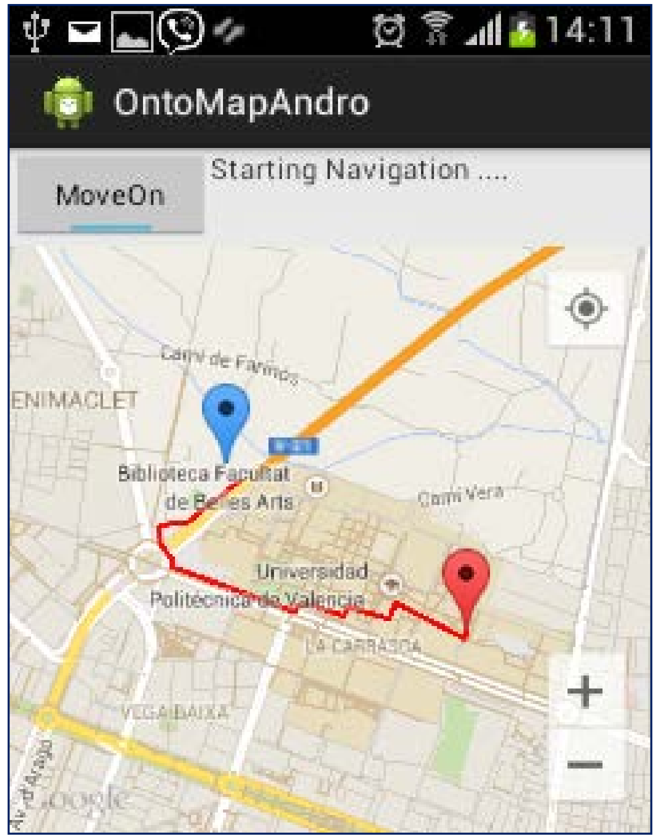

Figure 9. Campus path

The application is structured according to the architecture layers illustrated in Figure 4, with self contained components and services within each layer.

The resource layer constitutes information sources as databases and ontologies for managing campus organizational data as well as contextual information to be stored and processed. The context ontology is implemented using the Protégé ontology editor and it is expressed by means of the Ontology Web Language (OWL).

The business or application model layer contains services for reasoning and querying the ontology using the SPARQL language and the Andro Jena API. These services have been implemented as an external Android service exposing its interface via the Android Interface Definition Language (AIDL).

The controller layer implements several categories of listeners related specifically to context change events as, for example, location changes or user's interactions with the map. These listeners are associated to event handlers which capture event information and delegate it to be processed by services in the application model layer.

Decisions made by this layer after considering new contextual information may specifically trigger *GUI* services to update the user's Interface. For example, Figure 10 shows an *OntoMapAndro* screenshot displaying information (text & image) about the object that is currently visited. This information is displayed over the *MapView* (Google Map based) as a consequence of triggering a *NextStep* event.

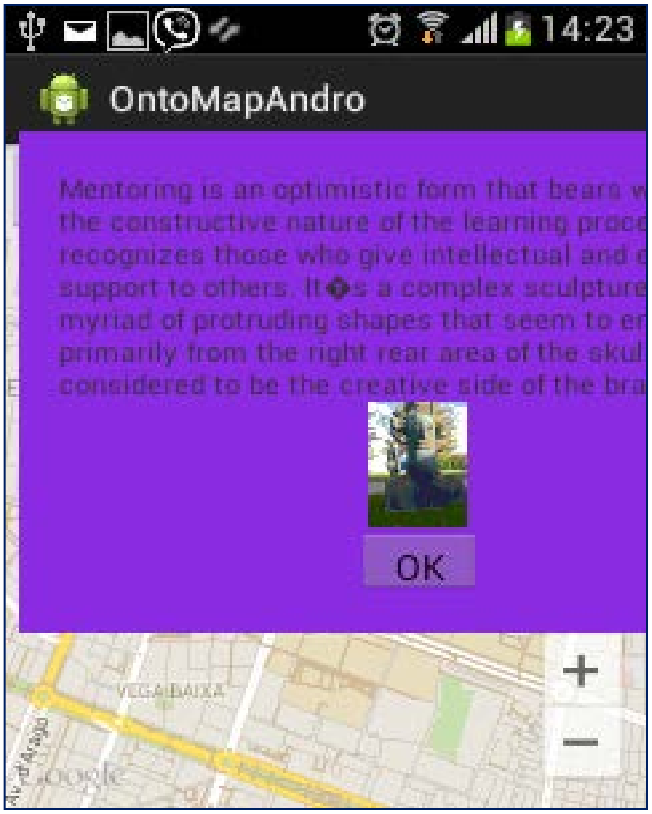

Figure 10. Object information display

Finally, the view layer represents mainly the client components or services that interact with the Google Map API. Client's services implement specifically functionalities to display maps, to change map attributes as the zoom level and camera position, to also display the user's positions, add specific markers, and draw paths among two or more POIs. These information items are adapted according to the ontology rules defined previously. For example, Figure 11 shows how the zoom level has changed because the distance to the next object to visit is under a specific threshold.

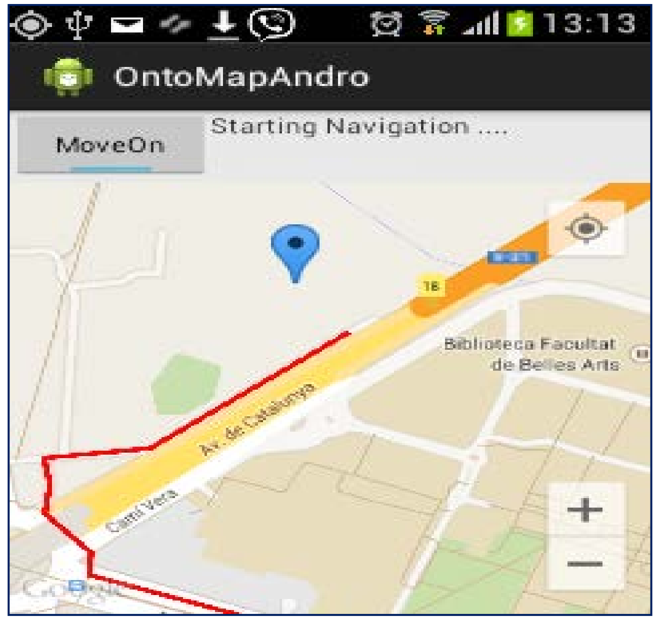

Figure 11. Zoom level adaptation.

5. CONCLUSION

The current work has presented an approach to support the modelling of contextual information in campus settings using a systematic development process. The proposed approach has been based on an ontology proposal focused on representing concepts and relationships either for indoor or outdoor campus scenarios. This ontology includes the definition of axioms and rules that are useful to reason or infer new information promoting learning purposes or sharing knowledge. An implementation of this ontology has been developed using well known semantic technologies such as Protégé, JENA and SPARQL tools demonstrating the feasibility of the approach.

Moreover, the developed ontology has been applied in the context of a university campus showing its potential to model context information that allows campus users to perform multiple kinds of queries focused on different types of interactions. It is important to highlight the possibilities provided by using ontology sources in order to drive the application execution and improve its adaptability in a changing context. Further works plan to address development issues such as the generation of mobile apps in multiple platforms and the improvement of accessing ontology sources via web services. Another research line consists in analyzing the users' interactions and their behaviour when they are using geolocated applications based on the current proposal. These findings could lead to recognize mobile behaviour patterns and provide better user adaptations.

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SEGA-ARM: A Metamodel for the Design of Serious Games to Support Auditory Rehabilitation

David Céspedes-Hernández[1], Jorge Luis Pérez-Medina[2],
[1]Universidad Autónoma de Aguascalientes
Av. Universidad 940, Ags., Mexico
{dacespedes, fjalvar, jmunozar}@correo.uaa.mx

Juan Manuel González-Calleros[3], Francisco J. Álvarez Rodríguez[1],
[2]Université catholique de Louvain
Place des Doyens 1
Louvain-la-Neuve, Belgium
jorge.perezmedina@uclouvain.be

Jaime Muñoz-Arteaga[1]
[3]Benemérita Universidad Autónoma de Puebla
Av. 14 Sur y San Claudio, Puebla, Mexico
juan.gonzalez@cs.buap.mx

ABSTRACT
Hearing impairments are widely recognized as one of the most common disability that affects many people. There are several works addressing the design and development of systems for the rehabilitation of users with disabilities, as well as for the definition of models to express their capabilities and disabilities. Unfortunately, when we want to develop interactive systems to assist hearing impairment therapy, knowledge of analysis and design, typical of the methodologies is absent. In this paper, we introduce SEGA-ARM: a metamodel to support the design of serious games for auditory rehabilitation, considering concepts related to speech therapy sessions, user capabilities, the context of use, and concepts related to serious games design. The proposed solution is provided using a semi-formal UML notation. Two game prototypes are presented to validate the viability of the application of the metamodel for serious games development and to point out its reutilization and extension.

Categories and Subject Descriptors
H5.2 [**Information interfaces and presentation**]: User Interfaces–*Prototyping; user-centered design;* K8.0 [**Personal computing**]: Games.

General Terms
Design, Theory

Keywords
Model-driven development, speech therapy, serious games, Human-computer interaction, hearing impairment, cochlear implant, user-centered design.

1. INTRODUCTION
In several contexts such as healthcare, military and educational, games have been applied as a way to improve skills and for training professionals [1] [2]. This type of games is called serious games [3] [4]. Despite the fact that the concept of serious games itself, might be considered as an oxymoron since "*Games are inherently fun and not serious*" [5], it is important to clarify that many works had been conducted in the field addressing the development of these games, always considering fun as a main component of them [6]. Several works addressing the design and development of systems for the rehabilitation of users with disabilities [7] [8], as well as for the definition of models to express people's capabilities and disabilities [9] [10] had been carried out. However, even though hearing impairment is widely recognized as one of the most common disabilities [11], there is a lack of work focusing on providing tools to ease the design and development of applications for the domain of auditory rehabilitation. In this sense, the objective of this work is not only to provide an application that may be used to help on the performance of assisted therapy sessions, but to propose a definition of modeling elements along with their relationships and rules in order to enable the creation of semantic models, that may later result on the implementation of a family of serious games with the purpose of supporting the process of auditory rehabilitation, meaning by this, a metamodel [12] for the design of serious games to support auditory rehabilitation.

The rest of the paper is structured into sections. Section two presents a state of the art with relevant concepts to auditory rehabilitation and serious games, as well as other related works, and the description of useful techniques and tools for the development of this project. For the description of the elaborated model, section three firstly presents the packages in which it is divided. Later, in order to facilitate the comprehension of the model's classes, a case study is introduced. Finally, instancing the case study, each one of the packages' element is described. In the fourth section, a discussion on the characteristics of the full model and the relationships that exist between classes of its different packages is carried out, introducing a second case study. Last, conclusions and future work are mentioned in section number five.

2. STATE OF THE ART

2.1 Concepts on Auditory Rehabilitation
In order to better understand the aim of the present work, a set of concepts relative to auditory rehabilitation and serious games has to be defined.

Rehabilitation is the dynamic process by which physical, sensory, and mental capacities are restored or developed in people with disabling conditions [13]. When it comes to rehabilitation for auditory disabilities, it is covered mainly by speech therapy and reinforced by occupational and physical therapy. The success of a rehabilitation program depends on various factors: timing, patient diagnosis and treatment planning [14]. For the purposes of this particular work, only speech therapy is addressed. Speech therapy, also known as speech-language pathology, is the rehabilitative treatment of physical and/or cognitive disorders resulting in difficulty to perform verbal communication. Speech therapists asses, diagnose, treat and help to prevent disorders related to speech, language and other elements of communication [15]. The ultimate goal of these specialists is to help patients develop or recover reliable communication and other skills. Most speech-language pathologists work with determined age groups, such as children or elderly and focus on the treatment of certain communication problems, such as those resulting from strokes or hearing loss [16].

Hearing impairment may be caused by different factors, such as, accidents, viral diseases, noise, and genetic causes [17]. Depending on the background of the patients with hearing impairment, among other classifications, they can be categorized into two groups: prelocutive (loss hearing toke place before the acquisition of spoken language) and postlocutive (patients whose loss of hearing has taken place after the development of the basic skills of spoken language) [18]. Once a hearing impairment has been diagnosed, the specialists involved on the patient's treatment, evaluate the best option in order to improve his/her conditions. In this sense, some of the patients may be candidates to receive a cochlear implant as the one mentioned in the case study (Subsection 3.1) of the present work.

A cochlear implant [19] is an electronic device that stimulates the auditory nerve to allow sound perception. It is composed by an external component that receives incoming sound, processes it and transfers the resultant signal across the skin. Another device receives and decodes the transmitted signal and stimulates the auditory nerve directly, bypassing the hair cells that implement the first stage of auditory neural processing in normal ears. According to the National Institute on Deafness and Other Communication Disorders (NIDCD) on the United States of America, by December 2012, approximately 324,200 people worldwide have received cochlear implants [20].

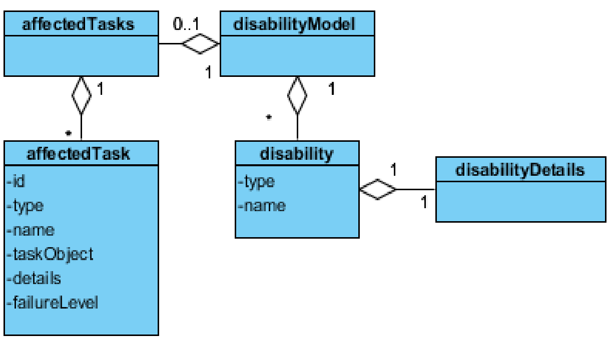

Figure 1. The disability model proposed by Kaklanis [10].

2.2 Concepts on Serious Games

To define a serious game, [21] begins by defining a game as a physical or mental challenge, that is played according to specific rules, with the objective of amusing or entertaining the participant. Then, continues to build the definition of a videogame as a mental challenge that is played through a computer according to certain rules for entertainment, fun or to achieve a goal. And finally, provides the definition of a serious game as a mental challenge, played through a computer according to specific rules, which uses entertainment mechanisms to achieve training or capacitation goals in areas such as education, health and military.

Notice that in the rest of the paper, this is taken as the definition of a serious game, just pointing out that it may also consist of physical challenges (e.g., tongue movement, phoneme pronunciation, and lips movement). The interest on the usage of serious games on rehabilitation lies on the fact that is has been demonstrated that they increase motivation towards therapy sessions, which represents a major problem due to the repetitive nature of exercises [14].

2.3 Related Work

Software designers may achieve the goal of expressing the capabilities and disabilities, along with other valuable insights of a user to developers via "*Personas*" models [9]. "*Personas*" are hypothetical archetypes of actual users and their description may consist on different aspects according to what is intended to make the development team aware of. Alternately, in [10] a metamodel was proposed by Kaklanis to allow the expression of the whole user capabilities and disabilities with the intention of virtual user modeling. The main advantage that was encountered while comparing the "*Personas*" representation to this second proposal, is that "*Personas*" provide only a natural language description of the characteristics of the user, while Kaklanis' disability and capability models' structure allows their representation on a machine-readable format.

For the present work, the disability model by Kaklanis, shown in Figure 1, is considered as it was defined, since it provides a generic description of any kind of disabilities with the affected tasks on it involved, while the capability model was in turn simplified to extract from it only those parts related to the hearing and speech skills, and enriched with characteristics that authors mention as relevant for the domain of speech therapy in children, such as loudness, speech rate and phrasing [22][23].

Concerning serious games design, an effort has been realized by several authors, in order to abstract components that lead to the definition of a guide on what to be aware of when developing a game with these characteristics [24][25]. However there is not yet a consensus on the components or elements that should be considered when performing design and implementation, Table 1 presents some of the design elements that are usually taken into account for the development of games [24-28].

Moreover, Longstreet & Cooper [29] proposed a conceptual guide for development of serious games to support higher education, their conceptual definition includes most of the design elements reported on Table 1, but a structural notation was not provided and the relationship between the involved elements is only explained in a narrative manner, making its reutilization complicated.

In this section, a general panorama of the domain concepts was provided in order to facilitate the comprehension of further sections. Also, related works are considered and described, pointing out their usefulness for accomplishing the objectives presented on section one, and also reporting their limitations.

Finally, taking into account the concepts addressed in the last two subsections, a decision was made to consider the proposition of a metamodel composed by three main packages: context, theoretical therapy, and performed therapy, and to add it the definition of a serious games design elements extension.

Table 4. Game design elements in the literature [24-28].

Game Design Element	Description
Characters	The definition of characters allows user engagement to the game, and provides the possibility to define actions. Helps improving the player experience. Considers both, player and non-player characters
Narrative description	The rational of the game described in a narrative way, promotes the immersion of the player, helps to define the needed resources, characters, game mechanics and challenges.
Challenges	The definition of challenges to be faced during the gameplay, gives the player the opportunity to try his/her skills and to compete either with a partner or with the game itself.
Type of view	Determines the level of immersion that is decided to use in the game. The most used point-of-view perspectives for gameplay are: first-person, third-person, third-person trailing, overhead, and three-fourths isometric.
Constraints	Constraints determine characteristics of the challenges (e.g., limited time or resources, competitive and sequential activities).
Rewards	Establishing a reward system (e.g., points, badges, levels, and leaderboards) allows improving the player experience and motivating him/her to achieve a goal.
Punishments	As with rewards, the establishment of punishments, such as a decrement of points, and losing a life in the game, motivates the user to achieve a determined goal.
Interactive elements	The definition of interactive elements supports the immersion of the player on a virtual world. Their definition helps to design player tasks.
Feedback	For each action performed by the player, the game provides a reaction. In this way, the user is aware of the consequences of his/her acts on the game and an appearance of continuous dialog is given to him/her.

3. SEGA-ARM: A METAMODEL FOR THE DESIGN OF SERIOUS GAMES TO SUPPORT AUDITORY REHABILITATION

For achieving the objectives mentioned on the introduction, a metamodel (SEGA-ARM) is proposed, considering for its definition concepts related to context, auditory rehabilitation, planned therapy, performed therapy, and serious games design elements. The elaborated model is divided for its best comprehension and usage into three packages, presented in Figure 3, and an extension shown in Figure 4, each one of them identified by a different color and name, and designed to contain elements that support the design of serious games for auditory rehabilitation.

In the rest of this section, SEGA-ARM is described in detail and explained through a case study of a serious game design for supporting the process of rehabilitation of a patient with a deep hypoacusia condition, recipient of a cochlear implant.

3.1 Case Study

The case study consists on a scenario in which the design of a serious game is required in order to support the therapy sessions conducted by a speech therapist for a six year old male patient diagnosed with deep bilateral hypoacusia who has recently received a cochlear implant. The therapist has already performed tests over the patient to determine his exact condition and counts on a full expedient describing his capabilities towards hearing and speech skills. The intention with the required game is to extend and complement the therapy sessions that the patient already receives with sessions conducted by himself in his home as those suggested in [30]. The language therapist wants the game to reinforce one of the therapy activities that the patient finds to be repetitive since it has to be performed in almost every single session.

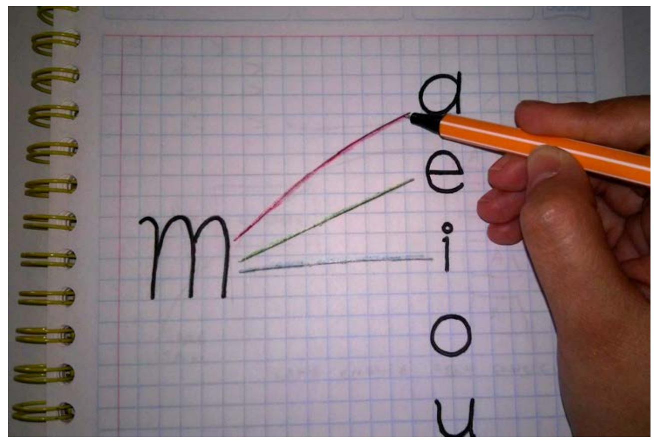

Figure 15. The exercise conducted in the therapist's office.

The exercise consists on that the therapist chooses a series of phonemes sharing a consonant (e.g., ma, me, mi, mo, and mu), write them down on a notebook as shown in Figure 2, putting the consonant on one column of the page and the vowels in another next to it, then asks the patient to pronounce each one properly while connecting the consonant with the vowels with lines, and then repeat this task several times and with different phonemes. This activity is designed to be performed in approximately ten minutes and also considers phoneme visual recognition by the patient. It is also known by the therapist that the patient counts on a 10.1" tablet with Android 4.2 OS. The information that the specialist possesses has been structured in terms of the here proposed metamodel as a way to facilitate the communication between the speech therapist and the game development team. The following section reports as an instantiation of the metamodel's classes and how data was arranged and organized.

3.2 Description of the Classes Involved on the Model

The following subsections are for used for providing a detailed description of the packages and classes that take part on SEGA-ARM. For every single package that is described, there is an instantiation in terms of our case study introduced on section 3.1.

3.2.1 *The Context Package*

A package designed to understand the ***Context*** [31] in which the user interacts with the system, and to provide the developers with a brief description of relevant characteristics to make decisions about what interactive modality to implement, and resources selection among others. The ***Context*** is identified by an id and a descriptive name, and conformed by an ***Environment***, a ***Platform*** and a user (***Patient***).

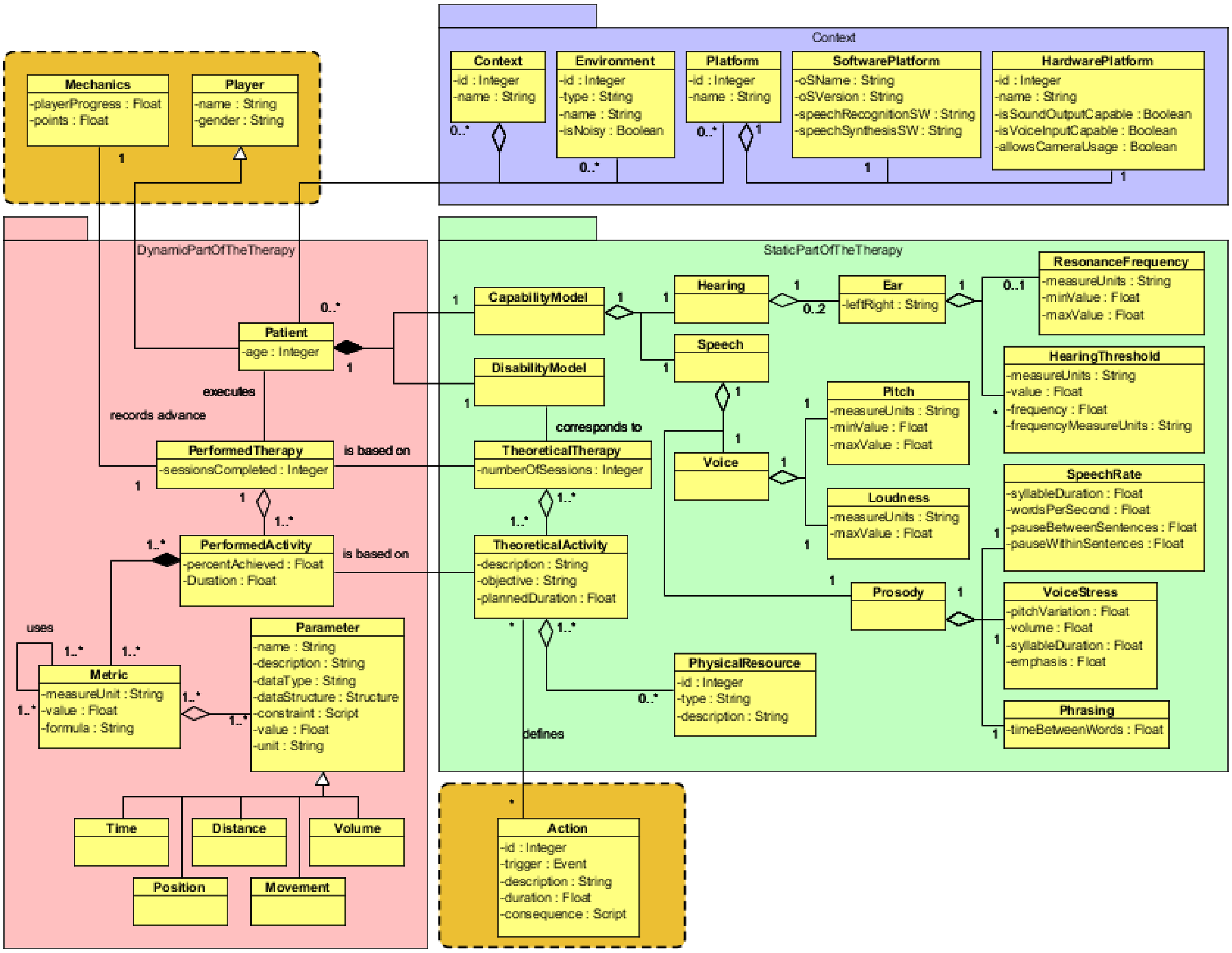

Figure 3. The Context, Theoretical part of the Therapy, and Dynamical part of the Therapy packages with their relationships to the serious game extension of the SEGA-ARM metamodel proposed.

The ***Environment*** describes the physical place in which the interaction occurs. For the specific domain of this work, it is necessary to point out if it is noisy or not, and to give it a name, an id and a type (i.e., exterior or interior).

The ***Platform*** definition is carried out to determine the characteristics of the device that is going to host the application, and is formed by a ***SoftwarePlatform*** and a ***HardwarePlatform***. The ***SoftwarePlatform*** represents those characteristics relative to the software in the hosting platform i.e. operating system name and version, as well as the speech recognition/synthesis software on it installed, while the ***HardwarePlatform*** class defines characteristics regarding the hardware of the hosting platform and relevant to the domain, such as the possibility of using sound outputs, voice inputs or a camera.

In our example, the context in which the therapy sessions take place is defined by a therapist's office as a non-noisy, interior environment, has not platform and the user role on it is taken by the patient, meanwhile, the context of use of the application that is intended to be developed, is composed by the patient's home as non-noisy interior environment, a 10.1" tablet with Android Jelly Bean 4.2 operating system, audio output, voice input and camera usage enabled, with android speech recognition/synthesis software as platform, and the patient as user. Note that even though the characteristics of the context must be taken into account by the serious game's designer; the implemented solution may work under other similar contexts as well.

3.2.2 *The Static Part of the Therapy Package*

The purpose that is pursued with the design of this package is to provide the speech therapist with a semiformal notation to express the characteristics of a therapy plan, keeping that information structured in a way that results understandable for serious games designers. The definition of this part of the model was inspired mainly by the work done by Kaklanis for modeling a Virtual User [10], extended to allow the expression of a full auditory therapy session program, and enriched with concepts found out to be relevant for patients of auditory rehabilitation on the literature [22] [23] and through the attendance to speech therapy sessions. Abstracted from the full capability model [10] that describes physical, cognitive and behavioral user characteristics, for the specific domain of this work, the ***CapabilityModel*** presented as part of this paper, only considers the elements related to speech and hearing.

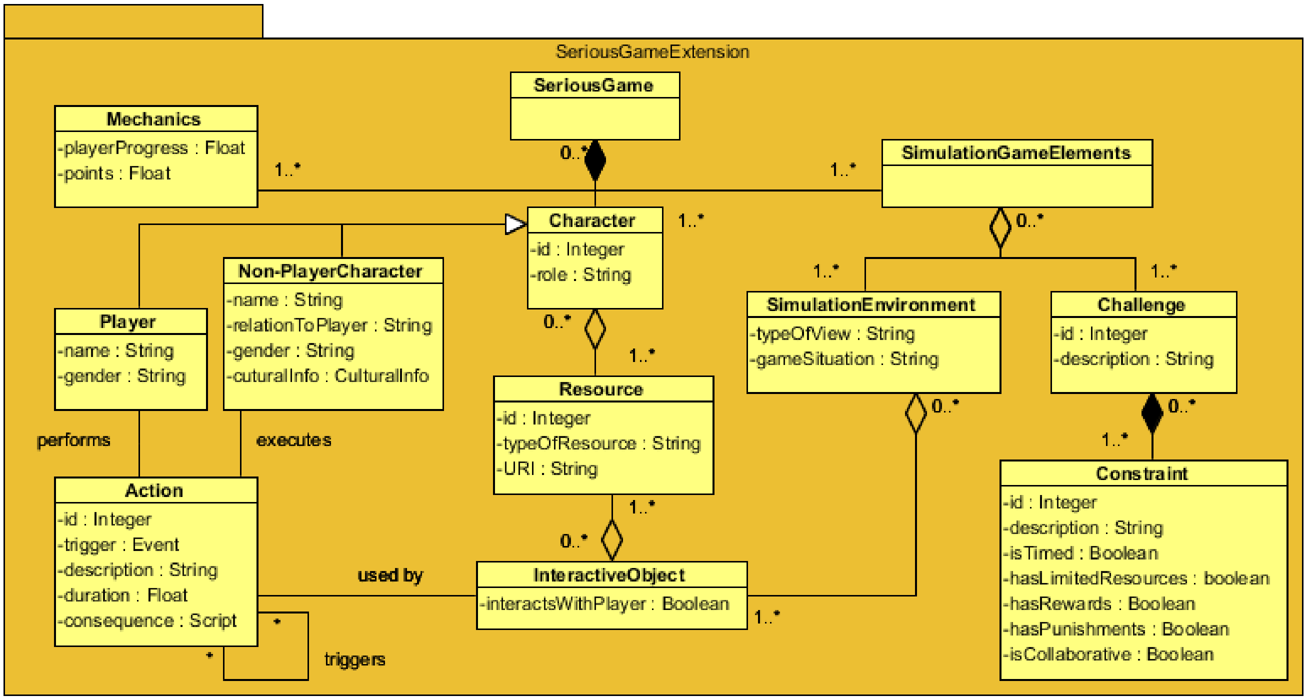

Figure 4. The serious games design elements extension provided for SEGA-ARM

The only parameter in the ***Hearing*** container is the ***Ear*** that in turn acts as one for the values related to each ear of the user: ***ResonanceFrequency*** and ***HearingThreshold***. The ***Speech*** container includes ***Voice*** and ***Prosody*** elements. ***Voice*** elements include ***Pitch*** and ***Loudness***, each one with its measure units and values; while ***Prosody*** is formed by ***SpeechRate***, ***VoiceStress*** and ***Phrasing***.

A ***DisabilityModel*** [10], allows the description of all the disabilities of the user as well as the affected by them tasks. For each disability, a name and a type (e.g. motor, auditory, and vocal) must be provided, and it is related to affected tasks. For a determined ***DisabilityModel***, a ***TheoreticalTherapy*** may be proposed. A ***TheoreticalTherapy*** is a full rehabilitation plan and consists of a certain number of sessions and a series of theoretical activities. A ***TheoreticalActivity*** is in turn, a series of actions with a common objective to be performed by the patient either using or not ***PhysicalResources*** (e.g., a mirror, sticks or cards). The planned duration, objective and description are attributes of a ***TheoreticalActivity***.

For our case study, the disability and capability models correspond to the diagnosis that was realized by the specialist in speech therapy. The disability that was encountered is deep hypoacusia, and the affected tasks by it, are hearing and speaking. For the capability model, in the hearing branch, the patient presents hearing thresholds of more than 90 dB nHL for frequencies of 1000, 2,000 and 4,000Hz in both ears; and a resonance frequency between 800 and 1,200Hz. For the speech branch, the patient's voice was measured, getting as values for the pitch 250-300Hz, and 73dB for the maximum loudness. The prosody was also analyzed, obtaining for it typical results for a patient of the age and condition as the previously described. Corresponding to the identified disability, a rehabilitation program was designed comprising approximately 300 hours, to be provided in half an hour, two times a week sessions. One of the activities to be performed by the patient consists on repeating a series of phonemes in a determined order. The therapist mentions a phoneme and expects the patient to repeat it. If a phoneme is not correctly pronounced, the therapist reinforces its pronunciation and motivates the user to try again. The objective of the task is to improve the patient's pronunciation and to get him/her used to repeat the sounds that he/she listens to. For this particular activity, only a notebook and a color pencils are used.

3.2.3 *The Dynamic Part of the Therapy Package*

In order to represent the current progress and performance of the ***Patient*** towards the therapy program, and to provide the development team with a structure to understand how to evaluate patient's activities, the dynamic part of the therapy package was created. This package contains then the ***Patient*** class, with an age attribute, related to a ***PerformedTherapy*** which reports the number of completed sessions and groups objects of type ***PerformedActivity***.

A ***PerformedActivity*** is based on a ***TheoreticalActivity*** and its main goal is to keep a record of the advance presented by the patient while performing a given activity. In order to allow the evaluation of a ***PerformedActivity***, a ***Metric*** class was also defined. Metrics allow the use of a formula in order to compute a value and to express it on a determined measure unit (e.g., centimeters, seconds and decibels). For the evaluation of a formula, a series of ***Parameters*** i.e., criteria to be used while evaluating, may be defined. There could be nested metrics since some formulas may need some others to be previously computed in order to take values from them. Metrics in this domain may be useful for measuring among others, tongue movement (i.e., tongue tip position, tongue vibration, and tongue position), lips movement (upper lip movement and lower lip movement), pronounced phonemes and blow action.

In the context of the case study, the performed therapy and performed activity classes keep track on how the patient is evolving and advancing through the therapy program and their involved values are constantly updated. The metric to be used for the specific theoretical activity described in section 3.2.2, consists on evaluating how a phoneme is pronounced by the patient, recognize it and compare it to an expected phoneme passed as parameter according to a specific tolerance, using for this purpose the formula represented on Figure 5 where the pronounced by the patient phoneme (pp) is compared to the expected phoneme (ep) and then, if the *distance* between them is smaller than the tolerance value (t), the utterance from the patient is accepted as correct.

$$\text{Recognition} = \text{distance}(ep, pp) - t$$

Figure 5. Formula for recognition considering expected phoneme (ep), utterance (pp), and a tolerance value (t).

3.2.4 *The Serious Games Extension*

In attention to the main objective of this paper, an extension to the therapy metamodel for considering serious games design elements was elaborated. For the proposal of this extension, mainly Longstreet´s approach is considered [29], enriched with concepts obtained through a deeper survey on serious games design elements [26-28]. The intention on the definition of this extension is to provide developers with a tool for passing from a narrative description of a game to a semiformal structure that may be related to the one of the core metamodel. A ***SeriousGame*** is composed by ***Mechanics*** to record the player progress and to manage the punctuations, one or many instances of the ***Character*** class to define players as well as non-player characters (***NPC***), and ***SimulationGameElements*** such challenges, rules, scenarios and interactive objects.

A ***Character*** object represents an entity that realizes actions. These instances can be either a ***Player*** or a ***Non-PlayerCharacter***, and need ***Resources*** in order to be properly displayed. For the definition of ***NPC***s, it is necessary to give them a name, decide the relationship that they maintain towards the ***Player***, and when possible, provide their gender and cultural information e.g. language, nationality, degree among others [29]. In order to handle events on the game and describe their consequences, it was necessary to define the ***Action*** class. An ***Action*** is represented by an event (e.g. key press, click, tap, recognized word or movement, or scripts) that triggers it, along with a description, duration, and a script to execute as consequence. Actions are performed by ***Players*** or executed by ***NPC***s and may whether use or not an ***InteractiveObject*** that are in turn, objects that belong to the ***SimulationEnvironment*** and are created to support the game interaction, for instance, the scenario, the floor, and colliding objects. The ***SimulationEnvironment*** description contemplates the definition of a type of view (e.g., first person, third person, or isometric) [26], and helps to hold the game situation i.e. level, state, and maximum amount of errors [27] in a narrative manner. Finally for this package, a series of challenges has to be designed to represent the goals that are pursued while playing the game. A ***Challenge*** consists of a description and is composed by at least one ***Constraint***. Constrains may include one or several conditions (viz. time, limited resources, rewards, punishments, and mandatory collaboration).

For the given case study, taking into account the description provided by the speech therapist for the context, theoretical and dynamic packages, the serious game designer proposes to elaborate a game with the characteristics that are presented in Table 2 and which resultant user interface is shown in Figure 6.

It is important to point out that the definition of some of the game design elements was achieved through the establishment of relationships between the therapy packages and the serious games extension (e.g. ***TheoreticalActivity*** and the ***Action***). Next section emphasizes this characteristic of SEGA-ARM along with others that had not been yet addressed.

Table 2. Characteristics of the designed serious game.

Game name	Froneme the frog.
Narrative description	Froneme the frog is in the edge of a river looking for food to eat. In order to go find it, he has to jump between leaves avoiding to fall on the water. To perform a jump, the player has to identify the phoneme associated to the destination leaf and pronounce it. If the player is unable to provide a correct utterance, Froneme falls down into the water and therefore the game is over.
Player	The patient represented by a frog.
Interactive objects	Mosquitoes representing Froneme's food; leaves to allow Froneme jump from one to another identified by a phoneme; water that has to be avoided by Froneme.
Player actions	Eat mosquitoes by landing on the leaves that they are on, jump from one leaf to another by pronouncing phonemes, and fall down on the water if not correct utterance is provided on the given time interval.
Simulation environment	The game is designed with an isometric type of view, and the following game situations: Froneme in the border of the river (initial state of the game), Froneme on a free leaf, Froneme on a leaf occupied by a mosquito (eating), and Froneme falling on the water.
Challenges	The challenges involved in the game are the following: jump from a leaf to another pronouncing a correct phoneme, jump from a leaf to another within a determined time interval (time limit) to earn points (reward), or let Froneme to fall into the water (punishment); choose a leaf to jump on from a series of provided options (limited resources) and if there is a mosquito on the selected one, earn a bigger amount of points (reward).
Mechanics	For each time the player takes Froneme to a valid leaf, 10 points are going to be added to the budget, If there is a mosquito on the occupied leaf, ten extra points should be added. The time available for producing the phoneme

	is five seconds. Time and punctuations are recorded and reported.

4. DISCUSSION

As it may be seen in Figure 3, there are relationships between the therapy packages and some of the serious games design elements extension classes. These connections allow the developers to know where to extract information that is supposed to be represented in the game, and how to present it. Punctually, there are relationships between: the ***Patient*** (Dynamic part of the therapy) and the ***Player*** (Serious games) to remark the fact that the patient has to be considered as the player and to get some information from his/her profile; the ***PerformedTherapy*** (Dynamic part of the therapy) and the ***Mechanics*** (Serious games), to track the advance of the player through the game and give a feedback for the therapist; and the ***TheoreticalActivity*** (Theoretical part of the therapy) and the ***Action*** (Serious games) in order to understand the tasks that the patient is supposed to perform while playing the serious game. It is also important to point out that three levels were considered while modeling the therapy: (1) the patient (capabilities and disabilities), (2) the therapy program (theoretical therapy), and (3) the involved activities to meet the plan (theoretical activity). Each one of those three levels has equivalence on the dynamic part of the therapy in order to keep track of the advance and performance of the patient through the therapy.

When compared to the proposal in [29], our metamodel has the advantage of providing a semiformal notation which may be used in a methodological process as a conceptual guide for achieving the goal of expressing and therefore implementing serious games for a specific set of therapy activities. Along with its description, it also allows identifying the actor that is supposed to fulfill the different classes and attributes, and provides a definition of the relationships that exist among them. However, in this paper the use of knowledge bases and taxonomies is not considered resulting on the lack of a repository of activities to provide to the developers.

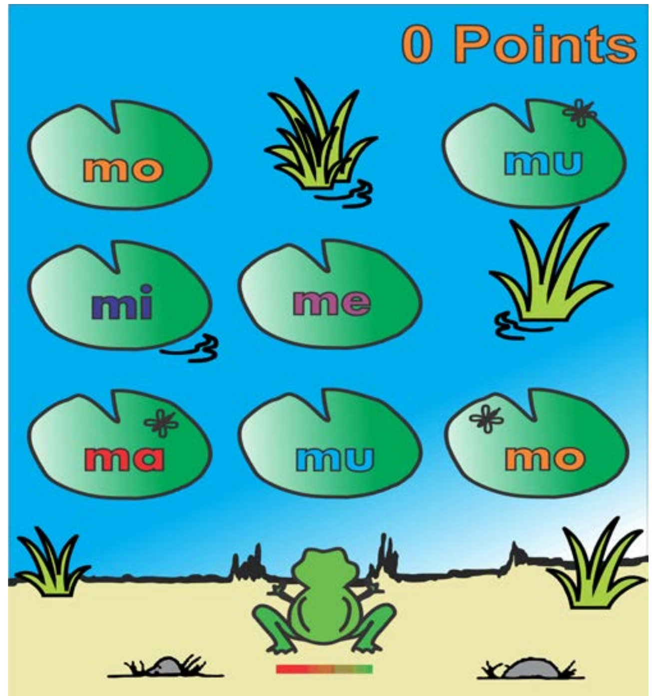

Figure 6. Screenshot of the serious game Froneme the frog.

One of the aimed advantages of our proposal is reutilization, and in order to demonstrate it, a second instantiation of serious game, called Roberto the robot, was realized in which the very same definitions of the case study described in section 3 for the context and for the static and dynamic parts of the therapy packages are taken into account, varying only the serious game extension elements and therefore creating a different serious game but for the same rehabilitation purpose. For this second game, a character representing the player called Roberto the robot is set on a scenario representing the moon surface looking for pieces to assemble a rocket to return to the Earth. In order to find them, he has to run and jump over rocks avoiding hitting them. To perform a jump, the player has to pronounce a required phoneme. If the player is unable to provide a correct utterance, Roberto hits a rock and finally after 5 impacts falls down. The interactive objects are: small rockets representing rocket pieces, and rocks that have to be avoided by the player. The player actions are: to take rocket pieces by reaching them, jump over rocks, hit rocks if no correct utterance is provided on a given interval. The game was designed with a third person type of view, and the following game situations: Roberto on the surface of the moon, Roberto jumping over a rock, and Roberto reaching a rocket piece. The challenges involved in the game are the following: jump over rocks pronouncing a correct phoneme (limited resources) within a determined time interval (time limit) to earn points (reward), or hit rocks and fall (punishment); and if a rocket piece is reached earn a bigger amount of points (reward). As mechanics of the game, for each time Roberto jumps a rock, 10 points are added to the budget, if a rocket piece is reached, ten extra points are added. The time available for producing the phoneme is five seconds. On the development of this game, shown in Figure 7, also interface elements from the Froneme the Frog game were reused. There are also works on the definition of rules for defining different user interfaces as output [32] but those objectives are out of the aim of this paper.

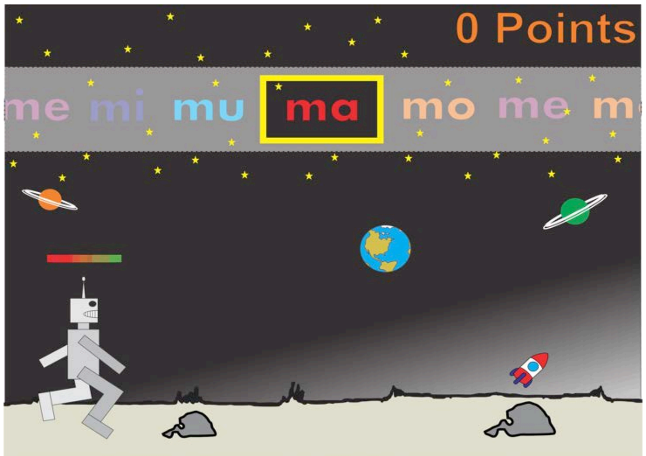

Figure 7. Screenshot of the serious game Roberto the robot.

It is important to note as another advantage of the here proposed metamodel that since the packages included on it keep a certain level of independence towards the serious games design extension, it is possible to use them, and to define new extensions in order to design and develop other types of software solutions for auditory rehabilitation (e.g., diagnosis, tracking, and advising systems). Likewise, by developing models for other domains than auditory rehabilitation such as educational and military, it may be possible to relate them to the extension here provided to enable the development of serious games for those ambits.

5. CONCLUSIONS AND FUTURE WORK

In this paper we proposed SEGA-ARM, a metamodel for the design of serious games to support auditory rehabilitation. The mentioned model consists of three packages, regarding the context of use, the theoretical part of the therapy, and the dynamic part of the therapy; and an extension for its implementation through serious games. As the description of every single package and class was provided, the actors on it involved (i.e., designer, development team, and speech therapist) were mentioned along with tasks to be performed by them, and a case study was in it instanced to allow a better understanding. Two prototypes of serious game to support a therapy activity were developed. In the near future the developed serious games are going to be evaluated by a speech therapist in order to determine if it is possible to include them at first as support tools for in-consulting-room therapy sessions, and then as a way to complement and extend the received therapy sessions with sessions conducted by the patient himself. Also, more extensions are going to be developed in order to verify the completeness of the metamodel for different scopes.

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Towards the Definition of a Framework for the Management of Interactive Collaborative Learning Applications for Preschoolers

Liliana Rodríguez-Vizzuett[1], Jorge Luis Pérez-Medina[2],
[1]Universidad Autónoma de Aguascalientes
Av. Universidad 940, Ags., Mexico
lilianarv90@gmail.com, {fjalvar, jmunozar}@correo.uaa.mx

Jaime Muñoz-Arteaga[1], Josefina Guerrero-García[3],
[2]Université catholique de Louvain
Place des Doyens 1
Louvain-la-Neuve, Belgium
jorge.perezmedina@uclouvain.be

Francisco J. Álvarez-Rodríguez[1]
[3]Benemérita Universidad Autónoma de Puebla
Av. 14 Sur y San Claudio, Puebla, Mexico
jguerrero@cs.buap.mx

ABSTRACT
The adoption of technologies in education has been changing the traditional teaching system considerably. New educational paradigms make use of technological tools to enhance the knowledge given in a classroom. In the literature review there aren't reports of Frameworks that are based on models and methods for developing Interactive Collaborative Learning Applications for Preschoolers (ICLAP). This paper proposes a meta-model for a Framework supporting the development of ICLAP taking into account the technology, the educational aspect and collaborative techniques that were observed during the attendance to sessions in schools. The ICLAP meta-model includes useful concepts for the use of Augmented Reality since we found that it emerges as a technology of interest in diverse areas and especially in education. Our contribution could be used for teachers, designers and developers as a conceptual guide. In addition, a study case is presented to illustrate the main concepts included in the meta-model.

Categories and Subject Descriptors
D.3.3 [**Programming Languages**]: Language Constructs and Features – frameworks; H.5.2 **[User Interfaces]:** Prototyping, User- centered design; K.3.1 **[Computer Uses in Education]**: Collaborative Learning

General Terms
Design, Human Factors, Collaboration.

Keywords
Collaborative Learning, Augmented Reality, Framework, Collaborative Application.

1. INTRODUCTION
The inclusion of technology in education should be considered only a tool to support since it is not to coming to replace the professor, but to help the student to have many auditory and visual elements to enrich the process at teaching–learning. An important factor to be considered is the help that Communication and Information Technologies (TIC) give because it provides the students with many kinds of tools to be used within in the classroom and for enhancing the way in which knowledge is acquired [1]. In traditional education, the teacher is responsible for student learning by defining learning objectives or content area learning tasks, and designing and making an assessment of what has been learned by the students. In the traditional model of learning, the concept of collaboration is included to allow individuals to enrich the experience of acquiring knowledge. In most countries, preschool education begins at the age of three years, but there are cases in which children between 2 and 6 years are enrolled into it. However, our proposal focuses on children aged between 4 and 6 years.

Preschool educational institutions of several countries established official documents which are provided to educators, with skills that must be met by the children, so that at the end of this stage students have begun a process of formal contact with the language writing, through the exploration of texts with different characteristics (e.g., books, newspapers and instructions) [2-6].

Augmented Reality (AR) can be used in many application domains. In recent years, a number of prototypes and applications have been created in areas such as Computer graphics, Human Computer Interaction (HCI), vision, and collaborative work including the following sectors: architecture, design, engineering and production planning, games, education and learning [7-9]. AR can be designed not only to support learning related disciplinary contents but also to provide other skills such as critical thinking, collaboration and information sharing [9]. Applications that make use of AR achieve to generate the basic principles of Collaborative Learning: (1) Positive Interdependence; (2) Promotion of Interaction; (3) Individual Accountability; (4) Interpersonal and Small Group Skills; and (5) Group Processing. Positive Interdependence ensures that team members perceive that they are linked with each other so that one cannot succeed unless everyone succeeds. In Promotion of Interaction the students promote each other's success by assisting, supporting, encouraging, and praising each other's efforts to learn. The Individual Accountability means that each individual student's performance is assessed and the results are given back to the group and the individual. The Interpersonal and Small Groups Skills suggests that the student is required to work as part of a team (teamwork), and finally for the Group Processing the team members discuss how well they are achieving their goals and maintaining effective working relationships.

Our proposal, for the specific case study that is here presented, makes use of Augmented Reality. The role of the AR is to facilitate interaction among preschoolers using QR codes. These codes are the markers that will be recognized by the application.

There are many interactive applications to support the learning of reading and writing, however, these do not report to use a methodology of development involving educational content, making the applications not only to entertain children but also to help them to obtain knowledge [10]. Moreover, the literature survey does not report models for Interactive Applications supporting Collaborative Learning in Children, despite the fact that there are collaborative applications, those do not report to be developed under a user-centered paradigm, besides, even though they count with collaborative characteristics, the absence of a model describing their design makes their components reutilization limited. In order to develop literacy skills in children and considering the benefits that TICs offer, in this paper a set of rules and constructs for the ellaboration of semantic models for ICLAPs is proposed, meaning by this, a meta-model for development ICLAP involving several actors (i.e., student, professor, software engineer, designer and programmer) within each development phase, this meta-model pursues the purpose of including a collaborative component that allows its reuse in any type of ICLAP, and is based on the available literature, the observation of the techniques used by preschool professors, as well as technological and educational aspects.

The rest of this paper is structured as follows: Section 2 introduces our approach by making an analysis of the literature related to the concepts of framework, collaborative learning, learning technologies, augmented reality, and a subsection with related work. Section 3 introduces an ICLAP Meta-model. The meta-model is later discussed using a case study in section 4. Finally, section 5 presents our conclusions and future work.

2. REVIEW

2.1 Framework

A framework provides an abstraction of a solution to different kinds of problems that have some similarities. It also provides the steps or phases that must be followed to implement a solution without getting into the details of what activities are done in each phase [11]. The using of a framework for developing ICLAP aims to generate a conceptual and technological support structure, in which other software development can make reuse of required components. For this purpose, firstly the construction of a meta-model that possesses basic elements such as collaborative learning, learning contents and the technology is required.

2.2 Collaborative Learning

A skill is defined as the ability to coordinate knowledge and know-how to respond to a given situation or to solve problems in everyday life [12]. The skills in preschool that children should develop are: (1) the ability to assume different roles, both in the game and in various activities, (2) rely on their peers to achieve goals, (3) resolve conflicts through dialogue, and (4) respect and recognize the rules of coexistence in the classroom, school and beyond [2][13][14]. Within the strategies that have to favor the learning, collaborative learning is the most important activity that takes place in small groups mainly in a classroom in order to share different viewpoints to form a more complete knowledge [15]. The collaborative learning supported by technology consists on that two or more persons share the responsibility of building knowledge, based on the interaction and decision making using the technological resources as mediators for this process. The collaborative learning process consists of several tasks that must be performed by a facilitator or teacher and students, also, has as key elements, the cooperation between group members, active learning, positive interdependence, responsibility, coordination and communication [16]. Collaborative learning has as goals to promote the interaction among students, valuing the individual contribution of each student that assumes tasks and responsibilities, development of group and personal skills such as listening, participating, coordinating activities and leading. For last the self-assessment is promoted since the students need to continuously know from their performance and their equipment. To carry out collaborative learning, four important components are needed: students, the professor or facilitator, technological resources, and the environment for the collaboration. In collaborative learning there are different roles to carry out a task, however, each member of team is responsible for a task and when all the team members finish their activities, they present to the rest of the team what they did, so it is important that there is good communication between all team members to do a better work. Collaborative activities enhance learning by allowing individuals to exercise, verify, solidify, and improve their mental models through discussions and information sharing during the problem-solving process [17]. Collaborative learning helps to generate a common language, by establishing rules for the group functioning and in order to reduce the fear of criticism and to promote feedback. By taking advantage of the knowledge and experience of the team, according to their area of expertise and different viewpoints, the quality of the decisions and of the obtained products is improved.

2.3 Learning Technologies

Technology is a tool that can change the nature of learning [19]. The multimedia resources have the potential to create high quality learning environments because they provide to the students a better way to learn. In the literature, some authors say that for any design to be successful, it must be based on the needs and interests of users as this ensures that it will fulfill the functions for which it was elaborated [20]. In a classroom supported by technology, students don't "learn" technology because it only provides the tools to be used for authentic learning, so the technology is a mean, not an end. It is well known how difficult it is to engage children in learning, however, it has been reported that children enjoy the process when their tutor uses a touch screen and other devices in order to make classes more interactive and interesting [21]. This leads to the assumption that by involving technology, it's easier to attract the kid's attention and to make the educational process more enjoyable for both, the tutor and the pupils. As classroom computer technology is being used for different types of communication i.e. for presentation, for class interaction, and for collaboration, students are required to assume different roles and must be willing to collaborate with others. Another advantage of using technology in the classroom is its flexibility and adaptability to different type of learning [22]. A collaborative application is a software application that allows multiple users interaction to achieve a common goal, receives input from multiple users and displays outputs to multiple users. Also couple those users, ie, allows the entrance of one of them to influence the output shown to the other [23].

2.4 Augmented Reality

Augmented Reality (AR) is a paradigm of interaction that stems from the desire to merge the processing capabilities of a computer in the user's real environment. The goal of this technology is overcoming the boundary between the real world, including the user, his/her environment and the computing world. A key feature of AR systems is that real-world elements are involved in the interaction. The existence of real and virtual worlds implies that the purpose of the task may match to one of the two. The term Mixed Reality corresponds to the interval between the real and the virtual. Likewise, Dubois [7] proposes a taxonomy based on the objective of where the crucial point in their approach was identifying the task supported by the system to be analyzed and designed. The taxonomy considers two continuous: (1) Augmented Reality and (2) Virtual Reality (VR). In AR systems the user's interaction with the physical world is enriched by the aggregation of data and services offered by the numerical world (computer), in the natural environment of the user. Comercial applications such as Dokéo+ (http://www.dokeo-realiteaugmentee.com/), and L'Aphablet (http://www.clementoni.com/) make use of AR and help to reinforce learning in children, however, they do not report being designed to support collaborative learning. Dokéo+ allows children to learn different topics (science, animals, history, mathematics), but does not allow the interaction of more than one user at a time. L'Alphabet enables learning letters as well as objects which names contain them. This tool uses audio and animation resources, and has a bilingual mode, however, it doesn't report either to enable collaboration among children. It is important to point out that both applications use AR markers. Figure 1 allows distinguishing the two streams corresponding to the both extremes of a continuum between real and virtual worlds.

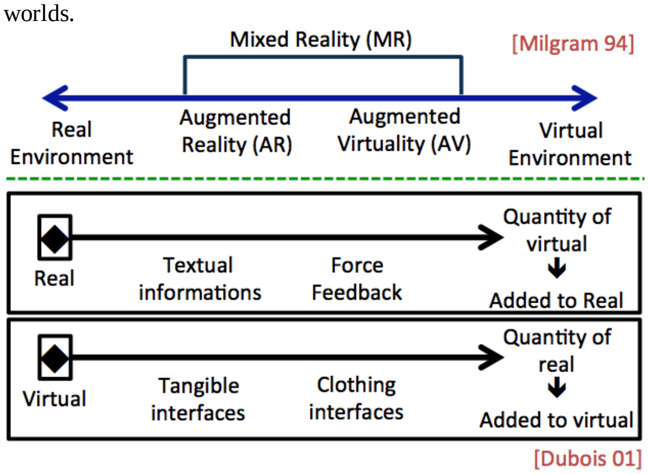

Figure 1. Classification of Mixed Systems [7][24]

2.5 Related Work

In [25] the theory of the activity is defined as a strategy for the development of collaborative learning systems in which takes into account the activity, goal, result, community, rules, works' division and tools. Likewise, the modeling methodology AMENITIES [26] define four views for cooperative systems. They're: group view (groups, roles and actors), cognitive view (tasks, sub-activities and actions), interaction view (protocols, devices, media) and information view (resources, documents, messages). Penichet [27] highlights the importance of user interaction with collaborative systems, and makes a proposal to collaborative environments from obtaining requirements to final system maintenance, through the phases of analysis, design, implementation, and evaluation. Finally [28] makes a literature review which mentions that it is important to consider the user interaction with the system to be developed, with special emphasis on user interfaces, without leaving aside the user model (apprentice and facilitator), the content model which mentions that the contents are characterized as learning objects, the communication model where the process is defined by which is conducted the interaction between users and fosters collaboration and finally the assessment model which takes into account the evaluation of service quality. The points that are evaluated are: number of subscriptions that are the recognized users by the application, the number of connections of each subscription, the statistics of users who sent a message, the response time of the facilitator to respond a message sent by an apprentice user, the evaluation of the contributions made on collaboration and lastly the relevance of the message to both the learner and facilitator.

3. AN INTERACTIVE COLLABORATIVE LEARNING APPLICATIONS FOR PRESCHOOLERS META-MODEL

This section shows the meta-model for ICLAP. The purpose of this meta-model is to present a conceptual guide that allows the development of ICLAP considering collaborative techniques that were observed while attending sessions in schools in Mexico. The ICLAP meta-model follows a User-Centered approach. The authors have had the opportunity of proposing activities for the children, carry them out and thus obtain the definition of collaborative strategies that are used by teachers to accomplish the acquisition of collaboration skills.

3.1 General Description

The main concepts of the ICLAP meta-model are presented on Figure 2 that is divided into six packages. The first one refers the *Evaluation* package of the whole application and its usage. The second package concerns the *Technology* and is formed by *Interface* and *GameElement*. The third is for description of *Collaborative Learning,* conformed by the class *InteractiveCollaborativeLearning* and by the one referent to *InteractiveCollaborativeApplication*. The fourth package concerning the *LearningContent* and formed by *LearningContent* and *LearningStyle*, the fifth package concerning the *Context* model formed by the *User*, the *Platform* and the *Environment*. Finally, the *Interaction Resources* package consisting of the elements that will be used to develop an application.

3.2 The Evaluation Package

An important part to be considered, is the evaluation of interactive applications concerning usability, skills and collaborative learning using instruments and also using quality metrics [2] [29-33]. The *evaluation* is the measurement of knowledge, skills and performance of students when using a collaborative interactive application. It uses *instrument* that are documents which purpose is to justify that interactive collaborative applications working for learning and collaboration. An *Instrument* class is composed of an *IntegratedMeasure* element that compute the *Measure* of each *Metric*. Each *instrument* has one or several *sections* that relates to the topic to be evaluated (usability, learning skills, collaborative skills, perception of technology, collaborative work, and quality assessment). In turn, the *section* has a *name* and one *order*. Moreover the *dimension* refers to each of the characteristics to be evaluated in each instrument (e.g., Easy to remember, language and communication, cordination). The dimension is composed of a *description* and *order*.

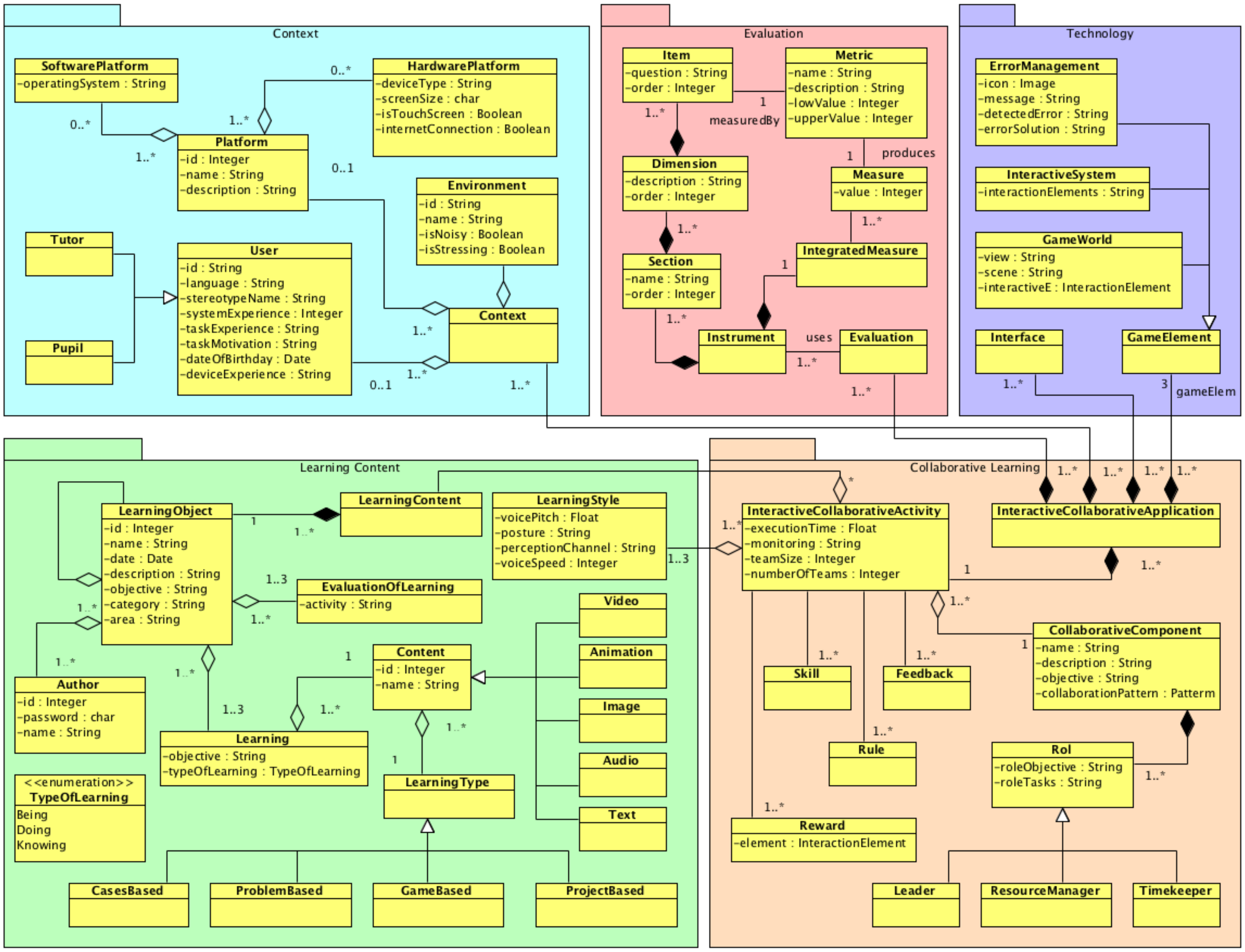

Figure 2. An Interactive Collaborative Learning Applications Meta-Model

Every dimension must carry at least one *item*; the attributes of an *item* are the *question* to be answered, and the *order* representing the value that was given to it. *A Metric* is a mean to understand, monitoring, controlling, predicting and testing the software development and maintenance projects [34]. *Metrics* has a set of attributes: *name*, *description*, and also a *lowValue* and *upperValue* that are the measured values for each metric. *Metrics* produce *measures* that throw values that are the results for each instrument.

3.3 The Technology Package

For the part of the model concerning the *Interface*, the model provided by [35] is taken. Its definition is achieved by using the theoretical framework CAMELEON [36] that comprises four levels of abstraction: (1) Tasks & Concepts: description of the users' activities. (2) Abstract User Interfaces (AUI): Definition of abstract containers and individual interaction components. (3) Concrete User Interfaces (CUI): Definition of the interaction modality and usage of concrete interaction objects. (4) Final User Interfaces (FUI): Operational elements, this is, the implemented UI for a determined platform. Elements for the design of videogames according to [37] are considered. Those elements being: *ErrorManagement*, for the presentation of errors to the *User*, including an *icon*, a *message*, a trigger called *detectedError*, and the *errorSolution*; *GameWorld*, considering the *scene* in which the game takes place, the *view* (e.g. first person, third person, isometric and cabin view), and the *interactiveElements,* which are those elements that the *User* may use to interact with the system (e.g., images, audio and animations); and *InteractiveSystem*, to describe the modality of interaction. Table 1 shows an OCL Rule defined to ensure that instances of *InteractiveCollaborativeApplication* class have three different elements of type GameElements at the same time

Table 1. OCL rule for InteractiveCollaborationApplication instances

```
context InteractiveCollaborativeApplication inv:
    self.gameElem->select(oclIsTypeOf(GameWorld))->size()=1 and
    self.gameElem->select(oclIsTypeOf(InteractiveSystem))->size()=1 and
    self.gameElem->select(oclIsTypeOf(ErrorManagement))->size()=1
```

3.4 The Collaborative Learning Package

For the part of the model concerning the *CollaborativeLearning*, an *InteractiveCollaborativeActivity* [38] is an activity that involves the *Feedback* between two entities (viz. tutor-pupil and pupil-pupil) [39], and a series of attributes: *rules* to follow during the activity, *collaborativeSkills*, *rewards* as incentives for the *User (e.g., badges and levels)*, *executionTime* in seconds, *monitoring* performed by the *Tutor*, *teamSize* that is the number of members in each group between 2 and 6 [40], and the *numberOfTeams* participating on the collaborative activity. The *collaborativeSkills* are those to be achieved during the collaborative learning process, and are determined by a set of strategies to allow the development of mixed skills (concerning learning and personal/social development), in which every team member is responsible for both, his/her and the other members' learning. The *InteractiveCollaborativeActivity* is related to a *CollaborativeComponent*. The *CollaborativeComponent* has as attributes a *name*, a *description*, an *objective* and a *collaborativePattern*. Papageorgiu [41] defined a collaboration pattern as a means to capture best practices about recurring collaborative problems and solutions. As part of this component, there are *Roles* defined for each team member. For the *Roles* definition, it is necessary to specify a *roleObjective* and *roleTasks* that are the purpose of the role and the actions to be performed by each one. For their relevance to this work, the Roles that are considered are: Resource Manager, Time Keeper, and Leader. The Leader is in charge of asking the teacher for assistance whenever it is needed. This role also must be able to organize other team members in order to properly carry out the activity. The Resource Manager is supposed to ensure that the given application is used in a proper manner, and finally the Time Keeper must notify each member of the group about the available time for successfully performing the assignment [42].

3.5 The Learning Content Package

The *LearningContent* is the information referent to a subject of study and is formed by a *LearningObject* [43] that is a basic reusable structure that contains detailed information about certain topics and allows the relation to other similar objects. A *LearningObject* has as attributes an *id*, a *name*, a *date* of creation, a *description*, and an *objective*. And it's contained into a *category (e.g., Reading and Writing)*, subset of subjects that are related to an *area (e.g., Language)*. The *LearningObject* contains in turn, *Content*, which is the information to be presented and has as attributes an *id*, a *name*, and an associated *LearningType* (e.g. *casesBased*, *problemBased*, *projectBased* and *gameBased*). *Content* may be presented in several formats such as videos, texts, images, audios and animations. Related to the *LearningObject*, there are the *Author* class that represents its creator, the *EvaluationOfLearning* and the *Learnings* class that conform it. *Learnings* [44] are that knowledge acquired during the education process and are specified as learn to be (*Being*), referring to the skills developed to be practiced on the daily life; learn to do (Doing), that is the integration of knowledge to be useful on the professional life; and learn to know (*Knowing*), meaning not only the acquisition of theoretical knowledge, but comprehension, and discovery of the environment.

Table 2. The Structure of Learning Content

Name		
Description		
Objective		
Learn to know	Learn to be	Learn to do
Evaluation of learn to know	Evaluation of learn to be	Evaluation of learn to do
Learning Type		
Learning Style		

The *LearningStyle* describes the way in which *Users* learn as well as the actions to be performed in order to promote a more effective learning(e.g., Felder and Silverman models, Neuro linguistic programming, Kolb model, and Multiple Intelligences model). However, due to the generality of the model proposed, more styles can be adapted to this class. The attributes that are considered for the definition of the *LearningStyle* are the *voicePitch*, the *posture* of the *User* while conducting activities, the preferred *perceptionChannel* for the *User* to get knowledge (e.g. images, audio and physical activities), and *voiceSpeed*.

Stakeholders may invoke Table 2 to elaborate the Learning Contents. The table is formed based on the elements of the package. The elements are: *Name*, *Description* of the learning content, *Objective, Learnings, EvaluationOfLearning, LearningType and finally the LearningStyle*.

3.6 The Context Package

The *Context* [45] represents the conditions in which interaction is carried out and is formed by the *User,* this class contains as attributes an *id*, that is a key for the identification of each *User*; the preferred *language* for communication; a *stereotypeName*, the role assigned for an activity (viz. Tutor or pupil); the *systemExperience*, representing how experienced is the *User* on the usage of interactive applications; the *taskExperience*, containing the explanation of how familiar the activity is o the *User*; the *taskMotivation*, motivation or stimuli that cause interest on the *User* for completing the task in a correct manner; the *deviceExperience*, the experience of the *User* on the usage of electronic devices such as tablets, smartphones, computers and consoles; and the *age* of the *User*.

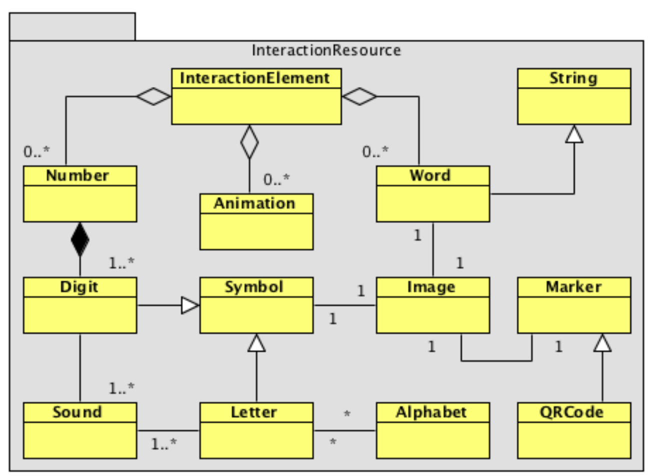

Figure 3. The Interaction Resource package

The *User* can be either a *Tutor* (professor, parent or supervisor) or a *Pupil* (student or trainee). The *Platform* entity represents a series of elements that allows the execution of interactive applications. The attributes are *id*, *name* and *description* and is composed by *softwarePlatform* and *hardwarePlatform*. The only attribute for the *softwarePlatform* is the *operatingSystem*, while for the description of the *hardwarePlatform*, it is necessary to specify a *deviceType* (e.g. tablet, smartphone and computer), the *screenSize* in inches, the availability of a touch screen on it (*isTouchScreen*) and the availability of an *internetConnection*. The *Environment* class describes properties of interest about the place in which the users perform a collaborative activity. Their attributes are an *id*, a *name*, the statement of whether the place is noisy or not (*isNoisy*), and the statement of whether the place is stressing or not (*isStressing*), this means, if there are or not characteristics that propitiate a change on the *Users'* behavior during the activity. The definition and consideration of the last two attributes of this class is important since they may help to determine characteristics that directly impact on the learning process.

3.7 The Interaction Resources Package

The interaction resources package presented in Figure 3 considers all interaction elements. Its elements are important within any application that is implemented because they are the basis with which the user interacts. These elements may be images, audio, numbers, words or letters regardless of the amount used of these. AR applications should require markers associated to these resources. For example, QR codes as those shown in Figure 4. Moreover in Figure 4, we show the interaction resources that can be used in any type of interactive application.

Figure 4. The interaction resources

4. CASE STUDY A COLLABORATIVE LEARNING ALPHABET APPLICATION

In this section we consider a demonstrative case study. The aim is to carry out benefits of the proposed meta-model. In this case study the following packages are being instanced: Learning Content, Collaborative Learning and Technology since they are most important for the design phase. In order to take decisions for the development phase, the Context package should be considered and on the evaluation stage, the Evaluation package has to be taken into account. The case study consists of a set of sequential tasks accomplished for children in order to indicate the letters of the word that is presented by the application. The interaction scenario is defined in a task tree model depicted by Figure 5.

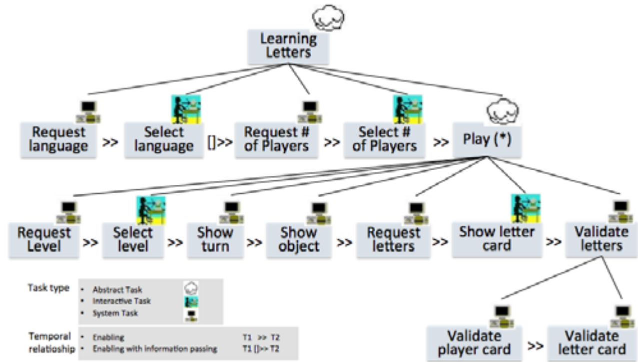

Figure 5. The Task tree model of the case study application

The task model shows the activities that must be carried out in the application. The application is aimed at learning the letters and objects that children see in their daily lives and must do so collaboratively. The first task that user need to do is select the language in which they will play, for this, the users have French and Spanish as options. Next, the user must select the number of players, the application allows to play for 2-5 players, followed by this, the user must choose the difficulty level, these levels are: easy, medium and hard. After this selection the game begins. To play, each child will have a pack of cards with QR codes and must be sequentially showing to webcam the letters to complete the name of the object that appears on the screen. The game consists on presenting pictures (animals, household items, food, human body, etc.) and boxes where users must place the letters of their names. For the first level of difficulty the application will show the boxes with the letters in watermark to point out where the user should place each one. For the second level, the system only will show the first letter of the word and the users should be able to complete it, and finally at the third level there will be only boxes, without any aid, in which users should be able to complete the word. Figure 6 presents screenshots for each level of difficulty. When the letter shown by the user is correct the application will fill the corresponding box with it and also, the application will present an animation with balloons, a trophy and audio. When a user makes a mistake, the application shows an image to the user asking him to try again.

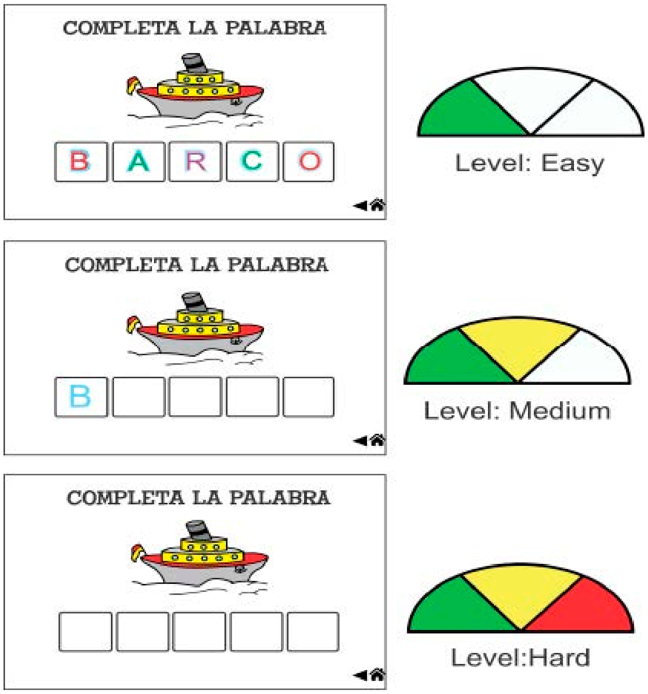

Figure 6. The levels of difficulty on the developed application

Collaborative skills to be achieved in children using this interactive application are: (1) Show facility to interacting with others; (2) Accept to perform different roles and assume their responsibility with the team; (3) Respect the turns when carrying out an activity; and (4) Respect their peers. To achieve these collaborative skills, it is required to have a collaborative strategy. One is the use of turns. A turn consists of assigning a task to a particular child. The collaborative component implemented in this application will be the Turn Assignation pattern as shown in Figure 7.

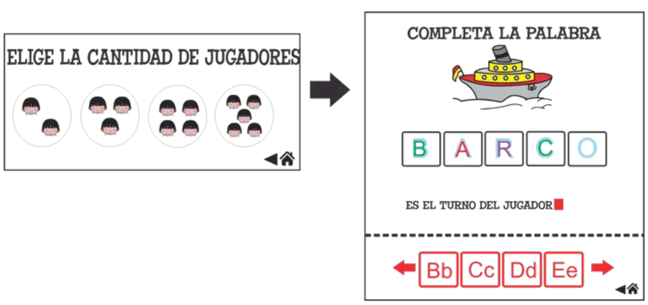

Figure 7. Collaboration Pattern in Spanish

The objective of this pattern is to allow each team member to fulfill a role and carry out assigned activities. The pattern begins with an activity to do, then the number of participants who will perform the activity should be select, later it is possible make a turn assignation in a sequential or random manner as requested by the teacher. To ensure the participation of all team members in our interactive application turn assignation must be performed sequentially. We must also ensure that all children participate. This will be done as follows: Each child will be given a pack of letters with QR codes as those shown in Figure 8; each package will have different colors to allow children to identify those that correspond to each one. To identify each child within the system, distinct markers must be used.

Figure 8. Cards with QR codes given to each child

The application displays the word to be completed and among all children should complete the word based on each turn generated by the application. When the letters are insufficient for every child to participate, turn assignation in the next word should start with those who did not. Table 3 shows the design of Learning Content required by the interactive application. The table is constructed by the professor based on skills for learning and collaboration that he/she wants to develop in children by using the application. Once this table is constructed, with help of a designer, prototypes of interfaces are created and the type of elements to be used for displaying learning content is defined. The most important elements that the developer is supposed to know in order to implement the interactive application are: a name, a description, an objective, the learnings and their associated evaluations, as well as a learning type and a learning style.

Table 3. The Learning Content for "Learning the letters"

Learning the letters		
Use the knowledge that they have of their names and other words to write something they want to express		
Recognizes characteristics of the writing system use resources (marks, graphs, letters) to express in writing their ideas		
The letters and its representation are shown to the student. Also, their utility in daily life is explained	Show some images with daily objects that contain letters	The words in watermark are shown to the students and they are required to put letters in place
Students should recognize letters and their order in the alphabet	Questions are asked about the letters in objects' names. Students are asked to complete those words to check if they correctly identify them	The words without watermark are shown to the students and they are required to put letters in place
Based on Games		
Visual, Auditive and Kinesthetic		

5. CONCLUSIONS AND FUTURE WORK

This paper presents a meta-model for ICLAP to support the education process. It will serve as base to our framework and permits a conceptual guide for teachers, designers and developers for the implementation of this type of applications. The proposed model considers technological and educational aspects, as well as collaborative techniques that were observed during the attendence to sessions in schools in Mexico through the performance of activities that teachers carried out with children using collaborative strategies for teaching letters and their use on daily life. One of the advantages that the meta-model provides is the capability of its packages to be reused in other type of collaborative applications, another advantage is that it can be used in other areas where there is collaborative work. The Technology Package allows to add other game design elements according to the requirements of the application to be developed. The learning content package allows adaptation to learning styles and types as required. The proposed meta-model presents concepts that can be easily understood by the different actors involved the development process of interactive collaborative learning applications i.e., professor, software engineer, designer, programmer and tester. Actually, the presented case study is in development phase and once a first prototype is produced, we will be able to easily evaluate the interest and the feasibility of our approach by conducing user experiments supported by the instruments that were mentioned as part of the evaluation package. Besides, in parallel a methodology is being designed in order to guide the development process, by establishing different actors and the tasks that each one must fulfill for producing collaborative interactive applications, taking into account all concepts of ICLAP meta-model. As well, we will perform different case studies with children.

6. ACKNOWLEDGMENTS

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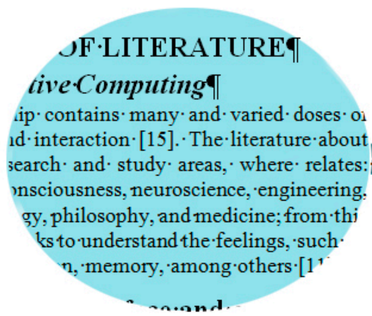
DOCTORAL COLLOQUIUM



Intelligent Playful Environments for Animals

Patricia Pons, Javier Jaen, Alejandro Catala
Grupo ISSI, Departamento de Sistemas Informáticos y Computación
Universitat Politècnica de València
Camí de Vera s/n, 46022 Valencia (Spain)
ppons@dsic.upv.es, fjaen@upv.es, acatala@dsic.upv.es

ABSTRACT
We are evolving towards an interconnected and ubiquitous world, where digital devices and interfaces progressively adapt themselves to fit our needs and ease our daily activities. Although we coexist with plenty of animal species, such as our pets, we are approaching the evolution of technology in a strictly human-centric manner. A new field in Computer Science, called Animal-Computer Interaction (ACI), aims at filling this technological gap by developing systems and interfaces specifically designed for animals. Supporting animals' natural behavior and habits with suitable technology could improve both humans and animals' wellbeing. As a consequence, this doctoral research aims to explore, design and develop animal-centered intelligent systems that focus on enhancing one of the most natural animal behaviors: play. Therefore, the main goal of this research is to expand ACI with the ability of automatically manage and adapt animals play activity in order to improve their wellbeing.

Categories and Subject Descriptors
H.5.3 [**Information Interfaces and Presentation**]: User interfaces – *interaction styles, user-centered design, input devices and strategies.*

General Terms
Design, Experimentation.

Keywords
Animal Computer Interaction; Playful Interaction; Intelligent Environment; Animals; Interfaces.

1. INTRODUCTION
Human Computer Interaction (HCI) has brought countless benefits to human wellbeing. By easing the interaction with computer systems, technology has become more user-friendly and it is being applied to our everyday activities in a seamless manner. However, other species are not taking advantage of all these progresses. Due to different physical features or mental perceptions of the world, animals are not able to understand our technology as we do. Therefore, a new research field called Animal Computer Interaction (ACI) [3,4] has emerged. It focuses on providing animals with similar technological improvements to the ones humans already have. ACI considers animals as the target users of digital systems, and proposes the development of interfaces specifically designed for them. The doctoral research presented in this paper proposes expanding ACI with the ability of automatically managing and adapting animals play activity in order to improve their wellbeing, focusing on animal pets and specifically in cats and dogs.

2. RELATED WORKS
There have been several research studies involving animals which use technology as a bridge to communicate or interact with them. The *LANA Project* [9], the *Ai Project* [5] or the *SpeakDolphin* [12] initiative are studies where the animals interact with specialized keyboards and/or touch screens to communicate with the trainers. Technology has also been used to improve critical tasks of some animals: ACI principles have been applied to develop suitable dog-oriented interfaces for Diabetes Alert Dogs (DAD), allowing them to alert emergency services when their owners suffer a hypoglycemic attack [8].

In recent years, several studies have focused on enhancing animal play using technology for different purposes. *LonelyDog@Home* [1] proposes a web interface where the human can connect to a web camera located at her home and check how their pets are, feed them or play with them remotely. *Canine Amusement and Training* [11] is a training system where, using a projector and cameras, the training activity becomes a playful experience. *Felino* [10] is a tablet-based game where a human and a cat can play together capturing different creatures on the screen. The human controls several aspects of the game, adapting it to the cat's reactions and preferences.

Although there are already games for animals which make use of technology to improve their experience, these games have some limitations which will be outlined in the next section.

3. INTELLIGENT PLAYFUL ENVIRONMENTS FOR ANIMALS
3.1 Motivation
The focus of this research activity on animal play is motivated by two reasons. On the one hand, play is one of the most natural behaviors among all animal species. Animals do not need to be taught on how to play [2], as it stands as a natural and voluntary activity, which has also its repercussion in elder stages of their lives. As an example, felines' play is always based on hunting or chasing behaviors, as in the wild, these animals traditionally used to hunt for food. On the other hand, verbal or written communication is unfeasible when considering animals as target users, and thus, other methods should emerge in order to determine the perceived usability and usefulness of the system. Therefore, playful interactions could be an effective way of communicating with animals and gathering information about the usefulness of a system. As summarized in Section 2, animal play has already started to be the object of a digital revolution. However, existing digital games for animals are focused on a single activity or purpose and only use one digital device. Moreover, they require human mediation for the animal to play and with time the animal might lose interest when it gets used to play the same game.

The main contribution of this doctoral research is two-fold. Firstly, we will consider digital games for animals as playful environments composed of several interconnected digital devices. Those devices have to be appealing and suitable for the animal and for the purpose of the game. Secondly, a playful environment of this characteristics will be an intelligent system which should intelligently make use of its composing devices in order to create suitable playful activities for different purposes. The intelligent environment should gather reliable information about the animal, its preferences, physical features and its surrounding context. With this knowledge, the intelligent environment should create an engaging playful activity for a specific situation, deciding which devices and interaction mechanisms would be more suitable for the given context. There are plenty of scenarios where intelligent playful environments could help to improve animals' wellbeing, e.g., create playful activities to alleviate the stress and anxiety of animals alone at home, zoos or shelters. It could also encourage these animals to perform physical exercise by means of play. The system should adapt the game to the animal's attributes such as species, weight or age - old animals should not perform as much physical exercise as young ones. An intelligent playful environment could also assist in animal training, making the activity more amusing and less repetitive, and without requiring human supervision. The environment could chose the optimal time of the day to perform training, i.e., when the animal's attention and motivation seems to be higher.

3.2 Definition

As part of the planning stage of the research, we have already defined the scope of the systems being developed [6,7]:

An intelligent playful environment for animals, or IPE4A, is an animal-centered ecosystem with intelligent capabilities which is able to learn from the animals' behaviors and interactions, using the acquired knowledge to adapt itself to the context, creating engaging playful activities which do not necessarily need human mediation to evolve.

We have also outlined the different features and dimensions of intelligent playful environments which can affect the design and development of these systems [6,7]: number of participants, species of the participants, human participation, human presence, control, information acquisition, learning inputs, types of stimuli, purpose of the activity.

3.3 Research questions

This thesis will give answer to several fundamental questions on how to provide successful interactions and communication between the animal and the intelligent system. Some of these research questions are:

- Q1: Which are the most appropriate interactive mechanisms for the animal, e.g. a cat or a dog?
- Q2: How can the system gather information unobtrusively about the animals' preferences, actions and context?
- Q3: How can the system use all these information in order to adapt the playful activity to the context and the animals' preferences and wills?
- Q4: How can we objectively measure the success of the system?

4. CONCLUSIONS AND FUTURE WORK

This thesis proposes the definition, design and development of intelligent playful environments for animals, focusing on pet animals. These systems aim to automatically create and adapt playful digital experiences for animals, improving their wellbeing and providing a better understanding of their interactions with digital systems. We have already defined these environments, their features and potential [6,7]. Our immediate future work will be conducting a set of experiments in order to answer question Q1 in Section 3.3. For this purpose, we will study how different devices and stimuli affect the attention and motivation of the animal for starting a playful activity. Based on the results of these experiments, we will design suitable activities in order to conduct future studies to answer the remaining research questions.

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Multi-Display Environments to Foster Emotional Intelligence in Hospitalized Children

Fernando Garcia-Sanjuan
fegarcia@dsic.upv.es

Javier Jaen
fjaen@upv.es

Alejandro Catala
acatala@dsic.upv.es

DSIC/ISSI, Universitat Politècnica de València
Camí de Vera, S/N, 46022 Valencia (Spain)

ABSTRACT
Long-term and frequent hospitalized children are under high loads of emotional stress, which affects their well-being in addition to the illness they are suffering. This thesis proposes and will focus on an approach to use Multi-Display Environments (MDE) in pediatric hospitalization contexts to improve patients' emotional intelligence so they can deal with the negative emotions produced by their situation.

Categories and Subject Descriptors
H.5.2, H.5.3 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces – *Input devices and strategies, interaction styles*. Group and Organization Interfaces – *Computer-supported cooperative work*.

K.3.1 [**Computers and Education**]: Computer Users in Education – *Collaborative learning, Computer-assisted instruction (CAI).*

General Terms
Design, Experimentation, Human Factors, Standardization

Keywords
Multi-Display Environments (MDE), Hospitalization, Emotional Intelligence, Child-Computer Interaction, Socialization

1. INTRODUCTION
According to hospital morbidity statistics from INE for 2013, the number of pediatric hospital stays in 2012 in Spain amounted to 1,813,009. Besides the fears associated to their illness, frequent and long periods of hospitalization provoke on children high loads of emotional stress and insecurity for being away from their home and their comfort zone with parents and friends. To tackle these problems, there are previous studies that demonstrate that play activities allow children to face the anxiety, conflicts, and fear caused by hospital experiences [4]. However, the application of new technologies in the context of hospital schools has been limited mostly to scenarios of individual use in which emotional stress is addressed in a simplistic way by using technologies to enable communication channels between children and their homes or external schools. However, we not only aim at deviating the children's attention from the clinical processes they are subject to, but also at facilitating the emotions that help them accept their new medical situation and adapt their mental state to face the issues that could arise by means of collaborative game activities.

Since emotional intelligence is mainly of social nature, traditional desktop computers are not the best option to support its training because these devices are mostly designed for individual use. On the other hand, digital tabletops have been shown to be very suitable tools for use in collaborative environments (e.g., [3]). Their multi-touch capabilities allow simultaneous interaction, which contributes to a more democratized participation [9] and a better workspace awareness, since face-to-face settings allow users to know what the others are doing.

Despite research showing these advantages, it is rare to see tabletops embedded in real settings. This is due to a number of disadvantages: their high cost; their limited workspace dimensions, which can only accommodate a certain number of participants; and the fact that their form factor complicates mobility. Therefore, this work will address the development of a collaborative play environment based on multiple interactive surfaces to support the learning of emotional intelligence in pediatric hospitalization contexts aimed at reducing the negative emotional impact caused by long-term or frequent hospital stays.

2. RELATED WORK
2.1 Emotional Intelligence and Tabletops
Several previous works have considered technology as a way of acquiring emotional intelligence abilities. Morris et al. [6], for example, involve several users collectively around big interactive surfaces in an emotional identification task, through the tagging of different images according to the emotions they cause. During the course of the activity, the researchers observe the users speaking with one another about their feelings towards the images, and, before tagging an image, they self-reflect and ask themselves questions like: "Am I happy?", "Am I sad?" According to the authors, their explorations show people's desire of having technologies that allow the complex expression of emotions through a game experience. However, most of previous works in this area target adults or adolescents, and the activities performed aim mainly at identification of emotions, whereas the practical use of those emotions to solve problems has not yet been fully explored.

Others target children with autistic spectrum disorders (ASD) to increase socialization through technology. As an example, Gal et al. [1] make use of an interactive tabletop to perform storytelling activities to foster collaboration among kids with ASD. They observe an increment of the number of approaches between the children, a higher load of positive affect as well as a higher tendency to express emotions. These type of works, however, are not aimed at making these children reason about their emotions in a way they can overcome an unfavorable personal situation and they rely on interactive tabletops, which may be complex to implant in real hospital environments, as stated previously.

2.2 Multi-Display Environments (MDE)
MDE have been object of much previous research. Traditionally, their main purpose was enlarging the visualization space via the physical union of several smaller screens (e.g. [8]), and the interaction played a more secondary role, therefore leading to mono-user environments with difficulties to favor collaboration, which is fundamental in emotional learning. Besides, the configurations tended to be static (i.e., the number of screens was

fixed a priori), and to not allow the mobility of the participants. The posterior popularization of mobile devices, such as phones and PDAs, introduced a higher degree of mobility and multiuser (parallel) interaction since each user could interact with their own device, which they carried with them. Mandryk et al. [5] study the impressions of teenagers when using PDAs in a collaborative game. Because of the reduced dimensions of these devices, the researchers encouraged them to enlarge the visualization space by joining the screens. The participants, however, reported low sense of liberty of movements because they had to maintain the devices together during the course of the activity. Therefore, the mobility was achieved in detriment of the visualization space. This problematic is due to the fact that the approaches commented so far rely basically on joining smaller screens to form a bigger one (and, therefore, rectangular). In this respect, some existing works have proposed alternatives. For instance, Pinch [7] is a technique to couple smartphones and tablets via a manual gesture, and it supports free-form topologies and dynamic modification of the device group to the extent of not needing the displays to be physically joint once coupled. A limitation of this work, however, is that the resulting topology is still flat and the only interaction technique supported is touch. As this analysis suggests, previous research on MDE has mainly focused on technical aspects, and their capabilities have not yet been proven in real settings but rather in experimental contexts in order to show the performance of a given approach. This implicates that, in their design, the ultimate activity to be performed by the users with these MDE has not been considered deeply enough. In our context, the software system and underlying interaction techniques will be considered effective not only if the children are able to perform quickly the manipulations and they understand how to make them, but also if the system supports effectively the construction of experiences that develop emotional intelligence through games.

3. RESEARCH OBJECTIVES

From previous works' limitations, we have identified several technical dimensions that will be addressed in our work in order to successfully build collaborative MDE for children in hospitalized environments. These are classified into dimensions regarding the construction of the environment and interaction requirements.

With respect to the former, our approach will allow several displays to form a common environment of any topology, not necessarily the traditional rectangular one, and possibly discontinuous to remove the need for the devices to be physically joint. This way, the users will be able to choose more freely their location. The number of devices will be unbounded, and their annexation to one another will be done in a transparent way in order to avoid complex registration methods. Concretely, our approach to address these requirements will rely on using the built-in camera of tablets and smartphones to track their own position with respect to a wallpaper situated on the ceiling using computer vision algorithms, allowing the system to build a logical map of all the tablets in the group. Since the only requirement is having the wallpaper/marker partially in sight, this approach can also allow some 3D topologies by simply placing the displays in different planes.

Regarding the interactions that our MDE will allow, the most basic one, in order to benefit from the advantages of tabletops in terms of collaboration, is to consider all displays as part of a whole, public surface, and therefore to permit many users interact with the same display at the same time, and also a given user to interact with many devices at once. In order to achieve more dynamic scenarios users will be able to modify the resulting surface by moving the displays through the environment during the course of the collaboration. And, in order to obtain richer ways of interaction, our proposal will support interacting with alternative media such as tangibles, which can result more intuitive for children as they can grab and manipulate actual physical objects. Moreover, it will also accept aerial interactions using gestures with fingers or dedicated objects with the purpose of avoiding interference with another user's actions.

In sum, our goal is to design activities to foster emotional intelligence in hospitalized children. Since this type of intelligence is mainly social, we propose to build collaborative environments using several affordable surfaces such as tablets and smartphones. The dimensions identified previously will then be explored beyond their technical aspects regarding how they impact collaboration among the children and how they foster emotional intelligence that might help them overcome the stressful situations they experience during their hospitalization.

4. ACKNOWLEDGEMENTS

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KINDERTIVITY: Using Interactive Surfaces to Foster Creativity in Pre-kindergarten Children

Vicente Nacher, Javier Jaen
ISSI Group, Dpto. Sistemas Informáticos y Computación, Universitat Politècnica de València.
{vnacher, fjaen}@dsic.upv.es

ABSTRACT
Taking into account the existent educative and pedagogical techniques, which have proved its effectiveness to foster the innovation and creativity, this thesis poses to develop, experiment and evaluate a new technological framework based on interactive surfaces to be applied in the context of preschool education. The goal is to facilitate the three factors required for creative learning: knowledge, creative thinking and motivation but taking into account the cognitive and interaction limitations of these very young users.

Categories and Subject Descriptors
H.5.2. [**Information interfaces and presentation**]: User Interfaces - Evaluation/methodology, Interaction Styles

General Terms
Design, Experimentation, Human Factors, Standardization

Keywords
Pre-kindergarten, Touch interaction, Education.

1. INTRODUCTION
The European Union recognizes creativity as a key factor for the economic development, hence, "Increase the creativity and the innovation, including the entrepreneurship spirit, in all levels of the education and training" is the 4th goal of the strategic framework for the European cooperation in the field of education and training and it is one of the constituent elements of the new R&D strategy in the 2020 Horizon [3]. This is a necessary strategy because, as Cropley points out [5], the traditional education systems tend to frequently assume the existence of one valid answer (or, at least, a preferred one) for any type of problem. This fact prevents the generation of new ideas and innovation processes. According to this, a creative student, or with a different cultural basis, can be considered as a distortion source or distraction in the knowledge acquisition process imparted by the teacher. However, while the individual ability to obey exactly the given orders with discipline were in line with necessities of an industrial society and massive production systems, the ability to be part of collaborative processes and direct the divergent thinking as the motor of creativity and innovation are essentials nowadays in the *information society*.

Fostering creativity must be addressed from a very early age, even in the preschool phase, since the main cognitive processes associated to creativity have their sources in this phase of the individual development [6]. Moreover, the technological support to be used when developing creative characteristics in pre-kindergarten children is critical since the choice of the underlying supporting technology has a great impact on the nature of the pedagogical activities to be performed in a creative learning context.

The initial hypothesis for this thesis is that it is possible to trigger in a more effective way creative collective constructivist processes in pre-kindergarten children through the participation of multiple users in physical spaces of shared games based on interactive surfaces. Therefore, we pretend to study the use of these surfaces in the early phase of the cognitive development and its suitability for the creation of educational tools.

2. RELATED WORK
Multi-touch technology has evolved quickly in recent years, from the adoption of graphical user interfaces to its wide acceptance nowadays [1]. This technology offers new sophisticated input and processing mechanisms that enable users to interact in a more natural and intuitive way [19]. These characteristics have triggered a new approach to developing applications for even very young children. Supporting this evidence, the Horizon report [10] identifies mobile devices (smartphones and tablets) as one of the two emerging technologies suitable for children under two years old and Rideout pointed out that children between zero and eight years old are frequent users of digital media and they meet with touch technology often before they can even speak [4].

This inherent ability of touch systems to engage children's attention is being widely exploited to promote learning activities from pre-kindergarteners to adolescents [12, 18, 11]. Moreover, some studies have demonstrated that the technology can also be used to promote collaboration between peers [16, 17, 7] and to foster creativity [8, 2].

However, the increasing interest in multi-touch technology has not as yet given rise to studies on the design of multi-touch systems for the youngest age range (2-3 years old) [9].

Taking into account the previous works, we believe our proposal is a step forward because of the following reasons: (1) the suitability of the interactive surfaces to support social learning since several subjects share the same physical space and, as it happens in traditional technology-free games, the communication during the creation process, experimentation and reflection is direct and no mediated by a computer. (2) The collaborative nature of the technologic infrastructure, in which users can carry out different tasks in parallel and on the same table; and (3) the creative nature of the infrastructure in which users select the game elements and the reactive behavior that its offer. This allows educators to have a direct feedback about the evolution of children's creative mental models. These models are internalized in a collective way since the activity itself is based on reflection, creation and experimentation processes. The goal is that also educators have a tool on which they can measure in an effective way the level of knowledge development, in depth and breadth, of the divergent/convergent thinking processes and the motivation of users in the activity.

3. CONTRIBUTION

In order to assess the actual skills of pre-kindergarten children with interactive surfaces, we have performed an evaluation of a set of basic multi-touch gestures [14]. The results showed that although only the tap and drag gestures are used in commercial applications targeted to pre-kindergarten children, there are additional multi-touch gestures that can be performed by them (one finger rotation, scale up and scale down). In addition, this study provides a set of design guidelines to define and improve the interactions of these particular users. The application of several of these design guidelines [15] showed that more problematic gestures, such as double tap and long press, can be suitable for pre-kindergarten children too.

On the other hand, we have carried out another study addressing communicability of multi-touch gestures [13] and the results proved that the use of animated languages to communicate gestures to pre-kindergarten children is possible. This opens a new opportunity to new studies with training sessions in order to evaluate the acquisition ability of this type of languages with these young users.

These preliminary results have been published in international forums and allow tackling with a lot of motivation the important milestones that this thesis poses. To sum up, the main milestones of the thesis are the following:

-**Contextualization**: the evaluation of the types of interaction that can be performed by pre-kindergarten children in multi-touch surfaces.

-**Assistance**: the definition of assistive techniques of interaction that allow the increase of effectiveness of pre-kindergarten actions with interactive surfaces.

-**Communicability**: the definition of effective mechanisms to communicate which actions are expected from the user through animated languages that allow children to be autonomous when using the multi-touch technology without the continuous supervision of adults.

-**Adaptability**: the definition of strategies that allow the adaptation of the Assistance and Communicability mechanisms to the specific skills of each user.

-**Creativity**: the construction and validation of environments that foster creativity and allow collaboration between users (pre-kindergarten children) to obtain in the future more adequate educational tools for these users.

4. ACKNOWLEDGMENTS

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Facial Emotion Analysis in Down's syndrome children in classroom

Pablo Torres-Carrión
Universidad Técnica Particular de Loja
Ecuador
pvtorres@utpl.edu.ec

Carina González-González
Universidad de La Laguna
Spain
cjgonza@ull.edu.es

ABSTRACT
Sentiment analysis has allowed a degree of machines "intelligent" interaction, although its development is still at an early stage. This document presents the progress of the research project in this line, with a particular focus on children with Down Syndrome (DS). Their singularities are considered through personalized learning resources, and interaction with Kinect HCI, and the Tango:H platform. In this first moment we made an initial interaction, resulting in video images of the interaction, and a subjective assessment of emotions through one extension of EMODIANA. The next step will be the comparison of the patterns of facial recognition applied in people without SD, to identify whether there are significant differences.

Categories and Subject Descriptors
K.4.2. [**Computers and Society**]: Computing Milieux – Social Issues: *Assistive technologies for persons with disabilities.*

General Terms
Human Factors, Theory.

Keywords
Down Syndrome, Emotion, Affective Computing, AI, Digital Learning.

1. INTRODUCTION
The human person as a social entity, learn from inside the environment that develops and lives; it is necessary therefore to develop the skill of reading behaviors and emotions to infer the possible intentions [15]. In this context, the emotional intelligence as part of the multiple intelligences of Gardner [6], joins two types of intelligences: intrapersonal and interpersonal; that refer to how we know ourselves, the way in which we managed to control and regulate our feelings; the ability to understand others, what you feel and the skills to relate to others[7], respectively.

With the development of these intelligences, teachers and psychologists *comprehenden* (understand from inside) to each other and their environment (social field). Explicitly in the learning process, the student and teacher through educational activities can know, appreciate and share, generating one *compre-h-ensión integral* (comprehensive understanding), which is reflected in a significant learning [15].

The above applies to the entire student population, from initial training to top, without making a cognitive or mental age discrimination. Against this background, in this paper we focus on the people with DS, that within the population with Special Educational Needs (SEN), represent one of the largest and most vulnerable around the world [10]. The process of educational and social adaptation of this population requires an individual treatment, due to psychological, cognitive and kinesthetic abilities [1]. Scientific research about their characteristics and possibilities of performance in different areas of life: social, work and school, have expanded considerably in the last three decades [14] improving your quality of life standards.

People with DS usually have well-developed emotional intelligence, maintain good social interaction skills. They are communicative and respond well to the demands of the environment [2]. The emotions of the people seldom are expressed in words, so it is necessary to interpret them from non-verbal channels such as: the gestures, tone of voice and facial expression [7]. People with SD shows emotional sensitivity that allows them to capture emotions that others go unnoticed [2].

Each person's emotional state can be expressed in different ways; the facial expression is one of the most common ways to show others our feeling with respect to any act or thing [4]. In the case of persons with SD, we have to consider that certain facial characteristics distinguish them from the rest of population [3,9], therefore, studies and identification of emotions patterns based on face, may not extend and apply to this population in general.

2. AVANCE DE INVESTIGACION
Research in the field of the SEN, and specifically in people with DS have increased over the last three decades [14]. However they have not been significant in the area of human-computer interaction (HCI) with affective computing (AC), and the consideration of emotions during interaction.

2.1 Metodology
The methodology that guides this research, is a continuous work qualitatively and quantitatively (see Table1). In the first time we plan doing the emotional assessment in environments of interaction in the classroom. This work was done with a sample of six children (3 male and 3 female) of the Down Tenerife Association, located in the autonomous community of Canary, Spain.

The pre-test phase included meetings with teachers to identify the population, for the experimental group and the control sample, keeping the equity in terms of motor and cognitive profiles. We organized an initial intervention, composed of three working sessions. The experimental group used the platform Tango:H and MS Kinect; the control group used conventional resources.

The first data were obtained from a subjective assessment by teachers, about the emotions displayed by the children during the interaction; it was carried out according to the methodology of the EMODIANA [8] and their assessment scales. This instrument was adapted in a proprietary format, which allowed to measure continuously the 10 basic emotions, and their possible causes: subject, activity and external.

Table 1. Methodology for the emotional assessment[13]

Fase	Tool	Actors
Pre-test	- Competency Test	- Testers - DS's people
Test	- EMODIANA - Rehabilitation platform (cognitive and physical) TANGO:H. - Record of videos	- Testers - Teachers - Physiotherapist - DS's children
Post-test	- Competency Test - EMODIANA - Observation Method (videos) - HER Tool (videos)	- Testers - DS's people

For a further analysis all sessions were recorded on video. These videos will undergo evaluation patterns, to contrast with results obtained by these tools in environments of interaction with non-SD. This contrast, in addition to the subjective assessment performed with the EMODIANA, will allow establish scientific findings about the possible differences between people with and without SD, in terms of patterns and AI algorithms on recognition of emotions previously validated.

The objective pursued is to customize in real time, both teaching resources such as teaching strategies, based on the cognitive, motor and emotional profile of the student with SD. We believe that learning will be more significant.

3. BRIEF REVIEW OF LITERATURE

3.1 HCI and *Affective Computing*

Every human relationship contains many and varied doses of affection, knowledge and interaction [15]. The literature about "affective" includes research and study areas, where relates: psychology, science of consciousness, neuroscience, engineering, computer science, sociology, philosophy, and medicine; from this epistemological context seeks to understand the feelings, such as: emotion, motivation, attention, memory, among others [11].

3.2 Emotions through the face and gestures

Research about emotion recognition are held mainly in facial expressions, intonation of voice and gestural traits [11]. In the corresponding face, muscle movements associated with sentimental or emotional situation have been related to patterns that relate basic emotions like raised them by Ekman: joy, surprise, disgust, anger, sadness and fear, along with a Neutral option [4]. These emotions can be extended up to levels of valuation of complex emotions, product of its combination and semantic reading of the sequence in which certain gestures are shown [12].

The recognition of *genuine* emotions [5] against those that occur in environments where the user poses specifically for an evaluation of the emotion, varies significantly. Therefore, it is necessary that these studies are carried out in the natural environment of interaction, avoiding as far as possible the variation of expressions by external agents [11].

In the TED-Woman 2015 event, the PhD. Rana el Kaliouby of the Affectiva company, presented the *Affdex SDK*, that allows the recognition of emotions in real time, supported in a study of approximately two million videos, coming from more than 75 countries. This is one of the reference works in the area. Additionally, there is the need to relate these algorithms in classrooms and in our case with children with SD.

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CHILD COMPUTER INTERACTION

Métodos y técnicas para la evaluación de la experiencia emocional de niños y niñas con videojuegos activos

Carina S. González-González
Departamento de Ingeniería Informática y de Sistemas
Universidad de La Laguna
cjgonza@ull.edu.es

Vicente Navarro-Adelantado
Departamento de Didácticas Específicas
Universidad de La Laguna
vnavarro@ull.edu.es

ABSTRACT
En este trabajo se presenta una propuesta metodológica para la evaluación de la experiencia emocional de niños y niñas con videojuegos activos. Esta propuesta pretende dar respuesta a algunos de los problemas más frecuentes encontrados en la evaluación de productos interactivos con menores. Para ello, se ha realizado un análisis de los principales inconvenientes de las técnicas tradicionales de evaluación de la usabilidad, calidad de uso y de la experiencia de usuario y emocional en niños y niñas, así como de las relaciones entre las emociones, los videojuegos y los juegos activos. En base a este análisis, se ha elaborado una propuesta de evaluación que contiene: un conjunto de emociones más representativas para los videojuegos activos y diferentes instrumentos y técnicas creados y/o adaptados para el caso de los juegos motores con mediciones de tipo subjetiva (verbal, no verbal), objetiva (biométrica) y de interacción social (comportamiento), organizados en diferentes momentos de una sesión de evaluación. Esta propuesta permite conocer si las respuestas emocionales son debidas a razones internas a la persona, a la actividad realizada o externas (contexto).

Categories and Descriptors
H.5.2 [**User Interfaces**]: Evaluation/Methodology

Terms generals
Measurement, Human Factors

Palabras clave

Evaluación de emociones en niños y niñas, metodología de evaluación emocional, evaluación de la experiencia de usuario (UX) en niños y niñas, videojuegos activos, juegos motores.

1. INTRODUCCIÓN
La evaluación emocional intenta recopilar y medir información sobre aspectos cualitativos y cuantitativos de la experiencia de un usuario [1]. El instrumento de medición dependerá en gran medida de lo se busca obtener, pudiendo distinguir entre instrumentos no verbales (objetivos) y verbales (subjetivos). Actualmente existen distintas técnicas de medición emocional, tales como técnicas que permiten analizar las expresiones faciales, técnicas que miden reacciones fisiológicas (por ejemplo, latido del corazón, sudor, dilatación de la pupila o las ondas cerebrales) o las técnicas de medición subjetiva de sentimientos a través de cuestionarios, entrevistas y auto-informes [2-5]. Nuestra metodología de evaluación emocional utiliza técnicas objetivas y también subjetivas.

La definición, el modelado y la representación de las emociones sigue siendo objeto de estudio en el campo de la psicología y de la computación afectiva [6]. Existen dos enfoques fundamentalmente [7]: el enfoque categórico o discreto y el enfoque dimensional. El enfoque categórico se basa en la clasificación de emociones en categorías [8], por lo que supone una representación discreta de las emociones incapaz de reflejar el amplio rango de emociones complejas que un ser humano puede expresar. El segundo enfoque es dimensional [9], y establece que las emociones conforman un espacio continuo multidimensional en el que unas y otras no son independientes sino que se relacionan de forma sistemática, siendo el modelo tridimensional (valencia, activación y control) [10] uno de los más extendidos. Existen distintos instrumentos que realizan este tipo de evaluaciones, entre los que encontramos SAM [11] o Premo© (Product Emotion Measurement Instrument) [12]. Este último se basa a su vez en SAM, pero está especialmente diseñado para medir la experiencia emocional de los usuarios con productos. Aunque este método ha sido utilizado con éxito en niños, la cantidad de emociones que tiene (14) es potencialmente problemático para su uso como un método de auto-reporte durante una actividad [13]. Esto se debe a que la carga cognitiva que produce es significativa para los niños y niñas, ya que deben identificar, distinguir y seleccionar sus respuestas emocionales entre 14 emociones. Igualmente, existen dificultades de asociación entre el lenguaje utilizado por los niños y su asociación con la representación gráfica de la emoción [13]. Por este motivo nuestra metodología utiliza un instrumento denominado EMODIANA [14], específicamente diseñado y validado para tener en cuenta las dificultades cognitivas de los niños y niñas, y que se basa en las fortalezas de los métodos anteriores. Además, como videojuego activo utilizaremos una plataforma de juegos de rehabilitación cognitiva y física basada en interacción gestual creada por el equipo de investigación, llamada TANGO:H (http://tangoh.iter.es).

Para poder crear una metodología adecuada al caso de videojuegos activos y niños, primero se deben identificar los problemas más frecuentes encontrados en la evaluación de la experiencia del usuario (UX) con niños y cuáles son las técnicas más idóneas para la evaluación con menores. Luego se deben identificar las emociones relacionadas con los juegos y videojuegos, específicamente activos, para ver las técnicas e instrumentos que permitan medir de forma fiable una intervención lúdica-educativa utilizando juegos activos con niños. Por ello, a continuación, se describen los problemas más frecuentes de la evaluación emocional en niños y las técnicas de UX más recomendadas. Posteriormente, analizaremos el conjunto de emociones relacionadas al juego motor y videojuego activo. Luego, presentaremos la metodología creada específicamente para este caso y las conclusiones obtenidas.

2. TRABAJOS RELACIONADOS

2.1 Evaluación de la experiencia interactiva y emocional en niños y niñas

La diversión es un atributo de la experiencia de usuario que es importante medir, ya que es una de las principales motivaciones que tienen los niños/as para interactuar con la tecnología [15] y además, es uno de los factores más relevantes asociados con los juegos. Por tanto, podemos decir que la diversión es una variable que se requiere medir en un estudio de la experiencia del usuario con los niños/as. Existen varios métodos de evaluación de la experiencia del usuario con niños/as, entre los que podemos encontrar: tarjetas gráficas para la identificación de problemas (Problem Identification Picture Cards), el kit de herramientas de diversión (Fun Toolkit) y la escala (Laddering) [16]. Muchos de estos nuevos métodos de evaluación de la experiencia del usuario se basan en el uso de instrumentos como encuestas u otras técnicas relacionadas. El problema es que existen grandes diferencias en las habilidades cognitivas y de desarrollo entre los niños de la misma edad [17], lo cual en las técnicas subjetivas, se pone en juicio la validez y fiabilidad de las respuestas de los niños [18]. Al evaluar a niños/as encontramos problemas tales como complaciencia (satisficing), sugestionabilidad (suggestibility) e incomprensión (misunderstanding) [19]. Por ello, es necesario trabajar en la línea de maximizar la fiabilidad de las respuestas de los niños/as con el fin de asegurar la validez e integridad de los resultados.

La investigación ha evaluado el Fun Toolkit con distintos métodos de evaluación de juegos [16]. Los resultados de este estudio mostraron que los dos métodos produjeron resultados muy similares y fueron comparables para identificar las preferencias en el juego. También se han evaluado técnicas de evaluación de usabilidad usadas en adultos con los niños, tales como las técnicas de pensar en voz alta, entrevistas y cuestionarios [20]. Se ha demostrado que los niños pueden identificar y reportar los problemas de usabilidad. Por ejemplo, los niños fueron capaces de detectar problemas de usabilidad que ayudarían en el diseño de juegos para niños de 4-9 años [21]. Sin embargo, en la realización de una investigación de usabilidad con los niños hay una serie de retos que deben tenerse en cuenta. Así, en un estudio [22] de 70 niños sólo 28 de ellos hicieron observaciones verbales durante la prueba de usuario. Esto puede atribuirse a su personalidad, ya que un estudio mostró que las características de personalidad influyen en el número de problemas identificados [23], por consiguiente, se hace necesario investigar para comprender las limitaciones y aplicaciones en niños/as con relación a diferentes métodos. En Padilla Zea et al (2012) [24], podemos encontrar una clasificación de diferentes métodos de evaluación de productos interactivos procedentes de la evaluación de usabilidad y calidad de uso, y los pros y contras de su utilización en niños y niñas. Asimismo, los mismos autores proponen una metodología para la evaluación de la jugabilidad en videojuegos educativos en niños y niñas de 3 a 7 años.

Tabla 1. Métodos de evaluación de la experiencia interactiva con productos para con niños (Adaptado de Padilla-Zea et al. [24]).

Método	Ventajas	Inconvenientes
Observación pasiva (estructurada)	-La interacción con el sistema es más natural ya que el niño/a no se encuentra presionado por la evaluación y los evaluadores. -Permite observar la experiencia del niño/a en su entorno (familiar). -Adecuado para descubrir problemas inesperados en la interacción como son los patrones de uso. -Resultados fiables.	-La estructura de la observación puede influir en los resultados obtenidos.
Observación pasiva (no estructurada)		-Con alguna frecuencia aparecen cuestiones fuera del ámbito de la guía de observación que pueden pasar desapercibidas -Los datos obtenidos suelen ser demasiado difíciles de analizar.
Pensamiento en voz alta	-Los niños/as pueden explicar por qué encuentran el producto fácil, divertido, aburrido, difícil, etc. -Se puede adecuar la sesión de evaluación para hacerla cómoda y agradable, adecuada al niño/a. -El evaluador puede influenciar al niño/a y guiar el proceso hacia un determinado resultado o proceso.	- Puede ser exigente cognitivamente e incómodo para los niños/as. - Las respuestas suelen ir ligadas a cuestiones específicas planteadas y no sobre el proceso interactivo real. -Normalmente se realizan en laboratorio, fuera del contexto familiar al niño/a.
Método conductor		
Mago de Oz	-Permite evaluar un producto no terminado -Permite descubrir aspectos de la interacción no contemplados anteriormente -Para los niños/as puede resultar divertido y fácil realizar un juego de rol, por lo que se aumentan las emociones positivas hacia el producto	-Se requiere la participación de un evaluador que conozca todo el sistema que cumpla dicho rol y brinde las respuestas interactivas simuladas.
Cuestionarios	- Se puede preguntar a los niños a la vez y	- Poca fiabilidad en la respuesta de los

Método	Ventajas	Inconvenientes
	obtener gran cantidad de datos.	niños/as.
Entrevistas	-Permite conocer en profundidad la experiencia individual de cada participante. -Se pueden obtener datos cualitativos más ricos que los obtenidos en otros métodos.	-Dificultad de los niños/as en comprender las preguntas. -Análisis de datos laborioso, con mucha información de tipo cualitativa.
Grupos focales	- Permite debatir sobre diversos temas en profundidad - El evaluador guía la discusión hacia los temas que interesan evaluar, permitiendo ahondar en variables cualitativas de la experiencia del usuario (satisfacción, impacto emocional, etc.)	
Métodos basados en heurísticas	-Permite la evaluación cuando la participación de los niños/as es difícil. - Ayuda a obtener información con un número reducido de expertos (5) -Son válidos en evaluaciones tempranas de prototipos	-Las heurísticas se centran tradicionalmente en aspectos pragmáticos (usabilidad) y se puede perder información hedónica (diversión, entretenimiento, etc.) - Pueden mostrar problemas que no existen y se puede perder los problemas que realmente si están. - Los expertos pueden desconocer lo que realmente siente al interaccionar un niño/a con el producto interactivo. -Dificultad de encontrar expertos en los diversos tipos de videojuegos educativos/activos.
Métodos basados en recorridos		

La observación pasiva es uno de los métodos clave para nuestra metodología no invasiva.

En nuestro caso, el rango de edad para el cual hemos diseñado la metodología es de 8 a 12 años. En estas edades, aumenta la discriminación emocional, la interacción social y el juego grupal [25]. Sin embargo, no existen metodologías o un conjunto de métodos y técnicas que permitan evaluar la experiencia de usuario con videojuegos activos incluyendo elementos de interacción social y colaborativa. Por ello, en este trabajo se propone una metodología específicamente diseñada para la evaluación de este tipo de productos con niños y niñas.

Las respuestas emocionales pueden darse a través de diversos canales. El canal tradicional de detección emocional han sido las imágenes faciales, pero en los últimos años se han ido incorporado otros canales como el sonoro (voz) y, muy especialmente, los fisiológicos [26]. Asimismo, existen diversos tipos de instrumentos para medir las respuestas emocionales. Por ejemplo para las respuestas de tipo verbal, algunos de los instrumentos más comunes son la escala Likert, escala de diferenciador semántico, el perfil emocional estandarizado (SEP, el perfil de reacción (Reaction Profile) o la escala sentimiento hacia anuncios (Feelings Toward Ad Scale). Para las respuestas de tipo no verbal, los instrumentos más comunes son PrEmo, EmoCards, SAM,, LemTool o GEW. Y para medir las respuestas fisiológicas, para las expresiones faciales algunos instrumentos más comunes son: Affdex Facial Coding, FaceAPI, Facesense, Facereader, FaceSDK; para señales cerebrales el Emotiv-EPOC y para otras variables biométricas los Affective wearables [27].

En Méndez et al (2015) [27] se presenta un marco de referencia como complemento a la evaluación de sistemas interactivos con tres componentes principales de evaluación: comportamiento, fisiológico y subjetivo. El componente de comportamiento se centra en evaluar el comportamiento del usuario, considerando específicamente las características relacionadas con la expresión facial, dirección de la mirada, postura, movimientos de la cabeza y gestos. El componente fisiológico se centra en los aspectos fisiológicos de los usuarios, considerando específicamente la actividad cerebral del usuario durante la evaluación. Por último, el componente subjetivo se centra en recoger la propia opinión del usuario, al respecto de las emociones que el usuario considera que evocó mientras realizaba las diferentes tareas durante la evaluación del sistema interactivo. Este enfoque metodológico no contempla el componente social y cooperativo de los usuarios, cuestión que sí es abordada en nuestra propuesta.

2.2 Emociones, videojuegos y juegos activos

Aunque existe una gran variedad de interpretaciones y definiciones del concepto de emoción [28], podemos decir que se trata de un estado complejo del organismo caracterizado por una excitación o perturbación que predispone a una respuesta organizada [29], de acuerdo con la evaluación subjetiva que realiza cada persona del significado del evento que la ha originado [30].

Los videojuegos son poderosos generadores de emociones. Varios autores, se han centrado en analizar qué emociones pueden generarse, y de cómo surgen [31]. Es posible distinguir dos niveles en la vivencia de emociones [32]:

- *El jugador como observador-participante:* Se refiere a las emociones producidas por la interacción con las imágenes y el sonido del videojuego, por aquellos elementos que el participante no puede cambiar, y los mecanismos que las inducen son similares a los utilizados por las películas de cine. Por ejemplo, un jugador podría asombrarse al percibir la belleza de un escenario de juego.
- *El jugador como actor participante:* Se refieren a las emociones generadas por las propias acciones del

jugador, o de las interacciones del jugador con otros. Por ejemplo, un jugador podría sentir alegría como resultado de haber conseguido superar una fase de un videojuego. En los videojuegos, a diferencia de otros formatos multimedia, y particularmente los videojuegos multijugador, se posibilitan estas emociones.

Los juegos motores generan una vivencia intensa de reacciones emocionales asociadas a estados activos e interactivos [33]. Según Lavega et al. (2015) [28] "las emociones se relacionan al estado activo, asociado a diferentes tendencias de acciones, a códigos de comunicación no verbales o disposiciones corporales, y a la intervención procedimental; es decir, vivencial e interactiva". También, hay que distinguir entre el juego motor real y el juego interactivo simulado, así como tener en cuenta los fundamentos teóricos procedentes de la praxiología motriz de Parlebas [34,35, 36]. A partir del criterio de 'interacción motriz', se establecen cuatro grupos de juegos o 'dominios de acción motriz' [37]. Juegos psicomotores (sin interacción motriz), en los cuales el protagonista interviene sin tener ningún oponente que lo perjudique o compañero que le ayude en la realización de acciones motrices; b) Juegos de cooperación, en los que diferentes protagonistas han de ayudarse para superar un objetivo común; c) Juegos de oposición, en los cuales los protagonistas desafían a uno o más rivales para conseguir su objetivo y d) Juegos de cooperación y oposición a la vez, en los que varios jugadores que forman parte de un equipo deben enfrentarse y superar a otros adversarios, generalmente también organizados en equipo. La metodología que proponemos está especialmente diseñada para los tipos de juegos motores de cooperación, aunque puede ser adaptada para otros tipos de juegos con acción motriz.

Las emociones se pueden clasificar en tres categorías en función de si se cumplen o no las expectativas buscadas: emociones positivas (alegría, humor, amor y felicidad), emociones negativas (miedo, ansiedad, ira, tristeza, rechazo, vergüenza) y emociones ambiguas: sorpresa, esperanza y compasión [29]. A continuación se describen las 13 emociones seleccionadas por Bisquerra [29] y relacionadas con el juego motor (Tabla 2):

Tabla 2. Emociones relacionadas a juegos motores [28]

Emoción	Descripción relacionada con el juego
Alegría	Disfrutar de un suceso durante el juego satisfactorio.
Humor	Inspira alegría y mueve a la risa durante el juego.
Amor	Desear o participar con afecto respecto a otra persona del juego, habitualmente, pero no necesariamente recíproco.
Felicidad	Hacer progresos razonables hacia el logro del objetivo que plantea el juego.
Miedo	Sentir peligro físico real e inminente, concreto y arrollador durante el juego.
Ansiedad	Enfrentarse a una amenaza incierta durante el juego.
Ira	Sentir una ofensa contra mí o mi equipo durante el juego.
Tristeza	Experimentar una pérdida irreparable durante el transcurso del juego.
Rechazo	No admitir o aceptar a otra persona que participa en el mismo juego.
Vergüenza	Timidez que se siente ante determinadas situaciones de juego que impide o inhibe la realización de una acción motriz. Fracasar en vivir de acuerdo con el *yo* ideal.
Sorpresa	Reacción a alguna situación de juego imprevista.
Esperanza	Confiar en qué ocurrirá o se logrará el objetivo de juego que se desea alcanzar.
Compasión	Sentirse afectado por el sufrimiento de otro participante en el juego y sentir el deseo de querer ayudarle.

En el campo de los videojuegos en particular, varios autores han analizado cómo los videojuegos favorecen la motivación por ser intrínsecamente satisfactorios [38]. Esta satisfacción provendría esencialmente del caudal de emociones generado al obtener logros, al disfrutar de libertad de acción y al interactuar con otros jugadores.

Otros autores han investigado cuáles son las emociones más frecuentes en videojuegos. González Tardón [39] presenta una taxonomía de emociones frecuentes en videojuegos, las cuales son: interés, humor, felicidad, sorpresa, ansiedad, amor, hostilidad, tristeza, repulsión e ira. Moorcock [40] presenta los resultados basados en 1,040 respuestas sobre las emociones que más frecuentemente se daban al jugar a videojuegos, siendo las diez emociones más frecuentes: felicidad, alivio, satisfacción, sorpresa, triunfo, curiosidad, excitación, admiración, alegría, diversión. Perron [41] también intentó caracterizar algunas emociones en videojuegos tipos, teniendo en cuenta la teoría del cine. Este autor identificó las siguientes siete emociones: interés, disfrute, preocupación, miedo, sorpresa, ira y frustración. Asimismo, en el estudio de Ravaja et al. [42] se analizan los patrones de las respuestas emocionales de los usuarios ante varios videojuegos. Los resultados sugieren la utilidad del análisis de los patrones de las respuestas emocionales en el diseño de videojuegos.

3. PROPUESTA METODOLÓGICA

Como se ha mencionado en la Sección 2, la evaluación de la experiencia de usuario con niños y niñas conlleva una serie de inconvenientes para los métodos e instrumentos tradicionales, sobre todo en los métodos de tipo test, ya que son especialmente complejos para los niños por la cantidad de ítems, adjetivos, puntuaciones, abstracciones, entre otros métodos [24]. Por otra parte, para no afectar la evaluación emocional debe mantenerse un clima de familiaridad y confianza durante la realización de los tests, tratando de mantener los contextos conocidos y personas de su entorno. También se debe utilizar un lenguaje y elementos gráficos adecuados a las edades de los menores. La metodología que aquí se propone utiliza instrumentos y técnicas que permiten una evaluación emocional mínimamente invasiva y adaptada a los menores de 8 a 12 años. Estos instrumentos y técnicas se aplican en diferentes momentos de una sesión de evaluación: pre-test, test y pos-test. La duración de la sesión es de una hora. En la Tabla 3 se observan los momentos e instrumentos utilizados.

Tabla 3. Momentos e instrumentos para la evaluación emocional en niños y niñas con videojuegos activos colaborativos.

Momento	Instrumento	Tipo	Enfoque
Pre-test	EMODIANA	Subjetivo – No verbal	Categórico – Dimensional
Test	Pulsómetro – Acelerómetro Observacional pasiva-estructurada (grabación en vídeo)	Objetivo - Biométricas No verbal Verbal Interacción Social	Categórico Categórico
Pos-Test	EMODIANA REP (Escala de esfuerzo percibido de Borg)	Subjetivo – No verbal Subjetivo-Verbal	Categórico – Dimensional Categórico

A continuación describiremos los instrumentos utilizados en los diferentes momentos de la evaluación.

3.1 EMODIANA

En un trabajo anterior se presentó la elaboración y validación del instrumento EMODIANA [14] (Figura 1). En el mismo, se analizó, por un lado, el diseño gráfico del instrumento de evaluación emocional en referencia a la comprensión por parte de los niños y las niñas de las representaciones gráficas emocionales (expresiones faciales o caras), y, por otra parte, la intensidad emocional asociada a cada emoción. Además, en el mismo trabajo se presentó el estudio sobre la coherencia entre el lenguaje utilizado al definir las emociones en Premo© y el lenguaje de los niños y niñas utilizado en la identificación de las emociones.

La EMODIANA es un instrumento de evaluación emocional subjetiva para niños y niñas, con edades comprendidas entre 7 y 12 años. Este instrumento fue creado para evaluar emociones en situaciones educativas con juegos motores y videojuegos. La validación del instrumento se basó en el análisis del diseño gráfico y el significado emocional atribuido a las diferentes expresiones gestuales presentadas a 168 niños y niñas de entre 7 y 12 años. Asimismo, se validó el lenguaje infantil utilizado para definir las emociones y el grado de discriminación emocional de los 168 menores participantes en el estudio. Al conjunto de emociones de Premo© se añaden tres nuevas emociones no recogidas en la herramienta original (ansiedad/nerviosismo y sorpresa), y que son relevantes para la evaluación emocional en niños y niñas en juegos y videojuegos. También se evaluó la comprensión del significado de la intensidad emocional, y por ello se diseñó una diana, con mayor intensidad de color en el centro y menor en el exterior, y se les preguntó a los menores sobre su significado. El instrumento está diseñado estrictamente para valorar las emociones referidas al sujeto. Las emociones son consideradas mutuamente excluyentes para el análisis, aunque se recogen las explicaciones de los niños y niñas, de forma que puede extraerse cualitativamente si hay alguna otra emoción asociada a la emoción elegida (considerada predominante).

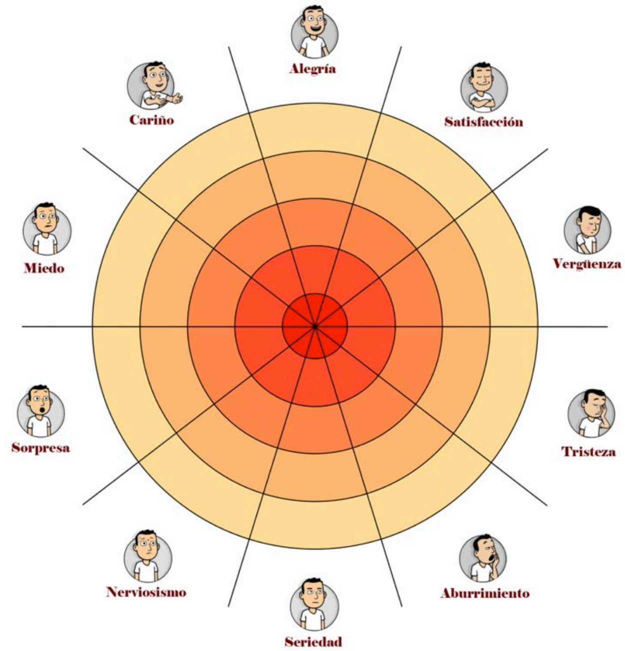

Figura 1. EMODIANA: Instrumento de evaluación emocional subjetiva para niños y niñas.

El procedimiento de utilización de la EMODIANA se divide en dos fases, según los momentos de la sesión en donde se aplicará el instrumento: fase pre-sesión y fase post-sesión. De esta forma, al entrar en la sesión, el evaluador/a presenta al niño la EMODIANA (en formato de cartel gráfico), le pregunta al niño/a cómo se siente y le pide que ubique un imán gráfico en la diana, diciéndole que en el centro de la diana es la mayor intensidad (mucho) y el exterior la menor intensidad (poco). Luego, le preguntará que explique las causas o razones de por qué ha dicho que se siente de esa forma. Este procedimiento se registra en una hoja de registro emocional de la sesión, incluyendo valores cuantitativos (emoción e intensidad) y cualitativos (explicaciones dadas por los niños y niñas). Al terminar la sesión, el evaluador/a repetirá el procedimiento de registro, pidiéndole al niño/a que diga qué siente, en qué intensidad y por qué se siente así, y lo registrará en la hoja de registro de la sesión. El registro se realiza tal y como el contenido es aludido literalmente por los niños y niñas. La información recogida en las sesiones de intervención se analiza siguiendo procedimientos estadísticos para el análisis cuantitativo (medias, frecuencias, varianzas), y para el análisis cualitativo (codes y categorías, fiabilidad, y concordancia). La EMODIANA nos permite además conocer si las emociones son internas o externas a la intervención que se está realizando, ya que los ítems de valoración subjetiva o justificaciones dadas por los niños y niñas, se clasifican como internos o externos a la actividad realizada. La dimensión interna incluye las justificaciones referidas al sujeto o persona (P) y las relacionadas a la estructura de la actividad (E). La dimensión externa comprende a las justificaciones o explicaciones referidas al contexto (C). Este sistema de categorías, permite al observador identificar las categorías que representan con más precisión la afirmación subjetiva de la justificación de la emoción declarada por cada niño/a. Así, para el análisis de las justificaciones subjetivas se definen 7 categorías posibles (Tabla 4).

Tabla 4. Siete categorías excluyentes para el análisis de la naturaleza interna o externa de las emociones manifestadas por los niños y niñas.

Categoría	Definición
1. Persona (P)	Cuando la justificación se realiza en primera persona, vinculándose a la justificación de la emoción declarada. Por ejemplo: “porque me reí y me divertí”, “porque tengo miedo de portarme mal como la última vez”
2. Estructura de la actividad (E)	Cuando la justificación se realiza sobre elementos o agentes de la intervención específica programada. Por ejemplo: “porque hoy voy a hacer ejercicios nuevos y voy a aprender a hacer juegos”, “porque los juegos eran muy divertidos”.
3. Contexto (C)	Cuando la justificación se realiza sobre aspectos del entorno del niño y de la actividad programada. Por ejemplo: “Porque hoy es el cumpleaños de mi padre”, “porque tengo *puente* y ahora vienen las navidades”.
4. Persona y estructura de la actividad (PE)	Cuando se dan de forma conjunta las justificaciones relacionadas con las categorías P y E. Por ejemplo: “porque me siento bien al hacer el ejercicio que he hecho”, “porque me gustan mucho los juegos pero me he portado mal”.
5. Persona y contexto (PC)	Cuando se dan de forma conjunta las justificaciones relacionadas con las categorías P y C. Por ejemplo: “porque hoy tuve un buen en clase, en mi casa y aquí”, “porque estoy satisfecho porque ya hice un examen”.
6. Estructura de la actividad y contexto (EC)	Cuando se dan de forma conjunta las justificaciones relacionadas con las categorías E y C. En este caso no se han encontrado en el estudio justificaciones que se correspondan con esta categoría.
7. Persona, estructura de la actividad y contexto (PEC)	Cuando se dan de forma conjunta las justificaciones relacionadas con las tres categorías P, E y C. Por ejemplo: “porque ya no vamos a venir más, solo una semana más”, “porque me siento satisfecho cada vez que vengo aquí, y además hoy tuve excursión”.

La dificultad del fenómeno de justificación de emociones en niños y niñas requiere de una validación que contenga opiniones de expertos relacionadas con distintos campos disciplinares (psicología, juego motor y videojuegos). Por ello, el análisis cualitativo en nuestra metodología se realiza por evaluadores expertos de cada campo, que analizan los codes y categorías de las justificaciones dadas por los niños y niñas a las emociones referidas. La fiabilidad del instrumento se ha calculado utilizando la Kappa de Fleiss [43] que permite analizar los registros observados por más de dos observadores. En la validación del instrumento realizada sobre 89 casos válidos, el índice de fiabilidad *k* ha sido 0,903 (donde 0 es la mínima concordancia posible y el 1 la máxima). Por consiguiente, podemos asegurar la fiabilidad de este instrumento de evaluación emocional.

3.2. Sensores biométricos

En nuestra propuesta metodológica incluimos sensores biométricos de bajo coste que puedan ser utilizados en la realización de actividades motoras con niños y niñas y que permitan medir frecuencia cardíaca, pulso y distancia recorrida, etc. Para ello, los sensores más comunes que podremos utilizar serán los pulsómetros y los acelerómetros. Los pulsómetros son aparatos diseñados para poder llevarlos durante el ejercicio con el propósito de medir y registrar la frecuencia cardiaca en pulsaciones por minuto. Estos dispositivos proveen un registro completo de las pulsaciones por minuto (bpm, del inglés *beats per minute*) durante una sesión de actividad física, con mayor exactitud que la toma manual de pulsaciones. Miden la frecuencia cardíaca, permitiendo ajustar la frecuencia límite, máxima y mínima. Existen diferentes tipos de pulsómetros, los más comunes se componen de dos piezas principales: la cinta emisora digital que se coloca a la altura del esternón y contiene un sensor y un transmisor que envía las señales al reloj-pulsera. Estos aparatos tienen diferentes accesorios y su precio puede variar entre los 30 a los 300 euros dependiendo de las características y ventajas que ofrecen, entre ellas el poder conectarse directamente a un ordenador para descargar y analizar la información a través de una memoria USB/SD. Los acelerómetros incorporan sensores que miden la zancada, la cadencia y el ángulo del pie, entre otras medidas posibles y con esta información generan datos sobre la distancia y velocidad. Los sensores vienen incorporados en el propio reloj, en los relojes de última generación.

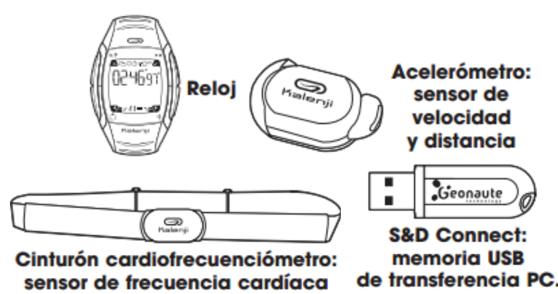

Figura 2. Solución empleada en la propuesta para la medición de variables biométricas.

Figura 3. Colocación de sensores antes de la sesión para la medición de variables biométricas.

En nuestro caso, hemos optado por una solución de bajo coste (menor a 100 euros) compuesta por un reloj, un acelerómetro, un cinturón cardio-frecuenciómetro (Figura 2 y Figura 3). Para facilitar la utilización de los diferentes sensores, acelerómetro y cinturón cardio-frecuenciómetro, se utiliza el protocolo de comunicación ANT+. Además, se pueden transferir y analizar las sesiones en el ordenador a través de una memoria USB SD Connect. Las medidas que obtenemos con estos sensores son las siguientes: FC: frecuencia cardíaca (salvo W 500 SD), VELOCIDAD: velocidad en km/h, RITMO: ritmo en min/km y CAL: calorías por hora.

3.3.Observación pasiva estructurada

Las sesiones se graban en vídeo y luego se realiza el proceso de observación estructurada. Se graban dos vídeos: uno de frente a los niños/as (se observan los rostros) y otro sobre la interacción de los niños/as con el sistema. Luego se combinan ambos vídeos para realizar el procedimiento de registro en un software específico de análisis de vídeos en deportes, ya que tiene elementos específicos para el análisis de actividades físicas grupales (etiquetas, categorías, subcategorías, equipos, jugadores, etc.), las cuales facilitarán nuestra tarea de registro estructurado observacional en videojuegos activos realizados en grupo. En nuestro caso el software elegido fue LongoMatch (http://www.longomatch.org). Los registros son realizados por 3 evaluadores y luego se analiza la concordancia de las decisiones de categorización y codificación emitidas.

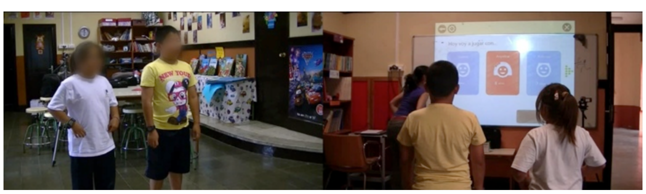

Figura 4. Vídeos combinados para el análisis estructurado en LongoMatch.

Las emociones observadas se agrupan en tres categorías indicando además la intensidad (alta, media o baja). De esta forma, tenemos los siguientes conjuntos de emociones: positivas (alegría, satisfacción, cariño), ambiguas (vergüenza, sorpresa, seriedad, aburrimiento) y negativas (tristeza, miedo, nerviosismo, enfado). Si bien la literatura habla de una categoría emocional "neutra" [27], en nuestro caso el equipo de psicología ha decidido cambiar esta conceptualización a "ambigua", ya que no se entiende que la vergüenza, sorpresa o aburrimiento sean estados emocionales neutros.

Al observar los vídeos se registran medidas atendiendo a tres dimensiones: el lenguaje no verbal, el lenguaje verbal y las interacciones sociales (con otros compañeros o con el profesor) que se hayan producido durante la interacción con el videojuego. En la Tabla 5 podemos apreciar las dimensiones, los criterios y su relación con las categorías emocionales.

Tabla 5. Guía para la observación.

Dimensiones	**Criterios**	**Relación con las categorías emocionales**
Lenguaje no verbal	Gestos ilustrativos (vinculados al discurso: por ejemplo, V de victoria etc.).	Se categorizan en positivas, negativas y ambiguas
	Expresiones faciales	Atenderemos a las expresiones positivas, negativas y ambiguas - Además se indicará su intensidad: alta, media o baja
	Miradas, por ejemplo si fija la mirada en el suelo si está distraído o si hay conflicto.	Se categorizan en positivas, negativas y ambiguas
	Gestos emocionales: • Reducir tensión: acicalarse el pelo, rascarse, etc. • Estados de conflicto o emociones negativas: chuparse el dedo • Cansancio: tocarse el pelo, orejas, bostezar • Agresividad: se inclinan hacia adelante • Empatía: imita a la otra persona • Otros	Se categorizan en positivas, negativas y ambiguas
	Tacto: contactos táctiles entre los niños/as, sienten nerviosismo o están molestos	Se categorizan en positivas, negativas y ambiguas
Lenguaje Verbal	Positivas: ¡Jajaja!, ¡Sí!, ¡Toma!, Yupi!, ¿Cuándo empezamos?, ¡Yo también quiero participar!, ¡Muy bien!, ¡Qué bien lo hiciste!, ¡Ánimo!, ¡Sigue así!, etc. - Negativas: ¡Nooo!, ¡Jolín!, ¡Aarrr!, ¡Psk!, ¡Diablos!, ¡Jo!, ¡Yo paso!, ¡Yo no puedo!, ¡Yo no sé!, ¡No me	Se categorizan en positivas, negativas y ambiguas Además se indicará su intensidad: alta, media o baja

Dimensiones	Criterios	Relación con las categorías emocionales
	atrevo!, ¡Me siento mal!, ¡Qué nervios!. - Ambiguas: Silencio ¡Pobrecito! ¡Lo siento! ¡Te ayudo! ¡Qué pena! ¿Estás bien? ¡Ojalá! ¡A ver si puedo!. - Duración o tiempo empleado	
Interacción social	-Tipos de interacción: 1. Interactúa con los con observadores (IO): los participantes preguntan, dudan, etc. 2. Comportamientos desencadenados por los observadores (OTB): si los comentarios de los observadores activan tanto las conductas verbales y no verbales en los jugadores. 3. Compartir experiencias (SE): los jugadores comparten experiencias con los demás, reflejando el comportamiento expresivo (por ejemplo, riendo juntos) d) Cooperación (COO): algunos jugadores compartieron consejos y se ayudaban unos a para superar las dificultades. e) Competencia (COM): los jugadores competían; por ejemplo, por la puntuación. f) Intentos de interactuar fallidos (AI): Los jugadores intentan interactuar pero el otro jugador hace caso omiso de ellos.	Se categorizan en positivas, negativas y ambiguas

3.4. REP (Escala de Esfuerzo percibido)

En la literatura científica especializada [44] se conoce por las siglas Rango de Esfuerzo Percibido (REP) o en inglés *Rating of Perceived Effort* (RPE) o escala de Borg. El instrumento consiste en una tabla con números entre 20 y 6, colocados verticalmente y acompañados de valoraciones cualitativas entre muy, muy fuerte y muy, muy ligero. Las valoraciones subjetivas de una persona que practica un deporte estarán influenciadas por el nivel deportivo, el grado de preparación, el estado de salud, la motivación por la actividad y otros factores. Este instrumento se muestra últil para evaluar tareas específicas dentro de una sesión de entrenamiento, así como para evaluar la sesión completa. En la elaboración de la escala del instrumento, se observó que añadiéndole un cero al valor de esfuerzo percibido, se podría obtener una estimación aproximada de la frecuencia cardíaca (por ejemplo, una puntuación de 8 equivalía a 80 pulsaciones por minuto, 15 a 150, etc.). Aunque no se ha podido comprobar que esta equivalencia sea real, sí se halló una relación lineal entre el esfuerzo percibido y la frecuencia cardíaca, que aconseja la utilización de esta medida subjetiva para evaluar y controlar la intensidad del esfuerzo en el entrenamiento [45]. La Tabla 6 muestra una equivalencia aproximada entre cuatro medidas de intensidad: la escala propuesta por Borg; las pulsaciones por minuto; una escala de 0-10 puntos; y el porcentaje de intensidad máxima posible [46]. Este instrumento puede ser de gran ayuda en el proceso de evaluación del entrenamiento, ya que son pocos costosos y fáciles de incorporar al entrenamiento, y al mismo tiempo permiten obtener un indicador de la intensidad del esfuerzo como feedback de la actividad realizada. Este indicador fortalece la percepción de autocontrol y el progreso, aportando información muy valiosa al diseñador de los ejercicios.

Tabla 6. Escala de esfuerzo percibido [46]

Escala de esfuerzo percibido de Borg		Equivalencia aproximada de pulsaciones por minuto	Grado de intensidad del esfuerzo (% de la capacidad máxima posible)	Equivalencia de una escala de esfuerzo percibido de 0-10 puntos.
6		60-80	10	0
7	Muy, muy suave	70-90		1
8		80-100	20	2
9	Muy suave	90-110		
10		100-120	30	3
11	Bastante suave	110-140		
12		120-140	40	4
13	Algo duro	130-150	50	5
14		140-160	60	6
15	Duro	150-170	70	7
16		160-180		
17	Muy duro	170-190	80	8

Escala de esfuerzo percibido de Borg		**Equivalencia aproximada de pulsaciones por minuto**	**Grado de intensidad del esfuerzo (% de la capacidad máxima posible)**	**Equivalencia de una escala de esfuerzo percibido de 0-10 puntos.**
18		180-200	90	9
19	Muy, muy duro	190-210	100	10
20		200-220		

4. CONCLUSIONES

En este artículo se presenta el problema de la evaluación de la experiencia interactiva y emocional en niños y niñas con videojuegos activos. Para ello, se ha realizado una revisión de técnicas y de instrumentos de evaluación de la UX, con sus ventajas e inconvenientes en la evaluación con niños y niñas. Además, también se ha realizado un análisis del conjunto de emociones que se presentan frecuentemente en la interacción con videojuegos y con los juegos motores o activos. En base a este análisis, se ha diseñado y presentado una propuesta metodológica de evaluación de la experiencia emocional de niños y niñas con videojuegos activos. Esta propuesta está especialmente adaptada para la evaluación emocional en edades comprendidas entre 8 y 12 años. Los métodos e instrumentos que componen esta metodología fueron diseñados para resolver algunos de los problemas frecuentes que se encuentran en la evaluación emocional con niños y niñas, siendo mínimamente invasivos y maximizando la fiabilidad de los resultados obtenidos.

La metodología se organiza en diferentes momentos (pretest, test y postest) y contempla medidas subjetivas del sujeto y del observador, así como medidas objetivas (biométricas). Se propone un procedimiento de análisis de las medidas subjetivas que permitan garantizar la fiabilidad, tanto para los cuestionarios subjetivo de la EMODIANA y de REP, así como para el procedimiento de observación estructurada. Por ello, en el análisis cualitativo, la metodología propone una inter-observación realizada por dos o más observadores buscando así más rigor en la observación. Asimismo, a través de los análisis cruzados de datos se pueden proponer y validar nuevas hipótesis, entre ellas, comprobar si el esfuerzo percibido no coincide con las pulsaciones registradas.

La metodología ha sido aplicada en la validación de un programa formativo sobre hábitos saludables llevado a cabo en un centro escolar. En este programa formativo se ha utilizado un videojuego activo con interacción gestual, denominado TANGO:H [47], tal y como se ha mencionado en la sección introductoria. Los resultados de la evaluación de dicha experiencia han sido altamente positivos. Sin embargo, debido a la limitación de extensión del artículo no pueden incluirse los resultados. Como resultado de lo obtenido, actualmente estamos desarrollando una librería de integración sensorial para poder conectar distintos tipos de sensores biométricos, así como realizar el análisis de los registros en un software especialmente diseñado para satisfacer nuestros requisitos y conseguir de este modo automatizar los registros y análisis para nuestro caso. También estamos adaptando el software TANGO:H para trabajar con Kinect 2, y registrar expresiones faciales de forma automática, ya que esto nos permitirá simplificar y automatizar el análisis de las expresiones faciales de los vídeos.

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The SARA Project: An Interactive Sandbox for Research on Autism

Diana Arellano
Filmakademie
Baden-Württemberg
Ludwigsburg, Germany
diana.arellano@filmakademie.de

Volker Helzle
Filmakademie
Baden-Württemberg
Ludwigsburg, Germany

Ulrich Max Schaller
University Medical Center
Freiburg, Germany

Reinhold Rauh
University Medical Center
Freiburg, Germany

Marc Spicker
University of Konstanz Konstanz, Germany

Oliver Deussen
University of Konstanz Konstanz, Germany

ABSTRACT

SARA is an ongoing research project that investigates in a novel and artistic way the causes for social communication and emotion recognition deficits in children and adolescents with high-functioning autism spectrum disorders (ASD). The novelty of our work resides in the real-time generation and parameterization of emotional facial expressions of virtual characters by means of speed, intensity and abstraction, the latter achieved by non-photorealistic rendering (NPR) techniques. Although the project is currently in an ongoing phase, it shows the potential of using virtual characters and real-time techniques for interactive experiments, which otherwise would be impossible using "linear stimuli" (e.g. pre-rendered animations).

Categories and Subject Descriptors

H.5 **[Information Interfaces and Presentation]**: Mul- timedia Information Systems; I.3 **[Computer Graphics]**: Applications; J.4 **[Social and Behavioral Sciences]**: [Psy- chology]

General Terms

Autism, Social Skills, Animation, Emotions

Keywords

Autism Spectrum Disorder, Non-Photorealistic Rendering, Real-time Animation, Facial Expressions, Interaction

1. INTRODUCTION

Autism spectrum disorder (ASD) is a developmental disability that tosses significant communication, behavioral and social challenges.

According to the Center for Disease Control and Prevention (CDC), research on ASD has increased a great deal in recent years [1], as well as the number of children and adults with this disorder. In 2014 the CDC estimated that about one percent of the world population has ASD. In the United States the prevalence of ASD was in the same year one in 68 births [5]. In Spain, the "Confederaci´on Autismo Espan˜a" communicated that approximately 350.000 people in this country has a form of ASD [8].

Motivated by these numbers and the amount of research done in this area, we propose SARA (Stylized Animations for Research in Autism), an ongoing project that investigates the causes behind communication and emotion perception deficits in children and adolescents with high-functioning ASD. To achieve this, SARA combines psychology, real-time non-photorealistic rendering (NPR) and 3D computer animation, with the main goal of studying how abstracted faces, with different levels of details are categorized by children and adolescents with ASD.

The interest in using NPR is that it permits a variation in the level of abstraction and visuo-spatial information, adapting images to "focus the viewer's attention" [6]. Thus the information load in the characters' facial expressions can be reduced, conveying the emotional information more efficiently. In the end, a set of virtual characters are used in an interactive computer-based psychological test, where each character displays emotional facial animations generated in real-time. In the following, we will shortly refer to previous research in this area, we will explain the current status and first results of SARA, and finally, we will conclude with the ongoing and future work.

2. RELATED WORK

Many interactive applications created to develop or enhance the social skills of individuals with autism make use of virtual characters. Among the tools used for research in a lab environment we found the work of Whyte et al. [14], who used game components (e.g., storyline, long-term goals, re- wards) to create engaging learning experiences, especially in computer-based interventions. Milne et al. [9] employed autonomous agents as social skills tutors for teaching children with ASD conversation skills and how to deal with bullying. Grawemeyer et al. [7] developed an embodied pedagogical agent together with, and for young people with ASD.

ECHOES VE [2] presents a virtual environment where children with ASD need to assist a virtual character in selecting objects by following the character's gaze and/or pointing at the object. In JeStiMulE [12] participants are taught to recognize emotions on the faces and gestures of virtual characters, while considering the context. LIFEisGAME [3] deploys a low cost real-time animation system embedded in a game engine to create a game that helps individuals with ASD to recognize emotions in an interactive way. FaceSayTM [11] aids children with ASD to recognize faces, facial expressions and emotions by offering students simulated practice with eye gaze, joint attention, and facial recognition skills. Let's face it! [13] is a program comprised of seven interactive computer games that target the specific face impairments associated with autism.

One thing all these applications have in common is the use of virtual characters to enhance or develop skills in subjects with ASD. In all the previous cases, the characters present a defined visual style, which can be either cartoony or realistic. In this sense, one of the assets of our project is the possibility to change the visual representation of the characters (from more realistic to more abstract) in real-time, opening up new possibilities for more personalized applications.

3. SARA

Similarly to previous research, SARA (Stylized Animation for Research in Autism) combines clinical psychology and computer animation to create a tool for assessing the categorization of dynamic emotional facial expressions by children and adolescents with high-functioning ASD. Moreover, our project's innovation includes real-time non-photorealistic rendering (NPR) algorithms to abstract the faces of the virtual characters used in the test. This will allow us to explore how a reduction in the level of details of facial expressions affects their categorization by individuals with ASD.

The core of SARA is the DECT (Dynamic Emotion Categorization Test) [10], an interactive computer-based tool created to assess the feasibility of using real-time animations by comparing virtual characters to video clips of human actors. A previous version of the test contained material of two human actors and two virtual characters displaying dynamic facial expressions of the basic emotions: anger, disgust, fear, happiness, sadness, and surprise, on three intensity levels: weak, medium, and strong. The results of this very first version of DECT showed that the three levels of intensity were equally categorized in the virtual characters and in the human actors. This motivated us to continue exploring the use of virtual characters in autism research.

The design and development of the DECT, as well as the implementation of the NPR algorithms and real-time animations is being done in the software development plat- form Frapper[3] , in particular using the Agent Framework [4]. Frapper is a C++, Ogre3D and Qt based development environment consisting of a node-based scene model, a model-view-controller architecture, a panel-oriented user interface similar to commercial 3D packages. The Agent Framework is the set of functionalities (nodes and plug- ins) that allow users the rapid prototyping of applications that make use of virtual characters. Both Frapper and the Agent Framework are provided with two human-like characters distributed under the Creative Commons Attribution-NonCommercial-ShareAlike 3.0 Unported License.

4. INTERACTING WITH DECT

DECT has been conceived as an interactive research tool, rather than as an intervention tool, where both experimenters and participants can work in a real-time environment. Currently, the interaction with the software has been designed in a way where the experimenter has more control over it. It is the experimenter who explains the child or adolescent what it needs to be done and even aids him in the selection of the emotional choice, as seen in Figure 1.

Figure 1: Participant during a DECT session.

The test deliberately does not contain any GUI-centric terms, so participants with ASD do not focus on other elements than the facial expressions of the characters and the emotional answers. A session with the DECT consists of several trials. Figure 2 shows the basic screens that are sequentially displayed in each trial. It begins with a pink-colored screen (Fig. 2(0)), which serves as separator in between trials. By pressing the Enter key the trial and the interaction is initiated. It begins with a fixation cross (Fig. 2(1)) that appears for 0.5 seconds and indicates where the participant should fixate his gaze. After this time, one of two characters (Hank, an old male; or Nikita, a young female) appear displaying a real-time generated animation of a facial expression with certain intensity (weak, medium, strong) and speed (very slow, slow, moderately slow, normal, moderately fast, fast, very fast) (Fig. 2(2)). Then, a screen with white noise ((Fig. 2(3)) appears for 0,5 seconds, loading participants' iconic memory with task-irrelevant information. Finally, a screen with the answers options represented by emotional labels is shown (Fig. 2(4)). Here the user needs to select the one corresponding to the expression that he just saw. In order to select an emotion, each of the basic emotions were mapped to a number between 1-3 and 7-9, which was then selected using the numeric pad of the keyboard. The reason for not using the row 4-6 was to allow space between the fingers and avoid experimental errors by inadvertently pressing the wrong key. The pairing emotion-number is done randomly each time the test is carried out.

For the SARA project, three versions of the DECT have been planned. The first version, R-DECT was implemented and executed in the context of a pilot study to assess "Rapid Social Cognition" of children and adolescents with ASD. The innovation

3 http://sourceforge.net/projects/frapper/

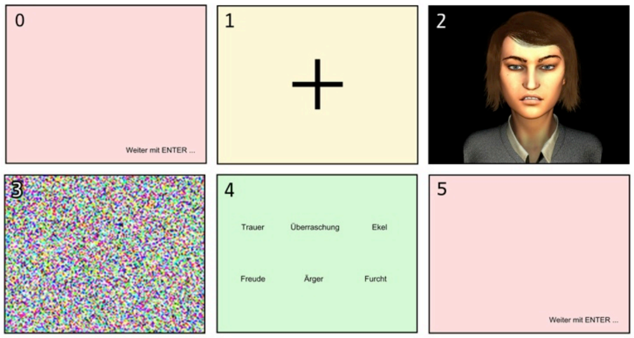

Figure 2: Screens of the DECT: (0) Initial screen, (1) Fixation Cross, (2) Character with an angry expression, (3) White noise, (4) Forced choices with emotion names, (5) Initial screen for next trial.

of this test was the random presentation of real- time animations of facial expressions with different speeds (going from normal to very fast) and intensities (weak, medium, strong). The R-DECT served also to validate the improved facial animation from the first DECT, as well as to validate the test itself as a tool for the interactive categorization of emotional expressions.

The second version called NPR-DECT comprises one of the novelties of our project: the use of NPR algorithms to abstract and manipulate visuo-spatial information in the faces of our virtual characters. It not only constitutes a way to reduce information load in the characters' facial expressions, but also a way to include more artistic approaches to investigate how these abstractions affect the recognition of the facial expressions of emotions, in comparison to their more realistic representations. Figure 3 shows different facial abstractions to be tested in the NPR-DECT.

Figure 3: NPR styles. Left to right: original, pencil drawing, watercolors, line drawing, loose & sketchy.

The third version called i-DECT is the one with the highest interactivity, stimulating a visual interaction between the participant and the virtual character. This test will study the differences in eye contact and mutual gaze between neurotypical subjects and subjects with ASD. It is worth mentioning that the interactivity to be achieved in this test is possible thanks to the real-time characteristic of our frame- work, providing flexibility and opportunity for more elaborated interactive experiments.

Another level of interaction that plays a main role is the one of the experimenter with the test. Having a tool that generates animations and visual representations in real-time allows the psychologists and experimenters to fine tune and parameterize the tests themselves according to their requirements, or the participant's needs. This flexibility makes them independent from the animator, an important aspect to consider when using a computer-based research tool.

5. EVALUATIONS

Until now we have evaluated the R-DECT, and partially the NPR-DECT with neurotypical participants.

5.1 R-DECT

Participants of the experiment were 39 adolescents with ages between 14.0 and 17.9 years and IQ ≥ 70. The group of neurotypically developed adolescents (NTD group: n=22) consisted of 18 males and 4 females. The group of individuals with high-functioning ASD (ASD group: n=17) consisted of 12 males and 5 females. The R-DECT consisted of 2 (characters) x 6 (basic emotions) x 3 (intensity levels), resulting in 36 animations. Regarding the speed variable, it was assigned according to a certain scheme to each of the 36 animations, ranging from 1 (normal speed) up to 2.25 times of normal speed. In total, six levels were used (1.00, 1.25, 1.50, 1.75, 2.00, and 2.25).

In total, 62.2% of the animations were categorized correctly. Accuracy rate for the NTD group was 65.7 % whereas for the ASD group was 57.7%. A 2x6 MANOVA with repeated measurements showed no significant interaction between group and basic emotion ($F < 1$). However, the two main effects were significant (basic emotion: $F(5,33) = 77.63$, $p < .0001$; group: $F(1,37) = 5.36$, $p = .026$), indicating that the ASD group performed significantly worse than the NTD group (Figure 4). The order of accuracy for basic emotions was the same for both groups, being "happiness" the one recognized with the highest accuracy and "fear" with the least. However, all post-hoc comparisons did not reach statistical significance. As for the intensity of facial emotions, we only considered the NTD group where typical facial emotion recognition is expected. The results showed that in general varying intensities from weak over medium to strong affected accuracy rates correspondingly: Weak: 59.5%, Medium: 65.5% and Strong: 72.0%.

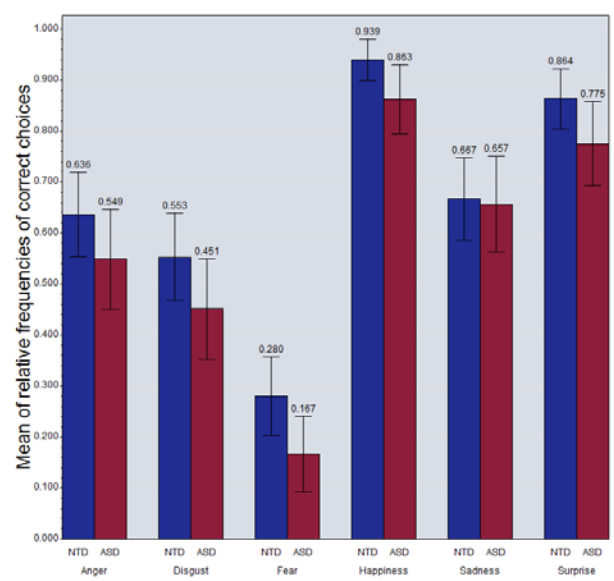

Figure 4: Mean of relative frequencies of correct categorizations of six basic emotions in ASD and NTD groups. Error bars represent 95% CI.

5.2 NPR-DECT

Participants of the experiment were 31 (9 male, 22 female) neurotypically developed psychology students with an age range from 20 to 35 years. The NPR-DECT comprised 2 (characters) x 6 (basic emotions) x 13 (1 + 12 NPR style x abstraction combinations) = 156 trials, which were presented in a pseudorandomized order. The NPR styles: coherent line drawing (CLD), pencil drawing (PD), image abstraction (IA) and watercolors (W) were instantiated in one of three levels of abstraction (low, medium, high). During the whole NPR-DECT session participants' gaze was tracked by an RED-250 eye tracker (SMI), which API was integrated in Frapper to allow the communication between each other.

In total, 71.4% of the emotional expressions were correctly categorized. However, we found a considerable difference of accuracy between both characters (Hank: 66.5% vs. Nikita 76.3%). Differences in levels of accuracy seem to be dependent on the character in a certain style with a certain level of abstraction. The lowest percentage for Hank was obtained with the CLD - high abstraction (55.9%), whereas the high- est percentage was with W - medium abstraction (73.7%). The lowest percentage for Nikita was obtained with the PD - high abstraction (71.5%), whereas the highest percentage was noted for both IA - low abstraction (81.7%).

As for the recognizability and likeability of the abstracted faces, they were measured through a computer-based questionnaire with 26 images of the two characters, stylized by the four NPR styles in three levels of abstraction, plus the original photorealistic representation. For each image, two questions were posed: (1) How good were you able to recognize the emotions from this representation? (2) How good did you like this representation? For each question, the answers were presented in a 7-point Likert scale ranging from very good ("1") to very bad ("7"). On average, recognition ratings were best for the original representation (mean = 2.02), followed by IA (mean = 2.44), CLD (mean = 3.69), W (mean = 3.73), and finally PD (mean = 4.17).

6. CONCLUSIONS

We have presented the ongoing research project SARA and the tests that have been implemented so far to assess the categorization of emotional facial expressions: R-DECT and NPR-DECT. In their current status, both are more a re- search tool than an intervention tool. Therefore, the interaction with the tool has not been exploited to its maximum. Results have shown that there is a significant difference in the categorization of emotions between the NTD and ASD groups, being the latter the one that performed the worst. However, it was not possible to say which emotion(s) contributed to this general difference. As for the NPR styles, no decisive conclusions were achieved. At the end of this project it is our goal to distribute all DECTs as a open-source tool. Moreover, based on the results obtained with SARA we will create new interactive applications or tests considering HCI elements, taking advantage of the NPR elements and artistic abstraction techniques.

7. ACKNOWLEDGMENTS

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Model for Analysis of Serious Games for Literacy in Deaf Children from a User Experience Approach

Sandra Cano
Universidad del Cauca
Grupo IDIS
Sandra.cano@gmail.com

Jaime Muñoz Arteaga
Univ. Autónoma de Aguascalientes, México
jmauaa@gmail.com

César A. Collazos
Universidad del Cauca
Grupo IDIS
ccollazo@unicauca.edu.co

Viviana Bustos Amador
Univ. Autónoma de Aguascalientes, México
ic.viviana.b@gmail.com

ABSTRACT
Learning to read and write, or acquiring skills in literacy, is a basic educational need. Deaf children traditionally face greater challenges and encounter difficulties particular to their abilities. Their inclusion today in regular schooling places much responsibility for their success on the support teachers designated to provide them with the assistance they need. More and more however, ICT is being used in the field of education. Video Games offer a first class option for generating meaningful learning experiences, and serious games in particular are employed in class to motivate learning. The design of serious games to meet the needs of teachers where deaf children are struggling to master literacy would therefore seem to offer a hugely important contribution. Based on the User Experience approach, a model is therefore put forward for the design of such a serious game. The model assesses the quality of the game and the user experience from others proposed games and examines the aspects that are important for creating a game in this case that can help teachers as support for the learning of both deaf and hearing children in the acquisition of reading and writing skills.

Categories and Descriptors
H5.m. [**Information interfaces and presentation**] (e.g HCI): User Interfaces

General terms
Human Factors, Design, User Experience.

Keywords
Serious games, Tablet App, Deaf Children, User Experience. User Profile.

1. INTRODUCTION
Information Technologies are transforming education. Serious games are being used as an alternative tool for generating meaningful learning experiences. The video game now plays a fundamental role in psychological development, learning, and in the emotional and social aspects in children. Video games help stimulate cognitive skills such as visual attention span, decision-making, visio-motor coordination and reasoning, so that these games, could quite well support the development of children's learning in many different contexts.

Visualization is a valuable communications tool that involves a variety of graphical aspects that can be used to represent knowledge in the teaching of pronunciation [46]. Various research works [23] [24] [28] [37] consider video games as an important educational tool able to foster a range of skills and development capabilities in learning in children. Other studies meanwhile [25] [36] have applied serious games to literacy as a form of support that enables children to improve their reading and writing skills, while motivating their learning. Literacy difficulties arise as a common special educational need in children most commonly by means of dyslexia[4] and dysgraphia[5]. In deaf children this difficulty represents a real challenge, since through their hearing loss they have great problems in the acquisition of written language and reading comprehension, resulting in limitations in language proficiency at the lexical, syntactic and semantic levels [27].

Recent studies have shown that games have positive effects on visual skills and working memory skills [34] [35]. Games are considered serious when they strikes a balance between the educational and simply entertainment [20], so the challenge for a new serious game is to meet its objectives based on these two scenarios.

Before defining the scenario of a serious game the different components that can influence user experience must be analyzed to understand how to create a positive experience for the user when interacting with a serious game in a specific context, and in turn, which factors allow selection of the qualities of serious games to match user aspects. *User eXperience* (UX) can be understood as the set of sensations and emotions that occur in a user on interacting with the serious game. Arthippainen & Tähti [10 define it as the experience that a person lives when he or she interacts with a product in particular circumstances. *Hassenzah & Tractinsky* [13] meanwhile define it as a consequence of the internal state of the user (biases, emotions, motivation, needs and mood), some characteristics of the system (complexity, usefulness, usability, functionality, among others) and of the

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[4] Language difficulties that render proper comprehension unattainable

[5] This is used to design the disorder of writing that affects the shape or content and is seen in children who do not show intellectual, neurological, sensorial, motor, affective or social problems.

context in which the interaction takes place. Elsewhere, Dillon [26] proposed a simple model to define user experience as the sum of three levels: *action*, that which the user carries out; *result*, what the user gets; and *emotion* (what the user feels). Using these definitions it is important to consider such aspects as graphical interface, challenges, goals, rules, etc., which are able to convey a positive user experience, but which in turn may vary according to the aspects of the user and the context of use.

This paper presents a model for designing a serious game from a user experience perspective for a case study applied to deaf children experiencing difficulty in literacy learning**.** The proposal of the model is that it can provide support for identifying the needs of the child with auditory discapacity and the teacher starting with the analysis of a set of existing serious games that are adapted for the use context in reading and writing. This analysis includes identifying aspects to be taken into account with the aim of creating a positive experience in literacy learning, to measure the quality of the game as educational material. The needs identified will be useful in extracting the requirements for the production of a serious game applied to deaf children in learning literacy. Section 2 provides a brief description of the problem faced by teachers in literacy learning for deaf children. In section 3, reference is made to the importance of the inclusion of serious games as educational material. Section 4 describes the user experience model in the context of literacy learning. In section 5, the user experience model in the context of literacy learning for deaf children in a school in Mexico. In Section 6, attention is drawn to research related to lines of user experience research and literacy using serious games. Finally, in Section 7 a number of conclusions and future work areas are presented.

2. PROBLEM OUTLINE

The program run in Mexico by the Regular Education Support Services Unit (USAER from the Spanish acronym) is a system of support services for regular schools, intended to encourage access and improve the performance of students with disabilities and outstanding skills integrated into regular school. In USAER [45], the role of the support teachers is to educationally integrate children with Special Educational Needs (SEN), with or without disabilities. Support of teachers use different strategies in literacy learning, and interest has grown in combining their activities with ICT as another way for children to improve and strengthen their skills in reading and writing. Management of ICT therefore requires new skills from support teachers to link the various tools within the learning strategies.

Today there still are many complications for deaf children as their main communication channel is sign language and there is a need to teach them how to communicate through reading and writing to be able to play their part in the wider society. They have difficulties learning spoken languages, and this becomes a challenge for reading comprehension and written language. Written language following after sign language is the most accessible way to get the information to enable them to be aware of what is happening around them.

Deaf children further, fail to develop skills at the same pace as a hearing child, making it difficult to identify problems in the development of their basic cognitive skills and this may affect progress in the acquisition of learning. However, they have a better developed visual attention capacity [34], [35], so teachers are using tools accompanied by images and texts as a communication channel to convey the extraction of meaning of a concept. As such, teachers require play-based tools that can motivate children in their learning and that can integrate them within their educational planning.

Besides, the serious games currently available do not meet all the needs of the deaf child with learning difficulties in literacy, since they are designed for hearing children with learning difficulties in literacy and have not taken into account that children with cognitive problems, such as ADHD[6], cognitive deficit, among others. As such, these cognitive problems that may arise in deaf children ought to be considered in assessing a set of aspects in the serious game. However, the deaf child by default has problems in cognitive development and to have some other deficiency can result in a greater challenge to learning literacy, which indicates that he or she may become frustrated and demotivated more quickly.

3. SERIOUS GAMES IN LITERACY LEARNING

Games promote the overall development of the child, as they allow the testing of rules, capabilities or limitations that can then be explored in real situations. A number of researchers in the field of pedagogy and psychology [1] [2] have proposed serious games that exist in the market and have studied how these games can be seriously used in classroom to support the educational process. One of the factors contributing to the success of these games for children is the motivation component, which is a crucial condition for the success of the children in their tasks, where they face challenges of learning while they play.

A hearing child develops language skills through sounds (sound-letter-word-meaning), which relates letter to sound to find the lexical component. A deaf child cannot depend on the same educational strategy, learning instead only sound-word. Schools are choosing pedagogical models that fit the characteristics of the child as well as aids that promote literacy learning in deaf children [27].

Serious games allow their participants to experiment, learn from their mistakes and gain experience safely. Serious games today are actively applied in the area of education, with the aim of learning, understanding and communicating a specific activity. It is therefore possible to make the most of the situation and enhance the use of serious games in order to help in encouraging the development of reading and writing skills in deaf children, and support teachers can in turn integrate them as educational material in their planning.

A number of researchers have conducted studies related to user experience that have suggested ways to make the game more fun, increasing the motivation of the player. In 2008, [8] proposed four keys for user experience. These are: analyze what the player likes to play, heighten emotions without making use of the story, analyze the most successful games, and apply psychological techniques for developing the personality of the characters in the games. Using the four keys, four types of user experience based on emotions are proposed. These are: Hard fun, Easy Fun, Altered States, and People Factor. In [9] a set of aspects were formulated that could help to improve motivation in the user experience.

[6] Attention Deficit Hyperactivity Disorder is a developmental neuropsychiatric disorder in which there are significant problems with executive functions (e.g., attention control and inhibitory control).

These are: challenges, curiosity, control, and fantasy. In 2009, [43] using existing frameworks for designing educational games proposed a framework for designing educational games, taking account of the pedagogical side and the content of the model. In 2010, [44] proposed a user-centered design method for serious games that involves three aspects: interactive design, evaluation, and validation that ought to be taken into account and are necessary in the different stages of design of the serious game. The model proposed has the following phases: research, validation, design, and implementation.

Elsewhere, [5] made a Tablet app for children with dyslexia, where the exercises are tailored to the specific difficulties of the player. Tests were also performed with children where they confirmed that the game is fun and more attractive compared to traditional activities. Further, in [27] the authors outline problems that teachers face in teaching literacy to deaf children, which involve pedagogical models that fit the characteristics of the child and in turn display all the aids that favor literacy learning in deaf children.

4. CONCEPTUAL MODEL

A model for the design a serious game is proposed, which involves user experience in evaluating a set of serious games for learning literacy. In the evaluation, aspects are identified that meet the needs required for the design of a serious game for literacy learning with deaf children are identified. The model (Figure 1) is composed of three elements. These are User, Learning strategies, serious games. The proposed model considers user responses obtained from hedonic attributes [14], pragmatic attributes [14] on interacting with the serious games, game responses on managing to communicate/transmit literacy learning, utility of serious games as educational material and adaptation of learning strategies incorporated in serious games according to the characteristics of user. Research methods (interviews, questionnaire and observation) are also applied with each specific game for each child according to needs and level of literacy learning found. The model identifies user characteristics to determine which game can adapt according to the user attributes in: learning level, age, genre among others. Learning strategies are then established, and in a further stage a set of serious games aimed at learning of literacy is selected and different aspects of user experience are evaluated, by which means information is obtained and problems identified to be transformed into new pedagogical objectives/entertainment to be accomplished which are reflected in a final stage responsible for designing a serious game. The methods are applied in order to obtain information about the user, their needs and so translate them into indispensable requirements for the use of the game.

When speaking about a game, it is not just how useful or usable it can be [14]. Other factors can be included, such as the capacity for recreation of a virtual world, story, character design, how the player feels, the rules of the game, and so on. The experience of a user can be widened compared to a traditional interactive system, which obliges greater reflection on properties that identify and measure these experiences.

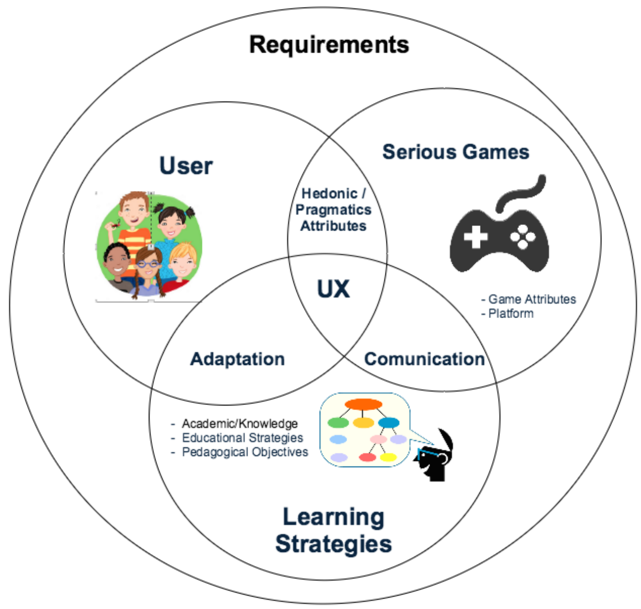


Figure 1. Model for the analysis of serious games to support literacy learning for deaf children, from a UX approach.

Using research techniques (questionnaires and observation) aspects are identified that can influence the experience with the serious game in its context of use, such as literacy. These aspects are: profile of deaf child, serious game-child interaction, quality attributes of serious game, usefulness, hedonic qualities (emotions, needs and motivation), and learning.

A description of elements that include the model:

4.1 User

The user is the person who will be using the game as a support for learning, so it is important to understand the needs of the student as well as those of the teacher. At this stage, therefore, it is advisable to apply research techniques in order to identify characteristics particular to each including for example concentration span, ability to express an experience, gender differences, experience of technology, cognitive abilities, and emotions. At this stage it is important to know the user profile to identify issues that could affect their experience of using the game. Aspects defined in the user profile are *name*, *age*, *gender*, *academic year*, *skills/abilities*, *physical/cognitive disabilities*, *learning level*, *emotion* and *motivation*. These features were selected from a previous study of investigations carried out [47] [48] [49] which have proposed a set of features for building a user profile in an academic context.

Table 1. Aspects for defining user profile.

Aspects	Description
Personal data	Involves important data that can act as a support to define the needs and learning level. These are: Name, Age, Gender, and Academic year.
Skills / Abilities	Discover skills that can be taken into account in establishing learning strategies.

Disability (Physical/Cognitive)	Involves physical disability, which is hearing-related, such as hearing loss (Mild, Moderate, Moderate-Severe, Severe, and Profound), but in turn is related to a cognitive impairment that can occur in children.
Learning level	This is related to literacy levels, these are: Pre-syllabic, Pre-syllabic-Syllabic, Syllabic, Syllabic-Alphabet, and Alphabet.
Emotion	These are the reactions that can be detected in the children on interacting with the technology to carry out their educational activities.
Motivation	These comprise determined actions the child carries out and persists with them until complete.

The user profile is therefore a representation of a set of attributes that describe a person, in this case the deaf child in his or her role as user on interacting with the games, so that they are adapted to the characteristics of the child and can be associated with the learning strategies.

In turn, the user is an input into the model since he or she interacts with the product and a number of results are obtained, such as the emotions the game might inspire. These emotions may be negative (frustration, stress, anger or boredom) or positive (joy, interest or fun). Using an analysis of the processes defined by [28], certain factors are included to be taken into account, such as anticipation, expectations that the user may afford the product, the connection as the first experience of using the product, the first reactions to the interaction and the interpretation that includes the sense that the user gives to his or her interaction with the product.

4.2 Learning strategies

Support teachers use strategies so that the child acquires knowledge and skills related to literacy. Within the strategies, the support teachers establish a set of support resources and educational techniques, included among these ITC mediated by games. The type of strategies used by the support teacher are support strategies, whose interest is to establish motivation, focus attention and concentration, and manage the time for interacting with the game.

The teacher performs activities that depend on the level the child is at in literacy learning. These activities depend on the fulfillment of educational goals to be achieved with the child. For this reason, the support teacher develops educational strategies that may involve use of a Tablet in activities for each child. Using different educational games, the experience that influences the teacher and the child are analyzed. Educational strategies where serious games are incorporated like support material for the literacy learning are developed. The support teacher carries out these strategies, he is who decides which game is best suited to form part of the activity. Such a selection process takes into account the level of literacy of the deaf child, expected knowledge, and the child's profile. It can also be said that this pedagogical scenario should be adapted to the profile of each child and the serious game must in turn establish a communication with the pedagogical scenario in such a way that it enables the child to acquire learning.

4.3 Serious Games

In this stage, it is proposed to use a set of serious games aimed at learning to read and write, according to the needs of each child. To select whether a game has a serious approach and can be applied to learning literacy the following attributes should be considered: objectives to be achieved, literacy level, and previous knowledge. In this stage it is proposed to conduct for each game a cognitive walkthrough test [29] with the help of the teacher to select one or more serious games that can support the process of literacy learning and that the teacher can integrate in the learning activities for deaf children.

A set of attributes (Table 2) is proposed in order to analyze the quality of the serious games to determine if they meet both educational and entertainment purposes, i.e. if there is a balance between motivation and learning. Therefore, if it is desired to keep the child motivated, he or she should be informed of the progress of the activity (Feedback), and there must be a balance between the levels of difficulty (Challenges) with respect to the level of ability of the child to achieve the objectives. Attributes that may affect the ease of use of a game are also identified, because for a deaf child the result may be different from that of a hearing child.

Table 2. Attributes for measuring the quality of serious games in learning literacy.

Attribute	Description
Challenges	Levels of difficulty in reaching targets. Challenges can add to the fun and the competition [19]. This attribute is related to the difficulty level, and in turn will lead to achieving the goal.
Rules/goals	The rules are the objectives of the game established in order to win, which is very important in the learning part. There are three types of rules. System rules (inherent in the game), procedural rules (actions in the game to regulate behavior), imported rules (rules oriented to real world situations).
Feedback	Display each of the actions carried out. The indications can be visual, audible or tactile. [19]
Assessment	This measure compares the performance between players. This can be identified as a measure of achievement. [20]
Surprise	Random elements within the game [21]
Interaction	Adaptability and manipulation of the game, where the game changes in response to player actions [22].
Fantasy	The environment through which the game, setting, and characters are developed, which involves the player [19].

Usefulness and usability influence the experience of the product. For this reason, it is sought to evaluate each proposed game using a usability test, where such attributes are taken into account as effectiveness, efficiency, satisfaction, emotions, and learning.

4.4 Requirements

On analyzing all the aspects that influence user experience, information was obtained on different factors such as the profile of the deaf child, educational objectives, learning scenarios, entertainment strategies, etc., that will be useful for proposing the design of a serious game to help improve literacy learning in deaf children.

5. CASE STUDY

The case study was carried out in Mexico in the USAER school in Aguascalientes, a school that enables children with hearing impairment to be included in regular secondary schooling. The deaf children here are aged from 12 to 15 and have problems in learning literacy. Using research techniques, including activities, such as observations, interviews with the teachers, and questionnaires, information is obtained on every child in order to discover the needs and level of literacy learning. Using the proposed model comprising four elements - user, learning strategies, serious games and requirements - a brief description is made of each element applied to the case study.

5.1 User

An evaluation to discover the profile of the deaf child was performed on the Likert scale with a score of 1-5. It was decided to evaluate the following aspects: *attention span, visual perception, visual memory, comprehension, spatial orientation, visual discrimination, social environment, learning level and degree of hearing loss*. Figure 2 shows the results of an inquiry evaluation conducted with six children with hearing impairment. Five are boys in high school and one is a girl in elementary school. Of the children assessed, 4 of them (Child 2, Child 3, Child 4 and Child 6) have a profound level of hearing loss (91-119db), so that their main channel of communication is sign language; Child 1 has a severe level of hearing loss (71-90db) and uses a hearing aid; while Child5 has a moderate level of hearing loss (41-55db). Both Child 1 and Child 5 use speech as their main means of communication.

The aspects evaluated indicate that the children have skills for acquiring learning but that their hearing impairment makes obtaining any level of learning difficult. Furthermore, it is observed that Child1 has low skill levels since he is unable to distinguish very much and this is because, in addition to having a hearing impairment, he has a disability known as ADHD (Attention Deficit Hyperactivity Disorder), which makes learning slower compared with the other children.

The girl meanwhile, Child 6, has low skill levels in such aspects as spatial orientation, comprehension and visual memory. She is unaware of many semantic concepts, leaving her in a low level of literacy compared to other children in the school. In the observations obtained, it is noted that the support teachers use visual aids in their educational strategies to convey the different concepts that are associated in the meaning of a word or sentence. visual.

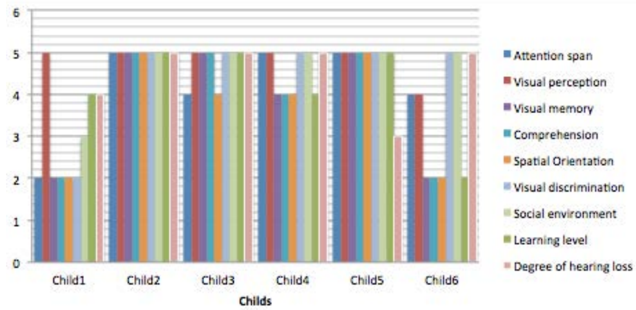


Figure 2. Results of the inquiry evaluation to determine the level of skills/abilities, hearing loss, and literacy, learning literacy for each child.

Of the children assessed, four are in the alphabetic literacy level and the other two at syllabic level. These deaf children are at a low academic literacy level compared to a hearing child and according to their academic grade. Therefore, they make less use of the phonological code because of the difficulty of uniting sounds with letters. They are able to use this code when graphic information is presented, though never reaching the levels of a hearing child due to the fact that they are faced with the difficult and complex task of memorizing vocabulary and if they come across a new word they will not understand its meaning until it is displayed graphically.

From the information obtained, a user profile is built for each child, paying attention to the attributes proposed in Table 1. The attributes, obtained from the inquiry test include *personal data, skills/abilities, learning level* and *physical/cognitive disability*. The attributes of *motivation* and *emotion* meanwhile are obtained by observing each child as they interact with the serious games. The emotions shown by the children were positive, as can be seen in Figure 4, however Child 1 with his ADHD suffered some frustrating moments when he did not receive an immediate response to his actions or when he could not complete actions carried out with a game because it had a high level of difficulty. The support teacher must involve the game in their planning as educational material, so it is necessary to adjust their educational strategies in order to integrate the game in their activities as well as to assess the learning impact of the incorporation of the technology. It is further important to take into account that the learning material must be supported by a visual communication able to capture the attention, in order to motivate learning.

5.2 Learning strategies

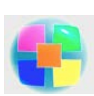
The support teacher carries out a planning strategy around the process and techniques to be used with each child, where every strategy has educational goals to be reached. This component takes place in the context of their use for teaching literacy, so that what is sought here is that, for each child, one or more serious games proposed is suitable to meet the level of literacy and skills. Support teacher must involve the game in their planning as educational material, so it is necessary to adjust their educational strategies in order to integrate it in their activities as well as to assess the learning impact of incorporating of the technology. It is further important to take into account that the learning material must be supported by a visual communication able to capture the attention, in order to motivate learning.

5.3 Serious Games

A search performed for games for Tablet applied to literacy learning produced 20 games able to be applied to such learning. The games proposed are for use only with Tablet, since children showed a better response, being more motivated to work with a tablet than with a computer.

Using the technique of cognitive walkthrough for each proposed game, the game's capacity to support learning was evaluated with the help of the teacher. The evaluation enabled five games to be selected for incorporating into the educational activities for each child. The games proposed are described in Table 3. These operate on Tablet Android and are applied to the deaf children in order to assess pragmatic attributes such as utility and usability and hedonic attributes such as emotions and motivation. For each child a usability test was applied to assess such aspects as *effectiveness, efficiency, satisfaction, emotions* and *learning.*

Table 3. Games selected for teaching reading and writing.

Game	Description
ABC Español 	Educational app for learning the meaning of different concepts, where an image is associated with the text [38].
Learning to read and write 	Educational app that helps in learning early words, as well as in understanding the basis for intuitively deciphering the meaning of new words [39].
Easy Fun Spanish 	Educational app for learning Spanish language concepts. This is contained in a range of activities as progress is made, with the aim of learning and memorizing the concepts [40].
Communication book 	App offering an alternative or augmentative communication system based on pictograms. Works with Fitzgerald keys, where grammatical categories are associated with colors [41].
Pictogram 	Augmentative and alternative communication app that comes accompanied by images and text [42].

The five games to be integrated into the learning strategies the support teacher comprise: three games used in the Syllabic and Alphabet levels of literacy (ABC Spanish, Easy Fun Spanish, and Pictogram) where the goal aims at teaching concepts in extracting meaning, and two games oriented to the Syllabic (Learn to read) and Alphabet (Communication Book) levels, beginning with an analysis of each of the proposed games where the attributes defined in Table 2 are applied, shown in Figure 3. It can thus be seen that the *fantasy* attribute was not achievable in any of the five games, since there is no character that the children can identify themselves with, nor a story that integrates the activities. Also the activities available in the games are not random, i.e. after playing the game several times it can become very repetitive and can cause the child to become demotivated. It can also be noted that some of the games have no difficulty levels, so that when faced a very high level challenge the child wants to stop playing and when it is too low, it results in boredom.

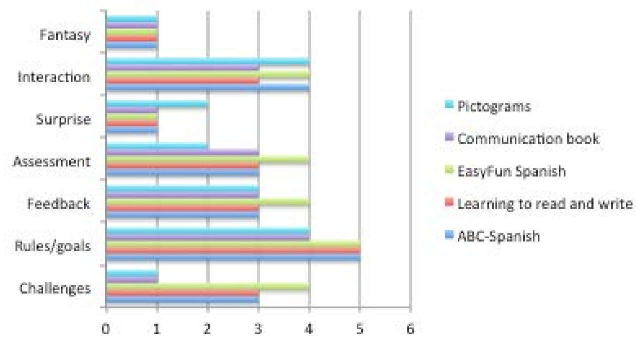


Figure 3. Results of assessing each attribute defined in Table 2, applied to each game.

To assess the experience of children on interacting with the games, a usability test was conducted using the observation technique. The game proposed for carrying out the analysis is ABC Spanish [38], since it is used in all the literacy levels. The objective of the game is to convey the meaning of words, and that is what the children need to improve their reading comprehension. Figure 4 shows the results produced using an instrument to determine the degree of acceptance of the game for the child, as well as its success as a learning tool. The test consists of a total of 50 questions, structured based on the QUIS [30], USE [31], GEQ [32] and UEQ [33] questionnaires, taking into account the effectiveness, efficiency, satisfaction, emotions and learning attributes.

The results obtained with the ABC Spanish game (Figure 4) show that the game is helpful in learning to read and write, but offers no feedback when the user fails to type the word correctly or does not know the word. In both cases it is not possible to proceed with the next word. Neither does it include an assessment within the activities, which robs the teacher of any quantitative support for the learning level. It was also noted that the vocabulary provided by the games contains words that are different to Mexican Spanish words for example for *peach*, *tennis shoes*, *jacket*, *t-shirts* among others meaning that some activities contained in the game are left out.

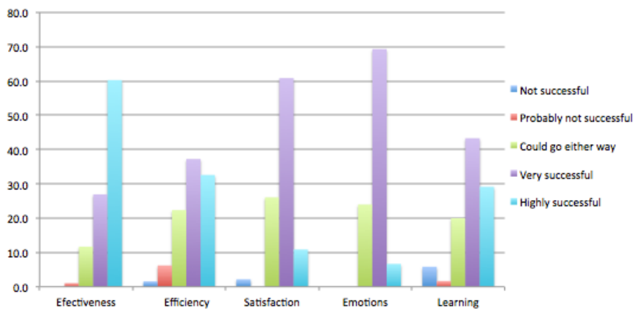


Figure 4. Usability test applied to the ABC Spanish game.

The *learning* attribute is related to the *motivation* attribute, implying that if the child experiences a low level of learning, the game should convey the concepts (objectives/rules) clearly enough to learn without effort so that the child feels motivated and has the confidence to face the various challenges posed by the game. In Figure 4, a value of 43% achievement is obtained, with respect to questions relating to assessment of the *learning* attribute. This is because when carrying out the activity of completing a word through writing, the game does not allow for steady progress if the activity is not performed correctly, nor offer any help to progress. This means that if the user cannot come up with the correct spelling of the word, they cannot pass to the next activity, resulting in a frustration in the child that may diminish the motivation to continue playing.

Easy Fun Spanish, on the other hand, has the same pedagogical goal as ABC Spanish, but contains more vocabulary and activities, leading support teachers to use it when they need to further extend concepts of meaning and reinforce more activities that enable the child to memorize the spelling of words, i.e. when they want to increase the level of difficulty in terms of linguistic competence. There is also Communication Book, which applies a methodology called FitzGerald keys. It is used for the teaching of language and grammar rules with deaf children. Through a set of categories, the child has to learn to string together words to form a sentence, beginning with whom, how, where, or when. The results in Figure 3 show that in the *challenges*, *surprise*, and *rules*/*objectives* attributes, the game has low values compared to the other games. This is because it does not assess the child or offer challenges to solve the activities. It functions more as a communication board, but no responses are obtained as to whether the action was right or wrong.

5.4 Requirements

After obtaining the results of the usability testing for each serious game and carrying out an analysis of it, it can be said that needs were identified and using these needs a set of requirements has been generated that will be used as a starting point for developing a serious game in literacy learning. The analyzed games tend to be more educational than entertaining. The need therefore arises to design a serious game taking into account the characteristics of deaf children, as well as aspects to be included in a serious game (Table 2), which in turn enables the generation of challenges in the children, with the aim of motivating them to achieve the educational objectives. It also requires the game to assess the child in each one of the activities. This can help the support teachers keep track of the activities and progress of the children in their learning. Support teachers currently use FitzGerald keys [6] in literacy learning for deaf children. This is a visual tool for organizing oral and written language. It is used to teach, practice and correct syntactic structures of the oral and written language. When the review of games for Tablet was conducted, few games were found that applied the keys. Of those selected, Communication Book does so (Table 2). However it also brings problems in the vocabulary, containing many concepts that are not the same in Mexican Spanish, while the structuring of categories is not very understandable for a child who is learning literacy. It also fails to keep track of the activities and achievements.

The proposed model therefore leads to identifying the needs and requirements of support teachers in learning literacy for deaf children. Already defined at this point are the following aspects to consider when designing a serious game (Figure 5) that meets the needs of teachers for a specified use context. Figure 5 shows the proposal for a non-functional prototype of the game, based on the previous stages and integrating FitzGerald keys, where some features that integrate both the educational and entertainment scenarios will be met, such as *challenges (difficulty levels), surprise, evaluation, fantasy, learning, feedback* and *rules/objectives*.

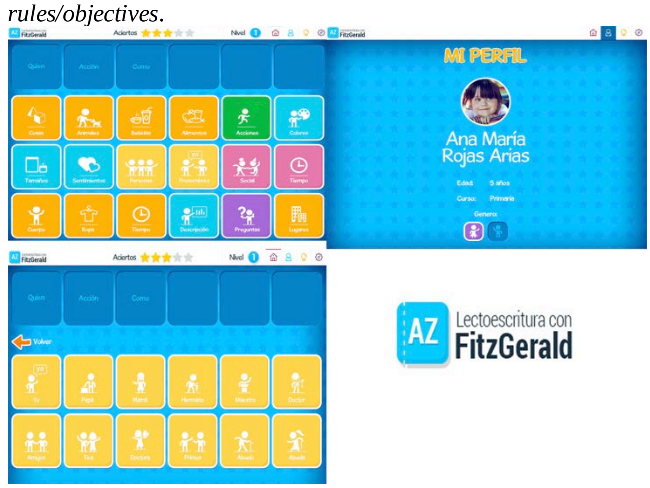


Figure 5. Proposal for a graphical interface for a serious game in literacy learning for deaf children according the requirements.

6. CONCLUSIONS AND FUTURE WORK

The process of identifying words by deaf children is slow and laborious, so they often make mistakes, such as substitution, omission and distortion. With the inclusion of ICT through video games in literacy activities, the desire is to motivate these children in their learning and in turn enable them to develop other skills. The video games proposed were shown to be an alternative for literacy learning for deaf children, where teachers can incorporate information technology as an educational material.

Furthermore, it can be seen that the games included in activities do not each perform a single function, and that in some cases they fail to meet all the needs required by the support teacher. The analysis model for serious games for learning literacy is useful for identifying aspects of user experience, content and product, through which it is possible to analyze in detail different factors that can be considered for the proposal, as future work, of a game that can be adaptable to the child profile and which in turn enables the assessment of the activity and benefit from a constant feedback of the actions carried out on interacting with the game.

The majority of the serious games assessed aim to enrich the meaning of concepts for the child, which is very helpful for them to have a better understanding of reading. However, they need more games that can serve as support to complement the methodology followed for the child to expand their repertoire of syntactic structures and learn the logical order of a sentence. It is also important to note that support teachers use only one or two games as educational material, so that it is not ideal to offer a game for each specific objective to be fulfilled. They therefore need a game that integrates the activities they undertake following the FitzGerald keys and which in turn allows them to assess the learning through different activities that help increase the semantic repertoire, since a single activity does not guarantee dominion of a subject, just as the number of activities required is not the same for each child.

The analysis model can deemed to have been useful for identifying the relevant needs both of support teachers and deaf children. The participation of children and their support teachers has enabled pedagogical aspects to be identified: learning curve, clear objectives, a clear progression, assessment, and support, which are important aspects to consider in designing a game.

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Uso de Aplicaciones Interactivas para Apoyo a la Escritura en Niños con Problemas de Aprendizaje

Jaime Muñoz Arteaga
Univ. Autónoma de Aguascalientes
Av. Universidad. #904
Aguascalientes, México
jmauaa@gmail.com

Dulce Morales Hndz
Univ. Autónoma de Aguascalientes
Av. Universidad. #904
Aguascalientes, México
dmmhdz@gmail.com

Ricardo Mendoza
Ins. Tecnológico de Aguascalientes
Av. Adolfo López #1801
Aguascalientes, México
mendozagric@yahoo.com.mx

Carina S. Gonzalez
Univ. de la Laguna
Avda. Astrofísico Fco. Sánchez s/n.
La laguna,Tenerife, España
cjgonza@ull.edu.es

RESUMEN.

En la actualidad, los problemas de aprendizaje en la población latinoamericana se han incrementado a un ritmo considerable, tal es el caso de México, donde se han realizado diversas estrategias para mitigar la diferencia que exista entre los alumnos regulares y aquellos con problemas de aprendizaje. Debido a que los problemas de aprendizaje se han diversificado, es imposible atacarlos desde un solo punto. Una de esas variaciones, son los trastornos de aprendizaje en la escritura. Como una solución alternativa se propone el uso de las aplicaciones interactivas para dispositivos móviles como recurso de apoyo en la estrategia docente para el área de escritura en alumnos con problemas de aprendizaje.

PALABRAS CLAVE.

Aplicaciones Interactivas, Dispositivos Móviles, Problemas de Aprendizaje, Escritura.

1. INTRODUCCIÓN.

En general, en una sociedad se presentan constantes cambios que requieren de una respuesta por parte de la tecnología. Actualmente, la necesidad de constante movilidad por parte de las personas ha motivado el desarrollo de una herramienta tecnológica muy útil como lo es el dispositivo móvil. El dispositivo móvil por definición, es aquel dispositivo que se usa fuera de una posición fija y que ha sido manufacturado específicamente para ser portátil y útil mientras se está en movimiento [1].

En la actualidad, los dispositivos móviles gozan de un gran número de usuarios, conforme un estudio realizado en 2014 por iabmexico.com tan solo en México el 84% de la población contaba con un dispositivo móvil. Un dispositivo móvil puede ser un teléfono celular, tablet's, PDA´s, smarthphones, entre otros. Cabe mencionar que el uso de los dispositivos móviles es muy variado, pueden realizar diversas tareas relacionadas con el entretenimiento, conectividad, actividades especializadas y continuar con las actividades elementales de sus funciones; de esta manera, los dispositivos móviles vienen a configurar un nuevo paradigma económico, social, cultural y educativo. Aunado a eso, los componentes de hardware y software del dispositivo móvil hacen posible el uso de nuevas formas de interacción, específicamente, pantallas táctiles y la interpretación de gestos. Esto permite que grupos de usuarios no especializados en el uso de componentes tradicionales (teclado, mouse, pantalla no táctil) [9], particularmente los niños, manejen con facilidad aplicaciones en estos dispositivos, debido a que la interacción resulta muy intuitiva.

Para sacar provecho de esta diversificación de funciones y aprovechando sus componentes físicos y lógicos, se propone el uso dispositivos móviles para apoyar la educación en niños que presenten problemas de aprendizaje.

Los problemas de aprendizaje se presentan cuando un alumno muestra una demora general en todo el proceso de aprendizaje, observándose lentitud, desinterés, deficiencia en la atención y concentración, afectando el rendimiento global [2]. Incluso la afectación puede resultar en un área más específica como:

- La comprensión y expresión de la comunicación escrita llamada dislexia.
- La afectación de la forma y el significado de la escritura conocida como disgrafía.
- Las dificultades en el desarrollo de las habilidades relacionadas con las matemáticas.

Por las necesidades existentes en el ámbito de la educación, resulta vital diseñar nuevas estrategias educativas con los recursos disponibles. Con el propósito de aprovechar las ventajas que brindan los dispositivos móviles, se propone el uso de aplicaciones interactivas como apoyo a la metodología utilizada por docente, para el desarrollo del aprendizaje de la escritura en los niños con problemas de aprendizaje.

Las aplicaciones interactivas proveen un alto grado de retroalimentación con el alumno, basándose en patrones de respuesta – interacción, se ofrece una instrucción que permite la experimentación con temas acordes al contexto de aprendizaje requerido [8], que en este caso es la escritura.

El objetivo principal de este artículo es proponer el uso de aplicaciones interactivas para dispositivos móviles, dentro de la metodología de aprendizaje para la adquisición de la escritura que se aplica en los niños con problemas de aprendizaje. En la siguiente sección se describe a detalle la problemática que existe en torno a la enseñanza de la escritura y el uso de dispositivos móviles como apoyo en las aulas.

2. PROBLEMÁTICA.

El problema relacionado con la adquisición de la escritura, provoca retrasos en el niño, en el desarrollo y el aprendizaje; concretamente en la recuperación de la forma de las letras y las palabras. Las características que presentan estos niños son las siguientes [7]:

- Dificultades para escribir palabras (trazo)
- Dificultades en la composición escrita (concepto)
- Raramente se presenta aislado, suele aparecer asociada con dificultades de lectura (trazo-concepto-comprensión)

El aprendizaje de la escritura demanda un doble proceso: cognoscitivo y perceptivo – motriz. El aprendizaje de la escritura inicia con el ejercicio repetitivo para lograr el dominio de trazos con diferente dirección y figura (hacia arriba, abajo, derecha, izquierda, en line recta o curva), para que posteriormente el trazo se combine para ajustarse a la forma de las letras del alfabeto. Esto solo indica que el alumno ha aprendido a dibujar las letras del abecedario con un mayor dominio de sus movimientos [10]. Pero ¿cómo hacer para que el alumno adquiera la conceptualización o el significado de lo que escribe?

Como se mencionó la escritura demanda dos tipos de proceso [6]:

Proceso cognoscitivo: Que enfocado al aprendizaje específico de escritura, consiste en el proceso de conceptualización o alfabetización de lo escrito.

Proceso perceptivo – motriz: Que consiste en la coordinación de los músculos para poder reproducir la información requerida.

La maduración de este doble proceso permite el desarrollo de las habilidades que se requieren para una reproducción gráfica apropiada de los sonidos del lenguaje [6].

En busca de mejorar diversos procesos de aprendizaje, en México se ha desarrollado material con diversas metodologías para el aprendizaje, dentro del marco de este material se encuentra el Manual para favorecer las competencias de lectura y escritura [5]: primer ciclo, que apoya al entendimiento del proceso de la escritura. En dicho manual se menciona que los niños pasan por varias etapas relacionadas con la hipótesis y la conceptualización que adquieren acerca de cómo funciona la lengua escrita. En cada nivel se explican las características específicas de la escritura y se proponen algunas actividades que permiten desarrollar este nivel. Un problema es que la forma de tratar al proceso de escritura, solo se ha realizado mediante actividades didácticas en papel.

Además de eso, se menciona que para esta metodología el proceso principal es la alfabetización del alumno [5], para después ayudarlos a formular hipótesis nuevas como:

- En qué dirección se escribe.
- Existe un espacio entre palabras.
- Existen artículos para formar ideas.
- En ciertas palabras hay letras que se repiten

Lamentablemente no existen los recursos suficientes dentro de las escuelas para que los maestros puedan implementar en sus metodologías de aprendizaje el uso de dispositivos móviles, además de que no cuentan con el conocimiento tecnológico suficiente para hacerlo. Lo cual lleva a que el maestro en general no considere el uso de herramientas tecnológicas para llevar a cabo sus actividades educativas.

Por lo anterior, en la siguiente sección se propone un modelo para incluir dentro de la metodología de enseñanza el uso de aplicaciones interactivas para apoyar al alumno al desarrollo de sus habilidades de escritura.

3. MODELO DE SELECCCIÓN DE APLICACIONES INTERACTIVAS.

Con el objetivo de brindar una herramienta que apoye al desarrollo de las habilidades de escritura de los alumnos, se propone un modelo que representa un proceso que se pueda utilizar para desarrollar aplicaciones interactivas que apoyen a la evaluación y recuperación de los niveles de en los alumnos con problemas de escritura (ver figura 1). Estas actividades se obtuvieron durante la primera observación realizada a un grupo de trabajo que apoyan en el fortalecimiento de las habilidades básicas en niños con problemas de aprendizaje. Inicialmente, el docente hace una evaluación al alumno para diagnosticarlo con respecto a los niveles de escritura y generar su perfil. Con el perfil del alumno y un listado de aplicaciones interactivas, el maestro de apoyo genera un plan de actividades para trabajar con el alumno. Finalmente implementa el plan de actividades con el apoyo de aplicaciones interactivas.

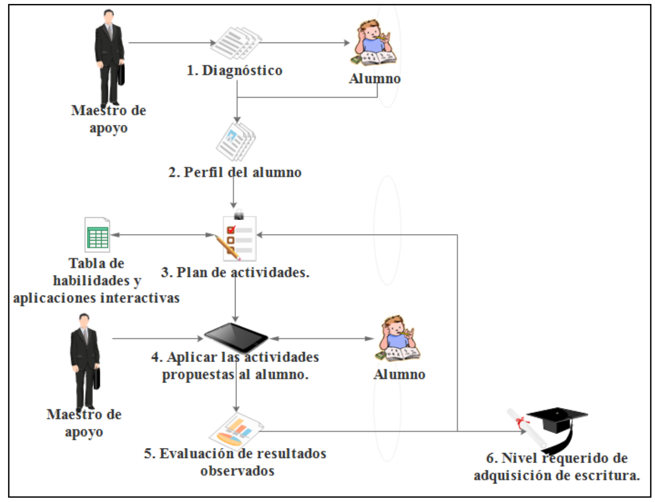


Figura 1. Proceso de asignación de aplicaciones de escritura en base al perfil del alumno.

A continuación se presenta una descripción detallada del modelo planteado en la figura 1 para el proceso de asignación de aplicaciones interactivas de escritura con respecto al perfil de usuario obtenido:

1. Diagnóstico. Inicialmente, el maestro de apoyo debe contar con evaluaciones de habilidades básicas ya desarrolladas, él interviene para aplicar dichas evaluaciones al alumno y observar cómo responde a cada una de ellas. Esto le permite realizar un perfil para identificar a cada alumno, es decir, realizar un diagnóstico. Algunos de los elementos que contiene la evaluación son: separación de elementos ya sea por color, tamaño o forma, clasificación de elementos y dictados.

2. Perfil del alumno. Con base en los resultados obtenidos de las evaluaciones y las observaciones realizadas por el maestro de apoyo, se define un perfil del alumno, identificando las debilidades en las habilidades requeridas para la correcta adquisición de la escritura. Dichos niveles se clasifican en 3:

- Pre – silábico.
- Silábico.
- Alfabético.

3. Plan de actividades. Con respecto a cada perfil del alumno, además de apoyarse en una tabla de relación de habilidades escritas y aplicaciones interactivas sugeridas, se genera un plan de actividades específico. Se busca seleccionar aplicaciones que sirvan de apoyo para trabajar, con el objetivo de apoyar al alumno a adquirir un nivel satisfactorio en cuanto a las habilidades escritas acorde a su edad.

4. Aplicar las actividades propuestas al alumno. La implementación del plan de actividades, se realiza en conjunto con las actividades planeadas por el maestro de apoyo. Es decir, aquellas actividades independientes de la tecnología que permiten la regularización del alumno.

5. Evaluación de resultados observados. Como último paso del modelo viene una nueva evaluación donde se observará el avance del niño al hacer uso de las aplicaciones interactivas. Con los resultados observados el maestro determina si el alumno avanza al siguiente nivel o se genera un nuevo plan de actividades con el uso de otras aplicaciones interactivas de apoyo.

6. Nivel requerido de adquisición de escritura. Tomando en cuenta los resultados del paso anterior el maestro de apoyo ya definió que el alumno ha alcanzado el nivel requerido de escritura acorde a su edad y diagnóstico, lo cual indica que al alumno se le puede continuar reforzando el aprendizaje o terminar las actividades de apoyo.

Para concretar el modelo propuesto en la Figura 1. Se presenta una tabla de correspondencia sobre los niveles de escritura y las actividades que permiten reforzar estos niveles y finalmente se presenta, por cada nivel, una lista de aplicaciones sugeridas que apoyan el desarrollo de estas habilidades.

La siguiente tabla se formó a partir de la consideración de que la escritura se adquiere por medio de un doble proceso que requiere habilidades de alfabetización y habilidades motrices. Las habilidades de alfabetización se tomaron de los niveles de adquisición de la escritura propuestos por Emilia Ferreiro y Ana Teberosky [4], mientras que para las habilidades motrices se consideró el trabajo de Swearingen [6] y de Lica [3].

Tomando en cuenta estos referentes, se propone una metodología para implementar aplicaciones interactivas (Tabla 1) para apoyar el desarrollo de los niveles de escritura. Inicialmente se describen los niveles de escritura, tomando en cuenta que el desarrollo de las habilidades perceptivo motrices difieren independientemente del nivel de alfabetización en algunos alumnos [5]. Además, se agrega una descripción de los niveles y una lista de aplicaciones interactivas encontradas en Play Store de Google para desarrollar cada nivel de escritura.
[7]

[7] https://play.google.com/store Ultimo acceso:14/06/2015

Tabla 1. Uso de aplicaciones interactivas en la planeación docente para la adquisición de escritura.

Niveles de adquisición de escritura	Nivel de desarrollo motriz	Descripción de niveles.	Aplicaciones sugeridas en los niveles.[1]
Pre – silábico	Motricidad visual	Se presenta cuando el niño solo realiza dibujos o simplemente raya la hoja, sin existir un orden claro en los trazos, conocido lo anterior como garabato. Algunas actividades propuestas - Trazo de líneas rectas, horizontales y verticales, curvas, diagonales, con una guía.	*Tracing line & shapes *Escribo en letras de imprenta.
	Memoria visual	Comienzan a aparecer símbolos, aunque siempre son los mismos, y al escribir se mantiene constante el número de símbolos que escribe. - Trazo de letras tanto con guía como sin ella. - Trazo de silabas con guía y sonido.	*Aprender escribir. *ABC Escritura. *Redacción ABC
	Percepción visual	Tanto la cantidad como la variedad de símbolos en cada palabra es diferente; sin embargo, se puede observar la presencia de un símbolo inicial igual cuando existen palabras que inician con la misma sílaba, sobre todo si se trata de vocales iniciales, aunque el símbolo no necesariamente coincide con las letras correspondientes. - Solicitar el trazo de silabas sin guía y solicitar el fonema de la sílaba.	*Aprender escribir. *ABC Escritura. *Silabario Lite. * Palabras domino.
Silábico	Motricidad visual	El niño no encuentra una idea acerca de la relación existente entre el símbolo y el sonido, por lo que en su escritura sigue sin existir una correspondencia sonoro-gráfica. - Solicitar el trazo de palabras y que al mismo tiempo se le indique el fonema de la letra de cada sílaba en la palabra.	*Silabario Lite. *Palabras domino. *Kids doodle.
	Memoria visual	El niño asigna una letra por cada sílaba que escucha, algunas de estas letras tienen correspondencia con la sílaba. - Formar palabras por medio de sílabas ya sea mediante imágenes o trazos.	*Palabras domino. *Leer y Escribir Jugando
	Percepción visual	Comienzan a aparecer vocales y consonantes correspondientes a la silaba que tratan de representar en una palabra. - Palabra generadora con palabras de dos silabas. - Dictado de palabras con sonidos similares.	*Tarjetas educativas. *Kids doodle.
Alfabético	Motricidad visual	Aunque todas las vocales escritas sean correspondientes, el fallo se encuentra en las consonantes, cuando existen múltiples errores donde no coinciden con la letra correspondiente; sin embargo, se respeta la relación entre símbolo y fonema. - Pedir que completen palabras a partir de un número de letras que contiene la palabra (Ahorcado básico).	*Primeras palabras 1 y 2. *Ahorcado educativo *Kids doodle.
	Memoria visual	Los errores grafo fonéticos de su escritura son menos frecuentes, generalmente se presentan en sílabas trabadas o mixtas, a razón de un error en cada palabra o por cada dos palabras, aunque puede ser menos frecuente. - Tomar un dictado o elaborar un dictado.	*Kids doodle.
	Percepción visual	En este nivel sólo se presentan errores polivalentes, siendo los errores grafo fonéticos muy poco comunes, o en el mejor de los casos, inexistentes. Cada letra escrita coincide correctamente con el sonido correspondiente. - Relatar las experiencias de un día anterior	*Kids doodle.

Con el objetivo de ejemplificar el uso del modelo de la Figura 1 y la Tabla 1 en la siguiente sección se describe un caso de estudio.

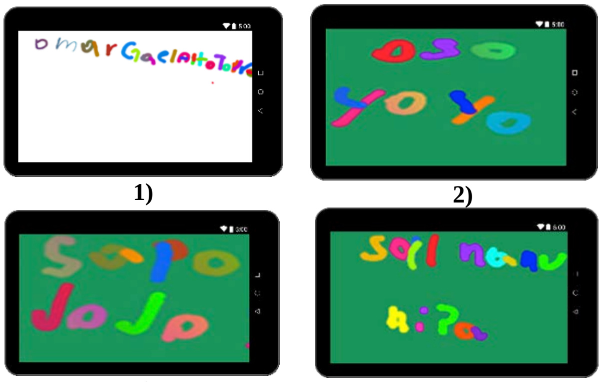
4. CASO DE ESTUDIO

Utilizando el modelo propuesto en la Figura 1 y las aplicaciones propuestas en la tabla 1, se presenta el siguiente caso de estudio, que en particular permite el desarrollo de percepción visual en el nivel silábico del niño. El caso de estudio se realizó durante una visita a una escuela de educación básica en la ciudad de Aguascalientes, México. Donde se nos permitió trabajar con algunos niños con problemas de aprendizaje, el presente caso es de un niño de 10 años que cursa actualmente su 4to grado de primaria y se encuentra en el nivel silábico de escritura.

Como primer paso del modelo, se aplica una evaluación de diagnóstico al alumno, una vez realizada, el maestro de apoyo tiene los resultados para determinar el nivel en el que se encuentra actualmente el alumno. Con respecto a este nivel, el maestro de apoyo generó una planeación de actividades regulares para trabajar con el alumno, con el objetivo de avanzar al siguiente nivel.

Con respecto a este caso que se encuentra en el nivel silábico, como se menciona en la Tabla 1, las actividades para trabajar con él son la palabra generadora y el dictado de palabras con sonidos similares. Se trabajará con el dictado de palabras ya que para la segunda actividad aún no se cuenta con una aplicación acorde a ella.

Dictado de palabras con sonidos similares. Para esta actividad se solicitó al alumno que escribiera una serie de palabras que se le dictaron, las palabras dictadas son sencillas de dos silabas y con un repertorio muy similar. En esta ocasión se utilizó la aplicación Kids doodle que es una aplicación que permite la escritura libre con elementos llamativos para realizar trazos y fondos de diversos colores. Las imágenes de la actividad se muestran a continuación.



1) 2) 3) 4)

Figura 2. Kids Doodle aplicación que permite al usuario el trazo libre de palabras.

En esta actividad se muestran 4 pantallas por orden: en la pantalla 1, se le solicitó al alumno que escribiera su nombre y él lo escribió completo. En la pantalla 2, se muestran dos palabras que se le dictaron al niño, oso y yoyo. En la pantalla 3, se muestra la representación del niño de las palabras sapo y ojo. Finalmente, en la pantalla 4, las palabras que se le dictaron al alumno son sol, nube y lluvia. Lo que se muestra en la figura 2 es la forma en la que el alumno representa de forma escrita las palabras. El uso de esta aplicación tuvo dos beneficios: el primero, es que el alumno pudo escribir en la Tablet palabras sin líneas que le sirvieran de guía; y el segundo beneficio es que permitió observar y guardar lo realizado por el alumno, para mantenerlo como evidencia de su avance.

5. CONCLUSIONES.

En este trabajo se propone un modelo que apoye la adquisición de la escritura en alumnos con problemas de aprendizaje, de esta forma se muestra que las aplicaciones interactivas pueden convertirse en un apoyo para los niños con problemas de aprendizaje, ya que el modelo puede ser tomado como guía para facilitar al maestro su metodología de trabajo, se agrega la intervención de aplicaciones interactivas en dispositivos móviles y la tabla generada a partir de una búsqueda de aplicaciones para cada nivel de la escritura. Sobre las aplicaciones interactivas encontradas, son útiles y pueden usarse en más de un nivel con diferentes enfoques, pero se necesitan aplicaciones más sistematizadas que permitan el avance del alumno en los niveles de escritura, ya que la mayoría de las aplicaciones existentes no tienen un sustento pedagógico fuerte.

Como trabajo futuro se pretende desarrollar aplicaciones sistematizadas en las que el contenido provenga de los requerimientos pedagógicos para la escritura, además se planea que exista una capacitación para los docentes sobre el uso de aplicaciones interactivas dentro de la metodología de trabajo con niños con problemas de aprendizaje.

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Enseñando Emociones a Niños Mediante Videojuegos

Noemí Marta Fuentes García
GEDES, Universidad de Granada
nmfuentes@ugr.es

Francisco Luis Gutiérrez Vela
GEDES, Universidad de Granada
fgutierr@ugr.es

Patricia Paderewski Rodríguez
GEDES, Universidad de Granada
patricia@ugr.es

Rafael López Arcos
GEDES, Universidad de Granada
jrlarco@ugr.es

Natalia Padilla Zea
GEDES, Universidad de Granada
npadilla@ugr.es

ABSTRACT
Los videojuegos tienen el poder de hacer sentir a quien los juega un amplio abanico de emociones de la misma forma en que lo haría si realmente estuviera en el mundo virtual en el que se está desenvolviendo el juego. La Inteligencia Emocional está cada vez más presente en los centros de enseñanza y se está utilizando con alumnos en edades cada vez más tempranas. Por ello, el propósito de este trabajo es proporcionar una introducción para encontrar la forma de enlazar un programa para la Educación Emocional de niños en edad de preescolar con mecánicas de juego. Para lograr este objetivo, hemos empezado por estudiar la inteligencia emocional y así como algunos programas y herramientas utilizadas para enseñarla. Hemos analizado también cómo los diferentes medios de entretenimiento producen emociones. Como resultado, hemos propuesto un conjunto de requisitos, basados en el estudio anterior,con el fin de poder fijar una base para el diseño de juegos cuyo objetivo sea doble: que los niños se diviertan y que los adultos puedan evaluar cómo estos jóvenes aprenden a identificar las emociones y a hacer frente a los sentimientos que producen.

Categories and Subject Descriptors
H.1.2 [**Information Systems**]: User/Machine Systems – *Human factors.*

General Terms
Human Factors, Design, Experimentation, Languages

Keywords
Videojuegos Educativos, Inteligencia Emocional, Infancia, Emociones, Interacción Persona-Ordenador.

1. INTRODUCCIÓN
La Inteligencia Emocional es cada vez más importante y tiene un gran impacto en diversos aspectos de nuestras vidas, tanto en el ámbito escolar como profesional [1-4]. El aprendizaje, las relaciones interpersonales, el trabajo en equipo o incluso la felicidad están relacionados con este tipo de inteligencia [5]. Por todo ello, los profesores tratan de introducir a los niños cada vez antes en el mundo de las emociones. En la actualidad, se intenta educar a los niños desde preescolar para que aprendan a identificar las emociones, ya que esto es importante no sólo de cara a ser capaces de transmitir sus propios sentimientos, sino de empatizar con los de los demás y facilitar su desarrollo y la forma en que se enfrentan a las distintas situaciones de la vida (tanto infantil como adulta) [1-4]. Para ello se suelen realizar ejercicios como nombrar los tipos de emociones cuando se habla con el niño de los acontecimientos de la vida diaria o realizar actividades con tarjetas para enseñarle a identificar los rasgos característicos de la expresión correspondiente a cada emoción [3][6].

De hecho, existen prácticas docentes especialmente diseñadas para hacerlo que especifican ciertas actividades, métodos y guías de actuación que se suelen aplicar para mostrar los diferentes tipos de emociones (especialmente las básicas, como son la ira, la alegría, la tristeza o la sorpresa) y cómo tratar con ellas de manera apropiada [4][6][7]. Se utilizan cuentos e historias [8][9][10] que se suelen apoyar en otros materiales como pueden ser tarjetas, cartas, fotos o vídeos que muestran rostros que ilustran lo que les están enseñando. Otras veces juegan a juegos adaptados y representan obras de teatro o marionetas que les ayudan a comprender estos conceptos complejos [11][12][13]. También existen algunas aplicaciones informáticas que son más o menos parecidas a los recursos descritos anteriormente, pero utilizando un apoyo digital [9][10].

Por otro lado, los videojuegos son una de las formas más conocidas de entretenimiento tanto en niños como en adultos [16][18]. Este uso generalizado de los videojuegos se debe a diferentes aspectos. Uno de ellos es que los jugadores son capaces de desempeñar un rol en una historia y ser transportados a otros mundos, donde sienten que pueden dirigir lo que sucede, sumergiéndose en la historia hasta sentirse parte de la misma. Los videojuegos tienen el poder de hacer que la gente sienta un amplio rango de emociones de la misma forma que si realmente estuvieran enfrentándose a los problemas que el protagonista tiene y viviendo las situaciones que el juego proporciona. Distintos estudios [16][17] han demostrado que estos juegos tienen como efecto colateral a la diversión el desarrollo de ciertas capacidades como la agudeza visual, los reflejos, la concentración, e incluso la socialización (especialmente en los juegos cooperativos y online). Es por ello que cada vez son más los profesionales de la educación que deciden incluir como parte de su metodología el uso de videojuegos, con el objetivo de hacer más eficiente y amena su labor.

El propósito de este trabajo es analizar las características de esta herramienta y comprobar cómo puede ayudar a enseñar a los niños cuáles son las principales emociones y cómo identificarlas y tratarlas, siempre de forma amena y motivadora. Para hacerlo se ha seguido un proceso de estudio y análisis de las principales áreas relacionadas: psico-pedagogía y educación de las emociones y diseño de videojuegos educativos, fundamentalmente; sin olvidar la premisa de que en cualquier videojuego de carácter educativo, siempre debe existir un equilibrio entre diversión y educación [26]. A modo de ejemplo, y como resultado del análisis realizado, se muestran los requisitos que debe tener un videojuego diseñado específicamente para enseñar emociones.

El resto del artículo muestra parte de la información obtenida en dicho proceso como sigue: en la *Sección 2* se muestra una recopilación del estudio realizado acerca de la Educación Basada en Emociones; la *Sección 3* identifica Elementos que Inducen Emociones; en la *Sección 4* se realiza una Propuesta de Requisitos para un Videojuego que enseñe emociones; finalmente, en la *Sección 5* se encuentran las Conclusiones y Trabajo Futuro.

2. EDUCACIÓN BASADA EN EMOCIONES

Existen varias definiciones del término *Emoción*, todas ellas con un punto en común: es una alteración del estado de ánimo que puede ser agradable o no, y en la que normalmente influyen las relaciones con los demás y la propia experiencia. Las dos siguientes definiciones parecen dar un sentido más preciso y completo del concepto de emoción:

"*Es un estado afectivo que experimentamos, una reacción subjetiva al ambiente que viene acompañada de cambios orgánicos (fisiológicos y endocrinos) de origen innato, influidos por la experiencia. Las emociones tienen una función adaptativa de nuestro organismo a lo que nos rodea*" [19].

"*Es un complejo estado psicológico que implica tres componentes distintas: una experiencia subjetiva, una respuesta psicológica, y una respuesta de comportamiento o expresiva*" [20].

Por otro lado, son muchas las interpretaciones que se han realizado sobre el concepto de *Inteligencia Emocional* (entre las que destacan las de Goleman [21] y Gardner [22]). Sin embargo, todas ellas parecen coincidir en definirla como la capacidad de reconocer las emociones, tanto propias como ajenas y saber tratarlas de manera adecuada. Se considera un complemento de la inteligencia cognitiva (concepto tradicional de inteligencia) y es posible desarrollarla mediante la aplicación de ciertas técnicas, actividades y ejercicios [1]. Esto es especialmente interesante y útil en edades tempranas, ya que es cuando el ser humano está desarrollándose y creciendo en todos los sentidos y aspectos. Esta capacidad se consigue mediante la *Educación Emocional*, que según Bisquerra [4] se define como "*El proceso educativo, continuo y permanente, que pretende potenciar el desarrollo de las competencias emocionales como elemento esencial del desarrollo humano, con objeto de capacitarle para la vida y con la finalidad de aumentar el bienestar personal y social*" y consiste en "*Optimizar el desarrollo humano, el desarrollo integral de la persona (desarrollo físico, intelectual, moral, social, emocional…)*".

2.1 Objetivos de la Educación Emocional

Considerando las definiciones anteriores, y en concreto el concepto de Educación Emocional, es lógico plantear una serie de objetivos o metas a incluir en los programas de estudio de las emociones. Dichos objetivos deben permitir que los educadores tengan claro a qué metas deberían aspirar cuando de inteligencia emocional se trata.

A continuación se muestra una lista de objetivos obtenida a partir de los trabajos de varios autores, relacionados tanto con la definición de inteligencia emocional como con la propuesta de programas especializados en la introducción de la misma en las aulas de educación infantil. Cada programa se centra más en unos u otros, dependiendo del enfoque del mismo.

Tabla 1. Objetivos de la Educación Emocional

	Programa Emocional			
Objetivo	**López'05 [2]**	**Bisquerra'12 [4]**	**López'10 [6]**	**Ribes'05 [7]**
Autoconocimiento	✓	✓	✓	✓
Identificación de las Emociones Ajenas	✓	✓	✓	✓
Vocabulario Emocional		✓		
Regulación Emocional		✓	✓	✓
Tolerancia a la frustración	✓	✓		
Prevención de los efectos nocivos de las emociones negativas		✓		✓
Generación de emociones positivas		✓		✓
Automotivación		✓	✓	✓
Actitud positiva frente a la vida		✓		✓
Desarrollar las Competencias Emocionales	✓		✓	

Uno de los términos más utilizados en la bibliografía relacionada con la alfabetización de las emociones, y de hecho se considera como uno de los objetivos a cumplir, es el de la *Competencia Emocional*. Ésta se define como el conjunto de conocimientos, capacidades, habilidades y actitudes básicas para la vida, esenciales para el desarrollo integral de la personalidad y necesarias para comprender, expresar y regular de forma apropiada los fenómenos emocionales [4][7]. En este sentido, el desarrollo de competencias emocionales a través de la Educación Emocional puede, por tanto, representar una mejora que afecta positivamente a múltiples aspectos de la vida.

2.2 Educación Emocional en la Educación Infantil

Como ya se ha mencionado, la Educación Emocional es muy importante a la hora del desarrollo y el éxito del individuo. Del mismo modo, una mala Educación Emocional, o lo que otros denominan *analfabetismo emocional* es la principal causa de fracaso escolar, así como de otros problemas que se generan a lo largo de la vida y que, en ocasiones, pueden llegar a ser graves si no se tratan a tiempo y se dan ciertas circunstancias que empeoran la situación [1][4].

Si a ello se le añade que el mundo emocional de los niños es complejo, se pone de manifiesto la necesidad de ofrecerles las herramientas que le faciliten la identificación de lo que sienten y cómo les afecta, así como la forma de enfrentarse a ello y a las situaciones de la vida diaria que les puedan perjudicar o dificultar sus relaciones. Esto se debe realizar desde la familia pero también en la escuela, optando por un modelo donde haya cabida para los conocimientos y las emociones y fomentando el desarrollo de la inteligencia emocional [1-4].

Es por ello que se hace imprescindible plantear un buen programa de enseñanza que permita identificar las capacidades a desarrollar y, de forma igual o más importante, la manera de llevarlo a cabo.

2.3 Estrategias y Propuestas

Existen varios programas propuestos por distintos autores que pretenden promover la Educación Emocional y el desarrollo de las Competencias Emocionales mediante su integración en la vida del niño, tanto a nivel familiar como en la escuela. En este apartado se reúnen algunos de los más destacados, aunque enfatizando más la parte que se refiere al colegio y a la enseñanza de emociones organizada en planes de estudio.

Cuando se trata de elaborar un currículum escolar para enseñar emociones, al igual que para cualquier otra materia, es necesario establecer la planificación del programa y de cada una de sus actividades, no sólo en cuanto al número de horas sino también en cuanto a la franja horaria más adecuada, así como la época del curso más idónea [1]. Es por eso que en la mayoría de los trabajos estudiados aparece una estimación del tiempo a dedicar en cada ejercicio. Además, se indican las edades y tipo de alumno objetivo, pues en ocasiones puede haber tareas más propicias para un niño con determinado perfil o, por el contrario algunas que no deba realizar, bien por no tener la edad adecuada, bien por sus circunstancias personales [1][4].

Según propone la autora María del Mar Vera en [3], la Inteligencia Emocional se puede desarrollar desde los primeros años de la vida, concretamente en la etapa que dura hasta los 6 años, donde se refuerzan las emociones enfatizando el elogio y la aprobación. Además, incluye las siguientes estrategias de estímulo:

- *Dar nombre a los sentimientos*: Consiste en ser capaces de nombrar emociones. Esto les ayuda a reconocer esas emociones cuando las sienten. Se puede realizar a través de cuentos, películas o tarjetas con dibujos.
- *Relacionar gestos con sentimientos*: Por ejemplo, conversar con el niño acerca de las emociones que podrían estar sintiendo los personajes de un cuento o los actores de televisión son buenas prácticas para enseñarles a identificar las emociones mediante el lenguaje corporal.
- *Orientar*: Una vez que el niño sabe reconocer sus emociones, hay que darle normas básicas para enfrentarse a ellas. Es necesario explicarle lo que sí puede hacer. Expresar cómo se siente es saludable siempre que se haga de manera aceptable. Es conveniente enseñarle a relajarse para afrontar esos momentos.
- *Actuar con empatía*: Imitar los gestos ayuda a entender lo que siente la otra persona.
- *Alabar lo positivo.* Felicitarle cuando se enfrente bien a sus emociones o muestre preocupación por los demás.
- *Enseñar con un ejemplo*. Consiste en mostrarle estrategias para calmar el estrés: respirar hondo, darse un baño de agua caliente, llamar a un amigo o escribir en su diario.

Muchos de los trabajos analizados incluyen en su contenido parte de las estrategias y consejos anteriormente citados. Algunos ejemplos son *Buenos días, ¿cómo te sientes?*[4], *La rueda de los sentimientos* [28], *Educación emocional. Programa para 3-6 años* [6], *Emotional Intelligence Activities for children ages 8-10* [23] o *Programas de reforzamiento en las habilidades sociales, autoestima y solución de problemas* [27]. Estos programas se centran más en unos u otros aspectos dependiendo de la edad de los alumnos a los que se dirigen y los objetivos concretos que pretenden lograr. Sin embargo, todas las propuestas de una forma u otra tienen como meta ampliar el vocabulario relacionado con las emociones y facilitar la exteriorización de sentimientos de manera adecuada y promueven la conciencia de las emociones, tanto propias como ajenas. Las actividades propuestas ayudan en la canalización de dichas emociones mediante ejercicios que suelen consistir en la relajación a través de la respiración u otras técnicas que la favorezcan.

2.4 Herramientas para Enseñar Emociones

Parte del trabajo realizado previamente a la propuesta que se plantea en este artículo ha consistido en la localización de material que tanto especialistas como padres pueden utilizar y utilizan para facilitar su labor educadora.

A continuación se muestra una clasificación que pretende agrupar los recursos encontrados atendiendo a sus características. En cada uno de ellos se citan algunos de los ejemplos más relevantes.

2.4.1 *Cuentos*

Colección Emociones [9]. Es una aplicación que incluye la colección de cuentos de Mireia Canals y Sandra Aguilar “Emociones” [8] para hacerlos más interactivos y enseñar a niños entre 2 y 8 años las emociones. Además de los cuentos en sí incluye una serie de actividades para favorecer la comprensión y asimilación de los conceptos.

Figura 1. Colección Emociones: "La Muerte. Mi Amiga Invisible"

The Allen Adventure [10]. Es una historia interactiva creada para fomentar el conocimiento de las emociones y, sobre todo, para aprender a interpretar las de los demás y saber qué les molesta. Pertenece al gobierno australiano y fue desarrollada en una iniciativa contra *el bullying.* Esta aplicación es para menores de 8 años pero existen otras para adolescentes. Narra la historia de un extraterrestre que llega a la tierra y tiene que integrarse y adaptarse a las costumbres propias.

2.4.2 *Videojuegos*

Gomins [14]. Es un juego que pretende ayudar a los padres a educar a los hijos emocionalmente. Esto se logra mediante la superación de pruebas que los propios padres van configurando con las indicaciones recibidas en la aplicación para padres (planes). Cada nivel superado supondrá un paso más en la evolución emocional del niño. El juego consiste en ayudar al protagonista "Gomin" a volver a su planeta, ya que se ha perdido. Para ello tendrán que cuidarlo y superar los juegos propuestos. Estos juegos pertenecen a los géneros *puzle* y *plataformas*.

IF… The Emotional IQ Game [15]. Este juego es una aventura gráfica en la que el protagonista avanza guiado por distintos seres que aparecen para explorar el mundo en el que está. Como parte de las pruebas a superar, se encuentra el reconocer los sentimientos que plantea algún personaje de los que interactúan con el protagonista.

Figura 2. IF... The Emotional IQ Game

2.4.3 *Sitios Web*

El Perruco [13] es una web para promocionar un proyecto que fomenta la educación de la Inteligencia Emocional (en niños) mediante el personaje que da nombre a la misma. Incluye varios recursos educativos, tanto informativos, para los padres: técnicas, definiciones y actividades (incluye un blog); como para los niños: el cuento de *El Perruco*, la presentación y el juego de mesa.

2.4.4 *Juegos de Tablero*

El Perruco [13] es un juego de mesa, similar al *juego de la oca*, para enseñar las emociones avanzando por las distintas casillas del mismo y superando pruebas.

El Bosque Encantado [12]. Es un juego de mesa online desarrollado por la AECC (Asociación Española Contra el Cáncer) ambientado en un mundo ficticio de ogros, hadas y duendes en el que se plantean pruebas relacionadas con las emociones en cada casilla y se avanza o retrocede según el comportamiento demostrado.

2.4.5 *Juegos de Cartas*

El Taller de Reparancio [11] es un juego de cartas en el que hay que elegir una en cada turno. Cada carta muestra la prueba a realizar (existen cinco distintas: *adivinanza*, *prueba*, *todos pintan*, *mímica* y *todos cuentan*); por ejemplo: "pensar en algo que…" (te asuste, te irrite… según la carta). Los demás tienen que averiguar lo que es con preguntas de tipo sí o no. Las cartas se dividen en grupos según las emociones (todas ellas negativas). El juego está basado en el libro *El utopífono*.

3. ELEMENTOS QUE INDUCEN EMOCIONES

Una emoción es algo muy subjetivo que, a pesar de estar presente en nuestro día a día, puede ser muy variable incluso en la misma persona. Depende de diferentes factores que van desde el individuo en sí mismo hasta el lugar en el que se encuentre y de sus experiencias vividas, tanto en soledad y como en su relación con los demás.

Por eso generar emociones no es algo trivial, sino que por el contrario es algo muy complejo. Por una parte se puede identificar el factor relacionado con los sentidos, aunque por otra se encuentra la asociación de ideas y conceptos. En ambos casos se suele relacionar estrechamente con situaciones y momentos ya vividos, así como con la propia cultura.

Partiendo del enfoque anterior, vamos a comenzar por analizar los sentidos que posee el ser humano [29], pues parte del entorno que nos rodea es percibido por ellos. Posteriormente veremos cómo se pueden combinar para inducir emociones con dos ejemplos de medios de entretenimiento: el cine y los libros.

- *Vista*. Por lo general, es el sentido más desarrollado en los seres humanos. Se dice que el 80% de la información que recibimos a lo largo del día se percibe mediante el canal visual [30]. Las principales características que se pueden apreciar son el color, la forma, la textura y el volumen de seres vivos y elementos artificiales, como pueden ser animales, personas y objetos.
- *Oído*. Es el segundo sentido más desarrollado. Con él se perciben vibraciones y ondas sonoras de orígenes diversos siempre que se produzcan en una frecuencia que seamos capaces de percibir. Lo más destacado probablemente sea la música, sin embargo, continuamente estamos expuestos a sonidos de diferentes tipos, como pueden ser los producidos por animales, personas (tanto en lo que se refiere a la voz como por ejemplo una palmada, caminar…) y objetos, tanto al moverse o caer, como los específicos que se utilizan para producir o emitir sonido (instrumentos musicales, radio, televisión…).
- *Gusto*. No existen muchos elementos con los que estimulemos este sentido, por lo general se reducen a comidas y bebidas.
- *Olfato*. Percibido mediante la nariz, a él se asocian más elementos que al gusto, por ejemplo el perfume, la comida, incluso lugares como el mar o el campo pueden tener un olor característico. De igual forma el humo, las hierbas o los excrementos se relacionan normalmente con el sentido del olfato.
- *Tacto*. Aunque no nos demos cuenta, es uno de los más utilizados, pues podemos percibirlo en todo el. Podemos relacionarlo con objetos, personas o animales, y nos permite describirlos con adjetivos como rugoso, suave, áspero, pegajoso, líquido, sólido, viscoso, caliente o frío.

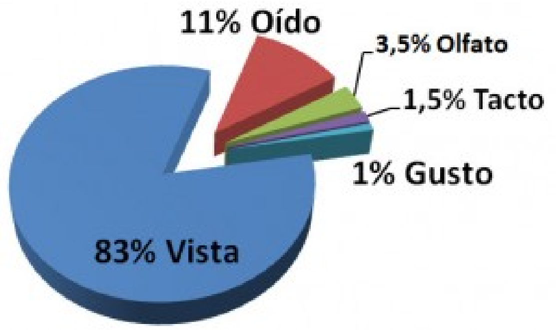

Figura 3. Porcentaje de uso de los sentidos humanos [30]

3.1 Sentidos, Medios de Entretenimiento y Emociones

Vamos ahora a mostrar la relación entre los medios de entretenimiento y los sentidos. Analizaremos cómo influyen estos últimos en la generación de emociones mediante dos casos concretos: el cine y los libros. Este análisis que proponemos se basa en la observación de los medios mencionados, realizada como parte del proceso de estudio para la identificación de elementos que ayuden a inducir emociones.

Ambos suelen utilizar de forma directa el sentido de la vista. Aunque en el cine, además se usa el oído como complemento al mismo, si bien en el caso del cine el énfasis es mayor.

A pesar de sólo aprovechar uno o dos de los sentidos humanos, estos medios son capaces de generar emociones tan profundas que llegan a hacer que el lector o el espectador sienta que forma parte de la historia, que llegue a creer que realmente está en el lugar donde se desarrolla la misma. En definitiva, que es el protagonista. Se sabe que los sentidos pueden ser el estímulo de muchas emociones, pero ¿qué relación existe y cómo consiguen entonces los autores de novelas y películas emocionar al público? La respuesta corta es "describiendo". Pero esto no parece ser suficiente para encontrar la clave de cómo utilizando tan sólo uno o dos de los sentidos se puede conseguir el efecto de inmersión deseado. Para lograr esto se hace uso de recursos como son la historia en sí, buenos personajes, un escenario convincente y una narrativa que consiga mantener la atención. En concreto:

Cine. Una buena película debería tener:

- Una *historia* que capte al espectador (guión).
- Los *diálogos* entre los personajes son fundamentales, tanto lo que se dice como lo que no marca el desarrollo del guión y por tanto la evolución de la historia.
- Actores que encarnan los *personajes*, y con los que el espectador se identifica y siente lo que ellos sienten.
- *Escenario/Fotografía.* Es lo que ambienta la escena, es decir, lo que da vida y soporte al argumento de la película y que además cambia en función del momento concreto de la misma.
- *Vestuario.* Este aspecto también es muy importante pues todo debe concordar para que sea creíble, incluso aunque se trate de ciencia ficción debe existir coherencia entre la trama, el vestuario, el escenario y los personajes.
- *Banda Sonora* que incremente las sensaciones y sentimientos, reforzando los momentos críticos de la película para que el espectador intensifique las sensaciones que percibe mientras la está viendo. Jugar con el tipo y el volumen de la música, incluso suprimirla puede ser fundamental para crear suspense y añadir emoción.
- *Efectos Especiales* que profundizan en la trasmisión de la historia y en la consecución de que el espectador forme parte de la misma. Pueden ser tanto visuales como sonoros.

Una de sus mayores ventajas es que consta de varias *dimensiones* para expresar lo que necesita y captar la atención de quien la está viendo (audio, vídeo, guión, y en ocasiones efectos 3D que favorecen aún más el sentir que se es parte de ella).

Su principal desventaja es que hay muy poco tiempo disponible para mostrar todo el contenido, por lo que hay que ser cautelosos para aprovechar al máximo los recursos disponibles y explotar las ventajas de este medio.

Las características anteriores podrían extenderse al teatro, aunque en este caso cobra mucha más importancia el escenario y la calidad de los actores, ya que todo trascurre en directo. Ganaría por tanto el poder de trasmitir de manera visual y a través del diálogo de los personajes.

Libro. Una buena novela debería tener:

- Una *historia* que capte al lector.
- *Personajes carismáticos*, con los que el lector se identifica y siente lo que ellos sienten.
- *Descripción* y *narrativa* que incrementen las sensaciones y sentimientos y que hacen que el lector se identifique con la historia narrada. En ausencia de elementos audiovisuales (como mucho alguna escena estática, probablemente en blanco y negro), se centran en la descripción y su mayor poder reside en la narrativa.

Su mayor ventaja es que puede recrearse en los detalles, ya que es parte de su atractivo; además, no hay límite de tiempo, y el lector es el que decide cuánto tiempo seguido lo lee. También es el lector el que aporta su propio enfoque, ya que interpreta lo que sucede según su propio criterio. La fuerza de las palabras y la habilidad del escritor para hacer uso de ellas pueden conseguir que un libro proporcione una experiencia más satisfactoria que la proporcionada por una película a pesar de sólo contar con la vista como sentido activo.

El inconveniente es que sólo cuenta con una *dimensión* para mostrar lo que necesita, y es por eso que debe poner todo su esfuerzo en ella. Necesita aprovechar los elementos descriptivos y el vocabulario para que el lector se sienta parte de la historia.

Tras esta pequeña revisión por dos medios de entretenimiento, parece claro que para obtener buenos resultados al generar emociones se utiliza lo que se puede mostrar explícitamente a través de la percepción sensorial. Pero esto no es suficiente, se deben combinar de manera adecuada para evocar recuerdos incluso relacionados con los sentidos no activos. No hay que olvidar que al fin y al cabo los sentidos no son más que dispositivos de entrada que nuestro cerebro, a modo de ordenador, interpreta en base al conocimiento adquirido con anterioridad. Por tanto, es posible que aunque no estemos oliendo o saboreando algo seamos capaces de recordar la sensación (positiva o negativa) debido a que en el pasado tuvimos en una situación similar.

Para mostrar una situación no basta con describirla sólo con palabras. Es necesario *hacer uso de la memoria asociativa* que los humanos tenemos. Así, mediante los sentidos de los que se disponga en el medio con el que se quiere trasmitir, se podrá estimular la memoria y evocar recuerdos, que al fin y al cabo son los que generan las emociones.

3.2 El caso particular de los Videojuegos

Los videojuegos se pueden ver, de manera muy simplificada, como una película interactiva en la que el jugador avanza de manera más o menos libre hasta finalizar el juego. Sin embargo, esto sería una definición muy pobre, especialmente teniendo en cuenta que existen distintos géneros en los cuales puede tener más o menos peso la historia, la acción, el escenario o los puzles. Aunque es cierto que la mayoría de los juegos se podrían caracterizar por tener una historia, un protagonista y unos objetivos, que variarán y tendrán mayor o menor impacto en el desarrollo del juego dependiendo del tipo del mismo.

Por tanto, cuando se trata de analizar qué elementos son utilizados para generar emociones en un videojuego se podría partir de la suposición de que el juego es una película, para posteriormente añadir matices que son los que lo distinguen de la misma.

Por una parte, como ya se ha explicado, la propia *historia* es un mecanismo de generación de emociones, debido en concreto a componentes como los *personajes* [24], los *sucesos* o *imprevistos* que surgen a lo largo de ésta y la *narrativa* [25].

El nivel de inmersión que puede provocar un videojuego en un jugador hace que las emociones sean vividas por el jugador de una forma mucho más efectiva. Además, los videojuegos tienen la particularidad de que pueden adaptar la historia al estado emocional del jugador. Para ello sería necesario hacer uso de mecanismos adicionales como la detección y el análisis de emociones en tiempo real. Esto a su vez repercutiría en un mayor nivel de inmersión por parte del jugador [18].

De igual modo, el *escenario* en el que se lleva a cabo cada escena es muy importante a la hora de trasmitir sentimientos al jugador. Dentro del escenario podemos distinguir entre el *Principal* o *Básico*, que ayuda a contextualizar la historia en sí, esto es, la ambientación general (por ejemplo, la historia trascurre en un castillo, en la época medieval, por tanto todo el escenario debe estar ambientado como tal) y el *Adaptado a la situación*, que ayuda a hacer que el jugador se transporte al juego, es decir, el que contribuye a mostrar hechos y escenas concretos (por ejemplo, si hay una escena de lucha, aunque sea dentro del propio castillo, podría incluir elementos como juegos de luces o algún otro tipo de alteración sobre el escenario base que ilustre mejor esa lucha).

La *música* (banda sonora) es uno de los factores más importantes cuando se trata de ambientar un hecho, situación o historia, en este caso se podría clasificar como: *de ambiente*, general y común a lo largo del juego; *adaptada* a momentos particulares que requieren mayor atención por parte del jugador; y *efectos de sonido*, que permiten enfatizar las escenas y situaciones concretas.

Cuanto mayor sea la relación entre estos elementos, mayor sensación de inmersión deben producir en el jugador y, por tanto, más efectiva será la generación de emociones en el mismo.

Pero lo que de verdad distingue un videojuego del resto de medios de entretenimiento es que permite al jugador *interactuar* realmente con éste. Le hace partícipe directamente de las acciones del personaje, pudiendo modificar el entorno en el que éste se mueve. Incluso aunque la historia esté pre-definida, es decir, que no sea un juego de final abierto o sandbox, el jugador tendrá la percepción de que lo que hace tiene impacto en el curso de la historia, y por tanto su sensación de inmersión y sus emociones serán más fuertes. Para ello se hace uso de mecánicas como plantear *retos* y *sub-retos*, que deben ser acordes con el tipo de juego y con el argumento del mismo. También se utiliza, como ya se ha mencionado en este mismo párrafo, la *interacción* con los elementos del juego, ya sean personajes u objetos, lo que permite sentir que se puede controlar y modificar la situación.

Cabe recordar que estas características, aunque comunes por lo general a todos los videojuegos, podrían variar e incluso suprimirse en algunos. Tal es el caso de los juegos de tipo puzle, que en ocasiones carecen de historia y personaje, aunque siempre existe un contexto narrativo. En ellos la emoción es el propio reto de conseguir avanzar a través de los niveles para lograr mayor dificultad y puntuación e incluso competir con otros jugadores para aumentar el valor de la misma. En estos juegos sigue presente el hecho de que es necesario conseguir uno o varios objetivos para poder superar el nivel y desbloquear el siguiente, y también la interacción, pues es la única forma de poder avanzar en la partida.

4. REQUISITOS PARA UN VIDEOJUEGO EDUCATIVO QUE ENSEÑE EMOCIONES A NIÑOS

A modo de ejemplo, en este punto vamos a presentar y analizar algunos aspectos que son relevantes a la hora de diseñar un videojuego que facilite la práctica de la inteligencia emocional en niños entre 3 y 5 años. El videojuego ayuda a identificar una serie de emociones y sentimientos, así como a lidiar con ellos y manejarlos de la mejor manera posible tanto para sí mismos como para su entorno.

Para ello nos hemos basado en las propuestas de experiencias docentes para enseñar inteligencia emocional en educación infantil consultados, y más concretamente en la propuesta de [6].

4.1.1 *Objetivos*

En el videojuego nos planteamos dos objetivos principales:

Objetivo 1. Va a ser una aventura con la que los pequeños disfrutarán resolviendo problemas, avanzando en el juego, consiguiendo logros y desarrollando súper poderes; así como con las actividades paralelas que se plantean.

Objetivo 2. Va a ser una herramienta que educará a los jugadores y les ayudará para que desarrollen su inteligencia emocional de manera natural y divertida, integrándola poco a poco en su vida diaria, permitiéndoles aprender a identificar y manejar emociones de manera práctica y contextualizada. A este objetivo hemos asociado una serie de *objetivos educativos* correspondientes con la primera fase de desarrollo:

- Enseñar a *identificar las emociones*. Para reducir la complejidad del problema se han elegido las tres que aparecen en el primer nivel: *alegría*, *enfado* y *tristeza*.
- Posteriormente se puede añadir el resto hasta completar los tres niveles propuestos. Cuanto más avanzado esté el juego, más se profundiza en las emociones estudiadas con anterioridad y más matices se incluyen dando lugar a nuevas emociones (estrés, celos…).

- Enseñar a *controlar las emociones*. Es necesario elegir las técnicas que se aplicarán para las emociones elegidas en el primer nivel. Por ejemplo: relajación mediante la respiración y la música, esto se consigue mediante la imitación.

4.1.2 *Requisitos de Jugabilidad*

El hecho de que sea un videojuego con propósito educativo no evita que sea un producto jugable, es decir, que atrape al niño desde el primer momento, lo haga disfrutar y sentir la historia sobre la que trata [18][25][26].

Para ello hemos establecido las siguientes características, prestando especial atención a los elementos clave mencionados en la sección 3 de este artículo:

- *Historia*, es necesario tener en cuenta tanto el contenido como la narrativa y los personajes.
- *Diseño* tanto visual como conceptual. Se deben cuidar los escenarios, la música, los sonidos y las formas empleadas en los elementos que aparezcan en el juego.
- *Retos*. Se plantean como elementos que permiten por una parte avanzar en la historia (y por tanto en el conocimiento subyacente) y por otra motivar al niño para que siga jugando.
- *Retroalimentación*. Es necesario hacer saber al jugador cuando hace algo bien o mal en el juego de manera que sea consciente de ello sin que llegue a afectarle negativamente pudiendo llegar a desanimarle. Este es un aspecto muy importante en la motivación del niño y también puede tener repercusión en su estado de ánimo y por tanto en sus emociones. Para ello proponemos el uso de *Súper poderes*: el niño puede ver cómo evolucionan a medida que avanza en el juego y querrá seguir jugando para comprobar cómo cambian o saber cuál es el nuevo poder que consigue.

4.1.3 *Control del Juego*

Para facilitar la empatía del niño con los personajes del juego, debe controlar un único personaje, *el protagonista*. De acuerdo con [24] el protagonista tiene que tener un aspecto amigable y con rasgos infantiles, de manera que el pequeño se identifique más fácilmente con él y por tanto sea más fácil generar emociones.

4.1.4 *Ayuda y Guía de Juego*

El juego debe tener un menú de ayuda que permita a los jugadores realizar consultas sobre aspectos del mismo que no entienden. También debe ofrecer guías para superar ciertos retos.

Para ello proponemos la existencia de la figura de *la mascota*, que se trata de un personaje que sirve de guía y apoyo a lo largo de todo el juego. Le ofrece consejo en situaciones que podrían ser complicadas para él, y permite que éste exprese los sentimientos a través de un diálogo que se facilitará mediante el uso de iconos y pictogramas representativos para el jugador. Esta mascota es también la representación del sistema de ayuda del juego. Así, el niño verá reforzada la confianza en este avatar y la acción de solicitar ayuda será simplemente consultar con la mascota.

4.1.5 *Retos y Objetivos*

Es importante plantear un conjunto de retos y objetivos a cumplir. Unas veces relacionados con el objetivo educativo, aunque mostrados como objetivo de juego de forma transparente al niño, y otras simplemente retos lúdicos, para mantener la diversión y la atención del niño.

4.1.6 *Retroalimentación: Recompensas y Puntuación*

Proponemos ofrecer varios tipos de recompensas (Tabla2). Por una parte las puramente lúdicas, con el objetivo de divertir y motivar por el simple hecho de conseguirlas. Por otra parte mixtas, con el objetivo de motivar y producir realimentación acerca de las acciones del niño en el juego, pero también de permitir conocer la evolución de su aprendizaje a los educadores. Estas últimas se caracterizan porque pueden ser también negativas. Un mal comportamiento también debe verse reflejado en ellas, de manera que se favorezcan las reacciones y sentimientos positivos frente a los negativos por la propia mecánica del juego. Para este último tipo hemos propuesto el uso de los poderes a modo de metáfora de su evolución real. Los poderes no deben cambiar igual para todos los niños, sino que varían dependiendo de distintos factores como el ritmo al que supera los retos y la forma en que lo hace.

Tabla 2. Recompensas

Recompensa	Descripción	Función
Recolectar de objetos	Aparecen en ciertas situaciones. Permiten conseguir beneficio extra posteriormente.	Motivación
Coleccionar piezas	Por ejemplo: frutas o juguetes. Cuantas más *piezas* se tengan, mejor.	Diversión y Motivación
Súper Poderes	Van adquiriéndose en función del comportamiento del niño en el juego. También se pueden perder como consecuencia de comportamiento negativo	Motivación Evaluación de la evolución del conocimiento

En todos los casos se hace uso del refuerzo positivo de la puntuación y recompensa cuando algo se realiza correctamente con efectos sonoros agradables, asociados al éxito. Para indicar que algo está mal también se emplea un efecto sonoro, pero de manera que no implique connotaciones negativas. Se identifica con sonidos de fallo que se suelen utilizar en otros videojuegos o en dibujos animados y que en ocasiones tienen un tono cómico o sarcástico para restar negatividad a pesar de la alerta proporcionada.

Todo ello está apoyado por un modelo interno de juego que refleja la estructura asociada al programa educativo seleccionado. Además, durante el juego se mantiene un modelo del jugador donde se almacenan los niveles y los objetivos que va alcanzando (tanto educativos como lúdicos).

4.1.7 *Introducción de Conocimiento*

Durante el juego hay momentos en que es necesario introducir conocimiento de forma explícita, pero sin que el niño sea consciente de ello y pierda la inmersión. Para ello se propone la inclusión de *Actividades Extra*. Sirven para presentar conceptos en forma de cuentos o vídeos que encajan en la dinámica del juego. Se utilizan también para añadir ejercicios de evaluación extra, que permiten a los educadores realizar un mejor seguimiento de la evolución del niño y saber que, efectivamente está adquiriendo el conocimiento esperado.

5. CONCLUSIONES Y TRABAJO FUTURO

Las emociones no sólo se pueden enseñar, sino también generar. Si sumamos los hechos de que los videojuegos son por sí mismos medios de generación de emociones y que hacen partícipe directo de su desarrollo a quien los juega junto con el hecho de que los niños ya desde pequeños están en contacto con dispositivos tecnológicos como tabletas y móviles, se da la circunstancia y la herramienta ideal para dirigir hacia este punto la educación de las emociones. Utilizar un videojuego que además se haya creado especialmente para niños con el objetivo de aplicar un programa de Educación Emocional puede ser un gran paso para las escuelas, ya que conseguiría enseñar de las dos formas más eficaces: jugando, que es la manera natural en que los niños aprenden; y practicando.

En base a los requisitos identificados en este trabajo, y al diseño inicial del videojuego, estamos trabajando en el desarrollo de una arquitectura y metodología específica para el diseño de videojuegos educativos que incluyan la Inteligencia Emocional como refuerzo del aprendizaje.

Por tanto, el trabajo futuro se dirige hacia el diseño formal del videojuego propuesto en este artículo, su prueba y evaluación en entornos reales. Durante este proceso se continuará la investigación en las técnicas de generación de emociones y se usarán las directrices propuestas por el grupo que investigan en el desarrollo de videojuegos educativos [18][25][26]. De esta forma, el objetivo es obtener un juego divertido y educativo, sin perder a favor de uno u otro aspecto. Además, se realizarán experiencias con prototipos que permitan guiar este diseño hacia un producto que realmente sea efectivo tanto desde el punto de vista de los educadores como de los niños.

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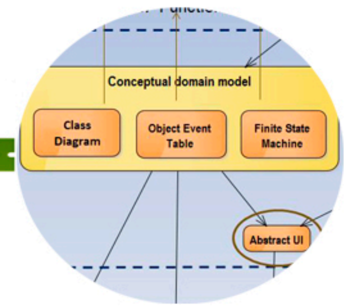

INTERFACE DESIGN

CamScan, an application to identify everyday objects for users with vision impairments

Rodrigo Capa-Arnao
Department of Mathematics and Computer Science
Universitat de les Illes Balears
Crta. Valldemossa km 7.5
07122, Palma, SPAIN
correo@derodrigo.com

Cristina Manresa-Yee
Department of Mathematics and Computer Science
Universitat de les Illes Balears
Crta. Valldemossa km 7.5
07122, Palma, SPAIN
cristina.manresa@uib.es

Ramon Mas-Sansó
Department of Mathematics and Computer Science
Universitat de les Illes Balears
Crta. Valldemossa km 7.5
07122, Palma, SPAIN
ramon.mas@uib.es

ABSTRACT
Technology can help users with blindness or vision impairments to overcome everyday challenges. Furthermore, the widespread acceptance and use of mobile phones, makes it suitable to develop accessible technologies on these devices. One common problem that users with vision impairments face is the identification of everyday objects, especially when these objects have a similar shape as others (e.g. cans, CDs). Different works have tackled this problem including object recognition and remote workers on the internet who answer questions on the image sent. This work approaches this problem and presents new features with the aim of bringing new capture possibilities and then discusses the findings

Categories and Subject Descriptors
H.5.2. Information interfaces and presentation: User interfaces. K.4.2 Social Issues: Assistive technologies for persons with disabilities

General Terms
Design, Human Factors

Keywords
Assistive technologies; vision impairments; object identification; Capture; RGB-D

1. INTRODUCTION
What is this? Which CD is that? What is inside this? Everyday objects identification can be a challenge for users with vision impairments both because objects have a similar shape such as CDs, currency or cans, or because the user is not familiar with the object. The continuous failure in the identification can be frustrating for the user.

Together with *reading* (text to transcribe) and *description* (description of visual or physical properties of a depicted object), object *identification* was one of the main categories [1] presented in a taxonomy of the types of visual challenges in the everyday lives of blind people.

In a home environment, someone else can label the objects, but this decreases autonomy for the user. To assist in this task and whenever the degree of vision impairment allows it, users can make use of magnification tools, either optical or computerized. However, this approach is not effective for users with severe vision impairments. Another solution, more difficult to ensure, is the correct labeling of the objects at a production stage. This is the case of the medication packaging, where they normally have information in Braille.

Instead of using specialized hardware like in the past for particular tasks such as barcode readers, color identifiers, currency recognizers or talking OCR, we can use only a mobile device. The increase of performance and the inclusion of cameras in mobile devices together with reliable and affordable Internet connections, has led to assistive technologies using only this device. Furthermore, the main operating systems on mobile devices include accessibility services such as screen magnifiers or built-in screen readers (VoiceOver in iPhone, or Talkback in Android) which support users affected by sight loss.

We present an application aiming at enabling people with vision impairments to identify everyday objects by taking captures with a mobile device (Android-based) and using remote services to answer the user. Our proposal includes the capability of filtering the captures with the information obtained by a mobile device with an integrated RGB-D camera and also allows the user to select among three capture modes (*infinity*, *autofocus*, *macro*). Finally, we conduct an informal testing to evaluate the object identification and observe the use of the added characteristics.

The work is organized as follows: Section 2 reviews works aiming at object identification with portable devices. Section 3 and 4 describe CamScan and the new capture enhancements that we propose. Section 5 reports the results of the evaluation. Finally, we discuss our findings and outline future work.

2. RELATED WORK
In this section, we review related works that use mobile devices to identify everyday objects, emphasizing virtues and shortcomings, with the objective of detecting potential improvements to implement.

Mining the literature, we can find works using computer vision techniques to identify a reduced set of objects previously classified such as currency [2][3] or objects previously recorded [4]. Liu [2] presented a work that helped identifying US dollars. LookTel Money Reader [3] is an app for iOS and recognizes currency and speaks the denomination. Several currencies are supported including the US Dollar, Euro, British Pound, Canadian Dollar, and Australian Dollar. LookTel also has a version, LookTel Recognizer [4] that permits users to store images of objects in a database, for its later recognition. In this case, it may be interesting to store different points of view of the object in order to improve the identification.

Google Goggles [5] is an image recognition mobile app developed by Google. It is used for searches based on pictures or barcodes taken by handheld devices and it returns a web with information on the place or object being identified (includes OCR). It is a very fast system although it does not always offer a satisfying answer. The system is not specially adapted to users with vision impairments, but it can be combined with screen readers. The app is no longer supported for iPhone devices and it is not too popular on Android mobiles. CamFind [6] is a free app, similar to Google Goggles, but more functional (according to users' opinion) due to its easiness. As drawbacks, its use in Spanish is not too effective and it does not include a barcode reader. In this line, we find TapTapSee [7], which uses the same search engine as CamFind, but the descriptions are more informative. One of the characteristics of this system is that if the image is not identified, then it is processed by remote workers on the Internet. The interface is totally accessible and it can be used in both Iphone and Android. However, the translation of the interface to Spanish is not too correct yet and even if the object identification is correct in English, the translation to Spanish is sometimes confusing. This system has a cost, that it can be a monthly service fee or pay per number of images.

The use of remote workers to assess in the task of identifying objects has been used in Vizwiz [8], Vizwiz:Locatelt [9] and in Chorus:View [10]. These systems enable the user to add questions attached to the image, which offers more flexibility and interaction possibilities. VizWiz and VizWiz:LocateIt only allow one question, but Chorus:View offers a more conversational crowd assistant.

There are other works that attempt to identify objects without using specifically a mobile device but striving for mobility. EyeRing [11][12][13][14] is a wearable interface, a ring that allows a person to point at an object to see or hear more information about it. The image captured by the device is sent to a mobile or to a PC so it can be processed by the appropriate software. One of the advantages is that the user directs his finger to the scene and does not have to worry about the position of the mobile device's camera. The system is a prototype and needs a particular dedicated hardware. OrCam [15] is a commercial product consisting of a portable device with a camera mounted on the frames of the eyeglasses. When the user points at something, this is identified and the information is given through a bone-conduction earpiece. The use of this system is more effective for users with a minimum degree of sight.

When analyzing the diverse systems, different aspects are taken into account. First, not all of the aforementioned systems are designed for users with loss of sight or blindness, but the mobile operating systems accessibility options, can help overcoming these limitations. Internationalization is an important factor too. Most systems are planned for English speakers, so the interface is in English and in some cases its translation is not correctly done (e.g. TapTapSee). Answers are usually also given in English. However, answers can be translated by automatic translators, whose translations can sometimes lead to confusion in other languages. In the case of those systems where the user records the object identification, the user is the responsible for the information given. Another aspect to analyze is whether they need specific hardware or not.

The drawback of systems based on reverse image search is that the result may not be always appropriate or related to the original image. In the case where remote workers participate, answers are usually subjective but are really related to the image given. However, they can be slower than reverse image search, as it depends on the cost of service and the workers income.

3. SYSTEM PROPOSAL

We have carried out an informal evaluation with different available systems (using only mobile devices), and we realized that frequently, the object under study is just occupying a small region of the image and sometimes the autofocus does not focus correctly on the object we want. An example of this situation is when a person picks up a product in a supermarket holding it in his or her hand and takes a photo. Behind, other products can be visible in the scene, so the autofocus may not focus correctly. These problems may not be noticed by users with sight limitations.

The result given by the different systems also differ. As stated before, all systems work in English and then they use automatic translators to translate it to other languages. Diverse services for translating are used. Based on [16][17] and our own informal testing with Yandex, GoogleTranslate and BabelFish, the last two have the best translations. Furthermore, the translation to Spanish improves when the result given for the object identification is included in a complete sentence such as "The image describes + [result of the object identification]" and sent to the translation services.

IPhone is considered very accessible for users with vision impairments [18], but we will work on Android devices basically because of its open nature. Further, we can find many different devices (makes and models) with it and a wide range of prices, making it more accessible economically.

Based on the observations done in the initial evaluation, we propose a system for Android devices with new image capture characteristics. The system will aim at identifying an object using a remote service that receives the image, searches for it in a database and if a satisfactory result is not found, then it is sent to a remote worker to be identified. First, we will offer the user three capture modes depending on the distance to the object: when an extreme close-up photography has to be captured, a *macro mode* will be used. If the object is a few centimeters away, an *autofocus* will be used. And finally, the third mode will be full-focus, for objects further than one to two meters. Full-focus is the capability to focus objects from different distances which allows focusing all objects. The inconvenience using it is that it does not allow focusing too close. Although not all devices include this feature, Android is able to do an infinity focus in these cases.

The second proposal is the use of images together with its depth map. RGB-D cameras in mobile devices are an emerging feature (e.g. HTC or Google in their TANGO project [19]. There are not too many devices yet with this characteristic, and the technology is still not mature enough. Results are not optimal, but are sufficient to test this functionality and to contribute with the insights for future developments.

In order to test these two functionalities, we designed and developed an app, which allows selecting the capture mode and use the depth information to remove the background of the object. We assume the use of TalkBack or other screen reader services for navigation purposes.

The usability will be taken into account for users totally blind or with sight loss, so the interface will aim for easiness reducing the number of controls and app states. The system must be able to be used in Spanish and in English, and to be translated to other languages in an easy way, following the Google recommendations for the app localization Android Developers. Localizaing with resources. http://developer.android.com/guide/topics/resources/localization.html. Last access April 2015..

4. CamScan

In the following subsections, we will describe the CamScan application, the device and tools used to develop the system.

4.1 Apparatus and development libraries

The mobile device used for testing the app and these features will be a HTC One M8, which uses Android Kit Kat 4.4.3 and includes two back cameras (denominated by the manufacturer as Dual Lens) (see Fig. 1) which capture images in the 2D-plus-Depth format, that is, a 2D image frame supplemented with a greyscale depth map (see Fig. 2). To process the images, developers need the HTC Dual Lens SDK which is still under development. Images have a resolution of 2688x1520 pixels and the image for the depth map has a resolution of 1280x720 pixels.

To translate the results we will use Google Translate, due to the number of languages that it supports and the results it achieves for Spanish.

TalkBack uses two fingers to interact, so all the app has to be prepared to interact with two fingers and all elements should have its description included to be read.

Figure 1. Cameras detail of the HTC One M8.

4.2 Design

To achieve an easy-to-use system, all the functions except for the settings, are accessible from the main screen. There are no graphical controls, as all the interaction is carried out by different multitouch gestures: 2-finger swipes or long-press gestures. This achieves an app with a reduced number of states, avoids interaction with graphical controls and facilitates the navigation with TalkBack.

In Fig. 3, a scheme of the functioning of CamScan is shown. Initially, the main screen is presented, where TalkBack will read the name of the app initiated and a welcome message followed by a specific pattern of vibrations, for the user to be sure that he or she is in the correct place. Moreover, the name of the app is written in big characters to help those users with sight loss but not totally blind.

Then, the three different capture modes are shown on screen, each of them is presented with a sentence and the screen is divided in three regions separated with thick lines and with no boundaries on the sides. By placing the fingers on each region, the text will be read aloud.

The design decision of dividing regions in the vertical axis and the position of the three modes is due to the natural position of the user holding the phone vertically and the proximity of each region to the user: the farthest region (higher region) is the *infinity* focus, the middle region corresponds to the *autofocus* and the closest region is the *macro* focus (See Fig. 4). The app is only designed for the portrait orientation to keep its simplicity; however, after selecting the mode, the user can rotate the phone to the landscape orientation to capture the image. In Fig. 5, the use of the app using one hand is depicted.

The design decision of using the long-press gesture instead of double tap to capture an image, was due to the initial evaluation where we observed that using the double tap could cause the image to be blur specially when using the device only with one hand. The long-press enables the user to maintain the device more stable than the double tap.

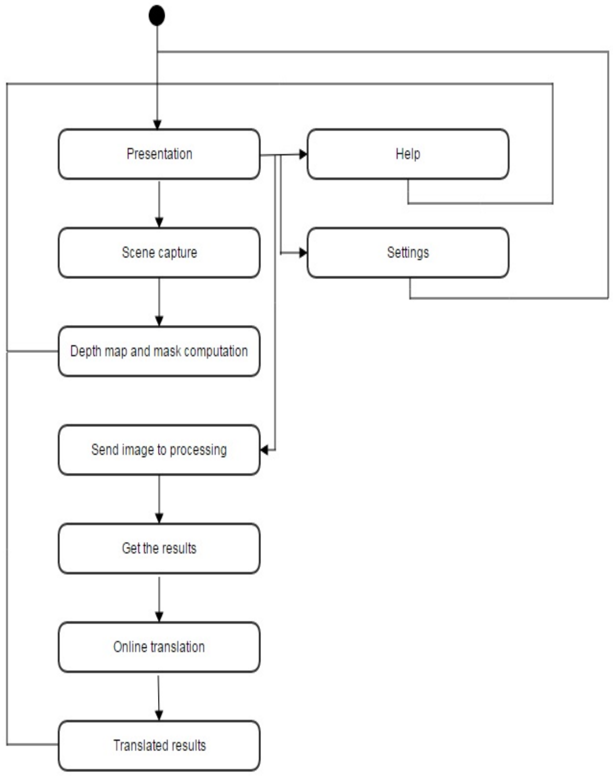

Figure 3. Functioning of the CamScan application

Figure 4. Presentation screen with the 3 capture modes.

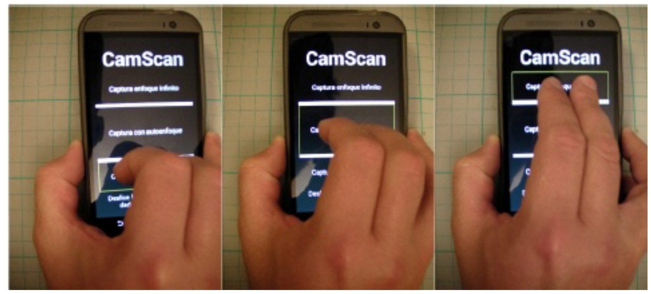

Figure 5. A user holding the device with one hand and sliding through the different capture modes

The help menu is a basic menu functionality included in the main screen, as the interface cannot be enriched with graphical elements. It adds an extra element to the presentation screen, but is fundamental that users can access the help menu in a simple way. Therefore, a small region at the lower part of the mobile screen has been reserved for the menu of help, for it to be read by TalkBack in the initial screen. The message given is "Slide down with two fingers to bring out the help menu". If TalkBack is not detected when the app is loaded, then the message is changed to "Slide down with one finger to bring out the help menu".

Once the capture is done, to access the other functionalities the user will perform a fast sliding towards different directions. Down will bring out the help menu, to the right will send the image to identification, to the left will go to the previous menu or will close the app and finally, up will bring out the settings.

The capture and identification has been divided into two tasks: the capture and the sending of the image. Sending the image for identification means time and can have a monetary cost or increases the user's data usage on the mobile. Providing these two steps allows users to repeat the image capture without sending the image, prevents unintentional sending and avoids multiple image sending. Expert users would maybe prefer this task to be done in just one step; therefore, this option can be activated in the settings.

The decision of sliding to the right for identification and going back with the left movement has been based on the reading direction for the Spanish (and occidental) population (from left to right). So going to the right would mean advancing and going to the left would mean going backwards. However this decision can be reversed in the settings section. Further, before going out from the app, the system will ask for confirmation to avoid unintentional actions.

5. Evaluation

The system was evaluated to analyze three factors: the easiness of the system, the functioning of the capture parameters and finally the effectiveness of the filtering using the depth map.

5.1 Easiness of use

The system was initially tested by 3 three 'proxy users' who represented actual users [21]. Working with research participants with impairments. Wiley. These users did not use the accessibility options on their mobile device and they were new to TalkBack. A training period of around 15 minutes was dedicated to TalkBack, however, to be an expert on it, users should train longer periods. Even though, this initial trial is important to explore the usability of the system and to analyze the first findings.

Three users with no vision impairments (2 male, 1 female with an average age of 35) were introduced to the app. The procedure we followed was:

1) Introduction to the app: participants were introduced to the app. We explained the aim of the app and its general working, without showing them any screen. We were interested in the first contact of users with the app.

2) TalkBack training: users went through a short tutorial about TalkBack. Without trying CamScan, they moved around the screens and menus on the mobile. The evaluator highlighted the concept of "sliding a finger on the screen is like looking at that zone", and all the text below the finger is read. Participants did not need to worry about tapping, as the system only responds at taps with two fingers. For these three users, the use of TalkBack was not intuitive, so they had problems interacting with it.

3) Hands-on the app: the mobile phone was then introduced into a cloth bag with CamScan active. The main problems came due to the interaction with TalkBack, as users were not used working in that manner and they got confused. This problem will probably not be encountered with users who are used working with screen readers. Then, the functioning of the app was shown to users, and then they all found its use simple and intuitive. When users were working at the beginning with TalkBack, as the description given to each region was a complete sentence, users felt it was more complicated that what it really was. The descriptions for TalkBack were shortened to: Close, Normal and Far in the main screen, and more detailed information was given in the Help menu.

4) Hands-on the app (2^{nd} attempt): the mobile phone was again introduced in the bag, and in this occasion users could carry out different capture tasks. In this stage, sometimes the user did not know the exact state of the app: after the capture, and while the depth map is processed, there is a delay of a few seconds until the main screen is shown again, and during the sending and identification of the image, there is a delay too. To improve the user experience, verbal and haptic notifications were included: a vibration after the capture and a periodic message with a vibration notifying that the identification is being processed.

Proxy users cannot simulate completely an end-user experience, as these users are already used to screen readers and exploring the apps using them. However, the design has been enhanced due to the findings of these tests.

5.2 Capture, focus and flash

TapTapSee uses an automatic focus and flash, but results are not always satisfactory as some focus take between several seconds and one minute and the flash is not always activated when needed. When the system has focused, an audible notification is triggered.

CamScan in *macro mode* can require a few seconds to focus. Every attempt focusing and failing will be notified with a sound and automatically it tries to focus again until it succeed, then it takes the photo and emits a sound of capture. Each attempt to focus is about 2 or 3 seconds, unlike TapTapSee.

The *normal mode* corresponds with the normal autofocus, but it has been configured for the focus to be done in the centre of the image. The focus can need 3 to 5 seconds. Sometimes, the photo will not have focused, but the user will not notice it until he or she receives the answer of the identification, where the remote users can notify that the image is blur.

Finally, the *full-focus mode* does not focus, there is a compromise between the distance and the image definition. The benefit of this mode of capture is that if the object is at an adequate distance, it is the fastest system.

5.3 Filtering using the map of depth

Filtering the image with the map of depth can be suitable in those situations where there are multiple objects in the background such as in a supermarket or at a home.

To evaluate this functionality, a field trial was held in a supermarket. Several captures were taken by holding the object with one hand, extending it and taking a photo with the mobile. Then, the captures were sent with the original image and the filtered image to compare the answers given by the system. 81 images were captured, but we select the most interesting cases to exemplify different captures.

When capturing objects with flat surfaces, the filtering achieved correct results segmenting the object using the depth map (See Fig. 6). With the original photo, the answer was "Cartón de leche" ("milk carton") and with the filtered image, the answer included the label of the milk carton.

When objects are not placed perpendicularly to the camera, the filtering is not too effective as there is a compromise between the distance to capture and the distance to filter. In Fig. 7, we find a packet of flour. In this case the top of the image (the farthest) was removed when filtering. However, answers to both images were not correct: in the first case, the answer was "Harunas comida de perro mallorca" ("Flour dog food mallorca" and the word flour was not well spelled) and the answer to the filtered image was "paquete rojo y blanco de la etiqueta" ("package red and white from the label", the sentence in Spanish does not make sense.).

We tested the system with non-flat objects like a bottle (See Fig. 8. There are some errors at the edges, but the object is complete and the identification gave good results in both cases: "Persona sostiene una botella de bebida Pago" ("Person holding a bottle of drink Pago) and "Botella de pago" ("Bottle of pago").

When testing with small objects, a can of anchovies of 10x5 cm, the filtering included part of the shelf behind (See Fig. 9). This fact can be due to the transparency of the shelf or because the depth map considered the shelf to be close enough to the can to include it at the same depth distance. In both cases the identification was correct "Anchoas consorcio" ("Anchovies consorcio").

Figure 6. Capture of an object with flat surfaces.

Figure 7. Capture of an object placed perpendicular to the camera

Figure 8. Capture of an object with non- flat surfaces.

To analyze how the material could affect the image and the filtering, a set of cans with shiny surfaces were captured (see Fig. 9). Filtering achieved good results, but the identification in both cases was not too successful due to translation problems. With the original image we obtained “Verde y blanco Malkon 6 latas de envase” (Green and white Malkon 6 can”, the label was wrongly spelled) and with the filtered image “Mahou verde puede” (“Mahou green can”, ‘can’ was translated as the verb can or to be able to instead of a can as a recipient).

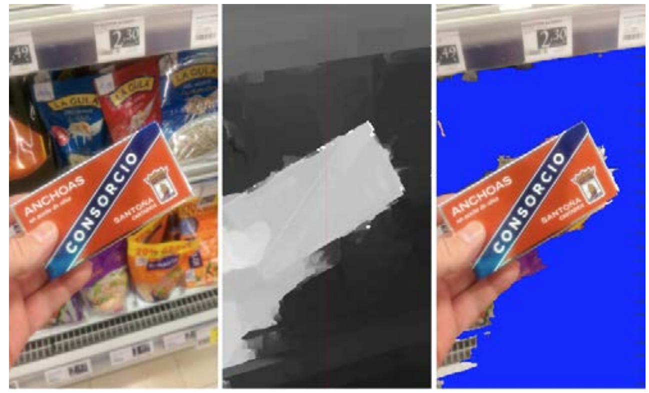

Figure 9. Capture of a small object.

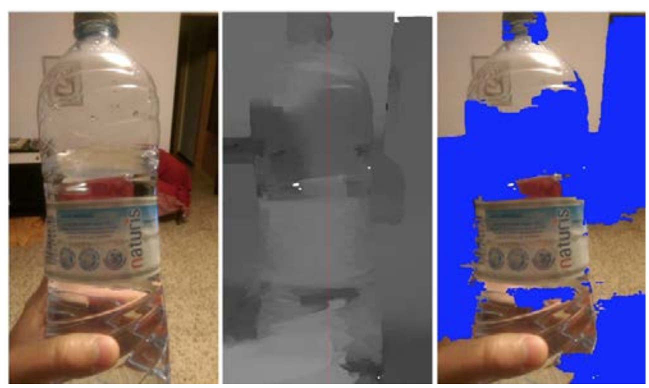

Figure 11. Capture of a transparent object.

Finally a transparent object was captured too, to test the map of depth in difficult conditions. In Fig. 11, the capture of a transparent bottle can be seen. The algorithm to compute the map of depth looses effectiveness, but as the label is still readable, the identification was correct answering “Naturis agua embotellada” (“Naturis bottled water”).

Once tested that the filtered image could achieve successful or similar results as the ones given by sending the original image, it is interesting to observe the decrease of the images sent. The average image size for the 81 images taken was o 143.113 bytes and the average size for the filtered images is of 98.157. That means a difference of 44.956 bytes.

6. FINDINGS AND CONCLUSSIONS

In this work we presented an app that uses the mobile device to identify everyday objects by taking a photo and sending it to remote services. This app has three capture modes: *macro*, *autofocus* or *infinity*. Each of these modes can help acquiring better photographs.

Further, several mobile devices offer the possibility to take photographs and compute the depth map. We use this depth map to filter the background of the image and keep only the object under study.

The user interacts with the app trough a simple interface with big interaction zones to require easy interactions with finger gestures without the need to tap precisely on any graphical control. The system has to use a screen reader such as TalkBack.

The option of offering three capture modes was not appreciated by all users, as some knowledge about photography may be needed to understand the different captures modes.

Regarding the usability of the application, once users understood how TalkBack worked and was combined with CamScan, they found the functioning intuitive and simple. It is important to test the app with end-users, as they will not encounter the same problems as the proxy users. However, we included a settings menu to offer a flexible app to adapt to users' preferences.

Using the map of depth to filter the original images, we can gain speed in the transmission of the image and reduce costs. Further, and maybe with a higher impact than the cost or speed, is that the user can preserve some degree of privacy of his or her environment, especially at home. By using the filtering option, the user just sends the object to be identified.

By sending only the object under interest, we help the remote worker to focus only on that object and they may give more concise descriptions, and if the identification is done by computer vision techniques, we remove the background which could improve the object recognition (if filtering is successful).

This assistive app should evolve as a holistic system including software, hardware and multimodal input and output. Multiple functionalities should be integrated such as OCR, colour detection, navigation information, local database of objects, or remote worker assistance.

A research line related to this project that has to evolve to improve the results of the identification is the automatic translation. In our testing, answers in English were correct in some cases, but the translation to Spanish was confusing.

Computer vision techniques could also improve object recognition to be able to recognize objects without the need of remote workers. However, when including them, it would be interesting to work with people close to the user's local or national environment to achieve more accurate responses.

7. ACKNOWLEDGMENTS

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Interacción de los Usuarios con Aplicaciones Web Offline: un Caso de Estudio

Félix Albertos Marco
Instituto de Investigación en Informática de Albacete (I3A)
Universidad de Castilla-La Mancha
felix.albertos@uclm.es

Víctor M.R. Penichet
Escuela Superior de Ingeniería Informática de Albacete
Universidad de Castilla-La Mancha
victor.penichet@uclm.es

José A. Gallud
Escuela Superior de Ingeniería Informática de Albacete
Universidad de Castilla-La Mancha
jose.gallud@uclm.es

RESUMEN

La interacción del usuario con las aplicaciones web ha sufrido cambios importantes durante la última década. El avance tecnológico permite que el usuario pase de ser un simple consumidor de información a producir gran parte de esta. Tanto es así que gran parte de la interacción y gestión de la información con estas aplicaciones se produzca en el lado cliente, en el navegador local. El auge de nuevos escenarios donde las aplicaciones web son utilizadas, ha hecho que en la interacción con las interfaces de usuario se introduzcan nuevos mecanismos. De entre estas aplicaciones web, las dedicadas al e-Learning son cada día más utilizadas, permitiendo la gestión de contenidos educativos en la red. Pero no siempre existe una conectividad a la plataforma web que estemos utilizando. Diversos motivos lo impiden: zonas rurales, desastres naturales o situaciones sin cobertura. Es por ello que surgen las aplicaciones web offline o desconectadas. El presente trabajo profundiza en la problemática de la utilización de aplicaciones web existentes en escenarios offline. Para tal fin, se introduce la herramienta Proxy Offline y se describe un test piloto que analiza cómo se ve alterada la interacción del usuario con las interfaces web offline con el objetivo de mejorarla.

Categorías y Descriptores

H.5.m Information interfaces and presentation (e.g., HCI): Miscellaneous.

Términos Generales

Design, Experimentation, Human Factors.

Palabras clave

Offline Web Applications, e-Learning, Case Study.

1. INTRODUCCIÓN

Las aplicaciones web fueron diseñadas desde su origen para ser utilizadas siguiendo el paradigma cliente-servidor, pero el avance tecnológico abre nuevas formas de interacción con estas aplicaciones. Por ello, las posibilidades de interacción con las aplicaciones web ha cambiado radicalmente. En la última década, y especialmente en los últimos años, los usuarios han pasado a ser responsables de la creación y mantenimiento de gran parte de los contenidos de la red [6][13]. Esto implica que se involucren de manera activa tanto en la creación de nuevos contenido, como en su modificación. Los usuarios han pasado a ser simples consumidores de información a ser productores de la misma.

Este avance ha implicado que gran parte de la interacción con la aplicación web y la gestión de la información se produzca en el lado del cliente. Además, también es cierto que cada vez se está más tiempo conectado, a través de un número mayor y más variado de dispositivos, así como en multitud de escenarios y contextos. Pero también es cierto que existen multitud de escenarios donde esa conectividad no es posible debido a numerosos factores como son las zonas rurales o aisladas, los desastres naturales o situaciones sin cobertura a la red (viajes en tren, avión …).

Uno de los campos de aplicación que han experimentado un mayor auge dentro de las aplicaciones web es el de las aplicaciones destinadas a gestionar contenidos educativos en la red, los denominados sistemas e-Learning. Si bien se han estudiado numerosos aspectos relacionados con estos sistemas, como son la colaboración, su utilización en dispositivos móviles o el *awareness* producido por estos sistemas, el estudio de escenarios offline adolece de una falta de propuestas y soluciones para paliar los efectos negativos que estos conllevan.

Es en este punto donde se necesitan estudios que proporcionen resultados acerca de cómo se ven afectadas las aplicaciones web en entornos offline. Pero dentro de estas aplicaciones podemos distinguir claramente dos aproximaciones. Por un lado, existen las aplicaciones web diseñadas y producidas teniendo en cuenta los escenarios offline. Por el otro, se encuentra la posibilidad de adaptar las aplicaciones web existentes para permitir la interacción offline.

En este trabajo se analiza mediante la evaluación de un caso de estudio la interacción de los usuarios con aplicaciones web existentes que han sido adaptadas para el trabajo offline mediante la utilización del Proxy Offline. El Proxy Offline es una aplicación que permite tanto modelar la interacción del usuario con aplicaciones web existentes en escenarios offline como el soporte para la interacción offline en ellas. Con los resultados obtenidos en este caso de estudio se espera comprender cómo se ven afectadas las aplicaciones web en estos escenarios y ayudar a desarrollar soluciones conceptuales y tecnológicas que permitan extender la interacción de los usuarios con la web hacia entornos offline.

El presente trabajo está organizado de la siguiente manera: el capítulo 2 introduce la problemática de las interacción offline en aplicaciones web, presentando el caso de estudio y las decisiones tomadas para permitir la interacción offline en aplicaciones web; el capítulo 3 presenta la evaluación realizada; en el capítulo 4 se exponen los resultados obtenidos; por último el capítulo 5 presenta el trabajo relacionado, mientras que en el capítulo 6 se presentan las conclusiones y el trabajo futuro.

2. LA INTERACCIÓN OFFLINE CON APLICACIONES WEB

Como paso previo a la evaluación de la interacción de los usuarios en aplicaciones web offline, describimos el escenario donde se produce esta interacción. En la actualidad, son pocas las aplicaciones web que permiten la interacción offline. Por este motivo, a la hora de realizar el caso de estudio, se han tomado una serie de decisiones con el fin de habilitar la interacción offline en aplicaciones web.

Previamente a las decisiones tomadas, se presenta el caso de estudio utilizado con el objetivo de ilustrar estas decisiones.

2.1 Caso de estudio

Las tareas web relacionadas con tareas e-Learning se encuentran entre las más comunes. Es por ello que para realizar el caso de estudio hemos seleccionado una de las plataformas web más populares dentro del ámbito e-Learning que se puede encontrar en la actualidad: Moodle [14]. Moodle tiene una estructura modular que permite la definición de cursos. Estos cursos están estructurados en diferentes partes, pudiendo ser por temas o fechas entre otros. A su vez, cada tema contiene una serie de actividades y recursos a disposición del usuario.

Para el caso de estudio se organiza la plataforma de modo que el usuario pueda acceder a unos cursos con el fin de realizar unas actividades en ellos. Para cada curso, las actividades consisten en la lectura de unos textos para posteriormente responder a preguntas sobre ellos. Los textos se pueden presentar de dos formas: 1) el texto está en la misma página web que las preguntas y el cuadro de texto proporcionado para las respuestas; 2) el texto se presenta como un documento PDF, mientras que las preguntas y el cuadro de texto proporcionado para las respuestas se encuentran en una página web independiente.

Cuando el usuario realiza la actividad en el caso de estudio, esto es, responder a las preguntas asociadas al texto, guarda esta interacción pulsando el botón de enviar ejercicio. A partir de este momento, los datos quedan guardados en el servidor para su posterior consulta o evaluación por parte del profesor del curso.

Cuando la interacción del caso de estudio se produce en modo offline, sin conexión a internet, la realización de las actividades se ve afectada, ya que no es posible interactuar con la aplicación. Es por esto que debemos de tomar las decisiones oportunas de cara al diseño de la interacción del usuario y las acciones a realizar.

2.2 Decisiones para la interacción offline

Cuando la aplicación web está en modo offline, puede darse el caso de que no toda la información esté disponible para su uso en todos los niveles que componen las aplicaciones web (Dominio de la Aplicación, Hipertexto y Presentación). Además, estos niveles no son independientes, existiendo una función de mapeado entre ellos. En la Figura 1 se muestra cómo la función de mapeo relaciona los elementos entre los niveles de la aplicación web. Estas relaciones indican cómo están conectados los elementos en los distintos niveles y sus dependencias.

De este modo, cuando la aplicación web está en modo online, con conectividad al servidor, todos los elementos del dominio de la aplicación están accesibles. Siguiendo la función de mapeado correspondiente, los elementos del nivel de hipertexto están a su vez disponibles. Esto permite que la navegación en la aplicación web se realice de modo normal. Siguiendo esta ascensión de niveles, y a través de la función de mapeado de presentación, el nivel de presentación permite que el usuario interaccione con la totalidad de elementos de los niveles inferiores.

Sin embargo al estar la aplicación web en modo offline, pueden no estar disponibles todos los elementos del nivel de dominio de la aplicación. En la Figura 1 se muestran atenuados los elementos que no están disponibles debidos al modo offline de la aplicación web. Siguiendo las funciones de mapeo anteriormente descritas se observa que los elementos de los niveles superiores tampoco están disponibles en su totalidad. Se puede apreciar como hay elementos del nivel de hipertexto no disponibles y a su vez elementos del nivel de presentación que tampoco están disponibles. Estas circunstancias condicionan la interacción del usuario con la aplicación web y las acciones que este puede realizar, por ejemplo, en la interfaz web (nivel de presentación).

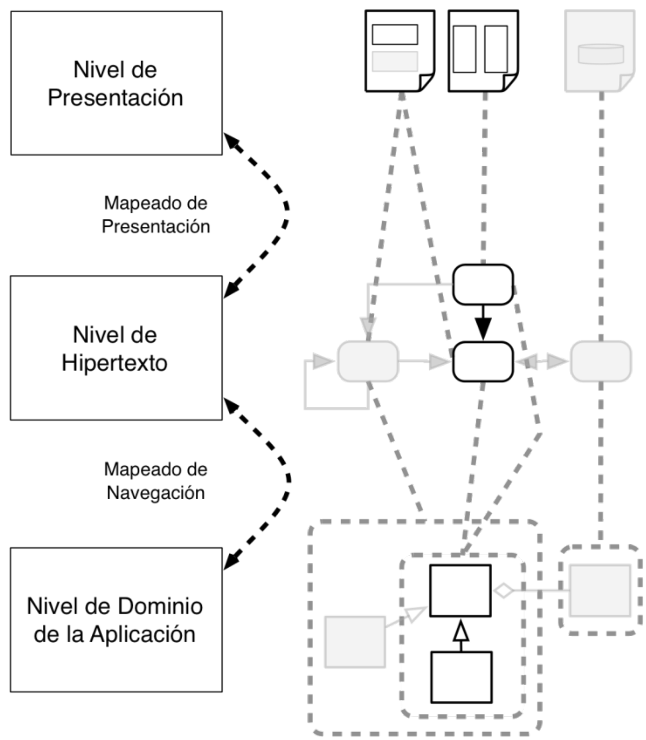

Figura 1. Disponibilidad de los elementos en los niveles de las aplicaciones web en modo offline

Dado que el caso de estudio se basa en una aplicación web real, lo ideal sería poder interactuar con ella sin necesidad de modificarla. Además, también permitiría extender el estudio en otras aplicaciones web ya existentes. De esta forma, los datos obtenidos de estos casos de estudio serán más cercanos a la realidad al utilizar aplicaciones web ya utilizadas por los usuarios.

Para ello se decide que la mejor forma de interactuar con las aplicaciones web ofreciendo el soporte offline será a través de la adaptación de los niveles de la aplicación web ya existente. Pero no todos los niveles se pueden adaptar de igual manera. En una aplicación web normalmente el modelo de datos se encuentra en el servidor, haciendo más difícil su adaptación. Sin embargo, el nivel de presentación y el de hipertexto son más fácil de adaptar ya que la interacción con el usuario se produce de forma directa en el navegador, de forma local. Es por esto que se decide adaptar esos niveles, dejando intacto el modelo de datos. La principal consecuencia es que se evita el tener que trabajar con la capa de datos, que es la que está más fuertemente ligada con la implementación de la aplicación web en el servidor.

Para conseguirlo se establecen los siguientes criterios por cada nivel en la aplicación web:

- Nivel de dominio de la aplicación: El modelo de datos no se modifica en la aplicación web original con el fin de poder trabajar con el mayor número de aplicaciones web posible sin que sea necesaria su modificación.
- Nivel de hipertexto: la navegación se podrá modificar de forma que permita la navegación entre las distintas páginas web dependiendo del estado de la conexión.
- Nivel de presentación: se adaptará la interfaz de usuario permitiendo decidir los elementos con los que el usuario puede interactuar dependiendo del estado de la conexión.

Con estos criterios como base para establecer la interacción con la aplicación web offline se presentan los siguientes desafíos:

- ¿Cómo habilitar la interacción offline en aplicaciones web?
- ¿Cómo diseñar la interacción offline con aplicaciones web existentes?
- ¿Cómo actualizar la interacción del usuario en modo offline cuando se retome la conexión con el servidor?

En los siguientes apartados se tratan estos desafíos con el fin de proporcionar los mecanismos necesarios para habilitar la interacción con aplicaciones web offline.

2.2.1 Habilitando la interacción offline en aplicaciones web

Para habilitar la interacción offline en aplicaciones web se recurre a la utilización de las tecnologías que ofrece el estándar HTML al respecto. A través de ellas se permite que el usuario interactúe con la aplicación web cuando esta no tiene conexión a internet. Para ello, se guarda una copia loca de los recursos asociados a la aplicación web. Cuando no exista conexión a internet, los recursos son leídos de forma local, permitiendo al usuario continuar la interacción con la aplicación web.

Pero guardar estos recursos de forma local es sólo parte de la solución al problema planteado. Necesitamos establecer qué partes de la aplicación web estarán disponibles en modo offline. Para ello, y según los criterios que se han establecido, necesitamos definir en los niveles de navegación y presentación qué elementos estarán disponibles para la interacción del usuario.

Esta descripción de ambos niveles forman lo que definimos como el *Modelo Offline*. Este modelo comprende las transformaciones y las reglas que definimos para la aplicación web. A continuación se presentan los conceptos y la notación utilizada para la descripción de los niveles de navegación y presentación.

Descripción de la Navegación

Para la descripción de la navegación en aplicaciones web offline se utiliza la notación presentada por Albertos [2]. Esta notación permite representar las páginas web como nodos. Las conexiones entre ellos representan la navegación en la aplicación web. Finalmente, los atributos de cada nodo definen las políticas sobre su disponibilidad en el escenario offline, así como la forma en que se crea la copia local.

En la Figura 2 se muestra el diseño realizado con la herramienta de soporte desarrollada utilizando la notación para la descripción de la navegación. Se establecen como disponibles tanto la página de entrada a la plataforma Moodle (nodo “Inicio”) y los cursos que contienen las actividades a realizar (nodos “Comprensión lectora PRIMERO” y “Comprensión lectora SEGUNDO”). Como no disponibles, se establecen las páginas para registrarse como usuario (nodos “Login” y “Logout”), cuya funcionalidad no está disponible cuando no hay una conexión con el servidor web.

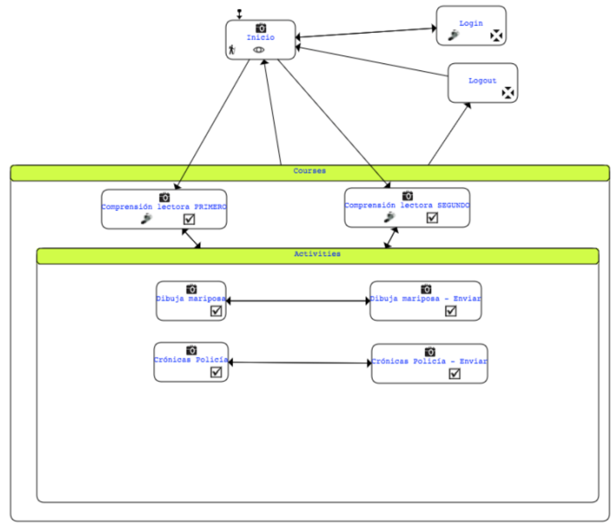

Figura 2. Descripción de la navegación offline para el caso de estudio

Descripción de la Interfaz

La interfaz de una aplicación web se compone de elementos. Estos elementos pueden ser cuadros de texto, botones, enlaces a otras páginas web, imágenes o formularios entre otros. Estos elementos pueden contener a su vez otros elementos. Para describir la interacción con la interfaz web en modo offline necesitamos definir cómo se van a comportar los elementos cuando no exista conexión a internet. Para ello, se realizan transformaciones y acciones sobre la interfaz web. Se definen las siguientes transformaciones y acciones para la descripción de la interfaz web:

- **Ocultar**: el elemento de la interfaz web se oculta de manera que no se muestra al usuario ni se puede interactuar con el cuando la aplicación web está en modo offline.
- **Deshabilitar**: el elemento de la interfaz web se muestra, pero el usuario no puede interactuar con el. Esta transformación afecta a los hiperenlaces que tienen como destino páginas web que no están disponibles en modo offline. Aunque se muestra el texto asociado al hiperenlace, no permite seguir la navegación asociada.
- **Guardar**: algunos elementos de la interfaz web enlazan a recursos tales como documentos PDF o imágenes para ser descargados o visualizados en el navegador. Indicaremos que el recurso se guarda para poder ser utilizado en modo offline.
- **Actualizar**: para el caso de elementos que permiten una interacción directa por parte del usuario que necesita ser

actualizada cuando se retoma la conexión a internet se indica que necesitan ser actualizados. Tal es el caso de cuadros de texto. En ellos, en modo offline el usuario introduce un texto en el. Cuando se vuelve a visitar ese elemento en modo online, este debe de mostrar el resultado de la interacción producida en modo offline. De esta forma la interacción queda registrada y el usuario puede actualizarla en el servidor.

Estas transformaciones y acciones en la interacción web se definen directamente sobre la interfaz de la aplicación web. Los mecanismos utilizados se presentan en el siguiente apartado.

2.2.2 Diseño de la interacción offline con aplicaciones web existentes

Para diseñar la interacción en aplicaciones web existentes se ha implementado una aplicación que se sitúa entre el servidor web que aloja la aplicación web y el navegador del usuario que interactúa con ella. A esta aplicación se le denomina *Proxy Offline.*

El Proxy Offline constituye un elemento software que contiene el Modelo Offline que es inyectado en la aplicación web existente y servida al navegador web del cliente. De esta forma se consigue utilizar aplicaciones web existentes sin ser modificadas en el servidor web original. En la Figura 3 se muestra cómo el Proxy Offline se encarga de incluir en las aplicaciones web ya existentes el Modelo Offline. Para cada petición que realiza el cliente a través del navegador, el proxy media de forma que solicita esa petición al servidor web. La respuesta del servidor web es procesada por el proxy inyectando los elementos necesarios para que la respuesta que recibe el navegador incluya el Modelo Offline con las adaptaciones pertinentes.

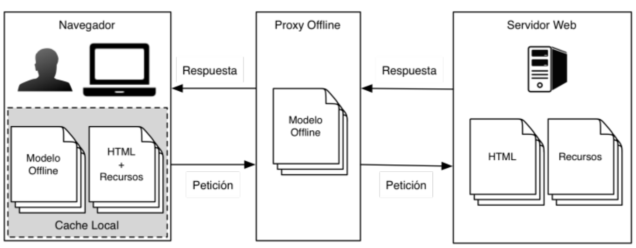

Figura 3. Funcionamiento del Proxy Offline

Incluir el Modelo Offline en la aplicación web no es el único cometido del Proxy Offline. También se encarga de incluir en ella el software que se encarga de la edición del modelo sobre la aplicación web. Esto permite seleccionar los elementos de la aplicación web y aplicar las transformaciones sobre la interfaz web y la navegación.

En la Figura 4 se muestra como se marcan los elementos de la interfaz con las transformaciones y acciones disponibles. Se indica con un recuadro punteado de diferentes colores los elementos que tendrán un comportamiento específico cuando la aplicación se encuentre en modo offline. Cada color indica la aplicación de una transformación o acción determinada sobre el elemento contenido.

Para realizar esta anotación de la interfaz web, se sitúa el cursor sobre el elemento en cuestión que es resaltado sobre la propia interfaz. En ese momento un menú contextual permite aplicar las diferentes acciones disponibles sobre el elemento. Cabe destacar que los elementos de la aplicación web están anidados. Esto implica que si se aplica una acción sobre un elemento, todos los elementos contenidos se verán afectados por ella.

Para el caso de estudio se muestran en rojo los elementos que se ocultan y no se muestran en la interacción offline. Estos elementos comprenden los foros, las búsquedas u otros elementos que por decisiones de diseño para la interacción offline se ocultan al usuario. Los elementos marcados en verde comprenden recursos que estarán disponibles en modo offline, la anteriormente denominada como acción guardar. Para el caso de estudio se muestra un documento PDF que está disponible en modo offline para que el usuario pueda completar la actividad que realiza.

Figura 4. Diseño de la interacción offline en la aplicación web

Todos los elementos marcados en la Figura 4 hacen que la aplicación web se comporte de un modo específico cuando se encuentre en modo offline. En la Figura 5 se muestra el resultado de las transformaciones en la aplicación web con respecto al diseño de la interacción offline definido en la Figura 4. Como se puede apreciar, los elementos marcados como ocultar no se muestran en la interfaz del usuario. Por otro lado, los enlaces a páginas web o elementos que no están disponibles se encuentran atenuados y deshabilitados, tal y como se puede apreciar en la barra superior de navegación. En ella sólo el elemento “Home” es accesible al usuario. El resto de enlaces está deshabilitado, a excepción de los incluidos en la Figura 2 y que forman parte de la navegación offline de la aplicación, como el primer enlace de la sección “Actividades”. De esta forma se limita la interacción del usuario con elementos que estén disponibles para su interacción offline. También se encuentra disponible en este modo el documento PDF, al cual se le dio la propiedad de guardar.

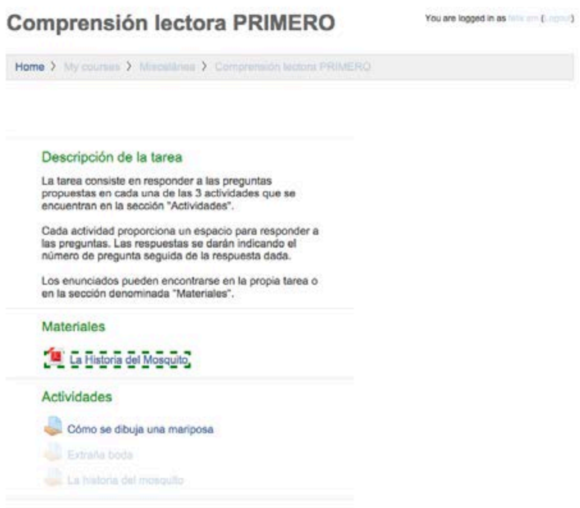

Figura 5. Transformaciones en la interfaz de la aplicación web en modo offline

Con estas transformaciones también se consigue que el usuario se centre en la actividad que está realizando. Al eliminar los elementos que no intervienen en la actividad que esté realizando en ese momento y que no están disponibles en modo offline, se facilita la interacción del usuario, esperando reducir el número de errores debido a este modo.

2.2.3 Actualizando la interacción offline en aplicaciones web

Una vez que el usuario puede interaccionar con el sitio en modo offline, el último criterio establecido que debemos de cumplir para permitir la interacción offline con la aplicación web es la actualización de las acciones realizadas por el usuario en ese modo cuando se retome el modo online.

Para ello, la aplicación que ejecuta el cliente con el Modelo Offline incluido incorpora mecanismos que permiten estas acciones. Cuando se establece un elemento con la opción de actualizar se permite esta actualización offline-online. Por ejemplo, al establecer un cuadro de texto con la opción mencionada, al estar la aplicación web en modo offline se introducen o cambian algunos elementos en la interfaz. Estos elementos se muestran ampliados en la Figura 6 :

- El botón de envío asociado al cuadro de texto cambia para indicar al usuario que lo que se va a hacer es guardar el trabajo offline.
- Se introduce un indicador en la parte inferior derecha de la interfaz que muestra el número interacciones offline pendientes de ser actualizadas en modo online, además de la fecha y la hora en que se realizó la copia local. Este elemento también establece un enlace directo con las páginas web que contienen las interacciones offline, el cual se explicará en detalle a continuación.

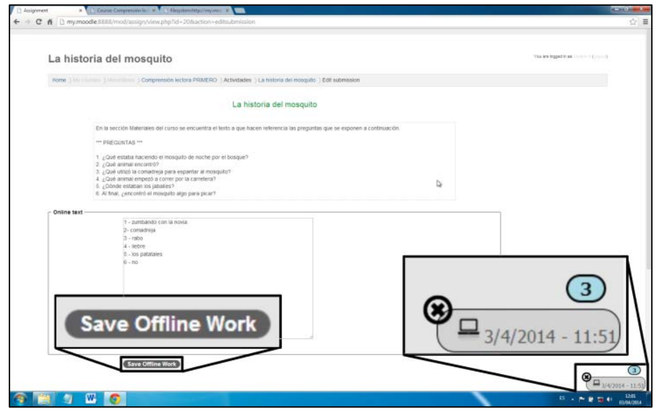

Figura 6. Cambios en la interfaz para guardar la interacción offline de los usuarios

Cuando la aplicación web se ejecuta de nuevo en modo online, el indicador con el número de interacciones offline se sigue mostrando. Así se permite al usuario actualizarlas simplemente haciendo *click* en el indicador. La interfaz cambia en ese momento, mostrando las páginas web que contienen la interacción offline, tal y como se muestra en la Figura 7. Se muestra una lista con estas páginas web y su título. También se incluye información acerca de la fecha y hora en que se produjeron las interacciones offline. Esta información ayuda al usuario a saber cuándo se realizaron las interacciones en modo offline en las páginas web indicadas.

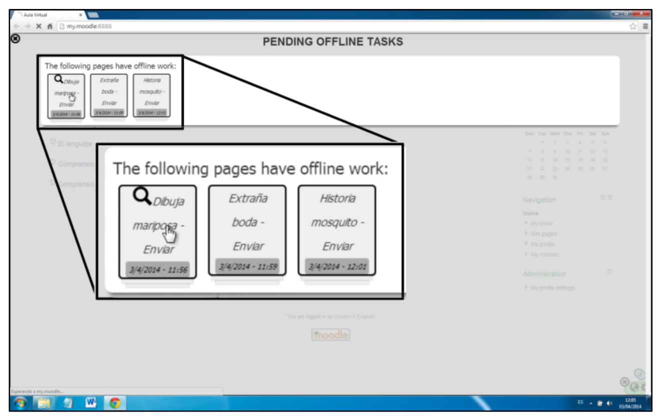

Figura 7. Interacciones offline pendientes de ser actualizadas

3. EVALUACIÓN

La evaluación se plantea como test piloto para obtener información de cómo los participantes interactúan con el sistema. En la evaluación se tomas datos cuantitativos (tiempos) y cualitativos (opiniones de los participantes).

El escenario utilizado para evaluar la interacción de los usuarios en las actividades anteriormente descritas se presenta a continuación.

3.1 Participantes

El número de participantes es de 10 personas, distribuidas en dos grupos de 7 hombres y 3 mujeres. El participante más joven tiene 22 años de edad, siendo la media de 24 años mientras que el participante con más edad tiene 42 años. El 70% de los participantes son estudiantes de post-grado. El 100% de los participantes utiliza aplicaciones web a diario. El 100% de ellos ha usado Moodle con fines académicos durante el último año, bien como estudiante o como profesor.

3.2 Aparatos

El hardware utilizado para llevar a cabo la evaluación consta de un portátil "Apple 15'' Macbook Pro (modelo de finales 2012)". El sistema operativo utilizado es Mac OS X versión 10.9 corriendo una máquina virtual Parallels Desktop versión 9. La máquina virtual ejecuta el sistema operativo Microsoft Windows 7. El navegador web utilizado es Chrome en su versión 33. Otro software disponible para el usuario durante la evaluación incluye: Microsoft Office 2010, Microsoft Notepad versión 6.1 y los accesorios disponibles en una instalación estándar de Windows 7.

3.3 Procedimiento

Todos los participantes son voluntarios no pagados. La tarea del usuario consiste en realizar una actividad en una aplicación web. La aplicación web utilizada es el entorno de enseñanza virtual Moodle. La tarea consiste en la realización de una actividad dentro de un curso. La actividad consiste en la lectura de un texto para responder a preguntas relacionadas con el.

A los usuarios se les dan instrucciones sobre las actividades. Estas instrucciones consisten en la estructura del curso y en cómo responder a las preguntas dentro de la aplicación web. De forma adicional, a los usuarios que realizan la evaluación utilizando el Proxy Offline se les explica cómo salvar el curso para uso offline y cómo salvar y restaurar el trabajo offline.

3.4 Diseño

En la evaluación de la propuesta se compara la interacción de los usuarios realizando una tarea en una aplicación web utilizando el Proxy Offline y sin utilizarlo. Para ello, las actividades de la tarea se realizan en dos escenarios: con el Proxy Offline y sin el Proxy Offline. Para realizar la tarea en cada escenario, se establecen dos grupos de 5 usuarios, siendo la selección de los usuarios al azar. Un usuario sólo participa en uno de los escenarios de los que consta la evaluación.

Para la tarea se establecen tres periodos: preparación (p1), ejecución (p2) y sincronización (p3). Estos periodos identifican las distintas fases por las que transcurre la tarea con el fin de analizar de esta manera los resultados sobre cada una de ellas. El periodo p1, denominado de preparación, comprende la fase durante la cual el usuario prepara la información necesaria para poder realizar la tarea antes de que la aplicación web se establezca en modo offline. El periodo p2, denominado de ejecución de las actividades, corresponde a la fase offline en la que el usuario realiza las actividades. El periodo p3, denominado de sincronización, corresponde a la vuelta al modo online. Durante este periodo el usuario actualiza el trabajo realizado en modo offline para que se actualice en el servidor Moodle.

4. RESULTADOS Y DISCUSIÓN

Las medidas para comparar la ejecución de la tarea en los escenarios online y offline son la productividad y la satisfacción. La productividad del sistema se analiza en base al tiempo usado para la realización de las tareas. La Figura 8 muestra los tiempos de los usuarios en la realización de las actividades sin la utilización del Proxy Offline. Cada barra vertical representa el tiempo que cada usuario tarda en cada uno de los periodos definidos anteriormente (preparación, ejecución y sincronización). En el cuadro inferior de la figura se muestran estos tiempos junto con el tiempo total que tarda el usuario en realizar la actividad. Los tiempos para la realización de las actividades utilizando el proxy online se reflejan en la Figura 9.

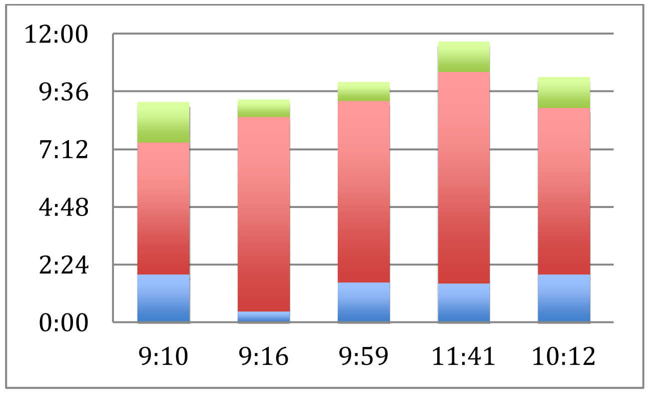

Figura 8. Tiempos sin la utilización del Proxy Offline

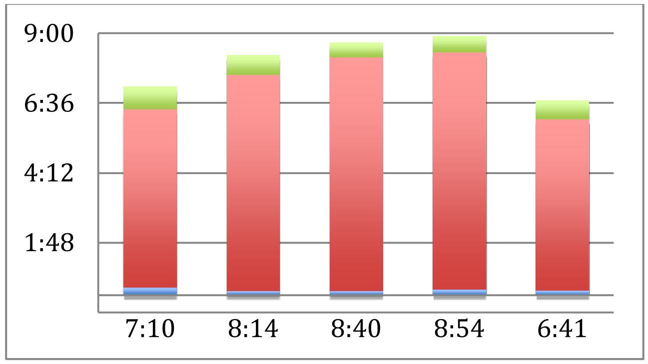

Figura 9. Tiempos utilizando el Proxy Offline

Respecto a los tiempos totales para la realización de la tarea, se puede observar que estos son menores utilizando el Proxy Offline. Si bien hay tiempos parecidos en ambos escenarios, offline y online, si tomamos la media como referencia obtenemos un tiempo medio de 10:03 minutos sin la utilización del Proxy Offline por una media de 7:55 minutos utilizando el Proxy Offline. De este análisis podemos concluir que, si bien la experiencia del usuario realizando este tipo de trabajo en escenarios offline puede hacer variar la duración de la tarea, de forma general se produce una disminución en el tiempo al utilizar el Proxy Offline.

Además, una comparación de las medias de los tiempos por periodo para la realización de las tarea tanto utilizando el Proxy Offline como sin utilizarlo se muestra en la Figura 10. En ella se puede observar como en p2 la diferencia no es muy elevada, ya que supone una reducción del 3% en la media de tiempo. Sin embargo, esta diferencia es mayor en p1 y p3. Mientras que en p3 la reducción es del 46% en la media de tiempos para las actividades en ese periodo, en p1 la reducción es del 89%.

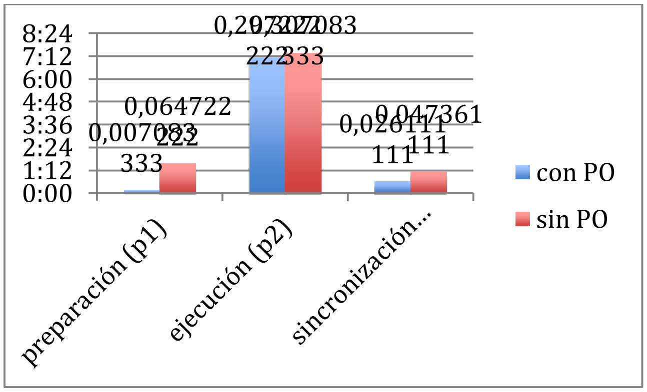

Figura 10. Comparativa de medias de tiempos por periodo según la utilización el Proxy Offline

Aún siendo la media de tiempos por periodo menor con la utilización del Proxy Offline, se puede observar tanto en la Figura 8 como en la Figura 9 que no todos los tiempos por usuario para p2 y p3 son menores utilizando el Proxy Offline. En estos periodos también interviene la experiencia del usuario y su pericia a la hora de gestionar los recursos y el uso de la plataforma. Sin embargo, en p1 todos los tiempos son menores utilizando el Proxy Offline.

De este análisis de los tiempos que los usuarios tardan en realizar las tareas utilizando el Proxy Offline y sin utilizarlo, podemos observar que se produce una reducción drástica en el tiempo para los periodos p1 y p3. Sin embargo, para el periodo p2 esta reducción es menos drástica, sino inexistente. Además, para el periodo p1 la mejora en el tiempo es generalizada y no depende tanto del usuario. Sin embargo, en los periodos p2 y p3 el usuario determina en gran medida el margen de mejora en el tiempo que le lleva la realización de la tarea utilizando o no el Proxy Offline.

Para la evaluación de la satisfacción de usuario se utiliza el test SUS (System Usability Scale) [4]. La puntuación obtenida sin la utilización del Proxy Offline es de 65.5, indicando que los usuarios no están satisfechos con el sistema. Los resultados obtenidos utilizando el Proxy Offline es de 95.5, indicando que los usuarios están muy satisfechos utilizando el Proxy Offline.

Otro de los resultados interesantes encontrados durante la realización de la evaluación es el número de aplicaciones que los usuarios utilizan durante la realización de las actividades. Mientras que utilizando el Proxy Offline el usuario sólo utiliza el navegador web (al igual que lo haría si no estuviera en un escenario offline), los usuarios que no utilizan el Proxy Offline utilizan 3 aplicaciones de media.

El uso de varias aplicaciones complica la interacción del usuario. No sólo se ve afectado el tiempo que le lleva realizar la actividad. También hay otros parámetros que se ven afectados, como lo son el aumento del número de acciones que el usuario realiza. Estas acciones son del tipo "salvar documento", "abrir documento", "copiar texto" … Según el estudio realizado, se introducen una serie de acciones al no utilizar el Proxy Offline que no se realizan en el navegador web, aumentando la probabilidad de que se cometan errores durante la interacción del usuario. Durante la evaluación se han contabilizado una media 0.4 errores en p1, 0.8 errores en p2 y 1.8 errores en p3 cuando no se utiliza el Proxy Offline. Cabe destacar que la media de errores utilizando el Proxy Offline es de 0 en p1, p2 y p3.

Estos datos se pueden aplicar a una problemática concreta: la ejecución del caso de estudio en dispositivos móviles. Si se realizan estas actividades en dispositivos móviles, como teléfonos o "*tablets*", la interacción del usuario todavía se complica más debido a las peculiaridades en la interacción con las aplicaciones en este tipo de dispositivos. De esta forma, la tasa de errores podría incrementar, al igual que disminuir la satisfacción de usuario.

Por último, durante el transcurso de la evaluación fueron significativos los comentarios de los usuarios. A continuación se recogen algunos de ellos utilizando el Proxy Offline: *"Creo que sería necesario un tutorial previo, aunque no sería necesaria mucha explicación. Con un poquito quedaría claro"; "Es fácil pasar los datos trabajados en modo offline cuando ya hay línea"; "La página se queda limpia con la tarea que tienes que hacer; te es más fácil concentrarte para resolver la tarea"*.

Por su parte, algunos comentarios durante la realización de la evaluación sin el uso del Proxy Offline fueron los siguientes: *"En base a la experiencia que tengo, para realizar la tarea offline descargo todo los documentos y los guardo en un dispositivo de almacenamiento externo USB. Luego trabajo en ellos en el tren para actualizarlo cuando llego al trabajo"; "Es complejo de utilizar porque tienes que abrir todas las tareas y los documentos relacionados para poder hacer las tareas una vez que no se dispone de internet. Hay que tener cuidado de cargar todos los contenidos o te quedas sin hacer las tareas"*.

5. TRABAJOS RELACIONADOS

5.1 Las aplicaciones web y el almacenamiento local de la información

Las aplicaciones web son accesibles a través de clientes ligeros, como los navegadores web, a través de redes como Internet o el uso de intranets [1]. Esta definición implica que la aplicación web está alojada en una máquina remota, el denominado servidor web, que sirve el contenido (como texto, imágenes o video) tanto de forma estática o dinámica entre los usuarios que lo requieren bajo demanda por medio de la utilización de un navegador web instalado en el dispositivo del usuario. El contenido servido por el servidor web se encuentra empaquetado como una mezcla de código HTML y código ejecutable. Cada vez que el cliente recibe este código junto con los recursos asociados, se crea una copia local, o cache, de forma temporal que el navegador procesa y muestra al usuario.

Es habitual la utilización de caches para aumentar el rendimiento de las aplicaciones web y mejorar la interacción con la aplicación web. Muchas de las aproximaciones para la gestión de la cache se basan en las tecnologías del lado del servidor como "*proxies*" o plantillas. Sin embargo, tecnologías como Gears-monkey [10], HTML5 [17] y Web Store [18] permiten el uso de nuevas estrategias para almacenar información de forma local en aplicaciones web. Gears-monkey permite la inyección de código en sitios web existentes para ser visualizados posteriormente en los navegadores. Los scripts del lado del cliente desarrollado por los usuarios pueden entonces soportar la interacción offline para la gestión de la información. Sin embargo, esta solución está limitada a unas pocas plataformas y no puede ser ejecutada en muchas de ellas, por ejemplo en teléfonos móviles. También requiere de usuarios experimentados para la escritura de los scripts. También existen soluciones *"ad hoc"*. Por ejemplo, McAllister [12] propone una aplicación web offline que utiliza tecnologías web offline para que los pacientes guarden la interacción con la aplicación de forma offline para poder trabajar con ella sin la necesidad de una conexión de red.

Para gestionar la información en las aplicaciones web de forma local la tendencia actual es la utilización de tecnologías HTML5. La más básica se gestiona a través de Web Storage. Esta introduce un mecanismo similar a las cookies de sesión HTTP permitiendo el almacenamiento de pares clave-valor. También se pueden utilizar mecanismos más complejos que permiten el almacenamiento local de información y su recuperación a través de estructuras complejas, permitiendo consultas avanzadas a través de Web SQL Database [19] o Indexed Database API [20].

Pero para poder usar todas estas tecnologías es necesaria la utilización de tecnologías que permiten la interacción con los sitios web en modo offline. Actualmente existen dos propuestas para llevar a cabo este fin dentro de la especificación HTML: 1) *Offline Web Applications* [21], que permiten declarar los contenidos que están disponibles de forma offline; y 2) *Service Workers* [22], que permite realizar una gestión más completa de la forma en que van a ser utilizados los recursos disponibles en la aplicación cuando estos no estén accesibles o estén disponibles sólo de forma local.

5.2 Gestión de la conectividad offline en plataformas e-Learning

Aún siendo las tareas académicas y la interacción con sistemas e-Learning unas de las actividades más comunes con plataformas web [8] no hay trabajos que estudien a fondo la interacción de los usuarios con este tipo de plataformas en escenarios offline.

Hay numerosas aportaciones sobre multitud de temas relacionados con software para educación, como puede ser el estudio del awareness para educación [7][23][11] o su utilización en dispositivos móviles [5][15] pero sólo unos pocos abordan de forma superficial la problemática offline en plataformas e-Learning [9][16][3]. Estos últimos no aportan resultados significativos de estudios con usuarios en escenarios reales donde se soporte la interacción offline con aplicaciones web existentes y que estén siendo utilizadas de forma generalizada.

6. CONCLUSIONES

En este trabajo se presenta una primera evaluación de un caso de estudio con usuarios en una aplicación web ampliamente utilizada adaptada a la interacción offline. Para ello, se presentan las decisiones y acciones a realizar sobre los diferentes elementos que componen las aplicaciones web en escenarios offline, identificando los aspectos a tener en cuenta especialmente sobre la interfaz de usuario. Una vez sentada esta base, se diseña la interacción offline a través de la aplicación denominada Proxy Offline, que habilita tanto el diseño como la interacción offline en aplicaciones web existentes tanto para la capa de navegación como para la capa de presentación.

La evaluación realizada a través del test piloto arroja unos primeros resultados acerca de cómo el Proxy Offline afecta a la utilización de aplicaciones web existentes en entornos offline: se reduce el tiempo en la realización de las tareas; desaparecen el número de errores cometidos por el usuario debido a la problemática offline; y por último, mejora de la satisfacción de usuario. Además, se ha obtenido información acerca de cómo los usuarios trabajan en escenarios offline y su opinión acerca de las soluciones presentadas.

Como trabajo futuro, se continuará con la evaluación del uso del Proxy Offline en diferentes categorías de aplicaciones web existentes, así como la publicación del funcionamiento y la arquitectura del Proxy Offline.

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Elaborating a Web Interface Personalization Process

J. Eduardo Pérez   Xabier Valencia   Myriam Arrue   Julio Abascal

Egokituz: Laboratory of HCI for Special Needs
Informatika Fakultatea. Universidad del País Vasco/EuskalHerriko Unibertsitatea
(+34) 943018067
{juaneduardo.perez, xabier.valencia, myriam.arrue, julio.abascal}@ehu.eus

ABSTRACT

This paper builds the required conceptual model for implementing adaptation systems intended to provide a personalized navigation experience for any user. To this end, aspects such as the users' needs, preferences, and navigational behaviour are taken into account in order to select the adaptation techniques to be applied for each particular user. The validity of the proposed conceptual model to provide the necessary components and mechanisms for implementing suitable web personalization systems is shown by means of a case study.

Categories and Subject Descriptors

H.5.4 [**Information Interfaces and Presentation**]: Hypertext/Hypermedia—*User Issues;* K.4.2 [**Computers and Society**]: Social Issues—*Assistive technologies for persons with disabilities.*

General Terms

Human Factors

Keywords

Automated web personalization, assistive technology, adaptation techniques, physical impairments.

1. INTRODUCTION

Several attempts have been made to automatically adapt web interfaces for users with disabilities. Performing appropriate adaptations requires taking several issues into account, such as the techniques to be applied for each specific user's needs, navigation behaviour and preferences. Most of the currently existing automated adaptation systems are not comprehensive enough to cover the full range of diversity among users.

The objective of this paper is to present a conceptual model for the automated adaptation of web interfaces. The conceptualization of this complex process will benefit from abstract modelling. This abstraction will allow a better comprehension of each of its phases and their interactions. In addition, it will facilitate the design of modular and interchangeable tools for each phase. A case study for users with physical impairments based on the results obtained in our previous work [12] is presented as a proof of concept for the proposed conceptual model.

2. BACKGROUND

Many automated web adaptation systems have been developed in the last decade. Most of them require the target websites to be semantically annotated. This method allows referring web contents to external metadata, which add semantic information for appropriately transforming a target web page [1]. Some of the automated adaptation systems perform user-type-centric adaptations based on basic stereotyped transcoding techniques. Other systems can be classified as generalist approaches. These systems include repositories for storing user models and adapting web content according to their content.

The system proposed by Takagi et al. in [15] is user-type-centric as it is devoted to facilitating the web navigation of blind users. The system is placed in a proxy, and inserts annotations into the HMTL of target web pages by means of XPATH expressions. The system performs simplification, rearrangement and text alternatives insertion based on crowd sourcing annotation techniques. Bigham et al. [2] also proposed a system focused on improving blind users' navigation experience. This system is capable to add the missing alt text of images by applying contextual analysis, OCR techniques and human-based crowdsourcing labelling functionalities. Other examples of user-type-centric adaptation systems are Dante [17] and SADIe [7]. Both are oriented to users with visual disabilities. The former implements structural adaptations such as segmentation of a web page in a number of simplified web pages by identifying meaningful content chunks, including a table of content, etc., whereas the latter implements the rearrangement of content and the insertion of navigation links in order to improve blind users' performance. Both perform semantic annotations: SADIe applies annotations to CSS elements while Dante make uses of Xpointer technology to annotate the web elements. Flatla et al. proposed the SPRWEB system [4] that adapts the colours of the target web page to people with colour vision deficiency. This system applies a model to predict the perceived temperature, activity and weight of the colours defined in the CSS file related to the web page. The Sasayaki system [14] is devoted to blind users and provides a secondary voice which augments with contextual information the primary voice output of screen readers. In addition, it provides methods to directly access to "semantically meaningful" components, to provide spatial information and to access social information supported by volunteers based on annotation techniques.

A lower number of works related to other user groups are available. For instance, Hurst et al. [8] proposed interface adaptations for the group of users with physical disabilities. The techniques employed are related to specific health conditions such as ataxia, dystonia, tremors, etc. Mankoff et al. [11] proposed web adaptations —such as increasing the font size to make links larger and reducing horizontal scrolling by means of page linearization— that can improve accessibility for users with physical disabilities. Hanson and Richards [6] proposed a proxy system for adapting web content for elderly people. It was later converted to an add-on [13] for enhancing the adaptations performed in the client-side. The adaptation techniques applied are magnification, line-spacing personalization, text size definition, high contrast option, etc. The adaptations are performed at the user's request by means of dialogs that collect users' preferences. Gajos et al. [5] proposed a system for automatically generating personalized interfaces for users with motor impairments. In order to define a personalized interface an ability test is performed by the user. However, the adaptation techniques performed are not based on semantics because these systems do not apply annotation techniques.

Fewer references to automated web adaptation oriented to multiple disabilities can be found in literature. Valencia et al. [16] proposed a system for automatically adapting websites according to the user characteristics based on WAI-ARIA annotations. This system incorporates a comprehensive repository of adaptation techniques appropriate for different groups of users and an ontology for user modelling.

3. PERSONALIZATION APPROACH

3.1 Conceptual Model

The automated adaptation of web interfaces to accessibility requirements is a complex process that requires formalization in order to enable the modelling of the whole process taking into account multiple factors, such as user needs, required adaptation techniques and user preferences. In addition, a comprehensive model helps to structure and specify the necessary phases of the process: web interface annotation, adaptation techniques selection and the definition of user preferences.

The conceptual model presented here defines the components and mechanisms required for performing this process. The basic components of the model are:

Web_Interface, which is a set of elements enabling users to interact with the web application. A *Web_Interface* can be defined as a set of *Presentation, Navigation and Content* elements:

Web_Interface (Presentation, Navigation, Content)

Annotated_WebInterface is a new web interface obtained after an annotation process performed with the aim of providing semantics to the elements contained.

Annotated_WebInterface (A_Presentation, A_Navigation, A_Content)

A *User_Model* contains information about the parameters that characterize each user and are relevant to determine the adaptation techniques to be applied relating to the needs, preferences and behaviour.

User_Model (User_Needs, User_Preferences, User_Behaviour)

An *Adaptation_Technique* comprises the components that are applied to obtain the adapted web interface for a given user. These adaptation techniques can affect one or more of the components of a *Web_Interface*: presentation, navigation, content.

Adaptation_Technique (Presentation, Navigation, Content)

The components of an *Adaptation_Technique* to be applied for a specific user are selected based on the information contained in their *User_Model*. Some techniques to be applied are related to the needs of the user due to their abilities (*Core_Adaptation_Technique),* others are related to their preferences *(Preferences_Adaptation_Technique)* and the remainder to the set of restrictions imposed by the assistive technology used and the set of strategies applied by the user for the interaction *(Behaviour_Adaptation_Technique).*

Adaptation_Repository is defined as the data structure that contains all the adaptation techniques:

Adaptation_Repository (Core_Adaptation_Technique, Preferences_Adaptation_Technique, Beviour_Adaptation_Technique)

The *Adapted_WebInterface* is an adapted version of the web interface obtained through the application of the corresponding adaptation techniques for a given user.

Adapted_WebInterface (Adapted_Presentation, Adapted_Navigation, Adapted_Content)

The *Personalized_WebInterface* is a user-tailored web interface considering user preferences.

Personalized_WebInterface(Personalized_Presentation, Personalized_Navigation, Personalized_Content)

Each of the phases involved in the automated adaptation process can be defined as the application of a set of transformations. Some of them are applied to the original web interface (*Web_Interface* component), others to the annotated web interface (*Annotated_WebInterface* component) and others to the adapted web interface (*Adapted_WebInterface* component). The formal definition of a transformation is the following:

New_Web_Interface (New_Presentation, New_ Navigation, New_Content) **« transformation (Transformation_Parameters)** Web_Interface (Presentation, Navigation, Content)

where *Transformation_Parameters* are the required information for performing the conversion.

The transformations applied in each of the adaptation process phases are the following:

3.1.1 Annotation phase

*Annotated_WebInterface(A_Presentation, A_Navigation, A_Content) « **annotation (annotation_language semantics)** Web_Interface (Presentation, Navigation, Content)*

3.1.2 Adaptation phase

Adapted_WebInterface (Adapted_Presentation, Adapted_Navigation, Adapted_Content) **« adaptation (*User_Model (U), Adaptation_Repository (Core_Adaptation_Technique, Preferences_Adaptation_Technique, Behaviour_Adaptation_Technique)*** *Annotated_WebInterface (A_Presentation, A_Navigation, A_Content)***)**

3.1.3 Preferences definition phase

Personalized_WebInterface (Personalized_Presentation, Personalized_Navigation, Personalized_Content) **« Preferences_Definition (*User_Model (U), Adaptation_Repository (Core_Adaptation_Technique, Preferences_Adaptation_Technique, Behaviour_Adaptation_Technique)*** *Adapted_WebInterface (Adapted_Presentation, Adapted_Navigation, Adapted_Content)***)**

Note that the *annotation* and *Preferences_Definition* transformations are manually performed by the system designer and the user respectively whereas the adaptation transformation is automatically performed by the adaptation system. Nevertheless, a comprehensive adaptation system must include utilities and assistants for facilitating both manual processes. In addition, the system must provide features for storing the results gathered in these phases in order to apply them in future interactions

3.2 Case Study

In our previous work [16] a comprehensive set of 99 adaptation techniques were identified from the literature and classified for application to cognitive, physical and sensory impairments. However, this approach was based on stereotypes and cannot deal with users' specific navigational strategies, preferences and heterogeneity of each user in a group. Results from recent studies about navigational behaviour of users with disabilities are now considered for obtaining appropriate personalization systems.

In addition, one of our previous research projects focused on users with physical impairments [12] showed that the type of assistive technology used has a significant impact on their navigational behaviour. Therefore, the defined conceptual model provides mechanisms for classifying adaptation techniques in three main groups: core adaptations, preferences adaptations and behaviour adaptations. According to this classification, we stored the adaptation techniques appropriate for all users with physical impairments as *Core_Adaptation_Technique* type. Those techniques appropriate for users using the same assistive technology were stored as *Behaviour_Adaptation_Technique* type. Finally, optional techniques selected by users according to their preferences were stored as *Preferences_Adaptation_Technique*. This classification is relevant because the adaptation techniques are applied in different phases of the process.

In this sense, the total number of 18 adaptation techniques (see Table 1) for physical disabilities identified in the literature [3][5][9][10] were classified in the proposed three groups. The core adaptation techniques identified as beneficial to all users in the group are:

- Content: (5) *Remove walking menus*, (6) *Avoid click and drag elements* and (7) *Avoid double-clicking elements.*
- Presentation: (10) *Hierarchically structure content*.
- Navigation: (12) *Provide navigation bars*, (13) *Provide quick access to different topics within a website*, (17) *Provide skip links (e.g., to main content).*

Observations made during the exploratory study about the pointing time revealed that users of specific pointing devices such as joystick, trackball or reconfigured standard input device needed more time to reach and click on targets due to their lack of accuracy. Therefore they would benefit from the following specific adaptation techniques which should be included into the group of behaviour adaptation techniques:

Table 1. Set of adaptations techniques specially focused to improve access to the Web for physically impaired users.

Categories	Adaptation Techniques
Content	(1) Add hot area around hyperlinks (2) Use stretchtext in main content (3) Incorporate specific scrolling icons on each page (4) Incorporate buttons for browser "Back" and "Forward" functionalities (5) Remove walking menus (6) Avoid "click and drag" elements (e.g., spinners) (7) Avoid double-clicking elements
Presentation	(8) Define large clickable area for links and buttons in a visible way (9) Define links and buttons well separated (10) Hierarchically structure content (11) Break pages into chunks of no more than one or two screens
Navigation	(12) Provide navigation bars (13) Provide quick access to different topics within a website (14) Provide an index with information in the page (15) Create a table of contents for website (16) Provide internal links to important content on the page (e.g., return to the top of page) (17) Provide skip links (e.g., to main content) (18) Disable non-recommended links (e.g., banners)

- Content: (1) *Add hot area around hyperlinks and* (4) *Incorporate buttons for browser "Back" and "Forward" functionalities.*
- Presentation: (8) *Define large clickable area for links and buttons in a visible way* and (9) *Define links and buttons well separated*.

Most participants from this group were not used to keyboard specific keys for activating scroll functions and preferred using standard scroll bar buttons instead, which requires additional time for pointing and clicking. For this reason, the next adaptations considerably improve the performance of these users and were also included in the behaviour adaptation techniques group:

- Content: (2) *Use stretchtext in main content* and (3) *Incorporate specific scrolling icons on each page.*
- Navigation: (16) *Provide internal links to important content on the page (e.g., return to the top of page).*
- Presentation: (11) *Break pages into chunks of no more than one or two screens*.

Our results indicated that the performance of numeric keypad users' when moving the cursor depends on the distance and number of keystrokes needed to reach a target. This condition had even a greater impact among participants using a head wand than those participants directly accessing the numeric keypad with their hand. The following adaptations will benefit the navigation experience of this group of users by reducing cursor movement or the number of total keystrokes needed to reach a target:

- Navigation: (14) *Provide an index with information in the page*, (15) *Create a table of contents for the website* and (18) *Disable non-recommended links (e.g., banners).*

Therefore, these techniques are included in the corresponding behaviour adaptation techniques group.

The preference adaptation techniques group include the following:

- Hide/show specific scrolling icons

- Hide/show buttons for browser “Back” and “Forward” functionalities
- Define the preferred location for scrolling icons
- Define the preferred location for browser “Back” and “Forward” functionalities
- Hide/show accesskeys for scrolling/browser “Back” and “Forward” buttons
- Hide/show accesskeys for main content sections in the website

The phases of the adaptation process were performed as follows:

- Annotation phase: WAI-ARIA annotations were applied to add semantics to the presentation, navigation and content elements in the web interfaces. This process is thoroughly described in [16].
- Adaptation phase: the core and behaviour adaptation techniques were applied to the annotated web interface in order to perform adaptations based on the users' abilities and navigational strategies related to the assistive technology used.

4. CONCLUSIONS AND FUTURE WORK

The conceptual model presented in this paper provides a high level abstract description of the automated web adaptation process, including the management of the necessary components and mechanisms considering users' needs, navigational strategies and preferences. To show its validity for designing complex systems for web adaptation a specific case study for users with physical impairments based on this model is defined and developed. Currently, the adapted interfaces, the personalized interfaces and the preferences definition features are being evaluated with users. Results obtained in these evaluations will be analyzed and included in future works.

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Goal Driven Interaction (GDI) vs. Direct Manipulation (MD), an empirical comparison

A. L. Carrillo
Department of Computer Sciences
ETSI Industriales. Campus Teatinos
29071 Málaga, Spain
+34 95195239
alcarrillo@uma.es

J. Falgueras
Department of Computer Sciences
ETSI Informática. Campus Teatinos
29071 Málaga, Spain
+34 952132792
juanfc@uma.es

ABSTRACT
This paper presents a work in process about *Goal Driven Interaction* (GDI), a style of interaction intended for inexperienced, infrequent and occasional users, whose main priorities are to use a system and achieve their goals without cost in terms of time or effort. GDI basic philosophy is to guide the user about the "what" to do and the "how" to do it in each moment of the interaction process, without requiring from the user a previous knowledge to use the interface. This interaction style was introduced in previous work, where a description of its characteristics and the most appropriate user interface for it, were described. Those works included a methodology for the analysis and synthesis of the whole interactive process through a language of specification. This paper presents partial results we are collecting in real user testing, with the main aim of comparing GDI with direct manipulation interfaces (MD), nevertheless the most extended and commonly regarded as the most suitable for novice and experienced users.

Categories and Subject Descriptors
D.2.2 [**Design Tools and Techniques**]: User interfaces;
H.5.2 [**User Interfaces**]

General Terms
Human Factors, Experimentation, Design.

Keywords
User testing, Empirical usability evaluation, Guided interaction, Interaction styles, User interfaces

1. INTRODUCCIÓN
Although *Direct Manipulation (DM) with WIMP (Windows, Icons, Menus and Pointer) elements* [1] is currently the most extended desktop user interface paradigm in use, there are still many users that need training and learning period, manuals and/or expert support to become efficient users. For this reason, in previous works [2, 3, 4], the authors proposed and presented a new and alternative style of interaction: *Goal Driven Interaction* (GDI). GDI was meant to become the interaction style of choice for applications where the main priority is ease of use and minimal learning time for a user to interact with the program (as occasional, infrequent or inexperienced users), even if sacrificing speed in task achievement, the ability of running parallel tasks, and other advantages of *WIMP interfaces*.

The fundamentals of GDI trace back to the works of Newell and Simon [5] that were devoted to the mechanism of human reasoning for problems resolution. Their vision of problem solving (as in GDI) was based in the breaking up of the main or general goal in a hierarchical tree of sub-goals, whose branches would have different lengths depending on the degree of their fragmentation into sub-goals. The leaves of the tree would be elementary actions or sub-goals.

Based on these works, Card, Moran and Newell [6, 7] developed the most important of the existing cognitive models, the Human Processing Model, whose initial paradigm (as in GDI) consisted in conceiving the interaction as a problem resolution task, and described a psychological model of humans formed by three interactive systems: perceptive, motor and cognitive, each one would have their own memory and their own processor.

This vision of the user as an information processing system, allows for the formalization of all the activities (both physical and mental) that take part in that task, and gave origin to the methods for modelling, specification and evaluation of the user interface that are widespread today, the GOMS (Goals, Operators, Methods, and Selection rules) methods [8, 9]. Among other things, that methods allow the description of the sequences of behavior and knowledge that the user need to correctly interact with the system and accomplish his goals. The models themselves are framed in the set of techniques that allow for a hierarchical task analysis, as their main goal is the decomposition of those tasks, so that the resolution method can be followed step by step. Authors extended the NGOMSL notation [10] to use it as a source specification language, which after a compilation process, generates the corresponding GDI user interface.

Therefore, because of this extended NGOMSL models include the hierarchical knowledge the user must have (the tasks to do, and the procedures to be followed), the aim of GDI is to preclude the user from having to devote time to acquiring such knowledge. GDI’s main strategy is to let the interface gradually provide the user with such knowledge, and to guide him in a hierarchical and progressive way through the whole interaction process, not only as far as the tasks and goals approach are concerned, but also about the sequence of steps to follow or the choices that can be made at any moment to achieve those goals.

This strategy is, in many respects, the opposite of the MD in the sense that the user has no freedom of interpretation or any possibility of experimentation with a metaphor. As *wizards* oriented interfaces, GDI gives the control to the system, as opposed to MD that gives the control to the user.

The user interfaces based on this interaction style will need an area (as seen in **Fig. 1**) called *Goals Driver Window* (GDW) that will be the place where the user will be presented with either the *steps* of the *method* to be followed or the different *alternatives* to *choose* from, to satisfy the specific *goal* at any moment. Then, GDW becomes the substitute (or alternative) to the typical menus, icons, toolbars and those elements in WIMP interfaces, that are not necessary in GDI (as seen in Figure 1).

2. TEST CONDUCTING

2.1 Introduction

To perform the comparison between the two interaction techniques (GDI vs MD-WIMP) a set of tests involving real users is being conducted [12, 13]. For these tests a familiar task was chosen, a task for which is likely the user has some experience or at least will understand it quickly. In particular, the theme chosen for this testing is the design and furnishing of kitchens, both because it is an infrequent scenario, except for professionals in this field; and, as we have said, is a familiar task domain for almost all users, at the same time requiring manipulation of diverse objects, reasons which, in principle, could be seen favouring MD interaction style.

Two prototypes in Java language, one with the GDI interface **(Fig.1)** and the other with a classic MD WIMP interface **(Fig.2)**, both sharing most of the code except, of course, the sections in which user interface and style of interaction are involved. Although simplified systems, both offer the same functionality and allow the user perform the same tasks. The application is inspired by the desktop version of the similar one offered by the company IKEA [11].

Before starting, all participants sign an Informed Consent, and are meanwhile advised that the tests are taken voluntarily, free to leave any time without any justification. This Informed Consent also clarifies that these tests are not intended to make any personal or psychological assessment, but for the evaluation of the computer user interfaces involved.

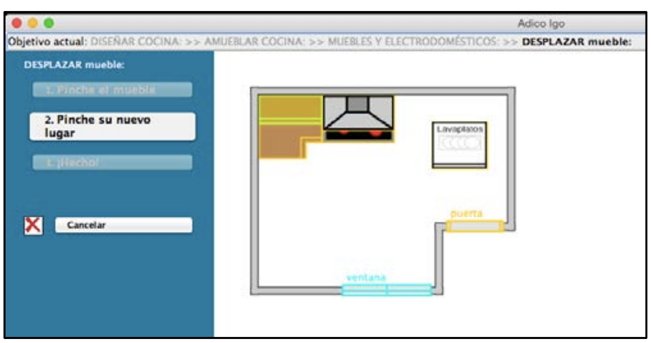


Figure 1. GDI interface screenshot

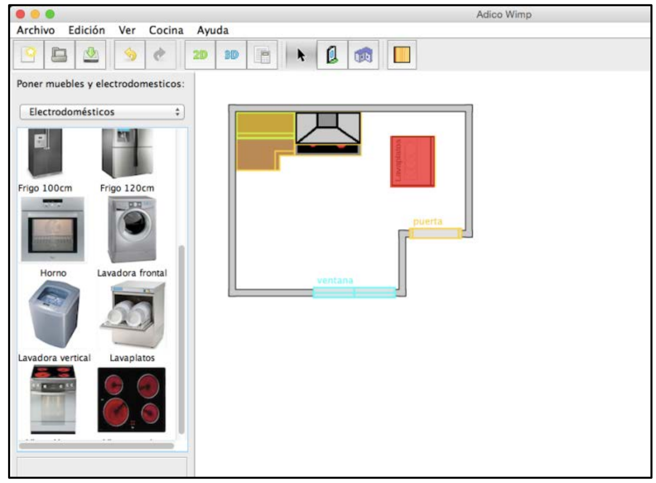


Figure 2. DM-WIMP interface screenshot

Each user should try to achieve the same goal with each of the two interfaces (GDI vs. MD-WIMP).

Data are collected both quantitative and qualitative, the former as time lengths, number of issues of assistance, number of errors (categorised by severity), etc., as well as qualitative data from the subsequent questionnaires.

2.2 User features

By the end of the study we will have tested around 25 participants. This number will include EyeTracker analysis for some of them. If any conclusions would deem it appropriate, a second phase with more users would be conducted.

All users, except a small percentage of them, will be inexperienced users. The rest will be users with an intermediate computer level, and a very small percentage of them will be kitchen design professionals, used to using specialised applications for this purpose.

The age range is planned to span from 10 to 65 years (with an average of 45 years) without any disabilities described.

2.3 Test conditions

The tests are performed individually, in controlled spots, without distractions, thus allowing both techniques Thinking Aloud as well as screen and sound recording. The user does not feel any other influence but the presence of the moderator and the applications under test.

The estimated time per user (including questionnaires) ranges between 45 to 75 minutes.

The whole process of interaction is collected with two recordings. The first one is taken with a external video camera, located next to the user recording the user hands and the screen, and any incidences, assistances, etc., for further re-examination, if necessary. And the other recording, even more useful, is that which is taken with computer screen recording software.

A common laptop computer is used for all tests, which facilitate their relocation and is less intimidating and more familiar to users than any other complex installation. External video recording is also more conveniently done with a small camera.

2.4 Test development

The tests follow the next steps:

1. The user fills out a preliminary questionnaire containing personal information such as their age, genre, experience with technological and digital devices, domain knowledge of the task, etc.
2. The user receives a single sheet briefly describing the three group of tasks to do **(Fig. 3)**. This sheet with the tasks is available to the user throughout all the process.
3. Then, following a *balanced* strategy *within-subjects*, each user is made to use both versions of the application, alternating the order among users. *Thinking Aloud* technique is used in a relaxed way, not making at any time the user to explain what is being doing, but leaving them freedom to give explanations when necessary. The moderator tries not to interfere at any moment, or if so, only in critical or blocking situations. In any case the incidents are reflected and graded as part of the data collected.
4. At the end of each of the two tests (each one corresponding to a type of interface), and before moving on to another type of interface, the user fills out a questionnaire with 10 questions on specific points of the process that has just experienced. This covers important aspects for the final evaluation.
5. Finally, after the two tests and the corresponding questionnaires are done, the user fills out a quick questionnaire comparing both styles of interaction. Among the questions asked are: with which interface have you had less hesitation about *what* the next step was; with which was it easier to know *how* to take every step; for which do you consider that more aided should be included; which one seemed easier to use and required less training; with which was it faster to operate; and, naturally, their final preference.

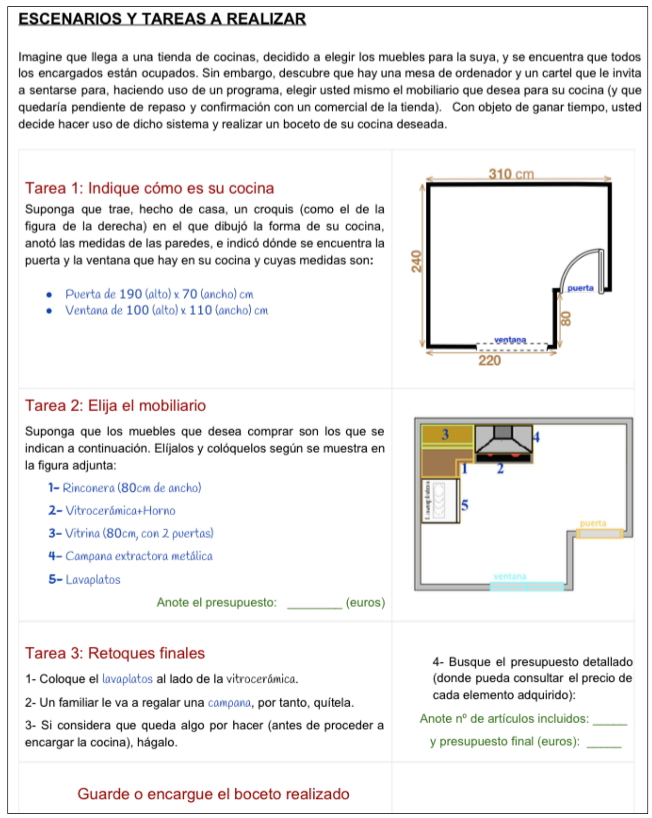
3. EVALUACIÓN DE RESULTADOS HASTA EL MOMENTO

The **Table 1** displays the partial empirical results of the first 8 users. The last columns of the **Table 1** display the types of incidences and, perhaps, the need of assistance by the moderator. There are three types of incidences: 1) slight, 2) non-locking, and 3) severe or locking. The most severe is the third type of incidence, which takes place when the user is stuck with something in the interface. This would prevent the user from finishing the task. This will require the assistance of the moderator in order to exploit the collected data and analyse the rest of the planned tasks for that user.

Non-locking issues correspond to detected or undetected mistakes that somehow affect the final results. For example a common error is repeatedly confusing the 'undo' action with the deletion of the last object added; or forgetting performing a task, or initially not choosing the correct geometry, erroneously keeping throughout the process the wrong shape of the kitchen, and perhaps requesting a warning by the moderator.

Finally, slight incidents could not be properly considered errors because could be sorted out by the user, perhaps with some delay. They are non-locking and did not need any moderator assistance.

An initial analysis of the empirical data obtained until this document was sent may be premature, nevertheless, two apparent tendencies can be drawn from those data: 1) GDI is more efficient in time (took less time in accomplishing the whole tasks), and 2) GDI needed fewer moderator warnings or assistances. On the other hand, from the questionnaires is explicit that all users have a sharp preference for the GDI interface. This might not be surprising among inexperienced users, but it was not expected for users of an intermediate computer level, and especially surprising in the case of professionals on kitchen design, who are used to more complete and complex MD interfaces. In addition, all users in the final questionnaire, that includes to compare both styles of interfaces, clearly opt for the GDI guided interface.


ESCENARIOS Y TAREAS A REALIZAR

Imagine que llega a una tienda de cocinas, decidido a elegir los muebles para la suya, y se encuentra que todos los encargados están ocupados. Sin embargo, descubre que hay una mesa de ordenador y un cartel que le invita a sentarse para, haciendo uso de un programa, elegir usted mismo el mobiliario que desea para su cocina (y que quedaría pendiente de repaso y confirmación con un comercial de la tienda). Con objeto de ganar tiempo, usted decide hacer uso de dicho sistema y realizar un boceto de su cocina deseada.

Tarea 1: Indique cómo es su cocina

Suponga que trae, hecho de casa, un croquis (como el de la figura de la derecha) en el que dibujó la forma de su cocina, anotó las medidas de las paredes, e indicó dónde se encuentra la puerta y la ventana que hay en su cocina y cuyas medidas son:

- Puerta de 190 (alto) x 70 (ancho) cm
- Ventana de 100 (alto) x 110 (ancho) cm

Tarea 2: Elija el mobiliario

Suponga que los muebles que desea comprar son los que se indican a continuación. Elíjalos y colóquelos según se muestra en la figura adjunta:

1- Rinconera (80cm de ancho)
2- Vitrocerámica+Horno
3- Vitrina (80cm, con 2 puertas)
4- Campana extractora metálica
5- Lavaplatos

Anote el presupuesto: ________ (euros)

Tarea 3: Retoques finales

1- Coloque el lavaplatos al lado de la vitrocerámica.
2- Un familiar le va a regalar una campana, por tanto, quítela.
3- Si considera que queda algo por hacer (antes de proceder a encargar la cocina), hágalo.

4- Busque el presupuesto detallado (donde pueda consultar el precio de cada elemento adquirido):

Anote nº de artículos incluidos: _____
y presupuesto final (euros): _____

Guarde o encargue el boceto realizado

Figure 3. Sheet with the tasks handed out to users

4. CONCLUSIONS

The work in process presented here complements the theoretical study of the GDI. This style of interaction is intended for applications that require the minimization of the learning time up to a point that makes them appropriate for inexperienced, infrequent or occasional users. The essential point here is no requiring previous knowledge. With this aim, these interfaces should guide the user towards their goal. To do so, indications of both the "what to do" and the "how to do it" must always drive the user at all times.

The partial results obtained so far show that, compared with a MD-WIMP interface, the total execution time is shorter, there is a fewer number of incidences, and finally the users show a clear preference for this guided interaction style.

Table 1. Partial empirical results (time and incidences) of the first 8 users.

User / (category)	Evaluation order	Task 1 Time		Task 2 Time		Task 3 Time		Total Time		Incidences		
										Slight	Non-locking	Locking
USER 7 (inexperienced)	GDI	6:20		9:20		8:11		23:51	▯		1	
	WIMP	14:23		11:26		11:32		37:21 (∞)			1	2
USER 2 (inexperienced)	WIMP	7:05		11:30		7:00	∞	25:35 (∞)			3	3
	GDI	5:30		7:00		3:30		16:02	▯			
USER 6 (inexperienced)	GDI	6:11		8:07		6:17		20:35	▯			
	WIMP	4:40		5:18		17:55	∞	27:53			3	
USER 4 (inexperienced)	WIMP	9:50		13:20		12:50	∞	36:00 (∞)	∞	2	2	3
	GDI	8:30		4:40		4:46		17:56	▯			
USER 1 (intermediate)	GDI	2:45		3:35		2:30		8:50	▯	1		
	WIMP	2:30		2:36		4:14		9:20			3	
USER 5 (intermediate)	WIMP	4:10		4:05		6:45		15:01		1	2	
	GDI	2:53		4:07		4:10		11:10	▯		1	
USER 3 (kitchen design professional)	GDI	2:30		4:15		1:45		8:30	▯			
	WIMP	5:55		1:50		2:00		9:45		1	2	
USER 8 (kitchen design professional)	WIMP	4:34		3:40		3:53		12:07				
	GDI	2:18		2:16		3:23		7:57	▯			

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Generating User Interface from Conceptual, Presentation and User models with JMermaid in a learning approach

Jenny Ruiz
University of Holguín
XX Anniversary Ave,
80100 Holguín, Cuba
+53 482672
jruizp@facinf.uho.edu.cu

Gayane Sedrakyan
KU Leuven
Naamsestraat 69
3000 Leuven, Belgium
+ 32 16 32 68 83
gayane.sedrakyan@kuleuven.be

Monique Snoeck
KU Leuven
Naamsestraat 69
3000 Leuven, Belgium
+32 16 32 68 79
monique.snoeck@kuleuven.be

ABSTRACT
Because of the pervasiveness of information technology in industry and the tremendous increase in User Interface (UI) design possibilities, the study of UI development has become an issue of great importance. To achieve short turnaround times when developing UIs, that moreover are of high quality and can adapt to various changes, the UI should be developed using a model-driven approach. Such model-driven development, generates a demand for IT professionals with model-driven UI development skills. The technical complexity of model-driven development adds up to the inherent complexity of UI design, and makes teaching UI development even more difficult. The evaluation of current environments reveals that none of them provides the necessary features to achieve good teaching support. Therefore the authors propose to extend the proven conceptual modelling teaching environment JMermaid by integrating of the W3C standard for Abstract User Interface meta-model and extending the existing models with presentation and user models. This tool will enable a student to generate a fully functional and feedback-enabled application with a single click and allow them to study how to design UI according to users preferences and skills.

Categories and Subject Descriptors
• **Human-centered computing~HCI theory, concepts and models** • **Human-centered computing~User interface design** • **Applied computing~Computer-assisted instruction** • **Applied computing~Interactive learning environments** • **Software and its engineering~Software prototyping** • Computing methodologies~Modeling methodologies

General Terms
Design, Human Factors, Theory.

Keywords
User Interface Generation, Model-Based User Interface Development, Model-Driven Engineering

1. INTRODUCTION
In the last decades, Information Technology (IT) industry has experienced significant advances that have led to the increased use of software applications with wide ranges of functionalities. While process automation for software applications has been an important focus of these advances [10], the range of User Interface (UI) design possibilities have tremendously increased as well.

Research in the early 1990s found that a significant proportion of software development time was devoted to implement the UI (48% of application code; 50% of application time) [17]. These figures are still considered relevant [7]. For this reason, the study of UI development has become an issue of great significance.

UI development is a difficult process [20]. Some authors [16], [8] emphasize that is really hard to understand the user´s characteristics and the task they perform with the system. Other authors [6] explain the increased complexity by the diversity of multiple platforms simultaneously, incorporating problems like the one of splitting User Interfaces in components. Moreover, the more easy to use the interface should be, the more difficult its development can be [16]. That´s why it is necessary to base the development of UIs on models that capture the essence of a UI design. To achieve short turnaround times when developing UIs, that moreover are of high quality and can adapt to various changes, such model-based UI development should preferably be expanded to a truly model-driven approach allowing to automatically transform models into code. Such model-driven approach allows implementing UI in a professional and systematic way, but it also generates a high demand for IT professionals with model-driven UI development skills. Therefore, teaching UI development is difficult due to the high inherent complexity of UI design and the additional technical complexity of model-driven development.

This paper investigates what optimal support to teach UI design would be, evaluates current environments against the necessary requirements for supporting UI design and proposes the integration of UI generation concepts in a didactic tool (JMermaid) which is based on a Model-Driven-Architecture (MDA) enterprise engineering method (MERODE) [27]. Based on the integration of the W3C standard for Abstract User Interface (AUI) meta-model and the enterprise layer meta-model of MERODE, the authors propose to generate part of the UI from a conceptual model, and to additionally incorporate presentation and user models. Using this tool, a fully functional application could be generated according to users preferences and skills. Moreover, the authors propose method for further expanding the feedback features already present in JMermaid to provide a learner with feedback on the UI aspects to help novices to understand the relationship between their design decisions, the models and the components of the UI.

This paper is structured as follows. Section 2 gives a brief description of Model-Based User Interface Development, the additional requirements needed to support a learning approach in UI generation and the analysis of the current approaches. Section 3 presents MERODE and JMermaid and the proposed extension of JMermaid as a didactic tool to teach User Interface design. Section 4 shows the evaluation of the proposed environment. Conclusions are provided in Section 5.

2. MODEL-BASED USER INTERFACE DEVELOPMENT

The generation process of User Interfaces involves the development of a conceptual model of the application and its functionality by the developer, on top of which the UI is then implemented, often using one or many metaphors [11]. Different kind of tools have been created to support UI development based on models, called Model-Based User Interface Development Environment (MB-UIDE) [7]. MB-UIDE is centered around the premise that a declarative interface model that represents information about UI characteristics can be used as a basis for building interface development environments.

MB-UIDE approaches and their supporting tools emerged because of the need for a comprehensive support of the whole life-cycle software development, and the need for a user-centered design methodology with corresponding environments [21]. However, in general, current User Interface tools support only the development phase of the User Interface life cycle.

A good MB-UIDE environment must meet certain requirements to satisfy the reasons why they emerged and to reap their potential benefits. On the other hand, if the environment will be used to learn UI development, additional requirements appear. Section 2.1 lists the key advantages of MB-UIDE, Section 2.2 explains the necessary additional requirements to provide effective support in teaching UI design, and Section 2.3 analyzes the approaches following the mentioned criteria.

2.1 Advantages of MB-UIDE

The model-based approach is instrumental in dealing with the inherent complexity of UI design. By describing the UI through the use of declarative models, developers can implement the UI in a professional and systematic way, more easily than when using traditional UI development tools. According to [21], [3] and other authors, this paradigm offers a number of key benefits: abstract and centralized UI specifications based on models able to target different delivery platform [21], [3], [33]; the use of explicitly represented design knowledge [21]; a user centered development cycle [21]; and facilities for the creation of methods to design and implement the UI in a systematic way: (1) model UI using different levels of abstraction; (2) incrementally refine the models; and (3) re-use UI specifications Da Silva.

Since UI designers need to understand the impact of design choices on the final result, the ability to create a full functional working application by integrating UI models with other models that represent a system´s functionality is essential to effectively support a teaching process. MB-UIDE approaches make the creation of UI more economical and maintainable by facilitating the automatic generation of UIs [7]. The term ‘model-based’ is a more general denomination that implies the use of declarative models. In the last few years, MB-UIDEs have evolved towards model-driven UI development. As [30] explains, there are comprehensive model-based approaches to develop UI but only a few of them are truly MDA compliant [15], [30].

2.2 Additional Requirements

Besides their use of models and ability to generate code, a MB-UIDE should satisfy a number of additional requirements in order to provide effective support in teaching UI design, amongst which relieving the novice modeler from technical complexities associated to MDE and providing learner-oriented feedback:

- Coverage of the development cycle: In order to facilitate learning, the environment needs to offer an integrated support for the complete software development process, and not only of developed interfaces [7].
- Generation of application code: [32] explains the importance of the application's code generation. To produce an accurate application at low cost, developers expect that both the User Interface and the application code are automatically generated.
- Concern with user perspective: This allows making more flexible UI in order to satisfy the different characteristics and skill of users.
- Language and template flexibility: This should allow the implementation of the UI in different ways on different delivery platforms.
- Ease of use: According to [18], MB-UIDEs have a high threshold of use because programmers must learn new languages to define the models. This can be avoided by offering easy to use MB-UIDEs.
- Level of learning support: As this research is intended to improve the learning of User Interface generation, learning support is also an important criterion to analyze in the different approach.

2.3 Investigating support by existing MB-UIDE approaches

In the last decades, different MB-UIDE approaches have been developed. Surveys of the most prominent MB-UIDE approaches provide in [3],[7] and [33] were used as a starting point. However, for this analysis AME []14, ITS [34], HUMANOID [12] and UIDE [28] were omitted. For AME and ITS there is not enough information available. Mastermind [29] (analyzed in this section) represents the continuation of the work of HUMANOID and UIDE. OO-Method [15], Mantra [1] and DB-Use [33] were developed in the last years, and so were added to the analysis.

Table 1 lists MB-UIDE approaches and shows the analysis of each approach using the mentioned criteria. If the criteria is achieved, it is marked with “+”; if not with “-”; “+/-” indicates that there is some, but not entirely concrete evidence that the criteria is supported.

In general, the analyzed approaches lack support for the complete development cycle. Only OO-Method provides complete support. DB-Use provides partial support with the support for create, update, delete and retrieve function. The ease of use is negatively affected by a lack of documentation, its (lack of) clarity and the low level of integration of tools. The automatic application code generation is only considered by the more recent approaches.

Most approaches generate only UI code (Adept [13], Mastermind [29], Janus [5], Teallach [9]). Fuse generates the user guideline of the application. Mantra is intended to generate the UI for web applications and these prototypes are integrated with the application core via web service protocols. DB-Use also generates the code for create, update, delete and retrieve functions related with the UI. Only OO-Method generates a full application with commercial tools that are not available for teaching purposes. The lack of concern of user´s perspective in most approaches shows that the end-user of the system is not adequately taken into account.

The criteria that are met the least are learning support and template flexibility. Design decisions are difficult to understand for novice up to medium developers, and there is no feedback that helps novices to understand the relationship between design decisions, the models and the different components of the UI.

Table 1. Criteria to analyze the MB-UIDE and its evaluation

Mb-UIDE /Criteria	Coverage of the development cycle	Generation of application code	Concern with user perspective	Language flexibility	Template flexibility	Ease of use	Level of learning support
Adept	-	+/-	+	-	-	-	-
Genius	-	-	-	-	-	-	-
Mecano	-	-	+/-	-	-	-	-
Mastermind	-	+/-	-	-	-	-	-
Trident	-	-	-	-	-	+/-	-
Janus	-	+/-	-	+/-	-	-	-
Fuse	-	+/-	+/-	-	-	-	-
Tadeus	-	-	+/-	-	-	-	-
Teallach	-	+/-	+/-	-	-	-	-
UI Teresa	-	+/-	-	+/-	-	+/-	-
Goliath	-	+/-	-	-	-	-	-
OO-Method	+	+	-	+	+/-	+	-
Mantra	-	+/-	-	+/-	+	-	-
DB-Use	+/-	+/-	+	+/-	+/-	+	-

Although there are many MB-UIDE approaches, generally they do not exploit the benefits of model-driven engineering for meeting the growing needs for UI generation. This raises the important issue of assisting software designers and developers in building such applications.

3. LEARNING APPROACH TO GENERATE UI FROM CONCEPTUAL, PRESENTATION AND USER MODELS

Given the lack of support of current environments for teaching User Interface design, and the high need for better support, this paper proposes to extend an existing environment to achieve better support. In the beginning of this section there is a presentation and motivation of the choice for MERODE and JMERMAID, the environment that will be extended. Subsequently, this section presents the limitation of the current environment in terms of support for UI design teaching. Finally, an outline of the proposed extensions to the JMERMAID tool is given.

3.1 MERODE & JMermaid

MERODE is an enterprise engineering approach that follows MDA/MDE approach of system engineering. It focuses on the development of a conceptual model (close to a Computational Independent Model) that is sufficiently complete to generate code out of it [27]. The method is supported by a didactic environment, JMermaid, allowing model creation and checking their coherence and consistency. The MDA-based code generator generates a fully functional prototype Java application [23] out of the model information that is stored in an XML file (called mxp-file). The prototype application moreover includes a number of feedback features, facilitating tracing the application's behavior back to its origin in the models. The didactic environment furthermore supports learning analytics based on process-mining of the learner's modelling process. This collection of features allows for process-oriented feedback rather than outcome feedback only. The effectiveness of this teaching support has been well tested and demonstrated by means of scientific experiments [25].

3.2 Current limitations

MERODE has no UI development support, but since it starts from conceptual models, it has a good potential for extension with UI-models. A MERODE-application has three layers: an enterprise layer, an information system service layer and a business process layer. JMermaid however only supports the development of the models of the enterprise layer. As a result, all the systems generated by JMermaid look alike: they have a standard set of services, accessible through a standard user interface. For example, the tool always generates a menu, in a vertical orientation, with tabs for all the object types in the model. All the methods can be accessed by buttons. The prototype generated by the JMermaid tool allows handling input and output data. Although JMermaid has a very good and consistent data validation, it always generates the same kind of representation format (e.g. textbox for an input) for attributes, no matter what the type of the attribute is. The JMermaid tool allows defining additional User Interface functionalities to e.g. search or filter information stored in the database but not in an easy way for the final user (e.g. it is necessary to manually query the database). As [20] explains, referencing the attribute by name would not be practical or correct if usability is considered a critical aspect of software quality. However, in JMermaid the name of the labels used in the generated User Interface are those from the attributes and methods of the objects in the class diagram. No possibilities are offered to specify other names. Furthermore, as it is now, JMermaid generates the labels with the name of the attributes and methods. It also presents the type of the attribute on the label. This is the way to show the user what kind of data he should provide. This tool always generates a simple input interaction object. JMermaid also manages input errors, so it can guide the user to enter the correct type of data in each input interaction object (a number or a character for example). The size of buttons are proportional to the name of the methods. This causes that not all the button sizes are equal.

3.3 Integrated UI development support in JMermaid

To improve the way JMermaid supports learning the different aspects of application modelling and development, it is required to extend the MERODE models with separate UI models. UI models exist at different levels of abstractions. The AUI is an expression of a UI in terms of interaction units without any reference to implementation and independent of any particular language. In order to standardize those concepts, the W3C Abstract User Interface standard has been introduced as a part of Model-Based User Interface Design to facilitate interchange of designs through a layered approach that separates different levels of abstraction. It is a standard meta-model for expressing an AUI as specified in the Cameleon Reference Framework Märtin. It defines the main concepts for the meta-model, as well as their properties and relationships, identifying its main requirements, proposing, describing and discussing a meta-model that provides a standard definition for AUI models Vanderdonckt, J., Tesoriero, R., Mezhoudi, N., Motti, V., Beuvens, F., and Melchior, J..

It is commonly accepted that simulation contributes to better understanding of modeling decisions offering a new standard of learning quality allowing the learner to “learn by experiencing”. Simulated environments are also known to promote successful transfer of the skills learned in classroom to real-world environments by allowing to simulate real-life situations where learners improve their technical and problem-solving skills. However, the existing standards for simulation technologies also introduce a number of shortcomings. The major disadvantages include being too complex and time consuming to achieve simulation by novice modelers whose technical expertise is limited. Another important disadvantage is connected with the difficulty of interpreting the simulation results. This makes MERODE particularly suitable for the context of our study since it provides an integrated environment for modeling and simulation, which in addition is enhanced with feedback that allows facilitating a process of model validation by novices [22],[24]. The method has proved to have a significant effect on learning outcomes of novices [26].

This work proposes an extension of MERODE to support feedback-enabled UI modeling to improve learning achievements of novice modelers. It is possible to link the concepts applied in UI generation with MERODE’s concepts in a way that not only a fully functional application could be generated, but also with a highest level of usability.

In order to validate the feasibility of such approach, the authors investigated to what extent MERODE-models can be merged with User Interface models. The MERODE enterprise layer contains (amongst others) a domain model that is defined as a description of the classes of objects used in an enterprise, while in UI design a domain model is used to show the description of the classes of objects manipulated by a user while interacting with a system. These two domain model definitions can be merged to obtain an improved software in the generation process. Fig. 1 shows the connection where the concepts of the AUI meta-model are linked with the relevant concepts in the MERODE enterprise layer meta-model. The green classes are those represented by the enterprise layer. The others represent the classes in the W3C AUI standard. The red lines are the links between the two layers.

In MERODE the enterprise layer is captured through 3 models: a class diagram that defines the domain object types, their attributes and associations, an object-event table that captures business event types and relates them to the domain object types by indicating how objects are affected by a business event (created, modified, deleted), and a finite state machine per domain object type that indicates in which sequence the events types are allowed to happen from the perspective of that domain object type. The principal concepts in the enterprise layer meta model are therefore the object type and its attributes, the business event types and the method, which defines the reaction of a domain object type to a business event type.

In the AUI meta-model, the AbstractInteractionUnit consists of the basic unit for expressing any piece of interaction in a recursive decomposition of an AUI in abstract terms. This decomposition could be linked to one or many context-dependent definitions like ObjectType and its Attributes. Since any level of the recursive decomposition is considered as an Abstract Interaction Unit, the same term is used both for elementary and compound ones. The class Reader is an interface to support a resource to be read which are define also by the ObjectType and its Attributes.

DataInputOutputSupport consists of an elementary AIU that is responsible for data input and/or output that could be linked to a domain via a domain reference in order to ensure data binding giving the associated domain model. UpdateEvent supports the state changes and it is related to the defined methods in the enterprise architecture layer that are responsible for making the updates. Method also is related to InteractionEvent that defines an interaction event of the AbstractInteractionUnit, not only for the updates. Finally, although in the enterprise layer meta-model the defined EventType is related to the business event that occurs in real life, this EventType also generates the TriggerEvent to manage all the necessary events to enable the use of the system.

The mentioned classes are presented in the JMermaid tool. Nevertheless, the W3C Abstract User Interface standard proposes attributes for all the classes like the AbstractInteractionUnit with its role, state, frequency, repetition factors and others. Those attributes are not present in the JMermaid tool. It is possible to incorporate the complete W3C Abstract User Interface standard to the MERODE concepts. This would allow generating a better UI.

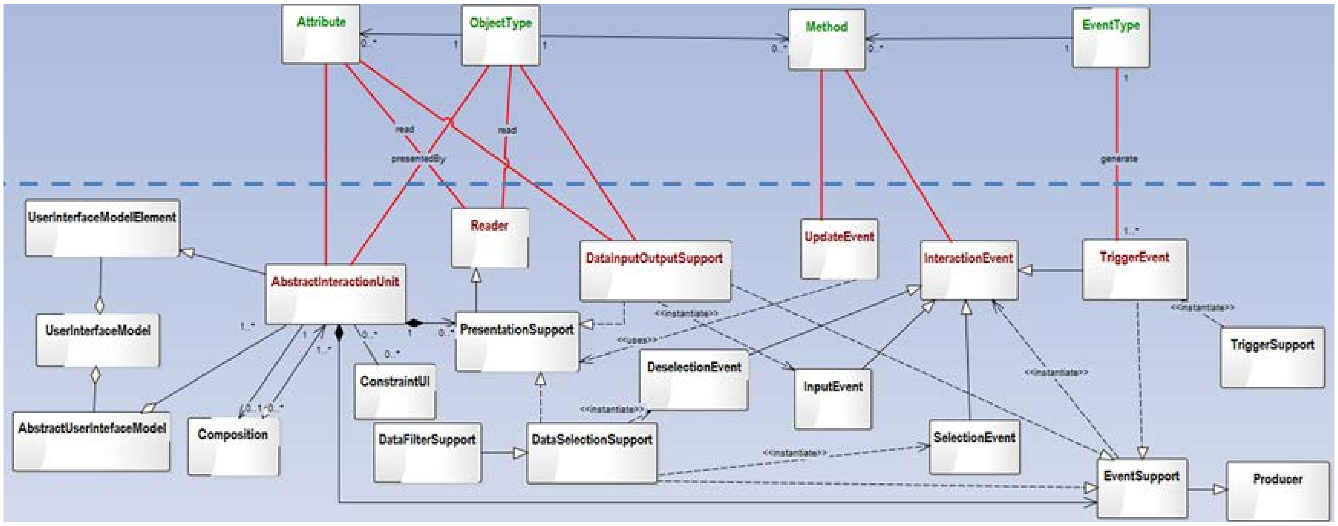

Figure 1. Links between Enterprise architecture and Presentation layers.

Although MERODE uses an MDA approach, and it is possible to generate different application for different platforms using the same source models, JMermaid does not yet take into account information from the user model such as preferences, capabilities, psychomotor skills, characteristics, of the end-user to support the UI generation. In order to generate a better UI it is necessary to incorporate into MERODE and its JMermaid tool an explicit presentation model capturing (amongst others) those preferences.

The UI generation process, as explained in [14], generates the Concrete UI (CUI) from the AUI and then the Final UI (FUI). The CUI expresses the UI in a more concrete level taking into account aspects like the platform where the system is going to run, the program language and the modality of interaction. However, in this state of the research the incorporated flexibility to JMermaid is related to the Presentation and User models only. Currently, the prototype is generated in Java, a multiplatform language. Since the developed tool is intended as teaching support and in order to ensure the feasibility of the project, the intent is to maintain the generation of a Java application for desktop computers as a start. For this reason, in this case, the platform, program language and modality of interaction are previously known, allowing skipping the elaboration of CUI and going directly from AUI to FUI, as shown in Fig. 2.

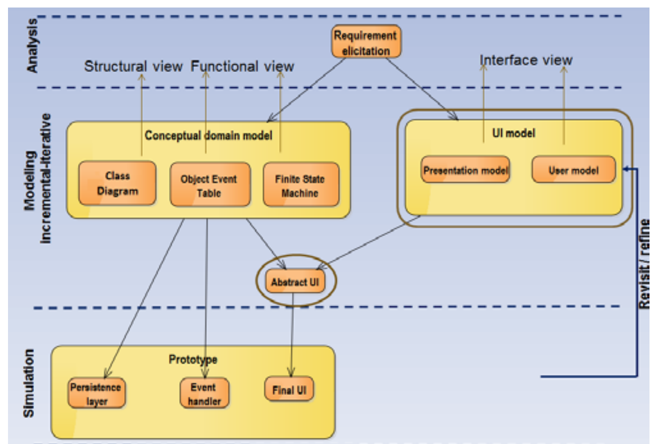

Figure 2. Artefacts and modeling cycle with AUI concepts incorporated to MERODE.

The generation process will use platform independent models according to 3 views: a structural view, that is established through the class diagram; a functional view, defined by a collection of Finite State Machines and the Object-Event Table; and an Interface view, defined by a Presentation model and a User model. After the modeling activity and the code generation step, in each iteration, developers can change the models in order to improve the quality of the generated prototype.

The code generation of the extended tool will enable the automatic creation of a UI. This gives the possibility to validate user requirements reducing the time and effort required to implement the UI. UsiXML [11] was the UI description language selected to generate the UI. Using the MDA approach a Model to Model transformation will be performed to obtain the AUI model using as a source the EDG, FSM and OET in the mxp file.

The proposed extensions will contain new rules for obtaining the control type of objects that can be added in order to improve the generated UI by JMermaid based on abstract level models. It should be possible to add a user model through JMermaid that defines, for example, based on the experience of the user whose control type is best in every situation. If there is more than one control type determined then the software could choose one of them based on the information in the user model.

The proposed approach comprises an iterative development process that enables the automatic generation of a fully functional prototype, including, of course, the UI code. The generated code can be obtained from early stages in the development process, as long as the used models are correct. The models will be based on the W3C AUI standard and MERODE Enterprise layer meta-models with links between Enterprise architecture and Presentation layers.

The tool will select the templates dynamically according to the information stored in presentation and user models. These templates will be used when generating programming code for the graphical components of the application. Following the transformation of the UI generation model, the generator will produce different final UIs according to the selected templates. Using this approach identical data can be displayed in different ways (within text fields, inside tables, with menus, etc.). This is showed in Fig. 3: the User Model and Presentation Model are stored in the mxp-file, jointly with the enterprise model. This collection of models is transformed into an AUI by means of a model-to-model transformation. Using different templates, this AUI is transformed into different prototype UI for the application that is generated from the enterprise model. This figure only shows the generation process of the extension of JMermaid for UI prototyping. As it was showed in Fig. 2, the persistence layer and the event handler is generated from the conceptual domain model, as in previous versions of JMermaid.

At the same time, developing such models for the UI development and generating the prototype according to this will allow iterative changes to the software solution and facilitate comparison between each one of them prior to final approval.

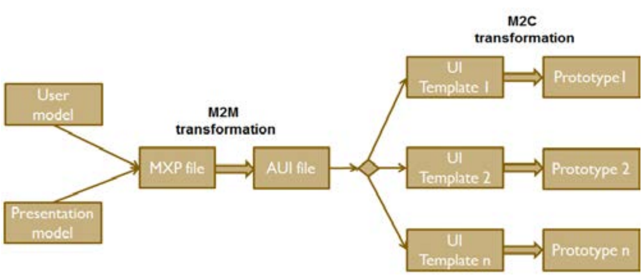

Figure 3. Extension of the JMermaid prototype generation using AUI concepts, Presentation and User models.

3.4 Automated feedback for UI development incorporated in JMermaid

While prototyping in itself is already an efficient instrument supporting the learning process, adding feedback features can offer further support of learning [23], [24], [26]. JMermaid already includes feedback features for the enterprise models.

The feedback features of JMermaid allow to explain reasons of execution failures with graphical visualization that link the failure to the model used for the simulation. For example, the user may be informed when trying to execute an event that is not allowed because of failed precondition checks. In this case, a message explains the reason of rejection by indicating what constraint of a model is violated [22].

JMermaid has implemented visualizations both for structural and behavioral aspects that include feedbacks on failures that can result from: (1) Mandatory one cardinality violation: an object is attempted to be created before the object it needs to refer to, is created or chosen to be associated with the newly created object; (2) Cardinality violation: a create-event execution fails due to a cardinality constraint of maximum 1; (3) Referential Integrity: ending-event execution fails due to existing referred (dependent) objects; (4) Sequence constraint violation: event execution fails because of the state of the owner object in which the event execution is not enabled [26].

The feedback features currently present in JMermaid are illustrated by means of an example of a generated system from a model solution for controlling the information about students. With this system the students can make an appointment to ask questions about the courses they are following to the teaching assistants of these respective courses.

The following scenario is an example of what is shown to the modeler when testing the prototype, : a teaching assistance is attempted to be created for a course before selecting a teaching assistant to associated to it. This is the case of a mandatory one cardinality violation. A popup window will explain to the modeler why it is not possible to create this object and a possible solution according to the model; in this case: creating an instance of a teaching assistant first or selecting an existing one. The feedback can be expanded showing the class diagram and highlighting the involved classes and associations with the same colors used in the explanation. This is shown in Fig. 4.

Similarly as for the Enterprise Model feedback, UI feedback features will assists the learners to validate the generated UI in a fast and easy way. At the same time, it will also allow to compare the impact of different decisions made in the Presentation, User and AUI models in the final prototype through experimenting with a concrete form of an information system.

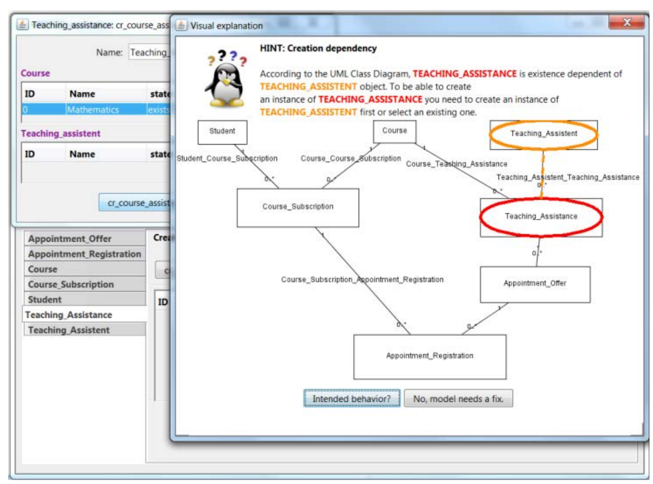

Figure 4. Feedback for mandatory 1 constraint violation.

The feedback can show to the modelers the reasons why the UI is generated in certain way. Fig. 5 shows the main window of an example of a generated prototype. The feedback explains that the orientation of the options, that could be vertical or horizontal, is selected according to choice made in the Presentation Model. It gives the possibility to see this Presentation Model and explains how to change it.

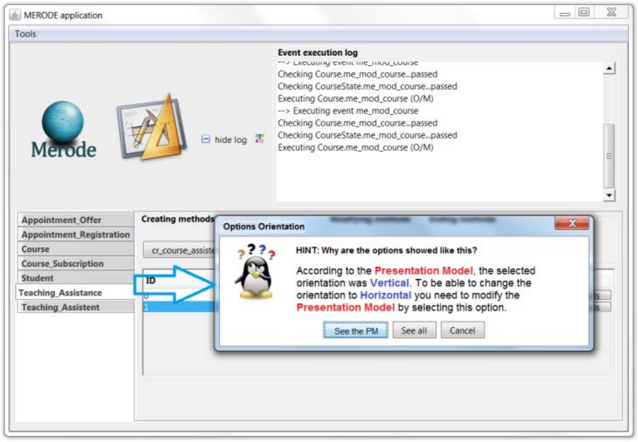

Figure 5. Feedback related to the orientation of the options.

Fig. 6 shows a window for the creation of an instance of certain object type. The feedback explains the relationship between the control input type and the type of the attributes of this object type. This, among other choices like the rules for determining the control type of the final interaction objects, allows to generate an UI according to the user´s preferences and skills, collected in the Presentation and User Models. It gives the possibility to see the rules related with this generated window and the Existence Dependency Graph with the object types and their attributes.

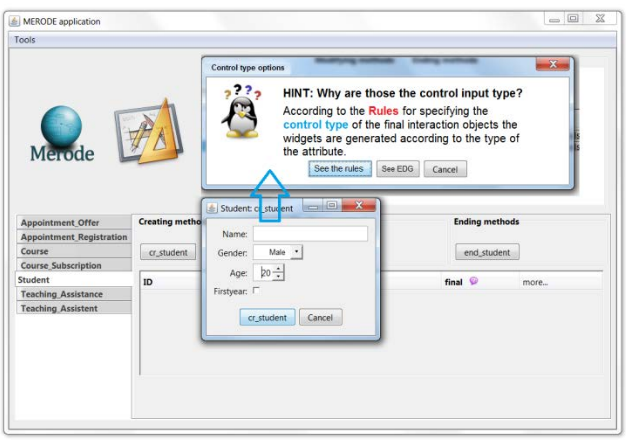

Figure 6. Feedback related to the control input type.

It is possible to show the links between the User Model and the generated UI, to see how JMermaid can select, based on the experience of the user, for example, which control, among the possible ones, is best in every situation. If there is more than one control type determined for one Abstract Interaction Object, then the software chooses one of them for based on the information in the User Model.

4. EVALUATION OF THE PROPOSED ARCHITECTURE

The previous sections presented an integrated architecture for UI development support and the automated feedback for UI development incorporated in the tool.

Table 2 shows the analysis of the proposed approach using the criteria presented in section 2.

Table 2. Evaluation of the proposed tool

MB-UIDE/Criteria	Proposed tool
Coverage of the development cycle	+
Generation of application code	+
Concern with user perspective	++
Language flexibility	+
Template flexibility	++
Ease of use	+
Level of learning support	++

These criteria allow to make a theoretical evaluation of the proposed approach in two directions: 1) for the User Interface development (the first four criteria) and 2) learning support (specially the last three criteria). Nevertheless, as was explained in section 2, all of them are important to provide effective support in teaching UI development.

The major advantages are achieved in level of learning support, template flexibility and dealing adequately with the user perspective. Specifically the two first criteria were met the least in the analyzed MB-UIDE approaches. With the proposed approach, design decisions should be easier to understand for novice up to medium developers, and there will be feedback that helps novices to understand the relationship between design decisions, the models and the different components of the User Interface. More in particular, this extended JMermaid environment will support the learning and teaching of UI design in the following way:

- **Coverage of the development cycle:** This tool offers an integrated support for the complete software development process, including UI development.
- **Generation of application code:** The tool provides automatic generation of software products (with both UI and application code) that are functionally equivalent to the system specification in one language for which a transformation process from an AUI is defined.
- **Concern with user perspective:** The proposed tool will generate the User Interface taking into account the user´s characteristics and skills in Presentation and User models. The generation process uses rules for specifying the control type based not only on the data types, primary key, foreign key, relationships between objects but also the actual needs of users.
- **Language and template flexibility:** Because the AUI and the rest of models used to generate the final application are totally independent of the platform, they can be transformed into different final UI for different platforms. The defined transformation process uses templates that can be changed in order to obtain the implementation of the software in different languages, platforms and ways of presentation.
- **Ease of use:** Only one tool is needed for the development process. Using this tool novice modelers are able to make the Conceptual, Presentation and User models. Once the models are in the tool the software is generated with only one click. This produces an “illusion of simplicity”, which makes it practical to use.
- **Level of learning support:** The tool offers to novice up to medium developers a running start on UI design, and

stimulate them to reflect on how come up with better UI with less effort. It is possible, using an iterative approach, to incorporate different aspects to the Conceptual, Presentation and User models and see impact of the UI by the generation process. The tool uses feedback to explain the correspondence between the UI models and the actual design when generating the prototype.

5. CONCLUSION

This paper proposes an architecture for an integrated UI development support environment. This environment will assist in involving the novice up to medium developers in real development and developing knowledge of what a good User Interface design requires. There are a few criteria that are necessary for the successful implementation of any new tool, in this case, for teaching the basics of good UI design.

There are a number of approaches and tools that support the different phases of UI development, as was shown in this paper. In general however, current approaches and tools either focus on the design phase, or on the development phase, and have a number of shortcomings that make interfaces difficult to build.

The solution proposed in this paper is an integrated approach that targets the entire software development process, focuses on the User Interface design and requires little technical expertise on behalf of the students. As the generation of a full-functional prototype pre-supposes the existence of a domain model and its generation, to keep the project feasible, the investigation will start from a proven existing environment (JMermaid) that already generates the core functionalities of the application based on a conceptual model. This environment is adapted to learning goals, and is equipped with feedback framework that makes it easier to expand to support UI. The proposed extended JMermaid environment will use UsiXML. It will incorporate a presentation and user models to improve the flexibility of the UI generation.

6. ACKNOWLEDGMENTS

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INTERACTION DEVICES (I)

Blind Source Separation Performance based on Microphone Sensitivity and Orientation within Interaction Devices

Navya Amin, Thomas Gross, Susanne Rosenthal, Markus Borschbach

FHDW, University of Applied Sciences,
Hauptstr. 2, 51465 Bergisch Gladbach, Germany
{ami, tgr,rsu,mbo}@fhdw.de

ABSTRACT
The use of smartphones has tremendously increased in the last decade. The coupling of a mobile phone with multiple sensors has expanded the usage of smartphones into a wider area. A basic research on pre-requisites of Blind Source Separation (BSS) to be used in interaction devices is performed. Our focus of research is the application of signal processing techniques for BSS of audio signals captured using interaction devices like the smartphones with the final aim of recovering the spatial listening experience of persons with reduced hearing abilities using the proposed app-based system. With this app, the user is able to interactively enhance speech or sound sources in his surroundings using the interactive interface on his smartphone. The sensitivity and orientation of the smartphone microphones (mics) play a very important role to achieve a better quality of BSS and hence is one of the prime prerequisites for BSS. Therefore, a benchmarking regarding the interdependence of the different internal and external mics as well as the orientation of the smartphones relative to the sources on the overall separation performance is discussed in this paper. Four smartphones are used to examine the influence of mic sensitivity on the BSS quality of captured signals. Further external mics with smartphones are tested for their influence on BSS. The captured audio signals are separated using PARAllel FACtor analysis (PARAFAC) based BSS algorithm.

Categories and Subject Descriptors
H.4 [**Information Systems Applications**]: Miscellaneous;

D.2.8 [**Software Engineering**]: Metrics-complexity measures, performance measures

General Terms
Theory

Keywords
Smartphone, Internal Microphones, External microphones, Microphone sensitivity, BSS.

1. INTRODUCTION
Smartphones have penetrated the mobile phone market in the last few years due to cost effectiveness and their applications into a wider area. People today depend on their smartphones to perform a lot of their day-to-day activities. According to Gartner, Inc. Smartphones accounted for 53.6 percent in 2013 [17] and two-thirds in 2014 [18] of the total mobile phone sales. With the rapidly increasing percentage of sales more than two billion people worldwide are expected to own a smartphone by 2016 as stated by eMarketer Inc. in [15]. Equipped with many sensors, a vast amount of applications previously performed on a computer are currently done using a smartphone. Using a smartphone as a hearing aid or even in combination with a hearing aid is the focus of our research. We intend to develop a smartphone application: SMARTNAVI app [35], [23] which captures audio signals in the surroundings of the user, separates the sound sources and allows the user to select his source of interest for hearing. The architecture of this app including a benchmarking of different open source BSS tools on three categorized acoustic challenging situations is presented in [35]. Application of such a BSS app in a smartphone is not just restricted to hearing impaired individuals but also designed for people without hearing disabilities. This is applicable in case when two individuals speak in a crowded environment, which in technical signal processing terminology is termed Cocktail party problem [7],[1]. The individuals are able to separate out the speech sources of their interest using this app.

Hearing impairment refrains the affected from recognizing the sounds in the environment and also distinguishing different sounds. Thus an interactive interface becomes essential in such scenarios. The SMARTNAVI app enables the user to interactively select the sound sources of interest using his smartphone or any other interactive smart device. The user is also able to recognize any dangerous sounds to avoid approaching danger, suppress the noise signals for better speech intelligibility and to overcome orientation and communication difficulties. This app is designed such that it is able to capture audio signals in the environment, separate the sources and provide visualization of the speech and noise sources. The number of separated sound sources depends on the number of mics built in the interactive device. Also the sensitivity of the mic influences the quality of audio capture and source separation thus influencing the final output.

The audio systems of smartphones are technically designed very differently with the consequence of high performance differences. The quality of in-built audio capturing systems in smartphones has improved to a large extent to sustain itself in the smartphone market race. Different phones or vendors provide different levels of sound quality. Using a smartphone for a BSS app requires a very high quality of audio-captures, good enough to enable source separation. In this paper we have captured audio signals in extremely Lower Level of External Noise (LLEN) using four different smartphones. The audios captured using these smartphones are compared based on the quality of BSS. The findings of this experiment would clarify the smartphones that are favorable for their usage as audio devices for capturing sound signals. The quality of the sound signals depends on the quality of the inbuilt mics in these smartphones or external mics as well as the orientation of the smartphones during the process of audio signal capturing. This totally depends on the sensitivity of the mic in the smartphones which varies to a great extent across vendors as stated in the review in [28]. In this paper, we have tested the quality of audio recordings captured in 2 different environments giving good quality separation of the mixed sources in the audio-captures into their individual sources. We have also tested the influence of the orientations of the smartphones during audio capturing. The focus of this paper is to examine interdependence of the mic-sensitivity and orientation of the smartphones relative to sources with the final aim of achieving optimum BSS quality. The audio data is qualitatively evaluated by informal listening tests regarding a subsequent successful BSS separation. Further, the influence of the mic orientation as well as the attachment of an external mic on the separation performance are investigated.

2. RELATED WORK

The use of smartphones is extended immensely from its usual purpose making it an ubiquitous communication technology. It is used not just for communication but also in the field of Health-care, Fitness, Navigation, Entertainment, Banking and Finance, e-commerce, etc.. The reason for this is the variety incorporated sensors in a smartphone allowing the handling of different tasks with one small device. The mics of the smartphone now-a-days are not just used to make a phone call or record a voice but for many other purposes like audio signal processing as well. Several modules for audio signal processing using smartphones are developed for their implementations in a larger application area: Sur et al. in [37] design and implement a so-called Dia system to overcome the inability of the smartphone to locate the spatial position of the speaker in noisy environments. They use a synchronized mic array to determine autodirective audio capturing and develop a practical speaker tracking and audio beam-forming module. Asakawa reports about sound signals used in different application areas like surveillance and artificial systems like BSS [4]. He exemplifies about Shot Spotter, a system developed by a American start-up company which works like a sound surveillance system. This system involves several mics set up in the city streets that alert the security companies and police of any abnormal sounds. He also discusses the work of Onu, where BSS methods are used for separating desired sound signals from a jumble [4], [25]. In [25] auxiliary-function-based independent vector analysis (AuxIVA2) for stereo signals is used for BSS which is implemented as an iPhone application. Mukai et al. develop a prototype system which estimates the Directions of Arrival (DOA) of the source signals in addition to the separation of these signals. They used 8 omni-directional mics to separate speech signals in real-time distributed in three dimensional space and a complex valued Infomax algorithm [6] for BSS. Pertila et al. propose a closed form temporal offset estimation technique and estimates the accuracy of this approach using 10 smartphones for audio capturing in three different rooms [27]. Li et al. develop an algorithm for non-linear multiple-regression based enhancement method for in-car speech recognition [22].

The uses of smartphones and their sensors have expanded tremendously in the field of artificial intelligence and robotics. Sensing technologies are now used by people owning a smartphone making their day-to-day activities easier. Application of SMART technologies for fulfillment of human disability is of great interest for the researchers today. Smartphones are becoming a common mode of assistive technology [14],[13],[11] for the disabled due to their simplistic learning, usage, integration and support methods. Several applications for blind, deaf, dyslexic, diabetic etc. are available for different smartphones. Peek Vision is one such example as a diagnostic tool for the visually impaired [39]. The OtoSense Mobile app enables the user to identify and distinguish the source of incoming audio alerts like alarms, sirens, timers, bells and other sounds making smartphone an assistive device for the hearing impaired [26]. Several other apps for assistive hearing systems are presented in [31], [32], [8], [9], [38] and [16].

3. SMART MIC

The conventional smartphones were equipped with only one mic for voice capturing unlike the state-of-the-art smartphones. Today the smartphones are equipped with two or more mics: one for capturing and the other for noise cancellation. Nokia Lumia 1520 (NL1520) has four bidirectional mics inbuilt for a better capturing quality. The iPhone models above 5S are equipped with three mics: one for noise cancellation and two for audio capture. Other phones like the Sony Experia Z2 (Z2), Z3 (Z3), Samsung Galaxy S4 (S4) and above, LG Nexus 5 (N5) and above are equipped with multiple mics for similar audio capturing and noise cancellation purpose. The internal mics of the smartphone are basically meant for voice capturing. However, the smartphone mics do not provide the high quality audio-captures like the hand-held recorder or external mics. In such cases, external mics are a better option used to fulfill the requirement of high quality captures for signal processing. The internal mics are able to capture a restricted frequency range of approximately 300 Hz to 3.4 kHz that is much lower compared to the external mics. However, not every state-of-the-art smartphone provides the audio jack for multi-channel audio-captures. So far, only Z2 and Z3 provide a 5-pole 3.5 mm audio connector to capture stereo audio data. The other Android phones including iPhone still have a 4-pole jack which captures only mono audio data. The mics as used by Onu [25] are directly connected to the dock like the TASCAM iM2 for the iPhone. Several other mics attachable to the micro-USB port of Android phones are used to capture multi-channel audio data. The directionality of the external mics is used as an advantage for audio processing especially in the case of BSS.

3.1 Internal Smartphone Mic

Traditionally, internal smartphone mics work best in the near-field range. For phones, the audio source (i.e. the mouth of the speaker) is mostly close to the mic. However, smartphones now offer far more options than just making phone calls. For example, they serve as a voice recorder or to record the sound when shooting a video. In order to cover all areas satisfactorily, mostly omni-directional Micro-Electro Mechanical Systems (MEMS) [48] mics are built into modern smartphones [46]. Omni-directional mics record all sound sources in the environment. These include both foreground sounds like conversations, as well as background noises like distant people talking or street noise. For our project, mics without any directionality could be a disadvantage. For hearing aids, it is proven that devices with directional mics improve the Signal-to-Noise Ratio (SNR) of speech occurring in a noisy background [5], [19], [12], [20], [33]. As described later, directional mics have noise-cancellation characteristics due to their design which can significantly reduce background noise during audio capture, without having to perform any subsequent software-based noise reduction. Such optimized audio-captures allow a better BSS. However, the sound source must be within the directivity angle, at which the mic is sensitive. For example - depending on the directional characteristic of the mics - the sound arriving from the sides is captured with a lower volume or is strongly attenuated. However, there are already solutions for this problem [20]. Another problem of the internal mic is its sensitivity. Originally telephones are intended to make phone calls. The audio source is normally close to the telephone mic. Due to the low sensitivity of audio sources, the sensitivity of the internal mic is no longer sufficient to record sources that are located a few meters away from the mic. As shown in Figure 1, the level of an acoustic signal decreases by around 6dB (one-half) each time the distance from the source is doubled. In addition, modern audio chips have hardware-integrated components for automatic noise cancellation during the audio capture independent from the used audio capture app [29].

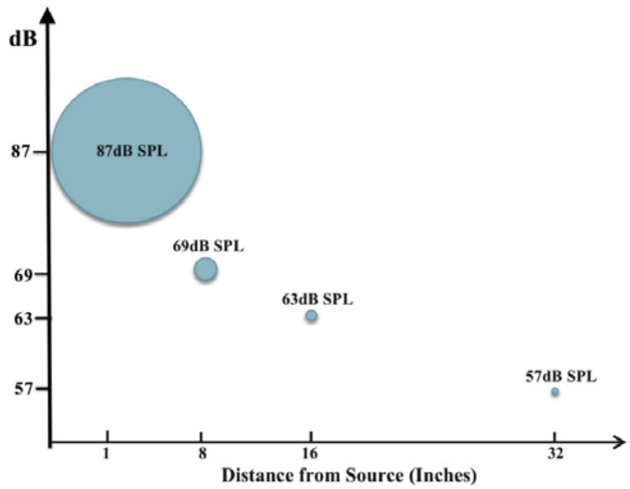


Figure 1. The volume is reduced by half when the distance to the mic is doubled. This image is a modified reproduction from [21].

3.2 External Smartphone Mic

There are numerous external mics for smartphones available. They differ in their directional characteristics, size and other technical specifications. Their advantage over internal mics is the previously described sensitivity. Audio sources from a distance of several meters could be recorded significantly better with external mics compared to the internal mics. A further advantage is the significantly greater frequency range obtained using external mics compared to internal mics. Frequencies in a range of approximately 150 Hz to 4000 Hz are necessary for the intelligibility of the human voice [36]. The full range of the human voice, e.g. a singing voice, is approximately in the range of 80Hz to 12 KHz [2]. In this frequency range, there are frequency segments that play a role in speech intelligibility, for example high-frequency sibilance [10]. Usually the main frequencies in the range of 200-3500 Hz (Narrowband) have been covered in the traditional telephones. Newer smartphones however use the HD voice or HD voice standard with a frequency range from 50Hz to 7kHz or higher [34] (wideband, or better known as Adaptive Multi-Rate Wideband (AMR-WB)). Modern Smartphone mics often cover a frequency range from 20Hz to 20kHz (full-band) [30].

4. EXPERIMENTS

4.1 Technical requirements

The hardware set up of smartphones is mostly for capturing less distant sound signals. This makes it challenging to use smartphones for BSS. As mentioned earlier, some smart-phones are equipped with two mics. But the captured audio channels are too similar since the mics are placed very close to each other. For example, the iPhone has mics placed next to each other. As a result, the channels of the audio output even though stereo, are very similar to each other. However, some Android phones provide a 5-pole output enabling better stereo audio capture with mics placed at opposite ends of the phone like the Z2 and Z3. The N5 has mics placed also at opposite ends but provides only a 4-pole output jack enabling mono audio capture [47]. Some applications that perform stereo audio capture using such smartphones convert mono audio signals to stereo. External mics play an important role here. However, external mics for phones like N5 having a 4-pole output must be connectable to the micro-USB port of the phone. The human ear is able to differentiate between different sounds due to its directionality [42]. A similar directionality approach using the smartphone for BSS is used in this paper. Two experiments are performed to infer on the mic sensitivity and orientation of the smartphone enabling better BSS quality of captured audio signals.

4.2 Performance of Mics for BSS

The aim of the first experiment is to compare the quality of BSS of captured audio signals using internal and external mics across different smartphones. The audio-captures for this experiment are done using the different smartphones presented in Table 1.

Table 1. Overview of smartphones and operating systems used for the experiments.

Operating System	Phones			
Android	N5	S4	Z2	Z3
iOS	iPhone 5S			
Windows	NL1520			

Two types of external mics are used for capturing audio signals with Z3 and Z2 namely STM10 and Edutige EIM- 001. STM10 is a stereo mic with a 5-pole audio jack as illustrated in Figure 2a, which is only compatible with the smartphones Z3 and Z2 and Edutige EIM-001 is an omni-directional mic with a 4-pole audio jack (illustrated in Figure 2b) and is compatible with all of the smartphones listed in Table 1. Therefore, STM10 is not usable with the other Android smartphones, iPhone or NL1520 and the Edutige EIM-001 is used for these smartphones instead.

Figure 2. a. SONY STM10 Stereo Mic (Image is taken from [40]), b. Edutige EIM-001 Omni-directional Mic (Image is taken from [41])

The apps for audio capture were selected based on the availability of the options to set the Sample rate, Bit Rate, Output format, Automatic Gain Control and ability to select channels (mono/ stereo). The app RecForge Lite [43] is used on the Android smart-phones (Z2, Z3, N5 and S4). The app provides the additional option to choose between mono and two different types of stereo channels (Native and Mono x 2). [43]. The app for iOS platform is Awesome Voice Recorder by the Newkline Co., Ltd. [44]. THE SOUND RECORDER app [45] from Windows is used for audio capturing in NL1520. The audio capturing is done in a room of the size length: 6m x 3m x 3m (length x width x height). The mics are placed at a distance of one meter from two sources S1 and S2 as depicted in Figure 3 and 4. These experiments comprise the influence of using two smartphones for simultaneous recordings as a mic array on the BSS quality: Therefore, audio-captures were done by two N5 mics which are at a distance of 0.5 meters from each other and both mics have a distance of one meter to the sources. Further, a BSS algorithm based on PARAFAC is applied on the captured audio signals.

4.3 Impact of Mic Orientation

The second experiment estimates the impact of the mic orientation relative to the sound sources. This was performed in LLEN environment. The smartphones used for this experiment were Z3 and N5 as we are mainly focused on open source Android platforms. In general, the smartphones Z3 and S4 are not further considered in these experiments since the performance of these phones are similar to Z3. The experimental set ups are depicted in the Figure 3 and 4:

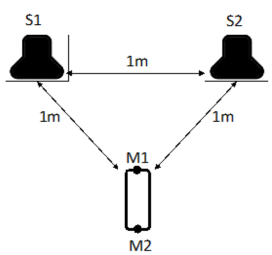


Figure 3. Layout of the experimental setup 1: Horizontal orientation of the mics M1 and M2 of the smartphone relative to the sources S1 and S2.

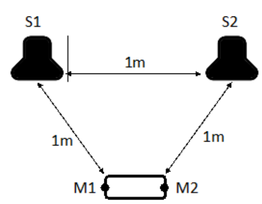


Figure 4. Layout of the experimental setup 2: Vertical orientation of the mics M1 and M2 of the smartphone relative to the sources S1 and S2.

where S1 and S2 are the sound sources and M1 and M2 are the internal mics of the smartphones. The mic of the smartphones Z3 and N5 are placed at a distance of one meter from the sound sources in two different orientations namely vertical and horizontal as shown in Figure 3 and 4. Two types of audios captures are used, male speech and female speech (left-right resp.), male speech and cafeteria noise (left-right resp.). The audio files have a length of approximately 10 seconds. The files are captured using 0 gain at 44kHz and 16 bits in stereo native WAV format. The phone is placed first horizontally and later vertically to examine if the orientation of the phone has an influence on the difference in the matrices. These set ups are guided by the idea that the mics at both ends of the phone in the horizontal position receive signals from the left and right speakers at different distances. The difference in the distance is a potential advantage for the separation algorithm. Further, a BSS algorithm based on PARAFAC is applied on the captured audio signals. The quality of source separation is estimated by informal listening tests for both test series. The quantification of the difference between the channels is done by calculating the difference between the two channels.

5. RESULTS

5.1 Technical requirements

The difference between the channels is very important for source separation algorithms. The audio files with higher channel difference achieved a better source separation com- pared to the audios with lower channel difference. However, even the good separated audio files have some crosstalk of the source which could be handled using some post-processing methods. The stereo audio-captures performed using the setting Mono x 2 in the audio recorder app gave absolutely no separation using the PARAFAC algorithm. On determining the difference between the two channels it is seen that both the channels are exactly the same and in some cases slightly different which is insufficient to determine a good separation. This is because of the conversion of mono channel to stereo by the sound recording app. Further, on testing the Stereo Native option, it is seen that the difference between the channels also depends on the specific mic sensitivity of the smartphones used.

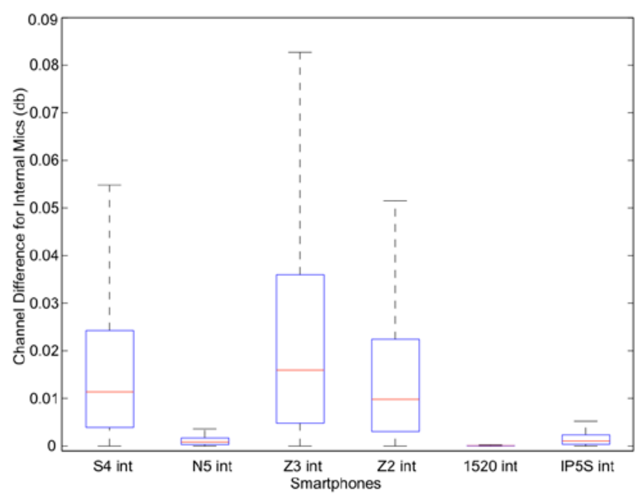


Figure 5: Difference between the channels captured using internal mics of different smartphones for male and female speech.

The source separation of the audio mixes captured using the internal mics of the smartphone gave very weak source separation with IP5S and NL1520. The NL1520 technical specifications states four directional mics. However, these mics could be accessed only with video capturing and not with audio capturing applications. Also the stereo audio-captures with this device reached no sufficient source separation. However, for S4, Z2 and Z3 source separation was obtained at different quality levels based on the informal listening tests. The boxplots in Figure 5 show that the channel differences for N5, IP5S and NL1520 are very low to achieve a good quality source separation unlike S4, Z2 and Z3. The mean channel differences for S4, Z2 and Z3 were in the range of 0.01 to 0.015 which was sufficient to achieve source separation even though the quality of this separation was weak. Further the recordings made using the external mics showed that the usage of external mics had a positive impact on the quality of source separation compared to the usage of internal smartphone mics. However, this positive impact was restricted to the usage of the STM10 stereo mic. The stereo audios captures using the Edutige EIM-001 mic gave no separation of source channels due to a very low difference between the channels as shown in Figure 6. This mic was only compatible with S4, N5, Z2, Z3 and NL1520 and thus the experiment is performed using only these phones excluding IP5S. This mic only allows good quality mono channel recordings and thus is insufficient for our purpose of BSS using PARAFAC which requires at least two input channels.

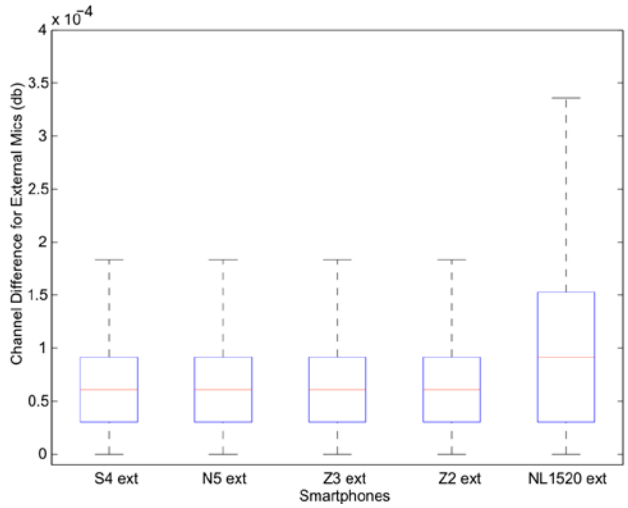


Figure 6: Difference between the channels captured using EIM-001 with different smartphones for male and female speech.

The audio captured using the STM10 stereo mic gave a good quality source separation due to a good difference between the channels as shown in Figure 7b.

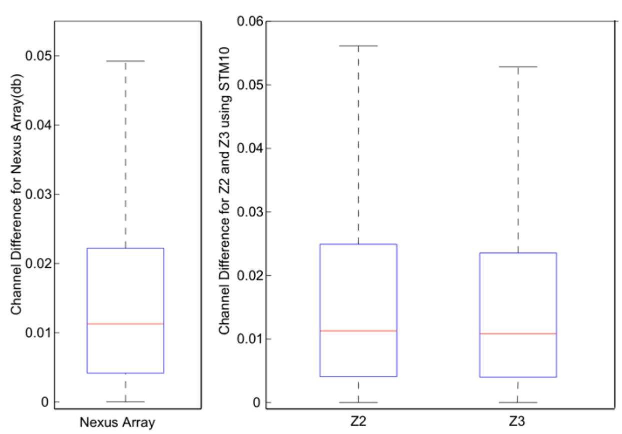


Figure 7: a. Difference between the channels captured using 2 Nexus phones as an array, b. Difference between the channels captured using STM10 with Z3 and Z2.

This mic is compatible only with the Z2 and Z3 and hence the experiment is performed using these two phones only. The mean channel difference for audios captured using Z2 and Z3 with the STM10 mic was similar to the mean channel difference for the audio captured using two N5 internal mics as an array both falling within the range of 0.01 to 0.015. A good quality source separation is achieved using the N5 phones as an array due to a comparatively higher distance between the mics (Figure 7a). The audio files from AMDecor [3] recorded by Anemueller et al. using PARAFAC gave a very good quality compared to the best source separation performing experiment using smartphones. The mean channel difference for the AMDecor audio is much higher as shown in Figure 8 compared to the smartphone recording due to the mics used for audio recording. The recordings were done using professional mics by Anemueller et al. and not smartphone mics.

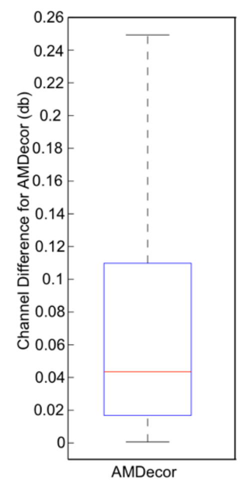
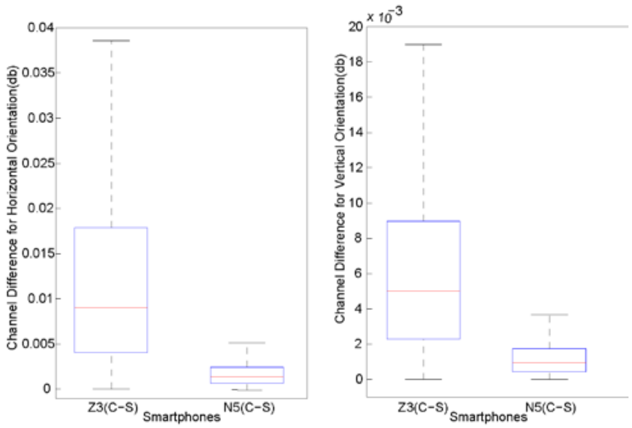


Figure 8: Difference between the channels captured using two mics for AMDecor.

5.2 Results for Impact of Mic Orientation

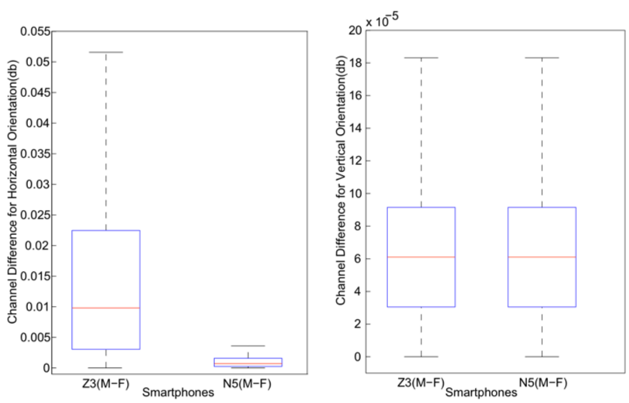
The orientation of the phone and thus the position of the mics relative to the sources while audio capturing also has an influence on the separation as noticed during informal listening tests. The cafe-speech (C-S) audio files captured Z3 in a horizontal orientation in HLEN gave a mean channel difference close to 0.01 which is sufficient to achieve a good quality source separation. Channel differences for N5 give comparatively lower mean as shown in Figure 9a but enabling source separation with higher cross talk compared to Z3 in horizontal orientation. However, the vertical orientation of Z3 gave lower quality source separation compared to its horizontal orientation and N5 gave no separation at all due to a very low mean channel difference as shown in Figure 9b.



(a) (b)

Figure 9: a. Difference between the channels captured using horizontal orientation of Z3 and N5 for Cafeteria noise (C) and speech (S), b. Difference between the channels captured using vertical orientation of Z3 and N5 for Cafeteria noise (C) and speech (S).

Further, an orientation experiment using male and female (M-F) speech audio files gave similar results. The mean channel difference for audio files captured using Z3 was much higher (0.01) compared to its vertical orientation (6x10-6) as shown in Figure 10, part a and b. Further, the mean channel difference for N5 in horizontal orientation was lower compared to Z3 but higher than its vertical orientation as shown in Figure 10, part a and b. Thus, the audio files captured in the horizontal orientation achieve a good quality source separation compared to the ones captured in vertical orientation.



(a) (b)

Figure 10: a. Difference between the channels captured using horizontal orientation of Z3 and N5 for male (M) and female (F) speech, b. Difference between the channels captured using vertical orientation of Z3 and N5 for male (M) and female (F) speech

6. CONCLUSION AND FUTURE WORK

The outcome of the experiments shows that the mics of different smartphones have different hardware specifications based on their usage and applicability. The applications common across similar platforms also perform differently even though having the same operating system. Thus the application of audio processing algorithms must be independent of these settings. In our case, audio-captures for Z3 and Z2 required a stereo mic to achieve a good source separation compared to their internal mics. The other smartphones tested have hardware specifications restricted for stereo audio capturing that is a prime requisite for BSS using PARAFAC to have a minimum of two channels as an input. Also the orientation of the smartphone plays a major role. The horizontal orientation of the smartphone relative to the sources resembles the human ear positioning thus making it easier for the source separation algorithm to separate the sources due to the directional behavior of the smartphone mics. External omni-directional mics are usable in multiple numbers (for example: as an array) to achieve multiple channels, kept at sufficient distance from each other to get a good source separation. It is necessary to have mics placed at a distance high enough to achieve a difference in the channel matrices that is a prerequisite for BSS. If the internal mics of the smartphones are used, then it is necessary to access both the mics of the device for audio capturing without any pre-processing.

Our main goal is to develop a smartphone app for BSS to enable the people with hearing disabilities to choose the sources of interest for hearing. The mics to be used for our purpose as mentioned previously are the smartphones internal and external mics or a combination. We intend to use these mics in a manner that they resemble the setup of the human ear to achieve better separation results. The audio capturing system must be such that it is able to access multiple inbuilt mics of the phone to estimate more sources in the audio mixture.

7. ACKNOWLEDGMENTS

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DIY computer mouse for special needs people

Lluís Ribas-Xirgo Francisco López-Varquiel
Microelectronics and Electronic Systems Department
Universitat Autònoma de Barcelona
(+34)-935811078
Lluis.Ribas@uab.cat, FLopez.Varquiel@gmail.com

ABSTRACT
People unable to use hands to interact with computers do require special devices to gain access to information technology services. The rise of do-it-yourself (DIY) electronics makes it possible to release construction kits of a wide range of gadgets, including hands-free computer mice. In this paper we present one such building kit for a full-featured computer mouse that is controlled by head movements. The result kit includes an easy-to-find bill of materials, instructions to build the device and to use it. The first experiments showed that the mouse was working fine with people that have good control on head movements but that its embedded program must be customized for other individuals.

Categories and Subject Descriptors
H.5.2 [**User interfaces**]: Input devices and strategies (e.g., mouse); evaluation/methodology; prototyping, and user-centered design. H.1.2 [**User/Machine Systems**]: Human information processing.

General Terms
Algorithms, Measurement, Documentation, Experimentation.

Keywords
Assistive technologies, accelerometer-based computer mouse, DIY mouse, special computer mice.

1. INTRODUCTION
Computer mice are vanishing from portable devices as their functionality is covered by a myriad of tactile sensors and accelerometers. While these new interfaces improve human-machine interaction, they rely mostly on hand movements thus becoming useless to those with impaired hands (section 2).

There are several interface gadgets that partially or totally cover the functionality of common computer mice through the use of elements that can be operated by body parts other than hands. Unfortunately, they are expensive, require software installations on the devices (computers of all kinds) with which they are to be used, and, besides, they do not offer all the functions of a regular computer mouse (section 3).

On one hand, these mouse-replacing devices are rare and expensive because of the inexistence of a big market able to generate enough return. On the other hand, thanks to the large-scale market of everything related to the information and communication technologies and, specifically, of DIY electronic components, we all have the possibility of building devices adapted to our needs.

In this work, we have taken advantage of the availability of DIY components to build a hands-free computer mouse at an affordable prize, as its development has been funded by a prize awarded to the authors and no economic profits are expected.

Most of the already existent mouse-replacing devices sense head movements instead of hand and finger ones to determine pointer displacements and mouse-actions. To do so, an accelerometer can be placed onto an earphone and data from it read and processed on an electronics board such as Arduino, BeagleBone or Raspberry Pi, to mention a few. At its turn, the electronics board emulates a conventional USB computer mouse so that no special drivers or software has to be installed (see Fig. 1.)

The result earphone-mounted computer mouse can significantly improve the life quality of those who cannot use their arms and hands, temporarily or permanently, providing an alternative to accessibility to computers and similar devices.

Therefore, the main goal of this work is to make available all the necessary elements to build a "computer mouse earphone" to anyone, and so, make it available to any other person in need of it, without any other requirements.

The proposed device (section 4) must be cheap, with components commercially available and easy to buy. Its assembly has to be easy, with no need to have any technical knowledge or specific tools, and the software must be downloaded for free on the Internet. Once built, the device will not need any software installation in order to use it in any computer or portable device.

The result device should be easy to use, so that the user will not need any special training (subsection 4.3).

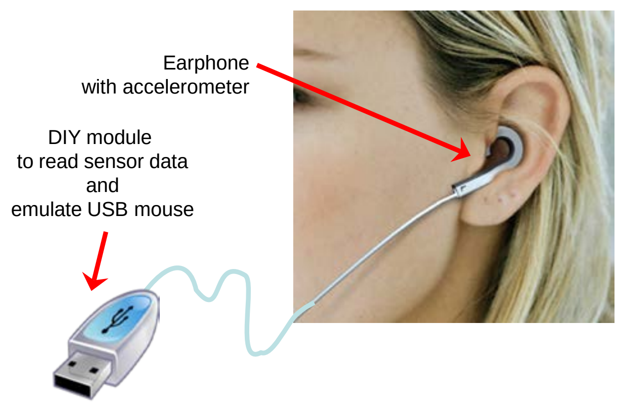

Figure 1. Earphone-mounted mouse. (Source of model photography: http://www.coroflot.com/yoonsangkim/portfolio1)

Some devices were built to be able to test them with real users to determine its user-friendliness and to be able to adjust both the head movement tracking and the identification of gestures of the users to their intentions (concluding section 5.)

2. TARGET USERS

Anyone that may take advantage of using a head-tracking mouse instead of a conventional one can use it. However, the focus of such kind of devices is on people with special needs willing to access to computing devices and applications like non disabled people. Unfortunately, diversity of impairments makes it difficult to know the amount of potential users.

According to the Instituto Nacional de Estadística (Spanish National Statistics Institute), almost four million people (out of 47 million Spaniards) have some type of disability and almost a 40% of these have problems with bones and articulations [1]. Many of these people are potential users of the proposed device.

A more specific segment of population that might be candidate users consists of those people having paraplegias, which account for fifty thousand people in Spain [8]. By extrapolating Mexican statistics from [2], approximately half of them have tetraplegias and are possible users of this kind of devices.

However, it is worth noting again that the diversity of people's conditions makes it difficult for a single product to suit all specific needs and only a fraction of them might be really taking profit of the proposed device.

Particularly those with good control on head movements willing to use common software on any device may find this gadget useful. Take into account that, apart from computers, mice can be connected to mobile devices with Android [6], iOS [9] and, even, Microsoft Windows Phone [19].

Furthermore, as people is getting used to interfaces other than mice, keyboards and touchscreens, a head movement tracking mouse can be used by any person that might find it interesting to.

In fact, the use of, for example, Wiis from Nintendo or Kinects from Microsoft, have familiarized people with new ways of interaction with computers. And this contributes to see hands-free mice as a complementary form of man-machine interaction.

To sum it all up, the target users of the proposed device are some of those people that cannot access computer applications because of a temporal or permanent disability to use hands and fingers to manipulate a pointing and selection device such as mice or touchscreens, and some of those that might look for a different user experience with computers.

It is also important to highlight that, by using the proposed full-featured mouse and virtual keyboards, any user can have access to regular computer applications without further ado. Therefore, users are able to establish and maintain social relations through Facebook, Twitter, or any other social network system, can play games and work with computer applications, regardless of their possible disabilities.

3. MICE AND MOUSE-LIKE DEVICES

The idea of substituting mice by more "natural" alternatives (or, for disabled people, "possible" alternatives) is not new. For example, back in 2006, Microsoft had foreseen a special glove [17] to replace mice and, more recently, Leap Motion offers a device to be used like a touchpad [15].

In fact, touchpads and touchscreens have made mice obsolete to most people. However, these "mouse substitutes" still rely on hands and fingers.

Fortunately, there are more and more machines that have frontal cameras, and they can execute programs that transform users' gestures in front of the camera into mouse movements and actions [5, 14, 16]. Free cam-based virtual mice include EyeMouse [13], HeadMouse [21] and Enable Viacam [12]. However, they do not implement all the features of conventional computer mice. EyeCan [10] also uses computer cameras, but requires extra components.

With the success of the video game consoles like the Wii of Nintendo and with the commoditization of accelerometers, there are also solutions that incorporate them to build computer mice or devices alike. Many of them are commercial and protected by patents [22, 3, 7, 20, 18]. However, commercial or not, these solutions require user adaptation and, besides, have accuracy [11] and fatigue [4] problems.

Anyway, special needs people do require hands-free mice and there are commercial products that offer a similar functionality (see table 1 for a short list of them.) Unfortunately, they are pricey and limited to some platforms.

Table 1. Pointer devices

Device	Body part	Price
Computer mouse	Hand	<100€
NoHands Mouse (Hunter Digital)	Feet	250€
SmartNav (Natural Point)	Head	350€
QuadMouse (Quadadapt)	Lips, tongue, chin	550€
IntegraMouse (Adapt-it)	Mouth	2150€

Another important drawback of previous mouse replacement options is that they need installing software, which limits the number and type of computers and other devices they can be used with.

The proposed device emulates an USB mouse so it can be used with any computer, tablet or, even, smartphone. Moreover, there's no particular software installation, and, to make it cheap, i.e., under 100€, it will be released as a DIY project open to even electronics or computer unskilled people.

4. THE DIY COMPUTER MOUSE

The idea of the work is to provide the information for anyone motivated to build a hands-free mouse for someone else needing it. Such information includes the bill of materials for the proposed device, instructions to build it, including how to embed the control program, and the user's guide.

4.1 Bill of materials

In order to build the device you need to buy the material, which includes a pair of earphones, an accelerometer and an Arduino board (Fig. 2). Typically, all materials cost less than 80€.

The Arduino Leonardo board processes the data from the accelerometer about the head movement and transforms them into mouse movements and actions. A buzzer is required to emit sounds to help the user during initial calibration of the device and to indicate when gesture recognition is on. The board connects to computers through a standard USB to micro-USB cable.

The accelerometer ADXL335 (board GY-61) is used to detect head movements. This very board can be directly powered from the Arduino board because it includes a voltage regulator on its own. Therefore, jumper cables link it with the Arduino board for power supply and data transmission.

The earphones are used as a support for the accelerometer, and can be used normally, too.

Apart from the previous component set, scissors and insulating tape are the only extra elements to build a mouse.

4.2 Assembly guide and software installation

The first step is to attach the accelerometer board to the left earphone with the tape and the last one consists of programming the Arduino board. (The accelerometer could be placed at the right earphone, but device calibration is more accurate if placed at the left side of the head.) In between, jumper cables have to be connected among them to form longer cables that connect the Arduino board with the accelerometer, and the buzzer must be mounted.

To program the Arduino board, people must go to the Arduino's official web page to download the appropriate software, and to our earphone mouse web page to download the program to be embedded into the Arduino board.

The device shall be ready to use when a message saying ‘charge complete’ appears on the Arduino programming application.

4.3 User’s guide

Upon connecting the earphone-mounted mouse to a PC it starts a calibration procedure. After that, the device is ready to emulate a mouse controlled by the head movements.

4.3.1 *Calibration*

The calibration procedure determines head movement range and is required to correctly interpret the gestures that will become mouse actions. It is automatically done every time the device is plugged.

An accompanying person, possibly the same that has put the device on the user, must wait until the calibration process is completed. Take into account that in case of an incidence, the device must be reset. Once the calibration is correct, the user can continue to use it in a fully autonomous way.

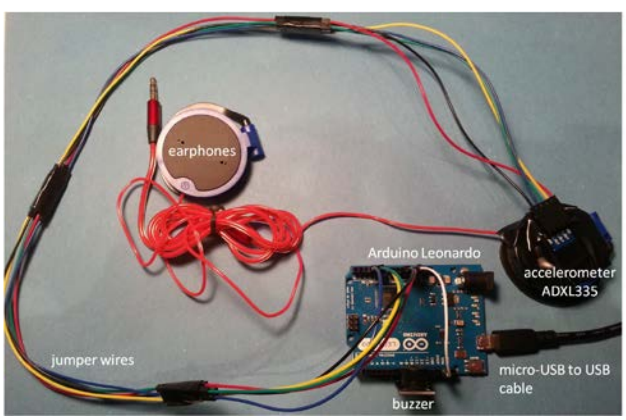

Figure 2. Earphone mouse.

The procedure is quite simple: the user has to keep his/her head in a rest position for 5 seconds, then lean it to the left for 5 seconds more and, finally, lean it to the right for other 5 seconds. Every step ending is signaled by a sound from the buzzer and by a blinking LED on the board.

Note that the rest position is the one in which the user feels comfortable looking at the screen. The movements and actions of the mouse will be achieved through the change of this position.

4.3.2 *Operation*

It is convenient to consider that this device has two operation modes: as a pointer and as a gesture interpreter. In the pointer mode, it transfers the head movement to the pointer movement on the screen. In the gesture interpreter mode, it transforms given head movements into mouse actions.

To switch from pointer mode to gesture interpreter mode you need to stop the pointer in the desired position. Each time the pointer stops on the screen, the buzzer module will emit a sound to show it. From this moment on, the user will have 2 seconds to make a movement that matches a mouse action. It is important that the head movement to perform the gesture starts when the sound is over.

If no motion is detected, the mouse will return to the pointer mode and the user will be able to move the pointer through the screen following the head movements.

All gestures involve moving the head from the resting position and going back to this position once finished.

The list of actions and corresponding gestures is shown below:

- Left click: tilt head to the left and return to the rest position just afterwards.
- Double left click: tilt head to the left and keep it this way until the action is performed (or as long as the pointer is still.)
- Right click: tilt head to the right and return to the rest position.
- Dragging: lean head to the right and keep it this way as long as the pointer is still.
- Scroll up: move the head upwards, as if to look at the ceiling.
- Scroll down: move head downwards, as if to look at the floor.

To exit the up and down scroll movements, leave your head in the rest position for 2 seconds until the device switches to pointer mode and the pointer starts moving again on the screen.

5. RESULTS AND CONCLUSION

Computer mice emulators that do not require hands are suitable for special needs people so that they could have access to information technologies just as average people.

We have proposed one such type of devices that fully emulates a conventional computer mouse, thus being the first of its class that does not require any specific driver or software installation.

We have created a web page (www.earmouz.org) to provide potential users with all the necessary information to build and use our earphone-mounted, accelerometer-based, USB mouse.

We have built several mice so they could be used by several testers. Non disabled people had little problem in using it after a few minutes, but it took them a while to learn the more complex gestures for double click and drag-and-drop.

Thus far, there have been few candidates with special needs to test the mouse because of several reasons: some of them were already using other pointing devices, some others had little control on their head movements, and others, simply, had other priorities. However, we had taken their opinions into consideration to make further adjustments to the device, which include being able to be operated more slowly and with higher tolerance to "movement noise." With this upgrade, we expect that the proposed mouse can be helpful to, at least, a handful of people.

In the near future, we plan to make calibration as seamless as possible and extend the tests to more persons so to broaden the set of potential users.

6. ACKNOWLEDGMENTS

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Explorando la Viabilidad de un Sistema de Tracking Inercial para la Mano Basado en un solo Sensor

Ernesto de la Rubia
Dep. de Tecnología Electrónica
Universidad de Málaga
Málaga, España
34-952 13 71 80
e@uma.es

Antonio Diaz-Estrella
Dep. de Tecnología Electrónica
Universidad de Málaga
Málaga, España
34-952 13 27 31
adiaz@uma.es

RESUMEN
Este artículo presenta un proyecto en progreso en el que se exploran las posibilidades de utilizar exclusivamente un sensor inercial para estimar la posición y orientación de la mano. El sistema sufre errores de deriva que afectan a la estimación de la posición y al ángulo yaw asociado al eje vertical. Se emplea filtrado de Kalman para reducir el error de las estimaciones durante los periodos de tiempo en los que la mano se detiene. También se explora la posibilidad de aplicar la técnica de reseteo selectivo de la matriz de error de covarianza (CESR) del filtrado de Kalman que ha sido empleada con éxito en el tracking de pies. Finalmente se presentan los resultados preliminares de las primeras pruebas realizadas y se sugieren diferentes estrategias que pueden contribuir a mejorar el comportamiento del sistema de tracking.

Categorías y Temas de Interés
H.5.2 [**Interfaces de información y presentación**]: Interfaces de usuario – *dispositivos de entrada y estrategias.*

Términos Generales
Algoritmos, medidas, diseño, ergonomía.

Palabras Clave
Sensores inerciales, procesado de señal, trackers, realidad virtual, interacción natural, inmersión, presencia.

1. INTRODUCCIÓN
El número de aplicaciones de los sensores inerciales ha aumentado sustancialmente durante los últimos años. Se implementan con frecuencia utilizando sistemas electromecánicos cuyo diminuto tamaño se mide en micras.

Habitualmente, los sensores inerciales son pequeños y ligeros. Su coste es reducido así como su consumo. Además, existen modelos inalámbricos. Estas características hacen que los sensores inerciales resulten especialmente adecuados en el campo de la interacción persona ordenador (IPO).

Un hecho relevante relacionado con el desarrollo de los sensores inerciales, es su presencia en dispositivos portátiles como smartphones y tablets. La combinación de elementos como conectividad inalámbrica, pantalla táctil, GPS, telefonía, conexión a internet, etc., en un dispositivo portable que puede ser programado fácilmente, da lugar a un planteamiento extremadamente versátil que permite desarrollar una gran cantidad de aplicaciones de diversa naturaleza. Esta situación favorece la evolución y mejora de los sensores inerciales.

De acuerdo a la tendencia actual, el coste de los sensores inerciales es cada vez menor mientras que aumenta la frecuencia de muestreo y se reducen los niveles de ruido.

En relación al modo en que se emplean, los sensores inerciales se utilizan principalmente como sensores de orientación. También se incluyen estos dispositivos en aplicaciones para detectar choques, caídas y vibraciones. Otro uso especialmente adecuado en el ámbito de la IPO, es la implementación de trackers de posición.

Los sensores inerciales se componen habitualmente de tres acelerómetros y tres giroscopios que se distribuyen en ejes perpendiculares. Registran la fuerza de la gravedad para determinar la inclinación del sensor y proporcionan estimaciones de orientación que solo sufren errores de deriva al calcular el ángulo respecto al eje vertical. A causa de este error de deriva, los sensores inerciales incluyen con frecuencia tres magnetómetros colocados sobre ejes perpendiculares entre sí que miden el campo magnético de la tierra actuando como brújulas para determinar la orientación del sensor respecto al eje vertical sin errores de deriva. Sin embargo, el campo magnético de la tierra es muy débil y sufre una fuerte distorsión en presencia de materiales ferromagnéticos que se encuentran habitualmente en la estructura de los edificios. Por ese motivo, se desaconseja el uso de magnetómetros en interiores. Este hecho tiene implicaciones en cuanto a la exactitud de las estimaciones de orientación que proporcionan los sensores inerciales en interiores.

Por otra parte, cuando se utilizan los sensores inerciales como trakers de posición, se estima la orientación y con ella se anula la componente de la aceleración asociada a la gravedad. De este modo, se obtiene la aceleración debida exclusivamente al movimiento. Integrando dos veces con respecto al tiempo este vector de aceleración, se obtiene una estimación del incremento de posición que ha sufrido el sensor durante el intervalo temporal aplicado en el cálculo de la doble integral. Las estimaciones de posición que se obtienen aplicando este planteamiento se basan en las estimaciones previas (dead reckoning). De este modo, los errores cometidos en las estimaciones se acumulan dando lugar a un error de deriva que crece con el tiempo. Este error es el mayor reto al que se enfrentan los sensores inerciales al ser usados como trackers de posición.

Una amplia mayoría de los sistemas que estiman la posición y orientación de las manos, se basa en sistemas ópticos que emplean procesado de imagen y cámaras de color o de profundidad. Su mayor inconveniente es que requieren visión directa con la cámara. Este hecho implica importantes limitaciones en cuanto a la movilidad del usuario.

Para resolver este problema, otras estrategias recurren a un conjunto de sensores inerciales colocados en distintas partes del cuerpo para estimar la posición y orientación de los mismos. Se trata de los trajes inerciales de captura de movimientos.

Eliminar o reducir el error de deriva en la posición que sufren los sensores inerciales, haría posible utilizar un solo sensor como tracker de posición que ofrecería importantes ventajas frente a los sistemas ópticos y a los trajes inerciales de captura de movimiento.

El resto del contenido de este trabajo se organiza de acuerdo a la siguiente distribución. En la segunda sección se presenta el trabajo relacionado con el tracking inercial de manos. La implementación del sistema objeto de estudio se describe en la sección tres. En la cuarta sección se estudia en qué medida es aplicable al tracking de manos una técnica que mejora el tracking inercial de pies. La quinta sección sugiere diferentes estrategias y técnicas complementarias al planteamiento base que también contribuyen a mejorar el tracking de manos. Finalmente se presentan las conclusiones y líneas futuras de este trabajo de investigación.

2. TRABAJO RELACIONADO

El número de estudios que abordan el tracking inercial de manos es muy reducido debido a la existencia de otras tecnologías que resultan mucho más adecuadas como los sistemas de tracking óptico o magnético. Sin embargo, los sensores inerciales aportan la ventaja de no necesitar una infraestructura de soporte que proporcione referencias. Además son los más adecuados para realizar ciertas tareas como el tracking de pies y el coste de los mismos es menor habitualmente.

La mayor parte de los estudios realizados con sensores inerciales abordan el problema de reconocimiento de gestos. Para ello se utilizan con frecuencia modelos ocultos de Markov [10], redes neuronales [13, 14] y algoritmos de alineamiento temporal dinámico (dynamic time warping, DTW) que determinan el grado de similitud de dos señales con independencia del tiempo y de su velocidad de cambio [3, 8]. [9] realiza un estudio en el que compara estos tres enfoques.

Un planteamiento más próximo al tracking de manos es el reconocimiento de caracteres, en el que se determina y analiza la trayectoria de la mano [1, 2].

En el tracking de pies sí se utilizan con éxito los sensores inerciales. La clave de este éxito es un hecho que pone de manifiesto [7]. Durante la marcha el pie se detiene por completo durante la fase de apoyo sobre el suelo. Entonces, es posible corregir la estimación de velocidad sabiendo que su valor real es cero. Esto permite corregir las estimaciones anteriores de posición y velocidad. Esta técnica es conocida como actualizaciones de velocidad cero (zero velocity updates, ZUPT) y permite reducir drásticamente el error de deriva del tracking de posición Foxlin [7].

Las correcciones ZUPT se implementan habitualmente mediante filtrado de Kalman utilizando una matriz de error de covarianza 9x9 que relaciona todas las componentes de las estimaciones de posición, velocidad y orientación [6].

Sobre el planteamiento anterior, [5] proponen una técnica que mejora la estimación de la posición y de la distancia recorrida. Dicha técnica se basa en la hipótesis de que no existe correlación entre un paso y el siguiente de ciertos elementos de la matriz de error de covarianza. En consecuencia, un reseteo selectivo de estos elementos mejorará las estimaciones en el próximo paso (covariance error selective reset, CESR).

Esta estrategia da lugar a excelentes resultados al estimar la posición y la orientación de los pies. En este trabajo se estudia la posibilidad de aplicar la misma técnica al tracking de manos.

3. IMPLEMENTACIÓN DE TRACKING INERCIAL DE MANOS

En el presente estudio se parte del algoritmo propuesto por [6] para tracking de pies y se adapta para abordar el tracking de manos. Se utilizan sensores InertiaCube3 inalámbricos de Intersense y cintas elásticas con velcro en los extremos que permiten fijar el sensor y la batería a la mano. Los sensores se configuran para funcionar a una frecuencia de muestreo de 120 Hz similar a la empleada por [6].

Existen tres factores fundamentales que dificultan el tracking de manos con respecto al de pies. La diversidad de movimientos que se realizan con las manos es mucho mayor. La aceleración en los pies es en general mucho más intensa que en las manos y por tanto las señales que se obtienen se ven menos afectadas por el ruido de los sensores. La tercera dificultad está relacionada con la detección del estado de reposo que es mucho más compleja en el tracking de manos. Esto se debe a que las manos no llegan a apoyarse como lo hacen los pies y adicionalmente, los pies cambian de orientación durante su movimiento. Esto no puede asumirse en el tracking de manos.

Estas dificultades tienen como consecuencia un error mayor de deriva en la estimación de la posición. Para controlar este error, es posible diseñar un paradigma de interacción que utilice el sistema de tracking propuesto en este trabajo y asuma que existe una posición inicial conocida desde la que parte la mano antes de realizar cualquier acción.

Para detectar la fase de reposo, el algoritmo propuesto por [6] compara el módulo de la velocidad angular con un valor umbral. Este criterio no detectaría movimientos en los que no cambie la orientación del sensor y por tanto no es válido para realizar tracking de manos. Por ello, se utiliza en su lugar el *detector óptimo de hipótesis de reposo* [12]. Para aplicarlo se utiliza la siguiente expresión:

$$\boldsymbol{T(z_n^a, z_n^\omega) = \frac{1}{W}\sum_{k=n}^{n+W-1}\frac{1}{\sigma_a^2}\left\| y_k^a - g\frac{\bar{y}_n^a}{\|\bar{y}_n^a\|}\right\|^2 + \frac{1}{\sigma_\omega^2}\|y_k^\omega\|^2}$$

Donde n se asocia a la primera muestra de la ventana de procesado. W es número de muestras de esta ventana. y_k^a es la aceleración en el instante k. y_k^ω es la velocidad angular en k. g es la aceleración de la gravedad. $z_n^a \triangleq \{y_k^a\}_{k=n}^{n+W-1}$ define la ventana de muestras de aceleración comprendidas entre n y n+W-1. $z_n^\omega \triangleq \{y_k^\omega\}_{k=n}^{n+W-1}$ es la ventana análoga de muestras de velocidad angular. σ_a^2 y σ_ω^2 son las varianzas de ruido de los acelerómetros y giroscopios respectivamente. $\bar{y}_n^a = \frac{1}{W}\sum_{k=n}^{n+W-1} y_k^a$ es promedio de la aceleración entre las muestras n y n+W-1.

Al resolver la expresión anterior para la muestra actual se obtendrá el valor $T(z_n^a, z_n^\omega)$ que se comparará con un valor umbral para determinar si el sensor está en reposo. En el presente trabajo se ha utilizado 400 como valor umbral para la comparación. Dicho valor se obtiene tras realizar pruebas en las que se aplica el criterio de reposo para distinguir movimientos muy leves de la mano de movimientos claramente definidos marcados. Además se emplean 3 muestras de tamaño de ventana y los siguientes niveles de ruido de los acelerómetros y giroscopios: $\sigma_a = 0.03\ \mathrm{m/s^2}$, $\sigma_\omega = 0.02\ \mathrm{rad/s}$. Estos valores de ruido se determinaron registrando las lecturas de los sensores en reposo y una vez alcanzada una temperatura estable de trabajo.

Es necesario señalar que no es posible crear un detector de reposo libre de errores. Esto se debe a una limitación física por la que el estado de reposo es indistinguible del de movimiento a velocidad constante.

Adicionalmente existe otra limitación que afecta a los detectores de reposo que se basan en el módulo de la aceleración como el empleado en este estudio. Cuando la mano desciende y a la vez se desplaza lateralmente puede ocurrir que las componentes de la aceleración vertical y lateral den lugar a un valor de la aceleración cuyo módulo puede coincidir con el valor de la aceleración de la gravedad (9.81 $\mathrm{m/s^2}$). En ese caso, el detector de reposo daría lugar a un falso positivo.

Con todo, al aplicar el algoritmo original con el detector de reposo descrito, se obtiene un comportamiento muy satisfactorio siempre que la mano se detenga con frecuencia para aplicar las correcciones asociadas a la técnica ZUPT a través del filtrado de Kalman. El algoritmo de tracking de manos propuesto en este trabajo se ha desarrollado utilizando la herramienta descrita en [4]. La Figura 1 muestra una traza procesada por esta aplicación que corresponde a 10 movimientos horizontales y 6 diagonales de la mano entre las esquinas de un ordenador portátil.

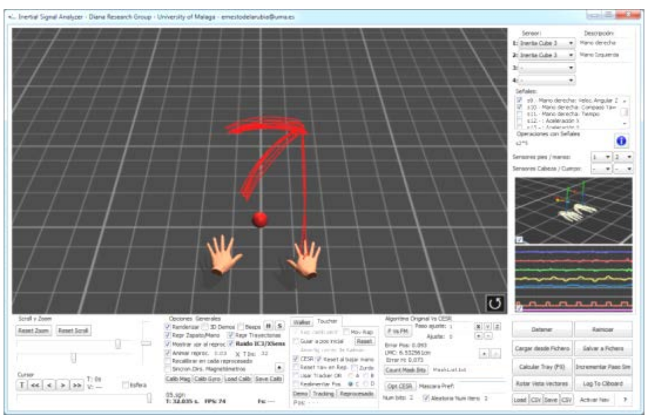

Figura 1. Movimientos de la mano (10 horizontales y 6 diagonales) entre las esquinas de un ordenador portátil.

Para aumentar la exactitud del algoritmo, cabe plantease la posibilidad de utilizar la técnica CESR que supone una mejora significativa en las estimaciones del tracking de pies.

4. ESTUDIO DE VIABILIDAD DE LA TÉCNICA CESR

La técnica CESR consigue mejorar el tracking de posición de los pies y reducir hasta en un 37% la longitud media de las correcciones (LMC) que se aplican a través del filtrado de Kalman cuando el sensor está en reposo (ZUPT).

Para evaluar si también mejora las prestaciones en el algoritmo de tracking de manos, se eligen 5 tipos de movimientos que comienzan y terminan en la misma posición. De este modo, la LMC será aproximadamente el error cometido al estimar la posición de la mano. Para cada tipo de movimiento se graba una traza de datos en la que se repite el movimiento 30 veces. Los tipos de movimientos son:

T1: La mano avanza 45 cm y vuelve a la posición inicial.
T2: La mano se eleva 45 cm y vuelve a la posición inicial.
T3: Circunferencia de 45 cm de diámetro en sentido horario.
T4: Circunferencia de 45 cm de diámetro en sentido antihorario.
T5: Avance y retroceso de la mano de 45 cm en direcciones que forman ángulos de -45, 0 y 45º con respecto a la dirección frontal.

La Figura 2 muestra algunos ejemplos de estas trazas.

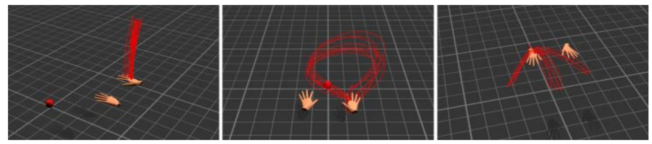

Figura 2. Ejemplos de trazas procesadas T1 (izq), T3 (centro) y T5 (der).

Existen 2^{45} patrones de reseteo diferentes para aplicar la técnica CESR. Para determinar el patrón óptimo, se generan aleatoriamente patrones de reseteo que se aplican a las 5 trazas. Se obtiene así la LMC para cada traza y se compara con la obtenida con el algoritmo básico. Una vez se haya simulado un número suficientemente alto de patrones, se recopilarán todos los patrones de reseteo que mejoran significativamente los resultados del algoritmo básico. De este modo, se podrá realizar un estudio estadístico en el que se determine qué elementos de la matriz de error de covarianza contribuyen a mejorar la estimación de posición.

No se han obtenido resultados concluyentes hasta el momento pero sí se han encontrado algunos patrones de reseteo que mejoran el comportamiento del algoritmo básico en las cinco trazas de datos. Este hecho apoya la validez de la técnica CESR aplicada al tracking de manos.

5. TÉCNICAS COMPLEMENTARIAS

Cuando surgen conflictos entre las distintas modalidades sensoriales, predomina la modalidad visual. De este modo, se pueden tolerar ciertas discrepancias entre la información visual y propioceptiva [11] que permitirán mejorar el comportamiento del sistema de tracking implementando algunas de las siguientes estrategias.

La primera técnica consiste en detectar cuándo la mano decelera a la vez que se aproxima a la posición inicial o a un punto de interés. Podrá asumirse entonces que la mano va a detenerse en una posición conocida y se realizará un ***guiado progresivo*** de la mano hacia dicha posición.

Cuando la mano se detiene se aplican las correcciones asociadas al filtrado de Kalman y a la técnica ZUPT. Esto da lugar a cambios bruscos de posición y orientación. Mediante una ***aplicación gradual de las correcciones*** cuando el usuario mueve la mano, mejorará la sensación visual que produce el algoritmo.

La clave del algoritmo de tracking inercial es la detección de los estados de reposo. Con ello se controla el error de deriva aplicando la técnica ZUPT. En el caso del tracking de manos, no puede asumirse que existirán periodos de reposo con frecuencia. Sin embargo, cuando la mano realiza un cambio brusco de dirección en un movimiento de ida y vuelta, puede considerarse que la mano se ha detenido durante un instante. Así, pueden identificarse los ***reposos instantáneos*** y aplicar las correcciones

ZUPT. Esta estrategia contribuiría a controlar el error de deriva y aliviaría las restricciones que debe imponer el paradigma de interacción que haga uso del sistema de tracking inercial de manos.

La última técnica complementaria que se propone en este trabajo se denomina ***procesado retroactivo*** y tiene como objetivo reducir la latencia que introduce la técnica CESR. El reseteo selectivo se aplica 6 muestras antes de que finalice el estado de reposo. Un modo de implementarlo es retrasar el procesado durante 6 muestras. Esta estrategia aumenta la latencia del algoritmo en 50 ms puesto que la frecuencia de funcionamiento es 120 Hz.

Para aplicar la técnica del procesado retroactivo es necesario guardar el estado del algoritmo y los datos de los sensores durante las 6 últimas muestras. Cuando se detecta que la fase de reposo ha terminado, se restaura el estado del algoritmo 6 muestras antes, se aplica la técnica CESR y se procesa el resto de muestras hasta llegar a la actual. Con ello, se consigue un procesado en tiempo real que estima la posición de la mano muestra a muestra sin retardo alguno. Tras aplicar el procesado retroactivo, se producirá un cambio en la posición de la mano debida al reprocesado de las 6 muestras siguientes al último reposo. Este reajuste es típicamente imperceptible ya que los efectos del reseteo selectivo de la matriz de error de covarianza se manifiestan progresivamente a lo largo del movimiento y no al principio del mismo.

6. CONCLUSIONES Y LÍNEAS FUTURAS

Se ha presentado el trabajo en progreso que explora las posibilidades de usar sensores inerciales para realizar tracking de manos. Se parte como base de un algoritmo que utiliza filtrado de Kalman para tracking de pies que se adapta para realizar tracking de manos. Al hacerlo, se han identificado las principales dificultades de esta tarea como la necesidad de nuevos criterios para detectar reposo. Para resolver este problema se ha utilizado con éxito un detector de reposo propuesto en la literatura y se han determinado sus limitaciones al aplicarlo al tracking de manos.

Se ha descrito el enfoque y los progresos de un estudio de viabilidad del uso de la técnica CESR para mejorar el tracking de manos y con el mismo propósito, se ha presentado un conjunto de técnicas complementarias.

En relación al trabajo futuro, queda pendiente determinar el patrón óptimo de reseteo de la técnica CESR y validar definitivamente su utilidad en el tracking de manos. La implementación y evaluación de las técnicas complementarias es otra tarea a abordar. También resultará de máximo interés comparar las estimaciones de orientación y posición de los algoritmos de tracking inercial con sistemas de captura de movimientos ópticos. Con ello, será posible determinar la evolución en el tiempo del error de deriva en posición y orientación.

También queda pendiente determinar si el patrón de reseteo óptimo de la técnica CESR depende del tipo de movimiento. De ser así, podría evaluarse si resulta efectivo detectar el tipo de movimiento realizado antes de aplicar el patrón de reseteo correspondiente.

La evaluación de las técnicas se realizará mediante pruebas con usuarios siempre que sea posible. Con ellas se podrá determinar además, en qué medida el comportamiento de los algoritmos de tracking dependen de cada individuo.

7. AGRADECIMIENTOS

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An investigation into the comprehension of map information presented in audio

Feng Feng
School of Electronic Engineering and Computer Science
Queen Mary University of London
Mile End Road, London E1 4NS, UK
f.feng@qmul.ac.uk

Tony Stockman
School of Electronic Engineering and Computer Science
Queen Mary University of London
Mile End Road, London E1 4NS, UK
t.stockman@qmul.ac.uk

Nick Bryan-Kinns
School of Electronic Engineering and Computer Science
Queen Mary University of London
Mile End Road, London E1 4NS, UK
n.bryan-kinns@qmul.ac.uk

Dena Al-Thani
School of Electronic Engineering and Computer Science
Queen Mary University of London
Mile End Road, London E1 4NS, UK
d.al-thani@qmul.ac.uk

ABSTRACT
The growth in mobile and multimodal Computing is leading to the consideration of alternative modes of information presentation, particularly in situations such as driving or walking in unfamiliar locations where the eyes are needed for primary navigation. We report the results of an experiment in which map information is presented to 10 normally sighted participants using an auditory display. Several measures of performance are reported, including the time to navigate a virtual route, keystroke errors and the ability to construct a visual representation of the route travelled based on audio instructions only. The results show significant variability in levels of performance between individuals, though most participants were able to make sense of the auditory display and produce a reasonable visual representation of the virtual route i.e. participants were able to comprehend the presented audio map.

Categories and Subject Descriptors
H.5.1 [**Multimedia Information Systems**]: User Interfaces – *audio input/output, evaluation/methodology*.5.2 [**Information interfaces and Presentations**]: User Interfaces – *auditory (non-speech) feedback, evaluation/methodology*.

General Terms
Design, Experiment, Human factors.

Keywords
Auditory display, spatial information, audio map system, audio information understanding.

1. MOTIVATION
While most people's interactions with digital devices are visual, there is a growing need for people to consider alternative modes of communication with devices they use every day and everywhere. This need arises out of the fact that digital interactions increasingly take place in the context of other tasks, and, due to the nature of mobile devices, when sight is needed elsewhere for driving, pedestrian navigation or other tasks. This paper explores the extent to which users with normal sight are able to comprehend and reproduce spatial information presented to them in audio. While the choice to present spatial information in audio may seem counter intuitive, the motivation becomes clearer when considering the difficulty of using visually based map information on small screens and in the context of extreme navigation, which is navigation under extreme conditions such as extreme darkness, fog or in the presence of smoke.

The next section reviews previous work on the development of auditory displays, before examining foregoing research on the development of auditory map systems. We then describe and analyse the results from an experiment in which 10 sighted people undertook tasks requiring them to understand and reproduce map information presented to them in auditory form. The paper concludes with reflections on how the tasks were performed and ways in which these levels of performance might be improved.

2. BACKGROUND
2.1 Auditory Display
Past work on auditory displays has focused on four distinctive techniques: auditory icons, earcons, actual (synthetic or pre-recorded) speech and spearcons [13]. This research makes extensive use of the first three but not spearcons -- verbal cues played back at very high speeds -- as they would have added learning effort for aspects that are well served by synthetic speech.

Gaver coined the term "auditory icons" in a 1986 article of the same title: "auditory icons are caricatures of naturally occurring sounds such as bumps, scrapes, or even files hitting mailboxes" [6]. Gaver explored this emphasis on `everyday listening' further in a 1989 paper on SonicFinder, an auditory interface which he developed for Apple [7].

Blattner et al. [3] developed the concept of "abstract earcons": musical "motives" that can be grouped to form "families, where earcons with similar meanings have similar sounds". The authors defined earcon motives as `a rhythmicized sequence of pitches' [3]. The best length, they argued, is two to four notes as longer diatonic patterns would tend to form tunes and be likely to annoy users. In 1992, Brewster et al. performed a series of experiments that investigated the use of earcons in much more detail, [5]; see also [4]. The finding was that earcons do work, but also that Blattner et al. had been overly optimistic regarding the degree of differentiation and hierarchical organization that is achievable by changing motives very slightly: participants were unable to tell one member of a given earcon family from another [5].

As [13] have observed, many auditory interfaces call for a hybrid approach, employing "complex mixtures of different techniques" [13]. This raises the issue of what the precise balance between speech, auditory icons and earcons should be. Each of the three has the potential to distract or annoy the user, so special care needs to be taken when recordings of actual sounds, earcon motives and synthetic speech coincide.

(Begault, 1994) [2] provides an authoritative guide to head-related transfer functions, distance cues, headphone distance errors, and reverberation in the context of 3D sound for virtual reality applications. Many of Begault's recommendations find a direct equivalent in the OpenAL specification and the effects extension that accompanies it.

2.2 Auditory Map System

The BATS (Blind Audio Tactile Mapping System) project [12] pioneered the use of auditory maps (albeit on the scale of whole countries rather than cities) for use by visually impaired people and so helped create a context for later studies. The researchers asked to what extent spatial sound can aid spatial understanding and learning, and highlighted two techniques in particular: “spatial auditory icons” (e.g. bubbling water for rivers) and “callouts” (spoken labels positioned in the auditory scene, e.g. “Raleigh”). Using tactile trackballs, gamepads and keyboard commands, users move a virtual listener across the map whose bearing never changes. The BATS developers were keen to ensure that the project should use “standard computer hardware and open source software” [12]. It appears that BATS development was discontinued after the two prototypes presented in the 2003 paper. The first was written specifically for one individual (whose feedback was that the interface was somewhat complicated) and evaluation of the second was limited to “a number of users, sighted and blind, informally interacting with the system” [12].

Heuten [8] developed an “auditory torch” system that bears some resemblance to BATS, but specializing in city maps. The user moves the listener across a map of Brussels using an “absolute input device”, a customized digitizer tablet with raised borders that correspond to the borders of the virtual map. Auditory torch walkthroughs” are not entirely immersive experiences in the sense of first-person navigation. Once more, users cannot change their bearing, for example. The project team conducted two formal evaluations, the first with eleven blind participants and the second with six untrained and presumably sighted participants. The results were impressive: participants were able to reproduce maps with considerable accuracy, that is, proportions and landmarks corresponded closely with the underlying map [8]. Heuten went on to describe a first person application of the auditory torch system in [9].

The Audio-based Environment Simulator takes a very different approach. It seems that the project's final findings have not yet been published, and what is known about it comes from a work-in-progress paper published in April 2010 [14]. This system focused on the representation of small-scale indoor spaces.

Evaluations are conducted using a relatively small group of individuals (seven in the case of the preliminary evaluation) in controlled circumstances. Here, the evaluation requires access to more than ten rooms, a `tactile model' of the floor plan with Braille labels, the Audio-based Environment Simulator itself as well as LEGO and plasticine for modeling. The authors concluded that the system allows the user to develop an accurate spatial cognitive map of a large-scale three-dimensional space that can be manipulated for the purposes of a real indoor navigation task.

3. AUDITORY MAP EXPERIMENT

3.1 The TEAM System

Full details of the auditory map system employed in the experiment reported here are given in (Loeliger, 2014) [11]. A summary of the key aspects of the system follows.

The system provides an immersive, first-person experience of the map. Two modes of navigation of the map are provided. The first allows navigation to any point on the map, the second, which is the default, only permits navigation along existing roads and paths. The user’s direction of travel is automatically adjusted as streets bend left or right. The sound that accompanies each step changes slightly when this happens to give audible feedback. This means that it is possible to trace a wide oval shape simply by instructing the system to walk straight ahead. When approaching sharp turns (that is, turns greater than 45 degrees), however, the user is asked to confirm the change of direction. At decision points, the user is given a range of options corresponding to the options available at that point in the physical environment. The fact one has reached a decision point is signaled by an earcon, the number of notes in which identifies the number of alternative paths from which a choice has to be made.

All turns are 45-degree turns. At any point, users are able to request the name of the street they are on, a rough absolute position on the map and their bearing. They can also trigger a sonar function, which gives the user an overview of the landmarks and points of interest in close proximity. Foregrounding connections between ways, landmarks and decision points helps users by reducing the number of salient features to be borne in mind.

Synthetic speech is used to announce street names, names of points of interest (POIs), system menus and changes in state of the system (such as switching ambient sounds on or off). Auditory icons are used extensively throughout the system to signal how busy specific streets are or the presence of POIs such as parks, playgrounds, pubs, bars, restaurants and train/underground stations.

To avoid sensory overload, the application allows users to filter out certain sound sources (e.g. restaurants or playgrounds). The volume of ambient sounds (e.g. market), non-ambient sounds (e.g. turn around) and synthetic speech can be controlled individually. However, these settings are fixed when taking part in the evaluation, to present a uniform interface to all participants in the experiment.

The system eschews haptic input devices in favour of basic keyboard commands. The essential consideration here is that keyboard commands should be as intuitive as possible and use large and/or easily reachable keys wherever possible. The cursor keys are clearly invaluable here as they serve to make walking and turning somewhat intuitive: cursor up is mapped to ‘step ahead’, cursor down to ‘turn around’ and right/left to ‘turn right/left’. Space (‘where am I?’) and Return (‘sonar’) have the advantage of being large and prominently placed. Escape is a convenient choice for interrupting lengthy verbal descriptions and dismissing dialogs. The goal was to make the system as easy to learn as possible without unduly hampering the user’s ability to navigate the map and so contribute to the evaluation. One key feature of the system is that it allows the user to explore any location on the planet, from Alcatraz to Brooklyn, New York. For example, entering ‘Camden’ and selecting ‘United Kingdom’ in the download dialog will take the user straight to North London.

From there, they can choose a start point and an end point from a self-voicing list. The software was implemented on a laptop which has a stereo sound card and uses the Open AL package to render its auditory display.

3.2 Experimental Design

3.2.1 *Task Design*

Participants were asked to navigate a pre-determined route using the TEAM system. The route was set up in the TEAM system before the experiment, and comprised nineteen points, including a start point, an end point and seventeen decision points. All participants could only access the auditory representation of the route presented by the TEAM system during the experiment. The participants were asked to navigate from the start point to the end point, and were required to complete six right turns, three left turns, and nine decisions to carry straight on to navigate the given route correctly. All participants were naïve to the route being used in the study. At each decision point, participants were instructed by the observer about the next step and needed to find the way to the next decision point relying only on the auditory display. Participants were provided with paper and drawing materials and were required to draw a sketch of the route that they traveled.

3.2.2 *Participants*

The route used is in London, all participants were screened to make sure they had not used that route before and were not generally familiar with the area. The demographics of the participants relevant to the study are given in table 1.

Table 1. The demographics of the ten participants

Participants	Participants' specialization	Sex	Age	Computer game experience	Driving experience	Nationality
P1	Material Science	F	27	Rarely play it.	No driving experience	Chinese
P2	Sustainable engineering	F	23	After 13, never play it again.	Experienced driver	Pakistani
P3	Computer Science	M	28	Never	Experienced driver	Mexican
P4	Computer Science	M	27	Good player	Experienced driver	Mexican
P5	Mechanical Engineering	M	26	Never	No driving experience	Chinese
P6	Computer Science	M	36	Never	Never	Argentinian
P7	Computer Science	F	23	Rarely play it.	No driving experience	Kazakhs
P8	Software engineering	M	26	Never	No experience	Mexican
P9	Biochemistry	F	26	Last time is 7 years ago	Experienced driver	Mexican
P10	ICT	F	20	Long time ago	Never	SRI LANKAN

3.2.3 *Procedure*

The following procedure was undertaken for each of the 10 participants separately. Firstly, they were introduced to the TEAM audio map application and overviewed the actions used to navigate a map. Each participant was allowed 15 minutes to familiarise themselves with the system working in audio visual mode (TEAM provides a visual presentation of the map as well as an auditory display). After this period of familiarisation, the screen was turned so that it was out of sight of the participant, who continued to operate the laptop using a separate keyboard and using the auditory display only. Each participant then used the keystroke to place themselves at the start of the preset route, and from that point on received scripted human instructions about how to reach the next decision point, which they had to translate into the appropriate keystrokes to navigate within the TEAM system, and respond to the auditory display of the map accordingly. Participants were also asked to construct a sketch of the route travelled as they navigated the route.

3.3 Data Collection

During the navigation task, participants' navigation time and their performance in terms of keeping on track, keyboard misoperation and auditory icon recognition were recorded. Additionally, the researcher made notes about how each participant seemed to be coping with the navigation and sketching while they navigated the route. At the end of the navigation task, sketches of the route were collected and reviewed by the researcher and the participant.

4. Results

4.1 Performance Assessment

We measured the participants' performance in terms of navigation time, their ability to keep on track, keyboard command accuracy, distance estimation and route review.

Table 2. Navigation time of the ten participants and the interruption time

Participants	P1	P2	P3	P4	P5	P6	P7	P8	P9	P10
Recording time	32:43	16:20	13:42	27:49	18:35	21:28	12:49	17:02	14:08	23:08
Pure navigation time	19:25	15:06	16:07	17:13	17:46	17:20	12:27	16:45	13:03	15:00
Interruption times	10	7	4	4	7	4	1	3	2	9

Table 3. Deviation on decision points

Deviation points	DP1	DP2	DP4	DP5	DP6	DP7	DP9	DP11	DP15	DP18
Navigation number	3	2	2	3	1	1	1	1	1	1
Back	2			2						
Lost	1	2	2	1	1	1	1	1	1	1

4.1.1 *Navigation Time*

Table 2 reports the times taken by the participants to navigate the set route. All 10 participants completed the navigation task successfully, though 2 of them got sufficiently lost on their first attempt that they started from the beginning again. The times reported in table 2 below are taken from the second start time for these two participants.

During the navigation task, the process were interrupted randomly by raising question, expressing opinion, losing orientation, confirming information and offering solutions. The process was ceased for a while during these interruptions. In order to get more valid navigation time, the time consuming on these behaviors are excluded from the whole recording time, show as the 'pure navigation time'.

4.1.2 *Keeping on track*

The route navigated comprised the start point, the end point and seventeen decision points (DP). We mark each point from start to end successively, and record all participants' deviations at each point in table 3.

4.2 Interaction Measures

4.2.1 *Keyboard Commands*

We recorded participants' keystrokes during the navigation task, and based on participants' performance, we identified five types of keyboard error:

(1) Orientation errors: navigating in the wrong direction or misinterpreting cursor navigation as compass directions rather than in relation to self. For example, when participants perceived the speech of 'heading south', they tend to press the down arrow key to move forward.

(2) Omitting error: omitting a keystroke to confirm the selection of a chosen direction.

(3) Unintentional pressing: keystroke happened without notice and participants usually couldn't be aware of this mistake.

(4) Incorrect keystrokes while self-orienting (show in figure 1 as attempting press): This type of error refer to the tentative keystrokes for the purpose of finding the orientation and exploring what would happen next.

(5) Miss-keying: this type of error happened due to incorrectly interpreting instructions from TEAM's auditory display.

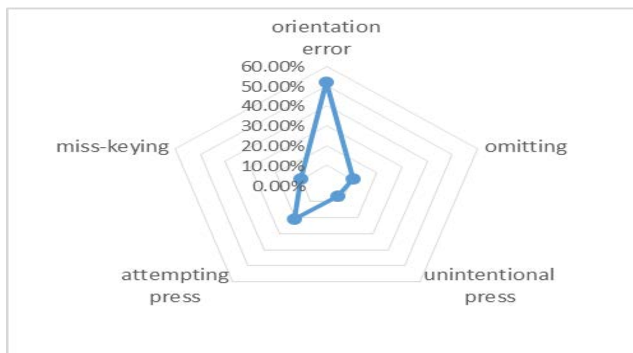

Figure 1. Keyboard command errors based on error type

4.2.2 *Distance estimation*

During the navigation task, participants were asked to estimate the distance according to the number of cursor key presses used between each decision point, and represent the distance on their sketches. Six of the ten participants were able to do the estimation on different parts of the route. Only one participant did the estimation throughout the whole process. Three of the ten participants did not attempt the estimation during the navigation process. Figure 2 shows the sections of the route which were divided by each decision points.

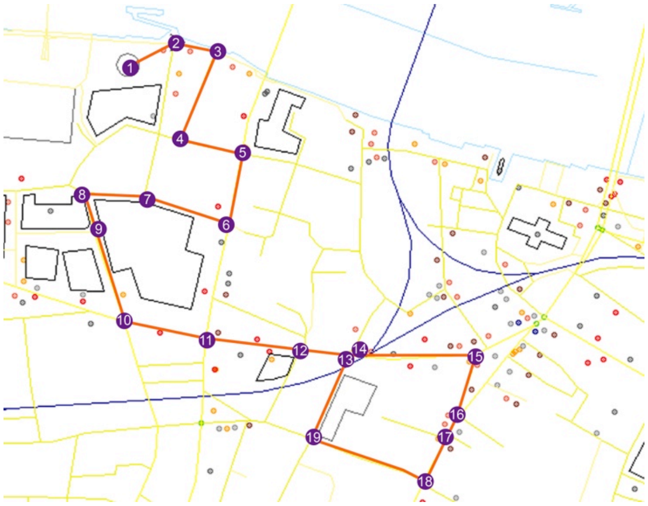

Figure 2. (a) Navigation route setup

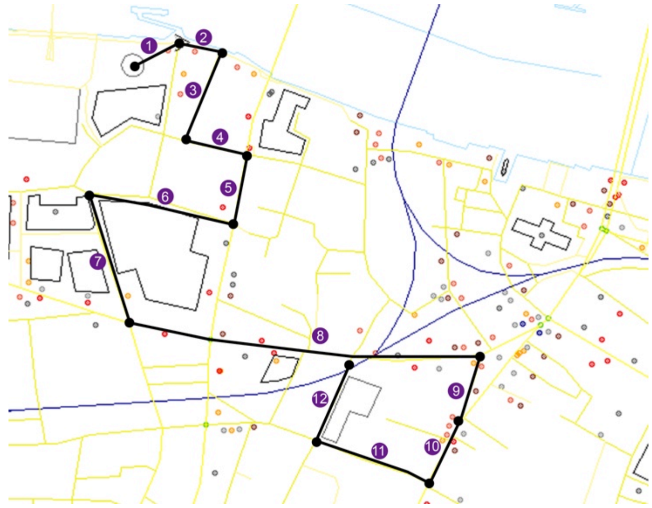

Figure 2. (b) Route segments

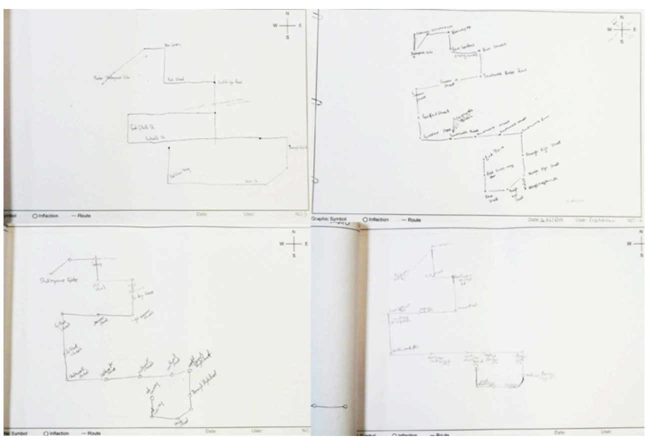

Figure 3. Sketches of reproduced map

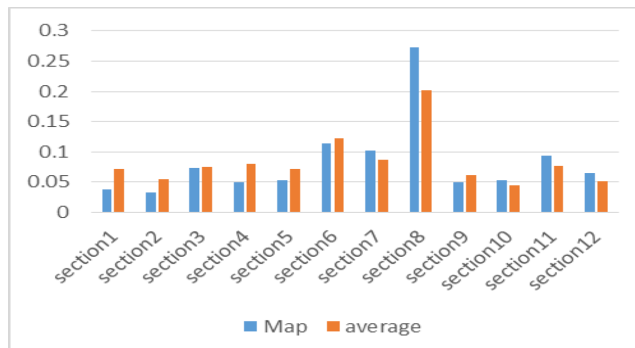

Figure 4. The average of relative length of 12 sections

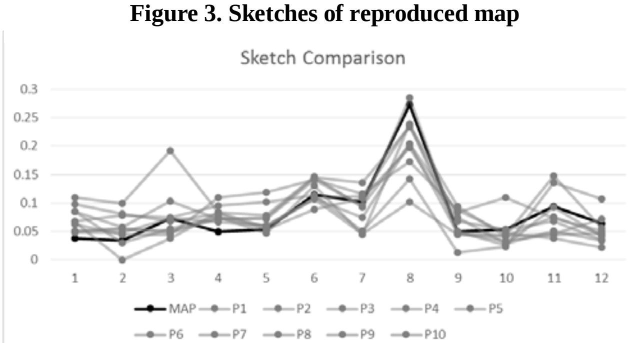

Figure 5. Comparison between participants' distance estimation on sketch and the original route

Each time when participants pressed the up arrow key to move forward one step, an auditory icon was played as the feedback. Therefore, the more times the earcons were heard, the longer the road. When participants estimated the distance, they translated the times of the earcon into the length of the line on their sketch. Figure 3 shows 4 of the 10 sketches collected from participants.

In order to get more valid comparison between the participants' sketches and the original route, we didn't calculated the road sections divided by nineteen decision points showed in the Figure 2. Instead, the route was divided into eleven segments based on the turning points, which could better reflected participants' understanding of the spatial configuration.

It is necessary to compare the absolute segment length directly since the sketches are all in different size. Therefore we could compare the relative length by calculate the segments 'proportion on the route. By comparing the relative length on sketches with the corresponding segments on the map, we can determine how well the participants were able to judge the relative distances of the route. Figure 4 shows the relative length comparison of the route segments between the original map and ten participants' sketches.

5. Observations and Exit Interviews

The following summarises the main findings from observations made by the researcher of participants during the navigation task, and the interviews conducted with participants following completion of the task.

5.1 The Sense of Current Location

It was clear from both the observations and the interviews that most of the participants were not confident about their spatial location at several points during the task. Five participant in the route review process mentioned that they lack a sense of localization. They expected some repeat mechanism would remind the current location, and they believed this was the crucial factor for spatial understanding.

Participants were quite used to take diagrams or picture as the external memory which could be checked back instantly [1]. However, in this pure audio display circumstances, participants found it difficult and confusing to try to navigate without the aid of a visual representation of the route. They reported that the auditory icons could possibly play the same external reminder function just as the graph information did. But this function was limited due to the hierarchical feature of the auditory representation.

5.2 The Sense of Distance

Participants' reproduction of relative distances, as shown on the sketches they reproduced from the auditory instructions (Figure 3), were often incorrect and distorted, though their representation of changes in direction made a turning points in the route was generally quite accurate. However, during the interview we discovered that most of the participants were able to figure out the longest road without referencing the sketch. They reported that pay attention on counting the earcon feedback is the key to estimate the distance. But what they actually did was estimate the distance by counting how many road sections they have passed. For example, when participants doing the navigation and estimation, the recording of their dialog is as follows:

'Counting the earcons of steps is not an efficient way to get distance information.'

'I think using blocks instead of steps can avoid distracting at some extent.'

This could explain why they tend to reproduce same distance of the sections on their sketches.

Another factor relevant to distance estimation is the auditory provision. Getting a general idea of the distance of the section or the walking time in advance is more explicit than counting the earcons. Always focus on the earcon display allocated too much concentration on counting the distance, result in the omition of other spatial information.

5.3 The Ability of Auditory Information Perception

Most of the participants seemed to have few problems interpreting the speech component of the auditory display. The non-speech parts of the auditory display however provoked much more mixed responses, with 3 participants reporting they found them helpful and that they complimented the speech effectively, while 4 participants reported that they found them both unhelpful and distracting. The three other participants were fairly neutral in their views of the use of earcons and auditory icons. The participants who were positive about the auditory icons and earcons also produced the better visual representations of the route.

7 out of the 10 participants realised that near the end of the route came close to the middle section they have just passed, the only one of these realised that the route did in fact form a complete circle not far from the end point. This was not the same as we expected, though the system offered an explicit clue of coming back by displayed the same distinguishable auditory icons successively. In fact, most participants reported that they did not catch the second auditory icons, and that's the main reason they could not figure out the circle configuration. It is not difficult to discover the reason through observation: when participants pressed the upper arrow key without release, result in a high speed moving on the road, which inhibited the generation of auditory icon at that point.

5.4 Unintentional Motion Matching

Since people's spatial perception is a multi-sensory integrated system, and this integration of visual and auditory is an experience getting process [10], participants tend to do the matches between the direction keys and the orientations respectively. Ideomotor theory also proved that when people process the spatial information mentally, haptic reactions could be easily measured [15]. This could explain the hearing-motion match phenomenon in the navigation task.

5.5 Individual Difference

Some broad correlations were seen regarding performance and background demographics. The participants who had driving experience were more likely to remember the route and to reproduce a more accurate visual sketch. The participants who were good at computer games had no problems with the keyboard control. Participants who are doing a degree in computer science spent less familiarisation time at the beginning of the experiment than participants from other disciplines.

6. Discussion

6.1 Navigation Time and The Interruptions

Table 2 shows the results of navigation recording time and actual time respectively. The individual times vary substantially between different participants. In both the recording time and the pure navigation time, participant 1 spent the longest time during the whole process, which is 32 minutes and 43 seconds and participant 7 spent the shortest time fulfilling the task, which is 12 minutes and 49 seconds. The results indicate that longer navigation times in the process tend to be accompanied by more interruptions, which include operation mistakes, keystroke errors and orientation confusion. The direct consequence of those interruptions was the deviation from the main road. Whether the participants were able to realize the deviation by self-checking or continue deviating until the auditory mismatching encountered, it took time to redirect the current orientation and get back to the main road. To the contrary, participants who spend less time during the navigation progressed smoothly, with less interruptions and confusions.

6.2 Keep On Track Measure

Table 3 show the results of participants' keep on track performance. In all the ten deviated places, there were one start point, six turning points for changing direction (DP2, DP4, DP5, DP6, DP15 and the DP18) and three interim points (DP7, DP9, DP11) for continue along the road. The result of those deviations reflects that the participants are more likely to make a mistake at the turning points than at the interim points. Following is two transcript examples of the participant's >action< and the system's <feedback> at a turning point and an interim point. Turning points involved the consideration of direction judgments, orientation checking, also involved more steps of keystrokes to choose the right road branch options, in this example which is ten steps and the interim point only involves five interaction steps.

At the turning point:

1. <Earcons> (Remind the participant here is the decision point)
2. >Right arrow key< (Participant flip road branch options)
3. <Right bear gardens> (Speech audio feedback of the system)
4. >Right arrow key< (Keep flipping road branch options)
5. <Turn around Footway> (Speech audio feedback of the system)
6. >Think of the destination and direct the orientation<
7. >Left arrow key< (Participant back to former option)
8. <Right bear gardens> (Speech audio feedback of the system)
9. >Enter key< (Participant choose the road branch)
10. >Up arrow key< (Continue the navigation)

At the interim point:

1. <Earcons> (Remind the participant here is the decision point)
2. >Right arrow key< (Participant flip road branch options)
3. <Continue ahead Park Street> (Speech audio feedback of the system)
4. >Enter key< (Participant choose the road branch)
5. >Up arrow key< (Continue the navigation)

The results also show that the decision point 1 and the decision point 5 are the places where the participants are most likely to make a mistake. However, these two places are the only places that participants were able to find the way back based on the spatial information that the system offered. Since the most of the deviations happened at the beginning part of the route, it seems that participants need time to make themselves be familiar with the interaction way of this system. This finding is in line with the observation results of gaining experience and getting better at navigation as they progressed through the route.

6.3 Keystrokes Analysis

Figure 1 shows the measurement of five type of keyboard commands errors. The results indicate that the orientation error is the most commonly occurring keystroke error with a per centage score of 52%. Six of the ten participants were made this type of error more than two times, another two participants who did not make this type of error reported that they tend to press up error key when move south, and they did not feel comfortable when moving south by press the up arrow key.

This result was expected since ideomotor effect (Stock, A., 2004) is a common feature in peoples' spatial related actions. This result indicates that spatial recognition ability has a strong association with kinesis to a large extent. From each of the participants' side, the hearing-action mismatching error also have a large proportion compare to other kind of keystroke errors that they made. This results was in line with participants' report in Observations and interviews.

The results also show that the attempting press error reached 21%. Two situations caused this type of error. One situation is the participants getting lost during the navigation. Thus they try to find out the heading direction and hope there's some auditory informing message show up by issue a keystroke action. Another situation is that when participants were not confident about their operation, what they did was try to figure out whether the reaction of the system is identify with their anticipation by press any key that they believe would be reasonable.

Miss-keying error and keystroke omitting error reached 10% respectively, and unintentional press error scored 7%. The purpose of these key presses during navigation is to obtain further feedback information, as participants were finding it difficult to make judgments about their next navigation action. This result shows the importance of clear and regular feedback in response to navigation actions.

6.4 Sketch measure on Distance Estimation

Figure 4 and Figure 5 shows the comparison of the relative length of twelve road sections between the ten participants' sketches and the original map. The result shows that most participants were able to get general knowledge of the distance through earcons display. From the figure 5 we could see the turning points on the sketches were congested at the point 3, 6, 10 and the 12, and the correlated route section 3, 6, 10 and 12 showed in the figure 4 are the most accurate estimation. This results indicate that participants were doing well when dealing with single segments estimation. Figure 5 also shows that the point 1, 7, 8, and 11, have more separated distribution, and the route section 1, 7, 8, and 11 in the figure 4 have larger difference value. This indicate that they tend to have biased estimation when dealing with continuity segments.

7. Conclusions

In this paper we first reviewed the development of audio displays and then introduced the audio map system, which use earcons, auditory icons and synthetic speech to represent spatial information. We then present the experimental design with ten sighted participants, and analyse the results from qualitative angle and quantitative angle. The measurements of the participants' performance include performance assessment and interaction measurement. The result show that all the ten participants were able to complete the navigation and reproduce the route configuration by listen to the auditory representation though the leverage of individual difference were vary significantly.

This study has identified many features that would facilitate people's spatial configuration. The keep on track feature facilitate the ability of navigation maintenance, but the passive way of information exploration confined auditory perception to some extent. Keyboards commands has positive effect on the familiarity of the system interaction, but the arrow keys have an implicit misleading on orientation judgment. Most participants were able to fulfill the distance estimation by listen to the earcons, but this task occupied too much concentration especially when their main task is navigation to destination. Audio information can only be represented hierarchically, thus the audio-only representation lack the instance reference mechanism. This is the main reason of the deviation and miscalculation.

The discoveries and the results of this study will not limited to the audio map systems since visual modality may not be suitable under visually inaccessible interfaces or situations, such as subsize wearable devices or in high visual occupation tasks. We hope the results and the discussion would shed light on the audio-based information cross-modal representation in the future.

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INTERACTION DEVICES (II)

InclineType – An Accelerometer-based Typing Approach for Smartwatches

Timo Götzelmann
Nuremberg Institute of Technology
Keßlerplatz 12
90489 Nuremberg, Germany
+49 (0)911 5880 1616
Timo.Goetzelmann@ohm-university.eu

Pere-Pau Vázquez
Technical University of Catalonia
Jordi Girona, 1-3
E-08034, Barcelona, Spain
+34 93 413 77 90
Pere.pau@cs.upc.edu

ABSTRACT
Small mobile devices such as smartwatches are a rapidly growing market. However, they share the issue of limited input and output space which could impede the success of these devices in future. Hence, suitable alternatives to the concepts and metaphors known from smartphones have to be found. In this paper we present *InclineType* a tilt-based keyboard input that uses a 3-axis accelerometer for smartwatches. The user may directly select letters by moving his/her wrist and enters them by tapping on the touchscreen. Thanks to the distribution of the letters on the edges of the screen, the keyboard dedicates a low amount of space in the smartwatch. In order to optimize the user input our concept proposes multiple techniques to stabilize the user interaction. Finally, a user study shows that users get familiar with this technique with almost no previous training, reaching speeds of about 6 wpm in average.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interfaces – *Input devices and strategies (e.g., mouse, touchscreen); Graphical user interfaces.*

General Terms
Interaction Techniques, Fat-finger-problem, Input Concepts, Keyboards, Mobile Devices, Acceleration Sensor.

Keywords
Small Devices, Smartwatch, Input Techniques, Text Entry, Fitts' Law, Wrist, Angle, Inclination.

1. INTRODUCTION
Smartwatches and other related wearables are becoming more popular. The launch of Apple Watch is expected to be the element that helps these devices to become mainstream. Many of those devices have a minimalistic UI and rely on speech for more complex input. Unfortunately, dictation is inherently a non-private task, and both sensitive information and public spaces are usually not suitable for speech input. Thus, typing in wearables is a requirement for many tasks.

The fat finger problem (e.g., [10]) is relevant to smartphones and even more prominent for smaller devices such as smartwatches. Since text input is required even for simple tasks such as answering a message, however, the common input technique present in Android Wear-based watches or Apple Watch (voice dictation) cannot be used in a broad range of situations, e.g., due to privacy. To overcome this limitation, some smart input techniques have been proposed. In this paper we focus on smartwatches, and present a method for input that makes use of a 3-axis accelerometer sensor. Our technique lets the user type by selecting a key using wrist movements, and single taps. We have performed an initial user study to determine the feasibility and the performance novice users may achieve with such approach.

2. RELATED WORK
Typing in devices without hardware keyboards such as the classical buttons of conventional Blackberry devices may lead to low typing performances. This issue can be partially alleviated using high profile predictive and correction techniques (e.g., Minuum, Swype, Fleksy…). However, even the excellent results of these techniques, they are still not perfect and may erroneously *correct* properly spelled words such as road names, main names etc. Moreover, some of them rely on the use of the relative large sizes of the mobile devices. For smartwatches, the typing is an even more difficult task.

For small devices such as watches, the techniques tailored to improve input follow two tendencies: adding hardware that makes the interaction richer, or make smarter keyboards. Our method falls in the second category. Small devices can be enhanced for input by adding sensitive back covers [1]. However

Figure 1: Typing by inclination of smartwatch.

these back-of-device interactions would require to take the smartwatch off. Other proposals include adding joystick sensors for panning and tilt detection [13]. However, it is unlike that all vendors will include these by default in mainstream consumer devices, which are our target devices.

Tilting ([7]) has previously been introduced to input detection both as a full typing solution with a WiiMote [5]. But this solution relies on the use of an external screen. It has also been used to disambiguate buttons in old feature phones [12], where the users had to tilt the device while pressing a button. It has also been used in conjunction with specialized hardware [8]. Our approach is similar in spirit to this one, but using a consumer device instead of customized hardware for the key recognition.

Finally, pure soft solutions create advanced keyboards. Similar to Minuum, Dunlop et al. [4] divide the screen in regions that group several keys and let the user tap on these regions. A powerful disambiguating software makes the rest to type correctly. Zoomboard is a keyboard that requires two taps for key selection. The keyboard is presented in reduced size, and the first tap on a region generates a zoom-in on that region. The second, respectively third tap effectively selects the key. Leiva et al. [6] compare the Zoomboard to other techniques such as the offset cursor and offset zoom and found that Zoomboard was a solid proposal for small screens, with speeds of 6 wpm in screens of 18mm. Another alternative to Zoomboard is Swipeboard [2]. This last approach uses swipes instead of taps. Initially, the screen is divided in regions with three to four keys, and a swipe activates one of the regions. A second swipe selects the key among the remaining ones. The main advantage is that it does not require precision because it is target agnostic, and they improve slightly over Zoomboard in wpm.

In contrast, our approach allows to select all letters of the alphabet solely by changing the angle of the user's wrist and a single tap on the screen. There is no need for extra hardware or multiple steps to enter a letter. Additionally, it works reliably without the use of automatic spell checking. Hence, uncommon strings can be entered easily.

3. OUR APPROACH

In our approach we rely on sensors for measuring the devices' inclination which are already built in several consumer smartwatches. One of our design goals was to facilitate the intuitive feeling of gravity to select an alphabetic letter. Another goal we addressed was to allow direct selection of letters with only one interaction step.

In our approach the alphabets letters are arranged clockwise manner along the screen borders (see Figure 1). Depending on the inclination of the smartwatch caused by raising and lowering the elbow relatively to the wrist (x-axis) as well as the rotation of the wrist along the forearms axis (y-axis), a specific letter can be selected. The currently selected key is presented in a highlighted fashion in order to support the user. If neither in x-axis nor in y-axis a significant inclination is detected, the space character is chosen. In this case, no letter is highlighted. Beside the alphabet characters, the period is presented and a hat character which allows to switch to capitalized characters, figures, and special characters. By tapping on an arbitrary point of the smartphone's touchscreen, the user enters the selected letter. On the contrary, long tap induces a backspace to delete accidentally typed errors.

Turning the wrist around a given point completely without inclination to select individual letters may have multiple disadvantages. First, the legibility of the screens contents considerably decreases when the user's visual axis diverts too much from the screens orthogonal. Secondly, forcing the users to hold the smartwatch constantly in an inconvenient position may be tedious. Hence, we implemented a null calibration feature to let the user decide (i) which is the preferred null position, and (ii) how sensitively the rotation around the x- and the y-axis affects the selection of letters.

In our first test runs during the design stage we discovered that minor changes in the smartwatches inclination often resulted in frequent unattended changes in the selection of two neighboring letters. Since this may severely impede the selection of the desired letters, our design includes the implementation of a hysteresis for the selection of letters which allows a smoother interaction.

Another point we discovered in the design stage of our approach was that there was often a difference between the desired letter and the letter which was actually entered by the users. This discrepancy was caused by the inherent design of our interaction, i.e., selection by inclination and tap for entering the letter which often induced slight changes in the inclination before the tap was detected. A simple but effective technique eliminated this issue: as a jitter prevention we recorded the interaction for selecting letters in a circular buffer for the timespan on 100ms. When a tap on the touchscreen was registered, the letter entered was the one that had been selected this timespan ago. Thus, more reliable inputs were possible even when the user was jittering during the touch input.

Alternative arrangements of letters

Letters are selected depending on the angle computed from the

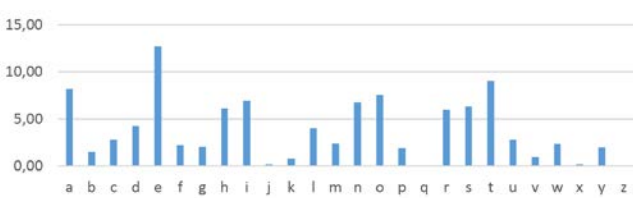

Figure 2: Letter frequencies in English sentences according to [2].

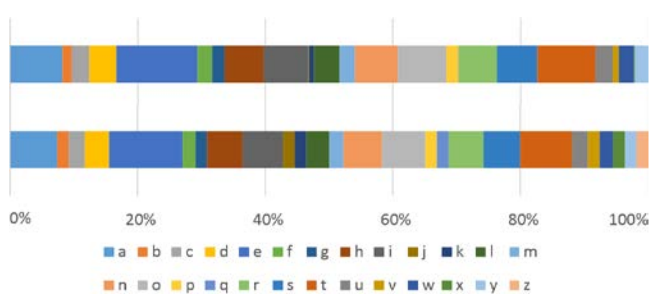

Figure 3: Distribution of letter frequencies and reserved space in respect of Fitts' law. Parts of bar representing according to actual letter frequencies (upper bar), and adapted version (lower bar) which maintains a minimum size for letters of low frequency.

inclination of the x- and y-axis. Hence, in the first version introduced so far, we assume that the index of difficulty (according to Fitts' law) to select an arbitrary letter is equal. Beside the conventional approach to distribute the alphabets letters uniformly at the corners of the smartwatches display, we also implemented a version which is optimized regarding the Fitts' law [4]. This principle assumes that the difficulty to hit a target mainly relies on the target's distance and size. It has already been considered for a study on tilt-based interaction by MacKenzie et al. [7] based on tablet computers. They used a virtual ball as input metaphor and provided 12 target regions (virtual holes). The users had to steer the ball towards these holes in a defined sequence. Whilst varying the size of the targets, they measured the time the users needed. They pointed out that Fitts' law can be applied to tilt-based interaction.

This motivated us to consequently adapt this principle to our approach. Since the inclination of the smartwatch always selects one specific letter the distance measure can be neglected. However, based on the fact that letter frequencies [11] are not equally distributed (see Figure 2) we adapt the targets' sizes (letters) according to their frequency. Directly adapting the letter frequencies to the size of selection revealed that it is nearly impossible to select rare letters such as j, q, x, z (see Figure 3 upper bar). Hence, we preserved a minimum size for these letters which proportionately decreased the influence of frequent letters (see Figure 3 lower bar). The actual arrangements of letters for both alternatives can be seen in Figure 4.

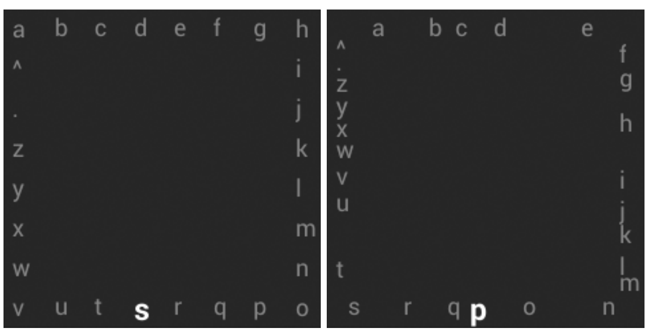

Figure 4: Normal target size for letters (left) and adjusted target sizes (right) depending on letter frequencies.

4. RESULTS

As proof of concept our approach has been implemented on a fully functional Android 4.2.2 smartwatch (Umeox KingKong Pro) with an integrated Bosch BMA050 3-axis accelerometer. Its 1.6 inch TFT screen has a resolution of 240x240 pixels.

We implemented an experimental application including the features for null calibration, hysteresis and jitter prevention. The smartwatch app allowed to switch between both alternatives of letter arrangements. We extended the experimental app by a logging feature which recorded the start and end of individual tests as well as each keystroke. Using the experimental application we tested the feasibility in a preliminary user study. Our user study was carried out with 11 test participants (3 females), with ages ranged between 21 to 37 (avg. 27.6±4.8) years which obtained a short explanation about smartwatches and both the input concepts using the uniform distribution of letters (standard version) as well as the distribution depending on letter frequencies (optimized version). Subsequently, the participants had the opportunity to test the input concepts for a short period (≤3 minutes). Additionally, they were free to decide whether they wanted to use an aclinic null position or they wanted to calibrate the null position to a convenient inclination of their wrist.

Both variants (standard and optimized version) were tested with the participants. The users had to type in a short sentence whereas the timings of the user input were logged. In order to limit learning effects, we alternated the order of the first version to be tested, i.e., if the standard or optimized version was tested in the first or the subsequent turn. We analyzed the automatically recorded data by Student's paired-sample *t*-test to evaluate our experiment.

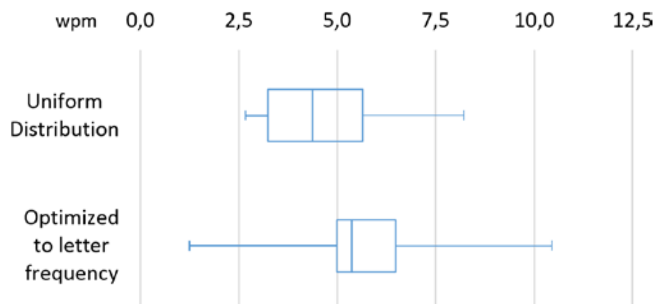

Figure 5: Performance in words per minute for both the standard version with uniform distribution of letters (top) and the optimized version (bottom).

We tested our null hypothesis H_0: *The optimized version (according to Fitts) of our implementation is not performing better (in terms of words per minute) than the standard version (uniform distribution of letters).* The arithmetic mean as well as the median of the optimized version (M=5.9, SD=2.43) showed a better performance (see Figure 5) than the standard version (M=4.7, SD=2.18). In average the optimized version allowed ~25% faster typing than the standard version. This difference in the performance of both versions of our user study was significant: $t_{10}=-2.105$, $p=.030$. Hence, H_0 can be rejected for this preliminary user study. Most of the users preferred the optimized version and reported the subjective feeling that this version allows a more convenient typing. Furthermore, the participants mentioned that a blinking cursor would have been advantageous, especially when space characters have to be entered. Which was in fact a shortcoming of our user test design – and could be easily implemented for future tests. Although they liked the possibility to calibrate the null position to arbitrary wrist inclinations most of them preferred the aclinic setting for the test. A possible explanation to this fact could be that they are used to recognize aclinic surfaces (e.g., water surface in a glass of water). In future studies a visual indicator for the null position should be included.

5. DISCUSSION

In this paper we introduced a novel input concept for typing by inclination of smartwatches without the need to press one or multiple hardware buttons concurrently. Our approach proposes multiple techniques for the stabilization of the user interaction. Additionally, we addressed the fact that letter frequencies are not distributed uniformly and adapted this to our concept according to the Fitts' law. Our technique is not dependent on dictionaries, i.e., arbitrary character strings can be entered at the same speed than well-known words. Another advantage of our concept is that this method occupies less screen space than the conventional input and the remaining screen space may stay squared (see Figure 6). Compared to voice input there are no privacy issues. Finally, the feasibility of our concept has been verified by an experimental application as well as a preliminary user study.

In this paper we only addressed the English language. As there also exist studies about letter frequencies of other languages (e.g., [9]), our concept could be transferred to them as well, as long as a minimum character size can be maintained. The support of languages with significantly more than 27 letters, e.g., the Chinese language would need to take additional effort (e.g., multiple interactions), but this applies also to other input methods.

Our approach has rather high requirements to motoric skills of the users. Hence, it is likely that persons with motoric impediments will not be able use this technique. The same issue may exist in very unsteady or turbulent environments. However, the authors assume that other approaches will have similar issues.

Some techniques of the related work need to train the users to an excessive extent. A design goal of our approach was to make it explicitly intuitive. Our preliminary user study aimed at testing untrained users and we obtained the unanimous feedback that this technique is very intuitive. However, testing completely untrained users resulted in mediocre performance for typing speed, compared to some of the approaches of the related work which partially trained their test users intensively. Since our approach allows interaction with minimized interaction steps and the letters are always presented in a consistent manner our technique leverages people's spatial memory. Thus, it is likely that well-trained users will be able to perform much better in typing speed and error rate.

Similar to other approaches this technique could be extended by automatic spell checking. Dependent on the concrete application this could significantly improve the typing performance, but as stated before, this may impede the input of arbitrary character strings.

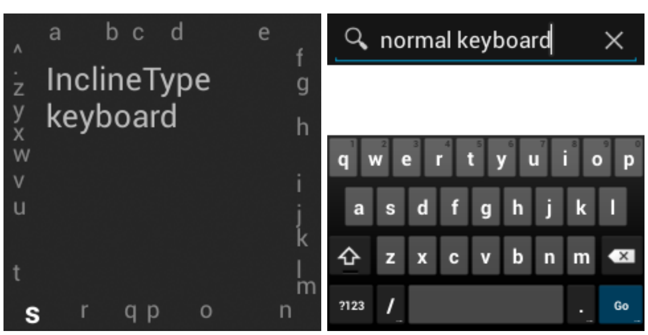

Figure 6: Relatively low space consumption and rectangular input by InclineType (left). Standard keyboard input consuming large screen area (right).

6. FUTURE WORK

We plan to carry out a comprehensive user study giving the tests users the chance to practice our alternative concept for text input for several hours. As it has been shown in other studies, we expect a significant increase in typing speed by experienced users. This user study will include an in-depth comparison of both alternatives of character arrangements to verify if our implementation of Fitts' law shows an optimization in users input performance.

Watches may be worn either on the wrist of the dominant hand or the other hand. For longer texts, some users could prefer to hold the smartwatch in both hands. Since these different application scenarios could significantly affect the input performance, our planned comprehensive user study will compare these variations.

Beside existing smartwatches, currently many other devices appear on the market which could be used in conjunction with future smartwatches. One of these devices is called *Myo* which is a gesture control armband which uses electromyographic sensors to detect arm and hand gestures. Although it is already possible to connect such a device by standard Bluetooth, in future smartwatches these muscle sensors could be integrated into the smartwatches armband. Our future work focusses this combination of hardware in order to optimize our input concept for replacing the touch interaction by muscle actuation in order to further improve the input performance of our concept.

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Basketball Activity Recognition using Wearable Inertial Measurement Units

Le Nguyen Ngu Nguyen
Universitat Politècnica de Catalunya – BarcelonaTech
Rambla de l'Exposició 59-69, Vilanova i la Geltrú, Spain
Queen Mary University of London
Mile End Road, E1 4NS, London, UK
le.nguyen.ngu.nguyen@upc.edu

Daniel Rodríguez-Martín
Technical Research Centre for Dependency Care and Autonomous Living
Universitat Politècnica de Catalunya – BarcelonaTech
Rambla de l'Exposició 59-69, Vilanova i la Geltrú, Spain
daniel.rodriguez-martin@upc.edu

Andreu Català
Technical Research Centre for Dependency Care and Autonomous Living
Universitat Politècnica de Catalunya – BarcelonaTech
Rambla de l'Exposició 59-69, Vilanova i la Geltrú, Spain
andreu.catala@upc.edu

Carlos Pérez-López
Technical Research Centre for Dependency Care and Autonomous Living
Universitat Politècnica de Catalunya – BarcelonaTech
Rambla de l'Exposició 59-69, Vilanova i la Geltrú, Spain
carlos.perez-lopez@upc.edu

Albert Samà
Technical Research Centre for Dependency Care and Autonomous Living
Universitat Politècnica de Catalunya – BarcelonaTech
Rambla de l'Exposició 59-69, Vilanova i la Geltrú, Spain
albert.sama@upc.edu

Andrea Cavallaro
Queen Mary University of London
Mile End Road, E1 4NS, London, UK
a.cavallaro@qmul.ac.uk

ABSTRACT
The analysis and evaluation of human movement is a growing research area within the field of sports monitoring. This analysis can help support the enhancement of an athlete's performance, the prediction of injuries or the optimization of training programs. Although camera-based techniques are often used to evaluate human movements, not all movements of interest can be analyzed or distinguished effectively with computer vision only. Wearable inertial systems are a promising technology to address this limitation. This paper presents a new wearable sensing system to record human movements for sports monitoring. A new paradigm is presented with the purpose of monitoring basketball players with multiple inertial measurement units. A data collection plan has been designed and implemented, and experimental results show the potential of the system in basketball activity recognition.

Categories and Subject Descriptors
H.1.2 [**User/Machine Systems**]: User/Machine Systems – *Human factors, Human information processing.*

General Terms
Algorithms, Design, Experimentation, Human Factors.

Keywords
Wearable computing, Activity recognition, Sports.

1. INTRODUCTION
Human activity recognition (HAR) has facilitated novel applications in healthcare, life monitoring, entertainment, and sports [1]. The main goal of HAR is to identify the activities of one person or a group of people from observations acquired by sensing devices such as wearable sensors and ambient cameras. While vision-based approaches suffers from occlusion, cluttered scenes and changes in illumination, advances in sensor technology allow us to deploy wearable devices for HAR and to enable continuous long-term activity monitoring beyond arranged areas. Moreover, the sensors embedded in these devices, such as accelerometers and gyroscopes, collect signals directly from body movements, in lieu of inferring from visual data. Multiple types of wearable devices are utilized to record sensing information, such as: accelerometers and gyroscopes for movements, GPS receivers for positions in outdoor areas, electromyography armbands for muscle activities, etc. Relying on required data, one sensor or a combination of sensors can be mounted on different parts of the human body.

An important application domain for human activity analysis is in sports activity analysis. Understanding athletic movements helps coaches and managers evaluate their players' performance, predict injuries, optimize training programs and support strategic decision making. To do that, a sport activity analysis system can identify actions through appropriate motion features, context and expert knowledge. Challenges in sport activity analysis include both generic and specific ones. Generic challenges [2] are:

- *Intra-class variability*: The same activity may be performed in different ways, depending on internal status of the player. For example, a basketball player moves slowly at the end of the match due to fatigue. Furthermore, each individual player has his/her own styles of movements.
- *Inter-class similarity*: Some activities are semantically different but produce similar characteristics in inertial sensing data. For instance, in basketball, acceleration signals of running with or without the ball may be almost identical.
- *The NULL class problem*: Not all inertial sensing data is necessary for sport activity analysis. The existence of irrelevant activities (the so-called NULL class) may confuse an activity classification algorithm.

In addition to the aforementioned challenges, sport activity analysis possesses its own challenges:

- *Definition of relevant activities*: A set of activities of interest should be proposed by sports experts. Moreover, human activities contain spatial and temporal constraints, which should be considered when modelling.
- *Class imbalance*: The same activity might have different durations and different activities generally have a different frequency. For instance, a soccer striker spends most of the time moving (e.g. walking and running) while he/she might shoot only few times in a match.
- *Data annotation*: Training a supervised HAR system requires a significant amount of data with annotation. The difficulty of annotation increases in case of team sports, where multiple players interact.
- *Sensing data characteristics*: Movements in a competitive match are generally much faster than those in daily living activities [13] [14]. Moreover, variations in acceleration in sport are larger than in monitoring systems for daily living activities. Therefore, parameters should be modified so that they adapt to the characteristics for each sports type.

In this paper, we introduce a new sensor design using accelerometers for recording and recognizing athletic movements in basketball. We are interested in movements such as jumps, lateral displacements, forward/backward moves and body rotations (pivot). We also consider sport-dependent actions such as for example dribbling and shooting. The new sensor is attached on a user's back and lower limbs establishing a multi-sensor system. Activities such as *walking*, *jogging*, *running*, *sprinting*, *jumping*, *jumpshot*, *layupshot*, and *pivot* are recognized using a Support-Vector-Machine-based classifier.

The rest of this paper is organized as follows. Section 249 reviews related work using wearable sensors in sport. The proposed sensor system is introduced in Section 3. Then, the data collection session and activity recognition method are described in Section 4 and Section 5, respectively. The experimental results and analysis are presented in Section 6. Finally, Section 7 concludes the paper.

2. RELATED WORK

Multiple types of wearable sensors have been used, independently or combined, for activity monitoring and performance evaluation in sport, including accelerometers, gyroscopes, pressure sensors, heart-rate monitors. The generic system pipeline includes feature extraction, classification and qualitative evaluation [3].

Several works analyze specific movements for different sports. For example, Kelly *et al.* [4] studied techniques to automatically identify tackles and collisions in rugby. Their sensor consists of a GPS receiver and an accelerometer placed between the shoulder blades overlying the upper thoracic spine. Support vector machine (SVM) and hidden conditional random field (HCRF) were applied to detect collision events. The authors used AdaBoost to combine the classification results produced by these two models. Morris *et al.* [5] used inertial sensors to discriminate non-exercise and exercise movements (13 exercise actions), and then to recognize and count the repetition of activities. Bächlin *et al.* [6] presented a wearable assistant for swimmers based on acceleration sensors and real-time feedback devices. The system extracts swimming parameters to evaluate body measurement (angle, rotation, and balance), performance parameters, and feedback effectiveness. Harle *et al.* [7] built an on-body sensing system to monitor the performance in sprinting training sessions. Force sensitive resistors were embedded in athletes' shoes to collect pressure data with millisecond-level accuracy in ground-contact time estimation.

With the purpose of replicating the role of expert evaluations in climbing sport, Ladha *et al.* [8] developed a wearable acceleration sensing platform to record climber's movements and assessment parameters including power, control, stability and speed. Their system was extensively experimented with 53 climbers under competition scenarios and could produce scores that strongly correlated with official expert results. Furthermore, some works provide a feedback to the athlete with the aim of giving a stimulus and ameliorate performance. Bächlin *et al.* [6] used LEDs to provide real-time feedback to swimmers; whereas the system of Velloso *et al.* [9] has a feedback mechanism that helps weightlifters to manipulate their movements. In baseball, Ghasemzadeh and Jafari [10] collected physiological data from a body sensor network to provide corrective feedback for the players. They interpreted complex movements to generate motion transcripts which were used for measuring coordination among limb segments and joints.

3. SENSOR DESIGN FOR BASKETBALL

A new inertial measurement unit, which is called BSK board, has been developed and is presented in this paper. The main task of this device is to record data from specific movements in basketball. Its size is 62mm x 35mm x 24mm and weight is 38g (and 62g with batteries). The BSK board is an inertial measurement unit (IMU) that captures inertial data that requires a long range of acceleration as well as experiments requiring barometric information. The BSK board is a development tool, which includes inertial sensors, a storage unit and a small interface in order to send and receive commands. The BSK board has four main parts, the power system, the microcontroller (µC) and its interface, the analog system and the communications module (Figure 1).

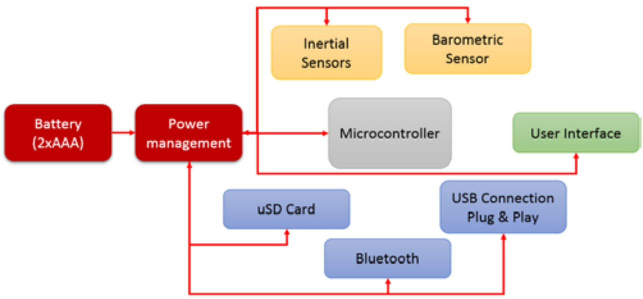

Figure 1. Block diagram with the structure of the newly designed BSK board proposed in this paper

The system is powered with two AAA standard batteries. The average consumption of the system (7 tests of five-minutes each) is 56.73±0.21mA, having an autonomy of more than 20 hours in a 1200mAh battery at 3 Volts. With a standard alkaline battery (750mAh), autonomy could be about 13.2 hours. Conditions of test have been analyzed with all the sensors on, a sampling rate of 200Hz and storing the inertial captured data within the µSD Card.

The power distribution is comprised with four regulators: *digital* regulator, *analog* regulator, *comm* regulator, and *backup* regulator. The *digital* regulator provides power to the digital system (microcontroller, inertial sensors I/O, µSD Card, and USB interface). The *analog* regulator supplies power to the inertial sensors, being separated and isolated from the rest of the circuit by means of an own ground plane. The *comm* regulator supplies voltage to the Bluetooth module. This device can consume more than 40mA alone, for this reason it should be isolated from the rest of the circuit in order to avoid peaks of currents that affects the voltage stability at the analog or digital system. Finally, the *backup* regulator keeps a regulated voltage to the µC's backup system and the real-time clock system.

3.1 BSK Microcontroller

The microcontroller that manages the internal processes from the BSK board is a STM32F415 from STMicroelectronics. This microcontroller is a Cortex™-M4 CPU with floating point unit, which lets computing advanced online algorithms. The maximum speed of this device is 168 MHz and contains 1MB flash memory and 192KB of RAM (compared to the 128KB and 16KB, respectively of the 9x2's µC). The BSK board contains two external clocks, one to run the internal oscillator circuit and a Real-Time Clock to count seconds with high accuracy. One of the main features of this µC is the Direct Memory Access (DMA), which is able to exchange data among the different peripherals and between the peripherals and the µC. Finally, the STM32F4 includes up to 15 communication interfaces among which UART, SPI, I^2C, SDIO and USB 2.0 full-speed On-The-Go controller are of main importance. The BSK µC is a 64-pin device with debug mode and is able to enter in different low-power modes in order to increase the autonomy of the BSK board. Figure 2 shows the expected consumption at different work modes.

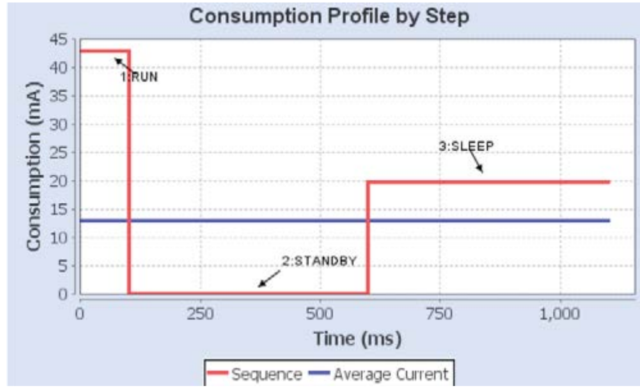

Figure 2. µC average consumption in different work modes

3.2 Embedded Sensors

The BSK board contains different microelectromechanical systems (MEMS) sensors, one the one hand it includes the LSM9DS0, a System in Package (SiP) which contains an Accelerometer + Magnetometer system and a Gyroscope system (Figure 3). On the other hand the BSK board includes a pressure sensor as well in order to detect fallings or movements with a change of altitude (mainly postural transitions).

The LSM9DS0 MEMS provide different interruptions in order to first notify the µC when data is ready to be read with a configured output data rate and, second, provide interrupts when a configured threshold is surpassed with the aim of awaken the µC just in case enough movement is detected. This mode of work allows saving much power analyzing data of weak importance such a static movements (sit, stand or lying).

The MEMS pressure sensor is a barometric sensor. The main feature is the RMS noise, which is 0.02mbar. It is considered that the traveled distance of the trunk in a sit to stand (SiSt) or stand to sit (StSi) posture transitions is 0.53m, which is considered to be a difference of 6.1Pa or 0.061mbar [11]. This means that according to LPS331AP's RMS noise minimum value, a posture transition (SiSt or StSi) could be detected. Furthermore, fallings, going up/down stairs or elevators could be also detected. For this reason, the MEMS pressure sensor is an interesting tool to be added at any human activity recognition system.

The LPS331AP offers an ODR up to 25Hz, although the minimum RMS noise can only be achieved with 12.5Hz. According to Zhou et al. this is a low frequency to catch all human movements [12], however, and having into account that posture transitions [13] and walking bands are below this frequency [14], 12.5Hz is enough to identify all these activities.

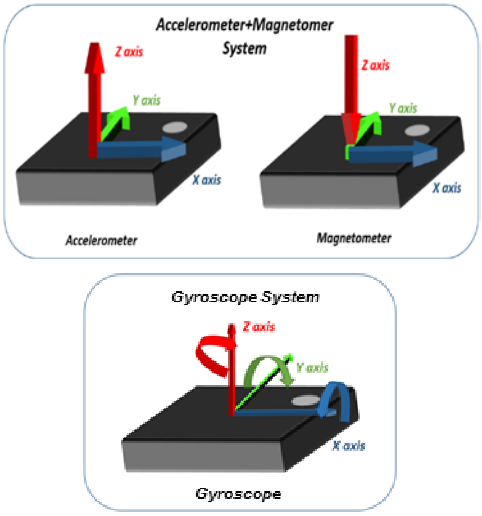

Figure 3. BSK board inertial MEMS (LSM9DS0)

3.3 Communication Component

The BSK board has been designed to allow downloading the data through USB connection (i.e. without removing any pieces of the device). Data is stored in a µSD card by means of the SDIO interface and with FAT32 system file format allowing storing much more data than the 2GB allowed by FAT16. The device contains a specific hinge socket where the µSD card is inserted. This socket does not allow the µSD card to move in aggressive execution tasks such as sprinting or jumping, avoiding then communication errors.

The Full-Speed On-the-Go USB system has been incorporated to the BSK board including a USB buffer device, which filters the noise and allows to isolate electromagnetically the BSK USB circuitry from PC circuitry in order to ensure a robust communication between the two devices.

4. DATA COLLECTION

We employed the BSK board with sampling frequency 200Hz to collect data from accelerometer, gyroscope, magnetometer, temperature and barometric sensor. The five sensors were attached to body as shown in Figure 5. The data collection plan is required to contain the activities-of-interest in a reasonable order so that it is feasible for the subjects to perform the activities (i.e. not feeling exhausted). Our data collection plan is designed with the consultation of sport experts and amateur basketball players.

The test protocol consists of nine activities executed continuously, including a *jump* at the beginning and at the end of each activity and a *standing* between the different series. We have performed the following activities: *walking*, *running*, *jogging*, *pivot*, *shooting* from different locations, *layupshot*, *sprinting*. We also use one more label, *undefined*, to annotate irrelevant movements. The dataset activities are repeated to obtain variability in the data. The test is video-recorded with two cameras to facilitate the annotation of the data from the wearable sensors (Figure 4).

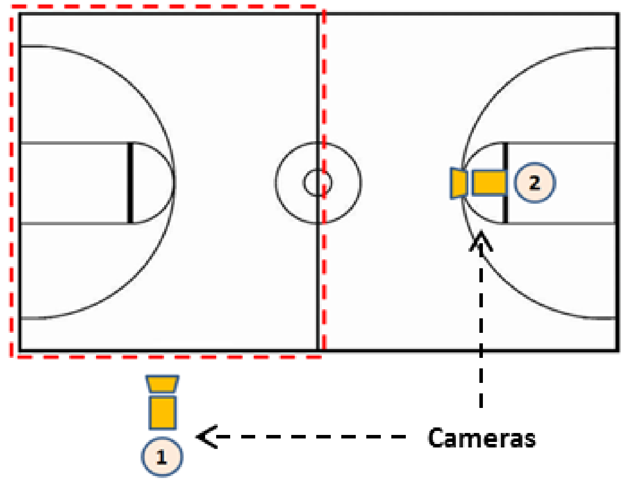

Figure 4. Layout of the cameras on the basketball court

At the beginning and at the end of each user data collection, a visual event is performed in order to synchronize cameras and inertial systems. Then, after data collection data integrity is checked, inertial signal is synchronized with video signal and, then, labeled according to recorded video. We propose two options:

- *Sensor falling*: When the device falls, the accelerometer generates a peak and change of axes. However, this step must be performed before attaching the sensors to human body. Thus, there is a significant amount of unusable signals in the recorded data.
- *Jumping action*: Similarly, when the subject jumps, a sudden change appears in acceleration signals. The annotator can detect that pattern and match it with the corresponding jump in videos. One limitation is that we are considered jumping as a class in our activity recognition method. Hence, the annotator should be careful to select the right jump (usually at the beginning of each data collection session)

5. ACTIVITY RECOGNITION

We aim to classify basic actions in basketball listed in the previous section. Although the five sensors have been used to capture data, only data recorded by the two accelerometers on player’s feet has been used for machine learning purposes. Our activity recognition method has five steps: (i) *preprocessing*, (ii) *segmentation*, (iii) *feature extraction*, (iv) *standing – moving separation*, and (v) *moving activity recognition* (Figure 6).

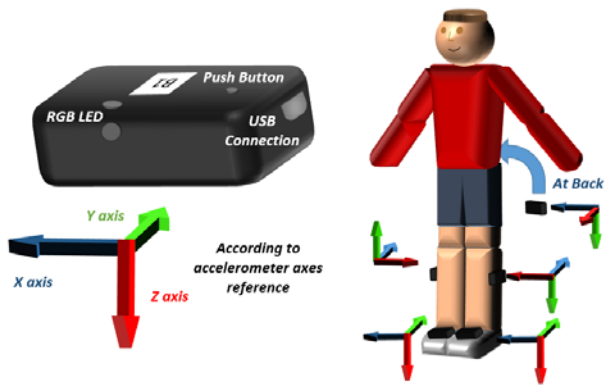

Figure 5. BSK board model and sensors set up

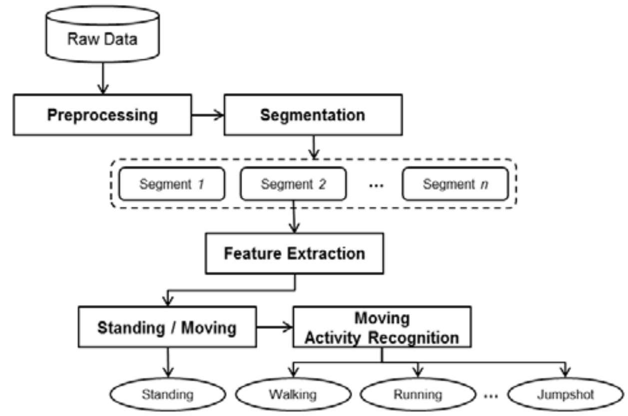

Figure 6. Our proposed activity recognition algorithm

First, preprocessing is performed on inertial signals, including downsampling and filtering. We downsample the acceleration signals from 200Hz to 40Hz to balance recognition accuracy and computational cost [12]. Afterwards, aberrant errors due to communication errors have been eliminated and signals are then passed through a low-pass filter with 15Hz as the cut-off frequency and divided into equal segments with 50% overlap. Features are extracted from each segment

In each segment of inertial data, we extract features from the three axes for each accelerometer. The root mean square value for each accelerometer is calculated. Thus, in each sample of each accelerometer, four values (three raw values and one amplitude value) are obtained. From each of them, time and frequency domain features are extracted, including: *range*, *sum*, *mean*, *standard variation*, *mean crossing rate*, *skewness*, *kurtosis*, *frequency bands*, *energy*, and *number of peaks above a threshold*. Moreover, correlation between three axes of each sensor and each pair of axes on two sensors are also considered.

In the third step, we use a simple feature to separate standing from moving activities based on the range values of acceleration on the Z-axis. In each segment, the difference between maximum and minimum values of acceleration, which is called *range*, is calculated. If the value is higher than an optimized threshold *k*, we classify the segment as moving; otherwise, it is a standing segment. To estimate this threshold, we trained a linear SVM classifier. Based on range values, this classifier can discriminate two classes: *standing* and *moving*. Then, we visualize the classification result and select the value that achieves the highest accuracy. Thus, it can be modified for different datasets.

The remaining non-standing segments are used to recognize moving activities. Each segment of inertial signals becomes a feature vector or sample of the classifier. We feed them to the classification algorithm for training and testing in two cases, which are called *same-person* and *cross-person*. In the former, we randomly select samples for training and testing from the same player. In the later, we train the recognition algorithm on a group of players and test it on the other one. In both cases, training and testing datasets are different. However, the latter is more challenging because players with distinct physical characteristics generate different inertial data, even when they perform the same activities.

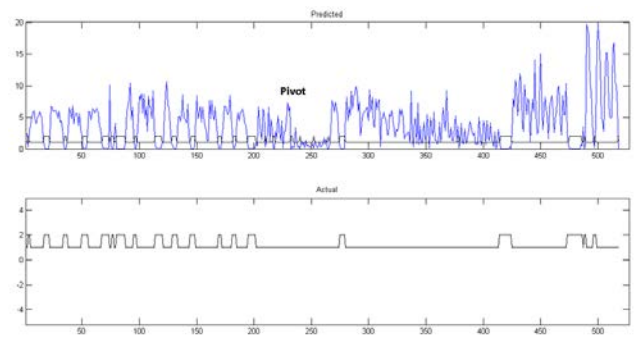

Figure 7. Actual and predicted labels of standing and moving. The blue plot is the range value of Z-axis acceleration (best view in color).

6. EXPERIMENTAL RESULTS

We set the window length to 128 raw samples and the overlapping percentage to 50%. The duration of each segment is 3.2 seconds. Then, we split the samples into training and testing datasets. Our dataset contains inertial signals of three subjects. Thus, in the *cross-person* setting, we use data from two players for training and one for testing. The final result is the average measures from all splitting configurations of subjects. This can be considered as *leave-one-subject-out* evaluation strategy. We use LibSVM library [15] to implement the multi-class SVM classifier.

In Figure 7, the actual and predicted labels of standing and moving of one player are depicted. Most of confusion appears when the player performs the pivot action. In this action, one leg of the player is kept stable and the other can moves. Thus, it generates similar signals to standing in one foot. The threshold for separating standing and moving is $k = 4$ and the accuracy is 92%.

Then, the moving activities are divided into two sets, namely *step* and *jump* activities. The step-related activities include *walking*, *jogging*, *running*, and *sprinting* while the jump-related activities contain *jumping*, *layupshot*, and *jumpshot*. Figure 8 shows the confusion matrices in both evaluation cases. It is possible to clearly discriminate step-related activities on the same player. Nevertheless, due to distinction in physical characteristics, two players perform the same activities in different ways. Therefore, in the *cross-person* evaluation setting, confusion appears in both step-related jump-related activities and the precision decreases. In the case of jump-related activities, all of them include a jumping action. Consequently, they produce similar inertial data.

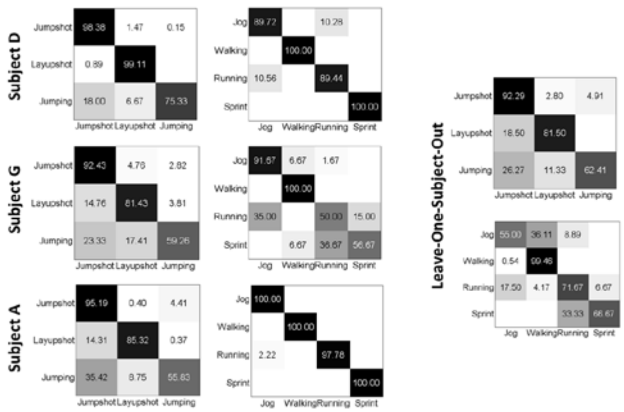

Figure 8. Confusion matrices of activity recognition in two sets (step-related and jump-related)

	Jog	Walk	Jumpshot	Layupshot	Pivot	Jumping	Running	Sprint
Jog	51.98	30.39	3.92	11.86			1.85	
Walk	1.25	80.98	15.65	1.15	0.64	0.32		
Jumpshot		10.87	78.65	2.25	2.86	5.38		
Layupshot	3.10	17.23	9.89	65.39	1.28		3.10	
Pivot			6.94		90.22	2.84		
Jumping		5.40	15.28	7.47	2.78	66.60	2.47	
Running	11.11	7.04		27.96			44.63	9.26
Sprint					11.43	4.17	25.12	59.29

Figure 9. Confusion matrix produced by our recognition algorithm on basic basketball activities

Figure 9 illustrates the performance of our activity recognition algorithm on all activities (*walking*, *jogging*, *running*, *sprinting*, *jumping*, *jumpshot*, *layupshot* and *pivot*) in *cross-person* setting. Similar confusion is revealed when we train and test the classification model on different players. Furthermore, when performing *layupshot*, the player dribbles then throws the ball to the basket. *Dribbling* (i.e. running with ball), generates acceleration signals which are similar to those in *jogging* or *running*. This motivates to integrate sensors in other body parts (e.g. on the wrists) to distinguish these activities.

7. CONCLUSION

In the paper, a new sensing system to record and recognize human movements in basketball has been presented. The new inertial measurement units are capable to record human movements at sport with high accelerometer ranges. The system has been employed to collect and analyze motion data in order to recognize basic activities in basketball. The proposed method is able to identify four moving types at different intensity (*walking*, *jogging*, *running*, and *sprinting*), as well as to discriminate shooting executions. Moreover, the promising results prove the applicability of our proposed system within basketball activity monitoring. We plan to add new features from accelerometer and include the gyroscope information to enhance the performance in activity recognition. In addition to this, a new dataset with more participants and, thus, with more heterogeneity of physical characteristics will be acquired.

8. ACKNOWLEDGMENTS

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EMG-based biofeedback tool for augmenting manual fabrication and improved exchange of empirical knowledge

Guillermo Bernal
MIT Design Lab
20 Ames Street
Cambridge, MA, USA
gbernal@mit.edu

Dishaan Ahuja
Massachusetts Institute of Technology
77 Massachusetts Ave.
Cambridge, MA, USA
dishaan@mit.edu

Federico Casalegno
MIT Mobile Experience Lab
20 Ames Street
Cambridge, MA, USA
casalegno@mit.edu

ABSTRACT
It can be time-consuming and frustrating to acquire any new skill, and for one that relies on muscle memory developed through observation and repetition it may require hours of supervised training to reach even minimal proficiency. This paper explores whether real-time feedback that compares data from bio-signals and physical movements of a novice learner and an expert can shorten the learning process via a wearable device. These signals include measurements of muscle activity using electromyography (EMG) and from sensors that include accelerometers, gyroscopes, and magnetometers. The signals are in the form of sets of illuminated RGB LEDs; the learner receives instantaneous performance evaluation that enables immediate realization of an error and allows for rapid and easy adjustment of movement. Preliminary tests using the wearable device in pottery making show effectiveness at aiding students to master movements more quickly than on average. Hence, the wearable device aids the user in acquiring muscle memory.

Categories and Subject Descriptors
H.5.3 [**Interaction, Learning and Teaching**]: User Interfaces; B.4.2 [**Input/Output Devices**]

General Terms
Adaptability, Interactive and Cognitive Environments

Keywords
Haptic knowledge, craft, knowledge sharing, wearable ACM Classification Keywords H.5.2. Information Interfaces and Presentation: User interfaces and Evaluation; User Interfaces; Haptic I/O. General Terms Human Factors; Design; Measurement.

1. INTRODUCTION
This paper explores the process of motor skill acquisition, with the goal of augmenting the traditional, observation-based approach to learning motor skills with a biofeedback loop. The effectiveness of this augmentation is explored by conducting user studies where novices attempt to use both the traditional method and our augmented learning system to learn the skill of clay centering. This research is part of a wider phenomenon of innovation in the process of teaching. Some contemporary examples are MOOCs [13] and the popular video game `Guitar Hero' [10]. Our system is more similar to the latter - we provide the user with real-time feedback based on performance of certain tasks involving a test of motor skills. It is widely known that many years of experience may be required before muscle memory has advanced to the stage where one can be called an expert at a motor skill. In the book `Outliers' [7], it says that it takes roughly ten thousand hours of practice to achieve mastery in a field. The author also claims that most people quit the learning process in the first two thousand hours due to the steep nature of the learning curve at the start of the knowledge acquisition process. It is at this stage that our system is most valuable to the learner, and can reduce the time spent on acquiring new muscle memory.

Imitating an instructor is traditionally at the center of methods of learning motor skills in sports and crafts. Learners typically imitate based on visual clues about speed and timing, the positions and stances of different parts of their bodies, and various other elements involved in mastering the skill. Watching someone else, though, leaves little room for catching the subtleties of an instructor's movement in real time or remembering them later. Our system overcomes this limitation by integrating real-time feedback that shows how the learner's motion characteristics and those of the instructor correspond to each other, providing a vivid, precise, and concrete way to compare and contrast movements. This makes it possible for learners to align their movements with those of the expert instructor without having to rely completely on memory.

Many movements have subtleties that cannot be seen by a learner, only felt. Hence, our system provides a real sense to the learner, for example how much pressure the expert uses for a particular task and whether, for example, the movement requires activation of the triceps rather than the bicep. Sports scientists who have measured such activity using electromyography [22] have found quantifiable differences in the EMG activity between a novice and an expert [2]. Our system therefore augments the standard method of learning through feedback by matching EMG signals of a learner and instructor and displaying this feedback to the learner in real time.

2. CONTRIBUTIONS

This research's main contribution is a system that augments the process through which learners acquire muscle memory related to a particular motor skill. The system first measures motion data and EMG signals from an expert performing a movement, measures the same data from the learner, and then provides real-time feedback via a wearable device that can help alter incorrect movements or reassure the user when movements are correct.

As the clay centering experiment discussed in this paper shows, real-time feedback aids fast and easy aids acquisition of a motor skill by informing a learner of a mistake immediately and providing the opportunity to iterate until it is corrected. The apparatus we describe could contribute to learning a variety of skills, for instance in sports that involve specific movements such as tennis (serving), golf (swinging), and basketball (dribbling).

3. RELATED WORK

In our research, we rely on concepts of sensory motor learning that expand our perceptual framework. For example, expert video gamers develop an extraordinary ability to extract information and extend their attention over a wider-than-normal spatial frame while experiencing no apparent decrease in attentiveness [8]. Notably, this integration process can account for the learning opportunities provided by external objects such as tools, which means optimal visuo-haptic integration is possible even when tactile input comes through a hand-held tool [18].

Researchers have highlighted motor learning processes and the importance of the type of information that is being learned, rather than how it is being learned. Wolpert, Diedrichsen, and Flanagan further explain in their 'Principles of Sensorimotor Learning':

"Learning can occur at different levels of the motor hierarchy. To understand how these changes are implemented in neurons, we need theories of the processes and representations through which learning is achieved. The processes of motor learning can be distinguished by the type of information that the motor system uses as a learning signal. Although different sensory modalities, such as vision, proprioception and touch can all play an important part in motor learning, we focus here on the nature of the information, independent of modality, that is used during learning."[21]

In sports today, this theory has proven to be correct as it has proven to be beneficial to first determine which skills need to be improved upon, and secondarily determine how to best teach the players and other members of the team how to acquire said skills. EMG-based feedback learning systems have been used for basketball dribbling training, taking advantage of the differences in sharpness and timing between EMG signals from a novice and an expert. Researchers compared the differences in EMG signals between an expert and a learner and provided the learner with a visualization highlighting the differences [2].

In this particular experiment, six basketball novices were divided into two groups of three, only one of which received visual EMG feedback. Both groups were given dribbling technique instruction and then trained for 30 minutes, using a metronome to calibrate dribble period. Performance tests then determined that in the group that received EMG feedback, the forearm muscle activity was much closer to correct than in the other group, indicating that the feedback led to the acquisition of proper dribbling technique. This confirmed the researchers' hypothesis that real-time EMG-based feedback is an effective addition to the process of motor skill learning.

4. RESEARCH METHOD IN BRIEF

To develop our project, we first did some initial research on how the human body generates natural electric signals and how these signals are evaluated in the medical field. The data generates vast, unorganized amounts of data, so we next created a circuit that would enable us to collect data for later organization and analysis.

Having determined that a wearable device would be the most appropriate medium through which to collect data from body movements, we developed a prototype that fit close to the body. Our design focused on the ability to monitor specific body movements and muscle groups.

Next, having decided that the craft of ceramics would be a good domain within which to test our hypothesis, we interviewed a master ceramics craftsman to learn how certain tasks within the craft are habitually performed. We recorded measurements of muscular movement when performing these tasks from two master craftsmen, and also employed EMG to capture bio-signals. This data became the data against which we would later test and compare data generated by our experiment's learner subjects.

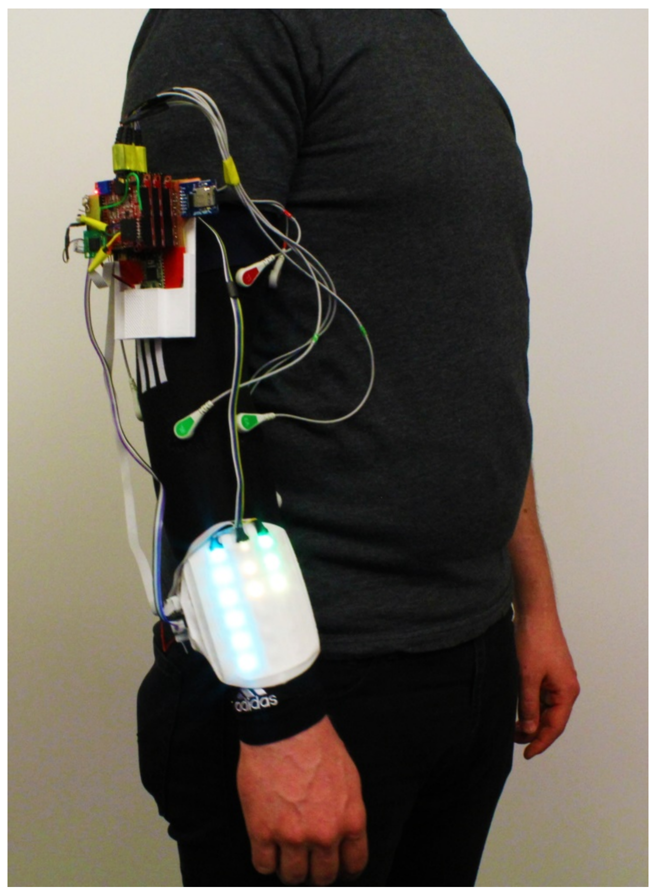

Figure 10. Sleeve prototype.

We next developed a computer program to enable the real-time comparison and analysis of the data. The program produces the appropriate visualizations that allow users to perceive differences between the two data sets, which is a prerequisite for establishing a useful feedback loop.

Needing a group of participants to test our program with the wearable device, we found ideal subjects who had very little knowledge and experience working with their hands. We had these participants work with clay for a limited time while wearing the device, performing the same tasks. We collected a mean range of data from this activity in sessions approximately 1 hour in duration, with small breaks every 25 minutes.

In our final step, we inferred a set of conclusions based on the data analysis. Our objective was to determine whether the wearable device had a significant impact on the speed with which the learners in our experiment familiarized themselves with the technique and the specific tasks of the craft.

4.1 Hardware & Sleeve Prototypes

Several researchers have explored the design space of wrist-worn devices. For example, Augmented Forearm [14] is made from a row of four interconnected displays worn on the forearm. DisplaySkin [4] wraps six displays around the wrist, acting as a visual display for mobile device information. The focus is to describe the apparatus (hardware components, integration, and real-time software implementation) as well as some of the experiments possible under the system architecture. We present experimental measurements for illustration that compare single muscle work-loops under zero and non-zero admittance loads, as well as methods for conducting experiments on controlled and uncontrolled environments. The primary goal is to provide a supervised input to the person learning a task in an attempt to prove the hypothesis that biofeedback signal representation is suitable for learning. We based our hypothesis on the work done by Debaere et al [6] who over the past few decades have shown how providing augmented visual feedback also facilitates learning bimanual coordination patterns [12], [16], [6], [15] and gives rise to complex multisensory integration mechanisms [17].

4.2 Device Components

1. Electrodes provide information to the myoelectric sensor board. It also has several electronic components that allow for adjusting the input and for filtering any incoming noise, enabling a clear signal quickly and thus eliminating the processing load on the plate board. The design of analog filters and amplifications are derived from standard EMG practice [11]. The amplified myoelectric sensor data are connected to the analog inputs of the micro-controller Cortex-M4 Teensy 3.1 [19] which samples the analog inputs at approximately 10kHz and sends out RMS values to the on-board SD card for each sensor with a window size of 32 values at a rate of 63Hz. This reduces both the amount of data to be transferred and the required processing power.

2. A compression sleeve is fitted over the arm of the participant, from shoulder to wrist of the dominant hand. The sleeve features small patches of conductive fabric placed strategically over the general areas of the bicep, wrist flexors, and forearm flexors. These patches have snap connections that allow the electrodes to snap onto the sleeve while maintaining a conductive connection.

3. At the top of the bicep near the should joint, the electrodes connect back to the EMG Band, which slides over the sleeve and tightens down with a simple flexible fabric band similar to an armband one might use to secure an MP3 player while jogging. The program is loaded in this EMG band and the computation occurs using a Teensy micro-controller.

4. The Glance-Based display at the wrist, on a strap made of 3D printed flexible plastic, allows users to visualize the data produced by their actions. Glance-Based interfaces do not demand a user's focal attention, providing visualization to the eyes quickly and only when needed [3]. An array of LEDs is concealed within the strap's three narrow slots and therefore the LEDs are visible to the subject when illuminated. (Figure 3)

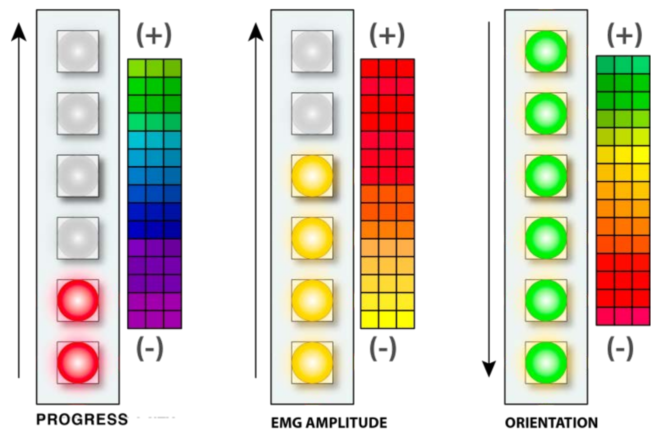

Figure 11. LEDs Color interface chart.

5. The LEDs on the visual display of the wrist serve as the interface between the apparatus and the user; the LED strips run vertically along the arm (see Figure 6 for clarification on the orientation of the LED array) and measure both the position of the forearm as well as the speed of movement when performing a given task.

LED Strip 1 – Progress: When performing the specific task, the first of the LED strips that is closest to the thumb (worn on the right hand) measures accuracy on matches for the position of the forearm, speed of movement, and the EMG data. The number of lit LEDs increases with proper movement. The LEDs change color to show progress, beginning with a purple light and proceeding to blue, yellow, and then to green to show mastery of the skill. Clearing a color bar means the user has matched or surpassed the data block set from the master recording.

LED Strip 2 – EMG Amplitude: The middle strip of LEDs measures the EMG signals the user's body produces during the task. These lights increase in quantity and change color to indicate progress, moving from yellow to orange and then to red (signifying the highest level of muscle contraction) to show improvement.

LED Strip 3 – Orientation: The final strip of LEDs at the pinky side of the display compares the current position and EMG signals of the forearm to those of the control data. This strip operates slightly differently from the other two in that the lights do not progress but instead remain green when the participant's arm position is considered to be 'correct' and turns red when 'incorrect.'

5. EXPERIMENT OVERVIEW

In the experiment we recorded how master ceramics craftsmen perform a particular task and then compared how closely a learner could replicate the master's force, position, and speed. By providing the comparison to the learners, they can determine which alterations they need to make to their own motions to replicate the master's techniques more closely.

The learners performed the given tasks during 25-minute intervals and did not find the sleeve and apparatus to be uncomfortable or fatiguing. The compression sleeve allowed us to keep the electrical components tight to the body to prevent any issues with balance. In total, the sleeve and electrical components weighed 58 grams.

To ensure accurate data from both sources, we created a controlled environment suitable for work with clay. We set up video equipment in the space to record important motion-tracking information that we could digitize and convert into visual simulations. We also used EMG monitoring devices to determine which muscles both the master and the learners were using most frequently.

5.1 Master Craftsmen and Subjects

We engaged two master craftsmen for the experiments. Master craftsman 1 is a pottery instructor, aged mid- to late-30s, with more than a decade's experience in the craft and more than 6 years of experience instructing new students in pottery making. Master craftsman 1's artwork has been displayed in museums throughout the United States and abroad.

Master craftsman 2, aged mid-30s, has close to 20 years' experience working with clay, having first apprenticed for many years with experienced pottery makers in Japan and India. For the past few years, master craftsman 2 has been teaching at a university in Cambridge, Massachusetts.

Subjects in the experiments were all students from our university between ages 18 and 30, selected because students in this age group typically have a close relationship with technology and thus were less likely to face certain technological challenges that might have adversely affected the conduct of the experiment.

5.2 Control Group: Experiment 1

To test the system we proposed in experiment 1, it was crucial to establish a control group and to collect data in a state-of-the-art facility with proper equipment. By being able to compare data collected with the system prototyped for this study from such a facility, one can begin to gauge results. Conducting the initial experiment in an ideal environment provided an opportunity to record data with the lowest level of noise possible, which will then provide a baseline against which all other experiments can be compared.

We employed a 12-camera VICON motion-capture system [20] to track markers (9 mm in diameter) at a rate of 120 frames/second. Marker tracking was accurate within 1.5 mm. Markers were placed on subjects as follows (Figure 3): four on the head, left, and right shoulder; one each on the center of the clavicle, the C7 area of the spine, right scapula, left and right elbow mid and ulna, left and right upper arm, left and right lateral side of forearm, left and right radius and ulna, left and right thumb, and left and right middle finger.

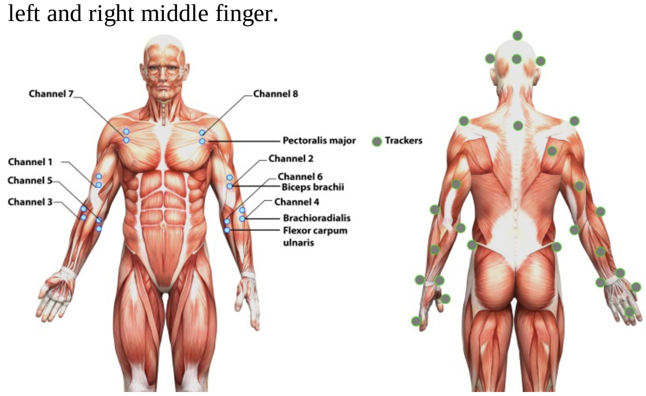

Figure 12. Tracker Placement on users

Both analog and digital devices can be connected to the Vicon System mainframe, just as a wireless mouse can be connected to a computer. Such versatility allowed continuous storage capabilities for 16 Trigno sensors (Delsys's EMG wireless system) operating at a full bandwidth, with 3 DOF accelerometer data per sensor. Once all sensors were placed on the body, the subject could move into the space where the group of calibrated infrared cameras was ready to begin collecting motion-tracking data.

The first users were master craftsmen, so we could collect data from their movements. We asked them to perform the initial actions when working on the potter's wheel for extended periods, which allowed us to identify specific patterns for later use. We made a total of five recordings, which produced an interesting result of the translation to the digital space of materiality. By tracking the motions of the hands while working with clay, a translation of materiality was embedded into the 3D data.

To establish the other end of the control group, we had someone as a second user (Subject 2) with no pottery experience making things by hand. Subject 2 began with a 25-minute demonstration of the sort one would receive in an introductory pottery course; it emphasized centering the clay on the wheel and coning the clay up and down (thus the demonstration corresponded with this paper's focus). The subject was also shown how to create a hole in the clay's center, open the hole, and make a cylinder. The explicit information provided by the master craftsman in the demonstration included key actions to which the subject should pay close attention. During the experiment, the master craftsman also provided verbal instructions to help Subject 2.Figure 4 shows the representation model of the two subjects while working on the wheel. The raw EMG data are shown as a series of plotted graphs, each representing a channel, with the length of the plot related to the recording's duration. Evidently, there is a difference between the master's EMG signal on the left and the beginner's on the right, which show clearly the contrast between the moment of muscular contraction and muscular extension. The EMG signals from the master show bursts only at intended times, whereas those of the beginner oscillate continuously, showing nervousness and a lack of knowledge of the technique.

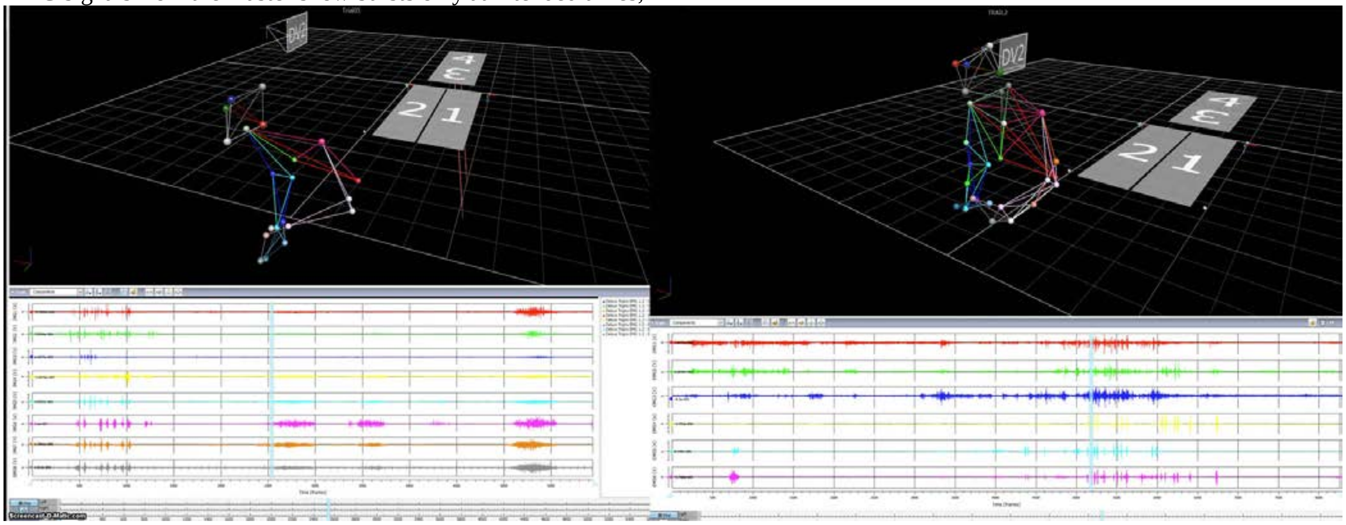

Figure 13. Master and novice MoCap and EMG visualization

5.3 Technique Comparison: Experiment 2

The second experiment tested the EMG sleeve and the bio-feedback LED display for accuracy and effectiveness in assisting the user to perform a desired task. Some subjects had no visual feedback from LEDs and had to rely exclusively on the indications from the instructor to perform the task. Others had to wear the components while performing the task, comparing the two different sets of data afterwards. All participants were recorded to track their motions using the sensors placed on their bodies. The ability to track the participants' motions provided an opportunity to compare those wearing and not wearing the device and determine whether the visual feedback had an effect on the user's technique. Figure 5 shows a direct comparison of a master craftsman and a novice performing the same task: creating a cylinder on the pottery wheel. It is clear that the master craftsman on the left has achieved a high comfort level with the medium, as seen by the tall, rigid walls of the cylinder. The student on the right has created an uneven and incomplete cylinder, illustrating a lack of familiarity with the material and technique.

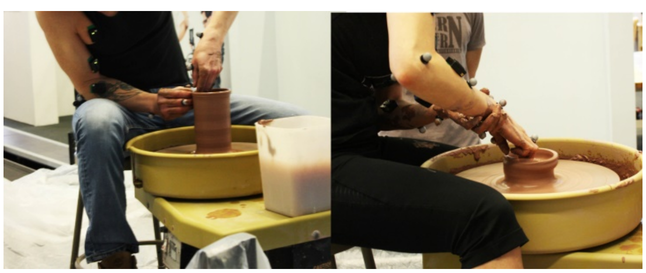

Figure 14. Expert and Novice pulling clay walls

5.3.1 Evaluating the Sensitivity of Sensors

The first test using the devices focused on a simple movement, which the subject performed and then had to match to evaluate sensor accuracy (Figure 6). It involved the subject wearing only the visual display (i.e, we did not use EMG data), which enabled us to isolate the sensors' measuring of arm position over time and produce a speed and trajectory of the arm's movements - information displayed through the first row of LEDs. The test subject was asked to perform the same motion once to compare motions to the previous test run, but multiple test runs became necessary because the subject was unable to match the control data set with ease. Despite the subject's belief that the same motion was being reproduced, the LED display showed a different evaluation of the movement. The subject required time and effort to slow motions and focus on the display, which enabled the arm adjustments needed to match the previous test. We determined after a few trials that a gradual increase in the accuracy threshold would give the subject greater leniency in motion and produce a positive result.

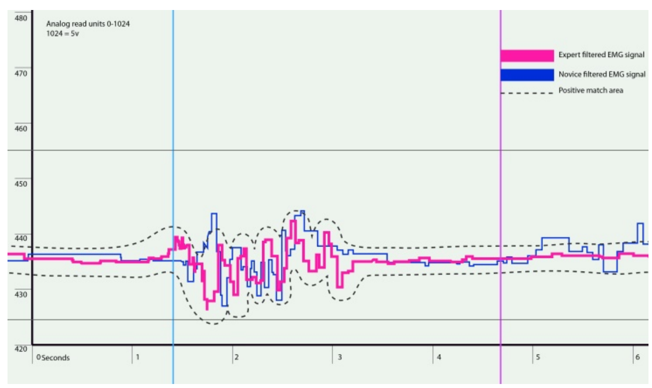

Figure 15. Window and Envelop filters

5.3.2 Evaluating System Efficiency

For the second preliminary test, we asked the subject to wear all three components so we could test the device in totality. This involved a few different experiments with the subject to test the posture and force applied by to the material. The subject crushed a rubber ball using one hand, and we used the electromyography to monitor muscular contraction and expansion. The subject then traced the outline of a lamp and we monitored the speed and accuracy of movements over time; for the latter, the subject attempted to match a recorded data control set.

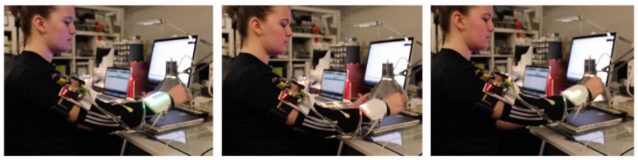

Figure 16. Evaluating sensor sensitivity through repetition

5.4 Pilot with Ceramicist: Experiment 3

Gauging the accuracy of the EMG sleeve and LED display with the pottery wheel became crucial to our experiment's success, so we had the subject perform some initial calibration routines derived from tests mentioned earlier in this paper. As in Experiment 1, the master craftsman showed each subject how to perform some simple pottery techniques, which the subject then tried to replicate. We had to adjust program parameters to get the EMG signals to match and increase the threshold that assigns a numerical value to the degree of accuracy so the subject could adapt and understand how the system works. The initial goal of subject accuracy within 10 degrees of the master's movements proved unachievable, but increasing the threshold to 25-percent accuracy made it possible for the subject to evaluate mistakes and make corrections with the aid of the LED signals. All subjects were given the typical length of a pottery class, one hour, to perform the experiment.

The master craftsmen were extremely deft at centering the clay on the wheel, as would be expected. Master craftsman 1 needed only 4 minutes and master craftsman 2 only 7 minutes (see Figure 8). Novice subjects all required the entire 60 minutes without feedback, but once they used the biofeedback sleeve they all were able to reduce the time significantly and complete the clay-centering task. One subject who had been unable to center the clay during the first 60-minute period succeeded in 12 minutes with the biofeedback

6. RESULTS

The preliminary experiments demonstrated the considerable ease with which participants could become familiar with the movements involved in the task at hand without paying close attention to the visual display; the participants felt they were performing the task correctly even when different results were displayed on the device. Refocusing on the visual display helped participants adjust their technique to meet the readings of the control data set.

As we developed the feedback display software, it became apparent that the strip of LEDs on the pinky side of the wrist (worn on the right hand) performed extremely well in monitoring forearm position. Users could easily tell when their arm angle differed from that of the control data because of the change in the LED display from a full strip of green light to a single, small red light. A slight elbow or shoulder adjustment would correct participants' posture immediately, changing the red lights back to green. Obvious shifts from negative to positive feedback made clear to users that their movements did not match those from the master craftsman data.

Recording the movements of both the master craftsmen and learners using motion tracking sensors made clear that a combination of motion tracking video and EMG feedback provides an extremely accurate digital representation of the craft and makes it possible to understand movements without the need to watch the action in real time. These data could be used to create a three-dimensional learning environment or an archive of movements made by masters of a particular craft. Digital recordings of both motion tracking and EMG would allow remote teaching from anywhere.

7. IMPROVING THE DEVICE

At present, our work focuses on improving EMG signal acquisition and employing more advanced digital signal processing techniques before comparisons are conducted. Improving the feedback system for learners constitutes an important future area of work.

The custom hardware from which EMG signals are acquired, processed, and compared works by using an on-board microcontroller. Feedback is provided through colored LEDs. This setup, though, may be inappropriate for some physical tasks, and the on-board microcontroller seems to be a limiting element of the system for advanced digital signal processing in real time. The user faces some challenges in looking at the LED feedback signals while moving. So, we are looking for ways to decouple the various functions of the current hardware and thus overcome these challenges.

7.1 Signal acquisition improvements

We are considering the Myo armband [1] for the task of acquiring and communicating raw EMG signal data, as well as data regarding physical movement such as pose, orientation, and velocity. This would replace the custom EMG sensor device. Several characteristics of the Myo are particularly attractive in this regard: it is inexpensive, lightweight, and sufficiently accurate, while also interacting easily with the device using a.

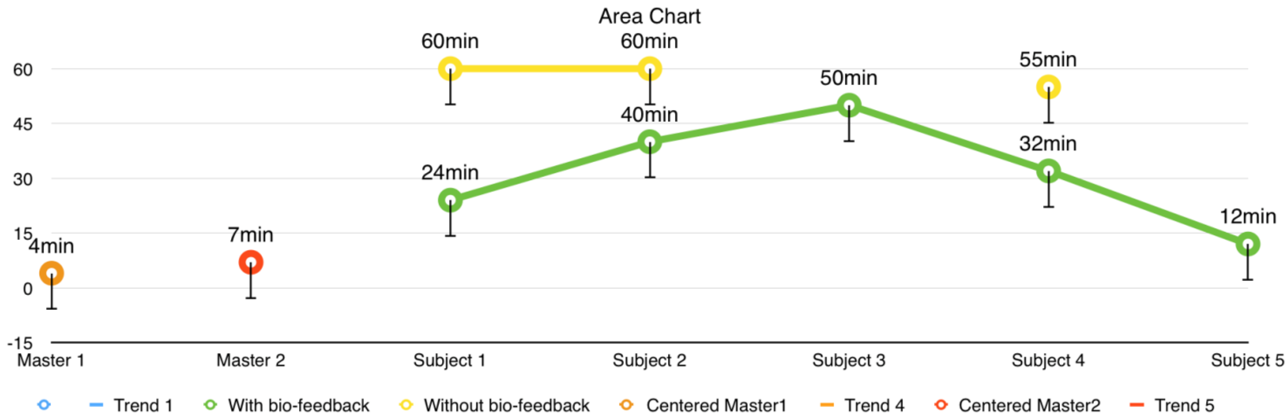

Figure 17. Task completion times of masters and novices both with and without bio-feedback.

number of popular programming languages. The latter allows us to use a language such as Python, which is particularly well suited to digital signal processing. We are also exploring modifying the device so it can be used with muscles other than those in the arm.

7.2 Signal processing improvements

The EMG signal reported by the Myo undergoes some basic processing. Currently, this is used mainly for the purposes of smoothing in the existing implementation. The processing includes removal of DC offset by de-trending, rectification by taking absolute value, and smoothing using a low-pass filter. The specifics of the low-pass filter vary based on the source and characteristics of the data. For example, a fifth-order Butterworth filter with a cutoff frequency of about 1% of the sampling rate has worked well for data collected using the custom hardware described previously in the paper. Figures 9 and 10 show the raw and processed EMG signals across the same time period when the subject touches the thumb to the middle finger several times. The current developments in this area include normalizing the signal against the peak or mean values of a subject for purposes of easier comparison among subjects across trials, and if deemed necessary, addition of pre-processing to remove noise from the raw EMG signal.

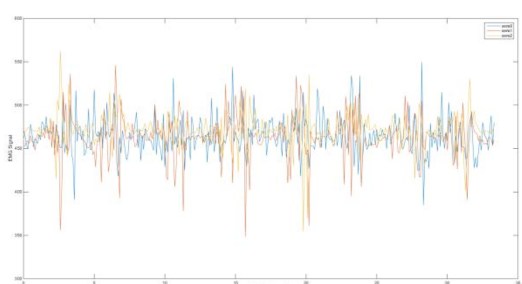

Figure 9: Raw emg while touching thumb to middle finger

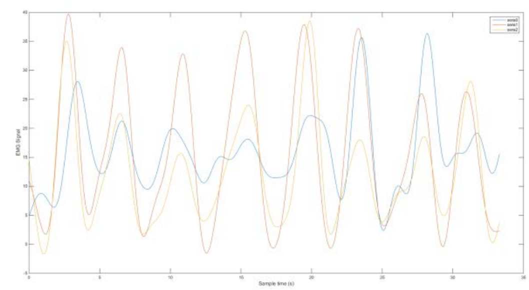

Figure 10: Processed emg while touching thumb to middle finger

7.3 FUTURE WORK

From our system and from previous research [2] it has been seen that a movement that is part of a craft or a sport can be well described using data on motion characteristics and EMG activity. One possible avenue of further exploration is the generalization of the bio-signal comparison and real-time feedback system. This means that a user could access a portal containing files that describe a particular motor skill in terms of the bio-signals mentioned previously. A user could interact with this portal by choosing a motor skill to learn, and an instructor whose movement the user wishes to learn from. The portal would then interact with a wearable device that is located at an appropriate location to measure the learner's EMG signals. Feedback would be provided based on a comparison between the learner's EMG signals and those of the chosen instructor, after undergoing some processing [5] and normalization [9]. This could include visual feedback in the form of LEDs, overlaid graphs, or words. Another possibility is haptic feedback via the wearable device, perhaps to nudge the user in a certain direction or to provide immediately understandable status feedback. This portal would allow a user to more quickly and easily learn many motor skills involving muscle memory acquisition, including clay-centering, basketball dribbling, swinging a golf club or tennis racquet, or throwing or pitching a ball. This paper's contribution is an early version of this system, minus integration with an online portal. Our current system can thus be seen as a proof of concept of such an online learning portal to augment the traditional in-class learning experience in many fields.

8. CONCLUSION

This paper presents a system aimed at easing and hastening the process through which one acquires muscle memory. The method involves collecting signals about pose, velocity, and muscle electrical activity (EMG) from someone who has mastered a given skill and then comparing the signals generated by a learner of the same skill in real time. The learner receives real-time feedback based on the comparison through colored LEDs on a wearable device. The results of our initial experiments show that the system does augment tradition imitation-based learning and make it possible for learners to pick up a skill much quicker than those not employing the system. The promising nature of the outcomes compels us to make enhancements to the system, including more convenient signal acquisition, more sophisticated signal processing, and the most learner-friendly feedback system possible.

9. ACKNOWLEDGEMENT

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INTERACTION FOR PEOPLE WITH DISABILITIES

Performing universal tasks on the Web: interaction with digital content by people with intellectual disabilities

Tânia Rocha
University of Trás-os-Montes and Alto Douro and INESC TEC
Quinta de Prados, 5000-801Vila Real
Campus da FEUP, Rua Dr. Roberto Frias, 4200 - 465 Porto
+351 912620074
trocha@utad.pt

Maximino Bessa
University of Trás-os-Montes and Alto Douro and INESC TEC
Quinta de Prados, 5000-801Vila Real
C Campus da FEUP, Rua Dr. Roberto Frias, 4200 - 465 Porto
+351 939012174
maxbessa@utad.pt

Luís Magalhães
University of Minho and INESC TEC
Largo do Paço
4704-553Braga
Campus da FEUP, Rua Dr. Roberto Frias, 4200 - 465 Porto
lmagalhaes@utad.pt

Luciana Cabral
University of Trás-os-Montes and Alto Douro and CITCEM
Quinta de Prados, 5000-801Vila Real
lcabral@utad.pt

ABSTRACT
With this study we intent to better understand how a group with intellectual disabilities interacts with digital content, namely web content, when performing equivalent tasks from their daily school activities, such as: painting, making puzzles, playing games. To accomplish this we observed how a group with intellectual disabilities, without experience using computers, performed universal tasks (selection, manipulation and navigation) when presented with different activities on the Web such as painting, playing games or searching. We aimed at evaluating usability and accessibility and for this we registered the following variables: successful conclusion of activities, type of difficulties found, errors, satisfaction, motivation and autonomy indicators.

Participants showed motivation and learning skills when performing all the three universal tasks (selection, manipulation and navigation) which is confirmed by the number of participants that was able to conclude the activities. Concerning errors, it was observed that despite the large number of errors made by the participants, their motivation lead them to complete the tasks. When handling the input devices the participants had a good performance using the computer mouse. On the other hand, they could not use the keyboard alone because of their reading/ writing difficulties.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation**]: User Interface – *Input devices and strategies, Interaction styles, Training, help and documentation.*

General Terms
Human Factors, Performance.

Keywords
Digital literacy, intellectual disability, learning disabilities, universal tasks, Web interaction.

1. INTRODUCTION
We live in an advanced technological world and the Web resources provided numerous advantages, professional and social, "just a click away". As Tim Berner-Lee, stated "The power of the Web is in its universality. Access by everyone regardless of disability is an essential aspect" [1]. Although, some users see their Web access hampered, in the particular case of people with intellectual disabilities, these barriers are increased, enhancing digital exclusion of this group of people [2].

This reality was presented to the research team when they were challenged to start working with a group of people with intellectual disabilities. After the first meeting with their teachers, we realized that they had many difficulties in motivating their students to perform school activities as well as choosing which learning material resources to use with a group of people that discourage very quickly and present many unfinished tasks. Such aspects lead us therefore to study not only if resources from the Web can be a viable option to enhance learning for this group of people as well as an option for special education teachers (and possibly a tool leading to the digital inclusion of a group previously excluded).

Thus, this paper presents a study on how a group with intellectual disabilities performs universal tasks on the Web (selection, manipulation and navigation). The activities presented to them were based on their daily school activities, such as: painting, making puzzles, playing games and word search. These activities were chosen to: motivate the group to perform daily school activities on the Web; enhance their abilities when performing selection, manipulation and navigation tasks; and train the use of the computer mouse and keyboard handling.

We observed and took notes of major barriers found in their interaction and their potential technological skills (manage to complete successfully digital activities using the usual input devices), errors and difficulties found, when using the Web. For this assessment we allied ethnography and usability evaluation (user tests).

2. Background
According to World Health Organization (WHO), an individual with special needs ("disability") has impairment (a problem in the body's function and structure), conditioned activity (difficulty in

performing a task or action) and a restrained participation (it is a problem experienced by an individual, on a daily basis situation) [3].

Particularly, a person with intellectual disability is characterized by having an intellectual quotient (IQ) significantly below average and limitations in the performance of functioning capacities in daily life areas such as communication, self-care, and social coexistence and in school activities. Despite this disability, they can and should learn new competencies and abilities. However, their development will always be slower when compared to a child with medium intelligence and adaptive competencies [4]. It is therefore crucial to be aware of different pathologies (and degrees of severity) among the group of people with intellectual disabilities in order to choose appealing school activities and appropriate didactic methodologies and thus motivate these students to learn [2].

Several national and international studies indicate that the use of the computer and other technologies have major advantages in the learning process, pointing to increased motivation, performance and promotion of the use Information and Communication Technologies (ICT) [5] [6] [7] [8]. Explicitly, ICT provide several possibilities of communication, new ways to transmit knowledge, motivational tools to enhance learning, access, efficiency and quality of the learning process [9]. Moreover, the International Institute for Communication and Development (IICD) (2007) study reveals that 80% of the users “felt more capable by their exposure to ICT” and 60% said were “direct and positively influenced by ICT” [6].

Likewise, there are several studies that recognize the advantages of ICT use with students with special needs and disabilities [10] [5] [11] [8] [12]. In these studies it is strengthened benefits provided to these students by the ICT in education. ICT are more efficient and effective due to the user’ motivation in the interaction with the computer, used as assistive technology or pedagogical tool [13] [14]. Although the great number of ICT studies in literature, it is highlighted the importance of further research on users-interface interaction, accessibility of contents, pedagogical approaches using ICT to support inclusion in special needs education [10] and usability of the different applications developed. It is also evident a lack of ICT solutions for people with disabilities, such as visually impaired people, but when compared with people with learning difficulties this number decreases [11].

We believe that the Web can be an unlimited source of activity resources to enhance education for people with learning difficulties and for people with intellectual disabilities. However, there are several accessibility barriers in this environment, particularly raised by their own disability, due to their slower learning, low reading comprehension, limited fine motor control, reduce spatial perception, low visual acuity, less hand/eye coordination, finger dexterity and lowered information overload thresholds [20], leading to digital exclusion of these users [15]. In several studies it is even questioned the possibility of finding a guiding principle when planning Web sites for people with learning and intellectual disabilities [16], also related to difficulties resulting from the wide range of disabilities among such group of people. Other studies highlighted problems found in Web interaction such as: text entry is problematic and multi-options are referred as difficult to use [16] [17]; hyperlinks recognition are difficult [18] [17] and also typing, scrolling, reading of instructions and understanding that users are in a Web environment [19]. One even stated that W3C-WAI guidelines for accessibility are insufficient to ensure access to people with intellectual disability [19]. Other study refers that despite these guidelines had important issues about learning disabilities, almost all elements regarding this disability are identified as lower priorities [20].

3. Web interaction study per people with intellectual disability

In this study we had the responsibility to train a group of people with intellectual disabilities (without Web experience) using the Web, by performing tasks related to their daily school activities. We aim at assessing their Web learning evolution process, by using the mouse and keyboard input devices, observing user-interface interaction and performing selection, manipulation and navigation activities.

3.1 Participants

Twenty participants were invited to partook in the pilot study, whose ages ranged from 19 to 46 years old. These participants were selected by a special education teacher and a psychologist, according to the average rate of literacy and primary education (coincident with the first grade). All were volunteers and had permission of their parents or tutors to perform the activities.

Concerning their intellectual disabilities, individuals were not associated to one pathology, but a set of pathologies (for example, fetal alcohol syndrome with dysgraphia). These pathologies can be classified according to severity levels, between mild to moderate, only one of the participants presented a high level of disability [4].

Furthermore, fourteen participants have normal vision and six have corrected to normal vision. Participants had no experience with digital environments or the Internet.

3.2 Methods

In this study, we allied ethnography (to overcome difficulties found in communication within the group) with user tests. The methods of data collection used were directly related to the research methods adopted: interviews, direct observation and videotaping. The activities defined were similar to the ones they performed daily in school, however we they used the Web to perform the activities. These activities were chosen to motivate the group to perform daily school activities, providing technological abilities on Web selection, manipulation and navigation tasks and also exercise mouse and keyboard handling.

3.3 Activities

The activities were defined to train users’ selection, manipulation and interaction skills in the Web. We intended to increase activities’ difficulty to assess their apprentice level related to mouse and keyboard handling and success of goal reached. This was measured through the increase number of clicks and adding specific objectives to successfully finish the task. All activities and difficulty levels are specified next:

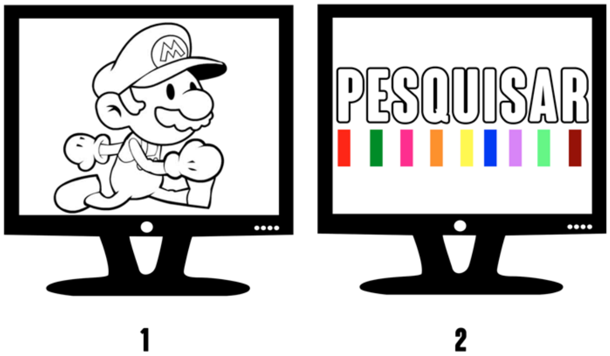

Figure 1. First activity (Painting).

In the first activity, participants had to paint two drawings. In the first drawing, participants had to paint it with colors random (7 to 12 clicks) (Figure 1). In the second, had to paint a word (9 clicks) matching each letter with a specific color (Figure1).

This activity aims to assess the **selection task (**fine motor skills aspects with the mouse use) and comprehension (painting with a specific order and color).

Figure 2. Second activity (Puzzles)

In the second activity, participants must build three puzzles. Specifically, in the first, participants must build a six pieces puzzle; in the second, a puzzle with twelve pieces and in the third, a puzzle with twenty-four pieces (Figure 2). In this task it is intended to evaluate **manipulation,** click, drag and drop movements and fine motor skills, with the mouse use.

Figure 3. Third activity (Games).

In the third activity, it was requested to play two games to introduce keyboard interaction. The first, participants play a game called Puzzle Bobble. This game consists in throwing colorful globes and group them by color, using only three keyboard keys (left and right arrows and space). Whenever they are grouped in, at least 3 equal balls, they disappear. The player wins when there are no globes left. If the player does not eliminate all globes before them pass the bottom central bar the Game is Over. The game duration time depends on each player and the time it takes to complete the level or lose it (Figure 3).

The second game, the participants played a cars game called Extreme Racing 2. In this game, the player must move away of several obstacles that appear on the road. The full game duration is 1 minute and 30 seconds. They had to use the same three keyboard keys (left and right arrow and the space key) to accelerate. The level difficulty increased with the number of obstacles that appear in the road and with the limited time to finish the level (Figure 3).

With this activity we aimed to initiate keyboard handling and assess users' interface **interaction and navigation** and fine motor skills (speed control and precision).

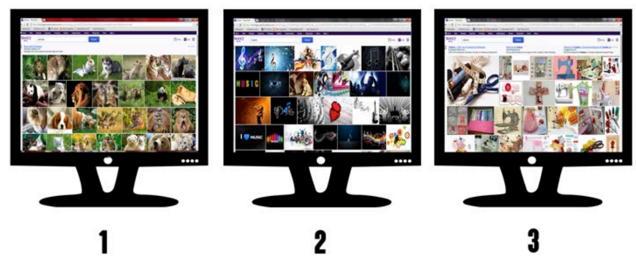

Figure 4. Forth activity (Web search)

Participants performed a forth activity. With this activity we aimed to train them with both devices, mouse and keyboard, and user's interaction with a Web search engine, Yahoo! (Figure 4).

In this activity, users had to perform three searches, with the following keywords: animals, music and sewing tools. First, they had to recognize the search field and click in it with the mouse, then write the word in the search field (previously written in a paper) and click the search button. This task was performed on the Yahoo! Images so that participants can comprehend all search results because of their reading and writing disabilities. Note that this group presents a low level of literacy and it is not intended that they be constrained with text results, once they could not read. This task aimed to initiate user's interaction with the Web, assessing the interaction with Yahoo! layout (by the keywords insertion on the search field of the web browser engine) and fine motor skills, using both devices: mouse and keyboard.

3.4 Apparatus

The following material resources were used: a HP keyboard, optical computer mouse, Chrome Web browser.

3.5 Procedure

Before starting the planned activities, for two weeks approximately thirty-five hours in total and two and a half hours per subject) the group was faced with basic and essential issues needed to use the computer and the Internet. The participants were told how to connect a computer and how to handle the mouse/keyboard and its use. Also, we presented the basic features of the Web browser. It was given a brief explanation on how to open/close the browser, use buttons on the browser and their functionalities: the previous and next arrows, maximize, minimize and close windows, search the Web pages activity in the favorites options (previously recorded) and click in the Web page to start the activity. Furthermore, they were shown how they might recognize a link, or when the content is clickable or not clickable, based on the transformation experienced by the mouse pointer icon (e.g. when the mouse pointer is over a link the original icon, the arrow, becomes a hand).

After this preliminary stage, the group performed the four Web activities, in 16 weeks (approximately forty eight hours in total and two and a half hours per subject). The activities were performed individually, in a controlled environment. Each task was explained before the participant initiated it. Participants were seated correctly in front of the screen. All tasks were displayed in the computer and performed in the Web. The evaluator/observer did not help the participant on the input device interaction or resolution of the activity unless him/her asked for it.

3.6 Results and discussion

3.6.1 *First activity - selection*

In the **first activity**, participants painted two drawings. The **first drawing** was painted by nineteen participants (one user was absent from the class). The average time of conclusion of the task was 292 seconds. The fastest participant took 59 seconds to conclude the task and the slowest, 601 seconds. During this assignment, it was observed that ten participants use the mouse correctly; seven had difficulties with its use and control and two participants had difficulty in the beginning but overcome those difficulties before finish. No one quit.

The **second drawing** was painted by nineteen participants (one participant was absent from the class). In this activity we register: time to finish successfully the task (to match the predefined color to the letters), errors on color correspondence (an average of approximately 1.7 errors) and mouse clicks to finish the task, difficulties and dropout rate. The average time to complete the task was 326 seconds. The fastest participant finished in 90 seconds, with 18 clicks and 0 errors on color correspondence and the slowest 600 minutes, 53 clicks and 8 errors on color match. Errors observed were on color match (a total of 32) and on painting the surrounding area (six participants). Concerning the difficulties observed, five participants show difficulties in the mouse handling, such as: in the correct hand's positioning, correct use of the buttons and in cursor precision. Participants revealed interest and motivation to successfully finish this second drawing. No participant quit.

In this activity we observed a learning evolution on the mouse handling as, in the first drawing, seven had handling difficulties and in the second, five. Two participants improved their performance between the two drawings tasks. Specifically, in the first drawing, it was observed difficulties in the mouse input device handling when they had to painting small areas. In the second drawing, participants had difficulties on the colour matching. Despite these difficulties, no participant asked to quit. Another observation made, in the second puzzle, users painted the surrounding area of the drawing when trying to paint the character, they did not had the mouse handling precision needed to make the selection. When asked why, they answered the area (character) was too small. Regarding the results, we conclude this selection activity is ease to perform by the group and they will have technological abilities to repeat in another context.

3.6.2 *Second **activity – manipulation***

In the **second activity**, users made three puzzles. The **first puzzle** was made by nineteen participants (one was absent), with an average time of 112 seconds to complete the puzzle. The fastest participant did the puzzle in only 18 seconds, on the other side, the slowest took 231 seconds due his/her difficulties handling the computer mouse. Three participants have difficulties in handling the mouse and two in the correct position of the puzzle pieces, however no one quit.

In the **second puzzle**, from twenty participants only seventeen accomplished the task (three were absent). The average time for the level conclusion was 277 seconds. The fastest participant finished the puzzle in 64 seconds. The slowest user concluded the puzzle in 618 seconds due to him/her difficulties in the mouse handling. Three participants still had difficulties in mouse handling and five in the correct position of the puzzle pieces. Due to mouse handling difficulties, two participants refused to finish the task.

In the **third puzzle**, nineteen participate in the task (one was absent). This puzzle had a time average of 557 seconds. The fastest user concluded it in 289 seconds; on the other hand, the slower user finished the task in 1171 seconds, presenting many difficulties in mouse handling. Regarding difficulties found, three participants had problems with the mouse handling (specifically, one presents difficulties in the mouse' hand positioning) and five with the correct position of the puzzle pieces. Three users quit the task due to puzzle construction difficulty.

In figure 5, it is compared the average time for conclusion of the three puzzles made on the second Web activity.

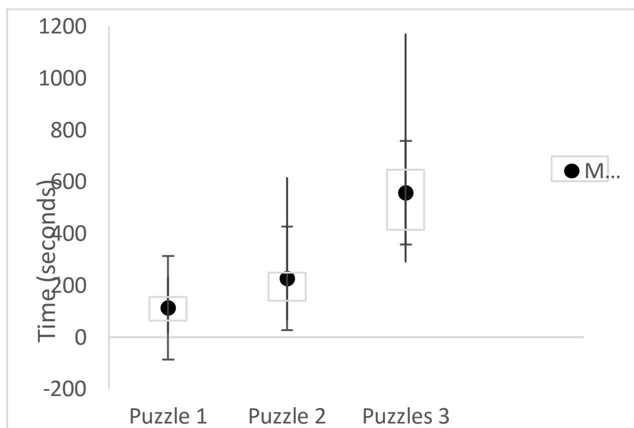

Figure 5. Average time for conclusion of the three Puzzles.

As expected, users take more time to finish puzzles with higher number of pieces because it increased the complexity of the activity, despite users having more experience with manipulation tasks and mouse handling.

In the **second activity** (puzzles) it is noted that previous learning with the mouse input device handling was not forgotten, once the participants improved their performance. After the first puzzle, three participants showed difficulties in the mouse input handling. In the second puzzle, the same three participants had difficulties and two quit this puzzle. However in the third puzzle, no one refuses to perform the task, three had difficulties but no one quit. Regarding puzzle construction (put the puzzles pieces in the correct places), in the first, two asked for help but no one quiet; in the second, five users needed help; and in the third puzzles, six participants asked for help and because of the large number of pieces, users showed some frustration in finishing and three wanted to quit. Despite the increased number of dropouts (when compare with the selection activity), we notice although users quit the task in hands they did not refuse to participate in the next Web activities. This was considered an important result by the group' teachers because they confirm that when participants refused and quit a school daily task (without using the Web) they never wanted to repeat a similar task (in such a short time) and teachers had to insist very hard to make them performed it. Regarding manipulation, we notice participants gained abilities to perform these activities with proper training.

3.6.3 *Third activity – navigation*

In the **third activity**, participants had to play two games. The **first game** was played by eighteen participants (two were absent). Only eight concluded successfully this level, i.e., eliminated all colour balls before "Game Over". The average time of playing was 171 seconds. The fastest user took 57 seconds to eliminate all balls and the slowest, 310 seconds. We also noticed that from the eight participants that successfully concluded the task, five did have difficulties in handling the keyboard. From the remaining ten, nine had difficulties but two participants overcame their difficulties during the task. Thus, thirteen participants showed difficulties in this first interaction with the keyboard. The difficulties observed with the keyboard handling, were: users press two keys simultaneously and switch the correct order of the arrows. Seventeen participants asked to repeat the game. No participant quit.

The **second game** was performed by eighteen participants (two were absent). Nine users did not present any difficulty in the keyboard handling, one improved during this level (however he/she did not successfully complete the task- before "Game Over"). Regarding, successfully conclude the task, four participants did not finished the game (not because of keyboard handling difficulties but due to the fact that they did not reach the requested velocities in order to finish before "Game Over"). It is noticed an improvement in the users' keyboard handling between levels. Eighteen participants asked to repeat the game. No user quit.

Regarding these results, it was notice that in the first game (Puzzle Bubble) the success conclusion rate was low (when compared with previously activities), ten participants did not finished the game successfully, i.e., before "Game Over". In the second game (Extreme Racing 2) only four participants did not finish successfully the game (before: GAME OVER). With these activities, they started to handle the keyboard (started to use the arrows, enter and space keys), and the major difficulty was found was that they click in two keys at the same time but they overcome it during the task. No one quit and just one participant did not ask to repeat the first puzzle. They seemed to be very comfortable in the interaction and showed great satisfaction and motivation to perform these activities. Concerning interaction, with proper training and time for learning, users showed technological abilities to perform these activities.

3.6.4 *Forth activity – characters insertion*

Regarding the **forth activity**, three Web searches, nineteen participants performed the task (one was absent from the classroom). In the **first Web search,** the average time for task conclusion was 373 seconds. The fastest participant finished the task in 249 seconds and the slowest in 803 seconds. The major difficulty observed was in the keyword reproduction, i.e. identifying the character to write the right word, seventeen participants had this difficulty. Regarding input devices handling difficulties, no participants had difficulties with mouse input device and four had difficulties with the Keyboard (they click in two keys at the same time). Also it was observed satisfaction on the search performance once they laugh and clap their hands showing great happiness went the result appear in the screen. Another observation was that users often clicked on the images found within the search results. No one quit the task.

In the **second Web search,** the average time for task conclusion was 386 seconds. The fastest participant concludes the task in 243 seconds and the slowest in 976 seconds. Twelve had difficulties in the keyword reproduction and three with the keyboard handling. No participants had difficulties with the mouse input device. They showed satisfaction and motivation to perform this search, asking to repeat the Web search. No one quit the task.

In **last Web search,** the average time for task conclusion was 390 seconds. The fastest participant concludes the task in 244 seconds and the slowest in890 seconds. Eight had difficulties in the keyword reproduction and three with the keyboard handling. No participants had difficulties with the mouse input device. They asked to repeat the Web search, showing satisfaction and motivation. No one quit the task. Here it was observed that they use the ENTER keyboard instead using the mouse and click in the search button.

In figure 6, we compare the average time for conclusion of the three Web search users made on the forth activity.

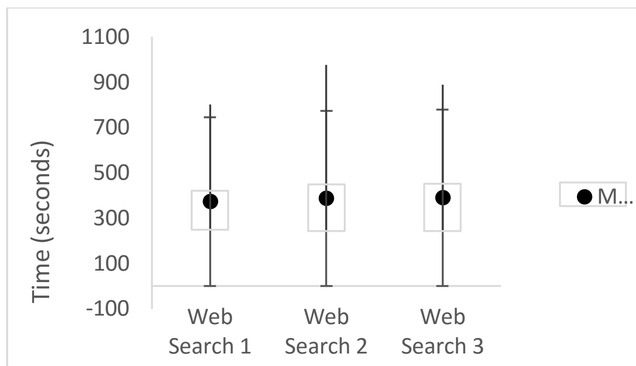

Figure 6. Average time for conclusion of the three Web searches.

Comparing average time between the three Web searches, it is noticed that the results were very similar.

In the **fourth activity (Web search)**, they performed three Web searches and it is noted an evolution in the users performance during the activity. Notice here they had to handle both, input devices, mouse and keyboard, and it was not observed any difficulties in the mouse handling, with the keyboard, users several times click in two keys at the same time or click continuously in one key but they overcome during the task. To write the keyword with keyboard to start the Web search was the major difficulty observed, participants struggled with character recognition (on the paper and keyboard keys) and with word formation. In relation to navigation, after the keyword insertion, users naturally navigate on the page, by clicking on the images presented and using the mouse input device.

4. Conclusion and future work

As this group often do not have the opportunity to perform activities with the computer and the Internet, because many professional (teachers, developers) feel that they have no abilities or the will to do so, this study pretend to shows that they can carry out (with training) basic tasks of selection, manipulation and navigation. The results showed that this group had great motivation and satisfaction to perform Web activities. Despite the difficulties found with the keyboard input device, they had an excellent performance in handling a normal mouse input device.

From the beginning of the activities they showed great progresses on the mouse and keyboard handling. After performing all activities they all could correctly handle the mouse. Regarding the keyboard, they did not have difficulties using the function keys (such as: arrows, enter and space) but had many difficulties with the character keys. This appended because of their reading and writing difficulties. Thus, we believe it will be very difficult to these users to use the keyboard input device with autonomy.

Also, we observed when asked users to perform complexes activities, which are difficult to conclude due to the participants own disability restrictions, can discourage the users with intellectual disability and lead them to quit.

Global results showed performing activities in a Web environment provided a high group's success and a low dropout's rate. We believe with regular training they can gain technological abilities.

As future work, we want to study alternatives solutions for keyboard input devices such as: voice application or search with images, to overcome reading and writing difficulties presented by the group with intellectual disability. Also, we intend to increase the number of participants to allow a more detailed analysis of the results with respect to the level/type of impairment. And thus continue to draw attention to this group of people that is digital excluded.

5. ACKNOWLEDGMENTS

We thank all people who directly or indirectly helped in this study. Specifically:... and ... in the activity's execution, … and ... for your willingness.

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Towards Intelligent and Implicit Assistance for People with Dementia: Support for Orientation and Navigation

Nam Tung Ly[1], Jörn Hurtienne[1], Robert Tscharn[1], Samir Aknine[2], Audrey Serna[2]

[1] LS f. Psychologische Ergonomie, Julius-Maximilians-Universität, Würzburg, 97074, GERMANY
{nam.ly-tung, joern.hurtienne, robert.tscharn}@uni-wuerzburg.de
[2] LIRIS CNRS UMR 5205, 69622 Villeurbanne, FRANCE
{samir.aknine@univ-lyon1, audrey.serna@insa-lyon}.fr

ABSTRACT
To date, most healthcare technologies for orientation and navigation for people with dementia or with cognitive impairments have been developed for outdoor environments. These systems require skills in handling smartphone or PDA applications from users. In this paper, the authors focus on the needs of people with moderate and severe dementia, who are unable to use smartphones and are living in nursing homes or specialized fulltime care facilities. A new approach is presented, based on iterative people-centered design processes, explores calm computing and implicit interaction paradigms for guiding people with subtle cues integrated in the indoor environment. This intelligent and implicit assistance is supported by a three-part framework: a tracking system, a separate guiding system and an intelligent system. The guiding system approach has been tested on several people with dementia. The first results are promising and the feedback from stakeholders is positive but more participants are needed for an empirical analysis.

Categories and Subject Descriptors
K.4.2 [**Computers and Society**]: Social Issues – *assistive technologies for persons with disabilities*; H.1.2 [**Models and Principles**]: User/Machine Systems - *human factors*; H.5.2 [**Information interfaces and presentation (e.g., HCI)**]: User Interfaces – *user-centered design*; I.2.0 [**Artificial Intelligence**]: General – *cognitive*.

General Terms
Design, Human Factors.

Keywords
Healthcare technologies; dementia; orientation; navigation; calm computing; implicit interaction; intuitive guiding; context-aware computing.

1. INTRODUCTION
The growing number of people at old ages entails more age-related deficits and diseases. One of which is dementia, a complex neurodegenerative syndrome that by 2050 could affect about 106 Mio. people worldwide [1]. People with Dementia (PwD) experience a progressive decline in their cognitive abilities and have serious problems coping with activities of daily living, including orientation and way-finding tasks. They even experience difficulties in finding their way in familiar environments [2]. Henderson [3] reports that more than one-third of PwD were diagnosed with visuospatial disorientation and getting lost behavior. The ratio of affected people is even higher in complex and unfamiliar environments such as hospitals or healthcare facilities, where most residents exhibit moderate or severe stages of dementia. Being lost or fear of getting lost may consequently develop into other psychological deficits such as anxiety, suspicions, illusions and aggression [4]. Frequent results are social isolation and a reduced quality of life [2]. Moreover, the lives of relatives and caregivers of PwD are also negatively affected.

Healthcare technologies and assistive systems are designed to support everyday life of PwD, improving their autonomy, safety and quality of life. The design and acceptance of such systems raises real challenges, in particular when considering advanced stages of dementia. Regarding navigation and orientation, most current approaches focus on outdoor environments [5]. And in the majority of systems, users need the capability to use mobile devices, which is only appropriate for early stages of dementia, e.g. [6, 7]. Rasquin and colleagues [8] observe that even a device with three buttons may be too complicated for people with moderate-to-severe stages of dementia. In addition, people who are living in care homes mainly perform indoor activities. Given this background, the authors focus on designing a system for indoor environments like care homes for people with moderate-to-severe dementia, who are unable or reluctant to use smartphone technology.

The authors suggest taking the opposite view of existing approaches by exploring calm computing and implicit interaction paradigms. The authors argue that for severe stages of the disease, it is necessary to free people from interacting directly with complex systems. Interaction becomes implicit when actions performed by the user are not primarily aimed to interact with a computerized system, but which such a system nevertheless understands as user input [9]. Applied to assistive technologies, this means that the system automatically gains an understanding of the current states, contexts and intentions of PwD and assists them with simple and intuitive stimuli subtly integrated in the environment.

This paper presents a new approach of intelligent and implicit adaptive assistance for PwD and introduce a three-part framework for supporting this approach: a subtle tracking system, an implicit guiding system and an intelligent part that refers to context-aware computing [10].

2. RELATED WORK
According to literature reviews of PwD and assistive technology [5], [11, 12], the number of projects for PwD in navigation is limited, especially for indoor environments. Remarkably, many of them are research prototypes without clinical studies involving PwD, e.g. [13], [14]. In the few projects that have been developed as outdoor navigational tools for people with mild to moderate dementia, Activity Compass [13], “Walk navigation system” [14] and COGKNOW [7] are considered. These systems are using mobile devices, locating people with GPS and instructing next steps by images, texts, or voices. In contrast, Context-Aware

Wayfinder [6] is an indoor navigation system. Instead of GPS, the user's PDA provides location information by scanning the QR code tag, which are placed on a door, a turn or an elevator, and sending it to the server over Wi-Fi. Then the device receives images of the next waypoint from the server and guides the user by overlaying directions.

Although such projects show the positive effects to PwD in navigation tasks, they are not suitable for people with severe dementia due to their lack of ability to manipulate mobile devices. Moreover, these devices and guidance cues used (e.g. photographs, alert) have some drawbacks. First, the users have to constantly watch displays or scenes which could be dangerous at crossroads and on stairs [14]. Second, uncharacteristic photos or places with similar scenes (e.g. intersections) may confuse users. Third, warning sounds surprisingly have a negative effect on the quality of way-finding for people with mild dementia [15].

Some projects tried to overcome the limitations of mobile devices by focusing on designing assistive devices. KITE [16], for example, proposes two prototypes for two participants: an armband for a runner and an electronic notepad for a driver. The tracking technology is GPS in cooperation with Global communication system (GSM). If PwD get lost, they can push a button to send a message to their carer. Although the design and functionality seem to work well, the devices are too large and too heavy for users. Furthermore, the panic button on the device might be too easy to press. Without incorporating localization techniques, Grierson and colleagues [17] introduces a wearable belt to facilitate navigation for PwD using four small, vibrating motors that are corresponding to front, back, right and left.

3. A NEW APPROACH OF INTELLIGENT AND IMPLICIT ASSISTANCE

For this project, the authors adopted an iterative and people-centered design approach [18, 19]. The partners are two healthcare facilities and one hospital for PwD in Würzburg and Dresden in Germany. The different stakeholders (i.e. PwD, caregivers, healthcare managers, but also family members) are included in the design process to ensure the system's usefulness and acceptance. It also proved vital to visit and observe PwD in their everyday environments to be sure to understand their difficulties, needs and requirements. The observation lasted two weeks of full time and continued in following six weeks during the study of guiding cues. Along with that, qualitative data (included preferences, biographies of PwD) are also collected from conversations with PwD, their relatives and caregivers.

The authors then realized all of the residents experienced difficulties with orientation, navigation and way-finding. The caregivers' added workload by this was usually overwhelming. The caregivers have to go along with PwD almost every time they want to go somewhere. In addition, all of the residents in the three places do not use any technical devices.

3.1 Design Considerations

In contrast to previous approaches, the authors devised the navigation support system as two separate parts using different techniques and devices: one for tracking and one for guiding. To bridge these two systems, a third intelligent system is requisite to detect the context, determine PwD's intentions and select a relevant assistance as and when necessary.

Choosing a well-suited solution for the indoor tracking system proved a challenge. The first barrier deals with incorporating technology into the daily lives of PwD, whether or not they remembered to take the device with them. Another difficulty concerns the size and weight of the device or embedded sensors that should not prevent or hinder the activities of the person. Moreover, ethical aspects should be considered as well. The device should not make them feel being monitored and that their freedom was taken away. Localization external to the person via cameras and visual tracking had other problems. Identifying individuals and recognizing their activities for the intelligent guidance system based on video-processing techniques can be computationally expensive. For that reasons, a solution that uses iBeacon devices is proposed (section 5.1).

Regarding the guiding system, the authors focus on integrating guiding cues into the environment of PwD. The main approaches in static architectural design are providing supportive floor plan topologies (e.g., direct visual access to the common room, simple circulation routes, and small-scale settings) and distinctive environmental cues (e.g., signage, furniture, and intimate items with personal meaning). Although many of these approaches have shown positive effects on orientation and navigation [20], they are not adaptive. The long-term goal is to turn the traditional means of assistance into flexibly controllable ones using a variety of distributed interactive low-cost components. This way, the guidance cues are expected to be dynamic, adapted to context, and implicit since many PwD do not understand explicit cues such as floor plans or symbols. Light and colors are chosen to orient PwD because they can be implemented to meet above criteria.

3.2 Preliminary Studies on Implicit Guiding Cues

To evaluate the relevance of using implicit guiding cues using LED light, the authors conducted two studies with PwD from one of the cooperated healthcare facilities.

Light projections on the floor or ambient spatial sounds are also considered. But the feedback from PwD showed that the light projection was more likely focal point and not ambient as LED strip. About ambient spatial sounds, PwD could get confused when hearing unknown and un-located voice.

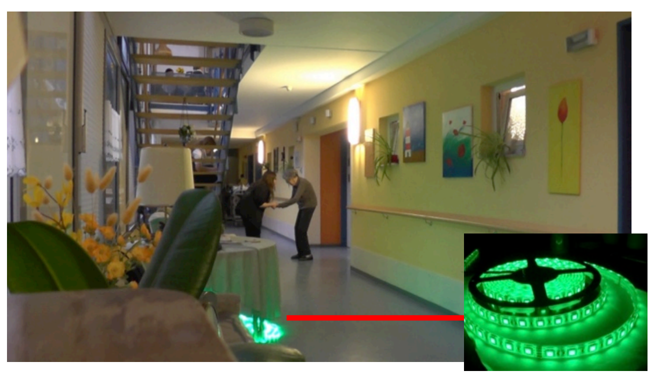

Figure 1. Implicit guiding cue experiment – Indoor environment

The first study was conducted to determinate how PwD perceived colors. The authors asked 12 PwD to choose the color they like. The colors were shown randomly under pairs (2 colors per time), multi-colors (12 colors per time), and different shapes (round, rectangle, triangle). As a result, bright colors got PwD's attraction and preference.

Based on this result, a second study was conducted using bright light for navigation assistance. The experimenters asked four participants with moderate to severe stages of dementia to find a place that they did not know before. They started at a decision point where it was mandatory to turn left or right. There were two conditions: base line (no light) and illumination (left or right area was illuminated by bright light emitted by an LED strip). The light was manually controlled using the Wizard of Oz technique. The results show that PwD tended to go towards the brighter area (Fig. 2) and they find the way easier with light (rating by experimenters – Fig. 3). As feedback from PwD, the light on the left is not clear as on the right (due to a sofa). It could be the reason for the difference in results between the case light (left) and the case light (right). These first results reinforce the approach of using implicit stimuli in the environment for guiding PwD. More studies will be conducted for empirical analysis and investigation of specific combinations of color and light. The idea is that lights combined with a personalized favorite color could become the personal guidance cue of an individual.

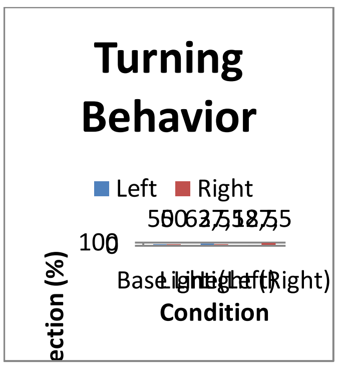

Figure 2. Turning Behavior

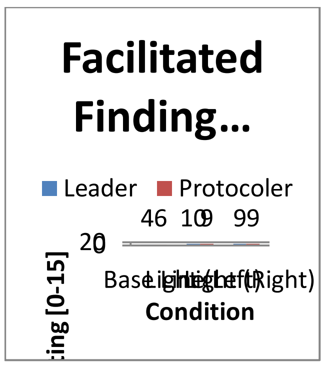

Figure 3. Facilitated Finding Level (the higher level is, the easier users find the way)

4. A FRAMEWORK SUPPORTING INTELLIGENT AND IMPLICIT ASSISTANCE

To support the intelligent and implicit assistance system, the authors are developing a three-part framework, illustrated in Fig. 4: the tracking system, the guiding system and the intelligent system.

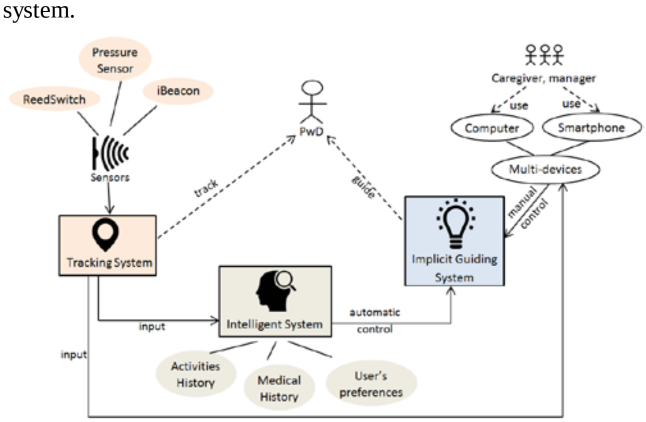

Figure 4. System Architecture

4.1 Subtle Tracking System

The objective of this system is to track the location of PwD in the environment in real-time. Location data will then be handled by the intelligent system to determine the current context and will constitute a history of PwD activities. In order to detect contact between PwD and environment (bed, chair, door), ambient sensors (pressure sensor, reed switch sensor) are set-up. Along with that, iBeacon technology (Fig. 5) is used as tracking device, because of their small size and weight that are easily accepted by PwD.

The indoor map based on OpenStreetMap data can be accessed, customized, controlled in real-time (Fig. 7) by caregivers.

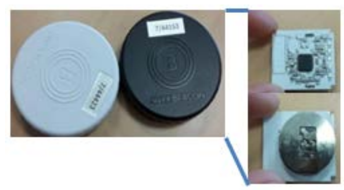

Figure 5. Onyx iBeacon

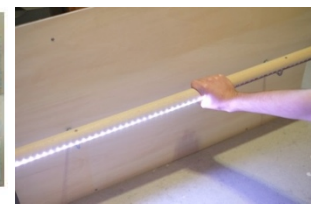

Figure 6. Handrail with light

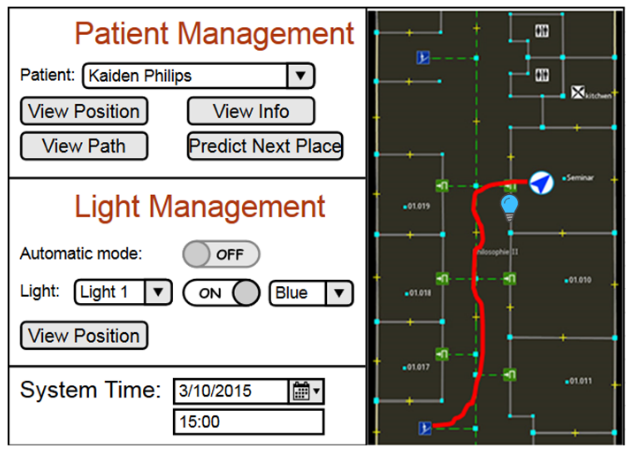

Figure 7. Web-UI for caregivers/managers

4.2 Implicit Guiding System

The purpose of this system is to support PwD completing daily way-finding tasks by providing relevant cues. The ideal guiding cues should be implicit and dynamic. For the first iteration, LED strips was used and controlled remotely by a human controller. Later, the intelligent system will control the guiding system allowing dynamical adaptation to various situations. Another advantage is that PwD do not need any skill to manipulate and control the system. Different configurations and positions to place the light cues are still being explored. For instance, the light can be placed on the floor (Fig. 1) as in the above study or attached on a handrail as in the newest prototype (because handrails are ubiquitous in care homes, Fig. 6). Other cues like recorded voices from PwD's relatives or portrait pictures from their youth days (that are more likely to be recognised by PwD) are also considered to enhance assistance efficiency. These cues will be tested in next studies.

4.3 Intelligent System

The system's main function is to choose the most relevant assistance in the current context. The authors thus aim at developing an online intention recognition method and a decision-making process. The logical-approach model (e.g., [21]) is considered using to transform low-level sensor data to high-level behavior. Then, the decision-making process should choose whether and which assistance is needed. The user's history of activities and expert data (e.g. medical history) are also taken into account in order to offer the most appropriate assistance to the current situation (Fig. 4). The system suggests and stimulates PwD to go to the direction that has been judged as the most suitable for the situation. In this way, according to the model of automation levels of Sheridan et al. [22], the system corresponds to level 4.

5. CONCLUSION & OUTLOOK

In this paper, a new approach is presented for offering implicit guiding cues for orientation and navigation assistance for people with moderate to severe dementia in indoor environments. Taking the opposite view of current approaches, the authors take inspiration from calm computing and implicit interaction paradigms. This paper also presented the first implementation step towards a three-part framework supporting this intelligent and implicit assistance. The authors adopted an iterative people-centered design process and have already conducted first studies to evaluate the potential of the approach. The implicit guiding system, tested thanks to Wizard of Oz techniques, showed positive navigation outcomes. In addition, perspectives in terms of technical feasibility and expert feedback were optimistic. The caregivers and managers in the healthcare facilities were satisfied with the results of the studies. They showed excitement to see the further steps implemented. The platform development is still under progress, including exploring other technologies for the tracking system and developing the decision-making process. At a longer-term perspective, the guiding cues will be dynamically controllable, taking into account PwD's current activities, emotional state, and also changing abilities and limitations. The overall approach will be then tested formally with all relevant key stakeholders.

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Terapia Ocupacional para Personas con Discapacidad Física utilizando Ambientes Interactivos

Héctor Cardona Reyes
Jaime Muñoz Arteaga
Univ. Autónoma de Aguascalientes,
Av. Universidad #940
Aguascalientes, Ags., México
C.P. 20131 +52 (449) 910 8417
k6550g, jmauaa{@gmail.com}

Francisco Acosta Escalante
Univ. Juárez Autónoma de Tabasco
Av. Universidad s/n, Zona de
la Cultura, Col. Magisterial,
Villa Hermosa, Tabasco, México
C.P. 86040 +52 (993) 358 15 00
francisco.acosta@ujat.mx
mailto:juan.gonzalez@cs.buap.mx

Francisco J. Álvarez Rodríguez
Ángel Eduardo Muñoz Zavala
Univ. Autónoma de Aguascalientes
Av. Universidad #940
Aguascalientes, Ags., México
C.P. 20131 +52 (449) 910 7400
fjalvar, aemz{@correo.uaa.mx}

ABSTRACT
Este trabajo propone los ambientes interactivos como una solución accesible y de bajo costo que permita dar soporte al proceso de recuperación de las personas en rehabilitación que reciben terapia ocupacional. Se presentan un método para el diseño de ambientes interactivos basado en modelos que permite identificar las capacidades de interacción que se deben tomar en cuenta al producir ambientes interactivos para usuarios con distintos niveles de capacidad/discapacidad, que permite capitalizar las buenas practicas establecidas en la terapia física permitiendo la generación de diversos escenarios digitales de rehabilitación con la tecnología adecuada, y que cubran las diversas necesidades de rehabilitación del usuario con discapacidad física. Por ultimo este trabajo presenta un caso de estudio en el cual se comprueba el método propuesto por medio de la aplicación de ambientes interactivos en personas que reciben terapia ocupacional para la rehabilitación de la mano en el DIF, Aguascalientes, México.

Keywords
Ambientes interactivos, Discapacidad, Terapia Ocupacional, Actividades de la Vida Diaria, Rehabilitación, Enfoque MDA.

1. INTRODUCCIÓN
La discapacidad forma parte de la condición humana, casi todas las personas en algún momento de su vida sufrirán algún tipo de discapacidad transitoria o permanente, y las que lleguen a la senilidad experimentarán dificultades crecientes de funcionamiento. De acuerdo con la Organización Mundial de la Salud (OMS) entre 110 millones y 190 millones de adultos tienen dificultades considerables para funcionar físicamente [1]. Existen diversas técnicas y métodos que forman parte de la terapia física, uno de ellos es La Terapia Ocupacional hace uso del termino "ocupaciones" o actividades tales como las Actividades de la Vida Diaria (AVD) con el propósito de ayudar a las personas con discapacidades físicas, de desarrollo o emocionales, a llevar una vida independiente, productiva y satisfactoria [2]. En los últimos años ha incrementado el interés en el diseño y desarrollo de software interactivo. Una de las principales razones es el interés en la necesidad de permitir que el mayor numero de personas pueda acceder a software para el mayor numero de propósitos [3]. Sin embargo el realizar este tipo de ambientes interactivos dirigido a personas con algún grado de discapacidad física implica tomar en cuenta un gran numero de factores en el diseño, por lo que una de las discusiones de este trabajo se orienta hacia una identificación y desarrollo de un método para diseñar ambientes interactivos que puedan ofrecer un soporte adecuado a las tareas, el contexto de uso, identificar las necesidades de rehabilitación y condiciones del usuario. Con esto se pretende obtener beneficios en mejorar la productividad, la portabilidad, la interoperabilidad y la reutilización de los sistemas. Este trabajo esta estructurado en siete secciones. La siguiente sección presenta varios trabajos relacionados que defienden el uso de tecnologías para asistir el proceso de rehabilitación de personas con discapacidad física. La sección de problemática, describe la dificultad de incorporar ambientes interactivos para asistir el proceso de rehabilitación de las personas con discapacidad. La siguiente sección propone una método para establecer las bases para la producción de ambientes interactivos. La sección de caso de estudio, en la cual el método propuesto es probado a través de la aplicación de ambientes interactivos a pacientes con discapacidad física que reciben rehabilitación de la mano. Finalmente en la sección de conclusiones se presentan los principales resultados así como los trabajos futuros.

2. TRABAJOS RELACIONADOS
El la literatura existen varios trabajos sobre rehabilitación, la tabla 1 muestra algunos trabajos que abordan el soporte a la rehabilitación por medio del uso de la tecnología.

Tabla 1. Trabajos relacionados que dan soporte a la rehabilitación por medio de ambientes virtuales

Trabajo	Dominio
[12], [10]	Modelo de diseño
[5], [8]	Sistema Interactivo
[6], [7], [9]	Juegos serios, video juegos, realidad virtual
[4], [11]	Diseño de interfaces

Uno de lo principales problemas que enfatiza este trabajo es que los usuarios pueden tener problemas para comprender lo que se apoyan en las tareas presentadas o cómo asociar las acciones lógicas deseadas con acciones físicas de la interfaz de usuario. Esto puede abordarse si se cuenta con métodos para representar explícitamente modelos requeridos y ofrecer indicaciones sobre las técnicas de interacción y de presentación más adecuadas para apoyar las posibles actividades para este tipo de usuarios y con ello lograr las interfaces adecuadas que los usuarios con algún tipo de discapacidad física requieren para alcanzar sus objetivos de rehabilitación.

3. PROBLEMÁTICA

El presente trabajo plantea la incorporación de ambientes interactivos al proceso de recuperación de pacientes en rehabilitación, con el fin mejorar las actividades de rehabilitación y ser un medio accesible para el paciente en donde pueda rehabilitarse incluso sin salir de casa y realizando tareas de la vida diaria en un ambiente interactivo. Esto es una tarea complicada que requiere considerar un diseño centrado en el usuario para la creación de software que resuelvan necesidades concretas de sus usuarios finales, establecer un método basado en modelos que permita capitalizar aquellas buenas practicas de rehabilitación para así propiciar la producción sistemática de ambientes interactivos y que estos se adapten de acuerdo a las necesidades de las personas con discapacidad física permitiendo incorporar las diversas áreas multidisciplinarias y aquellos actores involucrados tales como especialistas, diseñadores, analistas, programadores, usuarios finales al proceso de producción de ambientes interactivos. Por lo que es necesario aplicar técnicas de la Ingeniería de Software e Interacción Humano-Computadora para diseño y desarrollo de diversos tipos de usuarios con el fin de desarrollar un entorno interactivo que de soporte a las necesidades y cuestiones planteadas. A continuación se presenta un método de producción de ambientes interactivos como solución a la difícil tarea de producir ambientes interactivos y tecnologías e integrarlas al proceso para la recuperación de pacientes en rehabilitación.

4. PRODUCCIÓN DE AMBIENTES INTERACTIVOS

Uno de los fines del proceso mostrado en la figura 1 es la creación de un ciclo iterativo e incremental en el sentido de avances graduales y para cada logro en el paciente establecer un ambiente interactivo diferente permitiendo adaptarse con esto a las necesidades de rehabilitación con el fin de lograr la total funcionalidad del paciente y que este pueda reincorporase a sus actividades de la vida cotidiana.

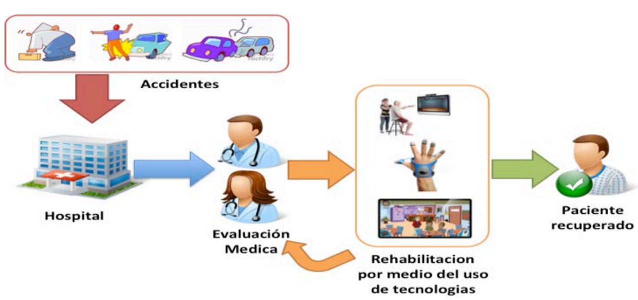


Figura 1. Proceso de Terapia Ocupacional para Personas con Discapacidad Física utilizando Ambientes Interactivos.

Dado que se requiere producir varios ambientes interactivos se propone una método basado en modelos, tal como se presenta en la figura 2. El método inicia con la definición de las habilidades de acuerdo a situaciones reales tales como actividades de destreza, sensoriales, resolución de problemas por medio de movimientos, recrear situaciones de la vida diaria o del trabajo [13].

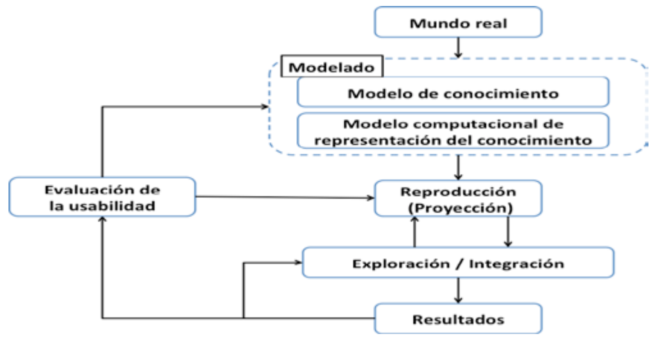


Figura 2. Método para el Desarrollo de Ambientes Interactivos utilizados en Terapia Ocupacional.

Este método tiene su base en las Guías Practicas Clínicas (GPC) [14] que son un elemento de rectoría en la atención médica en México y están basadas en recomendaciones sustentadas en la mejor evidencia disponible, a fin de contribuir a la calidad y la efectividad de la atención médica. De acuerdo con el método propuesto se inicia con la identificación de las situaciones del mundo real cuyo objetivo consiste identificar la evaluación de la funcionalidad del paciente, en establecer una definición de las habilidades cognitivas deseadas del paciente y conocer las limitaciones de los usuarios potenciales. Después se genera un modelo de conocimiento donde se determina un conjunto de actividades a realizar para dar tratamiento a la rehabilitación. A su vez un modelo computacional permite elaborar una representación computacional del entorno, sea esta en 2D o 3D considerando las limitaciones funcionales del usuario identificadas en el modelo de conocimiento. De acuerdo al tipo de actividad ocupacional y usuario se requiere de un modelo que capture los requerimientos e información que permita que solo pueda se usado por usuarios con cierto nivel de funcionalidad física. Una vez establecidos los parámetros y entidades del modelo, las acciones son captadas para obtener información vital para el especialista y el paciente permitiendo la evaluación y clasificación con fines de retroalimentación y obtener datos sobre la aceptación del modelo de diseño insertado en el prototipo de ambiente interactivo producido y si es o no una representación del escenario de rehabilitación del usuario. A continuación se explican cada una de las fases propuestas en la figura 2 con un caso de estudio en el cual se asiste la rehabilitación motora de los músculos de la mano.

5. CASO DE ESTUDIO

Esta sección aborda la puesta en marcha de ambientes interactivos en personas jóvenes y adultas con discapacidad física que reciben terapia ocupacional para la rehabilitación de la mano en el Sistema para el Desarrollo Integral de la Familia Estatal Aguascalientes, México (DIF) [15]. El DIF cuenta con una Unidad de Terapia Física con diferentes módulos en los que hay distintos aparatos que facilitan la rehabilitación de los pacientes. Este caso de estudio conto con la participación de pacientes y expertos que acuden a la Unidad de Terapia Física, aquí los pacientes presentan diferentes condiciones en cuanto a edad, discapacidad y tipo de tratamiento a seguir. El objetivo es asistir a los pacientes por medio de la utilización de ambientes interactivos además de comprobar cada de las fases que componen el método para el diseño de ambientes interactivos propuesto en la figura 2.

5.1 Fase del Mundo Real

En esta fase se identifico un grupo de cinco pacientes voluntarios cuyas edades son de: 9, 50, 58, 63, 68 años respectivamente, con diagnósticos que incluye secuela de cirugía, distrofia de la mano y eventos cerebro vascular principalmente.

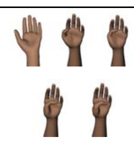
Figura 3. Rehabilitación de la mano por medio de terapia ocupacional en la unidad de terapia física DIF Aguascalientes, México.

El tratamiento para estos pacientes es llevado por 2 especialistas en rehabilitación física dentro de una sesión de 30 minutos la cual consiste en realizar actividades por medio de terapia ocupacional para recuperar la movilidad en las manos. Ver figura 3.

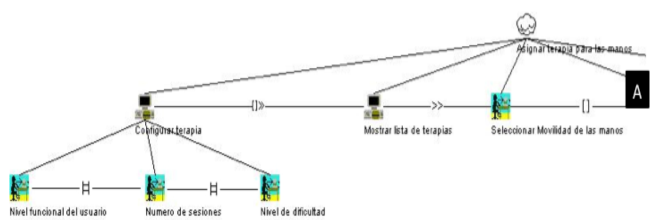
5.2 Fase de Modelado

Con ayuda del especialista en terapia física se determina un conjunto de movimientos como parte del tratamiento para cada paciente, estos movimientos tienen su fundamento en las técnicas documentadas de terapia ocupacional y se dividen en movimientos de los dedos y movimientos del pulgar, tal como se muestra en la tabla 2.

Tabla 2. Movimientos de la mano [16]

Tipo de movimiento	Acción a realizar	Imagen
Movilidad de los dedos	Con la punta del dedo pulgar, intentar tocar la yema de cada uno de los otros dedos.	
Oposición del pulgar	Llevar el talón del dedo pulgar a la base de los dedos, comenzando por el índice y terminando por el meñique	

Estos movimientos permiten definir modelo de tareas del usuario con el conjunto de interacciones a simular en el ambiente interactivo, e identificar variables importantes para la retroalimentación del experto y el paciente, tales como, numero de sesiones programadas, duración de la sesión de terapia, avance registrado, entre otras. Tal como se muestra en la figura 4.



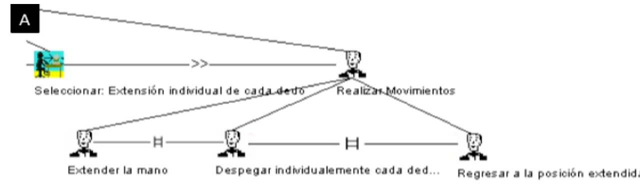


Figura 4. Modelo de conocimiento en forma de tarea del usuario: terapia asignada para la rehabilitación de la mano.

El modelo computacional [13] para el ambiente interactivo producido se compone de una plataforma Web creada a partir del lenguaje JavaScript para generar el escenario y objetos 3D, además un sensor que permite captar el movimiento de los dedos de la mano como medio de interacción del paciente con el ambiente interactivo.

5.3 Proyección

La proyección permite determinar la correspondencia de acuerdo al problema que se presenta y los usuarios objetivo [17]. El especialista en terapia física involucrado en el proceso de diseño del ambiente interactivo valida que efectivamente el ambiente interactivo producido, cuente con la retroalimentación requerida y sea el adecuado conforme al tratamiento y actividades de terapia ocupacional requeridas.

5.4 Exploración e integración

Durante esta fase con apoyo del especialista en terapia física se dieron instrucciones básicas a los pacientes sobre uso del ambiente interactivo, se describió en que consisten los escenarios virtuales y los objetos 3D en escena con los que se van a interactuar, y como usar el sensor de movimiento, por ultimo se indico como realizar las actividades de terapia ocupacional descritas en la tabla 2. Tal como se presenta en la figura 6.

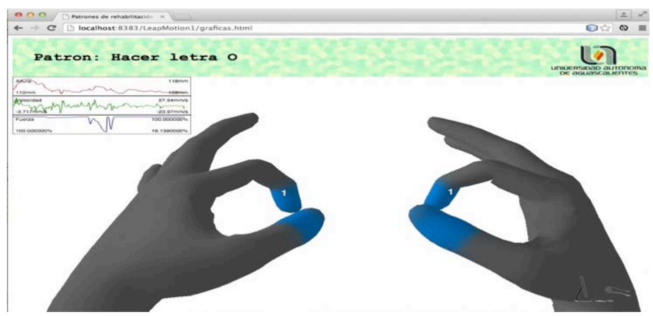


Figura 6. Rehabilitación de la mano por medio de terapia ocupacional en terapia física del DIF Aguascalientes, México.

Se estableció una sesión de 20 minutos en promedio por cada paciente donde realizo las tareas indicadas por el ambiente interactivo y la información captada en esta sesión permito obtener información que va desde la percepción de los pacientes a una nueva forma de llevar su proceso de recuperación por medio de la utilización de la tecnología hasta la forma de cómo estos ambientes ayudan a asiste el proceso de rehabilitación y obtener información para la retroalimentación para el especialista y el paciente.

5.5 Fase de Resultados

Los resultados permiten definir nuevas variables que permitan la retroalimentación del modelo con esto se puede garantizan en lo posible el modelo adecuado para asistir el proceso de rehabilitación del usuario. Ver tabla 3.

Tabla 3. Tabla de resultados de uso de ambientes interactivos en pacientes del DIF Aguascalientes, México.

Paciente	Grado de Fuerza	Velocidad de movimientos	Mov. de los dedos	Movimientos de alcance
Paciente A	Medio	Medio	3 / 4	Completado
Paciente B	Medio	Medio	3 / 4	Completado
Paciente C	Medio	Medio	4 / 4	Completado
Paciente D	Bajo	Bajo	3 / 4	Completado
Paciente E	Bajo	Bajo	1 / 4	Completado

Los resultados obtenidos son producto de la realización de las actividades descritas en la tabla 2. Estos resultados son de utilidad tanto al experto como al paciente para conocer la situación actual en cuanto a la movilidad de las manos, los ambientes interactivos expuestos en este experimento permitieron que el paciente conociera nuevas formas de interacción para poder realizar su sesión de rehabilitación.

5.6 Evaluación

Al concluir la fase de exploración con los pacientes, un cuestionario de usabilidad basado en escenarios [18] es aplicado, con el propósito de ser un soporte para medir la satisfacción de los usuarios en relación con la facilidad de uso de los sistemas informáticos. La aplicación de este cuestionario a los pacientes participantes en el caso de estudio se realizo por medio de la observación, un punto importante a considerar es que muchas veces los usuarios con discapacidad no les es tan sencillo poder contestar un cuestionario como lo haría una persona sin discapacidad, ya que en algunos casos se requiere la asistencia del profesional en rehabilitación por lo que se deben definir estrategias para la evaluación de la usabilidad para este tipo de usuarios.

6. CONCLUSIONES

Este trabajo resalta la importancia de contar con una método para el diseño de ambientes interactivos como una solución donde se capturan no sólo los aspectos funcionales de los usuarios, sino también aquellos que se relacionan con el contexto de la rehabilitación, además de considerar las mejores prácticas utilizadas por los especialistas en rehabilitación y llevarlas a un espacio de rehabilitación interactivo. El caso de estudio permitió probar el método propuesto y dar seguimiento a la problemática planteada. La puesta en marcha de ambientes interactivos en los pacientes del DIF para la rehabilitación de la mano, permitió obtener resultados para la retroalimentación de los expertos y pacientes además de observar un efecto cognitivo de una mejor percepción de los objetos en relación con el miembro en rehabilitación. Por ultimo, los ambientes interactivos permiten adaptar el entorno a las necesidades de los usuarios y especialistas, lo que brinda a los usuarios contar con un soporte en su proceso de rehabilitación.

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Experiencias de evaluación de herramientas tecnológicas para la asistencia de personas con discapacidad cognitiva

Juan C. Torrado
Universidad Autónoma de Madrid
Escuela Politécnica Superior
c/ Francisco Tomás y Valiente, 11
+34914972292
juan.torrado@uam.es

Javier Gómez
Universidad Autónoma de Madrid
Escuela Politécnica Superior
c/ Francisco Tomás y Valiente, 11
+34914972292
jg.escribano@uam.es

Germán Montoro
Universidad Autónoma de Madrid
Escuela Politécnica Superior
c/ Francisco Tomás y Valiente, 11
+34914972210
german.montoro@uam.es

RESUMEN
Este artículo describe un conjunto de técnicas, recomendaciones y métricas para validar herramientas software que tengan como objetivo la asistencia a personas con discapacidad cognitiva. A continuación se describen tres experiencias reales de evaluación de tres herramientas de este tipo (para guiado en tareas cotidianas, desplazamiento en interiores y desplazamiento en exteriores), en las cuales se aplican total o parcialmente estas métricas y recomendaciones. Por último, se discute cuáles de ellas han resultado más válidas para describir la usabilidad de los sistemas propuestos, y se señalan posibles vías de mejora de las mismas.

Palabras clave
Evaluación de usabilidad, discapacidad cognitiva, experimento con usuarios, métricas, experiencias de uso

1. INTRODUCCIÓN
Cualquier tipo de herramienta tecnológica que quiera ser difundida o puesta en el mercado ha de ser evaluada previamente. Esto se aplica de la misma forma a tecnologías para la asistencia, que son "aquellas que facilitan la ejecución de actividades o la interacción con el entorno físico y social de las personas en situación de discapacidad" [13]. Todo tipo de tecnología utilizada para ayudar a estos usuarios debe asegurar que ha sido probada en las circunstancias suficientes como para que se desempeñe su uso adecuadamente. Por ejemplo, una silla de ruedas deberá pasar múltiples pruebas de resistencia y ergonomía, al igual que unas muletas prostéticas o unas gafas especiales.

En este artículo nos centraremos en un tipo particular de tecnologías para la asistencia, que son las denominadas "de alta tecnología", y que comprenden todas aquellas soluciones relacionadas con Tecnologías de la Información (TIC). Actualmente están creciendo las líneas de investigación que se centran en este tipo de tecnologías para la asistencia, por lo que el método de probarlas y evaluarlas planteará un problema creciente a resolver. Se trata de un problema cuya dificultad radica en la naturaleza compleja de la propia discapacidad cognitiva [5]. Además, cuando ya se trata de herramientas software, la evaluación se concibe de distinta manera, ya que un programa no es un objeto físico que podamos evaluar de la misma manera que haríamos con otro tipo de tecnologías para la asistencia como las prótesis.

En estos casos, surgen varias preguntas: ¿Cuándo se considera que una herramienta software de estas características está evaluada? ¿A dónde queremos llegar? ¿Qué tipo de pruebas debemos realizar? ¿En qué fase del desarrollo? ¿Incluimos o no a los usuarios en el proceso?

El proceso de desarrollo es el objeto de estudio de la disciplina llamada Ingeniería del Software, que proporciona, entre otras cosas, modelos de proceso que esquematizan y regulan el desarrollo de software. Estos modelos de proceso distinguen varias fases a lo largo del desarrollo, entre los que se incluyen la extracción de requisitos, el análisis, el desarrollo, la implementación, la evaluación y el mantenimiento. Como vemos, estos modelos de proceso incorporan el proceso de evaluación en el plan, y las distintas fases se llevarán a cabo de una forma u otra y en un determinado orden dependiendo del modelo de proceso concreto que se haya escogido. Estos modelos de proceso se prescriben teniendo en cuenta el tipo de software que vamos a desarrollar, y en qué circunstancias.

Por tanto, cabe preguntarse a continuación: ¿existen modelos de proceso y tecnologías concretas y normalizadas para evaluar software destinado a este tipo de usuarios? Podemos afirmar que es un área poco trabajada desde el punto de vista formal, y entender la tendencia a la hora de evaluar tecnologías para la asistencia implica hacer una revisión de las publicaciones al respecto de estos productos y propuestas, pero desde una perspectiva diferente, es decir, estudiar cómo han evaluado los investigadores sus propias propuestas, en lugar de centrarse en las mismas.

En el Laboratorio de Inteligencia Ambiental (AmILab) hemos desarrollado tres herramientas software destinadas a asistir a personas con discapacidad cognitiva y situación de inclusión laboral en sus tareas de la vida diaria [9]. En concreto, son tres aplicaciones Android instaladas en sus *smartphones* que les proporcionan guías interactivas para realizar tareas cotidianas (AssisT-Task), guiado en exteriores a partir de localización GPS (AssisT-Out) y guiado en interiores a partir de códigos QR (AssisT-In). A la hora de realizar su evaluación, con el objetivo de difundirlas y mejorarlas, surgieron los interrogantes que planteamos anteriormente. Al no encontrar ninguna metodología orientada específicamente a validar software para personas con discapacidad cognitiva, planificamos esta fase a partir de la recopilación de técnicas puntuales utilizadas por otros investigadores a la hora de validar sus herramientas.

En este artículo analizamos las técnicas que se suelen utilizar en la fase de evaluación de este tipo de sistemas, así como su nivel de adecuación a estos casos. Por otra parte, describiremos el conjunto de técnicas y métricas que hemos utilizado para evaluar nuestras propias herramientas, con el objetivo de aportar elementos de base a posibles formalizaciones de una metodología para estos casos.

2. TÉCNICAS DE EVALUACIÓN

En esta sección analizamos el conjunto general de técnicas y metodologías empleadas en la evaluación de software en cuanto a su adecuación a la validación de herramientas de asistencia para personas con discapacidad cognitiva. Esta adecuación se valora teniendo en cuenta el uso que se le ha dado en experimentos evaluativos realizados en la literatura, o bien la opinión de los educadores con los que hemos tratado durante nuestros experimentos y los resultados obtenidos.

En primer lugar acotaremos nuestro estudio a técnicas de evaluación que pertenecen al ámbito de metodologías centradas en el usuario (MCU [8]). La razón para hacerlo así es que el tipo de usuario al que va dirigido. Por lo tanto resulta más adecuado partir de metodologías de diseño centradas en usuarios, en general, para analizar cómo se pueden adaptar para usuarios con discapacidad cognitiva, concretamente. Además, podemos descartar de inicio técnicas de validación que implican un grado de participación del usuario medianamente complejo, como el *card-sorting*, el recorrido cognitivo con usuarios [10] o las cartas de reacción de Microsoft [2].

2.1 Planificación

Planificar una evaluación de software a través de experimentos con usuarios implica planificar un número de sesiones, unas tareas a realizar, un lugar en el que hacerlo y un grupo de usuarios significativo. Ahora bien, realizar el estudio con personas con discapacidad cognitiva dificulta el acceso y la planificación de varios de estos puntos.

2.1.1 *Lugar de las sesiones*

Estos usuarios ofrecen unas particularidades de comportamiento que se deben tener en cuenta a la hora de escoger un lugar en el que realizar las sesiones que conformarán el experimento. Podemos planificar las sesiones en un lugar desconocido para ellos (normalmente, el entorno académico que convenga a los evaluadores). En un usuario sin discapacidad esto no supondría ningún problema, ya que el desconocimiento del lugar no suele afectar a la experiencia de uso de un producto software. Sin embargo, para estos individuos, puede suponer un problema conductual porque la expresión del miedo o la incertidumbre es más acuciada, y la concentración que mantendrá en el experimento no será la misma. Para paliar este problema sugerimos varias alternativas. Por una parte, es muy conveniente que los educadores y terapeutas con los que están familiarizados estén presentes durante las sesiones. Servirán de ayuda para centrar a los usuarios y advertir a los evaluadores y observadores acerca de qué particularidades conductuales son normales en ese usuario y cuáles son reacciones naturales al experimento.

A lo largo de experiencias evaluativas propias, hemos observado que también resulta muy conveniente hacer que los usuarios se familiaricen con los propios evaluadores. Inicialmente, esto se puede conseguir visitando los centros previamente para explicarles lo que van a hacer y para qué sirve, así como insistir en presentarse y recibir preguntas. También es recomendable planificar visitas previas a las sesiones al centro donde realizarán las sesiones. Además, los centros de educación especial agradecerán el aporte académico que proporciona a los usuarios visitar centros universitarios y de investigación. Estos consejos también son válidos para cuando las sesiones de entrenamiento se llevan a cabo en un centro laboral que aún no conocen, y donde desempeñarán unas tareas. Estos centros suelen contar con tutores propios para estos casos.

Por otra parte, en ocasiones es necesario realizar las sesiones en los propios centros. Esto puede deberse a que el experimento requiere material inmueble de los mismos, o que por razones que atañen a los propios usuarios, resulta inviable realizar la visita. Esto supone para ellos un ambiente de confianza, aunque también es recomendable que los educadores estén presentes.

2.1.2 *Selección de usuarios*

En muchas ocasiones la selección de usuarios vendrá motivada por factores externos como la disponibilidad de los individuos y sus educadores, o del material necesario para recrear las sesiones (por ejemplo, para realizar entrenamiento laboral, se debe tener el mismo material que usarán en su puesto de trabajo). La dificultad de lograr planificar una evaluación con un grupo de usuarios con discapacidad cognitiva implica que la mayoría de los experimentos de la literatura cuenten con un número reducido de usuarios (en torno a la decena de individuos por experimento). Cuanto mayor sea el número de participantes, más significativos serán los resultados de los análisis que se realicen sobre los datos de las sesiones (e.g. estadística descriptiva). Existen estudios con grupos mayores de usuarios con discapacidad cognitiva, pero se trata de encuestas telefónicas y experimentos en entornos no controlados [7].

Con un grupo numéricamente significativo de usuarios, se suelen realizar grupos, de tal forma que se puedan hacer comparaciones entre medidas tomadas. El criterio de agrupación depende enormemente del motivo que lleve a agruparlos, pero existen varias tendencias:

- Nivel de discapacidad: los centros de educación especial cuentan con varias escalas para clasificar la diversidad funcional cognitiva de sus estudiantes (nivel de dependencia, porcentaje de discapacidad, conjunto de destrezas o perfil laboral, entre otros), y es conveniente que los evaluadores pidan esta información si desean estratificar los grupos adecuadamente.
- Cantidad de experiencia: si la evaluación requiere el manejo de una tecnología concreta (ordenador, teléfono móvil, Smartphone o Tablet) se puede realizar un sondeo previo (a través de encuestas o entrevistas con personas del entorno) para calcular la experiencia previa de los usuarios en el uso de esa tecnología.
- Disponibilidad: por motivos de horarios académicos y laborales, existe la posibilidad de que se tengan que agrupar a los usuarios según su tiempo disponible para la evaluación, de no ser homogéneo.

Aplicar estos criterios no implica necesariamente que los grupos de usuarios tengan que formarse agrupando individuos con las mismas características de cada clase. Puede resultar interesante formar muestras estratificadas de usuarios. Por ejemplo, si observamos el nivel de discapacidad de una muestra determinada, podemos formar los grupos de tal manera que haya una distribución homogénea de niveles de discapacidad en cada grupo, de tal forma que podamos compararlos como algo equivalente, asegurándonos además de que cada uno de ellos presenta variabilidad interna. Dado que el nivel de discapacidad es uno de los factores que más influyen en los resultados de este tipo de experimento [11], es conveniente formar grupos equivalentes a partir de muestras con variedad de niveles de discapacidad. Si el experimento, hecho de esta manera, ofrece resultados positivos (aplicando métricas que veremos en secciones posteriores), se puede afirmar que el software evaluado ofrece soporte para un rango amplio de usuarios con discapacidad. Este es uno de los resultados más buscados a la hora de diseñar estos productos, ya que la discapacidad cognitiva es por naturaleza compleja y difícil de clasificar en subtipos, por lo que las herramientas que presentan este tipo de tolerancia a niveles de discapacidad dispares son muy apreciadas en la investigación y en el mercado.

También atañe a la selección de participantes saber la manera en las que vamos a tomar medidas y vamos a realizar las sesiones, en cuanto a los siguientes modos:

- Medidas intra-sujeto (*within-subjects*): varias sesiones por usuario en una misma tarea, para medir aprendizaje y tiempos; hay que tener en cuenta que estos usuarios se fatigan en mayor medida que otro tipo de usuarios, por lo que hay que planificar las sesiones para evitar que afecte al rendimiento de las pruebas o buscar otras alternativas de compensación. También hay que tener en cuenta el aprendizaje acumulado de una sesión para otra, y si ello afecta a otros resultados al margen de la curva de aprendizaje.
- Medidas inter-sujeto (*between subjects*): se trata de comparar el rendimiento de varios usuarios para una única tarea.
- Medidas mixtas: comparan grupos de usuarios equivalentes a lo largo de varias sesiones, añadiendo significación a las medidas inter-sujeto y permitiendo, a su vez, comparar el rendimiento de cada usuario consigo mismo a lo largo de las sucesivas sesiones (intra-sujeto).

Escoger el modo de realizar las sesiones y la configuración de sujetos depende enormemente del objetivo de la evaluación. Si queremos realizar una comparación entre dos elementos de asistencia (por ejemplo, el utilizado tradicionalmente en su formación en comparación con la propuesta tecnológica del estudio en cuestión), es necesario realizar medidas inter-sujeto. Si, por otra parte, se desea analizar directamente el aprendizaje de los usuarios con el uso de la tecnología aplicada, se deberían realizar varias sesiones y efectuar medidas intra-sujeto. Las medidas mixtas, por tanto, son idóneas para cuando se quiere realizar un estudio simultáneo de la mejora que produce la aplicación de tecnología en la realización de tareas para estos usuarios y el aprendizaje que obtienen con esa ayuda a lo largo de las primeras etapas de uso.

Desde un punto de vista formal, tener en cuenta este tipo de circunstancias e integrarlas en una experiencia de usuario caracterizan este tipo de validación como de inspección (los expertos, que en este caso son los educadores, observan la herramienta y sugieren cambios), de indagación (hablando con los usuarios y obteniendo información directa de ellos y de su actividad usual relativa a la herramienta) y de test (poniendo a los usuarios a utilizar la herramienta a lo largo de una serie planificada de sesiones) al mismo tiempo [10].

2.2 Métricas

2.2.1 *Métricas objetivas*

Las métricas que vamos a presentar a continuación son aquellas que ofrecen resultados derivados de la observación y cuantificación de eventos que se producen a lo largo de las sesiones de evaluación. Se han seleccionado estas a partir de la combinación de las métricas clásicas de experimentos de usabilidad con usuarios, recopiladas por Tullis y Albert [1], y aquellas métricas que utilizan varios autores en la literatura en sus experimentos con usuarios con discapacidad cognitiva. A su vez se señalan algunas medidas útiles que indican los educadores de estos individuos. También es frecuente utilizar medidas *ad hoc* que atiendan a la naturaleza de la asistencia que se pretende proporcionar con la herramienta.

2.2.1.1 Tiempo de completado

Si bien en la mayoría de experiencias con usuario, el tiempo que se tarda en desempeñar una tarea es una de las medidas más importantes a la hora de validar una herramienta software, en el caso de individuos con discapacidad cognitiva no se trata de una medida tan relevante. Los educadores, a lo largo de nuestras experiencias de evaluación, insistieron en que tanto en el ámbito académico con el laboral, se prefiere que los usuarios completen la tarea exitosamente a que lo hagan en un tiempo determinado. Sí es cierto que se atiende a excepciones en las que el tiempo de completado es exageradamente amplio, en cuyo caso se observarán los motivos a través de otras métricas como la confusión o las peticiones de ayuda; u ocasiones en las que los individuos emplean un tiempo mínimo en completar la tarea, o en finalizarla, creyendo que la han completado exitosamente. Este último caso es frecuente cuando los individuos presentan una conducta impulsiva frente al aprendizaje de tareas, que a su vez es un caso muy frecuente en individuos con discapacidad cognitiva.

Por tanto, es necesario medir este factor durante las sesiones pero analizar los resultados que se derivan de él a través de la relación con el resto de métricas, en mayor medida que en las siguientes.

2.2.1.2 Fluidez

Ya que, como hemos visto, el tiempo de completado comprende aspectos muy amplios y contingencias muy variadas de la actividad del usuario con diversidad funcional de carácter cognitivo, es necesario definir métricas nuevas que reflejen el carácter temporal del rendimiento de los usuarios de forma más precisa. Proponemos para ello medir la fluidez con la que se desempeñan las subtareas que comprenden la tarea realizada en cada sesión. Entendemos fluidez como la distribución homogénea y consecuente del tiempo empleado en completar dichas subtareas.

Esto se puede medir de forma cualitativa, estableciendo una escala de fluidez y asignando una puntuación dentro de dicha escala, deducida a partir de la observación de las sesiones (teniendo en cuenta el factor subjetivo que conlleva esta asignación deliberada) o calcular un valor de fluidez a partir de los tiempos medidos objetivamente entre cada par de subtareas. Hacer uso de algún cálculo de estadística descriptiva como la media o la desviación típica de estos tiempos dentro de una sesión pueden dar una idea de si estos tiempos presentan un carácter homogéneo o si, por otra parte, se ha tardado mucho más en desempeñar una subtarea que otra, derivando en un valor de fluidez comprometedor.

Si el análisis de la fluidez evidencia que este valor se altera en una misma subtarea para varios usuarios, se debe estudiar, a través del resto de métricas o de la observación directa de las sesiones, la razón que lo motiva. Debemos tener en cuenta además que, al igual que ocurre con el tiempo de completado, este tipo de métricas, de carácter temporal, se ven influenciadas en gran medida por la diversidad conductual que presentan estos individuos, y cuyos efectos emplean tiempo en las sesiones (por ejemplo, individuos con trastornos del espectro autista, que implican ayuda de los educadores para la comunicación con ellos y la interpretación de sus gestos y reacciones a lo largo de las sesiones).

2.2.1.3 Tasa de error

Cuantificar los errores que comenten los usuarios durante las sesiones da una idea de la precisión con la que realizan la tarea. Sin embargo, los educadores insisten en que uno de los aspectos fundamentales que deben trabajar estos individuos es la percepción del error. Si, al finalizar una serie de sesiones, preguntamos a los usuarios si han realizado la tarea bien o mal, las respuestas muchas veces no coincidirán con la realidad. En algunos casos, la impulsividad les lleva a acabar cuando antes, y erróneamente, una tarea, afirmando tajantemente que lo han hecho bien. Otras, emplearán mucho tiempo y se bloquearán en el proceso, de forma que aunque finalicen correctamente afirmarán haber completado erróneamente la tarea simplemente por las dificultades que han encontrado durante la realización.

Por ello, es importante complementar la medición de los errores con la pregunta a los propios usuarios de cómo creen que lo han hecho. Aunque más tarde los educadores pueden puntuar en una escala más amplia cómo de bien lo han hecho, para ellos es conveniente presentarles la pregunta de forma binaria, de manera que no se añada más dificultad de la que ya les supone la propia autoevaluación.

2.2.1.4 Número de intervenciones

Como complemento a la tasa de error se propone incluir como factor de evaluación el número de veces que los evaluadores o educadores han tenido que intervenir durante el proceso [6] [16], por las razones que sean. Recomendamos realizar estas intervenciones de forma mitigante (cuando el usuario haya realizado alguna acción que le impida continuar) y no preventiva (dejarle cometer el error, de tal forma que perciba claramente que ha fallado, y que no peligren otras métricas que se basan en el error). Muchos investigadores observarán que el número de intervenciones arrojan resultados mucho más significativos que la tasa de error, ya que el concepto de error, como comentábamos, está menos definido con estos usuarios, mientras que la necesidad de intervenir está muy clara. Este resultado es particularmente interesante cuando la herramienta que se valide sea una propuesta de mejora de su inserción laboral, ya que en este ámbito la autonomía del usuario es el objetivo óptimo.

2.2.1.5 Confusión

Son momentos de confusión aquellos en los que el usuario se bloquea y no realiza ninguna acción representativa para avanzar con la tarea. Su presencia en las sesiones (o, visto de otra manera, su ausencia) da una idea de la precisión con la que los usuarios utilizan la herramienta. Aunque es una métrica de significado muy simple, los resultados que ofrece son enormemente significativos en el análisis del rendimiento de estos individuos. Se debe prestar atención a no confundir error con confusión: el primero es una acción que impide el éxito de la tarea, mientras que el segundo es la ausencia de acción, durante un intervalo de tiempo prolongado. Una ofrece un resultado de usabilidad global, y la otra aporta datos sobre la actitud y el comportamiento concretos del usuario, respectivamente.

2.2.1.6 Satisfacción o frustración

Es necesario que los evaluadores observen atentamente los comentarios de los usuarios durante las sesiones. En muchas ocasiones, se muestran muy expresivos (sobre todo, en ambiente de confianza [12]) y comentan en voz alta las impresiones que van obteniendo de la experiencia (a modo de *Thinking Aloud* [3]).

2.2.1.7 Peticiones de ayuda

Se incluyen aquí peticiones de ayuda explícitas a los evaluadores o educadores, o implícitas, cuando necesitan una intervención pero no llegan a formular la petición, por timidez o bloqueo.

2.2.2 *Métricas subjetivas*

La valoración subjetiva de la experiencia de uso se dificulta enormemente en el caso de usuarios con discapacidad cognitiva, ya que los cuestionarios y las encuestas, que son la forma más común de obtener este tipo de valoraciones, implican cierto grado de comunicación con el usuario.

Por tanto, en caso de realizar entrevistas, tendrán que ser mediando a través de los educadores, quienes servirán de ayuda para entender sus respuestas y para transmitir las preguntas. Ocasionalmente, aunque el usuario sea capaz de entender y responder a las preguntas del evaluador, no contesta adecuadamente por problemas conductuales o timidez y desconfianza, en cuyo caso la presencia del educador sigue siendo necesaria. En el caso de realizar cuestionarios escritos, los evaluadores deben asegurarse de que todos los implicados tienen el nivel necesario para realizarlos, aunque incluso así se puede seguir necesitando a los educadores.

En cuanto a los cuestionarios concretos, se suelen utilizar los cuestionarios normalizados de usabilidad (SUS [4], USE [15]), siempre que se adapte el lenguaje para que los usuarios los entiendan. Sin embargo, pese a la adaptación que se pueda realizar, existen muchos factores que restan utilidad a estos cuestionarios. Como hemos señalado anteriormente, problemas conductuales como la impulsividad o la dificultad de comunicación hacen que las respuestas puedan perder valor (un usuario impulsivo responde que sí a todo, u otorga la máxima puntuación a todas las preguntas, con tal de acabar rápido, y otros usuarios confundirán el entender la pregunta con el entendimiento de la herramienta que han utilizado, sin mencionar la capacidad de memorización y razonamiento que requiere contestar a este tipo de preguntas).

3. EXPERIENCIAS DE EVALUACIÓN

En esta sección describiremos tres experiencias de evaluación con usuarios con discapacidad cognitiva que llevamos a cabo el Laboratorio de Inteligencia Ambiental (AMILAB) de la Escuela Politécnica Superior de la Universidad Autónoma de Madrid, con la colaboración de la Fundación Síndrome de Down de Madrid (FSDM) y el Instituto de Psico-Pediatría Doctor Quintero Lumbreras (IPP).

Los tres experimentos se enmarcan dentro del proyecto AssisT, cuyo objetivo es el desarrollo de herramientas software para móviles que ofrezca una asistencia integral a individuos con discapacidad cognitiva, abordando tres aspectos de su vida: los desplazamientos en interiores (AssisT-In), desplazamientos en exteriores (AssisT-Out) y tareas cotidianas (AssisT-Task). Se propone ofrecer asistencia en estos tres ámbitos mediante el uso de sus respectivas aplicaciones *smartphone*.

Al tratar de validar las tres herramientas es cuando surgió la necesidad de adaptar técnicas de evaluación a las necesidades y el contexto de estos usuarios. Dichas evaluaciones dieron lugar a las experiencias que describimos a continuación.

AssisT-Task

AssisT-Task proporciona guías interactivas para la realización de tareas de la vida cotidiana, como cocinar, poner una lavadora o imprimir un documento. Los usuarios escanean con el *smartphone* un código QR que contiene la etiqueta identificativa de la tarea, y reciben la ayuda para completar la tarea en cuestión. Estas guías interactivas están enriquecidas con distintas posibilidades, como bifurcaciones, repetición de pasos y adaptación de secuencias de pasos a los usuarios.

Para probarla, contamos con un grupo de 10 usuarios de la FSDM durante su capacitación laboral. A lo largo de su formación para obtener empleo, el entrenamiento que realizaban era a través de soporte en papel, que contenía la lista de instrucciones para completar cada tarea, como hacer fotocopias, ordenar folios, encuadernar libros, etc. Por tanto, el interés de evaluar nuestra propuesta residía en la comparación entre el rendimiento con este soporte tradicional y el rendimiento con la herramienta. Por esta razón separamos a los 10 usuarios en dos grupos (medidas inter-sujeto), ambos con variabilidad interna en cuanto a niveles de discapacidad cognitiva, de forma que los podíamos comparar. De esta manera, un grupo realizaría la tarea con soporte tradicional y el otro con AssisT-Task. Sin embargo, también queríamos probar con dos tareas diferentes, para evitar sesgar nuestro experimento por la selección de la tarea. Así, un grupo realizó una tarea con soporte tradicional y la otra con AssisT-Task, y viceversa para el otro grupo, a modo de *Latin Square*. Una tarea fue realizar fotocopias (más destreza manual) y la otra archivar contratos por año, código identificativo y orden alfabético (más destreza cognitiva). Era interesante, por otra parte, estudiar el aprendizaje que acumulaban con ambos soportes, de cara a su capacitación laboral, por lo que repetimos esta disposición a lo largo de 7 sesiones (medidas intra-sujeto).

Debido a razones de material, elegimos como lugar de las sesiones su centro de estudios, donde se recrearon los escenarios de empresa que se van a encontrar en sus puestos de trabajo: un rellano con fotocopiadora y una habitación de archivo. Para minimizar la necesidad de presencia de los educadores por motivos conductuales de los estudiantes, los evaluadores nos presentamos previamente a lo largo de varios encuentros en los que les explicábamos el experimento y el interés que motivaba validar la aplicación, así como la utilidad en el futuro que podría tener para ellos mismos.

Una vez planificado el lugar, los usuarios, su disposición, y el esquema de sesiones, llevamos a cabo las mismas. Para ello, dos evaluadores observamos in situ la actividad de los usuarios, tomando notas y grabando en vídeo la misma.

Posteriormente, analizamos los resultados a partir de un visionado detallado de los vídeos, en los que detectábamos cada eventualidad en la actividad del usuario (inicio y fin, subtareas, comentarios, errores, intervenciones y momentos de confusión), a partir de etiquetas que almacenamos en un fichero de registros. Por otra parte, la propia aplicación almacenaba en otro fichero de registros los datos de interacción con el dispositivo. Todos esos datos fueron procesados de manera automática, recopilados y etiquetados para cada usuario. De esta manera, obtuvimos los resultados de las métricas en comparación para uno u otro grupo, así como su evolución a lo largo de las sesiones. De las métricas comentadas anteriormente, las peticiones de ayuda y la cuantificación de comentarios de satisfacción o frustración no resultaron significativas, ya que obtuvimos pocas muestras.

3.1 AssisT-Out

AssisT-Out asiste a usuarios con discapacidad cognitiva en sus desplazamientos en exteriores. A través del sensor GPS del dispositivo, se detecta la posición inicial del sujeto y se le ofrecen imágenes a pie de calle adaptadas para guiarle a lo largo de su recorrido hasta el destino seleccionado.

De nuevo tuvimos acceso a los estudiantes de la FSDM; esta vez, a 18 de ellos. El entrenamiento que reciben en este centro para el guiado en exteriores consiste en el acompañamiento del individuo, que se va retirando progresivamente hasta que aprende la ruta por sí mismo. En este caso, el interés de validar la herramienta no residía en comparar nuestra propuesta con este soporte presencial (la necesidad de sustituir este soporte, más que por el rendimiento, es por el coste logístico y económico que requiere precisar de una persona en cada sesión de entrenamiento del usuario), sino con otros tipos de herramientas de guiado en exteriores de uso común, como Google Maps. Por tanto, dividimos a los usuarios en dos grupos y precedimos de la misma manera que AssisT-Task: comparación cruzada (*Latin Square*) entre los dos grupos de usuarios y dos rutas seleccionadas.

Previamente, realizamos varias presentaciones ante el grupo de estudiantes con el objetivo de generar un ambiente de confianza e informarles del experimento y sus condiciones. En el inicio de cada sesión realizábamos un recorrido mínimo (andar unos metros y doblar una esquina) con cada usuario para explicarle el funcionamiento de una aplicación, y a continuación se realizaba la ruta completa. Un evaluador utilizó una cámara para obtener una grabación en tercera persona, y el evaluado llevó durante la sesión una cámara GoPro para obtener una vista en primera persona. Esta segunda modalidad de registro nos permitía añadir más medidas al experimento, como cuantificar la atención al móvil o al entorno, obtener comentarios y percibir la experiencia del usuario con más claridad.

Las sesiones fueron espaciadas, con semanas intermedias sin sesiones, pues el experimento era exhaustivo y queríamos mitigar en la medida de lo posible los efectos de la fatiga y el aprendizaje acumulado sobre nuestras medidas. Después de cada sesión, realizábamos un test corto en el que mostrábamos imágenes a los usuarios; algunas pertenecían a la ruta realizada y otras no. Preguntándoles si habían pasado por ahí, obteníamos una medida adicional del reconocimiento espacial que habían adquirido.

Se procesaron los datos de la misma manera que AssisT-Task, con la salvedad de que introdujimos dos medidas nuevas: si llegaban o no al destino (no confundir la tasa de error, que es el número de errores puntuales que cometen a lo largo del recorrido, no miden el éxito global de la tarea) y el porcentaje de atención que prestaban al teléfono y al entorno; esta última es necesaria en tanto a que una aplicación que ofrece un guiado mientras se desplazan por la calle no debe acaparar una atención excesiva: no debemos olvidar que la intención principal de este método de asistencia sería el aprendizaje de las rutas y la adquisición de autonomía (en definitiva, retirar la asistencia progresivamente).

3.2 AssisT-In

AssisT-In ofrece guiado en interiores a partir de códigos QR. Estos códigos se utilizan para etiquetar puntos de un entorno, de tal manera que la aplicación ofrece asistencia interactiva para llegar a un destino desde un punto inicial.

Para la validación de esta aplicación contamos con un grupo de 14 usuarios del IPP, con índices de discapacidad cognitiva muy variados, y algún individuo con trastorno del espectro autista. Era necesario probar el prototipo en un entorno que no conocieran, para que la asistencia fuera totalmente necesaria, por lo que las sesiones tuvieron lugar en la Escuela Politécnica Superior de la Universidad Autónoma de Madrid (divididas en dos días diferentes, para facilitar el acceso a todo el grupo de alumnos al centro). Los usuarios comienzan escaneando un código QR y seleccionando un destino, y la aplicación les va mostrando imágenes de los puntos intermedios que deben ir visitando y escaneando, hasta que llegan al destino. Para facilitar el acceso al centro, dividimos las sesiones en dos días, con 7 usuarios y sus respectivas sesiones cada uno. En el experimento contamos con la presencia de 2 educadoras del centro, que sirvieron como puente de comunicación con usuarios con trastorno del espectro autista y para adaptar los cuestionarios. Antes del experimento, realizamos un cuestionario sobre el uso de las tecnologías para confirmar la idoneidad de los *smartphones* como plataforma para estas aplicaciones.

En este caso, no había soporte previo con el que compararlo, y tampoco había un interés por parte de los educadores por que aprendiesen este entorno en concreto, por lo que se realizó una única sesión para cada usuario (medidas inter-sujeto). Además, realizamos con cada uno una breve sesión de entrenamiento con tres códigos QR para enseñarles el manejo básico de la aplicación. Después, realizaban la ruta de test, acompañados de un observador, con cámara de video, y una de las educadoras. Tras cada sesión, se pasó un cuestionario SUS adaptado a los usuarios.

El análisis de los datos fue idéntico a AssisT-Task y AssisT-Out: un análisis manual de los vídeos y uno automático de los registros derivados del mismo y de los generados por la interacción del usuario con el dispositivo. Además incorporamos las medidas de los cuestionarios pre-sesión y post-sesión como factores subjetivos para esbozar la impresión y la satisfacción de los usuarios con el sistema.

4. DISCUSIÓN

En esta sección vamos a considerar la validez de las técnicas y métricas propuestas en la sección 2 a partir de su aplicación en las tres experiencias de evaluación descritas en la sección 3.

En primer lugar, es interesante señalar que, aunque los tres casos de evaluación están aplicados a tres herramientas concretas, abarcan un rango de posibles ámbitos de asistencia (realización de tareas, desplazamiento en exteriores y desplazamiento en interiores) capaz de englobar múltiples casos futuros de validaciones de herramientas software para asistir a estos usuarios. Es por ello que consideramos que, a través de las experiencias descritas, la validez resultante resulta considerablemente significativa. En todo caso, no se descarta que las particularidades de futuras experiencias y casos de evaluación exijan la aplicación de métricas nuevas, o la eliminación de algunas aquí propuestas. Como se ha comentado anteriormente, la misma naturaleza compleja de la discapacidad cognitiva es un obstáculo para la generalización de técnicas y afirmaciones categóricas.

Desde el planteamiento de las distintas opciones acerca de dónde realizar el experimento, se sugirió en cualquier caso la presencia de educadores o personas conocidas. Ciertamente, en los tres casos de evaluación este hecho resultó indispensable: en AssisT-Task y AssisT-Out, los propios evaluadores se dieron a conocer previamente a los estudiantes pese a que los entornos eran su centro de estudios y alrededores; y en AssisT-In, el experimento no se hubiera podido llevar a cabo sin el acompañamiento de los educadores a lo largo del trayecto. Esto supone un problema logístico al organizar el experimento, pero se ha comprobado que amortigua posibles problemas conductuales que afectarían a las medidas tomadas durante las sesiones.

La elección de usuarios también está sujeta a vicisitudes externas al experimento, como su disponibilidad, la de sus educadores, y el número de usuarios. Partiendo de la base de que en nuestros experimentos este hecho no supuso gran problema, ya que dispusimos de grupos completos de alumnos, la elección se llevó a cabo bajo criterios de discapacidad cognitiva. En AssisT-Task y AssisT-Out, donde eran más numerosos y además teníamos que comparar el rendimiento con otra herramienta, realizamos dos grupos, organizamos dos tareas diferentes, y realizamos una comparación cruzada. La composición interna de ambos grupos estuvo estratificada, de forma análoga, entre ellos. Posteriormente, esto nos permitió aplicar estadística descriptiva asumiendo que ambos grupos eran comparables. Sin embargo, para otros experimentos, sugerimos analizar con cautela si, de cara al análisis de resultados, la composición interna de cada grupo podría ser homogénea. Por otra parte, las medidas intra-sujeto, es decir, la repetición de sesiones a lo largo del tiempo, resultó ser más valiosa, porque nos dio información detallada del aprendizaje de cada individuo, y el análisis conjunto de estos datos de cada grupo nos dio ya una información similar a la extraída de los estadísticos provenientes de las medidas inter-sujeto. No implica esto que se deba descartar la primera, ya que proporciona datos formales sobre la mejora producida por la aplicación del software propuesto.

En cuanto a las métricas, como ya se advertía, existe mucha más posibilidad de combinación. En dos de los tres experimentos realizados, añadimos medidas *ad hoc* que interesaban a raíz de las particularidades de los mismos. Por otra parte, se comprobó que algunas de las propuestas de índole general, no proporcionaron resultados significativos: en primer lugar, los comentarios de satisfacción o frustración, ya que los usuarios fueron menos propensos de lo esperado a proporcionarlos; y por otra parte, las peticiones de ayuda resultaron ser muy escasas, de una manera similar. Podría ser interesante entrenar a los usuarios previamente en el uso de técnicas como el *Thinking Aloud*, que proporcionaría directamente datos aprovechables para estas métricas, o decidir aplicarlas estudiando inicialmente si el grupo de usuarios del experimento es particularmente elocuente. También se observó que la métrica de fluidez no proporcionaba datos que aportasen algo diferente a la de tiempo de completado, por lo que quizá resulte interesante redefinirla, en caso de que se pueda extraer un dato aprovechable de ella, o directamente omitirla.

Los cuestionarios de usabilidad fueron muy difíciles de aplicar a los usuarios, pese al esfuerzo de adaptación del lenguaje y presencia de las educadoras. La impresión subjetiva de cada usuario acerca de la herramienta es imprescindible, y de ello depende en gran medida que posteriormente su aplicación en un caso real sea exitosa [7]. Por tanto, uno de los puntos más importantes en los que se debe trabajar a raíz de estas impresiones es la necesidad de idear un medio por el que obtener el grado de satisfacción de los usuarios tras un experimento. De nuevo, la complejidad y diversidad funcional de la discapacidad cognitiva es la gran barrera que obstaculiza este trabajo.

5. CONCLUSIONES

En este artículo hemos hecho una recopilación de técnicas y métricas que se suelen utilizar para evaluar experimentos de validación software para usuarios con discapacidad cognitiva. La escasez de estándares y métricas formalizadas nos llevan a adaptar las que se utilizan ampliamente en el mundo de la Ingeniería de Software. Muchas de estas técnicas implican la observación de las características conductuales del conjunto de usuarios de quienes disponemos y medir el nivel de dificultad para los usuarios que supone aplicar algunas de ellas. Muchas de las adaptaciones que se proponen consisten en adaptar el lenguaje que utilizan muchas técnicas como plataforma de obtención de información, minimizar la actividad cognitiva que suponen otras, y contar con la presencia de personas de confianza, como educadores o familiares; ya sea bien para la asesoría durante la planificación de los experimentos, como en las propias sesiones. En cuanto a las métricas que proponemos, describimos el tiempo, al fluidez, la confusión, el número de intervenciones, la tasa de error, las peticiones de ayuda y los comentarios de satisfacción y frustración como guías básicas de qué se debería medir en un producto software para estos usuarios; sin embargo, realizamos algunas especificaciones que se deberían tener en cuenta a la hora de medir dichos factores. Por ejemplo, las peticiones de ayuda no siempre son explícitas (de hecho, debido a la timidez y habilidades sociales de los usuarios objetivo, casi nunca lo son), y las intervenciones deberían ser mitigantes de errores, no preventivas, de manera que no sesguen los resultados de nuestro experimento.

Para ilustrar estas recomendaciones, hemos descrito también tres experiencias de evaluación donde tuvimos la oportunidad de aplicar algunas de estas ideas. Además, cada una de ella ofrecía particularidades distintas que requerían seleccionar unas técnicas u otras. Por ejemplo, la aplicación para asistir a través de *smartphone* en tareas de la vida cotidiana (AssisT-Task), suponía la sustitución de un soporte antiguo en panel, por lo que las técnicas se orientaron a estudiar la validez de nuestra propuesta en un sentido comparativo entre las dos ayudas. AssisT-Out asiste en los desplazamientos en exteriores, por lo que resultaba particularmente interesante estudiar la atención que los usuarios prestaban a elementos del entorno: utilizamos una cámara GoPro durante las sesiones, y al final de las mismas hicimos un test de reconocimiento de lugares por los que habían pasado. Para el guiado en interiores teníamos la aplicación AssisT-In, para la cual desplazamos a los usuarios a un entorno desconocido, y les pusimos a recorrerlo con la ayuda de la aplicación y la presencia de una educadora.

Un objetivo interesante a partir de estas ideas consistiría en formalizar una metodología de evaluación de productos software orientados a la asistencia de personas con necesidades especiales. Esta metodología, por múltiples razones que hemos ido analizando, debe ser flexible y adaptable a las diversas particularidades que presentan estos individuos, así como especificar un conjunto robusto de métricas de carácter objetivo y subjetivo que proporcionen un resultado de validez útil y que reseñe el grado de usabilidad de la herramienta. También conviene que esta metodología establezca las técnicas particulares de observación de las sesiones (por ejemplo, nuestro método consistía en grabar las sesiones, en tercera persona, y a veces primera) así como las de medición y recogida de datos (en nuestras experiencias, establecimos una serie de eventos a contabilizar, y repasamos los vídeos marcando y etiquetando estos sucesos).

Insistimos en que formalizar esta fase del proceso de desarrollo de este tipo de tecnologías para la asistencia responde a la necesidad de estructurar y organizar los experimentos que se están realizando en estas líneas de investigación, que han ido en considerable aumento a lo largo de los últimos años [14]. De esta forma, los productos que salieran al mercado tras este proceso tendrían más posibilidad de éxito, menor tasa de abandono, y su asistencia sería, en definitiva, más efectiva.

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ENGENDERING TECHNOLOGY (I)

An ICT experience in Computer Women Role promotion: WikinformáticA! in Aragón. Promoting the use of Wiki tools and visualizing the role of women in ICT

María Teresa Lozano
Centro Universitario de la Defensa de Zaragoza
Mayte.Lozano@unizar.es

Raquel Trillo-Lado
DIIS - EINA
Universidad de Zaragoza
raqueltl@unizar.es

María Villarroya-Gaudó
DIIS - EINA
Universidad de Zaragoza
maria.villarroya@unizar.es

Ana Allueva
Facultad de Veterinaria Universidad de Zaragoza
allueva@unizar.es

Eva Cerezo
DIIS - EINA
Universidad de Zaragoza
ecerezo@unizar.es

ABSTRACT

Nowadays, the number of female students that enroll in technical (architectural and engineering) degrees is quite low. So, numerous initiatives have arisen to promote these degrees and encourage female students to develop activities related to technical areas. In particular, we have organized the contest called Wikinforma´ticA! in Arago´n.

This contest was designed in order to achieve the following main goals: 1) encouraging female students to study degrees related to Information and Communication Technology (ICT), 2) disclosing the history of prominent women in the field of ICT in order to serve as role-model for new generations of female students, and 3) promoting collaborative work by means of Wiki tools and the use of search tools for images.

In this paper, we describe in detail how the context was organized, its development, and the results obtained by the different teams that participated.

Categories and Subject Descriptors

K.4 **[Computers and Society]**: Organizational Impacts: Employment

General Terms

Human Factors

Keywords

Women in engineering, engineering perception, gender equality, engineering studies, DokuWiki, outreach activities.

1. MOTIVATION

From the 90's the number of women enrolled in computer science has decreased significantly, from almost 30% of students to an actual 15%. In Spain, this situation comes together with a change in the degree name from Computer Science to Computer Engineering, produced at the early ninety's. Figure 1 shows the evolution of the students cursing Computer Engineering at all the Spanish Universities (5 years degrees, previous to the actual European grade system) Women rep- resent between 20% and 15% of all the students the data have been obtained from the Spanish National Statistics Institute [4]. From a sociologist point of view, a minority is considered below 30% of population, so women in computer science are a clear minority. In the case of the University of Zaragoza, our home university, the same trend has been observed, considering the same time period, despite in Figure 2 where yearly the presence of women has decreased 1%, from 25% to 15% in 10 years. Recent work from the University of Navarra shows same situation [7]. In other countries as the US [5] or other EU ones, same behavior has been observed.

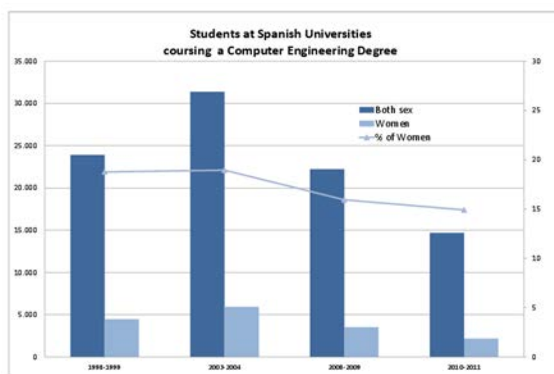


Figure 1: Evolution of students enrolled in computer engineering at Spanish Universities (1998-2011). Source [4].

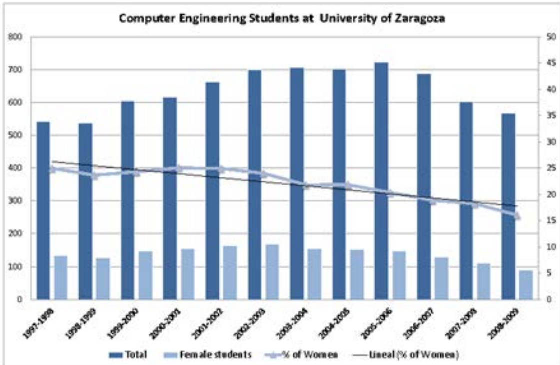


Figure 2: Evolution of students enrolled in computer engineering at University of Zaragoza. Source [9].

1984 is the year considered as the beginning of the decrement of women presence in programming[1], particularly relevant is the fact that the women in CS were the first that begin to stop programming. Nowadays, this trend is not going to change, if no external action is done.

An underline point on the EU agenda attending ICT is the women representation. Citing words by Neeliec Kroes, Vice-President of the European Commission and responsible for the Digital Agenda "This is not just about women's equality; we need to get more women in digital jobs and ICT research for the sake of our future competitiveness and prosperity" [3]. The lack of women in ICT has to be considered as a loose of part of the talent for this field, but also, as the reduction of the perspectives to face the research and innovation, which would influence dramatically the final results.

It is necessary to encourage young people to view engineering studies as a feasible and rewarding option, which is exciting and a valuable contribution to the society. Gender diversity has demonstrated better results in plenty of fields, stronger development and higher market success. Many companies are already aware of these facts [6]. Governments, Universities and industry can take important actions to encourage this trend, as for example the action shown in [8].

One of the specific measures to focus is the recruitment of women, in particular female student ambassadors and speakers from industry as role models [3]. From the UN, girls' situation in ICT was detected a handicap, thus the Member States of the International Telecommunication Union (ITU) agreed in 2010 to celebrate the International Girls in ICT Day on the 4th Thursday of April, every year [2]. In particular, in the online knowledge generation our contribution detected the lack of women. Particularly in Wikipedia less than 13% of editors are women, even worse are the contribution of women researchers, lower than 7% [1]. Not only the contributions are pour, but the visibility is still worse.

With all this background, with the objective of recruiting more women on CS and visibilizing the contribution of many others, counting with the collaboration of our colleges from the University of A Corun˜a, we focus the organization of WikinformáticA!

2. WIKINFORMÁTICA!

Early positive experiences with technology are recognized as important to involve women in these fields. So, some colleagues at the University of A Corun˜a decided to organize a contest oriented to High School students to provide them with a good ICT experience. Moreover, they also encouraged us to organize something similar at the University of Zaragoza. After an initial contact among the members of both institutions and motivated by the low percentage of female editors in Wikipedia (currently less than 20%), we decided to promote the use of Wiki tools and organized the contests Wikinform´aticA! in A Corun˜a and Wikinform´aticA! in Arago´n, respectively.

These contests were celebrated inside the first edition of the Semana de Anita Borg in Spain (https://wiki.fic.udc.es/semanaanitaborg), which was part of the Anita Borg Celebration 2015 (hashtag: #anitaborgbirthday).

2.1 Anita Borg Birthday Celebration

Anita Borg (1949-2003) is the inspiration for the community of women in Computer Engineering. Anita received her PhD in 1981 from the New York University and worked in several computer companies in the United States such as Xerox Network Systems Laboratory. She was a researcher in computer science that developed synchronization mechanisms and fault tolerance for operating systems and web information systems. She is famous because of her efforts to promote the presence of women in technological areas. In 1987 she co-founded Sisters, an online community that nowadays has over 4,000 members from at least 54 countries around the world.

As it is said in Systers' official webpage (http://anitaborg.org/get-involved/systers) this community continues to serve this purpose by providing women a private space to seek advice from their peers, and discuss the challenges they share as women technologists. Many Systers members credit the list for helping them make good career decisions, and steering them through difficult professional situations. At the final stage of her career, in 1987, she founded the Anita Borg Institute for Women and Technology (ABI) (http://anitaborg.org), a digital community for women in computing, headquartered in Palo Alto, United States. Today, ABI works with women technologists in over 50 countries, and partners with leading academic institutions and fortune 500 companies.

She also founded (in 1994) the Grace Hopper Celebration of Women in Technology (GHC), the world's largest gathering of women in computing and one of the most important events in relation to computers. It is a series of conferences designed to bring the research and career interests of women in computing to the forefront, that every year bring together thousands of computer professionals.

A year after she died, Google took an initiative. Google decided to promote the image of women in computers, creating the Anita Borg Memorial Scholarship (from 2004). Every year computer students are prized, based on their excellence. The principal idea of the Anita Borg Memorial Scholarship is to promote the labor of women in the computer society.

From this community, the Anita Borg Scholar Alumni (ABSA) was created. It is formed by every woman having received the prize or being finalist. The ABSA was created with the idea of

[1] http://www.engadget.com/2014/10/20/what-happened-to-all-of-the-women-coders-in-1984/

continuing with the ideas of Anita Borg and continuing with her mission: to create links among all these professionals. The ABSA is reachable in Facebook: Anita Borg Scholarship Alumni.

2.2 WikinformáticA! in Aragón

WikinformáticA! In Aragón is a competition for groups of high school students in which they develop a wiki on prominent women in the history of ICT. The objective is the visibility of women involved in technology. The action took place from December 19th, 2014 to February 6th, 2015, when the awards ceremony took place.

It was organized by several members of different groups: Departamento de Informática e Ingeniería de Sistemas (DIIS) de la Universidad de Zaragoza, Asociación de Mujeres Investigadoras y Tecnólogas (AMIT) and Red EuLES (Entornos uLearning en Educación Superior), in collaboration with the Anita Borg Scholarship Alumni (ABSA) association.

Each participant group developed a Wiki on prominent women in the field of ICT. Participants were required, from a photograph, to guess who was the woman (or who were the women) on it and to elaborate a biography in a Wiki format. This biography was published in a Wiki that was created for the contest. In addition, it could contribute to Wikipedia in anyone of the official languages of Aragón.

In order to participate, teams were leaded by a teacher. The rest of the participants in the group were students of a high school, a professional school or equivalent academic centers. Groups should be composed of at least three students and a recommended maximum of 15. The registration period began on December 19th, 2014 and remained open until a week before the end of the competition, i.e. until January 23rd, 2015. Participating teams were required to complete its work before the January 26th. The winning teams were announced on January 31st.

2.3 Contest Rules

In order to the participation was accepted, a series of rules were to be accomplished. These roles are presented below:

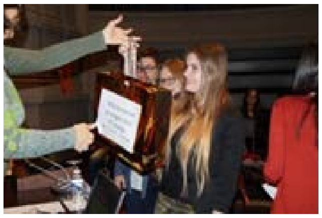
- The competition consists of developing a Wiki on prominent women in the field of ICT.
- The organization will provide the infrastructure of Wikis and photographs of different women whose career has been highlighted in the field of ICT.
- Contestants teams must guess who the women in the photographs provided by the organization are and develop a biography of each one in a Wiki.
- To enter the contest, it is mandatory to include the biography of the women proposed by the organization and possible extra Wiki contributions to be evaluated.
- Although it is possible to include other biographies, the jury will assess whether taking them into account or not (especially if the number of members of the group exceeds widely recommended).
- Groups able to participate in this contest should be formed by high school students and/or training courses students (or equivalent) that will include the supervision of a teacher from its center. The supervisor is the one to directly contact the organization to formalize participation and the creation of a user account.
- Groups may be formed as determined by the secondary sch. However, groups from 9 to 15 students are recommended. A teacher may be responsible for several groups.
- Participating teams may join at any time between the date December 19th, 2014 and January 23rd, 2015. However, the work must be completed before the end of January 26th, 2015.
- The Wiki should have a page detailing who is part of the team.
- The jury will be composed of members of the organization. In case of incorporating partners and sponsors, their assessment will be considered.
- Registration is open from December 19th, 2014 until one week before the end of the competition.
- Participating teams must finish its work before January 26th, 2015.
- The winning team will be announced the week of Anita Borg and the Wiki will be disseminated through the website of the DIIS of the Escuela de Ingeniería y Arquitectura (EINA) of the Universidad de Zaragoza.

2.4 Proposed Women

As it was said, the competition consisted of developing a Wiki on prominent women in the field of ICT. This set of women was specified by the organization by providing the different student teams some photographs of these women. The pro- posed pictures included not only well-known women inter- nationally such as Ada Byron and Barbara Liskov but also young researchers and entrepreneurial that develop their activities in Arago´n such as Alicia Asín, María López Valdés and Belén Masiá. Nevertheless, the students could also include other biographies and photographs of other women related to ICT in their works.

Once the different teams received the photographs provided by the organization, the students should investigate about who they were. After that, they looked for the reasons why they were important in technology and other data of their biography in order to elaborate a Wiki with them.

Thanks to the contest, the theme was treated in several High Schools (http://hendrix-http.cps.unizar.es/dokuwiki/doku.php/noticias).



(a) 1st prize delivery (b) Winning team

2.5 Awards Ceremony

The winning teams were announced on January 31st. The awards ceremony was held on February 6th, 2015, at 18h. in the Aula Magna of the Paraninfo, Universidad de Zaragoza.

At the beginning of this ceremony, the Anita Borg Week was briefly introduced. Later on, awards were given to the winning teams. Three prizes (first, second and third) were granted. The jury who evaluated the Wikis developed by the different teams, consisted of professionals in the field of ICT. They, after a long and arduous deliberation, given the high quality of the works submitted to the contest, decided to award the following prizes: a) 1st prize: Enrique Osso, because of the quality of the content, b) 2nd prize: J. Lanuza, because of the quality of the content and the originality in the format, and c) 3rd prize: Blecua, because of the quality of the content. In addition, all participants received a certificate and there were gifts and surprises for every participant at the awards ceremony. Finally, our colleague María Villarroya Gaudó gave the conference El enigma de las Ingenieras en Informática.

2.6 Results

The call for the registration of the teams in the contest was published on December 19th, 2014, and the teams that participated had to finish their work before January 27th, 2015. Despite the short period to develop the work, 98 High School students, divided into 8 different teams participated and enjoyed the experience very much.

In this project, most of the participants were teenagers. Thus, considering the current legislation issues related to personal data and privacy, we decided to ask only for the name of the teacher, who supervised each team of students, in order to allow a team of students to be registered in the quiz. Nevertheless, the team was asked to put a page where they could provide information about the members in its wiki. Some teams provided information about their members but others preferred not to show their identities.

The team which won the first prize was composed by 20 girls and 5 boys, the team which won the second prize was composed by 5 male-students, while the team in the third position did no provided information about its composition. The percentage of female students in the rest of the teams where data about their composition was available was around 50%.

Most teams granted publication permission of their wikis. So, they are available on the website of the DIIS, EINA of the Universidad de Zaragoza (http://hendrix-http.cps.unizar.es/dokuwiki/doku.php/start). Thanks to this con- test, the number of biographies of women technologists in the Internet has been considerably increased. Also Wikipedia expressed its interest to publish them. At last but not least,

We also would like to mention that every participant team reached its objective of finding the women who corresponded with images and prepared good Wikis, working collaboratively and learning several ICT aspects.

3. CONCLUSIONS AND FUTURE WORK

The contest has been very successful, for the short term available. There were around 100 participants. Given the good results obtained there are already some companies interested in sponsoring the next edition. This was the first edition of a competition WikinformáticA!, which we plan to continue with, annually, we hope that for a long time.

In relation to the goals of WikinformáticA!, along with L'Oréal, the UMYC and Wikipedia, AMIT organized a session of incorporation of female scientists to the Wiki and the improvement of the ones that already were represented there. This action took place on April 17 and has received the name Editatón por la visibilidad de las científicas en Wikipedia [1].

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Inclusion and promotion of women in technologies

Beatriz Revelles-Benavente
Researcher at GENTIC, UOC
brevelles@uoc.edu

Lidia Arroyo Prieto
PhD candidate, UOC
larroyop@uoc.edu

Nùria Vergés Bosch
Investigadora doctora, COPOLIS UB
nu.verges@gmail.com

ABSTRACT
In the information and knowledge society gender transformations have characterized the social changes of recent years, while information and communication technologies (ICT) have taken an essential role for social development. Nevertheless, even if women have accumulated an incredible talent in order to confront today's challenges, the technological system seems not to be prepared to include, retain and promote them through the technological careers that they deserve. Research about gender and technology related with female occupation has pointed out several causes for female exclusion that should be addressed from an interdisciplinary approach. Most of the research has been focused on finding out the barriers that make more difficult to access and promote women in technological occupations. However, there is still a need to identify and foster enablers of women's full inclusion in technologies. Carrying out a mix methodology in between quantitative and qualitative methods, we aim at providing different solutions to facilitate and promote women's presence and retainment in technological careers.

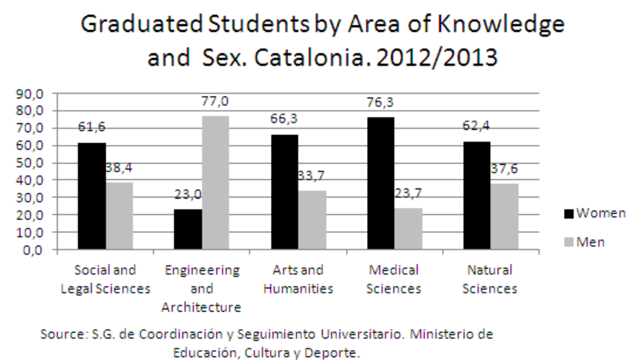
Categories and Subject Descriptors
H.4.2. [**Co-op**]: Better practices in the enterprises – *experimentation for the workforce, gender, ICT.*

General Terms
Management, Measurement, Design, Economics, Human Factors, Experimentation, Documentation.

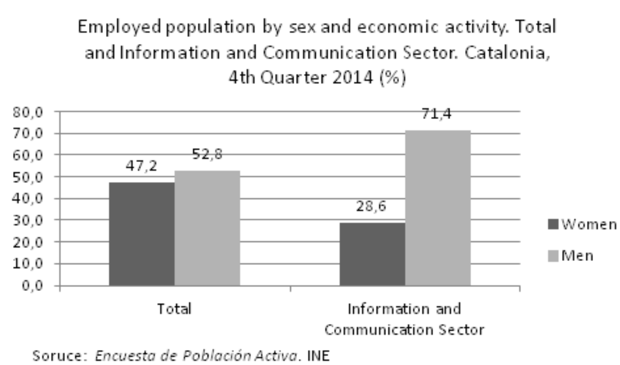
Keywords
ICT professions, women's empowerment, knowledge society, gender

1. INTRODUCTION: WOMEN IN TECHNOLOGICAL CAREERS
The information and knowledge society is characterized by the preeminent role that information and communication technologies (ICT) have undertaken for the development of social and cultural practices. Gender transformations in these social and cultural practices have been paralleled to the social changes of last year albeit this does not include equal opportunities in determined professional areas. Having demonstrated by far their talent to confront today's challenges, women are not included yet in the technological system since they retention and promotion has not been facilitated. (Castaño et al., 2011; Castaño & Webster, 2014; Cohoon & Aspray, 2006). All this is directly related to the economic crisis affecting women and those minority groups more vulnerable in our societies. Tight economic crisis generates inequality, makes it difficult to access resources, time management and working places inequity, as well as positions of power where fundamental decisions are made to improve the current production model.

The majority of Spanish and Catalan women hold a university degree (INE, 2012). In fact, the Catalan case is remarkable. In 2013, according to Idescat, 53.9 % of women between 30-35 years-old hold a degree, higher than the Spanish (45 %) and the European (39 %) average. However, there is still an important unbalance between the areas of knowledge of graduates. In Catalonia, only 23% of students who graduated with an Engineering and Architecture degree in 2012-2013 were women. In the case of natural sciences the percentage of women was 62,4%.



Moreover, this talent is not translated into women's occupation, especially in jobs related to technological fields. While the female workforce represents 47,2% of the total of employed population in Catalonia in 2014, only 28,6% of people who work in the Information and Communication Sector are women.



This fact generates a serious problem of equality since it is preventing women from occupying creative positions with better salaries and more recognition; and it also implies a large talent loss because women have been proved to be a majority among highly qualified professionals. This also creates problems related with efficiency because diverse teams produce better decisions and products. It also has effects for the economic growth and the well-being of society. Thus, women also distribute knowledge and resources better and more widely (Castaño and Webster, 2014).

Research about gender and technology related to female occupations has pointed out causes for female exclusion which are often interwoven. On the one hand, historical factors should be included. That is to say, women (as any other minority group excluded from certain privileges), have been traditionally shut out from knowledge access and technological occupation, and because of that, women rarely appear as a reference for young women (García & Sedeño, 2002; González, 2014). On the other hand, this inherited exclusion effects and reinforces gender stereotypes provoking a bigger impact on younger women through family, school, and mass media making younger women distance themselves from technological practice and research (Sáinz, 2012). In addition to other questions such as curriculum and ways of working in some courses of technological itineraries; these factors produce that nowadays almost 20 % of the students in high school are girls and this continues up until ICT studies (Castaño et al., 2011; Vergés et al., 2011; Sánchez et al., 2012). Above all, it is necessary to take into account that the labour culture of technological environments is highly male dominated . Men make up the majority in technological research and professions and those environments are strongly competitive, as well as multiple other female discriminations have been depicted from unequal salaries to gender violence (Arulampalam et al., 2007; Vergés, 2012). Moreover, technological cultures are marked by ways of working that follow a bread-winner masculine model. In this sense, intense working days of 24 hours per day, seven days a week, and full availability are making time management more difficult (Gill, 2002), as well as lineal careers that penalize interrupted careers (Castaño & Webster, 2010; Valenduc, 2010; González & Vergés, 2013). Besides, these cultures have a great impact finding influential groups and informal networks outside the work environment (Faulkner, 2009; Kelan, 2009); thus, they present many different barriers to obtain the conciliation between work and family. Therefore, if we take into account that women are still those in charge of the home and family tasks (Domínguez & Carrasco, 2003), we find that many difficulties arise to retain and promote women in technological occupations.

2. AIMING AT THE INCLUSION AND PROMOTION OF WOMEN IN TECHNOLOGIES

2.1. Perspective of the research

Most of the research has been focused on finding out the barriers that make it more difficult to access and promote women in technological occupations. Lately, a research body is investigating factors of inclusion. Even though research is making a huge progress, there are many different aspects to study also in the Catalan context. Research on female inclusion in the technological world points at multiple factors that can help and facilitate this process. Some of these would only imply to reverse barriers, while others will try to move beyond and help to develop women's potentials in the technological world. A group of measures seek to modify technological images traditionally associated with masculine roles and models, in order to transform them into images that emphasize women's interests and orient marketing strategies in this sense. For example, marketing campaigns which attempt to attract girls to study engineering degrees, or make visible female presence in the technological world (Lagesen, 2007, 2011; Vergés, 2012, 2014). Apart from the failure in the education system and the importance of informal training in the learning of ICT, it is necessary to facilitate their technological training, such as public policies and additional formative actions (Vergés et al, 2011). Related to this, some measures have to do with increasing women's confidence and empowerment and they create and reinforce, for instance, networks and women's groups relating to technologies (Lee, 2011). To conclude, a final group of proposals deals with transforming labour cultures, especially the technological ones. hey look for ways to confront discrimination against women, for example regarding salaries or the implementation and development of equality plans for labour opportunities in enterprises. Other measures are planned to modify time management and facilitate work-life balance. These measures look at transforming women's limited flexibility or their familial responsibilities into an advantage for them, an example being tele-working for this sector and society in general (Sorensen et al., 2011).

Following these trends oriented to inclusion, with this project we aim at avoiding a paralyzing effect by providing solutions through research that can be implemented by different agents intervening in the problem/opportunity under study. In this case, the problem/opportunity is women's insertion and progression in technological occupation.

The development of information and knowledge society is characterized, on the one hand, by the inclusion of women in academia and labour and, on the other, by the growing importance of new technologies. However, neither the education nor the technological sectors seem sufficiently prepared to adequately recruit, retain and promote women into technological jobs, since gender inequalities are still present and generate equity and efficiency problems that hinder economic growth and welfare.

In this research, we propose to study the causes of gender inequality in the inclusion and advancement of women in technological occupations. Furthermore, we seek to find solutions to these by also exploring the factors that facilitate the recruitment, retention and promotion of women in technological occupations, as well as finding ways of enabling these solutions to reach both the technology sector and the education sector, together with women themselves. Apart from considering these factors for inclusion, we will take into account several dimensions that affect the processes of inclusion and advancement of women in technology, such as family, education, the use of time and conciliation, and labour culture or wage inequalities.

2.2. Methodologies and expected results

Methodologically, we will firstly carry out a review and update data related to the participation of women in ICT education and jobs in the Catalan context, in comparison to Spanish and European data. Secondly, based on the experiences of women in ICT, we will distribute an online survey in order to analyse the factors that have helped or hindered them to progress in the ICT sector. However, at the same time, by conducting semi-structured interviews we will try to connect these with the stakeholders involved in the process of recruitment and promotion of talent, such as staff of HR departments, recruitment agencies and managers of ICT companies. By working with these hiring agents we also seek to identify potential barriers and opportunities in our hiring systems, in relation to gender equality. Moreover, we also aim to understand how stakeholders identify talent and what their demands are regarding formal or informal qualifications and soft-skills. With them we seek to generate debate about attracting and promoting talent in relation to gender. Therefore, considering the previous results and further impact on the ICT sector, we will perform an action-research in the form of pilot projects to promote gender equality in ICT. This part of the research will be carried out in three companies in the ICT sector and will include the design and development of a training activity for each.

The project we are presenting here is at an early stage and, therefore, we can only refer to expected results. Taking this into account and regarding the results of the project and their dissemination and impact, we propose to develop, on the one hand, a series of open access material including a tool kit, a training guide, a weblog, a viral video and several academic publications. Since we aim to impact the education sector at school level we will design and launch a series of talks in schools for students and teachers, to facilitate motivations and in doing so, the incorporation of women into ICT studies. Apart from that we will produce a video for young students addressing the skills (hard and soft skills) needed to progress in ICT jobs. Finally, we will seek to intervene in society in general through coverage in the press and scientific papers. Therefore, through publicity and knowledge transfer, as well as replicating these in the future, we seek to bring our results to girls and women, as well as to the stakeholders involved in the recruitment, retention and promotion of women in technology. Finally, we aim to make the project sustainable in the medium and long-term to promote substantial changes in the ICT occupational structures.

3. CONCLUSIONS

With this project under progress, we aim at changing organizational practices in enterprises related with the ICT sector into more friendly environments for women, as well as promoting transparency in recruitment processes. Through a preliminary exploration, we have observed how women are kept under an in/visible barrier that enhances hostile cultures to reward their career. In occasions, these barriers are not noticed because organizational cultures heavily rely on a social premise that blurs free will with practical allocations. After a detailed analysis of the present data and semi-structured interviews with different agents and participants in this project, we will produce some results that aim at connecting stakeholders involved in the process of recruitment and promotion of talent, such as staff of HR departments, recruitment agencies and managers of ICT companies. By working with these hiring agents we also seek to identify potential barriers and opportunities in our hiring systems, in relation to gender equality. Assessing how stakeholders identify talent and what their demands are regarding formal or informal qualifications and soft skills, we seek to generate debate about attracting and promoting talent in relation to gender.

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Moving towards Accommodating Women with ICT: Paying Attention to Self-inclusion Mechanisms

Núria Vergés Bosch
Universitat de Barcelona
Departament of Sociology and
Organizational Analysis.
Avd. Diagonal, 696 08034 Barcelona
+34934021801
nuria.verges@ub.edu

ABSTRACT
Recent developments of new information and communication technologies, as well as feminisms are essential for understanding the major changes in our societies today. Feminist research of technology, traditionally, has been focused on explaining the exclusion of women from technologies. However, a move towards inclusion is already being carried out intensively. This involves investigating the experiences of women in ICT and thereby making visible their trajectories and mechanisms towards inclusion, as well as the challenges and opportunities that are generated thereby. In this article I aim to explore the processes of self-inclusion of women in ICT and specifically to show the main mechanisms that they have followed and activated to self-include in ICT. To do this I have relied on shared experiences of a purposive sample of artistic technologists and computer technologists in Barcelona, by conducting interviews and focus groups. As a result I show a series of mechanisms that women follow and activate to access, remain in, advance, and even transform ICT. These mechanisms go beyond learning and include not only doing gender but also undoing it as well as ICT. Thus, Women in ICT seek to access and progress in ICT adapting to certain circumstances but also changing them to generate and regenerate ICT in order not just to be assimilated but better to accommodate with ICT.

Categories and Subject Descriptors
K.7 The Computing Profession; K.4; Computers and Society

General Terms
Performance, Human Factors, Theory,

Keywords
Women; Doing Gender; ICT; Inclusion; Self-inclusion mechanisms; Undoing Gender; Technologies; Accommodation; Gender

1. INTRODUCTION
With the rise of New Information and Communication Technologies (ICT) and the development of third-wave feminisms, current feminisms of technology are experiencing a theoretical renewal, critical but at the same time optimistic, developing into new opportunities for research and practice. In this regard, it is diverging from the analysis of exclusion, quantities and the digital gender gap towards research on inclusion, i.e. the presence of women in ICT and gender impacts, qualities, as well as opportunities to and from women in a mutually constitutive and fluid relationship with ICT [52] [63] [67] [53] [62].

To carry out research around the inclusion of women in technologies involves techno-social processes that delve into technological and social aspects such as motivations, enabling factors, conditions of use, development and participation of women in the field of technology and even the mechanisms of self-inclusion and how all this, in turn, impacts ICT uses and its development. However, to consider these motivations and factors of inclusion is not only crucial to women's access to technology, but also to their persisting in its use and to allow us to actively, emancipatorily and critically participate in the design and development of ICT. In this article I will only focus on the mechanisms of self-inclusion of women in ICT, which are elements much less addressed in depth in the literature on gender and ICT. Therefore my main question underpinning this article concerns what mechanisms women follow and trigger to self-include in ICT?

In this sense, when referring to self-inclusion of women in ICT women are positioned as agents conducting their own ICT inclusion [45][46][61][62]. This entails considering the agency of women in their process of inclusion, i.e. the mechanisms that themselves activate and/or decide to follow to progress and even to contribute and transform ICT. Self-inclusion processes occur over time, dynamically and interactively, and involve to access, follow, stay, progress, recognize and be recognized, and contribute to ICT [61].

In this article I aim to explore the process of self-inclusion of women in ICT and specifically show the main mechanisms that they have followed and activated to self-include in ICT. To do this I have reviewed the key literature that investigates the exclusion and inclusion of women in ICT, but above all I have relied on the experiences and discourses of a purposive sample of artistic technologists and computer technologists in Barcelona.

In the next section, I will discuss what we have learned from research that focuses on the exclusion of women in ICT, as well as some negative impacts I think this entails. That leads me to strive to turn towards inclusion paradigms and, beyond that, to propose a move towards an inclusion that considers and fosters self-inclusion of women in ICT. Then I introduce the main methodological strategies undertaken in order finally to present the main results and conclusions of this research about the self-inclusion processes of women in ICT.

2. FROM EXCLUSION…

Traditionally, much of the research on women and technology has focused on showing and explaining the absence and exclusions of women in ICT. That is, much of the literature and public reports have focused on the various digital divides and asking why there are no women in ICT or why there are so few or why they are leaving ICT [58][7][13][35]. The main concern is currently focused on the underrepresentation of women in the areas of decision making and design of new technologies, traditionally associated with computing studies and engineering [11][10].

These investigations point to a number of factors that have led to the exclusion of women from ICT. Historically, women have been excluded from the study, research and production of technological knowledge through legal and social norms [21][32]. This discrimination has hindered the generation of models for other women and makes invisible contributions by women to the development of technology. This has fostered an image that alienates women from technologies and has fueled a stereotypical attribution of gender roles for women that result in discrimination against women. Gender stereotypes are being reproduced through family, school, media, social networks or even at the workplace [47]. Their influence defines what is considered appropriate for women or for men in a binary manner, besides marking the conditions of access to prestige, value and recognition that result in discriminate against women horizontally and vertically [35] [7]. In this sense, gender stereotypes are attributed as "natural" and therefore they are highly resistant to change. In this sense, technology is considered masculine and masculine means man. This constructs and maintains a masculine culture of technology, i.e. a technology associated with men, masculinity and their values [14][18] which implies that ICT learning and working environments tend to be unfriendly to women and, for example, show serious deficiencies in the possibilities of balancing work and family life [22][42]. Furthermore, it should be stressed that the exclusion of women from technology is also often aggravated by other forms of social exclusion such as socio-economic status, place of residence and / or socio-demographic factors such as age, ethnic origin or sexual orientation [7][3]. Thus, study and action to address the exclusion of women in ICT is still necessary, but it also has some drawbacks.

The results of these studies focusing on exclusion have been crucial to highlighting the situation of gender discrimination against women in ICT, the male dominance of technology as well as to identifying a need for public action, thus generating indicators and data for its analysis [58][44][35][7]. However, from a paradigm of exclusion, too often narratives of exclusion are still focused on the worlds of men and only encourage a change among women, rather than changing structures and the society as a whole. The view from exclusion also tends to stress the problem of quantities seen in a binary way that compares both sexes. This has also fostered a technophobic and pessimistic perception of the women and technology relationship, has solely focused on the negative, the absences and barriers and has contributed to bring a pessimist, victimist and too chilling a message to public policy makers, academia and the rest of society (as criticism [52][56][15][17][61]. Beyond this, a focus on exclusion has distanced the analysis from the post-feminist proposals that appear with new theoretical proposals, many yet to be developed empirically and with open doors to critical and transformative optimism [55] [30][67] [61].

3. TO INCLUSION…

If we take into account some of the impacts of merely focusing on the exclusion of women in ICT and consider the urge to find new opportunities for women in ICT, a move towards the paradigm of inclusion is needed. This move should focus on the presence and experiences of women in ICT and allows us to visualize their contributions and wishes, but also the paths, opportunities and potential for the full participation of women in today's technological developments. Moreover, as explained by Sorensen[52] to know the reasons why women are excluded from technology, is enough to understand and promote their inclusion? Or is it necessary to develop a more in-depth understanding of the presence and mechanisms for inclusion in ICT? Thus it makes sense that we also ask why there are women in ICT and how they accessed ICT? What do they do, how and why? And even, what do they want? As well as what does their presence imply?

Placing inclusion in the center of our research also becomes more consistent with feminist research that considers the experiences of women at the heart and point of departure of our research [4] [1][66]. In fact, feminism of technology research has begun a process to investigate the processes of inclusion of women in technology seeking a renewed relationship between gender and ICT [15][56][53][61][9][54]. These investigations, focusing on the presence and inclusion processes, have brought to light the contributions and uses that women make of ICT and thus have focused on the worlds and experiences of women [33][43][49] [57][56][53][10][61]. With this, we have generated role models for many more, as well as having weakened stereotypes about gender and ICT. In this sense, research has also questioned the binary tendency of the study of women in technology, by focusing on women while making visible its diversity and going beyond the dichotomous comparison to men. These research studies have tended to develop a large volume of information that qualitatively explores gender and ICT, leaving behind a debate which has traditionally focused on the amounts and percentages in order to deepen the quality of the participation of women in ICT. Finally, the contributions of these research studies for inclusion have helped to generate new inclusive opportunities for other women and collectives and have made visible alternative developments of ICT, or even improvement in business, since women are behind most purchasing decisions, including technological ones. In this sense, then, in addition to claiming the inclusion of women in ICT for gender justice, a greater diversity of voices, views, needs and wills that have become included are emphasized and, in turn, are creating opportunities to develop new ICT products which are more extensive and adaptable to a wider range of profiles. There is a need to avoid losing talented women, since they are becoming the majority of students of our universities. Moreover the inclusion of women in ICT could challenge existing power relations through an alternative and innovative ICT development that is more in line with society as a whole and, finally, women's inclusion in ICT could produce a redistributive effect of its benefits for their families and local communities [11][5][62][61][2][36].

Feminist research of technology has identified certain motivations that trigger the interest of women which could be summarized as Sorensen stated [52]; as the duty, which expresses a utilitarian motivation, or as love, expressing a passion behind the use of technologies. Also, research focused on the study of technological inclusion has identified a number of factors that facilitate the inclusion of women and their immersion in technologies [52][15]

[56][24]. The range of factors goes from friendliness to women in ICT environments or tools, to access to education, resources or infrastructure. Active encouragement from family, friends, media, school or gender specific public policies have also been stressed [6][10][53].

Although considering these motivations and factors of inclusion is crucial to women's access and progress in technology in this article I will precisely focus on the mechanisms of self-inclusion of women in ICT, which are elements much less addressed by previous literature, especially in a non English-speaking world. Furthermore, although self-inclusion has been targeted by some authors few times it has not been treated in depth. Finally, to carry out research on self-inclusion can help us consolidate and find new ways to continue generating self-inclusions and, ultimately, contribute to the inclusion of more women and other groups in ICT.

Taking all this into account, in the next section I will introduce the methodological strategies I followed to explore the mechanisms of self-inclusion of women in ICT and then, present the main results of this work that show a range of mechanisms that a sample of women followed and triggered to self-include in ICT.

4. METHODOLOGIES

Departing from the paradigm of inclusion, according to feminist epistemology and situated knowledges and thus, considering the need to depart from the ICT experiences of women [4][25][41][66], I selected a purposive sample of women technologists resident in Barcelona. Therefore, these women had already become advanced and specialist ICT users. However, considering that ICTs are increasingly transversal and, therefore, their advanced use and development is possible from any area of human activity, we need to turn our gaze to these other areas where, in addition, women seem to be better represented. This often involves a qualitative effort given the lack of data in many of these areas which intersect with ICT. Taking this into account I narrowed down the selection of the sample to computer technologists, but I explicitly open that to artistic technologists. Computer technologists would study or develop practices that have traditionally been considered ICT [40][7][10] and they would also clearly work in masculinized environments, at least quantitatively. In contrast, artistic technologists would study or develop practices in intersection with ICT [34][61], i.e. in this case where the artistic and technological components are combined and in environments with more gender parity, at least quantitatively speaking. Finally, responding to the need for of an investigation of proximity and considering the relevance of Barcelona as a South-European creative area, participants are residents in the province of Barcelona [27][48]. However, also in an inclusive manner, and to capture migrated trajectories, I considered diverse places of origin in an international sense.

According to what I revealed about the paradigm of inclusion, I understood that the best way to capture the experiences of women was through qualitative methodologies. This allows me to analyze the meanings, but also to work through conversation and narrative creation and thus delve deeper into a process, such as the self-inclusion in ICT one, that quantitatively would hardly be possible to address [41][16]. With this in mind, I carried out a combination of qualitative techniques as the most appropriate way to approach, understand and analyze the research topic and answer the research questions. I conducted 22 episodic interviews that combine narrative and semi-structured interviews [16]. In addition, to develop the key questions and explore and evaluate collectively the topic of research, I carried out two mini focus groups of three participants each [12]. One consisted of artistic technologists and the other of computer technologists. Thus there were 28 participants in this research, half of them women artistic technologists and the other half women computer technologists.

The analysis presented in this article is based on a bottom-up qualitative analysis using the software for qualitative analysis Atlas.ti. This has generated several codes and code families that have helped me to answer the research questions by including the words of the participants. In this regard, pseudonyms are implemented, as anonymity was requested by some participants. As a result, in this next section, I aim to answer a key question: what mechanisms have those women followed and triggered to self-include in ICT?

5. SELF-INCLUSION MECHANISMS OF WOMEN IN ICT

As pointed out by the majority of research on gender and technology, the most obvious mechanism to self-include in ICT is through the acquisition of knowledge and ICT skills [11][65][9]. Thus, one of the main mechanisms of self-inclusion, also for women, consists of learning, especially non-formal and informal-formal learning [68][69] since women are not studying computing in great numbers. This last is acquired by formal education, institutionally structured in a particular country. Non-formal learning is acquired through, for example, participation in workshops, courses and conferences. Finally, informal learning develops through interaction with friends, family, communities of practice or even at leisure times. This rarely results in certifications and often occurs unintentionally. However, as shown in the following discourse and in line with my previous investigations [63][65], the ICT learning arises through the combination of the various ways of learning that often overlap.

The design of the interaction, again, went back to a fairly traditional way of learning. Although there were more kinds of workshops or projects, every two weeks we had a project. Just as I'm learning in the master's degree in digital fabrication. Every two weeks we have a project on the subject. Scanning, molding, laser cutting, assembly, electronics, programming. Also a mix between working alone, finding resources on the network, connecting with other people informally, sharing things and a form of professional apprenticeship. (Marquès, Arts, Italy, degree in Pedagogy, Artist and Technoteacher)

In relation to learning and already pointed by many authors [59][8] most participants did not study computing or engineering, or formally followed a linear path from engineering to ICT jobs. In a way then, through more informal channels, the participants were creating their own ICT itineraries. The importance of non-formal and informal learning in women trajectories could be constituted as a potential for their ICT inclusion. However, in turn, it may represent a handicap for them due to lack of credentials combined with the stereotype of the inadequacy of women in technology [14][65].

Another set of mechanisms for ICT self-inclusion relates to labor issues. In this sense, the participants sought and accepted jobs directly related to ICT as a way to enter or to advance in the ICT practice, as well as to access some higher income. While artistic technologists showed a higher level of multi-occupation, even simultaneously, among computer technologists another mechanism related to labor appeared. Many engineering students started to work even before finishing their studies. This seems to be a feature of engineering courses that have close links to particular companies and should also be a feature of other degree courses.

I was finishing my third year and I wanted to get some experience, a bit, if I started to work the following year, I needed to build some CV... or maybe just to remain in the same company after finishing my degree. There, at the University, there is the "job campus" where they seek a job for you. Well, they've got job offers, you register there and get offers. Normally, what they used to send me was more related to computing than to Telecommunications and so... And finally, I went to an interview. Well, I went because there was another offer and you had to know how to program databases or whatever. When I was there in the interview I was told, no, but you do not know Oracle, and I said ... no, but when I get the offer it did not say that I needed to know this, right? And they said, well, we keep your CV in case we have any other job. Then they called me and that is how I started to work in this. (Daigenault, Computing, Catalunya, telecommunications engineering degree, upper computing engineering student and researcher in computer science at a university)

Almost all of the participants, when coming across obstacles or observing opportunities in another field or context, opted for mobility, both geographically and labor mobility, thereby also contributing to break the linearity of their careers. That is, as suggested by some literature [26][20] women tend to change company, sector, discipline or even country, seeking new opportunities, new ICT challenges and also more friendly environments as a way to advance their ICT careers.

Some of the participants opted for entrepreneurship as a means of ICT self-inclusion and labor, especially in the case of artistic technologists who generally showed more job complexity. They organized themselves, alone or with other partners, to perform their ICT practices. Sometimes their ICT practice was done in similar or better conditions as when being an employee. However, in many other situations this involved risk and insecurity as pointed out by previous literature in relation to freelance work and ICT [19]. In spite of that, some participants perceived free-lance work to have some advantages, such as the flexibility and freedom, but also for the challenges and opportunities involving technological innovation, because there were not so many directions already set compared to working in a specific project or company.

Another self-inclusion mechanism identified consisted of self-promotion, expressed by some participants as a major dilemma. Thus, clear self-promotion was used only on rare occasions, i.e. in situations or ways socially acceptable to women such as sending curricula, business cards or information about the next shows on the web in the case of artistic technologists, as previously pointed out by authors that explore the careers of women and self-promotion [38]. Therefore, in turn, most participants showed great reluctance for self-promotion, especially an exaggerated one, such as they saw being performed by some of their male peers and called in spanish "autobombo".

In my research group there are more boys, many more boys and we talk about this things among girls very often. They have a capacity of Me, that I am, I am .... And we are so modest ... And the problem is that people believes so much on your own propaganda.... And don't think it's only in the computer field. I think that in general, I'm not good at selling myself and yes it is likely that women will be less selling themselves, but I think it is a cultural issue. It is not that we are born without the gene for the ability to self-promote. (Fité, Computing, Catalunya, PhD in computer science, university professor and researcher)

Even if they were aware of the need for self-promotion, they actively avoided trying to prove themselves superior. Instead, they performed a kind of horizontal self-promotion and networking, perhaps to avoid unwanted gender discriminatory effects as women are heavily penalized if they self-promote in certain ways and less if they do so through others [51].

Related to this, another mechanism that has been evident consists of collaboration and sharing. Through establishing partnerships and processes of sharing knowledge, software, artworks etc. they were self-including in ICT. On the one hand, through sharing and collaboration they learned and helped others to learn informally. On the other hand, they were promoting themselves and their abilities and, therefore, this has also to do with self-promotion. Finally, it is worth noting that through using free licenses, many of the participants allowed that program, work or knowledge to be distributed and, in a sense, be inserted into other codes, works or applications. In this sense not only were they released and could be recognized, but also they were able to generate an effect of self-inclusion as the following discourse shows.

I need software that I can use as I like, to make inventions with it, to do research, to know how it's done ... That I can copy and recommend to my friends. That operates on any mobile phone, on any computer, that runs on any router. Practically I can't use proprietary software, which is telling you: do not help others. (...) I use public communication as a guarantee that this work is mine and a free license that leads others to use it. Now I use two licenses, before I only used the free license GNU, Free Foundation License, which was the one used by the Wikipedia, because it allowed that my work, part of my work, could be copied to Wikipedia, directly, or vice versa. All documentation, documentation of all GNU programs are registered under this. Since the Wikipedia happened to have a dual license, I kept the FL and added the creative commons, attribution and share alike, like Wikipedia. (Expósito, Info, Catalunya, degree in psychology and audiovisual communication, Hacker and PhD student in Computing)

Another mechanism that is still closely related to labor involves seeking the balance between different areas of life. In fact, the literature on gender and ICT has been interested in this issue and in claimed measures that balance work life and family life as well as labor with other areas of life, since the ICT sector appears to involve intense working schedules demanded by 24/7 [26][60]. Some participants, albeit with difficulties, sought working time arrangements that gave them enough time for family life or even technological experimentation, but also to spend time with friends or to practice leisure activities. It is worth noting that, in this regard, ICT and its ways of communication helped them to recover some family or social life. At the same time, the possibilities of teleworking made fluid the boundaries between home and work, as well as private and public spaces as shown in the discourse by St- Arneault.

I work at home. This means that somehow I have a very large living room, partly as the living room, partly as the kitchen and partly to work. Then there is no border in the same room nor nothing stops my body movement. Sometimes I get the computer to choose a movie to download or to play an on-line series, leisure *absolutely, then I'm doing four things at once, right? In the meantime, the washing machine is working, I hang the clothes, while I am rendering a video for work, all at once. (St- Arneault, Artist, Aragon, degree in fine arts, video director and editor, university professor and PhD student in communication)*

Another set of mechanisms would be more transversal and would go beyond the learning and the labor, but also relate to them, since the mechanisms are strongly associated with each other. First, I refer to what are called self-regulative processes [70][50]. Thus, participants worked to advance and promote themselves through their own efforts, organization and work well done and, if possible, testable and demonstrable accumulation of merits. For example, they established for themselves some working patterns, some disciplines, a specific organization of time, a number of qualifications to reach etc. This allowed them to overcome a difficult curve when they started learning as well as various obstacles they encountered along their career, besides encouraging themselves and progressing in ICT.

Another major mechanism of self-inclusion is related to networking. Participants built their networks with people with ICT interests, but at the same time, diverse enough to provide expertise or influence in another specific area. This was not always expressed as intentional but came up repeatedly in the narratives of the participants. Thus, it is confirmed what Morgan et al.[37] and Lee [31] pointed out, that networking becomes a crucial mechanism of progression in ICT and women activate it in various ways, from participating in existing networks to creating new ones. It is worth noting that this can play as a mechanism for informal learning as well as a self-promoting one, collaboration and empowerment that facilitates the generation of new projects and even new jobs.

We already met in Barcelona, and I had already worked with some of the members here ... Someone said, why do not we gather together and share a space? They proposed that to me and I thought it was fantastic. I really had no need for a space, because I already had my house, then this means to me now an extra economic cost to pay the rent together, but brings me to have relationships with other people who work like me and from there to get many projects. This latest exhibition came to be here, go talking about this and now this project with this one, the other with the other and so on. And from here we generate new dynamics. (Tatxé, Artist, Catalunya, Multimedia Engineering Degree. Artist and Cultural Manager)

A little further and more related to collective participation, some of the participants were members of, or participating in, ICT collectives and associations, from professional to non-profit entities, groups, or communities of a specific ICT practice. In this sense, women may be playing a role in a third sector related to ICT often unexplored [36][23][24]. Through collective participation they sought to learn but also to interact, give support, empower, generate new projects or simply make themselves be known. At the same time, most of them had participated in ICT events, meetings, , festivals, seminars or conferences. In some occasions these ICT associations and / or events also had to do with gender and activism simultaneously.

Finally, to overcome situations of discrimination and also to facilitate their progression, women could also be doing gender or undoing gender [28][29][14][39][64]. In this sense, they were doing gender, i.e. emphasizing feminine behaviors and performing according to the traditional characteristics associated with women in several situations, something already explored by the literature on inclusion. Similarly to traditional women only groups, the participants gathered with other women being aware of their difficulties for progression in certain areas or situations. They did so, on one hand, by participating in activities already promoted for women as, for example, a women only course or participating in a conference, association or festival of women. Moreover, on the other hand, they have even been more active in doing gender while being feminist. For example, participants consciously suggested other women as candidates for job offers in their current jobs to create a gender balance in their work environments. Similarly, some participants formally or informally offered themselves as mentors, as well as created content on gender and technology, or, indeed, created and / or organized activities, associations or networks together around feminism and technology. As Margolis and Fisher [35] noted regarding access to the Carnegie Mellon University, to have women can also lead to having other women. In this sense, the actions that they trigger can produce an effect of a protective environment, as well a promotional one. In this sense, they might create a women's self-inclusion multiplier effect, especially when there is gender consciousness.

Because my girl friends were working there and they have been introduced by other girl friends, I introduced my girl friends. Wherever I go, in later years, an increase in the female population occurs. Before, there were only two or three girls there, she, me and another friend. After I left the center they were mostly girls. And here, when I started last year, we were only 4 or 5 girls doing the master. But there are many more this year. And I think it's still less than 20%, but much higher than last year. (Codina, Iran, Software Engineer and PhD student in Computer Science)

However, on other occasions, the participants were undoing gender as a mechanism of self-inclusion. Contrary to what might seem a priori the participants did not want to be "one of the boys". Still, many adopted and performed some of the characteristics associated with masculinity because they felt they had to, or rather in order not to be treated as "the girl" and so make progress in certain situations and ICT environments. Thus, some participants diluted or made less obvious their feminity. In this sense, they did not seek to be or play the most aggressive, the most rational or strong, but just stood actively in an intermediate position with respect to gender. In a way, this active position in the middle becomes a very powerful mechanism of self-inclusion because it allows them access to the benefits of doing gender and, simultaneously, to the benefits of undoing it. When, on the contrary, placed in this position passively they could run the risk of suffering the drawbacks of both, as when doing gender means accepting discrimination or undoing gender by adopting exaggerated masculine behaviors that often they claim to reject.

Beyond the doing and undoing gender it is worth noting the possibilities of transformation of ICT that were observed throughout the investigation and, indeed, could be appointed as an additional mechanism of self-inclusion in ICT. This involves not only contributing to ICT, but also adapting ICT to women and their needs and interests [5]. In this regard, participants were adapting to ICT tools and given scripts, but some explicitly expressed that they were seeking to undo them. In this sense, not only by modifying the codes or forms of the tools they used, but also by changing their own uses, for example, by applying hardware or software typically used in arts or "internet of things" (like sensors or arduinos) in other areas of human activity where they were also working, such as early childhood education. This potential was more pronounced among activists and in many of the artistic technologists. The latter, quite logically, showed a great ability to imagine other ICT or other uses and meanings for technologies by developing them themselves. Thus, women in ICT could be developing a process of accommodating with ICT more than just getting assimilated by it, especially if we consider the possibilities of other self-inclusions that they open up and the changes they might be bringing in their contexts. In this process of accommodating with ICT they seem to seek to feel comfortable and progress in their environments and practices, adapting to specific circumstances but also changing the same circumstances to be more comfortable and regenerate their own ICT trajectories and practices.

6. CONCLUSIONS

Research on women in technology has traditionally concentrated on explaining their exclusion from it. However, feminist research of technology has recently strengthened investigations of the processes of inclusion of women in technology. By doing so, we are looking for a critical but renewed relationship between gender and ICT.

From the paradigm of inclusion the advantages of knowing, exploring and facilitating processes of inclusion and self-inclusion of women in ICT have been pointed out. Our inclusion would not only help us to advance in gender equality and maximize the potential of talented women, but also we might see improvements in terms of business, welfare and, of course, in the development of ICT generating new and more suitable technologies for the society as a whole.

Therefore, departing from this inclusion paradigm I have explored the mechanisms of self-inclusion of women in ICT by conducting interviews and focus groups with women artistic and computing technologists. To focus on women that are already technologists and to follow the proposal to turn to the paradigm of inclusion has the limitation of omitting those women that are still excluded from ICT. Similarly, to focus on the mechanisms of self-inclusion involves certain overlook to the factors of exclusion. However, those have received a lot of attention in previous research and so have been reviewed in the introduction. Finally, this research consisted of qualitative and exploratory research and, therefore, its results cannot be generalized and were just presented in a descriptive level. In spite of that, this has opened the door to studying in depth each mechanism in the future, also in new contexts beyond what is traditionally considered ICT.

The main self-inclusion mechanism commonly stated by the participants consists of learning. However, many women do not learn in formal education, nor study engineering, but engage in non-formal and informal learning. In addition, participants seek and access ICT jobs, but show important dilemmas when dealing with self-promotion. When finding barriers in a given context or seeking new opportunities most of the women have opted for mobility, both occupational and geographic. Some of the participants have even become entrepreneurs, alone or with other partners, to maintain and continue their ICT practices, as well as set several self-regulating practices as another mechanism of self-inclusion

I would like to highlight a set of other self-inclusion mechanisms, especially because they can bring new self-inclusions for women. The participants of this research have build new networks, as well as integrated old ones to further progress in ICT and generate new projects, while learning and promoting themselves. In relation to that, they have been collaborating and sharing knowledge but also works, codes and resources that could help and be used by others. Through collective participation they learn, interact, rely, are empowered, or generate new projects as well as new inclusions. Sometimes, in addition, they create new groups or events that, on occasions, foster women and technology at the same time. When doing so they have been doing gender, as well as feminism. Other times they have been undoing gender, for example when they have diluted gender marks in their communication or behavior. However, neither doing nor undoing gender dynamism appeared in an extreme form, mostly being softly performed in order to take advantage of that. Finally, the participants not only have been doing ICT but also have been giving new uses and meanings to ICT in a way of undoing ICT. Thus, women can be doing and undoing gender and even be doing and undoing ICT as self-inclusion mechanisms and not just to integrate in ICT but to accommodate with it.

Taking this into consideration, women in ICT could be developing an accommodating process rather than just being assimilated by ICT, especially if we take into account the possibilities of other self-inclusions that they might open up as well as the potential to regenerate ICT and the relationship between gender and technology.

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ENGENDERING TECHNOLOGY (II)

Influencia del Género en el Pensamiento Computacional

Elisenda Eva Espino Espino
Instituto Universitario de Estudios de las Mujeres (IUEM)
Universidad de La Laguna
alu0100940138@ull.edu.es

Carina Soledad González González
Instituto Universitario de Estudios de las Mujeres (IUEM)
Universidad de La Laguna
cjgonza@ull.edu.es

RESUMEN
Este estudio tiene como objetivo analizar la influencia del pensamiento computacional en relación al género, ya que es importante conocer las causas por las que en la actualidad la presencia de las mujeres en las carreras de ingeniería informática sea cada vez más escasa. En este artículo se presenta un análisis sobre las competencias y estrategias que se relacionan con el pensamiento computacional efectuado en la competición nacional de robótica educativa FLL (First Lego League). Los resultados confirmaron que hay mayor presencia masculina que femenina y una clara diferenciación de género. Sin embargo, en cuanto a procesamiento y aprendizaje de información, existe igualdad.

Categories and Subject Descriptors
H.1.2 [**User/Machine Systems**]: Human Factors, Human Information Processing, Software Psychology.

PALABRAS CLAVES
Género, Brecha de género, Pensamiento Computacional, Enseñanza de la Programación

1. INTRODUCCIÓN
El avance científico y tecnológico es uno de los principales desafíos que la comunidad mundial debe afrontar en este nuevo milenio. Sin embargo, cuando se habla de mujeres, la reacción inmediata es la de indicar la poca presencia de éstas en su desarrollo. Lo que sucede es que a lo largo de toda la historia y hasta la actualidad, ha existido una cultura androcéntrica [1] que ha prevalecido en la conciencia individual y colectiva de muchos y muchas, repercutiendo en la invisibilidad de destacables contribuciones femeninas [2] y abriendo una profunda brecha de género [3] en este campo. En primer lugar, cabe plantearse si las mujeres llegan a la educación superior en igualdad de condiciones que los hombres, dada la distinta socialización que experimentan [4]. En segundo lugar, hay que prestar atención a los estereotipos sexuales presentes en nuestras vidas desde el momento en que nacemos hasta que llegamos a la etapa adulta [5]. Por último, atender a la discriminación jerárquica, según la cual, mujeres capaces y brillantes son mantenidas en los niveles inferiores en la escala política, en negocios o en la ciencia; o topan con un “techo de cristal” que no pueden traspasar en su propia profesión [5].

Son muchos los estudios, nacionales e internacionales como el informe PISA 2015 [6] o la encuesta de Competencias de la Población Adulta de la OCDE de 2012 [7], los que revelan el ascendente rendimiento que experimentan las niñas y jóvenes en materias como matemáticas, física o tecnología; siendo incluso mayor que el de sus compañeros varones [8]. Por ello, en este estudio se atiende a la influencia del pensamiento computacional como un condicionante en la adquisición de conocimientos y habilidades en programación. Cuando hablamos de pensamiento computacional, nos referimos a un concepto que implica organizar y representar información de forma lógica, resolver problemas y automatizar soluciones con ayuda del pensamiento algorítmico, diseñar sistemas y comprender el comportamiento humano, haciendo uso de los conceptos fundamentales de la informática, tal y como expone Wing (2006) [9].

Teniendo en cuenta los estudios anteriores sobre la brecha de género en los estudios de ciencias, ingeniería e informática y la necesidad de que las niñas aprendan competencias tecnológicas, en concreto, la competencia de pensamiento computacional [9], este trabajo de investigación tiene como objetivo analizar si existen diferencias de género en la enseñanza-aprendizaje de la misma [10]. Para ello, necesitamos conocer cómo se está enseñando esta competencia en los colegios. En este sentido, existen distintas iniciativas que se están llevando a cabo a nivel internacional, nacional y local, y casi todas tienen como punto en común la robótica educativa y la programación de videojuegos. Entre estas iniciativas, destacaremos la FIRST LEGO League (FLL), que es un torneo que desafía a jóvenes de 10 a 16 años con una temática del mundo real relacionada con la ciencia y la tecnología. Cada año FLL propone un nuevo desafío, que tiene tres partes: el proyecto científico, el diseño y programación de un robot y los valores FLL (inclusión, descubrimiento, coopertición, respeto y trabajo en equipo). Para participar en el desafío los equipos se inscriben y organizan sus torneos microFLL, que dan acceso a los Torneos Clasificatorios FLL, realizándose competiciones en diferentes niveles: dentro del propio colegio, en la localidad, en la región, a nivel nacional y a nivel internacional. Por ello, como punto de partida, en este trabajo, nos planteamos estudiar las características y estrategias seguidas por los equipos que habían sido capaces de superar los diferentes torneos hasta llegar al torneo nacional. Para ello, hemos analizado las opiniones del profesorado de los grupos de estudiantes ganadores del campeonato nacional (España) de la feria de robótica educativa FLL, llevado a cabo en Tenerife en marzo de 2015 (Figuras 1, 2 y 3). Asimismo, se estudiaron las opiniones de los árbitros, del equipo de voluntariado y jueces que participaban en dicha competición.

Figura 1. Equipo en la compentencia. Programación del robot defendida por chicas.

Figura 2. Árbitros evaluando la programación del robot durante la competición.

Figura 3. Diferentes equipos de la competición nacional.

De este modo, exploramos dos hipótesis, siendo estas:

- Existen diferencias de género en el aprendizaje del pensamiento computacional siendo mayor la presencia de varones. (H1)
- En el procesamiento y el aprendizaje de la información, no hay una diferenciación relevante que justifique que varían según el género (H2)

Este artículo se organiza de la siguiente manera: primero, presentaremos algunas iniciativas relacionadas a nivel internacional, nacional y en Canarias donde se utilizan programas como el Scratch que proporciona una iniciación dinámica en programación a los niños y niñas, luego presentaremos el estudio que hemos llevado a cabo en la FLL Nacional 2015 y sus principales resultados. Finalmente, se discutirán dichos resultados y se presentarán las conclusiones del estudio.

2. MÉTODO

Diseño

Se ha realizado un estudio de tipo cualitativo, selectivo y co-relacional por muestreo probabilístico aleatorio estratificado.

Participantes

La población encuestada se compone de 53 sujetos: 39 docentes, 5 árbitros y 9 personas dedicadas al voluntariado en eventos sobre programación educativa. Aludiendo al género (Tabla 1), las distintas agrupaciones que encontramos son: género de Formadores, género de árbitros y género de voluntariado; denotándose una mayor asistencia masculina salvo en el voluntariado, donde existe una pequeña diferencia.

Tabla 1. Género de participantes

	Formadores	Árbitros	Voluntariado
Masculino	56%	80%	40%
Femenino	44%	20%	60%

A su vez, el grupo de Formadores, el de árbitros y el de voluntariado, provienen de las siguientes Comunidades Autónomas, destacando, por su mayoría, a Canarias y Catalunya (Tabla 2):

Tabla 2. Comunidades Autónomas

	Formadores	Árbitros	Voluntariado
Andalucía	3	-	-
Canarias	10	4	6
Catalunya	16	-	2
Castilla y León	5	-	-
Navarra	1	-	-
País Vasco	4	-	1

En formación adquirida, la mayor parte de los sujetos pertenecen a ramas técnicas. El 41% de los *docentes* son de Ingenierías Superiores; seguido de Ingenierías técnicas con un 20%, quedando detrás estudios de: magisterio, otras diplomaturas, licenciatura en matemáticas, física; licenciatura en psicopedagogía, pedagogía, arquitectura o doctorado. En el caso de los *árbitros*, se sitúan con un 80% en Ingeniería Técnica seguido de Ingenierías Superiores. Por último, el *voluntariado* se aleja de estos datos, caracterizándose por sumar un 66% de estudiantes y un 34% de diplomados en áreas no especializadas en contextos tecnológicos. En relación al grupo *docente*, es el que que acumula mayor experiencia profesional. Se sitúan con un 69% en más de 5 años. Sin embargo, los *árbitros* y *voluntariado* no presentan años de docencia, salvo un 2% del primer grupo con menos de 1 año. A su vez, las personas con más titulaciones afines al campo técnico y tecnológico son los docentes con un 72%, seguidos por los árbitros que presentan un 60%. Haciendo referencia al voluntariado, pertenecen a otras áreas en un 90%.

Tabla 3. Área de especialización por agrupamiento

Especialización	Formadores	Árbitros	Voluntariado
SÍ	72%	60%	10%
NO	28%	20%	90%

Instrumentos

Se confeccionaron tres cuestionarios (uno para el profesorado, otro para los árbitros y el último, para el voluntariado) con 6 apartados. Uno se dedicó a los datos referenciales (género, edad, residencia, formación, área de especialización y docencia). Otro, a la composición de los grupos de alumnado en el evento. El tercero, a los conceptos de programación que se trabajan con el alumnado. El siguiente, a las estrategias y metodología de programación adoptadas. Posteriormente, se aludió a las competencias trabajadas en el proceso de enseñanza-aprendizaje con esta actividad. A continuación, se introdujo una pregunta de respuesta múltiple para conocer opiniones acerca de la inserción de la asignatura de programación en el currículo educativo. Y un último apartado con una pregunta cerrada y otra abierta dedicado a valorar las posibles diferencias de género en el desarrollo del pensamiento computacional. Además, se efectuaron entrevistas informales con los tres grupos citados: formadores, árbitros y voluntariado; y se realizó una observación procesual no estructurada del comportamiento de los alumnos y alumnas.

Procedimiento

Los cuestionarios, junto con una explicación del estudio y una invitación a participar en el mismo, fueron entregados a los entrenadores responsables de los equipos participantes de la FLL el día del registro (día anterior al comienzo del evento). Asimismo, durante su desarrollo se puso a disposición de los formadores/as, árbitros y voluntarios/as. Una vez cumplimentados, se recogieron y se registraron telemáticamente en una base de datos que, posteriormente, se sometió a los pertinentes análisis estadísticos.

En relación a las entrevistas informales, se realizó un registro de las mismas y con respecto a la la observación no estructurada, se tomaron anotaciones del comportamiento del alumnado durante el desarrollo de la liga FLL Nacional 2015.

3. RESULTADOS

Los primeros datos, indican que la *composición del alumnado* de los equipos participantes es, mayoritariamente, masculino (64%). Haciendo referencia al segundo apartado, los *conceptos de programación* que más se suelen trabajar con los alumnos/as, por orden descendente son: los bucles, los condicionales y las secuencias. Además, se hace alusión al trabajo de distintos lenguajes de programación y a la comunicación entre dispositivos. Podemos comprobarlo en la Tabla 4 de este artículo en la que n_i son valores absolutos y f_i frecuencias relativas:

Tabla 4. Conceptos de programación

Concepto	n_i	f_i
Secuencias	11	73%
Ciclos	8	54%
Paralelismo	2	13%
Eventos	6	40%
Condicionales	11	73%
Operadores	9	60%
Datos	6	40%
Bucles	12	80%
Otros	6	40%

Con respecto a las estrategias para la programación que aparecen en la Tabla 6, destacan: ensayar y depurar y la enseñanza de sensores, seguidos de ser incremental e iterativo y la programación lineal.

Tabla 6. Estrategias de programación

Estrategia	n_i	f_i
Ser incremental e iterativo	9	60%
Ensayar y depurar	14	93%
Reusar y re-mezclar	5	36%
Abstraer y modularizar	2	13%
Bloques	7	47%
Sensores	10	67%
Programación lineal	9	60%
Programación por bloques	7	44%

Profundizando en la *metodología a*doptada por los responsables de la docencia, se menciona la dedicación de un trimestre a la enseñanza de los conceptos básicos y, posteriormente, se acogen a un sistema totalmente práctico con creación de Apps, Robótica, etc. También destaca el trabajo por proyectos y el trabajo cooperativo. En relación a las *competencias que pueden favorecer el proceso de enseñanza-aprendizaje de la programación* comprobamos en la Tabla 7 las que más destacan: autonomía e iniciativa personal, aprender a aprender y el tratamiento de la información, competencia digital e innovación. Hay que aludir también a la importancia que los encuestados/as dan al trabajo en equipo y la educación en valores.

Tabla 7. Competencias en programación

Competencia	n_i	f_i
Comunicación Lingüística	11	69%
Matemáticas	10	63%
Conocimiento e Interacción con el mundo físico	12	75%
Tratamiento de la información, competencia digital e innovación	13	81%
Social y ciudadana	10	63%
Cultural y artística	8	50%
Aprender a aprender	14	88%
Autonomía e iniciativa personal	15	94%

En cuanto a la *inserción de la programación en el currículo educativo*, podemos ver reflejado en la Tabla 8 como los/las docentes en un 70% coinciden en que la materia se convierta en obligatoria, al igual que los árbitros con un 60%. El voluntariado, por el contrario, opina en un 89% que sería más conveniente que la asignatura sea optativa, sobre todo, por gustos y preferencias y/o capacidades individuales.

Tabla 8. Inserción de la programación en el Currículo Educativo

Inserción	Formadores		Árbitros		Voluntariado	
	n_i	f_i	n_i	f_i	n_i	f_i
Obligatoria	27	70%	3	60%	1	12%
No obligatoria	-	-	-	-	-	-
Optativa	11	28%	2	40%	8	89%
Extraescolar	2	5%	-	-	-	-

Por último, los tres agrupamientos indicados en la Tabla 9, coinciden en que existen *diferencias de género en programación*, aunque en los/las formadores/as se observan más diferencias.

Tabla 9. Diferencias de Género en Programación

Diferencias de Género	Formadores		Árbitros		Voluntariado	
	n_i	f_i	n_i	f_i	n_i	f_i
SÍ	25	64%	5	100%	9	100%
NO	14	36%	-	-	-	-

A su vez, se realiza un desglose por parte de las tres agrupaciones de los puntos fuertes y débiles según el género, masculino o femenino. En la Tabla 10 encontramos los resultados del grupo de formadores, de los árbitros y, del voluntariado.

Tabla 10. Diferencias de Género formadores, árbitros y voluntariado

	Punto Fuerte	Punto Débil
	Formadores	
Masculino	+ Rapidez y Motivación +Prácticos +Competitividad +Liderazgo	- Constancia - Organización - Orden - Trabajo en Equipo - Focalización de intereses
Femenino	+Atención +Constancia +Creatividad +Organización +Trabajo en Equipo	- Poca práctica - Liderazgo - Gustos
	Árbitros	
Masculino	+Participación	- Organización
Femenino	+Liderazgo +Organización	- Participación
	Voluntariado	
Masculino	+Prácticos	- Organización
Femenino	+Trabajo en Equipo +Organización	- Carácter

4. DISCUSIÓN Y CONCLUSIONES

En términos generales, se observa que el grupo de docentes y árbitros, conocedores muchos y muchas en profundidad del área técnica, consideran que la asignatura de programación debería estar implícita en el currículo educativo según los datos obtenidos en la variable que alude a la inserción de la programación, en el apartado de resultados de este artículo. Sin embargo, aquellos/as no especializados en este ámbito, como es el voluntariado, exponen que debe incluirse pero de forma optativa. Las razones dadas por parte de este último grupo, no expertos en tecnología, tiene que ver con su complejidad y con que los intereses del alumnado pueden no estar orientados a esta temática. Tras un proceso de entrevista con estos sujetos, se denotó que relacionan la programación con conceptos puramente matemáticos y abstractos. Sin embargo, los docentes y árbitros, expertos en tecnología, abordan la programación como una materia con gran contenido transversal y multitud de posibilidades y beneficios con respecto al resto de asignaturas [7]. Respecto a a la cantidad de alumnado en este tipo de competiciones sobre robótica y programación, encontramos una mayor presencia de sujetos masculinos que ascienden a un 64% del total según los datos de este studio [4]. Por ello, consideramos que aún hay que trabajar profundamente en el fomento de vocaciones científicas y de ingeniería en las niñas. En el transcurso del estudio, observamos que en las etapas de infantil y primaria existe mayor homogeneidad entre niños y niñas, mientras que a medida que aumenta el nivel educativo disminuye, quizás por posibles intereses o estereotipos implantados.

En relación a la existencia de diferencias de género, comprobamos que los puntos fuertes de los chicos son, mayoritariamente, los débiles de las chicas, y con los puntos débiles ocurre algo similar. Si se analiza el género masculino, hay coincidencias entre las aportaciones de los/las docentes y el voluntariado en el punto fuerte que alude a que los chicos son más prácticos para realizar las tareas destacando los árbitros, además, su participación; mientras que si se alude al punto débil donde todos/as coinciden, destaca la organización. Por el contrario, estudiando al género femenino, el punto fuerte donde todos los grupos coinciden es la organización. En el caso negativo, se detecta en ellas falta de participación, dominio y liderazgo. Todo ello unido a las anotaciones recopiladas mediante las entrevistas efectuadas y la observación etnográfica, descubrimos que los chicos suelen destacar en aspectos relacionados con la práctica y taller, la competitividad y el liderazgo pero fallan en la organización y el trabajo en equipo. Por el contrario, las chicas son buenas organizadoras, saben trabajar en equipo, son más constantes y creativas pero descienden en liderazgo. Si reflexionamos acerca de este asunto y esta clara inversión, planteamos que la creación de grupos mixtos podría ser beneficiosa porque habría una notable complementariedad de cualidades entre ellos y ellas, algo que podría aumentar el rendimiento de dichas agrupaciones. A su vez, tenemos presente que todos los resultados pueden verse modificados por la existencia de variables que influyen considerablemente como son: las diferencias individuales, las inteligencias múltiples, los estilos de aprendizaje, entre otros [4].

Por último, no se han encontrado diferencias notorias que justifiquen que el procesamiento de la información y el aprendizaje varía según el género. Asimismo, los diferentes agentes estudiados han manifestado que no han observado desigualdades en su práctica profesional, sin embargo, esto puede ser debido a que no se ha estudiado directamente este fenómeno ni se ha prestando atención en profundidad. Por ello, planteamos la necesidad de continuar estudiando e investigando este asunto y plantear otro tipo de estudios que ahonden en este fenómeno, con instrumentos subjetivos como los que hemos utilizado en este estudio, así como otros instrumentos objetivos (por ejemplo, *eye tracking, brain computing*, etc.). En relación a esta investigación, nos ha abierto puertas para poder seguir trabajando en aspectos relacionados con la temática de enseñanza de programación desde una perspectiva de género, como puede ser la relación de competencias que se podrían desarrollar con el fin de convertirlas en fortalezas para el proceso de enseñanza-aprendizaje, previniendo problemática estereotipada y mejorando resultados. A su vez, consideramos que aporta datos susceptibles de seguir profundizando ya que su abordaje es justificable en otros contextos educativos, siendo solo un eslabón más de una larga cadena con gran proyección de futuro. De este modo, estaremos encantadas de que pueda servir de base para posteriores estudios.

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Dos sentidos de lo tecnológico en relatos de vida de mujeres tecnólogas

Adriana Gil-Juárez
Universitat Rovira i Virgili
Campus Sescelades
Departament de Psicologia
+34977558207
adriana.gil@urv.cat

Joel Feliu
Universitat Autònoma de Barcelona
Departament de Psicologia Social
Edifici B
+34935814502
joel.feliu@uab.cat

Montse Vall-llovera
Universitat Oberta de Catalunya
Estudis de Psicologia i Ciències de l'Educació
Rambla del Poblenou, 156
+34933563886
mvall-llovera@uoc.edu

Ester Conesa
Universitat Rovira i Virgili
Campus Sescelades
Departament de Psicologia
+34977558207
adriana.gil@urv.cat

RESUMEN

Los relatos de vida tecnológica nos ayudan a comprender la relación entre la experiencia con la tecnología y los múltiples significados que le otorgamos. Presentamos los resultados de un proyecto de investigación que elaboró las trayectorias de vida tecnológica de 15 mujeres del sector, de edades comprendidas entre los 19 y los 46 años, con la finalidad de conocer los recorridos que pueden facilitar o inhibir un uso experto de la tecnología. En sus relatos, observamos dos sentidos de lo tecnológico. El primero es producto de un contacto experto tardío con la informática, que no suele producirse hasta el momento de llegar a la universidad o al mundo laboral, lo que marca un punto de partida proclive a las dificultades y frustraciones, especialmente durante la carrera: genera sentimientos de competencia o autoeficacia ambivalentes, y conduce a caracterizar la tecnología como compleja, de difícil acceso y necesitada de gran dedicación. Sin embargo, en sus explicaciones encontramos también una visión de la tecnología como un mecanismo de transformación social, que sirve tanto para mejorar su entorno inmediato como para generar algo útil. Sus relatos nos ofrecen la posibilidad de resignificar las tecnologías, pensándolas como socialmente útiles, potenciadoras del cuidado y garantes de transformación. Focalizar esta resignificación de lo tecnológico podría ayudar a cambiar la situación actual de fractura digital de género creciente. Al mismo tiempo, también ayudaría evitar adoptar las trayectorias masculinas como referente, ya que esto contribuye a destacar las dificultades, suele llevar a una visión de la trayectoria de las chicas como deficitaria e invisibiliza las "rutas" diversas de las chicas y sus aportaciones en el ámbito tecnológico.

Categorías y descriptores temáticos

K.4.0 [**Computers and Society**]: General

Términos Generales

Human Factors

Palabras Clave

Brecha digital de género; Relatos de vida; Trayectorias tecnológicas; Significado de Tecnología.

1. INTRODUCCIÓN

El descenso en las personas matriculadas en ingenierías informáticas en el mundo occidental sigue produciéndose, hasta el punto que Caroline Clarke Hayes [1] llega a afirmar que: "If this trend were to continue at the rate experienced from 1986 to 2006, there will be no women bachelor degree graduates in computer science by 2032". Se cumpla o no, lo cierto es que las dificultades que siguen teniendo muchas mujeres a la hora de tomar la decisión de estudiar una carrera informática siguen estando ahí. Muchas de estas dificultades se explican a través de los itinerarios biográficos de las mujeres en relación a las tecnologías a lo largo del ciclo vital. En la abundante literatura académica dedicada a esta cuestión, encontramos que las trayectorias tecnológicas que pueden seguir las mujeres pueden dividirse en dos grandes rutas que se entrecruzan en cada persona: una de Exclusión y otra de Inclusión. Es decir aquellas rutas que tienden a expulsar a las mujeres del mundo tecnológico experto y aquellas que tienden a acercarlas, no sin dificultades, a él.

1.1 Rutas de la exclusión

Esta línea de investigación cuenta con una gran cantidad de literatura, es una literatura que suele reproducir la idea de la existencia de diferencias de género estables al explorar los diferentes usos e intereses que mujeres y hombres tienen y sus causas.

En el ámbito escolar se han explorado las políticas escolares, el diseño del currículum, la optatividad y los procesos para escoger materias como espacios donde se produce discriminación estructural (Aspray, 2006). Destacan también los estudios de las interacciones que exploran las relaciones maestras-alumnas y como se transmiten las creencias y prácticas sobre la informática y sus profesiones como dominio masculino. Es decir, el efecto de la transmisión de expectativas y la falta de apoyo o promoción de los intereses y aptitudes informáticas. Así mismo, se han explorado las relaciones maestras-ordenadores: lo que conocen o sienten hacia los ordenadores (desconfianza y desinterés en gran medida); el poco uso de los ordenadores para usos educativos; su poca formación; y, la falta de promoción del interés en las chicas. [3, 4, 5, 6, 7].

Varias autoras [2, 8, 9] han comparado la presencia y uso de ordenadores en casa y en la escuela, encontrando que:

- Los chicos dominan el uso de los ordenadores en la escuela y escogen más cursos optativos en informática que las chicas.
- Los chicos usan más los ordenadores en casa, para más cosas y más tiempo
- Los chicos empiezan de más pequeños.
- Los usos en la casa y la escuela se influencian mutuamente.

En general, la familia y la comunidad local (vecinos, amigos) suelen apoyar más los intereses en informática de los chicos que de las chicas.[6, 10, 7]. Las aspiraciones profesionales y vitales de las chicas se suelen corresponder con las expectativas de los padres, entre las que no se pueden obviar las expectativas sobre la vida familiar futura y las dificultades que puede suponer para ella un posible futuro entorno laboral absorbente. Los iguales transmiten también las creencias de las chicas y los chicos sobre lo inapropiados que son los cursos de informática para las chicas. Además, los chicos del entorno se apropian físicamente de los espacios y aparatos [2].

También se ha explorado abundantemente el imaginario que transmite la cultura popular, a través de la televisión y las revistas, que refuerzan sistemáticamente los estereotipos de quiénes son los expertos, los que tienen conocimientos avanzados de informática. El estereotipo del geek es una figura masculina [12, 13, 14, 15, 16]. Como parte de esta cultura ha sido también explorada abundantemente la cultura del videojuego, a nivel de creadores, jugadores y contenidos de los propios videojuegos [17].

Todo esto conlleva diferencias en las actitudes, la confianza, las habilidades y las competencias percibidas [18, 10, 19, Sabine 2009; 20, 21], y por lo tanto en el interés y las experiencias de chicos y chicas. En las chicas se describen menos actitudes positivas (especialmente a partir de los trece), menos confianza (los chicos sobreestiman sus habilidades mientras que las chicas las subestiman), más atribuciones internas de los errores o fallos (que suelen ser externas en los chicos [22], en definitiva, menos interés y por lo tanto menos experiencia. [23, 24].

1.2 Rutas de la inclusión

De forma paralela a la poca cantidad de mujeres presentes en los sectores tecnológicos existe también menos literatura respecto a la forma en qué han llegado ahí las que están. Esta literatura muestra los porqués del interés de las chicas, cuando lo hay, por la informática y los ordenadores.

En la opción por la informática tanto chicos como chicas invocan el gusto y el placer, pero ellas añaden factores prácticos y oportunidades, mientras ellos se centran más en considerarlos la consecuencia natural de su interés [25, 2, 26, 27, 28, 31]. En el interés y atractivo de la informática ellas enfatizan las aplicaciones y los usos, mientras que ellos “sueñan con código” [28, 27]. Porque para ellos la afición surgió de un “amor a primera vista” con la máquina, mientras que en ellas el interés surge de forma moderada y gradual [32, 33].

Los promotores de su interés siempre acaban siendo hombres, destacándose la ausencia de modelos de rol mujer. Las chicas mencionan a padres o hermanos mayores o amigos como apoyos o modelos [34, 32]. Sin embargo, para ellas, la experiencia y conocimientos adquiridos en casa son escasos, los primeros contactos suelen producirse en la escuela [35, 36]. Un hecho que seguramente contribuye a que incluso en las chicas que estudian informática la confianza en las propias habilidades sea menor que la de los chicos [37, 38, 26, 39, 40, 41, 42].

Los estereotipos sobre el estudiante de informática no ayudan, y para ellas acaba siendo una necesidad distanciarse del estereotipo, casi ninguna quiere ser vista como geek [43, 39, 35, 27, 28]. En muchos casos la afición “hardcore” a los videojuegos no es determinante puesto que aparece a posteriori, provocada por la relación con las amistades informáticas [34].

Estas experiencias, sin embargo, no son comunes a todas las estudiantes de informática, en algunas minorías, por ejemplo en afroamericanos, no existe una brecha digital de género, y entran en la misma cantidad hombres y mujeres. En el caso de migrantes la informática se percibe como un posible camino de ascensión social [29, 42].

Aunque algunas chicas llegan a la informática de manera parecida a los chicos (por enamoramiento de la máquina o pasión por los videojuegos), existen lo que podemos llamar rutas invisibles [30]. Dichas rutas nos muestran otros caminos, alternativos a los de los chicos, que las chicas pueden recorrer para relacionarse con las tecnologías. Son invisibles porque ni las estudiantes de secundaria, de bachillerato, el profesorado o los padres y las madres las conocen ni difunden, impidiendo de esta manera que las chicas que las siguen puedan ejercer de modelos de otras. No se ven no solamente porque sean chicas quiénes las siguen, sino porque no se suele considerar que lo que hacen sea informática propiamente, como por ejemplo cuando una médico crea su propio programa informático porque no encuentra el que necesita o una diseñadora crea programas para sus producciones audiovisuales.

Así, según Gil-Juárez et al. [30], se puede llegar a cursar una ingeniería informática por alguna o varias de las siguientes razones: por querer hacer algo útil para los demás; por curiosidad de saber cómo funcionan las cosas; por motivos políticos – como formar parte de Comunidades Hackers [44]; por llegar a la informática desde otras ocupaciones: medicina, arte, cine, animación, química, otras ingenierías, [45, 46].

Diferentes rutas, experiencias diversas, que nos muestran que debe evitarse adoptar las trayectorias masculinas como referente único porque esto contribuye a destacar las dificultades, suele llevar a una visión de las trayectorias de las chicas como deficitarias e invisibiliza sus “rutas” diversas.

Algunas autoras, como Judy Wajcman, han propuesto que el significado de lo tecnológico debe ser también considerado. Según estas autoras la asociación de lo tecnológico con lo masculino lleva también a excluir a las mujeres de este terreno al no considerarlo como algo propio ni apropiable. En esta comunicación exploramos el sentido que tiene lo tecnológico para un grupo de mujeres que han desarrollado una carrera en el ámbito tecnológico, y que por lo tanto han seguido alguna de las rutas de inclusión. En este grupo encontramos que lo tecnológico tiene sobre todo dos sentidos, en primer lugar como algo complejo, de difícil acceso y necesitado de gran dedicación, y en segundo lugar, también como mecanismo de transformación social y por lo tanto demasiado importante como para dejarlo de lado. Si el primer sentido puede interpretarse como efectivamente más "masculino" en su sentido tradicional, el segundo sentido puede permitir a más mujeres ver la tecnología de forma compatible con las exigencias del cuidado tradicionalmente impuestas a las mujeres.

2. METODOLOGÍA

A partir de la revisión bibliográfica, preparamos un guión de entrevista en profundidad, abierta y semi-estructurada con la finalidad de comprender la relación entre la experiencia particular con la tecnología y la conformación de la identidad de género femenino. Buscábamos conocer en detalle no solo la trayectoria que habían seguido estas mujeres en su relación con la tecnología sino especialmente el sentido que para ellas tenía esta relación y la tecnología misma.

La pregunta inicial era sobre el recuerdo del primer contacto con un ordenador y/o una consola de videojuegos, siguiendo de ahí una conversación sobre sus usos durante la infancia y adolescencia (tiempos, espacios y personas implicadas), los modos de aprendizaje, el contexto tecnológico familiar, escolar y de amistades, la decisión por el estudio, sus vivencias iniciales en la carrera y a lo largo de ella, los primeros contactos con el mundo laboral y el desarrollo de su carrera.

Pusimos a prueba el guión en una experiencia piloto durante el año 2012 en la que entrevistamos a 2 estudiantes de los últimos cursos de la carrera de ingeniería informática y a 5 trabajadoras en activo del sector tecnológico. Después de algunos cambios menores en el guión, utilizamos una estrategia muestral en "bola de nieve" a partir de contactos personales.

Entre 2013 y 2014 llevamos a cabo quince entrevistas a mujeres con relaciones distintas con el mundo de la TIC, y de edades comprendidas entre los 19 y los 46 años (ver **Tabla 1**)

Puesto que las entrevistas se centraron en las trayectorias de estas mujeres el objetivo era conocer los relatos de vida tecnológica que producían, con ello, pudimos conocer los usos de las tecnologías por parte de estas mujeres, analizar sus experiencias, percepciones y valoraciones, y, escuchar como las relatan para darle sentido.

Tras la transcripción literal de todas las entrevistas, llevamos a cabo un análisis cualitativo de contenido. El proceso de realización del análisis consiste en transformar las "datos brutos" (las manifestaciones directas recogidas en las transcripciones de las historias de vida) en "datos útiles". Es decir, sistematizar una información manejable que permita una nueva comprensión de la realidad.

Para el análisis seguimos las fases que describen Strauss y Corbin (1998): 1. Fase de segmentación; 2. Fase de codificación de apertura; 3. Fase de clasificación e interrelación de códigos de apertura; 4. Fase de codificación focalizada; y, 5. Fase de (re)contextualización. La finalidad del análisis es clasificar temáticamente el contenido de la entrevista, establecer relaciones entre sus diferentes partes, destacar los elementos que se relacionan con los objetivos de la entrevista e interpretar el sentido de estos de forma sistemática..

3. RESULTADOS

El análisis de los relatos de las mujeres entrevistadas nos mostró las maneras diversas en que éstas llegaron a las tecnologías, las usan, se las apropian y se relacionan con ellas.

Tabla 1. Muestra

Nº Entrevista	Formación	Institución y/o tipo empresa donde trabaja	Responsabilidad en la institución y/o empresa	Estado /Provincia	Edad
1	Doctora en Ingeniería	Universidad pública	Profesora e investigadora	Reino Unido /Lancaster	30-35
2	Doctora en Informática	Universidad pública	Profesora e investigadora	España /Madrid	30-35
3	Licenciada en Psicología	Universidad pública	Profesora Asociada	España /Tarragona	25-30
4	Técnico especialista en medicina nuclear y radiodiagnóstico	Servicio de Medicina Nuclear	Técnica	España /Ciudad Real	35-40
5	Bachillerato	Ayuntamiento	Auxiliar administrativa	España /Granada	45-50
6	Diplomada en Enfermería con tres posgrados	Hospital público	Enfermera instrumentista	España /Barcelona	30-35
7	Licenciada en Física	Universidad pública	Doctoranda en redes complejas	España /Tarragona	25-30
8	Licenciada en Telecomunicaciones	Universidad pública	Doctoranda en robótica y neurotecnología	España /Barcelona	30-35
9	Licenciada en Filología Francesa cursando un máster	Centro de Computación	Técnica de resolución de problemas informáticos	España /Barcelona	25-30
10	Licenciada en Ingeniería Informática	Multinacional Informática	Programadora de software para impresoras	España /Barcelona	25-30
11	Licenciada en Matemáticas	Instituto	Profesora de programación Ciclos Formativos de Grado Superior	España /Barcelona	35-40
12	Estudiante de Sociología	Universidad pública	Estudiante	España /Barcelona	20-25
13	Primer año de informática y estudios FP de técnica de sonido	Proyecto asociativo	Responsable de gestión	España /Barcelona	25-30
14	Licenciada en Física y Especialización en Astrofísica	Bachillerato público	Profesora de Electrónica	España /Navarra	30-35
15	FP de Diseño de Interiores, 2 licenciaturas iniciadas (área agrícola y artística) y cursos intensivos de aplicaciones informáticas y programación web	Empresa familiar ligada a una universidad	Imparte algun curso de alfabetización digital y realiza prácticas de programación	España /Barcelona	30-35

Cuando se les preguntó por sus primeros contactos con la informática, estos aparecen como diversos. En algunos casos se producen en la pre-adolescencia o la adolescencia, en casa, en la escuela, el instituto o a través de alguna actividad extraescolar. Sin embargo no es un contacto que se describa como intenso ni apasionante:

"...y el primer contacto fue, si no recuerdo mal, fue en plan actividad extraescolar, que me apuntaron a la típica academia que hay al lado de la escuela, y recuerdo que había mecanografía e informática."

"Yo, o sea, no tengo así mucha conciencia de cuándo utilicé la primera vez el ordenador, pero yo no tuve ordenador hasta supertarde. Y quizás las primeras veces fue en la escuela, en el instituto o así yo creo, sí."

A menudo porque el ordenador no es para ellas o bien porque se comparte de manera que no se puede acabar usando mucho:

"Bueno, mis padres compraron el primer ordenador a mi hermano, cuando él teníaaaa... él tenía 10 años y yo tenía 6 años, pero no era para mi el ordenador, no? yo lo ví pero... era cosa que no... o sea yo no tenía mucho que ver con esto."

"…pero si, los primeros contactos que tengo yo con ordenador pues es muy joven, yo creo que es como a los 16 o 17 años. Los primeros ordenadores que salen, pues estamos en el instituto. Y bueno que nos lo ponían delante como si fueran una cosa… una especie a visitar, no? El ordenador grande… y claro...participábamos poco …"

El ocio tecnológico produce más entusiasmo en algún caso:

"Con videoconsolas sí!!!! Con ordenadores no tocaba mucho, no!!! la verdad…."

Sin embargo, aunque todas en algún momento han jugado a videojuegos, y utilizaron consolas, algunas de ellas lo hicieron muy poco, y otras lo hacían con amigos o con miembros de la familia (hermanos/as y/o primos/as).

"...si sí...pues bueno a lo mejor con 16, o por ahí en casa de algunos amigos míos que si tenían videoconsolas de éstas de las antiguas, pues eran de los primeros videojuegos que salieron que eran como especies de comecocos, y también había de coches."

"…con mi prima sí nos enganchamos a las máquinas estas grandes de bar, en el Tetris, eso sí que recuerdo ..."

Aunque en la actualidad refieren jugar poco, la experiencia del juego suele contarse en pasado, algunas han seguido jugando, sin por ello considerarse muy hábiles.

"No sé jugar a ningún juego, y aunque le ponga voluntad…, pero se me da fatal, pero me gusta mucho, puedo pasarme horas…"

La familia juega un papel importante, en algunos casos, a la hora de proporcionar los medios materiales (o apuntar a la academia, como hemos visto) o constituirse en referentes que no siempre son los más esperables:

"A veces he culpado a mi abuela. Sí, porque ella ... aunque evidentemente la tecnología le queda super lejos, pero siempre digo que es algo que le atrae mucho, no? Yo recuerdo que se compraron un vídeo y que buscaba el manual del vídeo para programarlo, era mi abuela. Y entonces pues, a veces haciendo la broma no? digo, "ehh !! vi esto no ?!", no tuve un referente eh, super masculino o lo que sea, sino que veía mi abuela pues mirando manuales de instrucciones de cosas que no eran ordenadores …"

"... y mis padres también lo encontrarían interesante pues porque ... para estudiar o lo que sea, no? y me compraron el PC este y la, y una impresora enorme y ... y ya está…"

"Y hubo, sí, cuando era adolescente hubo un ordenador en la casa que era de mi mamá y sí que me acuerdo que para arrancar un juego tenía que escribir un comando, no?"

Las mujeres con formación universitaria en informática, casi todas, con alguna excepción, comienzan desde cero y se encuentran con dificultades y a veces frustraciones, especialmente durante la carrera. Consideran que en la carrera les enseñan poco a programar, y que el profesorado no las tiene en cuenta y a menudo tienen que recurrir a sus compañeros.

"Quiero decir a, Informática Básica, quiero decir lo que es Programación nadie te, nadie te enseña, quiero decir, nadie te dice nada ... ellos hacen sus clases y básicamente son más a nivel teórico [...] realmente no se preocupan de que tú sepas o no sepas."

"...para aprender las cosas nuevas que iban… incluso ahora no? que van surgiendo... es un poco aquí te pillo aquí te mato, "¿explícame como se hace esto?,¿ dime cómo has buscado lo otro?", mmm, "Esto para qué sirve?...¿cómo puedo guardar esto?". Mmmm, es un poco quizás más los compañeros, los amigos, los que me han ido formando."

Uno de los aspectos a destacar es su parte autodidacta. Tanto en las mujeres que se habían formado en el ambiente universitario, como aquellas que usan la tecnología en sus profesiones, pero sin formación universitaria en informática. Algunas sienten curiosidad y experimentan con ella, ya sea por placer o por querer saber.

"Una parte en el colegio, y yo creo que un 80% experimento yo sola."

"…me pongo hasta que lo consigo. Me da igual no saber….yo, busco, busco...hasta que lo hago."

"Pues claro, ahí ya como que con Arch Linux tienes que aprender estas cosas no? Y... y realmente me enamoré de este sistema y... no sé, en dos semanas con Arch Linux tuve que aprender mucho más que en dos años con Ubuntu, no? que era como una cosa que te exige, o sea…"

En cuanto a sus sentimientos de competencia o autoeficacia, a veces pueden resultar ambivalentes y, en ocasiones, autodefinen su relación con la tecnología por comparación a sus compañeros masculinos y no se ven a sí mismas como genios, más bien como alguien que ha tenido que esforzarse.

"…bueno yo siempre me veo que, que sé muy poco. Pero ... pero luego ves que hay gente que sabe menos que tú y es el ... tiene un nombre, eh, eso! y nunca me acuerdo ... como el ... como un complejo de ... de que tú no sabes, no? pero es que es imposible saber mucho y ... yo no sé si sé mucho o poco, pero ahora sí tengo que reconocer que hace muchos años que las toco, y eso quieras que no te da ... el experiencia es ... no tiene precio, no?"

"No sé, cuando están montando un ordenador. Ellos tampoco saben cómo hacerlo realmente! […] Claro, saben un poco más! pero... al principio no lo sabían, no? O sea, no lo sabían. No lo sabían! Te metes ahí, desmontas un cable, montas otro cable, y "funciona, mira bien", "no funciona, pues mejor, así aprendo".

Este contacto tardío con la informática a nivel experto, desapegado a menudo, y ambivalente respecto a sus capacidades "naturales", en el que se destacan los referentes y apoyos externos, supone un punto de partida proclive a pensar más en términos de dificultades y frustraciones, y en consecuencia conduce a caracterizar la tecnología como compleja, de difícil acceso y necesitada de gran dedicación.

"He tenido la sensación de ir ahí a toda prisa en toda la carrera en plan "venga, tochos tochos, tochos, profes que te dan materia materia, materia" y que de partida no me parecen conceptos fáciles de entender. O sea que son cosas que si eres un crack sí, pero para personas normales .. que es super abstracto eso. Y bueno, ... pues eso."

"Cuando empecé la carrera fatal. [...] Bueno, estudié, y saqué un cero, me decían que no sabía nada, no? Y me fue ... quiero decir, fue muy, muy duro no? para mí…"

Esta caracterización de dureza de lo tecnológico se asocia con lo masculino, una asociación cultural de la que son plenamente conscientes las entrevistadas:

"Tengo la imagen de ella metida en un ordenador bastante presente. …Así que también, bueno, o sea, mi madre estudió Matemáticas, que creo que es bastante significativo, no? Que ella como que hizo el primer camino dentro de algo que se supone que es un poco más masculino, no? y... cosas lógicas, o sea... Matemática y Informática van bastante juntas, no?"

Sin embargo, en sus explicaciones encontramos también una visión de la tecnología como un mecanismo de transformación social, que sirve tanto para mejorar su entorno inmediato como para generar algo útil. Hay un aspecto que destaca en particular, el de la transformación social a la que se puede llegar mediante las tecnologías, lo que se puede hacer con ellas, tanto para mejorar su entorno y que sean útiles, como desde un punto de vista más activista.

"… la única idea que sé es que quiero aplicar la informática a hacer algo bueno, porque la informática está como muy enfocada hacia el capricho, hacia el consumo. Quiero que la informática ayude a la gente […] yo quiero ... aplicar la informática a la medicina, a las operaciones de corazón, por ejemplo, de física cuántica ... O a algo que ayude, no sé, quiero hacer algo que tenga relevancia, que ayude a la gente."

"... Veo una manera de poder usar cosas que yo he aprendido de otra manera, aprender cosas nuevas también, pero poderlas utilizar para cosas que sirvan ... mmmm el rollo social, no? o sea con movimientos sociales…"

Sus relatos nos ofrecen también la posibilidad de resignificar las tecnologías, pensándolas como útiles, potenciadoras del cuidado y garantes de transformación social.

4. CONCLUSIONES

Los relatos de vida tecnológica de estas quince mujeres, nos permiten comprender la relación entre su experiencia y los sentidos que lo tecnológico puede adquirir. Es destacable que en las mujeres con conocimientos expertos apareció una comprensión de la tecnología que se aleja del modelo masculino dominante y que puede facilitar a otras mujeres acercarse a ella.

Sus primeros contactos con la tecnología son diversos, pero tienen en común no mostrar un gran apego a esta. En algunos casos se producen en la preadolescencia o la adolescencia, en la escuela, el instituto o a través de alguna actividad extraescolar. Han jugado a videojuegos, y utilizaron consolas, algunas de ellas muy poco sin embargo, y otras lo hacían con amigos o con miembros de la familia (hermanos/as y/o primos/as). Destaca su formación autodidacta en no pocos casos. Las mujeres con formación universitaria en informática, con alguna excepción, comienzan desde cero y se encuentran con dificultades y a veces frustraciones, especialmente durante la carrera, que llevan a sentimientos de competencia o autoeficacia que a veces pueden resultar ambivalentes. Sin embargo, una motivación importante es la transformación social a la que se puede llegar mediante la apropiación de las tecnologías, tanto para mejorar su entorno como para que sean útiles.

De cara a futuras investigaciones, es necesario explorar como a pesar de encontrar múltiples y significativas motivaciones las mujeres no se suelen pensar como genios informáticos y se encuentran con dificultades y frustraciones generadas por su entorno, que en muchos casos les generan la sensación de no ser suficientemente competentes. Como destacan recientemente Leslie et al. [47], las disciplinas donde existe la imagen de que se requiere ser un genio para triunfar en ellas son las que más brecha de género presentan.

Encontramos en nuestra investigación que a las mujeres se les ha negado el acceso práctico, pero también simbólico y placentero a los ámbitos tecnológicos, de forma que para muchas mujeres no es pensable encontrar ahí «su lugar». Si acceden, el camino que tienen que recorrer es otro y es más largo. Si intentan adoptar la forma del camino masculino pero sin haber seguido la misma trayectoria, se encuentran más frustración. Pero existen otras rutas de inclusión en el mundo tecnológico que no son las mismas que las de los chicos ni su reverso, que nos muestran otras prácticas, otras relaciones con la tecnología, sin embargo son rutas invisibles dado que no son la ruta normalizada, la marcada como estándar por el modelo masculino. Todo esto suele llevar a una visión de las trayectorias de las chicas como carentes, sin embargo esto no es así porque no hay carencia sino aportación: la resignificación de la tecnología, pensándola de una forma más completa y compleja, resaltando lo que pueden hacer para ayudar a la gentes, para ser útiles, para cuidar y buscar la transformación social. Generalizar esta resignificación podría cambiar la situación actual de fractura digital de género creciente.

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Acercando las mujeres a la ingeniería: iniciativas y estrategias que favorecen su inclusión

Patricia Paderewski
Universidad de Granada
patricia@ugr.es

Maribel García Arenas
Universidad de Granada
mgarenas@ugr.es

Rosa Gil Iranzo
Universidad de Lleida
rgil@diei.udl.cat

Carina González González
Universidad de La Laguna
cjgonza@ull.edu.es

Eva M. Ortigosa
Universidad de Granada
ortigosa@ugr.es

Natalia Padilla-Zea
Universidad de Granada
npadilla@ugr.es

RESUMEN
En este artículo se estudian las iniciativas que se han llevado a cabo tanto en España como fuera de ella para resolver el problema del bajo número de mujeres que realizan estudios técnicos o trabajan en empresas dentro del área de las tecnologías. Una vez revisadas estas iniciativas, y constatado que actualmente no se ha mejorado este número, se proponen otras actuaciones o iniciativas que podrían mejorar la situación, y por tanto, reportar todos los beneficios que esto conllevaría, entre otras se propone la co-creación empática que se llevaría a cabo desde la educación en primaria.

Palabras clave
Género, Ingeniería, Estrategia.

1. INTRODUCCION
Actualmente se puede apreciar un número excesivamente bajo de mujeres en las carreras técnicas, como son, por ejemplo, la Ingeniería Informática o la Ingeniería de Telecomunicación en las que se centrará este artículo principalmente. Este problema está presente en nuestra sociedad y preocupa, tanto que existen numerosos artículos tratando y discutiendo este tema, no sólo a nivel nacional, sino a nivel mundial.

Nosotras, las autoras de este artículo, impartimos clase en estas ingenierías. Casi todas estamos tituladas en estas carreras técnicas y consideramos que es importante intentar abordar este problema y realizar una revisión de las distintas iniciativas que se están llevando a cabo, junto con las que nosotras sugerimos que se hagan, tanto desde las Universidades como desde las empresas que podríamos denominar TIC. Esta ausencia de estudiantes femeninas es tan importante, que los enfoques, sin una visión femenina, son totalmente diferentes, lo que hace perder diversidad y puntos de vista complementarios para encontrar la solución a un determinado problema. Por otra parte, también estas estudiantes, aportarán mucho en sus futuras empresas al finalizar sus estudios.

En el último informe [1] que presenta el Ministerio de Educación de forma anual, y donde se analizan los datos básicos del Sistema Universitario Español, se comenta la bajada de estudiantes en el ámbito de ingeniería y arquitectura, pese a la demanda existente con una tasa de variación anual del -5,3% y decenal del -23,3%, lo que significa que esta rama ha perdido en los últimos 10 años uno de cada cuatro estudiantes femeninas.

Para ilustrar este descenso basta ver algunas cifras a nivel estatal así como los casos particulares de nuestras universidades, para entender la preocupación que provoca la poca presencia femenina en las titulaciones técnicas.

En el artículo de [2] las autoras exponen que, en 2º de Bachillerato del curso 2009-2010, el 53,64% hombres y 46,36% de mujeres optaron por la modalidad de Ciencia y Tecnología y sin embargo los datos de los y las estudiantes que se matricularon en el primer curso de grados universitarios en el curso 2010-2011 reflejan que solo 23% de las mujeres eligieron la rama de Ingeniería y Arquitectura, mientras que el resto de las mujeres se decantaron por otros estudios pertenecientes principalmente a las Ciencias de la Salud.

A modo de ejemplo ilustrativo y real, analizaremos los datos de nuestras Universidades en los últimos cinco años, tanto en las titulaciones relacionadas con la Informática, (Ingeniería, Ingeniería Técnicas y Grados), como en las titulaciones relacionadas con la Telecomunicación. La primera de ellas, la Universidad de Granada, aporta los siguientes datos:

- El porcentaje de alumnas matriculadas en el Grado en Ingeniería Informática oscila entre 8.84% y 13.57% y en el Grado en Ingeniería de Tecnologías de Telecomunicación oscila entre 14.53% (curso 2014-2015) y 22.95%.
- La tasa de abandono en el curso 2014-2015 fue 12.85% de mujeres y 87.15% de hombres en el Grado en Ingeniería Informática. En el Grado en Ingeniería de Tecnologías de Telecomunicación la tasa de abandono fue del 32% de mujeres y 68% de hombres. Son números sobre el total de los alumnos, no solo mirando los alumnos de primer curso, sino teniendo en cuenta el Grado completo que incluye cuatro cursos en esta universidad.
- El porcentaje total de mujeres matriculadas, a día de hoy, en el curso 2014-2015 en el Grado en Ingeniería Informática es 9.63% y en el Grado en Ingeniería de Tecnologías de Telecomunicación es 16.81%.
- El porcentaje de egresadas en el curso 2014/2015 en el Grado en Ingeniería Informática fue de 9.68% y en el Grado en Ingeniería de Tecnologías de Telecomunicación fue de 6.67%. Estas cifras realmente no son muy significativas porque este curso fue el primero en el que se impartió el último curso de ambas titulaciones, y tenía algún que otro

problema adicional que impidió que muchos alumnos terminaran sus estudios, en concreto, solo 31 en el Grado en Ingeniería Informática y 30 en el Grado en Ingeniería de Tecnologías de Telecomunicación.

Si comparamos estos datos con los de la Universidad de Lleida, utilizando el mismo periodo temporal, los de la Universidad de Lleida son incluso más alarmantes:

- El porcentaje de alumnas matriculadas en el Grado en Ingeniería Informática oscila entre 3.2% y 14% (curso 2012-2013).
- El porcentaje de tituladas en las carreras universitarias relacionadas con la informática (I.T. Sistemas, I.T. Gestión, Ingeniería Informática y Grado en Informática) fue, en el curso 2013-2014, del 14% frente al de titulados que fue del 86%.

En el caso de la Universidad de La Laguna, se han incluído no sólo los últimos cinco años, sino los 10 últimos años de las titulaciones relacionadas con Informática para que se aprecie más la evolución de los números. En este caso, el porcentaje de mujeres es aproximadamente el 17% de la matrícula (Figura 1). Asimismo, vemos una ligera disminución cuando la titulación cambio de nombre de Licenciatura a Ingeniería (desde el año 1998). Sin embargo, el porcentaje de egresadas de las carreras de informática en los últimos 10 años es superior, en promedio, al 17% (Figura 2).

Figura 1. Datos de la evolución de la matrícula por sexo de los últimos 10 años en la Universidad de La Laguna

Figura 2. Datos de la evolución de egresados/as por sexo de los últimos 10 años en la Universidad de La Laguna

Estos datos demuestran que la presencia actual de las mujeres dentro de las ingenierías, al menos dentro de la Universidad de Granada, de la Universidad de Lleida, y de la Universidad de La Laguna es cada vez menor, lo que hace que la diversidad y el enriquecimiento que aporta una visión desde diferentes puntos de vista se esté perdiendo, ya no sólo dentro del ámbito docente, sino también en el ámbito laboral al que se irán incorporando todas las personas egresadas de estas titulaciones.

Para intentar paliar esta deficiencia, hemos buscado iniciativas o actuaciones relacionadas con este problema intentando ver si el bajo porcentaje de matrículas femeninas en estas titulaciones está sólo presente en las tres universidades mencionadas, o por el contrario, se trata de un problema generalizado. En concreto, la sección 2 revisa las iniciativas nacionales e internacionales que se están llevando a cabo para paliar este problema, y la sección 3 presenta un conjunto de propuestas que se deberían llevar a cabo (o seguir llevándose a cabo) con el fin de llegar al objetivo de aumentar el número de mujeres que se adentran en el mundo TIC, examinando el por qué algunas no han funcionado. La sección 4 presenta nuestra opinión a modo de conclusiones, incluyendo una reflexión personal de las autoras de este artículo sobre la problemática presentada, intentando aportar nuevas soluciones y puntos de vista alternativos.

2. ESTADO DEL ARTE

En este punto queremos presentar, para después reflexionar sobre ello, las iniciativas que se están llevando a cabo tanto en España como en otros países para intentar aumentar el número de mujeres que se dedican a las TIC (ingenierías), tanto en el ámbito académico como laboral.

En este sentido, hay iniciativas en centros docentes tanto nacionales, como en la Universidad de Lleida, la Universidad de Granada y la Universidad de La Laguna, como internacionales como son el centro Rochester Institute of Technology o la Universidad de Michigan. Además, existen otro tipo de acciones, a otros niveles y con otros puntos de vista que se la iniciativa se están expandiendo por todo el entramado TIC, implicando también a grandes multinacionales como IBM [3], Google [4] o CISCO [5], Administraciones Públicas o Medios de Comunicación.

2.1 Iniciativas nacionales

En España se están llevando a cabo diversas iniciativas que hacen pensar que el problema de que las carreras técnicas estén faltas de mujeres es generalizado en todo el territorio nacional. Concretamente hay continuas referencias al problema en diferentes foros y medios de comunicación, ya sean de más o menos tirada. Por ejemplo, si se escribe en el buscador más utilizado el texto "carreras técnica mujeres" aparecen 340.000 resultados, dato que da una idea de que el problema está siendo abordado en diferentes ámbitos, niveles y canales.

Una de las entradas más antiguas que aparecen en la red, en un ámbito más o menos formal es el informe de Salud y Género del ministerio de Sanidad en los años 2007-2008. En este informe se comenta que es significativo el incremento en las especialidades Científico-Técnicas, aunque éstas solamente son perceptibles en los hombres. Además, son menos mujeres las que eligen esta rama en 2007 que en 2001. Es decir, ya en un estudio del 2007 con datos recopilados desde años atrás, se observa que el número de mujeres dentro de las carreras técnicas desciende paulatinamente.

Iniciativas dentro del campo de la investigación como la de [2] se basan en realizar estudios sobre las causas que hay tras esta problemática del bajo número de alumnas en las carreras técnicas. Sus autoras realizan una buena revisión de los estudios relacionados con las motivaciones sobre la baja presencia de las mujeres en las empresas TIC y en los estudios de ingeniería relacionados con las TIC.

Concretamente, presentan un estudio llevado a cabo en la Escuela Politécnica Superior (EPS) de la Universidad Carlos III de Madrid (UC3M) donde realizaron una encuesta preguntando sobre la motivación de las estudiantes para seleccionar una titulación técnica, y se destaca que sus motivaciones principales son: tener interés por las matemáticas y la existencia de posibilidades laborales. Son muy interesantes también algunas respuestas como: el hecho de que han tenido referencias cercanas, tanto masculinas como femeninas, en su ámbito familiar. También indican que a la mujer le interesa dedicarse profesionalmente a dominios de aplicación de temas sociales.

Otros estudios como el de [6] analizan los resultados y decisiones que toma el estudiantado del Bachillerato Científico-Tecnológico y Biosanitario que realiza la prueba de acceso universitaria (PAU) en la Universidad de Oviedo durante un largo intervalo de tiempo (2006-2010). De las conclusiones obtenidas, destacamos que las mujeres eligen materias científicas contextualizadas en la vida cotidiana y orientadas a cubrir las necesidades de las personas. Las mujeres eligen como opción preferente de estudios la rama de Ciencias Sociales y Jurídicas y se confirma la fuerte esquematización por género en la elección de los estudios de Ingeniería donde los hombres son una amplia mayoría. Sin embargo, exponen que no se puede hablar de rendimiento diferencial significativo entre hombres y mujeres con relación a las materias científicas y tecnológicas.

Las iniciativas de las universidades españolas son numerosas y diversas. A continuación se van a detallar algunas, aunque se quiere dejar claro que no son, para nada, una recopilación de todas las existentes, sino más bien una pincelada de lo que está vigente actualmente.

Per què no puc fer-ho? [7] es una jornada destinada a presentar al alumnado de cuarto de ESO de la demarcación de Lleida los estudios de la Universidad de Lleida sin estereotipos de género, con el objetivo de fomentar, en el seno del alumnado masculino y femenino, la elección de titulaciones en las cuales cada género está menos representado. El programa está coordinado por el Centre Dolors Piera d'Igualtat d'Oportunitats i Promoció de les Dones que nace fruto del esfuerzo del SIED (Seminari Interdisciplinari d'Estudis de la Dona) para fomentar la igualdad de oportunidades entre hombres y mujeres. La normativa de funcionamiento del centro se aprobó por Consejo de Gobierno en dicha universidad el 7 de marzo de 2006. En esta jornada, chicos y chicas realizan diversos talleres para que visualicen los trabajos que se llevan a cabo en las diferentes titulaciones. Desde su puesta en funcionamiento las chicas realizan talleres en la Escuela Politécnica Superior y los chicos en Psicopedagogía. Suele agradar la experiencia a nivel general, quedando cortos los talleres en cuanto a su duración, pues sólo se dispone de una mañana.

Campus Tecnológico UGR para Chicas [8] es la iniciativa de la Universidad de Granada en 2014 y 2015. Esta propuesta es pionera en el ámbito nacional y ha sido objeto de controversia en muchos sentidos. El objetivo principal es promover y difundir qué se hace en carreras técnicas como la Ingeniería Informática o la Ingeniería de Tecnologías de Telecomunicación a chicas en edad pre-universitaria. Para ello se organiza un curso de dos semanas de duración totalmente gratuito para las asistentes donde se les muestra qué se hace en realidad en dichas carreras. Para ello se imparten clases totalmente prácticas donde las alumnas pueden ir construyendo por ellas mismas, utilizando tanto software libre como hardware libre, diversos proyectos que ellas mismas seleccionan al principio del curso. La controversia de esta iniciativa viene por el hecho de que la iniciativa va orientada sólo a chicas en edad pre-universitaria, por lo que ha recibido diversas críticas de algunos sectores indicando que, al ser un curso gratuito, los chicos también deberían poder asistir. Sin embargo, si se admitieran chicos en dicha propuesta, sería muy difícil alcanzar el objetivo de la misma. Esta iniciativa ha sido financiada por diversas entidades y el equipo organizador busca financiación para que las chicas puedan hacerlo de forma gratuita, por lo que la acogida ha sido bastante numerosa en las dos ediciones. Algunas de las entidades que financian la propuesta son, Google, la Delegación TIC de la Universidad de Granada, la Oficina de Software Libre de la Universidad de Granada y la propia Escuela Técnica Superior de Ingenierías Informática y de Telecomunicación donde se imparte.

Women TechMaker Granada [9] es un evento que se organizó en abril de 2015 por el Google Developers Group (GDG) de Granada y la Escuela de Ingenierías Informática y de Telecomunicación de la Universidad de Granada. En ella la idea fue explicar lo que significa ser ingeniero o ingeniera, es decir, que la función de un ingeniero/a tiene mucho de creatividad (ideando soluciones a problemas reales de las personas), de trabajo colaborativo, de innovación y de sociabilidad. En este evento se invitaron a personas relevantes tanto del ámbito académico como profesional, todas mujeres, con el fin de dar mayor visibilidad a las mujeres profesionales en el mundo TIC y hacerlas así referentes para que las jóvenes que asistieron al evento puedan animarse a entrar en este mundo.

En el artículo [10] se describe una experiencia, llamada *Girl's Day*, que se está llevando a cabo anualmente en la Universidad de Zaragoza desde 2008. La idea es llevar a chicas que estudian secundaria a la Universidad y dedicarles un día donde se acercan tanto al mundo empresarial (o de negocio) como al mundo de la investigación. En cinco años, han aumentado la visibilidad que tienen las mujeres sobre la ingeniería, las estudiantes conocen en lo que consiste una ingeniería y se ha establecido una red de ingenieras en la región. La actividad central consiste en mostrar ejemplos de productos de ingeniería desarrollados por equipos que incluyen mujeres. Tal como las autoras explican en el artículo un gran problema es que los jóvenes no saben lo que es ingeniería ni en qué consiste el trabajo de un ingeniero. Por tanto hay que acercarlos a este mundo desde distintos puntos de vista. El Girl's Day fue una iniciativa que nació en Alemania pero actualmente se está celebrando en más de 10 países.

Tech & Ladies [11] es la iniciativa de las mujeres del grupo Google en España en colaboración con expertas mujeres tecnólogas. El objetivo del proyecto es dar visibilidad a las mujeres que crean y trabajan en tecnología. Para ello, en este proyecto se busca reconocer los problemas de las mujeres a la hora de conectar con la tecnología y buscar solución a sus desafíos, brindar formación especializada, divulgar patrones de mujeres en la tecnología, tener referencias femeninas y conseguir que chicas jóvenes se interesen por estudiar una carrera técnica. Como primera acción del proyecto, se ha creado un mapa tecnológico, este mapa va a servir para que todas las chicas que tengan un perfil técnico puedan darse visibilidad y hacer networking.

Se realizan también jornadas de científicas y tecnólogas para promover nuevas vocaciones científicas, tales como como la realizada por el Instituto Universitario de Estudios de las Mujeres

(IUEM) de la Universidad de La Laguna en mayo de 2015 donde se llevaron mujeres tanto de la parte académica (profesoras e investigadoras) como de las empresas para incentivar a las chicas a estudiar y trabajar en el ámbito de las TIC. En estas jornadas se invitaron a estudiantes de Bachillerato, tanto chicos como chicas.

e-igualdad.net es un espacio promovido y financiado por el Instituto de la Mujer y para la Igualdad de Oportunidades, que cuenta también con la cofinanciación del Fondo Social Europeo. Este espacio forma parte de los objetivos y líneas de actuación del Plan de Acción para la igualdad entre mujeres y hombres en la Sociedad de la información (2009-2011) aprobado en el Consejo de Ministros el 18 de diciembre de 2009.

2.2 Iniciativas internacionales

A continuación, se presenta una recopilación de iniciativas que han surgido fuera de nuestro país y se detallarán algunas características importantes:

En Rochester Institute of Technology [12] pretenden incentivar la participación de mujeres en carreras técnicas (STEM, Science, Technology, Engineering, and Mathematics) ya que dan por sentado que un equipo de trabajo y desarrollo se comporta mucho mejor cuando está formado por hombres y por mujeres. Se apoyan para esto en estudios que afirman que un equipo con diversidad es capaz de generar ideas más innovadoras y por lo tanto creativas. Para ello se fomentan proyectos de investigación en el ámbito educativo y en el lugar de trabajo para las científicas e ingenieras. Además, desarrollan programas de extensión que buscan fomentar el interés por la ciencia y las matemáticas entre las mujeres y las niñas en todos los niveles, primaria, secundaria o universidad.

La Universidad de Michigan [13] lidera la propuesta titulada “Women in Science and Engineering” (WISE) que incluye programas para chicas de primaria, pregraduadas e incluso postgraduadas o estudiantes de doctorado y postdoctorado ofreciéndoles una vía por la que obtener plazas en la universidad u oportunidades de empleo.

Existe iniciativas conocidas como: IGNITE (Inspiring Girls Now In Technology Evolution) [14] con una función de mentoría e información como la anterior, Engineer your life [15] donde, de una forma divertida, intentan explicar por qué es interesante ser ingeniera y convencer a las chicas que hagan grados de ingeniería.

También se realizan reuniones, a nivel mundial, de mujeres tecnólogas como The Grace Hopper Celebration of Women in Computing organizada por el Instituto Anita Borg en asociación con la Association of Computing Machinery (ACM).

La Comisión Europea para la Investigación y la Innovación lidera una propuesta para el llamado horizonte 20/20. Esta iniciativa intenta fomentar la aparición de mujeres líderes en investigación para así fomentar la igualdad en número en mujeres que participan en posiciones influyentes en el campo de la investigación. Esta iniciativa insta a los estados miembros de la Unión Europea a desarrollar la legislación necesaria para fomentar la aparición de estas líderes [16].

Technovation Challenge [17] es un programa mundial sólo para chicas de 13 a 17 años que enseña a usar la tecnología con un propósito, promoviendo el espíritu emprendedor.

ICT-Go-Girls! [18] es un proyecto europeo, cofinanciado por la Comisión Europea, dentro del programa Comenius LLP. Su principal objetivo es capacitar a las niñas de la escuela secundaria con los conocimientos, habilidades y valores para ayudarlas a ser capaces de crear futuras oportunidades para la innovación y empleo de calidad relacionado con las TIC. Dentro de este ámbito de proyectos europeos está también el proyecto FESTA (Female Empowerment in Science and Technology Academia) [19], el proyecto Genis-Lab (The Gender in Science and Technology Lab) [20], el proyecto HELENA (Higher Education Leading to Engineering and Scientific Careers) [21], el proyecto TWIST (Torwards Women in Science and Technologies) [22], o el proyecto WISAT (Women in Global Science and Technologies) [23], todos orientados en el mismo sentido.

Como se puede apreciar, no es una situación que se intente paliar sólo en algunas de nuestras universidades, sino que existen numerosas iniciativas, no todas ellas recogidas en este artículo, donde la temática es siempre el fomentar las titulaciones técnicas entre las mujeres.

2.3 Otras formas de acción

Este apartado revisa iniciativas con enfoques más originales o que difieren de los mencionados en el apartado anterior, pero que creemos que son importantes por los resultados que obtuvieron y que, en muchos casos, siguen vigentes:

Iniciativas pasadas provocaron la aparición de movimientos de asociación entre mujeres relacionadas con la informática. Así surge la llamada “Asociación para mujeres en Computación”. Esta asociación curiosamente, tiene un director hombre que intenta fomentar la visibilidad de mujeres dentro de este mundo que principalmente está compuesto por hombres. Otros proyectos relacionados con asociaciones de mujeres que intentan impulsar la participación de las mujeres en la tecnología son Girls who code [24] o Agile-girls [25], entre otras muchas asociaciones que actualmente están trabajando en este sentido. O los ejemplos de la American Association of University Women (AAUW) que vela por la integración de las mujeres y publican diversos informes sobre la situación de la mujer como por ejemplo: Why So Few? Women in Science, Technology, Engineering, and Mathematics (2010) [26] o Graduating to a Pay Gap: The Earnings of Women and Men One Year after College Graduation (2012).

La publicación de artículos de opinión en medios influyentes como el New York Times, donde Lina Nilsson (innovation director at the Blum Center for Developing Economies at the University of California, Berkeley) [27] muestra que sólo alrededor del 14 por ciento de los ingenieros/as trabajadores/as son mujeres. Ella piensa que se puede incrementar este número de forma simple y cuenta que una experiencia llevada a cabo en la Universidad de California, Berkeley, donde da clases, sugiere que si el cometido de los trabajos fuera socialmente más significativos, las mujeres se inscribirán en ellos en masa. Nilsson expone que en su centro, comenzó un programa que logró en sólo un año académico que un 50 por ciento de la matrícula fuera de estudiantes femeninas. El curso (2014) estrenaba un nuevo Ph.D. en ingeniería de desarrollo para estudiantes que iban realizan su trabajo de tesis orientado a crear soluciones para comunidades desfavorecidas (soluciones para obtener de forma asequible agua potable, equipos de diagnóstico médico para enfermedades tropicales desatendidas o creación de procesos de fabricación local en las regiones pobres y remotas). Según Nilsson, las mujeres se sienten atraídas por proyectos de ingeniería que tratan de mejorar la sociedad. Otras experiencias parecidas están en MIT, la Universidad de Minnesota, Penn State, la Universidad de Santa Clara, Arizona y la Universidad de Michigan donde han propuesto programas dirigidos a reducir la pobreza y la desigualdad y han logrado resultados similares. Esto demuestra que la clave para aumentar el número de ingenieras puede no solo hacer programas de tutoría o resolver problemas de conciliación, aunque son importantes. Se pueden reformular los objetivos de la investigación en ingeniería y en los planes de estudio haciendo que sean relevantes a las necesidades de la sociedad potenciando el compromiso social, y no enfocándolo sólo como un tema relacionado con la igualdad de género.

En [28], los autores proponen usar juegos educativos para enseñar habilidades básicas de informática de manera contextualizada y de forma interactiva, generando así entusiasmo e interés por el tema. Este enfoque, además, debe adaptarse a un método de enseñanza neutral del género. Los resultados fueron alentadores, mejorando el interés por la informática en estudiantes de ambos sexos.

En [29] presentan un estudio donde se refleja, basándose en una serie de experimentos realizados con mujeres y hombres, que la inclusión de objetos o elementos estereotipados en el diseño de las aulas virtuales y reales tiene una gran influencia tanto en la intención de matriculación en estos estudios como en la permanencia en ellos. Los autores concluyen con la idea de que el diseño físico de los entornos de aprendizaje, tales como aulas, laboratorios de computación y departamentos universitarios, puede proyectar mensajes basados en la identidad de quién pertenece o no a este mundo y con ello disuadir a algunas poblaciones de entrar en este campo y creer que no pueden lograr éxito en él.

Por otra parte, las empresas también se preocupan por el bajo número de ingenieras. En el estudio [30], se encuentran algunas claves para entender y solucionar, en parte, algunos problemas asociados que encuentran las mujeres que quieren acceder a un puesto técnico elevado en una empresa o corporación. Por un lado se reconoce en las grandes corporaciones que poseen hombres y mujeres en puestos de gran responsabilidad proporciona más versatilidad, flexibilidad y apertura a la innovación. Sin embargo, la percepción de las mujeres es que deberán extender su horario laboral o bien tendrán que tener redes de influencia o poder para ascender en la empresa. Estas son las barreras que perciben las mujeres, además de creencias sexistas como que la mujer en un puesto de responsabilidad es vista como menos competente que sus compañeros masculinos. También se apunta a parámetros como la raza o la etnia. Las mujeres latinas (0%) y de raza negra (1.6%) apenas aparecen en puestos de responsabilidad.

Incluso las Administraciones a diferentes niveles, con el objetivo de conseguir más mujeres al frente de la investigación, emprende acciones. Por ejemplo, la Comisión Europea desarrolló un informe donde se proponen medidas para promover la igualdad de género en el ámbito que nos ocupa detallando propuestas país a país y proponiendo buenas prácticas [31].

3. ALGUNAS PROPUESTAS CONCRETAS PARA FOMENTAR LA PRESENCIA DE LAS MUJERES EN LAS TIC

Hemos visto que existen muchas iniciativas con el fin de fomentar la presencia de las mujeres en las ingenierías, casi todas ellas están orientadas a mujeres jóvenes que están a punto de elegir una carrera universitaria que les llevará a ejercer su profesión dentro de las TIC. Estas iniciativas se basan principalmente en:

- Realizar estudios que evidencien cuáles son las principales barreras o problemas por los que las mujeres no eligen una carrera técnica.
- Programas de mentoría.
- Mejorar la visibilización de referentes tanto en el mundo académico como empresarial o laboral de mujeres con formación técnica.
- Realizar cursos, jornadas o eventos para explicar la función de un ingeniero/a.

Todas estas iniciativas llevan años realizándose, a veces de forma parcial y, sin embargo, no se han visto todavía resultados satisfactorios ni en España ni en el resto del mundo respecto al bajo número de mujeres con una formación técnica o tecnológica.

Uno de los principales escollos que parece evidenciarse es precisamente la percepción sobre el rol de las mujeres en trabajos técnicos. Ya sea bien por las propias mujeres como por sus congéneres masculinos. Por eso, muchas de las iniciativas que se proponen van en ese sentido. Hay que cambiar esa percepción, y eso se debe realizar desde que los niños y niñas se escolarizan. Como dice Virginia Valian [32] el interés de las mujeres en matemáticas y ciencias aumentará si tienen un sentimiento de pertenencia y una expectativa de éxito. Es necesario conseguir que las mujeres no se vean excluidas de las áreas tecnológicas, sino que sientan que son parte de ellas.

Las iniciativas presentadas a lo largo del artículo se consideran indispensables pero se deberían completar con las siguientes, que si bien, se han evidenciado en algunos estudios, no se están llevando realmente a cabo:

- La información de lo que es ser ingeniero/a y sobre todo, cómo es el trabajo (creativo, social, colaborativo, etc.) y los objetivos, los productos y servicios que crea debe llegar antes de que el estudiante decida qué rama va a elegir, es decir, desde la educación primaria, puesto que ya en la educación secundaria deben elegir unas asignaturas que condicionan el abanico de posibilidades de formación superior posterior.
- Se debe introducir alguna asignatura de forma temprana (primaria, por ejemplo) en el currículum del alumnado los conceptos básicos de la informática de forma amena y divertida. Existen lenguajes y métodos de libre acceso que se pueden usar y que creemos que crearía una familiaridad de todos los estudiantes con la disciplina de ingenierías y carreras técnicas evitando la animadversión que muchos estudiantes, principalmente femeninos, tienen con la informática. Actualmente existen iniciativas positivas como, por ejemplo, el hecho de que los alumnos en Andalucía podrán cursar una asignatura más de tipo tecnológico en secundaria para el curso 2016-2017 además de la que actualmente existe en el Bachillerato (noticia que salió recientemente en la prensa).
- El liderazgo del futuro depende de la formación de hoy, por ello, se deben promover programas formales en todos los niveles educativos ajustados a las demandas de los trabajos que necesitarán en el futuro, teniendo en cuenta que la tecnología es y será fundamental para este desarrollo. El profesorado actual no está preparado para enfrentarse a este desafío y necesitará para ello una formación especializada en didáctica de la informática. Esta formación no existe

actualmente, y debería incorporarse en los planes de formación de profesorado, como una carrera especializada.

- Se debe asociar un carisma o proyección social a la función del ingeniero/a. Esta profesión ayuda a mejorar la sociedad, el mundo en el que vivimos, porque aporta soluciones a problemas que tenemos habitualmente. En general, un ingeniero mejora el mundo para que sea un poco más cómodo para todos los que habitamos en él.
- En las aulas, los maestros deben usar la tecnología, los computadores, de una forma innovadora para que los estudiantes sepan disfrutarla y les guste la tecnología, evitando que surja un sentimiento negativo hacia ella. Esto se puede conseguir integrando nuevas formas de diseñar actividades y gamificándolas. También es importante personalizar en todo lo posible el aprendizaje centrándose en la persona, y para ello ayudarse de la tecnología para poder gestionar ese gran volumen de trabajo adicional que se genera.
- Se deben evitar los estereotipos, y esto se puede conseguir con la educación tanto en las personas mayores (progenitores, maestros/as, tutores, etc.) como para adolescentes y menores.
- Hay que incentivar que las propias mujeres no se vean menos capaces y se pongan barreras a sí mismas (autoexclusión). Se les debe explicar a niños y niñas que ambos géneros deben ser capaces de conciliar vida laboral y personal con sus parejas. Siendo obligación de ambos componentes de la pareja. En este sentido el camino está iniciado, pero hay que fomentarlo y seguirlo, qué es lo realmente difícil.
- Es necesario dar cursos a las niñas para despertarles la curiosidad en la ciencia y la tecnología. Por ejemplo, explicarles cómo está relacionada la ingeniería química con la cocina o con los tejidos textiles y que la ingeniería informática está relacionada de forma transversal con todas las disciplinas.
- Hay que incorporar, presentar y mencionar, empezando por los libros de texto, a mujeres que sean referentes en los distintos campos: académico, investigación y empresarial, para que sean tomadas como ejemplos para las futuras tecnólogas. Esto, desde educación infantil, de forma que siempre que se nombre un tecnólogo, también haya un ejemplo de tecnóloga que lo acompañe.
- Hay que enseñar a las mujeres a arriesgarse más dentro del campo empresarial en el mundo de las TIC, a no temer tener puestos de responsabilidad porque lo harán igual que sus colegas y a llegar a un compromiso entre su vida familiar y laboral sin auto-asignarse más tareas de las que debe realizar. Esto también entra dentro del punto de educación, muchas veces es la propia mujer la que no sabe delegar funciones familiares en los otros miembros de la familia o de su entorno.
- Fomentar el trabajo en equipo con mezcla de géneros como un valor añadido que permita afrontar problemas complejos de una manera más eficiente. En primaria en EEUU, se crean equipos mixtos donde se les presenta un reto, cada integrante debe desarrollar una estrategia que luego deberá compartir con sus compañeros de manera que entre todos buscan información para llevar a cabo el proyecto común. Esta forma de trabajar debería trasladarse a secundaria y a la universidad. Y en el caso español a todos los niveles. De esta manera, son los alumnos los que demandan los conocimientos, siendo proactiva la forma en que los consumen. Estos equipos deberían estar balanceados en cuanto a nivel intelectual/género/ habilidades/personalidad en todo lo posible. Así pues, cada uno tiene un rol dentro del equipo, fomentando el respeto y reconocimiento de cada uno de los integrantes del mismo.
- Co-creación empática: Los contenidos para ser realmente asimilados deben ser redescubiertos, entender sus relaciones y entenderlos dentro de un contexto, por eso se partiría de los PBL (Project Based Learning) desde primaria, donde los contenidos deben ser estudiados porque son necesarios para alcanzar uno o varios objetivos, de manera que se fomenta la motivación por aprender y los contenidos no quedan aislados en asignaturas sino ligados por un desarrollo y fin común. Sin embargo, esta propuesta puede ser mejorada si cabe, con múltiples actores/roles (co-creación) donde los integrantes deben pasar por diferentes roles (que preferiblemente deberían ser antagonistas, como jefe-empleado) para desarrollar empatía. A ser posible deberían aparecer figuras que respalden estos proyectos como asesores o consultores. Dichos roles podrían ser llevados a cabo por otros profesores o profesionales. Los grupos que participan en el PBL deberían ser mixtos y fomentar proyectos con vertiente más técnica/científica y otros más sociales. De forma, que se trabaje con personas que puedan desarrollar sus habilidades en un entorno favorable a ello. Consideramos la empatía un punto clave para la implicación social y emocional de los integrantes del grupo. Así como un potente catalizador para evitar conflictos en el seno del grupo. Por lo tanto, se fomentaría que tanto mujeres y hombres pudieran dirigirse a sectores profesionales que habitualmente no eligen tal y como se ha puesto en evidencia en el artículo.

4. CONCLUSIONES

En este artículo se ha descrito la situación actual en cuanto al tipo de iniciativas que tanto dentro como fuera de España se están llevando a cabo para paliar un problema importante: el bajo número de mujeres que se encuentran en el campo de la tecnología, de la ingeniería en cualquier ámbito (académico, laboral, investigación).

Una vez que se ha visto que las acciones realizadas hasta ahora no están dando los frutos esperados, se realiza una propuesta más amplia de iniciativas que creemos que faltan para completar las que ya se están realizando y que intentan paliar muchos de los problemas ya detectados y conocidos. Estas iniciativas básicamente se basan en modificar la educación tradicional empezando a trabajar desde muy pequeños y evitando cualquier sesgo referente al género.

Como opinión más personal, creemos que, a la vista de los datos y conforme a nuestra experiencia, las mujeres tendemos más a elegir carreras en las que nuestras expectativas de futuro esté más relacionado con la sociedad en general. Sin embargo, el estereotipo que representa a las personas que estudian las carreras de ingeniería, es un estereotipo poco social, con poca relación con su entorno, del que, sin ser totalmente conscientes, las mujeres intentamos escapar. Sin embargo, no captamos que las carreras de ingeniería cumplen un servicio a la sociedad en todos los ámbitos.

Sobra decir que hoy en día, un ingeniero informático puede prestar sus destrezas en cualquier ámbito ya sea relacionado con la Ciencia o no. La prueba la podemos encontrar en algunos campos más que otros, por ejemplo, ¿qué serían hoy todas las técnicas de diagnóstico sin la ingeniería informática o la ingeniería electrónica? o ¿qué serían, incluso de los estudiosos de la lengua sin una buena base de datos por detrás que les almacene toda la información existente respecto a la etimología, la pronunciación o la traducción de cierto vocablo?

Por otra parte, la ausencia de mujeres dentro de las ingenierías, causa una ausencia de diversidad en las propuestas de solución que los ingenieros, informáticos o de cualquier otro tipo, proponen a los problemas del mundo real. Pero, ¿queremos esta ausencia de diversidad?, en nuestra opinión, esta ausencia de puntos de vista diversos es, en todos los casos, perjudicial, no sólo para la ingeniería, sino en la sociedad en general, puesto que la ingeniería está al servicio de la sociedad. Siendo cada vez un valor en alza la parte emocional, baste mencionar el ejemplo de la ingeniería informática donde ya no es suficiente que una aplicación sea funcional y usable, debe emocionar, debe conectar de forma hedónica con el usuario. Es en este punto, donde el sector femenino puede aportar valor a estas propuestas.

En cualquier caso, está claro que las iniciativas que se están siguiendo en las diferentes universidades, tanto españolas, como extranjeras, están orientadas a paliar esa falta de diversidad en el alumnado. Y en ningún caso, estas iniciativas deberían dejar de crearse, fomentarse, subvencionarse o llevarse a cabo, aunque sea sólo por las pocas mujeres que estamos dentro de estas ingenierías, puesto que somos las que, en nuestra opinión, vemos más el sesgo presente en las clases que impartimos día a día.

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GAMES

Desarrollo de experiencias lúdicas interactivas geolocalizadas

A. J. Soriano Marín
GEDES Universidad de Granada
C/ Periodista Daniel Saucedo Aranda, s/n · E-18071 GRANADA (Spain)
+34 958 242 812
asoriman@gmail.com

J. L. González Sánchez
GEDES Universidad de Granada
C/ Periodista Daniel Saucedo Aranda, s/n · E-18071 GRANADA (Spain)
+34 958 242 812
joseluisgs@ugr.es

F. L. Gutiérrez Vela
GEDES Universidad de Granada
C/ Periodista Daniel Saucedo Aranda, s/n · E-18071 GRANADA (Spain)
+34 958 242 812
fgutierr@ugr.es

ABSTRACT
El presente trabajo tiene como objetivo principal ofrecer una visión específica sobre los retos de diseño de experiencias lúdicas geolocalizadas y cómo aplicarlas para la exploración turística. Este campo ofrece nuevos retos y desafíos para conseguir el éxito a nivel de interacción, los cuales ayudan a diseñar mecanismos para trasmitir una correcta experiencia de usuario en base a unir elementos lúdicos basado en sistemas de juegos y nuevos paradigmas de interacción como son la computación móvil, la realidad aumentada y mecanismos de geolocalización y posicionamiento tanto en interior como en exterior. En este trabajo mostramos un ejemplo de desarrollo de experiencia lúdicas geolocalizada a través del Campus de Cartuja (Granada) usando el factor social como una herramienta principal para la interacción entre los usuarios/as que hagan uso del sistema.

Categories and Subject Descriptors
H.1.2 [**Information Systems**]: User/Machine Systems - *Human factors*.

General Terms
Performance, Design, Human Factors.

Keywords
Gamificación, jugabilidad, contexto, realidad aumentada, experiencia de usuario, computación móvil, geolocalización.

1. INTRODUCCIÓN
Hoy en día los dispositivos móviles (teléfonos o tabletas) son elementos que habitualmente usamos para estar informados e intercambiar información. Organismos importantes, como es la UNESCO considera que el uso de nuevas tecnologías, especialmente paradigmas móviles, permitirá una mejora en la creación de contenidos cada vez más atrayentes y completos para el usuario creando un ambiente de intercambio colaborativo de la información, y en definitiva originando nuevas experiencias de usuario como la adecuación al contexto de uso y la geolocalización de los elementos con los que actuar.

El desarrollo de la computación móvil unida a nuevos paradigmas como la realidad aumentada ayuda a que aparezcan nuevos retos interesantes, como es hacer cada vez más eficaz los procesos de interacción y colaboración y generar experiencias más positivas y placenteras para los usuarios que ayuden a producir un aumento de la calidad en las aplicaciones desarrolladas.

El siguiente trabajo tiene como objetivo presentar diversas técnicas para mejorar la experiencia interactiva y la calidad en uso para el desarrollo aplicaciones geolocalizadas en base a diseños de elementos lúdicos que mostraremos en un prototipo desarrollado. Durante el segundo punto nos adentraremos en los avances de la realidad aumentada y la computación móvil y su uso en aplicaciones geolocalizadas o basadas en el contexto. En el tercer punto analizaremos conceptos como la jugabilidad y la gamificación, narrativa interactiva o métodos de exploración y así sus posibilidades como elementos para generar una experiencia interactiva positiva a la hora de interactuar o de realizar una tarea. A través del cuarto punto se presentará una propuesta de diseño de aplicaciones geolocalizadas, donde la experiencia interactiva se basará en el uso de técnicas vistas en apartados anteriores, unidas a elementos de diseño de videojuegos del género de las “aventuras gráficas” integrando actividades de geolocalización con realidad aumentada. De esta forma, visitando las distintas localizaciones que nos propone el juego, el usuario realizará un recorrido por diferentes enclaves de interés pero con una experiencia distinta, pues esta será diseñada en base a una aventura interactiva en forma de juego. Finalmente mostraremos conclusiones y trabajos futuros derivados del contenido de este artículo.

2. INTERACCIÓN MÓVIL BASADA EN EL CONTEXTO
Los dispositivos de ***computación móvil*** han propiciado que nuevas técnicas de interacción sean aplicadas a la hora de realizar tareas, permitiendo al usuario la libertad de movimiento a la hora de poder realizarlas y permitiendo el intercambio de datos con el entorno y con otros usuarios y creando ambientes cooperativos y colaborativos donde la información fluye mejorando la experiencia interactiva. Todos los avances técnicos hacen que los nuevos dispositivos existentes sean una herramienta fundamental para los sistemas de información basados en el contexto (suelen ser los sistemas de computación móvil, la posición, el lugar, los objetos que lo rodean, etc., para proporcionar información con la que el usuario puede interactuar), así como plataformas idóneas para la ejecución de juegos y mecanismos de interacción basados en realidad aumentada y computación ubicua dadas las características y elementos que ellos ofrecen.

La ***realidad aumentada*** (RA) se puede definir como la combinación de objetos de un entorno real y objetos virtuales generados por computadora (objetos, imágenes, texto, etc.) en tiempo real mediante un conjunto de dispositivos que añaden información virtual al entorno real ya existente. El usuario puede interactuar y realizar distintas acciones [35] siendo una de las disciplinas más innovadoras dentro de la investigación en el campo de la IPO. A diferencia de la realidad virtual, la realidad aumentada no pretende aislar al usuario del mundo real, sino poder interactuar de forma natural, con una mezcla de un mundo real y virtual usando los objetos generados. La realidad aumentada se encuentra entre un entorno real y un entorno virtual puro.

Existen distintas técnicas de interacción para sistemas de realidad aumentada [38]: basada en marcadores, basada en imágenes, basada en movimiento corporal, basada en geolocalización [34] o basadas en interactuar con otros sentidos como el tacto (sistemas hápticos), el oído (sistemas hipermedia o multimodales) o el olfato (simuladores).

La ***interacción basada en el contexto*** es aquella en la que el conocimiento del contexto y de los elementos socioculturales en los que se desarrolla la tarea se utilizan como parte y producto del propio proceso interactivo, ayudando a llevarlo a cabo [37]. De esta manera el dispositivo móvil actúa como mediador para realizar la tarea, siendo el usuario el que realiza la tarea de manera inmersiva en el medio, percibiendo un mayor grado de participación y credibilidad en las acciones a realizar. La interacción basada en el contexto acerca la tarea al usuario usando componentes y mecanismos de interacción que son familiares a este, generando una experiencia positiva que facilita la adquisición de nuevas habilidades y mejoras en la productividad de la tarea a realizar al reducir el proceso de aprendizaje de la misma.

El **contexto aumentado** se define como “la conjunción de información espacial, temporal y social que provoca que se produzcan determinados eventos dentro del proceso interactivo para determinar qué tipo de actividad se debe realizar y qué contenidos de dicha actividad son válidos de acuerdo a las características del usuario y de los elementos interactivos existentes a la hora de realizar una tarea, o lo que es lo mismo, un contexto enriquecido con información adicional que ayuda a mejorar su asimilación y mejora la experiencia inmersiva [43]. Para ello se hace uso de elementos gráficos como texto, objetos 2D/3D, videos, sonido o cualquier contenido multimedia con el cual el usuario puede interactuar directa o indirectamente.

3. DISEÑO DE EXPERIENCIAS LÚDICAS

Los videojuegos son sistemas interactivos concebidos para explotar al máximo la experiencia del usuario a nivel lúdico cuando se hace uso de ellos, pues su principal objetivo es explotar distintas emociones del usuario y asegurar el entretenimiento.

El estudio de los videojuegos y sus virtudes ha permitido dar un grado más de calidad a la experiencia del usuario, aumentando la motivación y el compromiso del usuario y provocando una experiencia distinta en aplicaciones “no de ocio”. Para comprender cómo podemos enriquecer la experiencia de usuario en un sistema interactivo, usando las características propias de los juegos, no hay nada mejor que analizar qué es lo que hace que los juegos sean divertidos y qué mecanismos podemos usar en nuestros diseños. Para ello es importante hacer referencia a los conceptos de jugabilidad y de gamificación.

La ***jugabilidad*** es un término empleado en el diseño y análisis de juegos que describe la calidad del juego en términos de sus reglas de funcionamiento y de su diseño como juego. Se refiere al conjunto de las experiencias que siente un jugador durante la interacción con sistemas de juegos. Este concepto surgió junto con las teorías de diseño de juegos en los años 80, el término jugabilidad era usado solamente en el contexto de los videojuegos, aunque ahora por su popularidad ha comenzado usarse en la descripción de otras formas de diversión incluyendo aplicaciones interactivas.

Nosotros, definimos la jugabilidad como el conjunto de propiedades que describen la experiencia del jugador ante un sistema de juego determinado, cuyo principal objetivo es divertir y entretener “de forma satisfactoria y creíble” ya sea solo o en compañía. Es importante remarcar los conceptos de satisfacción y credibilidad. El primero es mucho más difícil de conseguir en un sistema interactivo tradicional (por ejemplo Word) debido a sus objetivos no funcionales; el segundo dependerá del grado de asimilación e implicación de los jugadores en el juego [39]. La diferencia en los objetivos de la experiencia de usuario a conseguir en base a la jugabilidad (experiencia del jugador, *Player eXperience*) viene descrita en la Tabla 1. La jugabilidad se caracteriza por el grado de consecución en los siguientes atributos:

- **Satisfacción**: Agrado o complacencia del jugador ante el videojuego y el proceso de jugarlo.
- **Aprendizaje**: Facilidad para comprender y dominar el sistema y la mecánica del videojuego: objetivos, reglas y formas de interaccionar con el videojuego.
- **Efectividad**: Tiempo y recursos necesarios para ofrecer diversión al jugador mientras éste logra los objetivos propuestos en el videojuego y alcanza la meta final de éste.
- **Inmersión**: Capacidad para creerse a lo que se juega e integrarse en el mundo virtual mostrado en el juego.
- **Motivación**: Característica del videojuego que mueve a la persona a realizar determinadas acciones y a persistir en ellas para su culminación.
- **Emoción**: Impulso involuntario originado como respuesta a los estímulos del videojuego, que induce sentimientos y que desencadena conductas de reacción automática.
- **Socialización**: Atributos que hacen apreciar el videojuego de distinta manera al jugarlo en compañía (multijugador), ya sea de manera competitiva, colaborativa o cooperativa.

La ***gamificación*** o ludificación (gamification en el ámbito anglosajón) es la aplicación de los elementos propios de los juegos en contextos que no son estrictamente lúdicos con el fin de conseguir que las personas adopten ciertos comportamientos deseados. La aplicación de la gamificación busca potenciar la motivación, la concentración, el esfuerzo, la fidelización y otros valores positivos comunes al mundo del juego. Desde el punto de vista de los videojuegos, la gamificación está relacionada con el uso de elementos del diseño de videojuegos en contextos que no son “juego” para hacer que un producto, servicio o aplicación sea más divertido, atractivo y motivador. Esta definición nos interesa bastante ya que nos habla de cosas que nos acercan mucho a los objetivos planteados por la experiencia de usuario (UX) [46] .

Tabla 1. Diferencias entre objetivos de UX vs PX: Usabilidad respecto a Jugabilidad

UX-Objetivos de Usabilidad: Productividad	PX-Objetivos de Jugabilidad: Entretenimiento
1. Realizar una tarea eficientemente	1. Entretener el máximo tiempo posible
2. Eliminación de posibles	2. Divertir superando obstáculos

errores 3. Recompensa Externa: Trabajo Realizado 4. Fácil de Aprender e Intuitivo 5. Reducción de la carga de Trabajo 6. Asume que la tecnología debe ser humanizada	3. Recompensa Interna: Diversión 4. Nuevas cosas por Aprender y Descubrir 5. Incrementar mecánicas y metas de juego 6. Asume que el jugador tiene que ser retado por la tecnología

Los elementos básicos que componen la estructura básica de una propuesta de gamificación son las dinámicas, las mecánicas, los elementos o componentes de juego y los perfiles de usuario.

Las ***dinámicas*** están muy relacionadas con objetivos, efectos, deseos y motivaciones que se pretenden conseguir o potenciar en los usuarios. Tienen que ver con las necesidades e inquietudes humanas que motivan a las personas. No existe una lista cerrada de las dinámicas y pueden clasificarse de muchas formas. Una posible clasificación es la propuesta por Kevin Werbach que las clasifica en: Restricciones (limitaciones, reglas o compromisos forzados), Emociones (curiosidad, competitividad, frustraciones, felicidad), la Narrativa (la historia que da coherencia), la Progresión (el crecimiento del jugador a lo largo del juego) y las Relaciones (interacciones sociales, estatus, altruismo) [45] .

Las ***mecánicas*** son las acciones básicas que hacen que progrese la acción de jugar y que llevan al jugador a involucrarse en el juego. Las mecánicas las podemos ver como la forma en la que podemos "inyectar" dinámicas en las actividades para hacerlas más divertidas y motivadoras. Algunas de las más importantes son: los desafíos, la competición, la cooperación y colaboración, la suerte o la aleatoriedad, la realimentación, las recompensas y el coleccionismo de distintos ítems, entre otras.

Los ***componentes o elementos de juego*** dependen del tipo de juego y de la experiencia a generar. Algunos de los componentes más usuales son: los logros, los avatares, los emblemas o insignias, las misiones, las colecciones, el combate, el desbloqueo de contenido, los regalos, las tablas de clasificación, los puntos, los niveles, los equipos, y los bienes virtuales.

Aunque un buen diseñador de gamificación debe pensar cuales son las dinámicas que interesa provocar en los usuarios de su sistema (sobre todo a largo plazo), son las mecánicas las que se diseñan e implantan en el sistema ya que son las que consiguen despertar y avivar (a corto plazo) las motivaciones y actitudes en los usuarios. Sin olvidar que al final hay que traducir las mecánicas en componentes y en diseños concretos dentro de nuestro sistema. En los procesos de gamificación se le da mucha importancia a lo que se llama el "ciclo de actividad", Figura 1. El juego no es un proceso lineal sino que el diseñador del juego tiene que ir provocando en el jugador momentos de motivación, incentivándole (1) en el juego y desafiándole (2) con un conjunto de retos y puzles que el jugador tendrá que alcanzar, conquistando (3) los objetivos planteados y por los que recibirá (4) una serie de recompensas que le volverán a motivar y a repetir el ciclo de actividad. Estos ciclos de actividad o comportamiento son la esencia de un juego y un punto clave en el diseño jugable y gamificado.

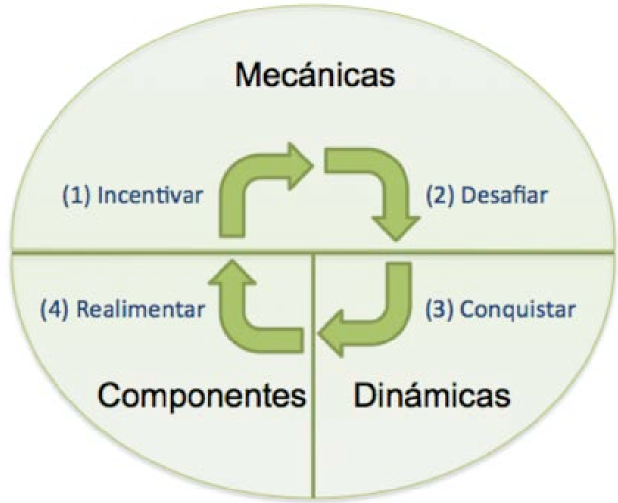


Figura 1. Definición de un ciclo de actividad típico en un proceso de gamificación.

No todos los jugadores son iguales, tienen los mismos intereses, ni les divierten las mismas cosas. Partiendo del estudio realizado por Richard Bartle en 1996 sobre los diferentes jugadores que podemos encontrar en un MUD (Multi User Dungeon) [36] podemos decir que existen 5 tipos de jugadores clasificados en dos ejes: por un lado, se encuentran aquellos que se centran en la consecución de los objetivos y en el resultado final del juego, y por el otro, los que se centran más en el valor participativo y lúdico que entraña el juego en sí mismo. Estos perfiles no son únicos y cada desarrollador puede proponer nuevos perfiles, lo importante es remarcar la existencia de varios perfiles para generar distintas dinámicas de juego asociados a ellos. Los perfiles de jugadores de ejemplo mostrados por este autor son:

- **Killer**: o ambicioso, muy motivado por ganar y ser el primero en todas las competiciones en las que participa.
- **Archiver**: o triunfador, jugador muy aventurero al que le gusta descubrir nuevas cosas, superar los retos que se les va marcando durante el juego y muy orgulloso de su estatus.
- **Socializer**: o sociable es un persona muy social y necesita compartir con los demás sus logros y objetivos y para ello suele crear una red de contactos o amigos con los que se relaciona.
- **Explorer**: Característica del videojuego que mueve a la persona a realizar determinadas acciones y a persistir en ellas para su culminación.

Emotional: o explorador, al que le gusta descubrir todo lo que le es desconocido, le motiva en gran medida la capacidad de autosuperación y le suelen divertir los retos que le ponen a prueba aunque sean muy difíciles.

También es interesante conocer la propuesta de Andrzej Marczewski, más centrada en la gamificación y en el estudio en profundidad de los tipos de usuarios y las mecánicas y dinámicas que podemos usar para motivarlos [42]. En su trabajo nos habla de 6 tipos de usuarios clasificándolos en función de si poseen fuertes motivaciones intrínsecas, como son los triunfadores, sociables, filántropos y los espíritus libres o si sus motivaciones son más flojas, como serían los disruptores y los jugadores, Figura 2.

A nivel de **Narrativa Interactiva** es importante mostrar los hechos de la historia como hilo conductor entre los distintos retos y lugares donde se realiza la acción del juego para poder alcanzar las metas y objetivos. Es necesario fijar el orden y la relación de los distintos elementos que aparecen en la aventura y cómo se narrará la historia al jugador.

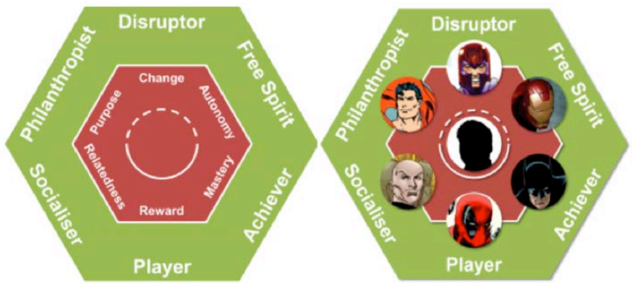


Figura 2. Clasificación de los tipos de jugadores en un proceso gamificado.

Es importante remarcar los **tipos de exploración basados en retos usando contextos aumentados** que se adapten a las experiencias propuestas, ver [41][40]. Se describe dichos tipos de exploración en las figuras siguientes y hacen referencia a RJ (Reto de Juego), AE (Actividad/Elementos), CA (Contexto Aumentado):

- **Estructura de Conjunto:** puntos de interés que carecen de relaciones explicitas entre sí, Figura 3. Destacamos:

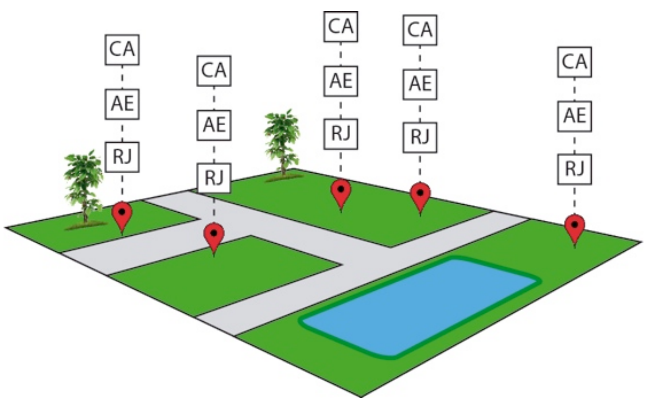


Figura3. Ejemplo de representación gráfica del recorrido de estructura de conjunto.

  - **Palabras Cruzadas:** es un conjunto de puntos de interés que contienen parte de una historia las cuales se han de combinar para construirla. No todas las combinaciones formaran una historia y el orden no es relevante.
  - **Recolectando Mariposas:** es un conjunto de puntos de interés donde cada uno de ellos contiene una historia. No es necesario superarlos todos y el orden no es relevante.
  - **Rompecabezas:** se han de superar todos los puntos de interés del conjunto para formar la historia. El orden no es relevante.

- **Estructura Secuencial:** puntos de interés con relaciones explicitas entre sí. En ella remarcamos:
  - **Estructura con bifurcación:** los puntos de interés se pueden representar como un grafo dirigido donde la consecución un punto de interés abre varios caminos alternativos. Un ejemplo es el “dominó” donde la consecución de un punto de interés condiciona los posibles puntos siguientes, Figura 4.
  - **Estructura lineal:** es una secuencia lineal de puntos de interés con un orden establecido donde solo existe un camino para completar la historia. Un ejemplo es la “búsqueda del tesoro”, donde la consecución de un punto de interés da acceso al siguiente, Figura 5.

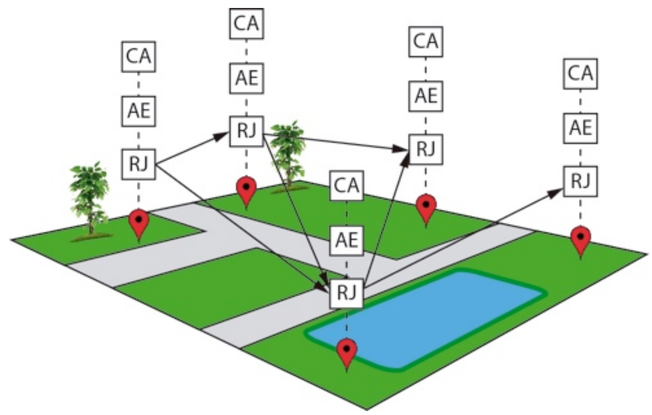


Figura 4. Ejemplo de representación gráfica del recorrido de estructura secuencial con bifurcación.

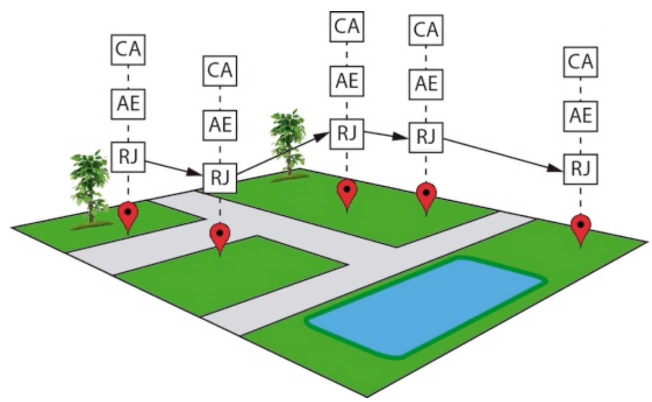


Figura 5. Ejemplo de representación gráfica del recorrido de estructura secuencial lineal.

4. DESARROLLO DE APP YINCANA BASADA EN EL CONTEXTO

A continuación presentamos distintos desarrollo de una aplicación típica geolocalizada como es una aplicación turística definida por un conjunto o lista de puntos a visitar en un espacio interior o exterior (desde ver una serie de monumentos a lo largo de una ciudad o visitar una serie de obras de arte en un museo) para mejorar la experiencia interactiva en base a las ideas propuestas en los puntos anteriores basada en una yincana social educativa. Este ejemplo ha sido realizado realizado conjuntamente por el grupo de investigación GEDES y SEJ-059 PROFESIOLAB ambos de la Universidad de Granada. El juego está desarrollado para un perfil de usuario adolescente y que hace uso de tecnologías móviles como del teléfono y una tablet que usaran para participar en el juego. Los objetivos principales a conseguir con la aplicación son los siguientes:

- Fomentar valores como, responsabilidad, respeto e igualdad.
- Iniciar al alumnado el conocimiento del espacio cultural desde la implementación de las nuevas tecnologías concienciándolos de la importancia del conocimiento de entorno donde se habita.
- Mejorar las habilidades y destrezas básicas y el desarrollo de las cualidades motrices a través del juego.
- Mejorar la capacidad imaginativa en base a los retos y narrativa interactiva del juego.
- Elaborar estrategias de forma individual y grupal para resolver las situaciones planteadas durante el desarrollo de las diferentes tareas.
- Desarrollar la creatividad y espontaneidad.
- Aprender a trabajar en equipo para la consecución de los objetivos comunes que se les han presentado.
- Motivar al alumnado usando el juego y el planteamiento de obstáculos como medio para conseguir una actitud positiva, participativa y placentera.

El primer paso es crear la estructura de juego a aplicar, para ello usaremos una estructura típica del juego de la Yincana donde aplicaremos mecánicas y elementos propios de videojuegos de tipo aventuras gráficas y RPG para mejorar la experiencia interactiva. Siguiendo las ideas del apartado anterior. Una Yincana consiste en “un conjunto de pruebas de destreza o ingenio que se realizan por equipos o de manera individual a lo largo de un recorrido, normalmente al aire libre y con una finalidad lúdica” y que se adapta al objetivo de crear experiencias geo localizadas. La experiencia de juego que se propone será capaz de detectar la localización actual del jugador, de modo que la información necesaria para superar los retos de la aventura será presentada de forma contextual. Es decir, dependiendo de en qué lugar, posición, edificio, complejo, sala, etc. Se podrá acceder a unos datos/eventos u otros. Esto permitirá definir rutas guiadas por las diferentes localizaciones, que obedecerán a criterios preestablecidos para lograr un mejor aprovechamiento de la visita por parte del usuario. De nuevo, el jugador percibirá este recorrido como parte la narrativa en la que está inmerso y dentro de la secuencia de retos que le propone el juego, bajo un proceso de gamificación de la visita. Finalmente, mediante el uso de la realidad aumentada proponemos fusionar y complementar los escenarios del juego con información real de los lugares visitados, a los que se añadirá información sensible al contexto que permita enriquecer y comprender mejor lo que el usuario está viendo en cada lugar. La aventura incluirá elementos generados de forma automática y adaptados al jugador, de forma que se mantenga su interés en el juego y se fomente la rejugabilidad, al cambiar dichos elementos entre dos instancias de la aventura (dos partidas) diferentes.

Antes de pasar a definir las dinámicas y mecánicas del juego es interesante analizar los roles o perfiles que proponemos para los distintos jugadores/usuarios para este tipo de juegos caracterizados por la exploración y la visita de lugares. Respecto a la clasificación mostrada en el punto anterior estos serían sobre todo del tipo “explorer” “archiver” y “socializer”. Estos son:

- **Cartógrafo:** lleva el dispositivo con el mapa y guía al grupo hacia los puntos donde se localizan las pruebas indicando el recorrido que se está realizando.
- **Custodio:** recoge las pruebas que ayudaran a resolver el enigma final si lo hubiese (anota en el dispositivo las pistas que se vayan consiguiendo).
- **Fotógrafo:** realiza las fotografías durante el recorrido (utiliza un dispositivo tipo smartphone).
- **Organizador:** controla que todos cumplan con su rol y debe ir asignando las tareas a desarrollar en cada momento. Vigila que en cada punto utilice el dispositivo un compañero distinto.
- **Portador:** se encarga de la Tablet o teléfono inteligente y debe entregarla a quien corresponda en cada momento, es la persona responsable del dispositivo.
- **Redactor:** redacta una crónica del recorrido (redactor de bitácora en formato digital utilizando un dispositivo móvil).

Cada equipo estará formado por varios miembros de un perfil determinado, pudiéndose dar el caso en el que dos perfiles recaigan sobre la misma persona o hayan perfiles repetidos. Además en cada equipo pueden darse varios dispositivos móviles (teléfono o tablet). La organización es un aspecto clave y fomenta el factor social, siendo una propuesta propia de cada grupo.

Además propondremos que cada usuario haga uso de un avatar. El avatar sirve para identificar al jugador del mundo real con el jugador o elementos del mundo virtual, creando una asociación bidireccional entre ambos. De esta manera proporcionamos mecanismos de identidad y de inmersión dentro de las dinámicas de juego. Otros de los aspectos a tener en cuenta es la narrativa interactiva. Para ello haremos uso de mecanismos comúnmente utilizados en aventuras gráficas y juegos de rol (RPG) que anteriormente hemos citado.

Como retos de juego planteamos unos retos (para crear mecánicas y dinámicas y elementos de juego similares a las propuestas en el apartado anterior) sencillos que se puede aplicar según el contexto. Los objetivos de estos retos pueden ser puramente lúdicos o con un objetivo de aprendizaje de elementos interesantes en la ruta turística basada en una yincana. Estos retos pueden ser:

- **Sopa de letras y crucigramas:** muestra una sopa de letras o crucigramas y cuadros de texto para introducir las respuestas encontradas relacionadas con la historia y el lugar donde se realiza la prueba o donde está situado el usuario.
- **Trivial y Test:** consiste en un conjunto de preguntas con distintas opciones de respuesta, siendo solo una de ellas la correcta. En el caso de los Test se acepta varias preguntas correctas válidas (opción múltiple).
- **Adivinanzas:** se presentan una serie de adivinanzas con su respectivo cuadro de texto para introducir la respuesta.
- **Validación mediante cámara:** se usará la cámara de móvil para analizar un elemento o tomar una foto y así desbloquear un reto o poder superarlo, como por ejemplo fotografiar la inscripción de una estatua de una plaza determinada.
- **Búsqueda y ensamblaje de objetos:** consistirá en encontrar distintos objetos siguiendo determinadas pistas para ir

cambiándolos y usándolos en la resolución de retos posteriores para avanzar en el juego.

Por otro lado usaremos **niveles de completitud** para los retos que tenemos pendientes (barras de progresos, listas de tareas, etc.) siguiendo algunos de los ejemplos de dinámicas y mecánicas mostrados con anterioridad, de manera que estamos generando una motivación extrínseca en el usuario que le genera un deseo de completar las tareas pendientes.

A su vez por cada reto ofreceremos tres **medallas** según la forma de completar el reto (grado de consecución). Por ejemplo simplemente por hacerla correctamente una medalla de bronce, por llegar a una puntuación media, una medalla de plata, y si su consecución es del 100% una medalla de oro. Si todas las pruebas llegan al 100% de completitud puede lograr la medalla de platino. Esta mecánica consigue que el jugador se motive y repita una y otra vez la prueba hasta conseguir las tres medallas. Además tendremos un sistema recompensas de emblemas/puntos y de clasificación. Los **puntos** (elementos de juego) son una forma efectiva de realimentación, tanto para que el jugador conozca su progresión dentro del juego como para mostrar los resultados a otros jugadores.

Los **emblemas** o **insignias** son una versión más sólida de los puntos. Los podemos ver como una representación visual de un logro destacable dentro de nuestro sistema de gamificación. Son una forma de darle objetivos específicos a los jugadores y también un escaparate de las diferentes posibilidades que nos da el sistema.

Las **tablas de clasificación** permiten ver el nivel o la puntuación alcanzada por otros jugadores así como comparar nuestros progresos en el juego. Son una forma clara de motivar a los jugadores a competir unos con otros. Para fomentar el factor social incluimos un **álbum de fotos** donde los jugadores/usuarios comparten imágenes de su proceso de juego.

Con los elementos anteriormente citados fomentamos propiedades de la jugabilidad indispensables para una correcta experiencia interactiva lúdica, como pueden ser la satisfacción personal (puntuación obtenida), la inmersión (toma de fotos a elementos del entorno), la efectividad (intentos y tiempo jugado/visitando los elementos), la motivación (número de medallas conseguidas), socialización (compartir fotos, retos en grupos/parejas) emoción (uso de tiempo en cada reto) o el aprendizaje (probar a superarse así mismo).

El recorrido propuesto está localizado en el recorrido de la Yincana y está localizado a lo largo del Campus de Cartuja de la Universidad de Granada. Este recorrido está caracterizado por tener puntos en el exterior e interior de algunos edificios, por lo que se aplicarán técnicas de localización en exteriores e interiores. Los jugadores/usuarios deben visitar edificios propios del campus para superar el juego propuesto, Figura 6. El recorrido propuesto es de tipo "**búsqueda del tesoro"** (estructura lineal), donde la consecución de un punto de interés da acceso al siguiente.

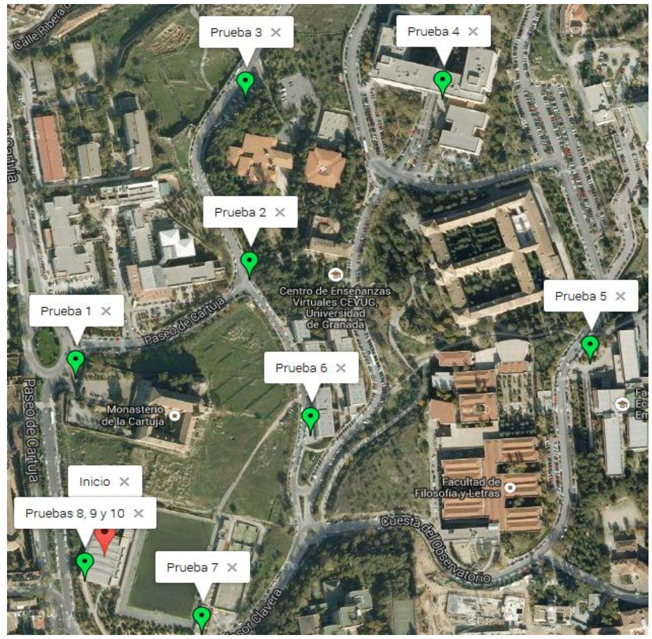
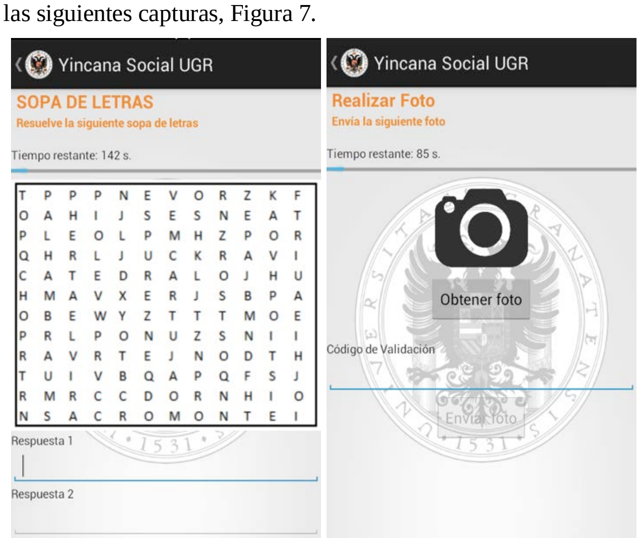


Figura 6. Ubicación de las distintas pruebas en el mapa del Campus de Cartuja

Para la localización en exteriores se utilizará como tecnología de posicionamiento el sistema GPS. Además se ha incorporado un sistema para aplicar corrección de errores y margen o radio de acción. Este radio de acción está parametrizado según las características de la Yincana. El objetivo de este componente es poder lanzar información al grupo de usuarios según vayan llegando al punto de destino, así como ampliar la zona de acción en caso de que coincidan varios grupos dentro de un mismo reto. Para la localización de interiores se utilizan marcadores con códigos QR con el objetivo de fomentar la exploración y el seguimiento de pistas que con ellos se ofrecen. Para utilizar la información temporal se hace uso del reloj del sistema con el objetivo de establecer un tiempo límite para la realización de las pruebas.

Ejemplos de las distintas pruebas en exteriores pueden verse en las siguientes capturas, Figura 7.



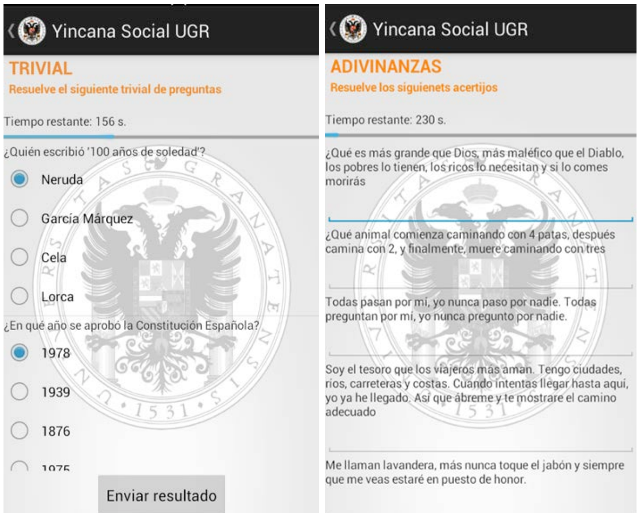


Figura 7. Ejemplo de retos: sopa de letras, toma de foto, cuestionario y adivinanzas

Para las pruebas que se realizan en interior se han diseñado actividades de ensamblaje de objetos siguiendo la estructura de los retos de la aventura gráfica y que se representan en una estructura jerarquizada representada en la Figura 8. En ella los jugadores deberán conseguir realizar la "poción gazpacho" a lo largo del mapa interior del edificio, Figura 9. Para interactuar entre elementos reales y virtuales se utilizan marcadores de objetos y de funcionalidad tal y como se indica en [43]. Ejemplos de capturas del juego en interior pueden verse en la Figura 10. En ella se muestra el proceso de cultivar un tomate, la información del elemento, la acción de recoger agua o amasar el pan necesario para realizar la poción gazpacho.

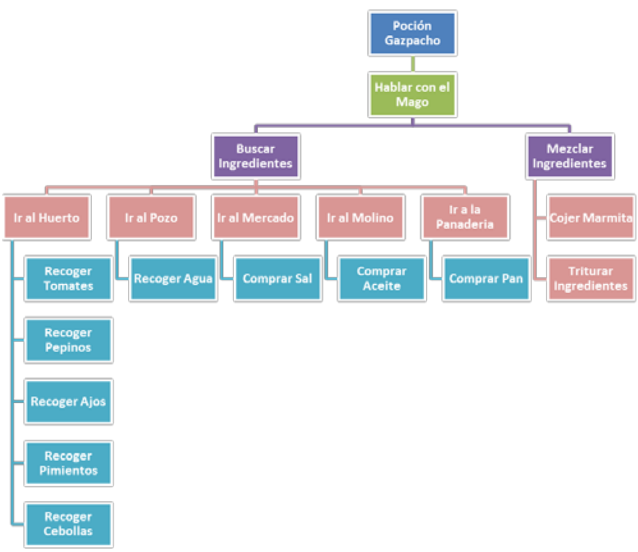


Figura 8. Ejemplo de retos de interior: Poción Gazpacho

Figura 9. Mapa de interior y localización de retos

Figura 10. Pruebas de interior usando realidad aumentada y marcadores de funcionalidad

Para fomentar el factor social se hace uso de un álbum de fotos donde los jugadores comparten sus experiencias durante el juego y pueden realizar comentarios de las mismas, Figura 11.

Figura 11. Álbum de imágenes y participación de los usuarios

El sistema ha sido desarrollado conforme a la arquitectura de elementos propuestos en [43][44] como son: estructura de juego, contenidos multimedia, contexto (temporal, posicional y social), planificador de rutas, motor de juego de realidad aumentada y los informes/estadísticas obtenidos. Además de la comunicación con un portal web donde compartir y visualizar los resultados.

Los elementos se han desarrollado usando UNITY 3D para crear el sistema móvil sobre plataformas Android con las librerías Vuforia de Qualcom para la parte de la realidad aumentada. Además se ha hecho uso de marcadores funcionales para implementar las acciones del juego, así como completar los mecanismos de localización interior tal y como hemos comentado en párrafos anteriores.

Para probar el sistema se diseñó una yincana turística con una participación total de 100 alumnos/as (estudiantes del grado de Educación Infantil). Tras realizar y completar la yincana y los retos propuestos siguiendo la aventura interactiva, se realizó un pequeño encuesta anónima de seis preguntas y cuya valoración va desde 1 (más negativo, peor valorado) hasta 5 (lo más positivo, mejor valorado) con el objetivo de recabar una primera impresión o información inicial de la experiencia obtenida con este prototipo a través de su participación. El objetivo de esta encuesta era obtener una idea inicial del estado del prototipo, y no se asemeja a un cuestionario de evaluación de la satisfacción, que tal y como se puede leer en el siguiente apartado, es uno de los retos que tenemos presentes para realizar como trabajo futuro. Las preguntas a responder individualmente identifica la experiencia interactiva personal de haber superado el juego en grupo:

- **Pregunta 1:** ¿Con qué frecuencia has usado aplicaciones de juegos geolocalizados?
- **Pregunta 2:** ¿Los retos propuestos te han motivado para completar el recorrido?
- **Pregunta 3:** ¿Son adecuadas las recompensas obtenidas (puntuación, medallas…) para este tipo de aplicación?
- **Pregunta 4:** Indica el grado de colaboración y participación con tus compañeros para superar los retos y completar el recorrido:
- **Pregunta 5:** ¿Participarías en futuras pruebas de este tipo de aplicaciones?
- **Pregunta 6:** ¿Cómo de interesante encuentras el uso de juegos geolocalizados en aplicaciones para visitas turísticas?

El resultado obtenido, Tabla 2, muestra como el diseño de la aplicación con mecanismos basados en experiencias lúdicas obtiene un alto grado de aprobación sobre las preferencias de realizar las actividades de esta manera (con elementos de juego) y no sobre la manera tradicional (simple visita), en ella se destaca ante todo el factor social y el poder compartir los resultados con el resto de usuarios, así como el participar de experiencias colectivas. Se destaca que los retos de juego han sido del agrado del jugador, así como la aventura que los incorpora dentro de una arquitectura de retos juego, destacando que las recompensas son adecuadas y mostrándose muy abiertos en participar en nuevas experiencias lúdicas usando este sistema para crear rutas de interés cultural.

Tabla 2. Resultados del cuestionario de satisfacción de la aplicación Yincana

	1	2	3	4	5
Pregunta 1	90%			10%	
Pregunta 2			3%	7%	90%
Pregunta 3				40%	60%
Pregunta 4			5%	5%	90%
Pregunta 5					100%
Pregunta 6			4%	11%	85%

5. CONCLUSIONES Y TRABAJOS FUTUROS

A lo largo de este trabajo hemos presentado el diseño y uso de experiencias lúdicas, basadas en la jugabilidad y la gamificación, para mejorar la experiencia interactiva en la realización de distintas tareas geolocalizadas. El uso de estas experiencias ayuda a mejorar la satisfacción, motivación y fidelización de los usuarios ante el conjunto de tareas a realizar en pos de un objetivo concreto.

En el ejemplo presentado se han aplicado mecánicas y dinámicas del juego, basados en aventuras gráficas y RPG interactuando con el entorno según el contexto haciendo uso de dispositivos móviles y realidad aumentada. Para ello la Yincana propuesta hace uso de perfiles de usuario, distintos retos, una historia y una forma de narración propias de este tipo de juegos que dotan a la aplicación desarrollada mecanismos atractivos para los propios usuarios que mejoran las experiencia interactiva con los retos de juego que en ella se presentan para realizar las tareas.

Aunque el porcentaje de aceptación del prototipo es elevado, aún se deben trabajar en la adaptación de mecánicas de juego específicas, así como mejoras en el factor social y adaptación de puntuaciones e insignias (tabla de rankings al perfil de usuario) para evitar situaciones de frustración y abandono de la tarea por exceso de componentes lúdicos. Es por ello que es recomendable analizar el impacto sobre los usuarios y conocer el equilibrio necesario en la utilización de estas técnicas para fomentar la experiencia adecuada según el caso de uso, proyecto propuesto o perfil de usuarios. Esto es uno de los puntos que marcan nuestro trabajo futuro a través de una evaluación de la experiencia interactiva mucho más profunda y detallada con esta aplicación y otras similares.

Además se está trabajando en mejorar la narrativa interactiva así como recoger las ideas de este trabajo para aplicarlas en mejorar la experiencia de la experiencia de los turistas y visitantes de la ciudad de Granada, y en particular por edificios emblemáticos donde los visitantes, que se verán impulsados por descubrir la información que se oculta tras los retos del juego teniendo como recompensa bonos de visita a museos y exposiciones propias que en algunos de los edificios son expuestos al público, así como premios que la propia universidad ofrecerá a sus usuarios.

6. AGRADECIMIENTOS

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La importancia de las emociones en el diseño de historias interactivas

José Rafael López-Arcos
GEDES, Universidad de Granada
jrlarco@ugr.es

Francisco Luis Gutiérrez Vela
GEDES, Universidad de Granada
fgutierr@ugr.es

Natalia Padilla-Zea
GEDES, Universidad de Granada
npadilla@ugr.es

Patricia Paderewski Rodríguez
GEDES, Universidad de Granada
patricia@ugr.es

Noemí Marta Fuentes García
GEDES, Universidad de Granada
nmfuentes@ugr.es

ABSTRACT
Los videojuegos se benefician del poder de la narrativa para hacer que el usuario se sienta inmerso en el mundo virtual que ofrecen. Los diferentes cambios de contexto dentro del abanico de mecánicas de juego pueden ser justificados mediante estas historias. Esto mantiene la motivación a través de la inmersión y favorece, por tanto, la enseñanza por medio de los videojuegos. El vínculo necesario para que el receptor de la historia se involucre con los personajes que aparecen en ella se consigue, a su vez, gracias a las emociones que se transmiten en la historia. El diseño de las historias contenidas en videojuegos presenta una complejidad alta debido a su carácter interactivo. En el presente trabajo, se expone la base de nuestra propuesta para diseñar y evaluar estas historias interactivas e incluirlas en un videojuego, prestando especial atención a la evaluación de las emociones contenidas en ellas.

Categories and Subject Descriptors
H.1.2 [**Information Systems**]: User/Machine Systems – *Human factors*.

General Terms
Measurement, Documentation, Performance, Design, Experimentation, Human Factors.

Keywords
Interactive Storytelling, Educational Video Games, Evaluation, Emotions, Interaction.

1. INTRODUCCIÓN
Las emociones son una componente fundamental en el ser humano, ayudándole a darle significado, valor y riqueza a las experiencias que viven [1]. En la actualidad, es reconocido, que las emociones juegan un rol critico e imprescindible en todas las relaciones con las tecnologías, desde el uso en videojuegos, la navegación por sitios web, el uso de dispositivos móviles, entre muchos otros [2] [3]. A nivel de investigación, existen numerosos trabajos [4] donde se analiza qué aspectos de las emociones son los importantes a la hora de realizar una evaluación de la usabilidad y de la experiencia del usuario y qué técnicas son las más adecuadas para realizar dicha evaluación.

Las técnicas de evaluación emocional son una forma importante de recopilar y medir información valiosa sobre aspectos cualitativos y cuantitativos de la experiencia de un usuario y van desde complejos cuestionarios hasta métodos más o menos invasivos.

Uno de los factores que otorga importancia a las emociones es que éstas pueden actuar como motivadores esenciales. Es decir, emociones como el afecto positivo o el placer pueden desarrollar una conducta motivacional dirigida hacia unos objetivos específicos. Estos objetivos pueden ser la propia diversión en el caso de un videojuego o el aprendizaje en el caso de un videojuego educativo.

A nivel educativo, teorías como el condicionamiento operante [5] afirman que la experiencia emocional placentera puede ser considerada como un forma importante de refuerzo positivo en los procesos de aprendizaje, incrementando la probabilidad de que se repita la conducta que dio lugar a esa experiencia emocional.

La narrativa, por su parte, juega un papel muy importante en el diseño de la experiencia de usuario de un videojuego. Además, en el caso concreto de los videojuegos educativos, proporciona una justificación motivacional a las actividades pedagógicas realizadas por el usuario.

Para diseñar una experiencia narrativa, es imprescindible definir las emociones contenidas en ésta. Las emociones en una historia son imprescindibles para crear un vínculo entre el receptor de la historia y los personajes y situaciones descritos en ésta. Así lo demuestran estudios como el presentado en [6], donde los autores definen métodos de interacción con la narrativa basados en las emociones. Esta relación, además, está basada en el interés que la experiencia despierta en el invitado a lo largo de la duración de ésta [7].

En anteriores trabajos hemos presentado [8][9] una aproximación para estructurar y analizar la historia que se incluye en los videojuegos educativos (VJE) como elemento que da sentido narrativo al proceso de juego. En ella, mediante un modelo conceptual y una serie de tareas, se proporcionan mecanismos para diseñar la historia interactiva que va a formar parte del VJE. Esa historia, gracias a su flexibilidad y adaptabilidad, permite dar una justificación narrativa a las diferentes tareas que el jugador realiza en el videojuego.

El resto del presente trabajo se organiza del siguiente modo: el apartado 2 explica las bases de la propuesta en la que trabajamos actualmente para diseñar historias interactivas. Para ello, en primer lugar se exponen herramientas para evaluar la narrativa, su estructura y su intensidad. En segundo lugar, se profundiza en la evaluación de la narrativa desde el punto de vista del nivel de intensidad emocional. Finalmente, en el apartado 3 se exponen las conclusiones y el trabajo futuro.

2. Convertir la narrativa y su aspecto emocional en algo mesurable

2.1 Análisis de la historia

Los autores de la historia del videojuego y diseñadores de las mecánicas de juego deben definir los elementos de la historia interactiva de tal forma que la experiencia de juego sea satisfactoria a nivel narrativo. De este modo, el jugador recibirá una historia coherente y atractiva aunque la esté transformando activamente por medio de sus acciones de forma interactiva. Basándonos en nuestros trabajos previos [9] y para llevar a cabo este complejo diseño, proponemos las siguientes tareas:

1. Definir las características de la experiencia que se pretende diseñar.
2. Elegir el tipo de historia correcta (género e importancia de la narrativa en el juego).
3. Escribir un guión tradicional (Evolución Narrativa) como base para el diseño.
4. Estructurar la historia en base a los modelos teóricos [8][9].
5. Realizar un guión esquemático de la historia.
6. Realizar un guión gráfico interactivo (o *storyboard* interactivo).
7. Evaluar la estructura y la intensidad de la historia diseñada, sus elementos y su efecto en la experiencia de juego. Para ello, es necesario tener en cuenta sus posibles diferentes instancias.

En el presente trabajo, nos centramos en la última de estas tareas. Para llevarla a cabo, nos basamos en la estructura diseñada en la tarea 4, que define las diferentes formas que una historia interactiva puede adoptar dependiendo de cómo el jugador se comporte en ella. A éstas diferentes historias las llamamos instancias [9]. Es necesario, por tanto, comprobar que cada una de ellas sea una historia coherente e interesante, y que proporcione una experiencia de juego óptima. Para poder analizar y evaluar esta forma de narrativa, proponemos un nuevo conjunto de tareas que podrán ser realizadas independientemente y de forma iterativa a lo largo del proceso de diseño:

1. Generación de las posibles instancias de historia.
2. Análisis de la estructura narrativa de cada instancia de historia.
3. Análisis de la intensidad de cada instancia de historia.
4. Evaluación de los *elementos* de la historia y de la experiencia del jugador.

2.1.1 *Generación de las posibles instancias de historia*

Al estructurar la historia de acuerdo al modelo conceptual propuesto en [10], se genera un grafo que recoge todos los eventos que pueden ocurrir en la historia interactiva.

Obtener una selección de instancias interesantes de esa historia en base al grafo construido, permite el análisis individual de cada una de ellas. Por tanto, es posible detectar aquéllas instancias que destaquen por su alta o baja calidad. En el caso de presentarse posibles instancias de una calidad pobre, los diseñadores podrán tomar las medidas necesarias en una reestructuración de la historia para que el jugador no pueda recibir estas malas historias. Profundizamos en dicho análisis en los siguientes apartados.

2.1.2 *Análisis de la estructura narrativa de cada instancia de historia*

Con la estructura narrativa nos referimos a estructuras formales tratadas en teorías clásicas sobre narrativa. Durante el diseño de la historia, cada escena ha sido etiquetada con información referente a esa estructura narrativa. Por tanto, como indicamos en [9], esa información puede ser extraída de cada instancia de historia para observar cómo está construida y conocer en qué grado cumple los cánones establecidos.

En [11] los autores proponen una serie de métricas y estadísticas para abstraer y organizar esta información dada una historia. Algunas de ellas son: 1) contabilizar la ocurrencia de escenas pertenecientes a cada etapa del *Viaje del Héroe* [12]; 2) calcular qué porcentaje del tiempo que ocupa la historia pertenece a cada uno de los actos de la estructura clásica narrativa de tres actos; 3) identificar eventos pertenecientes al núcleo de la historia y los eventos satélite y contabilizarlos; 4) contabilizar el número de personajes que correspondan a cada uno de los arquetipos definidos por Vogler [12] y 5) calcular en qué porcentaje de cada acto de la historia están presentes cada uno de esos personajes arquetipo.

En nuestra propuesta, los diseñadores del videojuego pueden obtener estas métricas y estadísticas automáticamente y comparar las instancias de la historia entre sí y con otras historias modelo. De este modo, se pueden detectar fácilmente posibles deficiencias en la historia interactiva.

2.1.3 *Análisis de la intensidad de cada instancia de historia*

Para poder medir la calidad de una experiencia de entretenimiento, es necesario encontrar un elemento evaluable a lo largo de la duración de la experiencia.

El interés despertado en el usuario invitado, en cada momento de la experiencia, puede ser evaluado y analizado. Gracias a ello es posible generar "curvas de interés". La Figura 1 muestra una típica curva de interés en una experiencia de entretenimiento óptima [7].

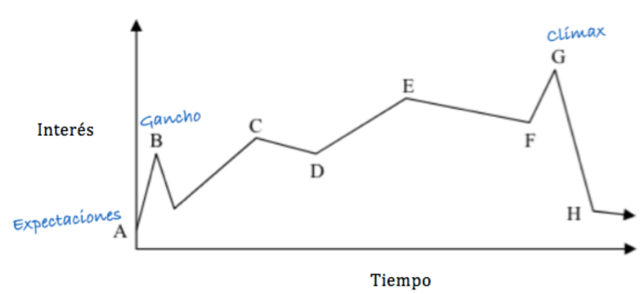

Figura 1. Curva de interés típica.

Estas curvas de interés son muy útiles para crear una experiencia de entretenimiento. Pueden compararse con otras curvas para comprobar qué experiencia es más efectiva. Además, puede compararse la curva de una experiencia real con la curva prevista por el diseñador de la experiencia.

En el caso del método que proponemos, basamos el interés en la intensidad emocional asociada a cada parte de la experiencia. El apartado 2.2 profundiza en el aspecto emocional y cómo medirlo y analizarlo.

2.1.4 *Evaluación de los elementos de la historia y de la experiencia del jugador*

Por último, proponemos que todos los elementos de la historia pueden ser evaluados por separado y dependiendo de la necesidad del proceso de diseño. Es posible que el público al que va dirigido tenga características especiales o simplemente que los diseñadores quieran asegurarse de que ciertas apuestas arriesgadas funcionan correctamente. Para ello, proponemos la realización de experiencias con usuarios mediante el uso de prototipos.

A modo de ejemplo, en [13] presentamos una serie de experiencias para evaluar y así mejorar el diseño de los personajes de un videojuego educativo. Proponemos que estas experiencias en forma de pre-test, test y post-test pueden extenderse a la evaluación de cualquiera de los elementos de la historia: partes concretas de la historia, intensidad emocional, personajes, escenarios, objetos, diálogos o cualquier otro.

2.2 El uso de las emociones para medir el efecto de la historia en el jugador

En el apartado 2.1.3 hablamos de la importancia de realizar un análisis de la intensidad de la experiencia de usuario en cada instancia de la historia.

Debido a que, como se ha mencionado anteriormente, ese interés y la relación existente entre el jugador y la historia están muy ligados con el aspecto emocional, en la presente sección, proponemos enriquecer ese análisis mediante la medición de las emociones concretas que participan en la experiencia. Aunque existen innumerables aspectos y variantes a las reacciones emocionales que puede mostrar una persona, para simplificar, proponemos regirnos por la lista de las seis emociones universales humanas elaborada por Ekman [14]: alegría, aversión, ira, miedo, sorpresa y tristeza.

Dependiendo del tipo de historia y de los intereses de los autores, será interesante centrarse en medir algunas de esas seis emociones. Proponemos el análisis de curvas de intensidad emocional específicas de las emociones seleccionadas. Sin embargo, el problema reside en cómo es posible medir emociones. Para realizar una estimación del impacto emocional de la historia, proponemos dos enfoques: a) realizar una estimación por parte de los autores, o b) aplicar técnicas de medición durante experiencias reales.

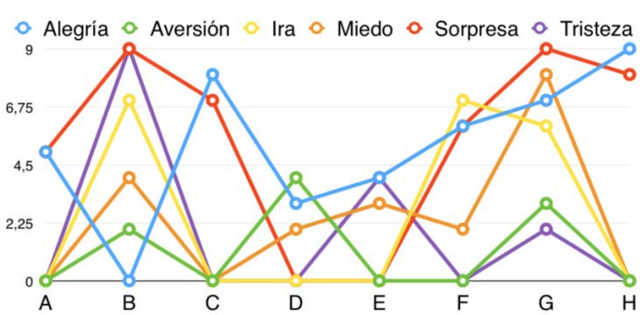

Figura 2. Valor de la intensidad de las seis diferentes emociones en siete eventos de la historia.

Respecto al primer enfoque, los autores pueden estimar en qué grado aparece cada emoción en cada parte de la historia que están construyendo. Al realizar la estructuración de la historia a la que se hace referencia en el apartado 2.1 y que se explica en [8], los diseñadores pueden asignar esos grados de emoción a cada escena o evento de la estructura de la historia. De este modo, de cada instancia de historia potencialmente generable se podrán obtener estos datos, analizarlos y compararlos para decidir si la historia ofrece instancias buenas o con el carisma emocional deseado (Figura 2).

Sin embargo, cada jugador reacciona completamente diferente a una experiencia de juego. Además, en una historia interactiva, los eventos cambiarán de orden o el jugador puede estirar o acortar deliberadamente el tiempo de la experiencia, perdiéndose en gran medida el efecto emocional esperado por los autores. Para poder estimar el impacto emocional real de una historia interactiva, es necesario realizar experiencias con jugadores reales y observar los resultados.

No obstante, medir las emociones de un jugador puede no ser una tarea sencilla. Para este enfoque, proponemos dos técnicas diferentes pero no excluyentes: a) solicitar a los jugadores de la experiencia que rellenen un cuestionario sobre el impacto emocional, y b) monitorizar las reacciones de los jugadores para extraer datos sobre dicho impacto emocional.

Respecto al uso de cuestionarios, proponemos hacerlo al finalizar la experiencia de juego. El cuestionario a utilizar estará centrado en los eventos más destacables de la experiencia o en los que sean objeto de estudio. Además, debe ser un cuestionario adaptado a la experiencia particular y a lo jugadores involucrados. En las experiencias descritas en nuestro trabajo previo [15], al ser los sujetos del estudio niños de edad muy temprana, el cuestionario se realizó de forma oral, y se usaron cartulinas con iconos que representaban emociones fácilmente identificables por ellos.

A diferencia de los niños, los participantes adultos pueden identificar distintos niveles para una misma emoción. Para ellos, proponemos usar un cuestionario impreso en el que para cada escena o evento de la historia interactiva que sea objeto de estudio, tengan que asignar un valor numérico a la intensidad de cada una de las emociones (Tabla 1).

Tabla 1. Cuestionario sobre intensidad emocional de una parte concreta de la historia de una experiencia

	Nivel de intensidad de cada emoción				
Emociones	**0**	**1**	**2**	**3**	**4**
Alegría					
Aversión					
Ira					
Miedo					
Sorpresa					
Tristeza					

De forma adicional, existe la posibilidad de monitorizar al jugador e interpretar sus emociones de forma poco intrusiva. En [16], los autores proponen un sistema con interacción emocional. En él, detectan las reacciones emocionales mediante el uso de una cámara y un software que detecta en la imagen del rostro del usuario signos de las seis emociones más la neutral. Para ello, identifica puntos clave en el rostro del usuario y las variaciones en la distancia entre ellos [17]. Este ejemplo es útil para comprender que es sencillo detectar las emociones que el jugador experimenta y comparar esos datos con los expresados por el propio jugador en el cuestionario

Estos datos sobre el impacto emocional de la experiencia de juego permiten estudiar este aspecto de la historia interactiva. Al integrar este estudio dentro del proceso de desarrollo del videojuego se pueden usar esos datos para mejorar el producto y diseñar así una experiencia interactiva basada en una historia compleja y satisfactoria para el jugador.

3. CONCLUSIONES

En el presente trabajo se propone una serie de tareas que incluyen la evaluación de la estructura de la historia y de su intensidad emocional. En el aspecto emocional, se proponen una serie de técnicas para poder contabilizar estas emociones y así obtener valores en base a unas métricas. Actualmente, estamos trabajando en experiencias para poner en práctica el uso del método. El objetivo es integrarlo en una metodología y, a raíz de esta, diseñar una herramienta automática para la construcción y la evaluación de la narrativa de un videojuego educativo.

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Agente virtual emocional para dispositivos móviles

Sandra Baldassarri
GIGA Affective Lab
Universidad de Zaragoza
Zaragoza
+34976762357
sandra@unizar.es

Eva Cerezo
GIGA Affective Lab
Universidad de Zaragoza
Zaragoza
+34976762356
ecerezo@unizar.es

RESUMEN

El rápido aumento de las capacidades computacionales de los dispositivos móviles ha posibilitado el desarrollo de aplicaciones que permiten la interacción multimodal con los mismos en tiempo real. Estos sistemas se suelen basar en el uso de agentes virtuales que facilitan la comunicación entre usuarios y servicios. Este trabajo presenta una aplicación basada en agentes que permite la interacción multimodal y emocional con los usuarios a través de los canales visual, oral y escrito. El sistema ha sido evaluado para comprobar percepción de los usuarios sobre la capacidad del personaje en expresar las emociones.

Categories and Subject Descriptors

H.5.2 [**User Interfaces**]: Graphical users interfaces (GUI), Input devices and strategies, Interaction Styles, Evaluation

General Terms

Design, Human Factors.

Keywords

Personajes virtuales, interfaces emocionales, interacción táctil, dispositivos móviles

1. INTRODUCCIÓN

La gran proliferación de aplicaciones móviles de hoy en día ha dado lugar a que la interacción a través del teclado se utilice cada vez menos, dando paso a aplicaciones totalmente táctiles. En estos casos, la interacción generalmente se realiza a través de gestos con los dedos o a través de la voz. Sin embargo, debido al continuo aumento tanto de la capacidad de procesado como de la memoria de los dispositivos móviles, empiezan a aparecer sistemas basados en agentes virtuales desarrollados para ser ejecutados sobre estos dispositivos. Una de las características más importantes de los agentes virtuales es que deben ser capaces de interactuar con el usuario en tiempo real, y de forma multimodal, teniendo en cuenta la interacción a través de la voz, la escritura y agentes animados.

En los últimos años, ya se ha estado trabajando en el uso de agentes virtuales en aplicaciones para móviles. Una de las primeras aplicaciones desarrolladas ha sido un presentador virtual encargado de narrar los titulares de las noticias más importantes del momento [1]. También se han utilizado como guía durante el entrenamiento del usuario, ayudando a realizar correctamente ejercicios de fitness [2], o como intérpretes, transmitiendo mediante el lenguaje de signos los mensajes escritos por los usuarios [3]. Existen también plataformas para la especificación de agentes virtuales que soportan interacción en dispositivos móviles, como Elckerlyc [4] que permite interactuar de forma oral, textual y visual, pero sin considerar las emociones; o la desarrollada para Android por [5] donde la interacción se puede realizar por dos canales, el oral y el visual, y aunque considera emociones, no lo hace en todos los canales.

En este trabajo presentamos un agente virtual para dispositivos móviles que permite la interacción con el usuario por los canales oral, escrito y visual, teniendo en cuenta la expresión de las emociones en todos los canales.

2. INTERACCIÓN CON EL AGENTE VIRTUAL

En la Figura 1 se presenta la arquitectura del sistema desarrollado, describiendo posteriormente en detalle cada uno de los módulos que intervienen.

2.1 Comunicación oral

El módulo de comunicación oral incorpora un **Reconocedor de Discurso**, basado en la aplicación **Google Voice Search**, que se encarga de captar el mensaje hablado del usuario a través del **micrófono** del dispositivo móvil, convertirlo a cadena de texto y transmitirlo al módulo **Gestor de Diálogo,** y un **Sintetizador de Voz**, basado en el sistema **TTS Android**, encargado de la conversión a voz de las respuestas en formato texto procedentes del **Gestor de Diálogo**. Este sintetizador ha sido dotado de **voces emocionales** con las que pronunciar el mensaje. La reproducción del discurso se lleva a cabo a través del **altavoz** del dispositivo.

2.1.1 *Reconocedor del discurso*

Entre las distintas posibilidades existentes para realizar el módulo **Reconocedor el discurso** del usuario en dispositivos móviles Android, dos opciones destacan sobre el resto: utilizar el sistema de reconocimiento de voz PocketSphinx, específico para sistemas embebidos y dispositivos móviles o realizar peticiones de reconocimiento de voz a una aplicación especializada instalada en el dispositivo móvil. Una vez analizadas ambas opciones, se opta por la segunda opción, para reducir los requerimientos de procesado del sistema y porque ofrece mejor calidad en el reconocimiento del discurso, lo que permite dotar de mayor realismo a la interacción oral con el usuario, a pesar de que sea necesaria una conexión a internet.

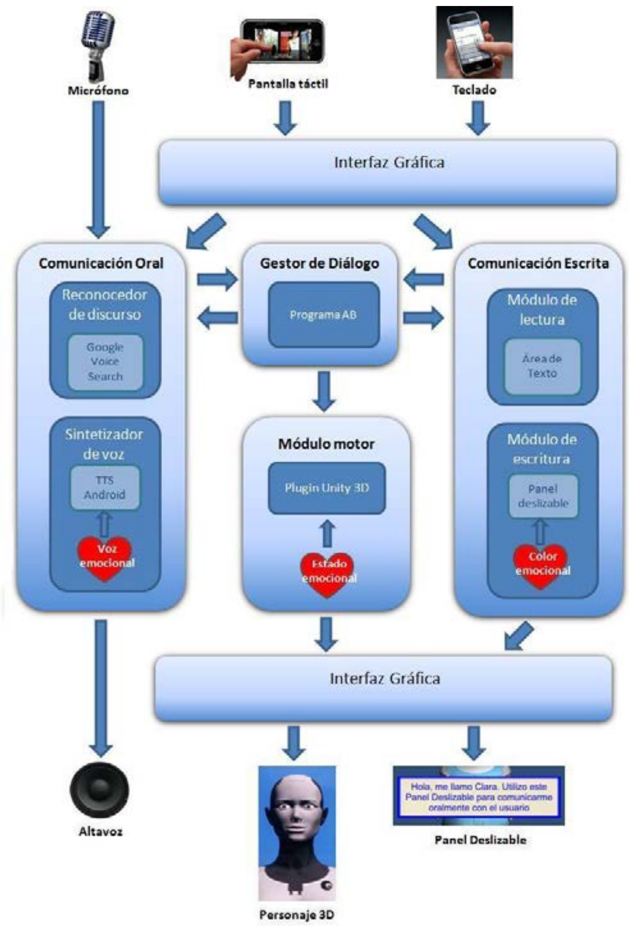

Figura 1. Diseño del sistema

De entre las posibles aplicaciones de reconocimiento de voz disponibles para Android: Voice Action Plus, Cyberon Voice Commander, VoicePOD, Konele, Vlingo y Google Voice Search, se selecciona esta última ya que puede ser instalada de forma gratuita, viene integrada en los dispositivos móviles Android más modernos, y es uno de los mejores reconocedores del habla disponibles, siendo compatible con varios idiomas.

2.1.2 *Sintetizador de voz*

El módulo Sintetizador de Voz recibe las cadenas de texto que proceden del Gestor de Diálogo con las respuestas para el usuario y las reproduce a través del altavoz del dispositivo móvil.

Para lograr este objetivo es posible desarrollar un motor de síntesis de voz propio que sea compatible con Android o hacer uso del motor de síntesis de discurso (Text To Speech o TTS) que incorpora la plataforma Android. Se opta por esta última opción que minimiza los requerimientos de procesado del sistema y utiliza la aplicación de síntesis de voz seleccionada por defecto en cada dispositivo móvil. Además, soporta múltiples idiomas y permite modificar ciertos parámetros del discurso como volumen, tono y velocidad. Sin embargo, esta opción presenta el inconveniente de que no aporta información temporal ni para la reproducción de los visemas, por lo que es imposible realizar sincronización labial.

2.1.3 *Expresión de emociones a través de la voz*

Para dotar de mayor realismo y naturalidad al proceso de interacción oral con el agente, se considera necesario que la voz del agente pueda tener matices emocionales. Se decide trabajar con cinco emociones: alegría, enfado, sorpresa, tristeza y neutra. Para ello, se procede a modificar los tres parámetros que el sistema TTS de Android permite manipular: volumen, velocidad y tono. Tras estudiar varios trabajos relacionados con la expresión de emociones a través de la voz [6] [7] y realizar pruebas con 48 usuarios que se detallan en [8], los valores seleccionados para cada voz emocional generada se presentan en la Tabla 1.

Tabla 1: Valores de volumen, velocidad y tono para cada categoría de voz emocional

	Voz Triste	Voz Enfadada	Voz Neutra	Voz Alegre	Voz Sorprendida
Volumen	9.28	12.8	10.7	12.6	13.6
Velocidad	0.8	1.6	1.0	1.3	1.2
Tono	1.3	1.2	1.7	2.1	2.3

2.2 Comunicación Escrita

Este módulo, paralelo al anterior, se encarga de gestionar la interacción con el usuario a través del canal escrito. Dispone de un **Módulo de Lectura** cuya función es trasladar los mensajes del **Área de Texto**, escritos por el usuario a través del **teclado** del dispositivo, al módulo **Gestor de Diálogo**. Además, dispone de un **Módulo de Escritura** encargado de mostrar al usuario las respuestas procedentes del **Gestor de Diálogo** a través de un **Panel Deslizable** que se encuentra en la **Interfaz Gráfica**.

Con el objetivo de que el uso de la comunicación escrita del sistema no implique pérdida de información con respecto a la la comunicación oral, el sistema permite que agente exprese su estado emocional a través del color de la fuente y de los bordes del panel deslizable de los mensajes de texto. Los colores seleccionados para cada emoción son: Neutro: Azul, Alegría: Verde, Enfado: Rojo, Tristeza: Gris y Sorpresa: Amarillo [9] [10].

2.3 Gestor de Diálogo

El Gestor de Diálogo se encarga de recibir los mensajes provenientes del usuario, interpretarlos y generar una respuesta acorde a los mismos. Para ello recibe la información obtenida tanto del **Reconocedor de Discurso** como del **Módulo de Lectura** y envía las consiguientes respuestas al **Sintetizador de Voz** y al **Módulo de Escritura**. Para el desarrollo de este módulo se estudiaron diferentes alternativas: Episteme Engine, uso de diccionario, de listas, de tablas hash, árboles, expresiones regulares, y el Programa AB. Una vez analizadas, se opta por el Programa AB [11], ya que es de libre distribución y permite una gestión del diálogo más compleja y realista. Esta gestión se lleva a cabo mediante ficheros AIML (Artificial Intelligence Markup Language) con información de forma estructurada, lo que permite que el desarrollador la comprenda y modifique fácilmente.

2.4 Módulo motor

La función de este módulo consiste en gestionar las animaciones que incorpora cada uno de los **personajes 3D** utilizados en el sistema. Este módulo recibe del **Gestor de Diálogo** la información que se utiliza para establecer y transmitir a través de las animaciones reproducidas sobre el personaje el **estado emocional** en que se encuentra el agente. Para la implementación de este módulo se ha utilizado un ***Plugin* de Unity 3D** [12].

2.5 Interfaz Gráfica

La interfaz gráfica permite al usuario interactuar con el sistema a través de la **pantalla táctil** del dispositivo y se encarga de iniciar tanto el proceso de escucha del discurso del usuario como la lectura de los mensajes de texto, gestionando a su vez el nivel de volumen y los distintos modos de interacción del sistema. El elemento principal de la interfaz gráfica es el agente virtual, cuya representación gráfica se realiza a través de distintos personajes tridimensionales (ver Figura 2).

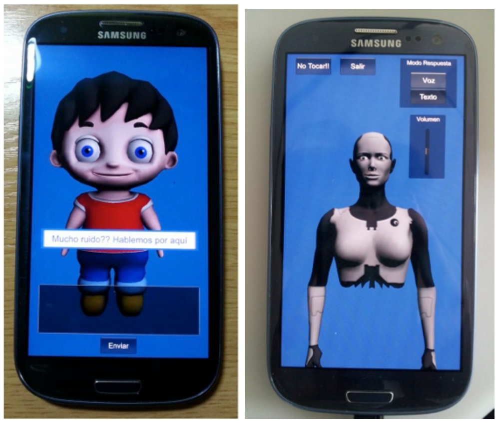

Figura 2. Interfaz gráfica: modelo 3D de niño (izquierda) y modelo 3D de una mujer-robótica (derecha)

3. EVALUACION DE LA EXPRESIÓN EMOCIONAL DEL AGENTE

En este apartado se presenta la evaluación de la expresividad emocional del agente con el objetivo de determinar la calidad de las voces generadas y su relevancia con respecto a otros dos aspectos del sistema que denotan emociones en el agente: el contenido semántico del discurso y las animaciones del personaje.

En esta evaluación han participado 48 usuarios, siendo la mayoría alumnos universitarios. La metodología seguida en todas las sesiones ha sido: realización de un Pre-test, para definir el perfil de los participantes, un Test compuesto por las Pruebas 1, 2 y 3, que se describen a continuación, y un Post-Test para determinar la opinión de los usuarios acerca de las pruebas realizadas.

3.1 Reconocimiento de las voces emocionales

La primera prueba se realiza con el fin de evaluar la capacidad de los usuarios para reconocer el estado emocional en que se encuentra el agente únicamente a través de la voz emocional escuchada. Para esta prueba, realizada a través de una encuesta de elección libre modificada, se toman las siguientes medidas: no se hace uso de imagen, se llevan a cabo cuatro repeticiones de cada reproducción, con orden aleatorio y se separan las reproducciones con 10 segundos de espera.

En la Figura 3 se muestra el porcentaje de respuestas obtenido por las distintas voces para cada categoría de voz emocional.

Como se puede apreciar, las voces emocionales neutra y triste obtienen resultados notablemente satisfactorios, puesto que son reconocidas por más del 80% y 70% de los usuarios encuestados, respectivamente. Las voces emocionales de alegría y enfado presentan resultados moderadamente aceptables, siendo reconocidas por aproximadamente el 60% de los usuarios.

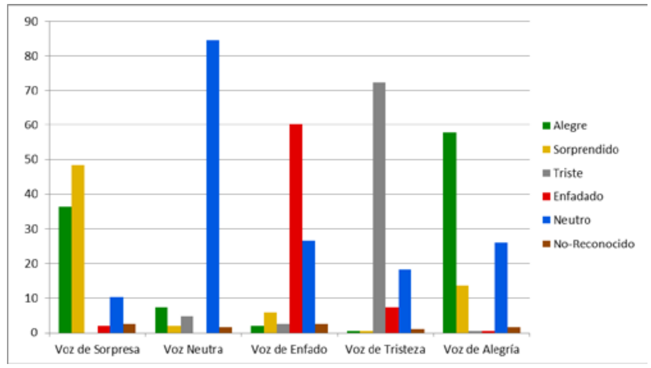

Figura 3. Resultados obtenidos por cada una de las voces emocionales.

Es importante reseñar que, en el caso de la voz emocional de alegría, la segunda opción más votada es la de sorpresa, aunque con un porcentaje muy inferior al obtenido por la opción alegre en el caso de la voz emocional de sorpresa. Por su parte, sorprende que la segunda opción más votada para la voz de enfado sea la neutra, ya que no se habían detectado confusiones notables entre ambas en las pruebas previas. Finalmente, la voz menos lograda es la de sorpresa, siendo reconocida por menos del 50% de los usuarios. Este hecho, unido a que aproximadamente un tercio de los usuarios se decanten por el estado emocional de alegría al escucharla, confirma las dificultades ya detectadas en pruebas anteriores para generar voces emocionales de alegría y sorpresa que no conlleven confusión entre sí.

3.2 Influencia del contenido semántico

Además de la calidad de las voces emocionales, se ha considerado interesante estudiar la influencia del contenido semántico de las frases reproducidas en la percepción emocional del usuario durante el discurso del agente. Con este fin, se ha llevado a cabo la segunda prueba seleccionando un conjunto de cinco frases con las distintas connotaciones emocionales.

Inicialmente se mezclan las distintas voces emocionales modeladas con las frases con connotación emocional seleccionadas previamente. Para ello, se ordenan de forma aleatoria tanto el conjunto de las veinte voces emocionales como el conjunto de las veinte frases a reproducir, procediendo posteriormente a la combinación de las voces y frases que se encuentran en la misma posición dentro de sus respectivos conjuntos, asegurando que, al menos una vez, la voz y frase correspondientes a un mismo estado emocional se reproduzcan simultáneamente. Tras haber llevado a cabo la mezcla, se reproduce la combinación resultante a los usuarios e instándoles a determinar qué estado emocional perciben en cada caso. Al igual que en la prueba anterior se toman las siguientes medidas: no se hace uso de imagen, se llevan a cabo cuatro repeticiones de cada reproducción, el orden es aleatorio y se separan las reproducciones con 10 segundos de espera.

Con un porcentaje medio de acierto del 88.89% en las reproducciones formadas por voces y frases emocionales acordes, se confirma que los usuarios encuestados perciben el estado emocional de forma más sencilla y acertada en el caso de que ambos factores emocionales correspondan a una misma emoción.

El porcentaje de aciertos obtenido (ver Tabla 2) supera en todos los casos el 70%, alcanzando tasas cercanas al 98% de acierto en los pares emocionales de enfado y neutro. En general, los resultados son altamente satisfactorios menos en los pares emocionales sorprendido y alegre, cuyas voces son las menos logradas.

Tabla 2: Porcentaje de acierto obtenido por la conjunción de voz y contenido de la frase para una misma emoción

Porcentaje Aciertos del par Sorprendido	Porcentaje Aciertos del par Neutro	Porcentaje Aciertos del par Enfadado	Porcentaje Aciertos del par Triste	Porcentaje Aciertos del par Alegre
75.00%	97.91%	97.92%	94.79%	72.92%

3.3 Relevancia de la imagen con respecto a la voz

Finalmente, la prueba 3 consiste en estudiar la relevancia que adquiere la imagen del agente con respecto a las voces emocionales modeladas a la hora de que el usuario reconozca un estado emocional. Para esta prueba, se utiliza el torso de la mujer-robótica como representación gráfica del agente de la Figura 2 (derecha) ya que las animaciones faciales y corporales que incorpora para representar estados emocionales son de mayor complejidad y realismo [13].

Inicialmente se mezclan las distintas voces emocionales modeladas con las animaciones de los estados emocionales. Para ello, se ordenan de forma aleatoria tanto el conjunto de las veinte voces emocionales como el conjunto de las veinte animaciones a reproducir, asegurando que, al menos una vez, la voz y animación correspondientes a un mismo estado emocional se reproduzcan simultáneamente. Una vez realizada la mezcla, se reproduce la combinación resultante y se insta a los usuarios a determinar qué estado emocional perciben en cada caso. De este modo, a través de la comparación de los resultados obtenidos con los resultados de la primera prueba, se pretende conocer la influencia de la imagen del agente virtual en la percepción emocional del usuario. En este caso, se hace uso siempre de la frase neutra con el objetivo de que el usuario no se vea influenciado por el contenido de la frase.

Con un porcentaje medio de acierto del 92.5% en las reproducciones formadas por animaciones y voces emocionales acordes, es posible afirmar que los usuarios encuestados perciben el estado emocional de forma más sencilla y acertada en el caso de que ambos factores emocionales correspondan a una misma emoción (ver Tabla 3).

Tabla 3: Porcentaje acierto obtenido por la conjunción animación y voz correspondientes a una misma emoción

Porcentaje Aciertos del par Sorprendido	Porcentaje Aciertos del par Neutro	Porcentaje Aciertos del par Enfadado	Porcentaje Aciertos del par Triste	Porcentaje Aciertos del par Alegre
89.58%	93.75%	95.83%	100%	83.33%

A pesar de haber cosechado excelentes resultados en todos los casos, se vuelve a repetir la circunstancia de que los pares emocionales peor evaluados sean sorprendido y alegre, cuyas voces emocionales son las menos logradas.

4. CONCLUSIONES

En este artículo se ha presentado una aplicación basada en agentes virtuales que permite mejorar la comunicación entre usuarios y sistema móvil a través de la interacción multimodal y emocional por medio de agentes virtuales. El sistema ha sido evaluado a través de encuestas y entrevistas a usuarios finales y, aunque los resultados son alentadores, en el futuro se pretende trabajar en ampliar la funcionalidad del módulo de síntesis de voz del sistema para aumentar el realismo y la naturalidad en las voces generadas, desarrollando mecanismos que permitan modificar los valores de los parámetros a lo largo de la reproducción del discurso, dando lugar a distintas entonaciones dentro de una misma frase o pudiendo enfatizar determinadas partes o palabras del discurso del agente.

5. AGRADECIMIENTOS

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Second Mind: A System for Authoring Behaviors in Virtual Worlds

Manish Mehta
Accenture Technology Labs
San Jose, CA, USA
manish.mehta@accenture.com

Andrea Corradini
Design School Kolding
Kolding, Denmark
andrea@dskd.dk

ABSTRACT
In this paper, we present a design solution that enables novice users to author the behaviors of non-playing characters in virtual worlds. We discuss the current authoring interface and the activities that the users need to conduct in order to generate behaviors. We also outline the system architecture, which we called Second Mind, with focus on the behavior execution system and the interface layer that connects it to the external virtual world. A series of user studies, show that our system can be successfully used by novice users to produce reliable behaviors while also improving the efficiency of the authoring task.

Categories and Subject Descriptors
[**D.2.2 Design Tools and Techniques**]: *User interfaces*; [**H.1.2 User/Machine Systems]**: *Human information processing*; [**H.5.2 User Interfaces**]: *User-centered design.*

General Terms
Design, Experimentation, Human Factors.

Keywords
Authoring tools; behavior generation; virtual worlds; non-playing characters; Second Life; Second Mind.

1. INTRODUCTION
In order to increase player experience, the virtual characters that populate video games and virtual worlds should exhibit believable behaviors. This does not apply only to the player characters, which are the characters that are controlled by the player, and as such are meant as more of an extension of the player. This also applies to any other character controlled by the game, usually through artificial intelligence: townsfolk, vendors, enemies, allies, historical figures, bystanders, quest givers, etc. These characters are referred to as non-player characters (NPCs) and are an integral part of the game. They exist to interact with the player characters, other NPCs, and the environment in a way that reflects their own distinct personalities and dialog capabilities. The behaviors of NPCs are usually scripted and are automatically triggered by certain actions, events, or dialogue. In that sense, player characters play the game, while NPCs display some facet of the game and help to further the storyline.

In early games, NPCs displayed only basic non-interactive dialogue capabilities. Monologues realized with screens of text, floating text, voiceovers, cut-scenes, text clouds and other non-branching dialogue techniques make it possible for NPCs to convey only an immediate impression of their personality in reaction to or interact with the player. However, the lack of interactivity turns the player into a mere passive consumer of content. More recently, advanced games allow for interactive dialogue where the player can engage in a compelling conversation with NPCs that results in witty and dramatic storylines that fit the contex. In those games, a conversation is typically modelled using dialogue trees [1] where the player is presented choose from a limited list of interaction options in response to an NPC's action. Each choice affects the course of the game in a different way since each of them may result in a different response from the NPC. Moreover, the possibility to choose between different options makes it necessary for the game designer to customize the NPCs' behaviors by modifying their default scripts or creating entirely new ones.

Branching the overall storyline puts the player in charge of learning about the game by engaging him in conversation with NPCs. In this way, uncovering the storyline becomes part of an increased overall player experience [2]. Besides engaging interactive narrative experiences [3] with unfolding storylines, it is necessary to have the tools that make it possible to design and create the appropriate behaviors. This is not just about making them funnier. It is also about creating more surprising and unpredictable behaviors within the game constraints so that no two interactions with a NPC turn out to be the same.

Digital games have much to gain from adopting AI techniques to author complex behaviors. This is however, a difficult task for it requires a great deal of competences and resources. Usually, only the game creators or people with specialized skills in both design and programming can carry out such a task. As a result, authoring behavior can even become a bottleneck in the process of creating the content displayed within digital worlds.

In this paper, we present Second Mind, a digital authoring tool solution that helps any players to populate virtual worlds with NPCs which can exhibit believable interactive behaviors. Our solution is based on a previous study [4] carried out using paper prototypes to investigate how individuals without programming and design experience (who we refer to as "novice users" throughout this paper) carry out the behavior authoring process. That study revealed some major limitations that we accounted for in the development of Second Mind. In Second Mind, novice users can easily design the behavior of graphical characters that impersonate different tradesmen such as shopkeepers, museum hosts, etc. in virtual worlds.

Following this introduction, we have organized the rest of the paper as follows. In the next section, we discuss related work, which has influenced our current system. Thereafter, we provide an overview of Second Mind's architecture and processing flow. Eventually, we conclude with an outline of the work in process and our ideas for further improvement.

2. RELATED WORK

Believable characters play an important role in many interactive stories and digital games [5] because they can contribute to the overall narrative. Thus, the improvement and the control of their behaviors is propaedeutic to better game experience for players.

Common methods for authoring behaviors rely on heavy scripting, where a blend of dialogue scripts, hand-coded animation scripts, motion-captured characters, and hard-coded behaviors is used to exhibit a character's features. Usually, artists, designers and programmers must work together to detail a character' attitude and to portray the appropriate character's movements given a set of constraints. However, scripting is labor intensive, it is rigid because it does not adapt to all variations induced by interaction, and it requires programming and design skills. An alternative approach is to use artificial intelligent (AI) techniques to adapt character behaviors in response to the different contexts that are induced by different interaction sessions. Despite its own inherent limitations, AI technology has been increasingly applied with success to digital game design and interactive narrative both to enhance interaction and to create novel gameplay scenarios [6]. AI techniques have been explored with diverse focus on character believability and expressivity in terms of e.g. synchronization of verbal and non-verbal modalities [7, 8], portrayal of emotion and personality [9, 10].

The ease of the actual process of behavior-creation has been explored by few researchers. The language ABL [11] is an early effort in this direction. ABL is a Java-like programming language that can be used to manually script behaviors [12, 13]. The production costs are high and the use of ABL requires advanced programming skills. Finite State Machines (FSMs) have also been used in digital games for many years as an alternative to scripting. However, FSMs can quickly become difficult to maintain and do not scale well with increasing game complexity [14]. Various FSMs modifications have been proposed to bypass part of these problems [15, 16]. The use of AI techniques such as Layered Statechart-based AI [17], Behavior Trees [18], automated planning and scheduling strategies [19, 20, 21], has been explored as well. All these works require human intervention and a great deal of effort and skills to create and to debug the scripted behaviors. A recent attempt at eliminating manual scripting in favor of automatic script generation is presented in [22] where the content creation for cyclic behaviors is facilitated using a tiered behavior architecture model. This model features a scheduling algorithm to determine the objectives of virtual characters and to specify the roles that satisfy these objectives dynamically during game play. The results of a user study that compares the creation of manually scripted behaviors with the behaviors generated by an implementation of their model are also presented. Three metrics, and notably behavior completion time, behavior completeness, and behavior correctness, are used as a measure for assessing behavior reliability and designer efficiency.

Unlike most of the works presented previously, our solution provides a graphical user interface with different constraint types. While a few graphical interfaces have also been put forward to help people create scripts, these tools are aimed at story designers and at people who want to learn to program. Our implementation targets any person who wishes to create behaviors with no prerequisites in terms of skills and experience.

3. THE SECOND MIND SYSTEM

3.1 Rationale and Context

In a previous study [4], we explored a design solution that would enable novice users to successfully author AI behaviors. That study provided, among others, the following key insights and design directions for creating the authoring interface:

- The process to link behavior constraints to lower level percepts must be as simple as possible; the conditions themselves must be limited, clearly understandable and should be expressed with an easy-to-use formalism
- The authoring task should be presented as a sequential process and not rely on deep hierarchical structures
- Authors need continuous feedback on the authoring activity so that they can see the results of their ongoing process and thus promptly identify possible problems

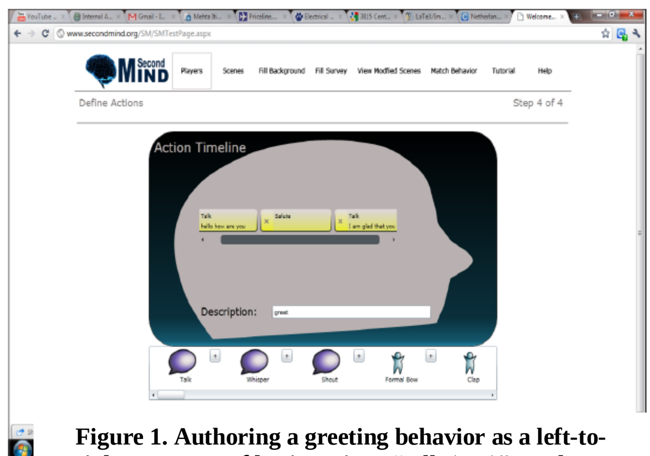

Figure 1. Authoring a greeting behavior as a left-to-right sequence of basic actions *"talk (text)"*, "*salute*" and *"talk (text)"* on the timeline.

On the one hand, reducing the set of conditions takes away some of the expressivity of the system, but on the other hand, it allows the authoring process to be kept simple. Conditions help the avatar identify when, what, and how a certain behavior must be performed.

We express conditions using what we refer to as "triggers". We provide a set of triggers that can be used individually or combined resulting in more complex constraints. An example of a trigger is "*User Clicks on (button label)*", which can be used when the player wants the avatar to perform a behavior in response to a button click ("*button label*" is a placeholder that must be provided during the authoring process). Many other triggers are also provided such as "*Avatar Close to (object name)*", "*Avatar Touches (object name)*", "*Player Close to (object name)*", "*Player Touches (object name)*", "*Behavior Ends (behavior name)*", "*Pause after Behavior Ends (behavior name, time)*", "*Run Event (event name)*", and so on. Triggers can be composed using logical operators. For instance, a "*Trigger And (A, B)*" can be used to specify a behavior for the avatar to perform when both trigger A and trigger B are specified.

In order to present the behavior creation task as a sequential process, we applied the notion of timelines. Timelines indicate a left-to-right sequential sequence, where each event occurs in chronological order. Various storyboard-authoring tools like Adobe Director and Apple's Garageband Timelines as well as AI-based interactive story authoring tools like Scribe [23], U-Create [24] and Viper [25] employ timelines as an interaction design approach. We use timelines to represent the ordering of story segments in a left-to-right sequence while also allowing story segments to be re-ordered on the timeline. In order to help the user conceptualize the task concretely, the authoring activity along the timeline is presented in a mind-like shape (Figure 1).

Eventually, in order to comply with the need to provide a continuous feedback to the user, we connect our authoring environment to an online virtual world named Second Life [26] where avatar's behaviors can be executed and displayed graphically in 3D. In Second Life, users can create, design and build their own clothes, buildings, artifacts, landscape, pets and much more. We chose Second Life as platform to display 3D-based user-generated content because it has a large user base, it allows for easy connection to external controllers through an API, and it provides a rich set of basic actions for the avatar in the form of emotions and physical actions. Using our authoring interface Second Mind, authors can create behaviors, execute them in Second Life, and immediately see the effects of their authored artifacts.

3.2 The Authoring Process

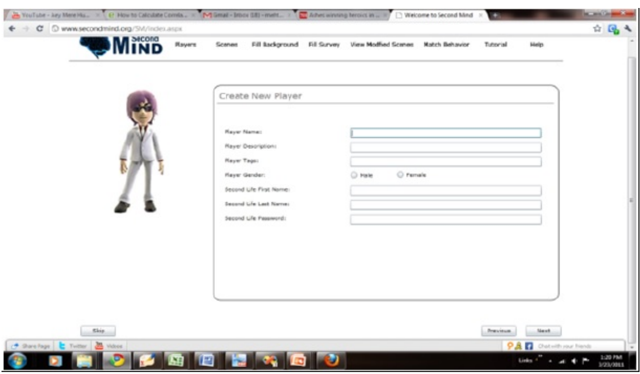

Figure 2. Initial steps for the creation of a scene.

In order to use Second Mind, the user needs to create an account where to store, among other things, his/her Second Life login credentials. Once the account is created, the user is guided through a tutorial, which explains the terminology used in the authoring interface (like triggers, scenes, behaviors, actions, etc.). The user then can define one or more characters in Second Mind and connect each of them to a different avatar in Second Life.

At this stage, the user is ready to create a scene and its corresponding behaviors. A scene provides a social context such as a furniture shop where the avatar acts as a shopkeeper whose goal is to sell furniture items. The author creates a description of the scene by entering some information such as the name and some details and then selecting one of the characters created in earlier steps (Figure 2). The user can also associate a limited set of constraints to the avatar in the given scene. For instance, a constraint to apply to the scene in the shopkeeper context could be "*likeable*" or "*salesman skills*".

Beside the contextual constrains, all scenes are associated by default with two additional general constraints, namely "*overall experience*" and "*avatar performance*". The author uses a set of sliders to specify matching values on a 0 to 5 point scale for each of the constraints s/he wants to set. Moreover, the user can associate semantic tags to the scene. Now, avatar behaviors can be added within the scene.

Similarly to the scene creation process, the author can create a complex behavior from a list of simple elementary behaviors. To define a new behavior, the author needs to enter a name that uniquely identifies it, followed by the list of behaviors that make it up and by the specification of the constraints that characterize the behavior as a whole.

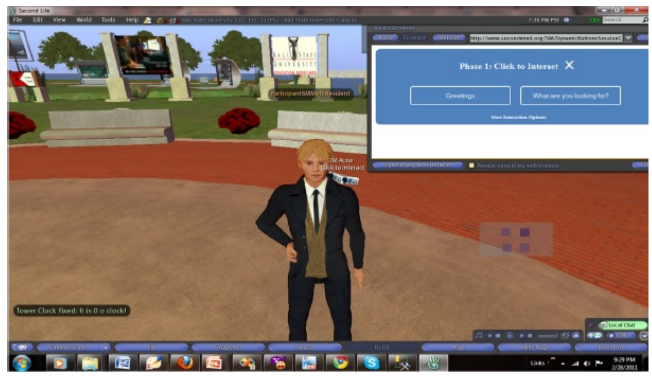

Figure 3. The player interaction with an avatar can be initiated by clicking on the device carried by the avatar on his left shoulder; clicking on the device causes a graphical interface to pop up with various scenes to choose from

Using a set of sliders, the author can specify the values for the constraints. For example, in order to have an "*enthusiastic*" and "*pushy*" shopkeeper for a "*greeting behavior*", the user has to select first the corresponding values for those two constraints that give an idea of the avatar personality. These values influence the way (e.g. speed, spatial extension, etc.) a certain behavior is rendered. The user can then assign triggers to the behavior in order to specify the context in which it should be carried out by the avatar. The process is iterative because more complex behaviors can be created as combination of both single ans complex behaviors. During the creation of a specific behavior, the author can also make use of a constraint, which forces the avatar to initiates the interaction. Once a behavior is created, the user can immediately play it out in Second Life and test its 3D graphical representation.

In order to interact with an avatar in Second Life, the player must click on an attachment on the avatar's left shoulder. Upon clicking, the player is presented with a GUI containing buttons labeled with the names of the scenes that have been previously authored for the avatar (Figure 3). Each of these buttons represents one "*User Clicks on (button label)*" trigger that is associated with the behaviors of a scene. To interact with the avatar, the player must simply click on a button.

3.3 The System Architecture

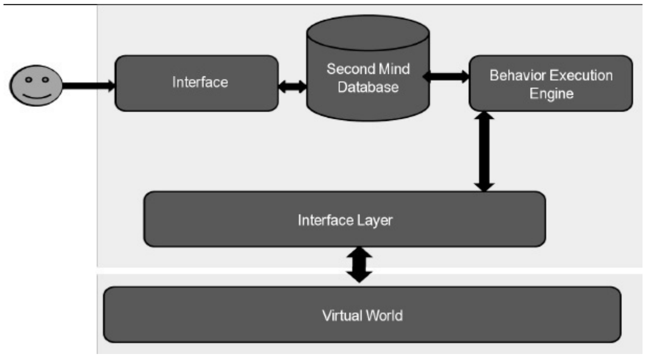

Figure 4. Overview of Second Mind overall architecture

With a basic understanding of the authoring activity, we can delve into the system architecture. As shown in Figure 4, Second Mind architecture has four core components and one application-specific component. The four core components are:

- Second Mind Database: a MS-SQL server based database that stores scenes, players, behavior elements such as triggers, basic action, etc.
- Behavior Execution Engine: an execution engine that loads the behavior elements and executes them in the external world. The behavior execution engine connects to the external world through the interface layer that is specific to the world that Second Mind is connecting to.
- Graphical Interfaces: provides the interfaces for creating user account, scenes and behaviors as described in the previous section.
- Behavior Recommendation Engine: provides suggestions during the behavior-authoring task

In order to apply Second Mind to a given graphical world, one application-specific component is required:

- Interface Layer: The architecture of Second Mind is domain-independent and can be connected to different virtual world simulations via a custom interface layer. The interface layer provides the ability to connect Second Mind to the simulation platform, such as Second Life or other virtual worlds. The interface layer requires the definition of percepts, actions, and other application-specific elements along with the APIs to connect Second Mind to the simulation.

3.3.1 Behavior execution engine

The behavior execution engine (Figure 5) loads the behaviors corresponding to the currently active scene, identifies the behavior(s) to carry out based on the current perceptual information from the world, and sends the information about these behaviors to the graphical world for execution through the interface layer.

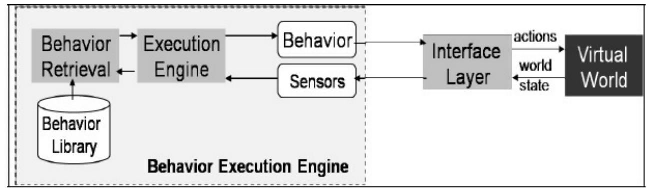

Figure 5. Overview of Behavior Execution Engine architecture e

The behavior execution engine can be correspondingly broken down into three main modules:

a) Behavior Library: it is part of the Second Mind database that holds behavior elements for a specific application domain. For example, if the application domain were Second Mind in an educational setting, the library would contain personalities corresponding to teachers, students, etc. If instead the application domain were a household robot, the library would contain personality elements corresponding to cooking food, cleaning the house, etc.

b) Behavior Retrieval: it is responsible for loading all the behaviors corresponding to the active scene from the behavior library. The active scene is the scene that the player selected when s/he was presented with all possible authored scenes associated with a certain avatar.

c) Execution Engine: it receives the currently active domain independent sensors from the interface layer and checks the triggers for the behaviors corresponding to the active scene to see if any of the behaviors were activated. It also takes the current active behavior and sends it through the interface layer to the virtual world for the avatar to perform it.

3.3.2 Interface layer

6.1.1 The Interface layer parses the domain dependent perceptual state into a set of domain independent sensors. The domain dependent perceptual state from Second Life contains the following items:

a) Object Info: contains the information about various objects in the environment such as their current position, rotation, type (whether an avatar or a passive object), region to which the object belongs, etc.

b) User Button Click Info: contains information regarding button clicks made by the player while interacting with the avatar.

c) Event Info: contains the information regarding various events happening in Second Life such as the player moving around in the environment, the player touching an object, etc. Objects in the environment can send various events to communicate with the avatar. If there are behaviors that have "Event happens (event name)" as triggers, avatar can react to events with name "event name".

The world specific information is parsed into a set of domain independent sensors that correspond to various triggers. This information is then sent to the execution engine, which checks the sensors against the triggers corresponding to the current set of behaviors to identify if any new behavior(s) has become activated. The interface layer module also receives the action corresponding to the active behavior and sends it to the virtual world. The interface layer provides an abstraction layer and maps the action name received from the execution engine to a virtual world specific action name. For example, an action "laugh" in Second

Mind is mapped to actions that express "express_laugh", which is the specific name used by Second Life virtual world. Table 1 shows the mapping of a few action names in Second Mind with the corresponding names in the virtual world Second Life.

Initially, in order to connect Second Mind to Second Life, we modified an open source version of Second Mind clients. We soon realized though that not all Second Mind users are willing to install a modified version of Second Life. Therefore, we instead created scripts in Second Life's proprietary scripting language named Linden Scripting Language (LSL). Those scripts make it possible to send and to receive information through the Second Mind interface layer from/to Second Life for controlling the avatar with any genuine Second Life client.

Table 1. Action names in SM and corresponding virtual world action names in Second Life

Domain Independent Action Name	*Virtual World Action Name*
Laugh	express_laugh
Shrug	express_shrug_emote
Bow	avatar_hold_bow

The collection of scripts is packaged in a component called Second Mind Controller and distributed through the Second Life marketplace. Second Life marketplace is a social web portal from Second Life where all the items from various vendors are listed and available for purchase. Second Mind controller is listed on the Second Life marketplace and is available for free. In order to have their avatar controllable through Second Mind, players need to download it from the Second Life marketplace. Purchasing items from Second Life marketplace is a common activity performed by Second Life users. Once users have bought the items from Second Life marketplace, the Second Mind controller is downloaded automatically onto their avatars, which they can then attach to their avatar in Second Life.

3.3.3 Behavior Recommendation.

During the behavior-authoring process, once the name of the behavior is entered, the user is presented with a list of recommended behaviors that he or she can use as a starting point. The behaviors are suggested based on similarity between the behavior name specified for the currently authored behavior and existing behaviors in the database. The semantic similarity is calculated based on a WordNet-based algorithm [27].

4. CONCLUSION AND FUTURE WORK

We proposed a digital authoring tool that addresses the issues raised by a user-study. To address the issue of having concrete feedback on the authoring activity, we hooked up the authoring interface with a concrete virtual world, namely Second Life, so that authors can play back, can view and can detect any possible problems with the created behaviors. In order to simplify the steps required to link behavior conditions to lower level percepts, we provided a base set of triggers that can be used individually or combined to create more complex triggers. In order to present the authoring task as a sequential one, instead of deep hierarchies, we used a left to right sequential action creation approach represented on a timeline. Eventually, we outlined the authoring steps necessary to create and run a behavior along with the system architecture and its four core components.

We evaluated the Second Mind approach to check whether it can be understood and easily used by non-programmers. In order to evaluate our approach, we invited 65 subjects to create a certain set of behaviors for an avatar (e.g. act as a shopkeeper) on a Second Life island using the authoring system. We divided the subjects into three broad categories: User Interface designers, non-programmers, and programmers (with experience in Java). We transcribed data from the subjects' responses to interviews as well as from the notes taken while observing subject actions during the authoring process. To analyze this vast quantity of data collected from the user study, we adopted a combination of qualitative and quantitative analysis. Specifically, we employed a Grounded Theory [28] approach to perform the qualitative analysis. A detailed report on the evaluation of the system is outside the scope of this paper. However, for the sake of completeness, the evaluation results show that non-programmers were able to easily create behaviors using the scaffolding provided by Second Mind. Moreover, no relevant statistical difference was noticed in the quantitative measures used to asses authoring skills among the different subject categories. This seems to indicate that designers, programmers, and non-programmers perform very similarly while authoring behaviors with Second Mind.

There is much work left to do in Second Mind, some of which is research, some of which is in development. There are also numerous open questions that form possible avenues of future directions for this research. Authoring Support through demonstrating behaviors is something we are considering. Learning from demonstration is also a point we would like to investigate. Human learning is often accelerated by observing a task being performed or attempted by someone else. These capabilities of the human brain are also evident in computer games where players go through a process of training and imitating experienced players. These results have inspired researchers in artificial intelligence to study learning from imitation techniques. By observing an expert's actions, new behaviors can quickly be learnt that are likely to be useful since they are already being used by the expert successfully.

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Juegos Serios Tangibles con Objetos Reales como Herramienta de Apoyo para Trabajar con Niños que Requieren Necesidades Especiales

Iván Durango, Alicia Carrascosa, José A. Gallud and Víctor M. R. Penichet

Universidad de Castilla-La Mancha
Campus Universitario, Albacete - España
{ivan.durango,alicia.carrascosa}@yahoo.es,{jose.gallud,victor.penichet}@uclm.es

ABSTRACT

Tras meses de trabajo con Mateo, los terapeutas del Centro de Desarrollo Infantil y Atención Temprana (CDIAT) quedan realmente sorprendidos al observar cómo usando el sistema interactivo diseñado en el presente trabajo (Panel de Frutas Interactivas o PFI), en sólo unas pocas sesiones, Mateo por fin consigue asociar de forma correcta cada una de las frutas con su pictograma correspondiente.

La aplicación interactiva que se presenta en este trabajo pretende transformar un juego tradicional habitualmente usado por los terapeutas de los CDIAT para establecer una asociación entre objetos reales (frutas) y su representación en forma de pictograma, en una actividad tecnológica e interactiva donde se establecen objetos reales como base de la interacción. De esta manera se trabaja con niños que presentan una serie de necesidades especiales en uno de estos centros con ayuda de los profesionales en atención temprana, obteniendo así una serie de resultados que presentan los beneficios que aportan el uso de este tipo de juegos en el proceso de enseñanza-aprendizaje de los niños, como pueden ser, la mejora de la atención en la actividad o el aprendizaje más rápido de la asociación entre los pictogramas y el objeto real correspondiente.

Categories and subject descriptors

Interaction for People with Disability - Interaction, Learning and Teaching – Child-Computer Interaction - Natural Interaction.

Keywords

Early childhood Intervention, Special Education, Child-Computer Interaction, Serious Games, Tangible Computer Interface.

1. Introducción

En la actualidad el estudio de la interacción de los niños con los sistemas interactivos es un área en constante evolución y crecimiento [1], esto es debido a su asociación directa con áreas en las que toma mucha importancia esta visión lúdica del mundo como: la psicología, el aprendizaje y el juego.

Si se observa la sociedad actual, puede detectarse cómo los niños se ven inmersos en un mundo tecnológico desde una edad temprana, lo que crea una necesidad inmediata a la hora de diseñar productos interactivos, ya que la interacción que tiene lugar entre un computador y un niño (Child-Computer Interaction - CCI) dista considerablemente de la interacción que mantiene un adulto (Human-Computer Interaction - HCI), con lo que se genera una nueva barrera de entendimiento para los investigadores [2], que tratan de comprender como los niños usan los sistemas y productos.

En esta perspectiva los *juegos serios* (del inglés "Serious Games"), se presentan como una herramienta de gran utilidad para el aprendizaje en niños [3].

Este tipo de juegos, permiten a los niños desarrollar habilidades de una forma entretenida y motivadora, y tienen una gran relevancia cuando estos niños presentan algún problema o discapacidad. De este modo, y debido a los numerosos beneficios que ofrecen, expertos como [4], establecen el juego como medio fundamental para el desarrollo adecuado de los niños.

En la actualidad, las *Interfaces de Usuario Tangibles* (TUI, *Tangible User Interface*), promueven una forma de interacción natural que aportan a los juegos serios un añadido cuando se pretende trasladar la interacción que se realizada en un mundo puramente digital, a un entorno físico y tangible, y por consiguiente permite que se interactúe directamente con objetos reales. Con esto, se establece un ambiente más familiar para el usuario, siendo particularmente apropiadas para el aprendizaje desde diferentes puntos de vista (sistemas colaborativos, juegos serios, etc.).

Un punto muy importante a tener en cuenta dentro de las TUIs, es el concepto de “espacio”, es decir, cómo será explotado el espacio de interacción, aprovechando al máximo la habilidad innata de actuar con objetos reales que establecen un símil metafórico entre el sistema y el mundo real. Desde este punto de vista, las TUI ofrecen una gran cantidad de beneficios como apoyo a la enseñanza y sobre todo en aquellas personas con dificultades de aprendizaje o necesidades especiales [5].

Por ejemplo, estudios como el realizado por A. Carreras y N. Parés [6], determinan mediante ejemplos que las interacciones desde una perspectiva táctil fomentan la participación activa del alumno, siendo además, muy apropiadas para superar el miedo de usar tecnologías para el aprendizaje, sobre todo cuando se trata de usuarios inexpertos o niños, fomentando así las habilidades exploratorias y experimentales del usuario que usa este tipo de tecnología. Un ejemplo de aplicación que usa TUI dentro de este campo es "Telestory" [7] (Figura 1).

Figura 2. Telestory - Ejemplo de uso

(Autor de la imagen: Proyecto Telestory)

Esta aplicación trata de que niños con problemas en el lenguaje puedan aprender un lenguaje de comunicación mediante pictogramas digitales.

El objetivo principal del trabajo presentado en este artículo es la adaptación de una actividad real, la cual se usa de forma habitual en los centros de atención temprana, a un sistema interactivo que se basa en una interacción tangible para hacer de ésta una actividad más entretenida, motivadora y con la que obtener mejores resultados terapéuticos.

2. Trabajos relacionados

En los últimos años han sido muchos los intentos de diseñar, crear y evaluar, juegos y actividades basadas en un soporte interactivo y virtual [8] [9] [10], orientadas a niños con necesidades especiales. De hecho, existen multitud de aplicaciones, en su gran mayoría, pensadas para tablet, smartphones y dispositivos de uso cotidiano que tratan de fomentar temas educativos implícitos en un videojuego (juegos serios) [11].

Desde esta perspectiva, aunque existen gran cantidad de recursos tecnológicos, como los que pueden encontrarse en iTunes, Google Play o la Tienda de Windows, éstos en un porcentaje elevado se enfocan a niños con un desarrollo típico o que no requieran ningún tipo de ayuda especializada, de tal modo que los profesionales encargados de intervenir con los niños con algún tipo de dificultad, encuentran un gran número de inconvenientes a la hora de buscar una aplicación que funcione con cada uno de los niños, pues no todas las aplicaciones tiene los mismos resultados terapéuticos, cuando se usa de la misma forma, ya que dependerá de las características y necesidades del niño que la esté usando.

En juegos como Co-Brain Training y Azlgame [12], se utilizan interfaces de usuario tangibles para ofrecer al usuario una forma de interactuar más sencilla y amena.

De este modo, se observa cómo se mejora la concentración del usuario y sus habilidades cognitivas, ayudando además a que éste use el sistema de una forma amena y entretenida. En estos juegos se usa una interacción basada en gran parte en pictogramas, que mediante el uso de tecnologías como NFC (Near Field Communication) permiten interactuar con el sistema de una forma natural.

Es importante tener en cuenta que aunque estos trabajos estén orientados a entornos de rehabilitación cognitiva, pueden ser observados desde un punto de vista educativo, pues siguen muchas de las pautas que se establecen en el proceso de enseñanza-aprendizaje con niños con necesidades especiales. Aunque en nuestro caso, y tomando el sistema Co-Brain como ejemplo, es complicado que los niños lo usen debido a la complejidad de las imágenes y a que es necesario que nos niños cojan un dispositivo para interactuar, aspecto que en ocasiones y debido a sus problemas y/o dificultades es algo muy complejo para ellos.

De otro modo, el uso de pictogramas en el aprendizaje es habitual en los CDIAT [13] y por consiguiente, estos son una herramienta indispensable en muchas de las terapias.

Por ejemplo en [14], se presenta una aplicación para iPad en la que niños con autismo pueden aprender a crear secuencias de acciones usando como base los pictogramas que describen estas (Figura 2).

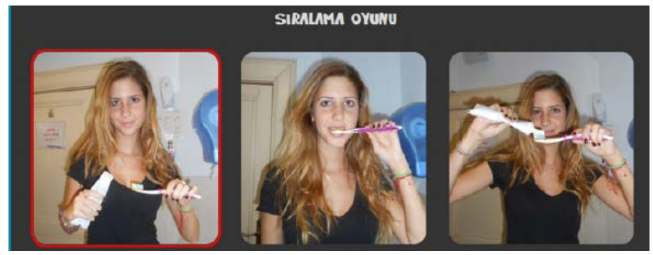

Figura 3: Secuencia de acciones necesarias para cepillarse los dientes

Este tipo de aprendizaje es de gran importancia dentro de los CDIAT, ya que es una de las formas utilizadas por algunos de los niños para comunicarse y por tanto es usada como una herramienta de apoyo en niños que no disponen de lenguaje oral.

3. Contexto del estudio

3.1. Centros de Atención Temprana

El sistema presentado en el presente artículo, se ha diseñado en el contexto de un centro de Desarrollo Infantil y Atención Temprana (CDIAT).Un CDIAT ofrece servicios autónomos cuyo objetivo es la atención a la población infantil de 0-6 años que presenta trastornos en su desarrollo o que tiene riesgo de padecerlos. Son centros con carácter interdisciplinar, donde profesionales de distintas áreas trabajan de forma conjunta. En estos centros se otorga una mayor prioridad a niños de entre 0 a 3 años. Esto es así porque los expertos consideran que es en esa etapa cuando el sistema nervioso está en plena maduración y presenta una importante plasticidad, por lo que las posibilidades terapéuticas muestran su mayor eficacia [4]. Es importante destacar que en los CDIAT no sólo se atienden a niños con discapacidad o patologías sino que también se aborda el carácter preventivo de otras posibles alteraciones, como podría suceder en casos de prematuridad, cuyos niños nacen antes de completar la semana 37 de gestación.

Cabe destacar la colaboración que se realiza entre los profesionales del CDIAT y el grupo de investigación autor del presente trabajo, creando así una unión de conocimientos tecnológicos y terapéuticos/educativos que pueden observarse a lo largo del presente trabajo.

3.2. Trabajo por objetivos en los CDIAT

La línea de trabajo que se plantea en los CDIAT está basada en las necesidades individuales que tiene el niño y no en el diagnóstico que presente. Este tipo de trabajo está avalado por numerosos expertos como [15], [16], [17]. Por tanto, se considera importante el planteamiento de trabajo realizado según unos determinados objetivos, ya que ante dos niños con diagnósticos similares existirán objetivos que se trabajarán de forma análoga y otros que se trabajarán de forma diferente.

Por consiguiente y a modo de ejemplo, se pueden perseguir objetivos diferentes al realizar una misma actividad con dos niños, aunque su diagnóstico sea similar. De este modo, tal vez el objetivo de uno sea aprenderse el nombre de las figuras geométricas y por el contrario, el objetivo del otro sea que las figuras en su representación de imagen sea asociada correctamente con su objeto real, de tal forma que si se diferencian dichos objetivos: en uno se trabajarían simplemente conceptos y en otro la abstracción de los objetos para su uso en un sistema alternativo de comunicación.

Por tanto no se necesita una etiqueta que nos diga donde encasillar el trabajo que se realizaría con esos niños, pudiendo además, trabajar objetivos similares en niños con diagnósticos totalmente diferentes. Por consiguiente, surge la siguiente cuestión: ¿Sería posible enfocar el trabajo de un niño con síndrome de Down y de otro con Trastorno del Espectro Autista según unos mismos objetivos?

Según los expertos, la respuesta a este interrogante depende de las características que presenten ambos niños, y por tanto se necesita en primer orden conocer sus habilidades y sus intereses, y a partir de ahí trazar su línea de intervención individual, donde se establecerán una serie de objetivos que serán comunes y otros que serán específicos de cada uno de los niños, permitiendo así la utilización de la misma actividad para trabajar en una dirección concreta aunque el objetivo final sea diferente. Cabe destacar que esta visión es contraria a estudios como [18], [19], [20], [21], donde todos los esfuerzos se centran en un solo tipo de discapacidad, como por ejemplo, el Trastorno del Espectro del Autismo [17], dejando de lado los objetivos terapéuticos que persigue la actividad.

3.3. Descripción de la actividad no tecnológica sobre la que se trabajará

Para seleccionar y describir de una forma adecuada la actividad o actividades sobre las que se llevará a cabo el experimento, se han llevado a cabo una serie de reuniones donde los profesionales del centro nos indican aquella actividad que es relevante tanto en su trabajo diario como a un nivel terapéutico. Tras estas reuniones, se decide tomar como base una actividad que los niños realizan a menudo y en la que se realiza un proceso de asociación entre un objeto real y su representación en un pictograma.

El aprendizaje de esta asociación es fundamental cuando se trata de niños con problemas en la comunicación y que requieren aprender un sistema alternativo de comunicación basado en pictogramas para comunicarse, como por ejemplo [22]. En este proceso de enseñanza-aprendizaje, los profesionales realizan un "juego" con el niño donde se le muestra un objeto real, como por ejemplo una fruta en forma de maqueta en miniatura, y posteriormente se le muestra una serie de pictogramas con diferentes frutas (Figura 3).

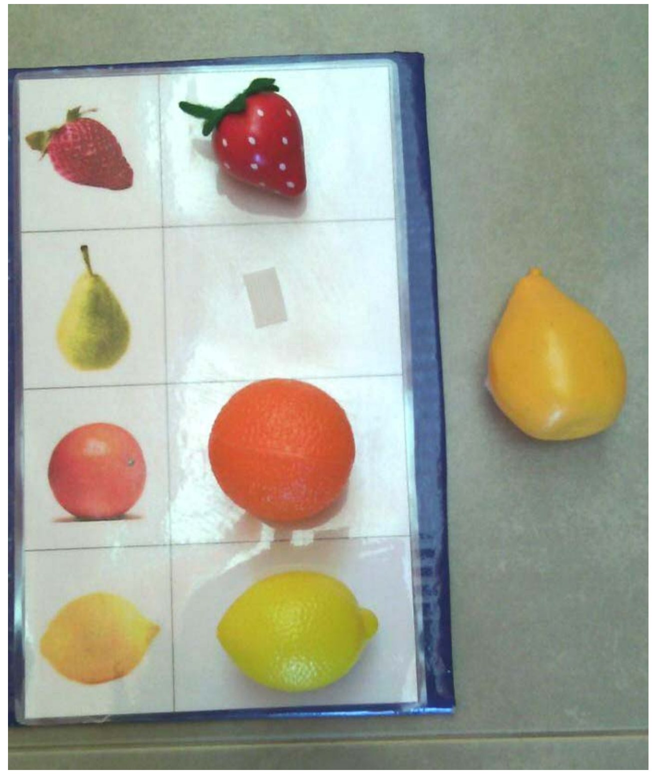

Figura 4: Juego de asociación tradicional

El fin del juego es que el niño sea capaz de asociar el objeto real con su representación en pictograma Este ejercicio es muy importante y frecuente en los CDIAT, más si cabe cuando el niño necesita aprender un sistema alternativo de la comunicación basado en pictogramas, donde esta asociación le ofrece al niño todas las herramientas que necesitará en su aprendizaje.

Cabe destacar que los profesionales advierten de que para que los niños lleguen a realizar esta asociación de forma adecuada se han de realizar una serie de fases evolutivas donde se aumenta la dificultad del juego y la abstracción de los objetos. Por tanto, en una *primera fase* se trata de identificar cada uno de los objetos reales, actividad que realiza el terapeuta con el niño; en la *segunda fase* el objetivo es asociar el objeto real con su imagen real asociada. Una vez adquiridas las asociaciones pertinentes se pasa a una *tercera fase* donde se comienza a jugar con pictogramas. De este modo, para que el niño consiga asociar un objeto real con su pictograma debe trabajar con cada uno de los siguientes materiales (pasando por cada una de las tres fases descritas anteriormente): *Objeto-Real - Imagen real – Pictograma.*

4. EL Panel de Frutas Interactivo

El Panel de Frutas Interactivo (PFI), es un juego serio tangible, en el que se puede realizar la actividad descrita en el punto anterior, para así aprender a asociar un objeto real con su correspondiente pictograma (con cada una de las fases necesarias en el proceso de enseñanza aprendizaje).

Figura 5:Panel de Frutas Interactivas (PFI)

Como se observa en la Figura 4, la aplicación estará compuesta de una parte puramente digital, es decir, un juego de escritorio, y un panel de frutas fabricado en madera y papel plastificado, donde se colocarán cada una de las frutas (reales) para que el niño pueda usarlas como medio de interacción tangible con el juego digital. De este modo, el medio de interacción con el sistema serían las frutas, ya que al ser tocadas por el niño se interactuará con el juego digital.

El objetivo de esta aplicación, es evolucionar las actividades que se realiza de forma habitual en los centros, para adaptarlas a un mundo digital e interactivo con el fin de hacer un juego más motivador, entretenido y que mejore la consecución de objetivos.

El objetivo principal de la aplicación es motivar a los niños a jugar para que adquieran la asociación entre pictogramas necesaria para adoptar un sistema de comunicación alternativo. Además, y desde una perspectiva cognitiva se desarrollan aspectos como la concentración, la activación del sistema visual, la memoria y la estimulación de la capacidad cognitiva para asociar objetos reales con su representación en imagen.

Por otro lado, se pretende convertir una actividad que a priori puede parecer aburrida en una actividad motivadora y divertida para los niños.

4.1. Diseño del sistema

Antes de comenzar a diseñar la aplicación, se establecen una serie de reuniones con los profesionales para determinar qué requisitos se debe tener para que cubra las necesidades que presentan tanto los niños como los profesionales con respecto al diseño del sistema. De estas reuniones se determina que la aplicación a desarrollar ha de ser un "juego" divertido y que motive a los niños. De tal forma que se estimule la atención de los niños en la actividad. Además, se establecen una serie de pautas a seguir con respecto a las imágenes, pictogramas y la interfaz que debe presentar, ya que en la mayoría de CDIAT, tanto españoles como internacionales, se utilizan los pictogramas diseñados por ARASAAC [23]. Asimismo, son los pictogramas usados de forma habitual por los profesionales del CDIAT donde se realizarán las evaluaciones, y se diseñan los aspectos terapéuticos del sistema.

Siguiendo algunos de los criterios detallados por Sweetser y Wyeth [24] en su teoría de flujo propuesta, se tienen en cuenta aspectos como el feedback, la inmersión del usuario en la actividad, el reto o desafío y la concentración.

Con respecto al ***feedback*** que el niño obtiene desde la aplicación tanto cuando selecciona la fruta correcta, donde recibirá un feedback positivo como cuando la fruta seleccionada no es la que se esperaba donde el feedback será menos positivo. Por tanto, al seleccionar una fruta errónea su pictograma mostrará durante dos segundos una cara triste (Figura 5).

Figura 6: Feedback No positivo

Mientras que si el niño toca la fruta correcta, se mostrará una cara muy feliz y a continuación una representación de globos acompañada de un sonido de ovación y aplausos por parte de niños (Figura 6).

Figura 7: Feedback Positivo

Por otro lado un punto muy importante a tener en cuenta es la **concentración**, ya que una de las mejoras que pretende aportar la aplicación interactiva con respecto a la actividad no tecnológica corresponde a que el niño mantenga mejor la atención y la concentración en el desarrollo de la actividad y esto incida de manera directa a la adquisición de conceptos. Para ello, se establece una interfaz de usuario que evita las distracciones innecesarias, de tal forma que el niño centre su atención en las frutas del panel y en las imágenes y/o pictogramas que se le muestran en la interfaz digital.

Con respecto a la **inmersión** del usuario en el juego, se trata de lograr que el niño se vea envuelto en un mundo virtual donde se interactúa con objetos reales. Para lograr esta inmersión se ha añadido a la presentación en forma de imagen o pictograma de cada una de las frutas una melodía característica, de tal modo que ayude al niño a establecer un sonido particular con cada una de las frutas. Desde el punto de vista del **reto o desafío,** y teniendo en cuenta que cualquier juego tiene que proporcionar un reto, se establece un sistema de puntuación donde al terminar la actividad se le muestra al niño la puntuación obtenida teniendo en cuenta la cantidad de frutas que ha acertado. Esta puntuación, se acompaña de una melodía característica que sirve a la vez para animar al niño a que vuelva a jugar para mejorar sus resultados y para que sea asociada esta melodía a la finalización de la actividad

Figura 8: Fin de el Juego

4.2. Funcionamiento

El funcionamiento del sistema para realizar la actividad es el siguiente:

1.Selección de la fase a trabajar o tipo de juego (véase Figura 8):
Al iniciar la actividad el terapeuta ha de seleccionar el tipo de juego que quiere usar para trabajar con el niño. En este contexto, existen tres modos de juego diferentes, según en la etapa de enseñanza aprendizaje que se encuentre el niño. Por tanto se debe seleccionar si se quiere jugar sólo con imágenes de los objetos, si se pretende jugar con imágenes y pictogramas o por el contrario se trabajará sólo con pictogramas.

Figura 9: Selección de la fase a trabajar

2.Configuración del modo de juego (Figura 9):
El terapeuta selecciona entre un modo de juego sencillo, donde las imágenes de las frutas aparecen siempre en el mismo orden, o un modo de juego avanzado, donde estas aparecen de forma aleatoria.

Figura 10: Configuración del modo de juego

3.Selección de las frutas con las que se quiere jugar (Figura 10):
Por último y antes de comenzar a jugar el terapeuta seleccionará las frutas con las que desea que el niño interactúe. Esta selección hace que la aplicación sea más flexible para el profesional, ya que en un principio puede comenzar jugando con un menor número de frutas para posteriormente aumentar el número de éstas según las necesidades del niño.

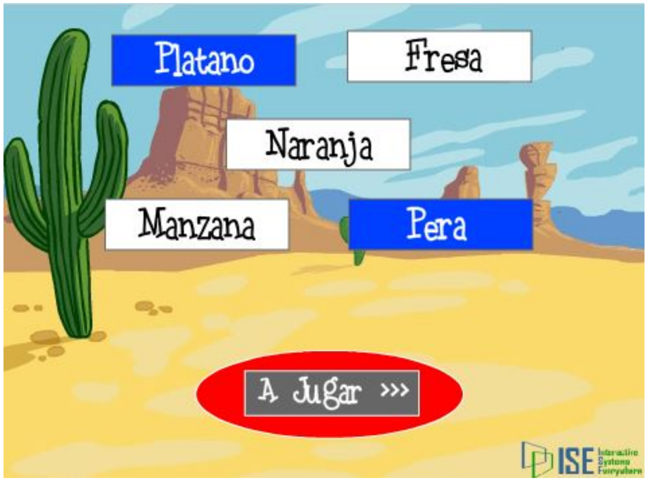

Figura 11: Selección de las Frutas que aparecerán en el juego

4.Comienza el Juego:
Una vez seleccionada la configuración del juego el niño comenzará a jugar.

5.Finalización del Juego
El juego finaliza cuando transcurren cuatro minutos desde el comienzo de la partida. El tiempo es establecido teniendo en cuenta la opinión de los profesionales, ya que es el tiempo que aproximadamente dedican a cada una de las actividades dentro de sus programaciones, consiguiendo así introducir la actividad como una más en la rutina diaria de los niños.

4.3. Mecanismos de Interacción

El sistema interactivo, se basa en la conductividad eléctrica que presenta tanto el cuerpo humano como los objetos seleccionados como base de interacción, es decir, las frutas. Estos elementos poseen un gran porcentaje de agua y por tanto muestran una gran conductividad eléctrica. Éste aspecto es importante, ya que debe tomarse como base para comprender como funciona la interacción que hace el niño con las frutas para cerrar un circuito eléctrico y generar así un pulso que es enviado al computador y que será diferente según la fruta que toque el niño. El pulso enviado, es el mismo que cuando se pulsa una tecla u otra del teclado, con lo que se puede diferenciar un pulso de otro de manera sencilla.

Por tanto, la clave reside en establecer como parte positiva cada una de las frutas expuestas, que se unen al circuito con una serie de clics metálicos, y como parte negativa o de masa, el propio cuerpo del niños, con lo que se hace necesario que este se ponga una pulsera fabricada en velcro y papel de estaño (Figura 11), de este modo cuando el niño toca la fruta, se consigue conductividad entre el usuario y la fruta cerrando de este modo el circuito eléctrico necesario para enviar el pulso con la tecla correspondiente.

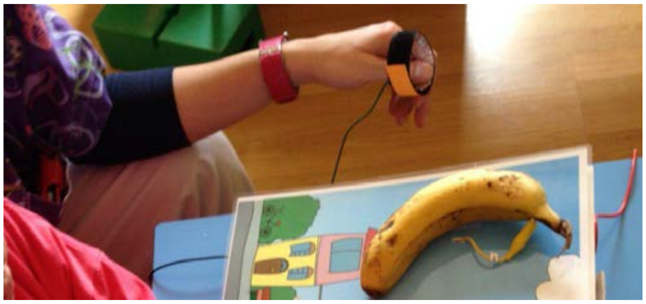

Figura 12: Pulsera que hace capaz la interacción entre el usuario y el sistema

Es importante destacar que debido el bajo amperaje que presenta la electrónica usada (Arduino), se presenta una forma de interactuar completamente segura e inocua para el usuario.

En nuestro caso en particular, tal como se muestra en la Figura 11, cuando el niño tenga puesta la pulsera en su muñeca y pulse el "plátano", cierra el circuito establecido para esa fruta en concreto y se genera un pulso de teclado que corresponde con la tecla "a". De este modo la aplicación interactiva, recibe la pulsación de la tecla "a" y comprueba si el pulso recibido corresponde a la tecla asociada al pictograma que se encuentra en pantalla, generando así un feedback positivo si la asociación es correcta.

4.4. Arquitectura del sistema

El Panel de Frutas Digital se compone de dos partes bien diferenciadas: una parte lógica que corresponde a un juego de escritorio, y una parte tangible, donde se encuentra el panel de frutas con los objetos reales.

La parte lógica de la aplicación ha sido desarrollada con Scratch [25]. De este modo, se desarrolla una interfaz de usuario fácil de transformar por los terapeutas, otorgando así una gran flexibilidad a la aplicación y dando la posibilidad de que el terapeuta use para cada uno de los niños aquellos fondos y sonidos que más les motiven [26]. Por otro lado, se separa la interfaz de usuario de la lógica de la aplicación, siendo ésta desarrollada en JSON (JavaScript Object Notation) ya que es el lenguaje que usa Scratch a nivel interno. La parte tangible del Panel de Frutas, ha sido construido con madera, pintura, papel y plástico. Internamente, se usa una placa Arduino Duo [27], para proveerlo de inteligencia. A continuación se muestra de forma general un esquema de la arquitectura interna que presenta el panel (Figura 12):

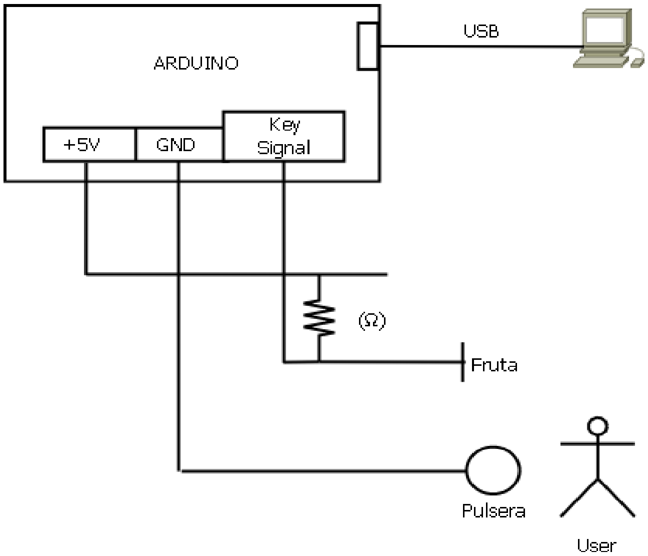

Figura 13: Esquema de la aplicación

Observando el esquema anterior, puede comprenderse cómo la placa Arduino es la encargada de comunicar a la aplicación de escritorio la fruta que ha sido tocada por el niño (proyecto similar [28]).

5. Evaluación

En el presente apartado se presenta la evaluación realizada para comprobar la reacción de los niños al usar el Panel de Frutas Interactivo.

5.1. Participantes

Los participantes seleccionados para jugar con el sistema interactivo, han sido 10 niños de entre 3 y 6 años de edad que necesitan adquirir un sistema de comunicación alternativo basado en pictogramas, con lo que tienen objetivos terapéuticos comunes.

Estos niños presentan diagnósticos variados como: trastorno del espectro autista, trastornos del lenguaje, dificultades de atención, síndrome de Down y otros.

5.2. Objetivos que se tratan conseguir a nivel terapéutico

El objetivo principal que se trata de conseguir en este ejercicio recae en la adquisición de la asociación entre un pictograma con su objeto real de forma rápida y fluida. Además, de este objetivo pueden detectarse otra serie de su subobjetivos asociados como:

La asociación de vocabulario con su pictograma para

- La asociación de vocabulario con su pictograma para la adquisición de un sistema alternativo de la comunicación.
- La mejora de la atención de los niños con respecto a su espacio.
- El entrenamiento y la mejora de la memoria visual.
- La adquisición de vocabulario asociado a los objetos, como: su nombre, su color, su forma, etc.

-

5.3. Dispositivos utilizados

Los dispositivos utilizados han sido los siguientes:

- Portátil Asus U33JC (512GB de memoria interna, 4GB de RAM, procesador Intel i3 1.8GHZ),
- Arduino Due.
- 1 cable de conexión (micro-USB macho a USB macho).
- 6 cables y 6 clics metálicos aislados.
- 5 frutas (1 plátano, 1 fresa, 1 pera, 1 manzana y 1 naranja).
- 2 piezas de madera contrachapada.

5.4. Procedimientos

Para realizar los experimentos se han dividido las evaluaciones en tres fases: Test de juego tradicional, test con el PFI y post-test con el PFI.

En la primera fase o Test de juego tradicional, el terapeuta juega con el niño usando el juego tradicional (sin tecnología), con esto se pretende establecer un punto de partida para determinar de qué punto se parte, con respecto a las asociaciones que el niño es capaz de hacer, y poder así comparar este inicio con la fase final de este experimento.

Tras terminar de jugar el profesional anota la cantidad de fallos y aciertos que comete el niño y a continuación responde a una serie de preguntas:

- Define la motivación y concentración del niño al realizar la actividad.
- Al realizar la actividad, ¿El niño quiere volver a jugar?
- ¿Se ha divertido el niño realizando la actividad?

En la segunda fase de las evaluaciones, el terapeuta usa el panel de frutas interactivo para trabajar con el niño. Tras esto, el terapeuta anota la cantidad de errores y aciertos y responde al siguiente cuestionario:

- ¿Ha mejorado la motivación y concentración del niño al realizar la actividad con respecto al juego tradicional?
- Al realizar la actividad, ¿El niño quiere volver a jugar?
- ¿Se ha divertido el niño realizando la actividad?
- ¿Se nota alguna diferencia entre usar o no usar el panel de frutas interactivo?

La tercera fase, se realiza a la semana siguiente de realizar la fase anteriormente descrita. En esta fase se vuelve a jugar al panel de frutas interactivos y después el terapeuta responde a las siguientes preguntas:

- ¿El niño recuerda el juego?
- Con respecto al número de fallos y aciertos, ¿Se ha mejorado el número de aciertos con respecto a la prueba anterior?
- ¿Cómo es el feedback que se percibe de los niños?

Es importante tener en cuenta que en cada una de las evaluaciones que se realizan con el panel de frutas, al finalizar éstas se guarda una captura de la interfaz donde se muestra el número de errores y aciertos del usuario, estableciendo la fecha y hora en la que se almacenó. De este modo, el terapeuta puede recuperar estos resultados de forma fácil (Figura 13)

Figura 14: Número de aciertos y errores

Además, se debe destacar que los niños juegan sentados y manteniendo una postura cómoda, relajada y a una distancia apropiada para facilitar la visualización tanto de la pantalla como el panel de frutas de una forma apropiada, ayudando además a centrar toda su atención en el juego.

5.5. Método

Para llevar a cabo la evaluación se debe tener en cuenta que, según los expertos, es muy difícil realizar una comparativa entre los resultados de los niños, ya que cada uno de ellos es un mundo. Si bien, el análisis se centra en comparar como aprende un mismo niño usando el panel de frutas y sin usarlo.

De este modo, se utiliza un test donde el terapeuta realiza una prueba a los niños para comprobar si son capaces de asociar la fruta real con su pictograma correspondiente.

Tras esto, se comprueba cómo es el aprendizaje del niño cuando el terapeuta usa otros objetos diferentes y otros pictogramas como por ejemplo: medios de transporte.

Una vez concluido el test, el terapeuta escribirá unas breves líneas ofreciendo su visión desde el punto de vista de la intervención y el logro de los objetivos establecidos en esta.

Para concluir realizará un test Smileyometer (Ver Figura 14). En este test el terapeuta podrá elegir el grado de satisfacción con la aplicación y con los resultados obtenidos, representándola mediante una de las siguientes emociones:

Horrible / No muy bueno / Bueno / Realmente bueno / Fantástico

Figura 15: Test Smileyometer

Este test permite que los profesionales se basen en sus propias emociones al finalizar la actividad con los niños, y teniendo en cuenta su sencillez, hace que estos lo realicen de una forma rápida y divertida.

5.6. Resultados

Una vez llevadas a cabo las evaluaciones se han obtenido los siguientes resultados: de los 10 niños, 9 han logrado mejorar la asociación entre las frutas y los pictogramas, consiguiendo una mejora aproximada del 40% en el número de aciertos y una disminución del 51% en el número de errores en sólo dos sesiones. De tal forma que se observa una progresión donde cada vez aumenta más el número de aciertos y disminuye el número de errores. Con el niño que no ha logrado una mejora, cabe destacar que aunque el número de aciertos y errores siguen siendo similares a los que se consiguieron en el test con el Juego tradicional (5 aciertos y 9 errores), sí que se ha logrado que el niño esté más concentrado en el juego y no se levante constantemente de la silla, cosa que ocurría en la primera evaluación pero no sucede cuando se usa el PFI.

Los profesionales han manifestado un grado alto de satisfacción con el PFI, ya que en el 80% de los casos se ha obtenido una buena valoración en el Smileyometer, en concreto se han obtenido: 8 "Realmente Bueno/Fantástico", 1 "Bueno" y 1 "No muy bueno" en la segunda fase de evaluaciones descrita en el punto 5.4, y para la tercera fase, se obtienen las siguientes valoraciones: 8 "Realmente Bueno/Fantástico" y 2 "Bueno".

Además, en los comentarios que los profesionales han realizado tras las evaluaciones, se detecta que los niños presentan un mayor grado de atención al usar el sistema interactivo que cuando realizan la actividad tradicional, lo que facilita que los niños asimilen de una forma más rápida la asociación entre los objetos y los pictogramas.

En la misma línea, se observa que al cambiar las frutas por otro tipo de objetos, como medios de transporte, los niños presentan un aprendizaje en la mecánica de trabajo que ayuda en el aprendizaje de nuevas asociaciones y conceptos. Desde la perspectiva del profesional, se detecta un alto grado de satisfacción a la hora de trabajar con otros objetos debido a la facilidad que presenta el sistema a ser modificado y adaptado según las necesidades del niño.

Por otro lado, se detecta que los profesionales tienen problemas con los niños al inicio del juego, ya que la mayoría se niega a ponerse la pulsera. Esto ha sido solventado añadiendo un velcro en la parte visible de la pulsera, el cual hace de base para que los niños que son reacios a ponerse la pulsera realicen un pequeño dibujo en un papel y a continuación este es acoplado mediante el velcro a la pulsera. De este modo, los niños personalizan la pulsera y el 100% de las ocasiones comienzan a jugar sin presentar mayor problema.

Por otro lado al realizar las evaluaciones, los terapeutas nos proponen que use el Panel de Frutas una niña autista. Esta niña aunque ya es capaz de hacer correctamente asociaciones entre los objetos reales y los pictogramas debido a que usa un sistema alternativo de la comunicación denominado PECS [22], presenta dificultades en la alimentación, ya que tiene intolerancia con algunas texturas, entre ellas las frutas.

Por tanto, en este caso el objetivo terapéutico no es la asociación entre el objeto real y el pictograma si no que se basa en que la niña sea capaz de interactuar con las frutas.

Nuestra sorpresa fue que la niña comenzó a jugar con el panel de forma instantánea y debido a su concentración en éste, se olvidó de su intolerancia a las texturas y jugó sin problemas. Al acabar el juego, la niña se acercó a su libreta de pictogramas y cogió el pictograma que representa una tablet para comunicarle al terapeuta que quería volver a jugar.

6. Beneficios de la aplicación

El PFI ha de establecerse como una herramienta de apoyo a los profesionales que les facilita su trabajo diario y ayuda a los niños a adquirir, a través del juego, una serie de habilidades requeridas para lograr tener un sistema de comunicación con el que comunicarse con su entorno diario. De este modo, el sistema interactivo presentado ha sido diseñado por profesionales y para profesionales de los CDIAT, esto conlleva a que el sistema permita no sólo trabajar y aprender la asociación entre las cinco frutas seleccionadas y sus pictogramas, si no que debido a su sencillez a la hora de modificar los objetos, las imágenes y los pictogramas los profesionales podrían usar el sistema para el aprendizaje de otros conceptos como hortalizas, medios de transporte, animales, etc. En esta misma línea, y tomando como base la forma de trabajar basada en objetivos y en las características de los niños, se establece una herramienta de apoyo que puede ser transformada para lograr otros objetivos diferentes, como por ejemplo el aprendizaje de los colores, donde el objeto real con el que interactuarían los niños podría ser simplemente plastilina (con un alto contenido en agua) de distintos colores, y los pictogramas representarían objetos de distinto color. Desde otro punto de vista, se presenta un sistema con un coste económico reducido y al alcance de todos los centros, ya que los objetos con los que se interactúa, en nuestro caso frutas, tienen un coste reducido y la tecnología y el material usado no supera los 40 euros (sin tener en cuenta el ordenador, ya que podría usarse con cualquier ordenador disponible en el centro).

7. Conclusiones

En este artículo proponemos PFI (Panel de Frutas Interactivo). Un juego interactivo digital basado en interfaces de usuario tangibles y donde los niños juegan tocando directamente los objetos reales. Este sistema se ejecuta en cualquier dispositivo con sistema operativo Windows o Linux. En este juego se presenta una forma de interacción natural y fácil de aprender donde para comenzar a jugar sólo se requiere que el niño se ponga una pulsera y comience a interactuar directamente con las frutas del panel.

De este modo el proceso de enseñanza-aprendizaje es motivador tanto para el niño como para el profesional, ya que ambos se ven inmersos en el juego. La evaluación por parte de los profesionales ha sido muy positiva, y los niños han disfrutado y aprendido jugando.

Como trabajo futuro, se realizará un acercamiento del sistema a los padres, donde se pretende llevar a cabo una evaluación del aprendizaje donde los niños se encuentren en un ambiente familiar y relajado. Tratando así de que tanto padres como profesionales dispongan de este tipo de sistemas para trabajar con los niños de forma conjunta y en una misma dirección.

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USABILITY AND USER EXPERIENCE (I)

ECUSI: una herramienta que apoya la Evaluación Colaborativa de la Usabilidad de Sistemas Interactivos

Andrés Solano
Universidad Autónoma de Occidente
Cll 25# 115-85, vía Cali-Jamundí.
(57)+2+3188000, ext. 11378
afsolano@uao.edu.co

Juan Camilo Cerón
Universidad del Cauca
Carrera 3 #3N-100, Sector Tulcán.
(57)+2+8209800, ext. 2133
jcceron@unicauca.edu.co

César A. Collazos
Universidad del Cauca
Carrera 3 #3N-100, Sector Tulcán.
(57)+2+8209800, ext. 2133
ccollazo@unicauca.edu.co

Habib M. Fardoun
King Abdulaziz University
Abdullah Sulayman, Jeddah 22254
(966)+5+45668512
hfardoun@kau.edu.sa

José Luis Arciniegas
Universidad del Cauca
Carrera 3 #3N-100, Sector Tulcán.
(57)+2+8209800, ext. 2114
jlarci@unicauca.edu.co

RESUMEN
La usabilidad es una característica de calidad fundamental para el éxito de un sistema interactivo. Corresponde a un concepto que incluye una serie de métricas y métodos con el objetivo de obtener sistemas fáciles de usar y aprender. Los métodos de evaluación de usabilidad son bastante diversos, por tal razón, la elección de un método o combinación de métodos para evaluar la usabilidad de un sistema interactivo no resulta sencilla. Por otro lado, la literatura ofrece descripciones a un alto nivel sobre el proceso de evaluación de usabilidad. En ese sentido, este artículo presenta la herramienta software ECUSI – Evaluación Colaborativa de la Usabilidad de Sistemas Interactivos, la cual pretende apoyar la ejecución de las actividades que conforman un conjunto de métodos de evaluación de usabilidad. ECUSI pretende ser útil para evaluadores de usabilidad de sistemas software interactivos.

Categorías y Descriptores Temáticos
H.1.2 [**Modelos y Principios**]: Sistemas Usuario/Maquina – *factores humanos.*

Términos generales
Factores Humanos.

Palabras claves
Usabilidad, métodos de evaluación, evaluación colaborativa de la usabilidad.

1. INTRODUCCIÓN
Los sistemas interactivos están creciendo en popularidad, y actualmente con las innovaciones tecnológicas, ocupan un lugar de importancia en la sociedad; esto incrementa el potencial de dichos sistemas para que los usuarios puedan entreteneerse, informarse, comunicarse o usarlos en diferentes áreas de aplicación. Lo anterior implica un constante desafío, como es mejorar la calidad de los sistemas interactivos.

En el entorno actual, en el que los sistemas interactivos están dirigidos a un público cada vez más amplio, a usuarios cada vez menos expertos en el manejo de los mismos, la *Experiencia de Usuario* (UX, por sus siglas en inglés *User eXperience*) [1] es un aspecto fundamental para el éxito de dichos sistemas. La UX se refiere a "cómo se sienten las personas acerca de un producto y su satisfacción cuando lo usan, lo miran, lo sostienen, lo abren o cierran" [1]. La UX abarca diferentes facetas relacionadas a la calidad de un producto software como [2]: usabilidad, accesibilidad, emotividad, multiculturalidad, jugabilidad, entre otras. Actualmente, el término UX está siendo ampliamente utilizado, tanto así que estándares como la ISO relacionada a calidad de uso y SQuaRE (Systems and Software Quality Requirements and Evaluation) [3], ya se refieren a esta terminología. Así, la herramienta software presentada en este artículo se enfoca exclusivamente en la faceta *usabilidad* de la UX, siguiendo el enfoque de una *usabilidad formativa* [4].

"La usabilidad es un atributo de calidad del software" [5] que conlleva una serie de métricas y métodos con el objetivo de obtener sistemas fáciles de usar y de aprender, además influye directamente en el éxito de cualquier nueva aplicación o sistema interactivo [6]. La usabilidad reduce los errores ocasionados por los usuarios y lleva a que estos realicen las tareas de manera más eficiente y efectiva, aumentando así su satisfacción y mejorando su experiencia global con la aplicación o sistema con el cual interactúan [4].

Ahora bien, una variedad de investigadores han ejecutado varios métodos que intentan evaluar el grado de satisfacción de la usabilidad de diferentes sistemas interactivos, sin embargo, en dichos trabajos la información detallada del proceso, como: entregables, requerimientos, roles, entre otra, no es lo suficientemente bien definida. Así, en [7] se propone la especificación colaborativa de un conjunto de métodos de evaluación (elaborada siguiendo los principios definidos en la Ingeniería de Colaboración [8]), la cual provee una secuencia de actividades bien definidas, especificación de entregables, descripción de los diferentes participantes del proceso de evaluación y especificación del proceso de comunicación entre los participantes. Esto con el fin de ofrecer documentación acerca de cómo ejecutar evaluaciones colaborativas de usabilidad de sistemas interactivos.

Por otro lado, la evaluación de la usabilidad de un sistema interactivo es una de las etapas más importantes dentro del diseño centrado en el usuario [9]. Los Métodos de Evaluación de Usabilidad (MEU), que permiten medir la aplicación de éste atributo en cierto sistema y bajo ciertos factores, son bastante diversos. Su realización depende de variables tales como: costos, disponibilidad de tiempo, recursos humanos, entre otros. Así, la elección de un método o combinación de métodos para evaluar la usabilidad de un sistema interactivo no resulta sencilla [10]. De esta manera, en [7] han sido propuestas una serie de combinaciones de MEU (según escenarios específicos) para evaluar sistemas interactivos que corresponden a diferentes áreas de aplicación. Dichas combinaciones de MEU son presentadas más adelante en la sección 3.

Con base en lo anterior, han sido especificados una serie de requerimientos con el objetivo de implementar una herramienta software que brinde soporte a la especificación colaborativa de un conjunto de MEU, así como también a la ejecución de los mismos. La herramienta denominada ECUSI (Evaluación Colaborativa de la Usabilidad de Sistemas Interactivos), pretende apoyar la ejecución de las actividades que conforman un conjunto de MEU, esto haciendo uso de documentos compartidos en Google Docs que permiten la participación de diferentes personas involucradas en el proceso de evaluación.

Mediante este artículo se pretende dar a conocer la herramienta a practicantes y/o evaluadores de usabilidad, la cual fue concebida con el objetivo de que les oriente durante el proceso de evaluación de usabilidad de sistemas interactivos que pertenecen a diferentes áreas de aplicación, tales como: televisión digital interactiva, web transaccional, aplicaciones móviles, redes sociales, entre otras.

La sección 2 presenta una serie de trabajos relacionados. La sección 3 describe un conjunto de combinaciones de MEU disponibles en la herramienta software. La sección 4 describe la herramienta software propuesta, luego, la sección 5 presenta información relacionada al proceso de desarrollo de la misma. Finalmente, la sección 6 presenta algunas conclusiones y trabajos futuros.

2. TRABAJOS RELACIONADOS

Existen herramientas que son capaces de sugerir una serie de métodos a utilizar en el proceso de evaluación de usabilidad, tal es el caso de *Usability Planner* [10]. Esta herramienta apoya el proceso de selección de los MEU más apropiados para ejecutar en función de las características de un proyecto y restricciones organizacionales. En dicha herramienta las reglas empleadas se derivan de las normas ISO y son complementadas con reglas según la experiencia del autor. *Usability planner* sugiere un conjunto de MEU a utilizar según una serie de reglas, sin embargo, no ofrece soporte para ejecutar colaborativamente las actividades que conforman los métodos sugeridos.

Por otro lado, expertos en usabilidad recomiendan aplicar métodos de prueba una vez se han aplicado métodos de inspección, esto con el fin de obtener información más adecuada respecto a la usabilidad de un sistema. Existe una gran variedad de servicios software para la evaluación de usabilidad, tales como los que se ofrecen en los sitios web: Usertesting.com, Userzoom.com, Loop11.com, entre otros. Sin embargo, en una buena cantidad de estos servicios los MEU pueden aplicarse de forma independiente. Es así como ECUSI supera estas desventajas y ofrece la posibilidad de ejecutar MEU de forma independiente o combinaciones de estos, combinaciones que están predefinidas o pueden ser creadas por el usuario.

En general, y teniendo en cuenta el estado actual de la literatura, son escasas las herramientas software propuestas para la evaluación de la usabilidad de sistemas software interactivos que contemplen la combinación de MEU, y que además, brinden soporte a procesos colaborativos. Adicionalmente, son escasas las guías existentes acerca de qué métodos son apropiados en qué circunstancias o escenarios, por lo cual la selección de los MEU se basa en la experiencia personal.

3. COMBINACIONES DE MEU

Los MEU se agrupan generalmente en [9]: métodos de inspección y métodos de prueba, los cuales pueden ser usados iterativamente y en etapas distintas del desarrollo de un sistema. Los MEU tienen fortalezas y debilidades y están enfocados a avaluar aspectos específicos de usabilidad, por lo que expertos en el área recomiendan combinarlos en una evaluación para complementarlos entre sí [11]. Así, es posible definir los problemas de usabilidad en una primera etapa (con expertos), para luego evaluar empíricamente la influencia de esos problemas (con usuarios representativos). Con base en lo anterior, ECUSI soporta las siguientes combinaciones de MEU [12].

3.1 Evaluación global: alta detección de problemas

Esta combinación está enfocada en el análisis completo de un sistema, incluye los métodos: evaluación heurística, interacción constructiva y entrevistas (ver Figura 1). Esta combinación se estima que funciona correctamente cuando es requerido un análisis de tipo global, mediante el cual será identificado un buen número de problemas de usabilidad, tanto por parte de los evaluadores como del análisis de la interacción de los usuarios representativos. Las entrevistas, como método de interrogación complementario, van a permitir obtener información adicional/complementaria acerca de la percepción de los usuarios respecto al sistema evaluado, con lo cual también sería posible confirmar problemas críticos identificados por los dos métodos antes realizados.

Figura 1. Evaluación global - alta detección de problemas.

3.2 Evaluación específica: reducción de tiempo

Esta combinación está enfocada a evaluar ciertos escenarios o funcionalidades de un sistema, incluye los métodos: evaluación heurística, método del conductor y cuestionarios (ver Figura 2). Esta combinación, resulta ser de utilidad para evaluar funcionalidades específicas debido a que la información obtenida mediante el método del conductor permite detectar problemas en aquellos puntos donde el usuario solicita ayuda/información al evaluador (conductor). Esto es, en los puntos donde hay comunicación entre el usuario y conductor es muy probable que haya necesidades de información en el sistema.

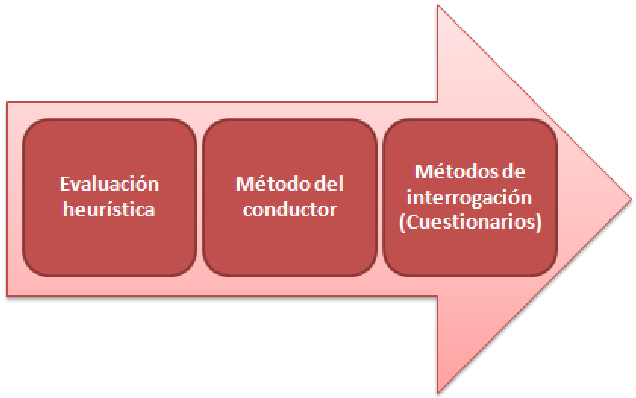

Figura 2. Evaluación específica – reducción de tiempo.

3.3 Evaluación enfocada a tareas específicas: sin restricciones de tiempo

Esta combinación tiene como objetivo analizar tareas concretas de un sistema interactivo, incluye los métodos: recorrido cognitivo, experimentos formales y cuestionarios (ver Figura 3). En esta combinación los tres métodos aportan sus importantes características, pero son los experimentos formales los que marcan la diferencia respecto a la *evaluación específica*. Los experimentos formales permiten realizar un eficiente análisis de las tareas de interés. Estos tienen un buen nivel de objetividad y se complementan de forma adecuada con los cuestionarios (pre-test y post-test), que también presentan buena objetividad y permiten obtener información cuantitativa. Así, al ejecutar los 3 métodos que conforman esta combinación, se estima que la información obtenida acerca de la usabilidad de las tareas sería completamente objetiva. Sin embargo, esta combinación conviene utilizarla cuando la disponibilidad de tiempo es alta.

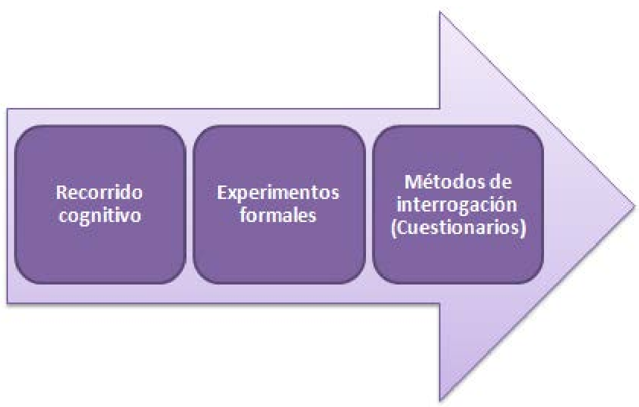

Figura 3. Evaluación enfocada a tareas específicas - sin restricciones de tiempo.

4. ECUSI - Evaluación Colaborativa de la Usabilidad de Sistemas Interactivos

ECUSI es una aplicación web que brinda soporte a la ejecución de las actividades que conforman un conjunto de métodos de evaluación de usabilidad. Esto haciendo uso de documentos compartidos en Google Docs que permiten la participación de diferentes personas–a menudo distribuidas geográficamente– involucradas en el proceso de evaluación. ECUSI fue concebida con el objetivo de ofrecer a los practicantes de la usabilidad una herramienta que los oriente durante el proceso de evaluación de usabilidad de diferentes sistemas interactivos.

4.1 Uso del sistema

ECUSI ofrece las siguientes funcionalidades generales:

- Consulta de la especificación colaborativa de un conjunto de métodos de evaluación de usabilidad (de inspección y prueba).
- Creación de proyectos de evaluación los cuales están conformados por la combinación de varios MEU.
- Edición de documentos compartidos para el desarrollo de las actividades (colaborativas y no colaborativas) que conforman los MEU seleccionados en un proyecto de evaluación.

4.1.1 *Consulta de la especificación colaborativa de MEU*

ECUSI brinda soporte a la ejecución de los métodos: *evaluación heurística*, *recorrido cognitivo*, *experimentos formales*, *interacción constructiva*, *método del conductor*, *entrevistas* y *cuestionarios*. Además, provee la especificación colaborativa de dichos métodos mediante los elementos [8]: Modelo de Facilitación del Proceso (MFP) y Agenda detallada. El MFP presenta el flujo del proceso de manera gráfica mediante una notación propuesta para el modelado de procesos colaborativos [13], mientras que la agenda detallada presenta de manera extendida información de las actividades que forman parte del proceso diseñado, tal como: nombre de la actividad, entregables, patrón de colaboración, proceso de comunicación (en caso de que la actividad sea colaborativa), participantes, entre otra. La especificación colaborativa de los MEU está dividida en 3 etapas: *planeación*, *ejecución* y *análisis de resultados*. Así, cada método de evaluación tiene asociados 3 MFP y 3 agendas detalladas, correspondientes a las etapas mencionadas.

4.1.2 *Creación de proyectos de evaluación*

En ECUSI, los usuarios registrados en el sistema pueden crear proyectos de evaluación de usabilidad. Cuando el usuario crea un proyecto asume el rol de *evaluador supervisor* (creador del proyecto) y debe ingresar información básica como es: título y descripción del proyecto. También, debe seleccionar el tipo de sistema a evaluar (web, nativo, videojuego u otro) y el dispositivo hardware que lo soporta (móvil, tableta, televisor, computador personal, consola de videojuegos u otro). Adicionalmente, un proyecto puede estar conformado por uno o más MEU. Para ello, el usuario puede seleccionar de forma manual el o los métodos a ejecutar, o incluso, puede seleccionar alguna de las combinaciones de MEU predefinidas (ver sección 3). Finalmente, el usuario debe seleccionar la lista de evaluadores que colaborarán en el proceso. Los evaluadores invitados reciben un correo electrónico mediante el cual pueden confirmar su participación en el proyecto.

El usuario puede gestionar (consultar, editar y eliminar) los proyectos creados. El *Gestor de proyectos* (opción disponible en el menú principal) permite al usuario observar la fecha de creación del proyecto, fecha de la última actualización, estado (activo o terminado) de un proyecto, incluso puede observar el porcentaje de cumplimiento de las actividades que conforman los MEU del proyecto. También es posible consultar aquellos proyectos en los cuales ha sido invitado como evaluador.

Una vez el proyecto se encuentra en ejecución, es posible que el *evaluador supervisor* seleccione las actividades cumplidas. De esta manera, el porcentaje de cumplimiento del proyecto es actualizado automáticamente. Adicionalmente, ECUSI presenta la lista de evaluadores que participan en el proyecto de evaluación de tal forma que es posible consultar su perfil y establecer contacto mediante correo electrónico. Es importante mencionar que en los métodos de prueba ECUSI ofrece la posibilidad de compartir material multimedia (grabaciones de las pruebas) a los evaluadores mediante un enlace creado en Dropbox, por ejemplo. Esto con el fin de que el material sea observado, y posteriormente, los evaluadores identifiquen los respectivos problemas de usabilidad.

4.1.3 *Edición de documentos compartidos*

Luego de que el evaluador ha creado un proyecto de evaluación, automáticamente son creados 3 documentos compartidos para cada método incluido en el proyecto. Cada documento compartido corresponde a una plantilla que contiene información sobre las actividades a realizar. Adicionalmente, por cada etapa de un método de evaluación (planeación, ejecución y análisis de resultados) son presentados como recursos adicionales imágenes de los MFP y agendas detallas.

Adicional a las funcionalidades anteriores, ECUSI ofrece una serie de recursos (documentos) que pueden ser de utilidad para los usuarios (evaluadores), tales como: formato de acuerdo de confidencialidad, formato de documento guía para una evaluación heurística, formato de documento guía para el usuario en los experimentos formales, entre otros.

Por último, al finalizar un proyecto de evaluación, se ofrece al evaluador la posibilidad de incluir realimentación acerca de la combinación de MEU utilizada. El evaluador puede calificar (mediante un número de puntos) la combinación utilizada, además, puede incluir información acerca de aspectos positivos y negativos según la experiencia con los métodos seleccionados. Esto con el fin de que los evaluadores conozcan dicha información y decidan qué combinación de MEU resulta apropiada, según experiencias de otros.

4.2 Ventajas

ECUSI trata de integrar tecnologías conocidas para los evaluadores, por tal razón hace uso de los documentos compartidos en Google Docs como herramienta ofimática colaborativa, los cuales resultan familiares y de uso constante para los evaluadores.

ECUSI es lo suficientemente flexible para permitir la inclusión de un mayor número de MEU. La primera versión de ECUSI incluye un conjunto de métodos de inspección y prueba, sin embargo, lo esperado es incluir la especificación colaborativa de más métodos con el fin de ampliar el abanico de opciones para la evaluación de sistemas interactivos. De igual forma, ECUSI permite la definición de nuevas combinaciones de MEU que obedecen a otros escenarios, factores u objetivos de evaluación.

Como ya se ha mencionado, ECUSI almacena información (especificación colaborativa) de un conjunto de MEU, tal como: actividades, entregables, patrones de colaboración, proceso de comunicación, participantes, entre otra. Así pues, ECUSI podrá ser utilizada tanto por practicantes de la usabilidad como por evaluadores de sistemas interactivos que deseen llevar a cabo un estudio desde un enfoque de *usabilidad formativa* [4].

La herramienta ECUSI puede ser utilizada en, prácticamente, cualquier etapa del ciclo de desarrollo de un sistema interactivo. De igual forma, las combinaciones de MEU pueden ser utilizadas tanto en etapas tempranas de diseño como en etapas intermedias, aunque probablemente se adaptan mejor en etapas tempranas, cuando se tenga un prototipo funcional (no necesariamente una versión final) que permita efectuar pruebas con usuarios reales. Se sugiere que el sistema a evaluar tenga cierto grado de avance o funcionalidad, para que los expertos puedan evaluarlo de una mejor manera y puedan obtenerse resultados más completos.

Mediante ECUSI puede contarse con la colaboración de evaluadores que se encuentran distribuidos geográficamente, con lo cual los gastos (de movilidad, por ejemplo) se disminuyen en gran medida. Por otro lado, se tiene la ventaja de que los practicantes de la usabilidad pueden consultar la especificación colaborativa de un conjunto de MEU, ya que en la literatura la descripción de estos se tiene a un alto nivel. Por último, se puede acceder a ECUSI mediante Internet, por lo cual es accesible desde cualquier lugar y desde cualquier dispositivo que disponga de conexión a la red.

Las combinaciones de MEU predefinidas en ECUSI permitirían cubrir los puntos más críticos para obtener la medida de la usabilidad con un nivel de precisión aceptable. Primero, existe, por lo menos, un método de inspección y un método de prueba. En segundo lugar, incluyen evaluaciones que realizan análisis cuantitativos y cualitativos, objetivos y subjetivos, y de evaluación global y evaluación específica del sistema. Por esto, es posible decir que se están cubriendo todos los factores necesarios para evaluar, en buena medida, la usabilidad de un sistema software interactivo.

5. PROCESO DE DESARROLLO

La herramienta ECUSI ha sido diseñada siguiendo el enfoque de *Diseño Centrado en el Usuario* [14]. Desde el inicio del proceso de desarrollo fueron incluidos practicantes de la usabilidad y evaluadores con el fin de conseguir que el producto sea agradable para dicho público objetivo.

En primer lugar, se realizó un análisis preliminar de requisitos que debía tener la herramienta software. Este análisis fue realizado con posibles usuarios finales de la herramienta, es decir, con un conjunto de personas que realizan frecuentemente diferentes métodos de evaluación de usabilidad (de inspección y prueba). De este análisis de requisitos surgieron las funcionalidades básicas de ECUSI y la información que esta debía incluir.

En segundo lugar, fueron diseñados prototipos en papel para mostrar a los usuarios una primera idea de cómo evolucionaría la interfaz y cómo sería presentada la información en ella. Una vez obtenida la realimentación de los usuarios sobre los prototipos, una serie de requisitos fueron ajustados y los prototipos actualizados.

Posteriormente, fueron planeadas y priorizadas las funcionalidades que tendría la herramienta, y de esta manera, hacer iteraciones incrementales con entregas constantes a los interesados para su respectiva verificación y validación. Durante este proceso fueron realizadas evaluaciones de usabilidad informales en las instalaciones de la Universidad del Cauca (Colombia), específicamente fue aplicado el método del conductor con el fin de descubrir las necesidades de información de los usuarios en el sistema.

Luego de seis iteraciones, la herramienta fue liberada en versión beta, la cual fue evaluada con expertos y usuarios potenciales mediante el uso de la combinación *específica* (ver sección 3.2). Esta combinación incluye los MEU: evaluación heurística, métodos del conductor y cuestionarios, tal como se presenta en la siguiente sección.

5.1 Evaluación de usabilidad

La evaluación heurística fue realizada por un conjunto de 3 evaluadores que inspeccionaron el diseño de la interfaz de ECUSI con base en una serie de principios específicos para aplicaciones Web, definidos en [15]. Este método permitió identificar una serie de problemas mayores y menores en el sistema. Si bien, no se trató de problemas que colocaban en riesgo el funcionamiento del sistema, sí atentaban contra la facilidad de uso, y por lo tanto, con el buen aprovechamiento que este pudiese tener. En general, el nivel de criticidad de los problemas fue bajo, una poca cantidad de problemas (6 de 24) fueron calificados, en promedio, con notas mayores a 6 (en una escala de 0 a 8), y 18 de los 24 problemas detectados fueron calificados con notas inferiores a 6. El alto número de problemas de usabilidad identificados tuvo su causa en que el sistema no estaba terminado por completo, con lo cual la versión beta de ECUSI presentó varios aspectos posibles de mejorar.

El método del conductor fue realizado por un conjunto de 3 evaluadores y 8 usuarios potenciales adecuados al perfil de usuario definido. Previa firma del acuerdo de confidencialidad, los usuarios realizaron las tareas indicadas por el conductor sobre el sistema (con escenario de uso preestablecido). Los sucesos ocurridos durante la prueba fueron grabados (previa autorización de los usuarios) y distribuidos entre los evaluadores para su análisis. La ejecución de este método permitió identificar 15 problemas de usabilidad en las funcionalidades estudiadas, entre los cuales fueron confirmados los 6 problemas más críticos identificados en la evaluación heurística.

Los cuestionarios fueron realizados luego de llevar a cabo el método del conductor, por lo cual el número de usuarios que diligenciaron los cuestionarios después (post-test) de dicho método fue 8, una cifra aceptable para obtener conclusiones sobre la percepción subjetiva de los usuarios. Los cuestionarios permitieron obtener resultados alentadores respecto a la satisfacción subjetiva de los usuarios con el sistema. Algunos promedios superaron la nota 4 (en una escala de 1 a 5), por lo que se puede decir que, en general, los usuarios estuvieron conformes con la consistencia y control sobre la aplicación, sin embargo, consideraron que el diseño de esta puede mejorarse para aumentar significativamente la productividad y satisfacción al usarla.

Una vez identificados los problemas de usabilidad por el método de inspección (evaluación heurística), y confirmados mediante métodos de prueba (conductor y cuestionarios), fueron sugeridos una serie de ajustes a la herramienta software. Luego de implementar los ajustes respectivos, se liberó una versión estable de ECUSI la cual está disponible en la URL: http://www.ecussi.com/.

5.2 Aspectos técnicos de la aplicación

ECUSI hace uso de los credenciales de *Google* para realizar la autenticación, de esta manera, con un correo de *Gmail* y su respectiva contraseña se puede acceder a las funcionalidades de la herramienta. También implementa la *API* de *Google Drive* la cual permite gestionar los documentos colaborativos al momento de crear proyectos de evaluación.

El *back-end* (lado del servidor) de la aplicación fue desarrollado con en el lenguaje de programación interpretado *Python*, implementando el framework para desarrollo web *Django*. Para el *front-end* (lado del cliente) se usó el lenguaje *JavaScript* y la librería *jQuery* junto con el framework *Twitter Bootstrap* para permitir que la herramienta contará con diseño adaptativo.

Debido al uso del framework *Django*, ECUSI cuenta con una arquitectura *MTV* (*Model Template View*), similar a la usual arquitectura *MVC* (*Model View Controller*). La herramienta corre en el servidor web *Nginx* y utiliza *MySQL* para almacenar los datos persistentes.

6. CONCLUSIONES Y TRABAJO FUTURO

ECUSI pretende ser una herramienta de uso frecuente para la evaluación colaborativa de la usabilidad de sistemas software interactivos que pertenecen a diferentes áreas de aplicación, tales como: televisión digital interactiva, web transaccional, redes sociales, videojuegos, entre otros.

Considerando que en trabajos relacionados la información detallada del proceso de evaluación de usabilidad no es lo suficientemente bien definida, la herramienta ECUSI presenta la especificación colaborativa de un conjunto de MEU. Dicha especificación provee una secuencia de actividades bien definidas, especificación de entregables, descripción de los diferentes participantes del proceso de evaluación y especificación del proceso de comunicación entre los participantes de la evaluación. En ese sentido, se estima que el aprendizaje, tanto de ECUSI como de los MEU soportados en ella, no llevaría una cantidad significativa de tiempo ya que se ofrece información detallada al usuario (evaluador) para que lleve a cabo un determinado proceso.

Por otro lado, se tiene escasa documentación (guías o lineamientos) acerca de cómo ejecutar evaluaciones colaborativas de usabilidad de sistemas interactivos. Con base en lo anterior, surgió la idea de desarrollar la herramienta ECUSI, la cual se espera sea utilizada por practicantes de la usabilidad o personas responsables de estructurar el proceso de evaluación de la usabilidad de diferentes sistemas interactivos. La finalidad perseguida es brindar una herramienta software a la comunidad para facilitar el desarrollo de una cultura de evaluación de la usabilidad de software.

Como principales actividades futuras se destacan el refinamiento de la interfaz gráfica de la herramienta. Adicionalmente, conviene incluir en ECUSI una segunda opción de idioma (inglés) con el fin de fomentar su proyección internacional. También, para una segunda versión de ECUSI conviene incluir requerimientos relacionados a la automatización de actividades que conforman la evaluación heurística (tales como: la calificación de severidad y frecuencia, generación de rankings de criticidad y severidad, entre otras) e inclusión de mecanismos que promuevan la comunicación entre evaluadores. Finalmente, animamos a la comunidad científica a utilizar la herramienta software con el fin de obtener realimentación acerca de las combinaciones de MEU que utilicen en los proyectos de evaluación.

En la herramienta software propuesta la faceta *usabilidad* ha sido considerada como eje central, por lo que convendría ampliar el alcance de la herramienta pasando de "evaluación colaborativa de la usabilidad" a "evaluación colaborativa de la experiencia de usuario". Así, para un trabajo posterior, sería adecuado incluir (o combinar) elementos de otras facetas, como por ejemplo: emotividad, multiculturalidad, entre otras, a la especificación colaborativa de los MEU.

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Towards an Integration of Usability and Security for User Authentication

Paulo C. Realpe, Cesar A. Collazos, Julio Hurtado
University of Cauca
IDIS Research Group
Popayan, Colombia
{prealpe, ccollazo, ahurtado}@unicauca.edu.co

Antoni Granollers
University of Lleida
GRIHO Research Group
Lleida, Spain
tonig@diei.udl.cat

ABSTRACT
Computer security is one of the more important tasks currently in the digital world. However, to the best of our knowledge, there is little research for designing effective interfaces in the context of security management systems. Security problems for these systems include vulnerabilities due to hard to use systems and poor user interfaces due to security constraints. Nowadays, finding a good trade-off between security and usability is a challenge, mainly for user authentication services. This paper presents a systematic review about usability principles, evaluation methods and development processes for security systems. Moreover, a research approach to integrate usability and security for user authentication systems is proposed.

Categories and Subject Descriptors
I.3 [**Security service**]: Authentication; J.2.1 [**Interaction design**]: Interaction design process and methods−*User centered design*

General Terms
Security, Usability

Keywords
Usable security, HCISec, authentication, principles, evaluation, design process

1. INTRODUCTION
Computer security is the area in computer science in charge of the confidentiality and integrity of the systems and data. In order to manage the security problems, the human aspects require a special attention at development time [1]. Security has been an important factor in many interactive systems, whereas, usability has been a driver required in these kind of systems. However, there is a belief that security is only related with technical aspects and it could be designed to user interface. On the one hand, only technical aspects are normally considered for designing the security requirements [2]. Also, the design of usable interfaces require that security issues be considered because humans are prone to mistakes. Usable security has focused in designing interfaces for achieving a trade-off between usability and security [3].

Usable security, according to Jøsang and Patton [4], deals with managing security information in the user interfaces. Security and usability can vary according to usage, including users profiles (who are the users), tasks, hardware (including network equipment), software, and physical or organizations environments [2]. However, there is little research in usable security in particular, about the relationship between security and usability. For designing secure and usable systems, these present critical challenges, for instance how conflicts between security and usability could be solved. The main question is how a balance suitable between security and usability in software applications could be achieved [5].

Usability principles (also called criteria or heuristics) represent an instruction manual for a HCI (Human-Computer Interface) designer. Although researches have been partially applying principles to security systems, some of these criteria have problems to be adapted to the overall methodology, especially in the design and development suitable of user authentication services [6]. Besides, usability evaluation methods are not entirely suitable for evaluating security-based systems, because they do not identify many of the negative effects on the usability [1]. Also, Zurko and Simon [7], Whitten and Tygar [8] and Chiasson and Biddle [3] have

shown that cognitive aspects definitely influence the usability of security mechanisms in the user authentication methods. Researchers argue that security concepts used in these mechanisms are not easily understood by many users.

Authentication is the process for establishing whether someone is who declares to be. In computer networks, authentication is frequently implemented using passwords. There are six factors of user authentication that might be employed to increase the security level: something you have (smart card), something you know (passwords or PIN), something you are (fingerprint), something you recognize (graphical passwords), something you do (keystroke) and where you are (GPS) [5].

The HCI community has been gradually developing research work in usable security guidelines for software such as design principles for security [9], and guidelines for designing and evaluating usable secure software [10]. However, to the best of our knowledge, there are no suitable usability principles to provide evaluation methods that take into account security and usability for developing a process or technique from the system design to implementation and the application for user authentication services [6].

This paper presents a systematic review about usability principles, evaluation methods and development processes for security systems. Moreover, a research approach to integrate usability and security for user authentication systems is proposed.

2. HCI SECURITY
Johnston et al. [11] define HCI Security (HCISec) as: “the part of a user interface which is responsible for establishing the common ground between a user and the security features of a system.

HCISec is human computer interaction applied in the area of computer security". They claim that the aim of HCISec is to improve in the user interface in order to achieve reliability and robustness. This leads to the system becoming more secure, robust and reliable. However, security features sometimes are perceived to make a system more difficult to use. HCISec addresses this issue using a set of principles for achieving a trade-o_ between security and usability.

HCISec has little associated research, particularly oriented to authentication methods [6]. Despite security methods are understood, implemented and used, human factors must be taking into account in their design. According to CompTIA (Computing Technology Industry Association), human error is the main cause of security breaks and it accounts the 80% of security problems in the organizations [12]. Whitten and Tyggar [8] presented the first work about HCISec where they evaluated usability of an authentication method for implementing privacy in an e-mail application, called PGP (Pretty Good Privacy).

Johnston et al. [11] propose seven principles for HCISec: convey features, visibility of system status, learnability, aesthetic and minimalist design, errors, satisfaction and trust. These criteria are based on Nielsen's heuristics [13] and have been modified and synthesized in order to address the essentials aspects in a security environment. The HCISec principles can be used by software engineers for allowing that usability is developed into a security user interaction. The principles can also be used for evaluating the interfaces of new security products [11].

Katsabas et al. [14] presented ten HCISec principles based in Nielsen [13] and Johnston et al. [11] for supporting the inclusion of security features within applications. The HCISec community has considered the challenge for designing usable security from two different viewpoints: design principles and user-centered security. Zurko and Simon [7] define user centered security as: "security models, mechanisms, systems, and software that have usability as a primary motivation or goal".

3. USABLE SECURITY PRINCIPLES

Please In order to design and evaluate user interfaces, a set of design rules and principles are required. Usability rules and principles give the direction to the designer to produce usable systems [15]. Among these principles we have: Shneiderman's eight golden rules [16], Nielsen's ten heuristics [13] and Gestalt principles of visual perception, where these principles help us to identify which is figure and which is ground [17].

The work of Whitten and Tygar [8] is a pioneer work in usable security field for an application of public key infrastructure (PKI). This application was evaluated as a good user interface, but the results shown that was not suitable usable to provide effective security for most of the users. Design strategies for developing usable security need take into account these properties.

Saltzer and Schroder [9], define the principle of psychological acceptability as: "it is essential that the human interface be designed for ease of use, so that users routinely and automatically apply the protection mechanisms correctly. Also, to the extent that the user's mental image of his protection goals matches the mechanisms he must use, mistakes will be minimized". According to the above, they present eight practical principles for the architecture-level software design, regardless of platforms or languages used. Software developers, use these design principles as a benchmark for building a more secure software [6].

The criteria used by Yee [10] for admitting an essential principle is that it should be a valid and non-trivial concern. Each principle is valid by showing how a violation of the principle would lead to a security breach. In the statement of these ten principles, the term "actor" is used to mean "user". The term "authority" only refers to the capability to take a particular action.

Garfinkel [18] proposes how a trade-off between security and usability could be improved implementing specific functionality in current operating systems and applications. To carry out this aim, Garfinkel developed a set of design principles for building and evaluating security systems using the Yee's principles [10].

Although end-users are the principal actors in the usable security field, the interfaces for security are important too since the consequences of usability problems can be vulnerable to attacks. Chiasson et al. [19] developed an initial set of ten design principles for security management interfaces. For their usability study using a two-password based authentication methods, they proposed two additional principles based in the Whitten and Tygar's principles [8].

Major risks are caused by poor usability. It is necessary to consider vulnerability analysis and risk assessment in order to properly manage current and emerging risks. Jøsang et al. [20] examine a set of eight usable security principles, they propose how can be incorporated into the risk management process, and discuss the benefits for applying these principles and process to current and future security solutions.

Herzog and Shahmehri [21] present concrete and verified guidelines for enhancing usability and security that delegates security decisions to users and captures these user decisions as a security policy. They hypothesized that existing tools for runtime set-up of security policies are not sufficient. As this proved true, they apply usability engineering with user studies to advance the state-of-the-art.

An analysis of user interfaces related to security has shown a need in for generating usable interfaces that help users to make decisions. Ibrahim et al. [22] proposed a further set of HCISec usability principles addressing the interface design of security alerts to the end-users; these principles take into account explicit and useful information for allowing a timely response and a consistent presentation of information.

The works presented in the literature have focused on identifying usability issues of security and propose guidelines and recommendations to address them. Nurse et al. [23] present an overview of the major developments in cybersecurity usability and HCISec, which provide guidance and recommendations for highly usable cybersecurity systems. One of the main contributions of this paper is to consolidate a number of existing design guidelines and offer an initial core list for future work.

4. USABLE SECURITY DESIGN PROCESS AND EVALUATION

Place Braz et al. [5] assert the need to develop a framework that provides evaluation methods which take into account security and usability for user authentication mechanisms. Braz et al. [24] introduce a new cognitive model that aims to model the tourist task when using a user authentication system. This method can to assist security designers to specify, design, inspect, and evaluate the security as well as usability aspects of user authentication mechanisms. This model integrates usable security concerns earlier into the requirements and design phase of the development lifecycle.

Mapayi et al. [25] develop a model for evaluating a functional usable authentication method using artificial neural networks. Jaferian et al. [26] propose and evaluate a new set of heuristics for evaluating ITSM (Information Technology Security Management) tools. The focus of these heuristics is oriented to and problems that hinder the use of tools in those ITSM activities that are distributed over time and space, involve collaboration between different stakeholders, and require knowledge to deal with the complexity.

Braz [5] proposes a trade-off between security and usability frameworks. She establishes a new usable security protocol using an inspection method called USS (Usable Security Symmetry), to address the usable security issues in the context of user authentication methods. These methods allow the design of authentication systems which are secure and usable. When trying to relate more closely to web-based authentication, the framework given by Straub and Baier [27] is very useful. They present a framework for evaluating PKI-based applications including 15 evaluation categories with accompanying example questions.

Mihajlov et al. [28] present a quantifying approach for evaluating security and usability that can be used in authentication mechanisms and is based in Renaud's work [29].The purpose of this approach is to guide the evaluation process of authentication mechanisms in a given environment by balancing usability and security and defining quantifiable quality criteria. Palmer [30] establishes over 200 evaluation criteria for aiding to take decision on the selection of the most appropriate mechanism for enabling computer systems to identify individuals using APIM (Automated Personal Identification Mechanisms).

The use of design tools suitable for a specific software development process, is a complex task that requires training and experience. Design tools selected for different requirements can conflict with each other, reducing their effectiveness and usability and causing security vulnerabilities. Hausawi and Allen [31] proposed principles to improve the selection of the appropriate design tools for security, usability, and usable security in order for the design process to meet the requirements' needs. Moreover, the principles help to identify trade-offs in the selection of design tools by dis covering conflicts and helping to overcome contradictions in design decisions.

Current approaches to security fail to implement user centered designs, resulting in systems hard to use and ineffective security mechanisms. A way for achieving a trade-off between security and usability, can include a description of how design decisions can lead to find vulnerabilities while users use the system. Collet [32] presents requirements and guidelines for designing usable and secure systems, and examines how these principles can be incorporated into the software development process.

AEGIS (Appropriate and Effective Guidance for Information Security) presented by Flechais et al. [33] was initially designed to help developers to identify security challenges early in the development process and supplying systematic methods. The main aim of AEGIS is to provide better support for the development of secure systems. This method includes asset identification, risk and threat analysis and context of use, and its application to case studies. An additional benefit of the method is that the involvement of stakeholders in the high level security analysis improves their understanding of security, and increases their motivation to comply with policies.

Markotten [34] proposed the concept of user-centered security engineering to bridge the gap between security and usability. This method has been pursued for the development and implementation of a security tool. This model can be a good starting point for developing a complete model for designing and implementing usability in security software. Yeratziotis et al. [35] present a framework within the context of on-line social networks that are particular to the health domain. The framework consists of three components: a phase process, a validation tool and a usability evaluation.

Faily [36] presents a framework called IRIS (Integrating Requirements and Information Security) for specifying usable and secure systems. The framework considers the system design process using three viewpoints: usability, security and requirements. This work shows that IRIS integrates techniques and tools for their supporting the design of usable and secure systems. Finally, Parveen et al. [37] propose a flow diagram for secure and usable requirements specification process which identifies functional and non-functional requirements which includes threats, vulnerabilities and risks.

5. ANALYSIS OF APPROACHES

5.1 Research Method

The research method is based in the systematic review proposed by Kitchenham et al. [38]. The systematic review starts establishing some research questions according to a proposed approach. The main research questions were:

*Q*1: What usability principles are applied to security systems, mainly for user authentication?

*Q*2: Which methodological approaches are used for evaluating the usability in security and in user authentications systems?

*Q*3: What processes aid to design secure systems and user authentication services based on principles and methods of evaluation according to usable security requirements?

For the search process, on-line databases such as IEEE, Springer, ACM, Science Direct, Scopus and Web of Knowledge were used. In order to filter the search, keywords according to the research questions were used. The keywords used for the systematic review were:

1. “usable security” AND “design process”
2. “usable security principles” AND “authentication principles”
3. “usable security evaluation” AND “usability authentication evaluation”
4. "authentication design process” AND “security design process”
5. “user-centered security” AND “user-centered authentication”

Also, the search process is limited to the years from 1995 to 2015. The papers found were filtered according to their title, keywords and an analysis of the abstract, introduction and conclusion. Table 1 presents the on-line databases, amount of papers found and relevant papers according to the above criteria.

Table 1: On-line Databases

Database	Papers Found	Relevant Papers
IEEE	18	3
Springer	7	3
ACM	14	4
Science Direct	11	2
Scopus	13	10
Web of Knowledge	10	3
Total	**73**	**25**

By using the systematic review method, about 73 papers were found and 25 of them which could answer the research questions were selected.

5.2 Results and Discussion

According to an analysis of the relevant papers obtained in the systematic review, the answers to the research questions are presented below:

*Q*1: **What usability principles are applied to security systems, mainly for user authentication?**

Table 2 presents a comparison of some usable security principles for the works presented in section 3. An important characteristic is that the principles proposed by the authors are similar and some of them with applications development [6]. However, these principles are not enough to solve problems of usability in the design of secure systems, especially for the design of user authentication services. Moreover, an agreement about a useful criteria for usable security design has not been established.

*Q*2: **Which methodological approaches are used for evaluating the usability in security and in user authentications systems?**

An important challenge in usable security is to achieve a user-centered development process that integrates usability and security concerns, and taking into account usable security principles. According to Table 3 we can see that although there are works about usability evaluation methods for security, lack of usability principles suitable for security systems mainly to user authentication, this makes that the evaluation methods are not complete because most of them, not take into account the user. The inability of users to evaluate the security properties, complicates the experimental design. Besides, users are not able to describe the security problems they have experienced [39].

*Q*3: **What processes aid to design secure systems and user authentication services based on principles and methods of evaluation according to usable security requirements?**

According to the works presented in Table 4, there are some process design methods considering usability and usability concerns. However, the lack of suitable usable security principles and evaluation methods taking into account to user, are not considered in these design processes mainly for user authentication. An important feature of these design processes is that they are focused on some phase of the development process. Therefore, software developers will need to combine independent process models making more complex the design tasks.

Based on the systematic review, usable security principles are not sufficient to solve usability problems in the design of user authentication services. The lack of suitable usability principles for designing user authentication systems, imply that the usability evaluation methods are not suitable because they do not take into account the user. Finally, the lack of usability principles and evaluation methods for de signing user authentication systems, is a disadvantage for developing a process or technique that extends from design to implementation and applications.

According to the above, the following research question is proposed: **What processes aid the design of users authentication systems through a user-centered approach based on usability principles and evaluation methods for security systems**?

6. CONCLUSIONS AND FUTURE WORK

In this paper we have carried out a systematic literature review on usable security, mainly about user authentication systems. Many users are not able to perceive the security issues correctly, generating a security threat due to misunderstanding and avoid tactics to protect the system. The usability principles presented above are very similar to each other. In this context, criteria based on existing usability principles to find the usability problems in software security are required. Although there are different methods for evaluating the usability of security systems, these methods are not user-centered due to the lack of suitable usability principles. Finally, we have presented some processes for incorporating usability into secure software design including integration and validation. Future work will be oriented to studying and analyzing the usable security principles for the design and development of user authentication services.

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Table 2: Comparison of some usable security principles

Principle \ Work	[8]	[9]	[10]	[11]	[18]	[19]	[20]	[23]	[21]	[22]	[16]
Aesthetic and minimalist design	-	✓	✓	✓	-	✓	-	✓	✓	✓	✓
Design Interfaces based on user's mental model	✓	-	✓	✓	-	✓	✓	✓	✓	✓	✓
Mental and physical load must be tolerable	-	-	-	-	-	-	✓	-	-	-	✓
Accommodate all type of users	-	-	-	-	-	-	-	✓	-	-	-
Trust and satisfaction	✓	-	-	✓	-	-	-	✓	-	✓	✓
Users must have sufficient knowledge to make decisions	-	-	-	✓	-	✓	-	-	-	-	-
Consistent meaningful vocabulary and terminology	-	-	✓	✓	✓	-	-	✓	-	✓	✓
Appropriate boundaries	-	-	✓	-	-	✓	-	-	-	-	-
Make security functionality visible and accessible	-	-	-	-	-	-	-	✓	-	✓	-
Security tools are not solutions	-	-	-	-	-	-	-	✓	-	-	-

Table 3: Comparison of criteria for usable security evaluation

Criteria \ Work	[24]	[25]	[26]	[27]	[28]	[30]	[35]
User-centered evaluation	✓	-	-	✓	-	-	-
Evaluation for user authentication	-	✓	-	-	✓	-	-
Uses usable security principles	✓	-	✓	-	-	✓	✓
Evaluate usability and security	✓	-	✓	-	✓	✓	-

Table 4: Comparison of criteria for design process

Criteria \ Work	[32]	[31]	[24]	[33]	[34]	[5]	[35]	[36]	[37]
User-centered design process	✓	-	-	-	✓	-	-	✓	-
Process applying to systems development	-	✓	-	✓	-	-	✓	✓	✓
Used to user authentication	-	-	✓	-	-	✓	-	-	-

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Evaluando la usabilidad de aplicaciones groupware mediante un método dirigido por modelos para el análisis de la interacción del usuario

Rafael Duque Medina
Department of Mathematics, Statistics and Computer Science
University of Cantabria
Avenida de Los Castros S/N
39005 Santander (Spain)
Rafael.Duque@unican.es

Alicia Nieto-Reyes
Department of Mathematics, Statistics and Computer Science
University of Cantabria
Avenida de Los Castros S/N
39005 Santander (Spain)
Alicia.Nieto@unican.es

ABSTRACT

La evaluación de la usabilidad de un sistema interactivo implica analizar el grado en el cual el sistema puede ser utilizado con efectividad, eficiencia y satisfacción en un contexto de uso específico. Este tipo de evaluaciones habitualmente tienen que enfrentarse con la dificultad de determinar la usabilidad de aplicaciones *groupware* que permiten a un grupo de usuarios interactuar entre ellos en cualquier momento y lugar mediante dispositivos móviles. Las evaluaciones de usabilidad realizadas en laboratorios pueden estar lejos de reproducir esta realidad donde usuarios geográficamente distribuidos interactúan entre sí constantemente. Sin embargo, las evaluaciones de usabilidad pueden aprovechar las ventajas de un soporte computacional que observe el comportamiento de los usuarios en contextos reales de uso (trabajo, hogar, lugares públicos, etc.) para calcular métricas que aporten información acerca de la efectividad y eficiencia de la interacción (tasa de errores, velocidad de ejecución, etc.). Para ello, este artículo describe un entorno que permite a los evaluadores especificar modelos que representen las interacciones de los usuarios que deben ser estudiadas y un conjunto de métricas que deben ser calculadas para analizar la usabilidad del sistema. Posteriormente, el entorno genera automáticamente el soporte computacional para ejecutar el proceso de evaluación de la usabilidad que ha sido modelado. Finalmente, el entorno genera un informe con los resultados de la evaluación y aplica un modelo estadístico para encontrar la relación entre los valores de estas métricas y la satisfacción del usuario con el sistema, la cual es obtenida mediante un cuestionario. El artículo incluye un caso de estudio donde el entorno ha sido puesto en acción para evaluar la usabilidad de una aplicación *groupware* para dispositivos móviles que permite la realización de apuestas deportivas.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces - *Evaluation/methodology, User-centered design*

H.5.3 [**Information Interfaces and Presentation**]: Group and Organization Interfaces - *Computer-supported cooperative work*

General Terms

Measurement, Design, Human Factors, Verification.

Keywords

Computer-supported cooperative work; Software; Usability.

1. INTRODUCCIÓN

Uno de los puntos clave en los métodos de desarrollo del software centrados en el usuario es la realización de frecuentes evaluaciones que verifiquen la usabilidad del sistema en construcción. La Organización Internacional para la Estandarización [83] define la usabilidad como "*la medida en la que un producto se puede usar por determinados usuarios para conseguir objetivos específicos con efectividad, eficiencia y satisfacción en un contexto de uso especificado*". Por tanto, la evaluación de la usabilidad de un sistema interactivo implicará llevar a cabo un enfoque metodológico para identificar problemas con el sistema para ser usado con efectividad, eficiencia y satisfacción. En la literatura se pueden encontrar un importante número de métodos de evaluación (heurísticas, inspecciones, test de laboratorio, etc.) [84], entre los que pueden seleccionarse aquellos que mejor encajen con factores como el tiempo disponible, la criticidad del sistema o los costes asumibles [85].

Las evaluaciones de usabilidad llevadas a cabo con usuarios finales en contextos reales de uso pueden implicar la necesidad de analizar actividades llevadas a cabo por grupos de usuarios que interactúan entre sí en cualquier momento y lugar mediante dispositivos móviles. Por tanto, una evaluación de la usabilidad mediante un experimento controlado en laboratorio podría estar lejos de reproducir este contexto real de uso de la aplicación bajo evaluación. Las herramientas software pueden contribuir a efectuar evaluaciones en estos contextos reales de uso mediante mecanismos que observen las interacciones de los usuarios y generen métricas con información sobre el grado en el cual el sistema es utilizado con efectividad y eficiencia (velocidad de ejecución, tasa de errores, etc.). Sin embargo, algunos factores deben tenerse en cuenta a la hora de construir este tipo de herramientas para que lleven a cabo el proceso de evaluación de forma efectiva. Primero, es preciso que estas herramientas permitan a los evaluadores definir las métricas más apropiadas para el sistema en evaluación y el correspondiente contexto de uso. Segundo, debe reducirse el esfuerzo extra de programación, y por tanto el coste asociado, que implica desarrollar un soporte computacional para observar la interacción del usuario y asignar valores a las métricas definidas. Tercero, estas herramientas deben ayudar a los evaluadores a determinar qué valores deben adquirir las diferentes métricas para considerarlas indicativas de un buen nivel de usabilidad en el sistema. Por ejemplo, cuál es la cantidad de tiempo que puede considerarse como aceptable para llevar a cabo una determinada tarea con el sistema. Cuarto, debe analizarse la relación entro los valores de estas métricas, calculadas automáticamente, y la satisfacción del usuario que puede conocerse mediante otros métodos de evaluación como un cuestionario. Así, el evaluador puede tener conciencia de qué aspectos evaluados por una métrica de usabilidad (operatividad, facilidad de aprendizaje, etc.) tiene mayor impacto en la satisfacción del usuario. Quinto, los métodos de evaluación ejecutados por este tipo de herramientas deben considerar las características específicas del sistema [86]. Por ejemplo, las aplicaciones *groupware* deben permitir al usuario no sólo estar al tanto de los efectos de sus propias interacciones con el sistema sino también conocer los efectos de las interacciones efectuadas por otros usuarios. Por tanto, la evaluación debe considerar criterios específicos como la efectividad de los mecanismos de *awareness* para que el usuario se sienta parte de un colectivo.

Para abordar estos retos, este artículo propone un entorno que automatiza la evaluación de la usabilidad de aplicaciones *groupware* en contextos reales de uso. Este entorno incluye mecanismos que permiten a desarrolladores y evaluadores definir, de forma flexible, las métricas que mejor se ajusten a la aplicación y a su contexto de uso. Esto se consigue mediante un enfoque dirigido por modelos que permite a evaluadores modelar las interacciones a analizar y las métricas a calcular con ayuda de un lenguaje visual. Además, este lenguaje permite clasificar cada interacción de acuerdo a su propósito (comunicarse con otros usuarios, manipular elementos compartidos, etc.). Posteriormente, el entorno crea automáticamente el código fuente del soporte computacional que lleva a cabo la evaluación para reducir así el esfuerzo de programación. Finalmente, el entorno aplica un modelo estadístico para determinar el valor que debe tomar cada métrica con objeto de maximizar la satisfacción del usuario con la aplicación.

2. TRABAJOS RELACIONADOS

Los métodos de desarrollo centrados en el usuario no han sido ajenos a las tendencias de los últimos años para automatizar la especificación y construcción del software. Este es el caso de la propuesta de Molina & Toval [87] que permite a desarrolladores especificar funcionalidades relacionadas con la usabilidad del sistema y generar automáticamente el correspondiente código fuente mediante un enfoque dirigido por modelos. Sin embargo, estos métodos dirigidos por modelos han sido utilizados generalmente para construir el sistema interactivo y no han sido aprovechados para generar soporte computacional que permita evaluar su usabilidad. Esta situación hace que el evaluador tenga a su disposición herramientas como USherlock [88] que evalúa una serie de propiedades predefinidas de la interfaz de usuario como el contraste de colores o el tamaño de los widgets para identificar problemas de usabilidad, pero no permite a los evaluadores configurar el proceso de evaluación.

Además, la evaluación de la usabilidad no tiene por qué limitarse a considerar una serie de propiedades de la interfaz de usuario sino que un análisis de las interacciones generadas por el usuario en un contexto de uso real puede enriquecer esta evaluación. Madan & Dubey [84] efectúan una revisión de los principales conceptos y atributos (facilidad de aprendizaje, flexibilidad, etc.) que pueden utilizarse en estas evaluaciones. Seffah et al. [89] definen un modelo llamado Quality in Use Integrated Measurement (QUIM) que incluye 127 métricas para evaluar los este tipo de atributos y conceptos relacionados con la usabilidad del sistema. QUIM trata de unificar en un único modelo los principales modelos conceptuales y estándares de la literatura. Aunque los autores hacen un esfuerzo para establecer un modelo consolidado, este tipo de trabajos no considera la posibilidad de disponer de un mecanismo flexible por el cual los evaluadores puedan diseñar sus propias métricas ni proporcionan unas pautas metodológicas para seleccionar aquellas métricas que mejor se adapten a un sistema específico ni a un contexto de uso determinado. Para ello, Suárez et al. [90] establecen una taxonomía de sistemas y proponen criterios específicos para evaluar la usabilidad de cada sistema, según sus funcionalidades y características. Esta clasificación incluye el *groupware* como un tipo específico de sistema. Entre las particularidades del *groupware*, cabe resaltar que permite no sólo la comunicación entre usuarios sino la creación colaborativa de artefactos en espacios de trabajo compartido. Las aplicaciones *groupware* soportan interacciones cuyos efectos pueden ser percibidos por otros usuarios [91]. Por tanto, la evaluación debe considerar criterios específicos como la efectividad de los mecanismos de *awareness* de la aplicación y el soporte para generar interacciones sociales. Mattsson [92] propone algunas métricas específicas que evalúan el grado en el cual la aplicación permite efectuar de forma intuitiva interacciones sociales. Sin embargo, esta propuesta tampoco proporciona un enfoque flexible para que el evaluador defina sus propias métricas.

El análisis de los valores que toman las métricas de usabilidad puede efectuarse mediante técnicas de aprendizaje automático que indiquen el grado de influencia de ciertos atributos (navegabilidad, comprensibilidad, etc.) en la usabilidad del sistema [93]. Este análisis puede procesar información generada por distintos métodos de evaluación y usar técnicas de minería de datos [94] para generar informes sobre los problemas detectados. De acuerdo a Nielsen & Levy [95], en la mayoría de los casos existe una correlación entre la satisfacción subjetivas del usuario y aquellas métricas que objetivamente cuantifican aspectos sobre la calidad de la interfaz de usuario. Sin embargo, los evaluadores deben identificar cuáles son esas métricas que están relacionadas con la satisfacción del usuario.

3. UN ENTORNO PARA ANALIZAR LA INTERACCIÓN DEL USUARIO

La Figura 1 muestra los principales pasos seguidos por el entorno para ejecutar el proceso de evaluación de la usabilidad. Estos pasos son los siguientes:

1. El evaluador define un modelo de observación con las acciones soportadas por la aplicación y que deben ser analizadas. El evaluador también define un modelo con las métricas a calcular y se genera automáticamente el código fuente del soporte computacional que ejecutará la evaluación. El proceso de evaluación es puesto en marcha para asignar valores a las métricas y se pregunta al usuario cuál es su satisfacción con la aplicación.
2. El entorno aplica un modelo estadístico para encontrar las relaciones entre los valores de las métricas calculadas automáticamente y la satisfacción del usuario.

3. El entorno genera un informe con los resultados del proceso de evaluación. Este informe incluye los valores que toman las distintas métricas y un listado de recomendaciones.

Las siguientes subsecciones describen el soporte que proporciona este entorno para llevar a cabo cada uno de estos tres pasos.

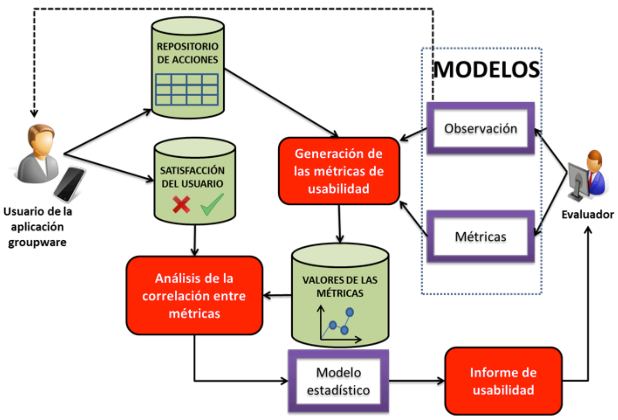

Figura 1. Ciclo de vida de evaluación de la usabilidad.

3.1 Modelando acciones y métricas

El entorno proporciona un Lenguaje Específico de Dominio (Domain-Specific Language, DSL) para representar las acciones soportadas por la aplicación bajo evaluación. De acuerdo a Hilbert & Redmiles [96], estas acciones deben ser capturadas porque suponen una fuente de información fructífera para conocer el comportamiento de los usuarios. El modelo de observación incluye mecanismos para clasificar el propósito de cada acción, la herramienta concreta de la aplicación que la soporta y cómo contribuye a resolver tareas de mayor granularidad. Posteriormente, el entorno transforma estos modelos de observación para generar código fuente del soporte computacional que procese las acciones de los usuarios y calcule las métricas definidas [97].

Este DSL ha sido representado utilizando un lenguaje visual que permite a los evaluadores modelar un diagrama jerárquico cuyo elemento raíz define la aplicación *groupware*. El segundo nivel de la jerarquía está compuesto de las herramientas integradas en la aplicación. Los evaluadores clasifican las acciones según su propósito en el tercer nivel de la jerarquía. De acuerdo al modelo dual de Barron [98], los procesos colaborativos incluyen un espacio relacional en el cual los usuarios efectúan acciones para interactuar socialmente con otros usuarios y un espacio de contenidos en el cual los usuarios ejecutan acciones para resolver tareas. El modelo de observación clasifica las acciones del espacio relacional como comunicativas o protocolarias. Una acción es considerada como comunicativa cuando existe un intercambio de mensajes entre usuarios. Las acciones protocolarias no implican un intercambio de mensajes entre los participantes, pero ayuda a coordinar o armonizar el proceso colaborativo, por ejemplo, votando una propuesta. Las acciones del espacio de contenidos son calificadas como instrumentales o cognitivas. Las acciones instrumentales modifican un elemento de un espacio compartido. Sin embargo, las acciones cognitivas usan un elemento compartido sin modificar su estado, por ejemplo, para hacer una copia de él.

Finalmente, los evaluadores asignan un nombre a cada acción en el cuarto nivel de la jerarquía. Además, los evaluadores describen cómo esas acciones contribuyen a resolver determinadas tareas. El concepto de tarea es considerado como una parte del proceso colaborativo que produce artefactos o resultado de interés. Para ello, cada acción puede relacionarse con una tarea con alguna de estas asociaciones:

- Asociación *start*: Esta acción se ejecuta por el usuario al comienzo de una nueva tarea.
- Asociación *end*: La acción implica la finalización de una tarea.
- Asociación *solve:* La acción contribuye a resolver una tarea, pero no la inicia ni la finaliza.

La Figura 2 (izquierda) ilustra el uso de esta herramienta con un fragmento de un modelo de observación. Este modelo incluye alguna de las acciones soportadas por una aplicación *groupware* que soporta el diseño de diagramas de flujo. Se puede observar como el elemento raíz específica el nombre de la aplicación (colEdit en la Figura 2, izquierda). El segundo nivel incluye las herramientas integradas en la aplicación. En este caso la aplicación incluye un chat estructurado y un editor colaborativo de diagramas. El tercer nivel incluye iconos que definen el tipo de acciones soportadas por cada herramienta. Las acciones soportadas por el chat son clasificadas como comunicativas. Las acciones soportadas por el editor son clasificadas como instrumentales. El cuarto nivel del modelo incluye un conjunto de identificadores para las acciones soportadas por estas herramientas.

El evaluador introduce asociaciones con información descriptiva de cómo las acciones contribuyen a llevar a cabo la tarea de edición de diagramas de flujo. Así, cada vez que el usuario abre una nueva ventana, comienza la tarea de edición. Posteriormente el usuario ejecuta una serie de acciones (*insert* y *delete*) para construir el diagrama. Finalmente, el usuario cierra la ventana (acción *exit*) y la tarea de edición finaliza.

Figura 2. Fragmentos de los modelos de observación (izquierda) y de métricas (derecha).

Tras definir el modelo de observación, los evaluadores pueden usar un lenguaje visual para definir un modelo con un conjunto de métricas que analicen la interacción del usuario. Para definir métricas de las acciones efectuadas por los usuarios, primero el evaluador puede especificar de tres modos las características de las acciones que deben ser analizadas: (i) son todas las acciones correspondiente a un tipo concreto (instrumental, cognitiva, comunicativa, protocolaria), (ii) es una acción específica (*insert*, *exit*, etc.), (iii) son todas las acciones soportadas por una herramienta (editor, chat, etc.). Posteriormente, el evaluador especifica si deben contabilizarse las ocurrencias de las acciones modeladas o el tiempo empleado en su ejecución. Finalmente, el evaluador puede definir nuevas métricas que son calculadas aplicando operaciones aritméticas y estadísticas a métricas calculadas previamente. La Figura 2 (derecha) muestra un fragmento de este modelo en el cual el evaluador define unas métricas elementales (*NActions*) para contabilizar el número de acciones ejecutadas y para conocer el tiempo empleado en ellas (*NTime*). Finalmente, el evaluador define una nueva métrica (ver *Actions_Density* en Figura 2, derecha) con el número de acciones ejecutadas por unidad de tiempo.

3.2 Relacionando métricas de usabilidad objetivas y subjetivas

Una vez que se han calculado los valores de las métricas, el entorno analiza esta información para identificar qué métricas, calculadas automáticamente (tasa de errores, tiempo de aprendizaje, etc.), tienen un mayor impacto en la satisfacción subjetiva del usuario, la cual no ha sido obtenida automáticamente por el entorno. Así, podemos distinguir entre métricas objetivas, aquellas calculadas automáticamente por el entorno, y subjetivas, aquellas especificadas por el usuario. El objetivo es determinar qué métricas objetivas deben ser considerados de alta prioridad en las nuevas iteraciones del ciclo de vida del software por estar relacionadas con la satisfacción del usuario.

Por lo tanto, el propósito principal de esta sección es encontrar una función de las métricas objetivas que explique la(s) métricas(s) subjetiva(s), como respuesta. Esto podría hacerse sencillamente mediante la aplicación de un modelo de regresión múltiple.

3.2.1 *Modelos de regresión múltiple*

La regresión múltiple es una metodología estadística que modela la relación entre dos o más métricas objetivas y una o más métricas subjetivas. El modelo de regresión múltiple más común es la Regresión Lineal Múltiple (RLM), cuando sólo hay una métrica subjetiva, y la regresión lineal múltiple multivariante, o simplemente regresión lineal multivariante, cuando hay diversas métricas subjetivas. Para facilitar la explicación, nos concentramos en el caso básico de una sola métrica subjetiva.

Así, dadas X_1, X_2, ..., X_p métricas objetivas, con p mayor o igual que dos, y Y una métrica subjetiva, el modelo de RLM busca β_0, $\beta_1, \ldots, \beta_p$ tal que $Y = \beta_0 + \beta_1 X_1 + \cdots + \beta_p X_p + \varepsilon$, donde ε es una variable aleatoria de media cero y varianza finita independiente de X_1, X_2, ..., X_p, conocida como ruido. La Ecuación 1 muestra la expresión que relaciona la estimación de la métrica subjetiva $\hat{Y}$ con las métricas objetivas (X_1, X_2,..., X_p,). $\hat{\beta}_0$ sería el término constante de la ecuación (véase la Ecuación 1).

$$\hat{Y} = \hat{\beta}_0 + \hat{\beta}_1 X_1 + \cdots + \hat{\beta}_p X_p.$$

Ecuación 1. Relación entre las métricas subjetivas y objetivas.

Para medir la calidad del ajuste de los datos al modelo estadístico se utiliza el coeficiente de determinación, calculado como $\sum_{i=1}^{n} (\hat{Y}_i - \bar{Y})^2 / (Y_i - \bar{Y})^2$, donde $\bar{Y}$ denota la media muestral y n el tamaño muestral, y toma valores entre 0 y 1; valores cercanos a 1 indicando un buen ajuste al modelo. Cuando el coeficiente de determinación no está cerca del valor 1, se debe utilizar un modelo más complejo que el lineal.

Dadas X_1, X_2, ..., X_p, una posibilidad es simplificar el modelo de RLM mediante un subconjunto de estas variables. Esto se realiza mediante el cálculo del coeficiente de determinación de cada una de todas las posibles combinaciones de variables X_1, X_2, ..., X_p. Por lo tanto, se selecciona la combinación que contiene menos variables dentro de aquellas que tienen un alto coeficiente de determinación.

Sin embargo, en el caso en el que la métrica subjetiva consiste en categorías ordenadas, variable ordinal, los modelos de regresión múltiple utilizados son los modelos logit ordenado y probit ordenado. Cuando la variable, subjetiva, categórica ordenada tiene J categorías, cualquiera de estos modelos consiste en un conjunto de J-1 ecuaciones. Un ejemplo de categoría ordenada se utiliza a menudo en los cuestionarios que preguntan a los usuarios si se sienten satisfechos con el sistema y deben responder: (i) muy en desacuerdo, (ii) en desacuerdo, (iii) ni de acuerdo ni en desacuerdo, (iv) de acuerdo o (v) totalmente de acuerdo. Podemos corresponder estas respuestas con los valores 1, 2, 3, 4 y 5, respectivamente. El motivo de aplicar el logit ordenado o el probit ordenado, y no una regresión lineal, es que los números asociados a las categorías ordenadas no significan mucho ya que las distancias entre los diferentes valores de la medición no son necesariamente equivalentes a las distancias entre los valores a los que las hemos hecho corresponder. Es decir, en el ejemplo anterior puede haber una distancia mayor entre las personas que están muy en desacuerdo y aquellas que están en desacuerdo sobre un asunto en particular que entre las que están en desacuerdo y las que ni están de acuerdo ni en desacuerdo sobre esa materia; mientras que la distancia entre 1 y 2 es la misma que entre 2 y 3.

3.2.2 *Propuesta para la medición subjetiva categórica ordenada*

Por lo tanto, la ventaja de RLM es que modela los datos utilizando solamente una ecuación, lo que simplifica la interpretabilidad del modelo; mientras que el modelo logit ordenado, o probit ordenado, requiere de múltiples ecuaciones. Si el modelo de RLM se aplica a un conjunto de datos donde la medición subjetiva es categórica, la variable $\hat{Y}$ resultante es continua, no categórica. La solución directa sería estimar Y redondeando $\hat{Y}$ a cero posiciones decimales, pero entonces tendríamos la problemática expuesta anteriormente que las distancias entre los diferentes valores de la medición no son necesariamente equivalentes a las distancias entre los valores a las que les hemos hecho corresponder. De esta forma, nuestra propuesta consiste en estimar los límites adecuados para hacer el redondeo. Es decir, el número 2.4943 redondea naturalmente al número entero 2, pero si los límites estimados son por ejemplo (1,5195, 2,4918) para 2 y (2,4918, 3,5062) para 3, tendríamos que 2,4943 redondearía a 3. Así, cuando la medición subjetiva es categórica, logramos el beneficio de ambos modelos, logit / probit y RLM, al obtener una sola ecuación al mismo tiempo que tenemos en cuenta la naturaleza categórica de la métrica subjetiva.

Para estimar los límites de cada categoría utilizamos el siguiente procedimiento fácil de implementar, aunque otros procedimientos más complejos pueden utilizarse también, por ejemplo, utilizando la estimación de máxima verosimilitud. Dada una métrica subjetiva categórica con J categorías, denotamos por $V_j \coloneqq \{\hat{Y}_i | Y_i = j\}$, $j = 1, \dots, J$, al conjunto de valores de la variable continua $\hat{Y}$ (ver Ecuación 1) que corresponden al valor j de la métrica subjetiva.

Por todo ello, denotamos $lim_j \coloneqq mean(maxV_{j-1}, minV_j)$. Por lo tanto, cualquier valor menor que lim_2 se redondea a 1, cualquier valor mayor que lim_J se redondea a J y cualquier valor perteneciente a (lim_j, lim_{j+1}) se redondea a j para $j = 2, \dots, J-1$.

3.3 Informe

El entorno proporciona un informe con los resultados del proceso de evaluación de la usabilidad. Este informe incluye, en primer lugar, el conjunto de métricas con sus valores y con una descripción de sus objetivos. Estas métricas se clasifican como de alta prioridad cuando según el modelo estadístico tienen una influencia directa en la satisfacción del usuario y de baja prioridad cuando no es así. El entorno calcula los valores óptimos de las métricas de alta prioridad como aquellos que maximizan la satisfacción del usuario según el modelo estadístico. Posteriormente, el informe muestra la distribución porcentual de usuarios según su grado de satisfacción con la aplicación. Así, cuando existe un bajo porcentaje de usuarios satisfechos con la aplicación, el entorno relaciona este dato con la necesidad de mejorar los atributos de usabilidad evaluados por las métricas de alta prioridad. Para lograr estas mejoras, el entorno sugiere al evaluador desarrollar mecanismos que mejoren los aspectos analizados por estas métricas de alta prioridad. Para que el evaluador sea consciente del tipo de mecanismos que debe desarrollar, el entorno procesa los modelos de observación y de métricas y muestra qué aspectos son evaluados por las distintas métricas (facilidad para usar con rapidez una herramienta, las interacciones necesarias para resolver una tarea, etc.). Por último, el informe también incluye los resultados generados por el modelo estadístico (gráficas, ecuaciones, etc.).

4. CASO DE ESTUDIO

Esta sección describe un caso de estudio en el cual el entorno ha sido utilizado para llevar a cabo una evaluación de la usabilidad de una aplicación *groupware* móvil que soporta la realización colaborativa de apuestas deportivas. La Figura 3 (izquierda) muestra la interfaz de usuario principal de esta aplicación. La aplicación gestiona una lista de eventos deportivos y un usuario puede seleccionar uno de ellos para efectuar una apuesta. Posteriormente, el usuario solicita la colaboración de un grupo de usuarios para pronosticar cual será el resultado del evento deportivo y discutir la cantidad de dinero a apostar. Para este propósito, la aplicación incluye un panel de votaciones (ver Figura 3, centro) que permite al usuario proponer un pronóstico y una cantidad de dinero a apostar. Los otros usuarios del grupo utilizan este panel para votar la aprobación o el rechazo de esta propuesta. Cuando la mayoría de los miembros del grupo aceptan la propuesta, el resultado se introduce automáticamente en un espacio con las apuestas deportivas del usuario. Los usuarios también pueden utilizar un chat estructurado (ver Figura 3, derecha) para intercambiar ideas sobre la mejor forma de generar las apuestas. Todas estas funcionalidades están explicadas mediante un tutorial interactivo incluido en la aplicación.

Un evaluador utilizó el entorno propuesto para evaluar la usabilidad de esta aplicación. Esta evaluación se llevó a cabo mediante un conjunto de métricas que analizan la interacción de 21 grupos de 4 usuarios, formados aleatoriamente, quienes generaron colaborativamente 5 apuestas deportivas. Las siguientes subsecciones describen el proceso de evaluación que se siguió.

4.1 Definiendo los modelos

El modelo de observación estuvo compuesto por un elemento raíz que identifica la aplicación para realizar apuestas. El segundo nivel de la jerarquía integra los siguientes seis herramientas o espacios de la aplicación (ver Figura 3, izquierda): (i) el espacio para seleccionar un nuevo evento deportivo, (ii) la lista de apuestas del usuario, (iii) el panel de votación, (iv) el chat estructurado, (v) el espacio para crear nuevos grupos y (vi) el tutorial. El tercer nivel de la jerarquía clasifica del siguiente modo las acciones de cada herramienta. Las acciones soportadas por el chat estructurado se clasifican como comunicativas, ya que permite a los usuarios intercambiar mensajes. Las acciones soportadas por la herramienta de votación se clasifican como protocolarias, ya que se utilizan para llegar a un acuerdo acerca de las apuestas. Cuando los usuarios logran un acuerdo sobre cómo realizar una apuesta, la aplicación realiza automáticamente una acción instrumental para generar esta apuesta. Las acciones soportadas por las otras herramientas se clasifican como cognitivas; no interactúan con ningún elemento compartido y tienen otros propósitos como mostrar las funcionalidades de la aplicación con un tutorial. Por último, el evaluador asigna identificadores a las distintas acciones en el último nivel de la jerarquía y describe la secuencia de acciones que debe ejecutar el usuario para generar apuestas.

Tras definir el modelo de observación, el evaluador utilizó el correspondiente lenguaje visual para modelar las siguientes cuatro métricas [99]:

- Tiempo de aprendizaje: Es una métrica que cuantifica cuánto tiempo necesitan los usuarios para aprender a usar la aplicación. La aplicación incluye un tutorial que explica las funcionalidades de la aplicación. El evaluador estableció esta métrica que cuenta los segundos empleados por los usuarios en este tutorial y en la exploración de la aplicación antes de empezar a realizar apuestas.
- Velocidad de ejecución: Esta métrica cuenta el tiempo que tarda el usuario en llevar a cabo las tareas soportadas por la aplicación. Para ello, el evaluador estableció esta métrica que contabiliza el número de segundos empleados por cada grupo en la tarea de generar cinco apuestas.
- Tasa de error por el usuario: Esta métrica cuantifica el número de acciones que realizan los usuarios y que no siguen el orden cronológico modelado en el modelo de observación para establecer una apuesta (por ejemplo, un usuario intenta introducir una apuesta deportiva antes de hacer una propuesta que cuente con el apoyo de los demás usuarios del grupo).
- Recuerdo en el tiempo: Esta métrica cuantifica el qué medida los usuarios pueden recordar cómo funciona la aplicación. Para este propósito, el evaluador reutilizó la métrica *tiempo de aprendizaje* en un nuevo caso de estudio que se llevó a cabo una semana después de este caso de estudio inicial. Por lo tanto, el evaluador pudo analizar en qué medida el usuario recuerda el funcionamiento de la aplicación ya que no tiene que volver a emplear su tiempo en el tutorial para recordar el funcionamiento de la aplicación.

La satisfacción del usuario es una métrica subjetiva, que no se calcula de forma automática por el entorno. Por esta razón, los usuarios contestaron un cuestionario que pedía cuantificar su satisfacción por medio de una escala Likert de cinco puntos.

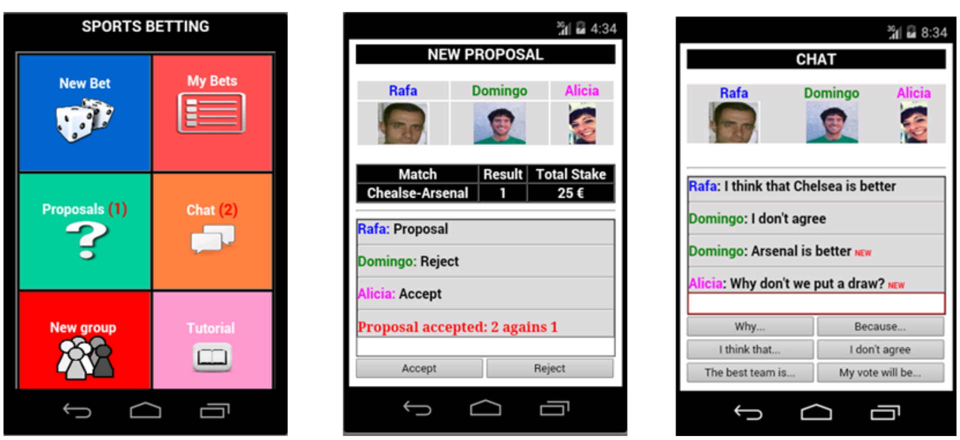

Figura 3. Interfaz de usuario principal de la aplicación (izquierda), panel de votación (centro) y chat estructurado (derecha).

4.2 El modelo estadístico

Tenemos un conjunto de 84 usuarios, organizados en 21 grupos, a los que se le han tomado cinco métricas. Cada una de las métricas se registró por usuario, con la excepción de la velocidad de ejecución que se registró por grupo. La Figura 4 muestra las cuatro métricas de usabilidad generadas por el entorno con respecto a la satisfacción subjetiva del usuario. De izquierda a derecha y de arriba a abajo, están representados el tiempo de aprendizaje, la velocidad de ejecución, la tasa de error por usuario y la retención en el tiempo, en comparación con la satisfacción.

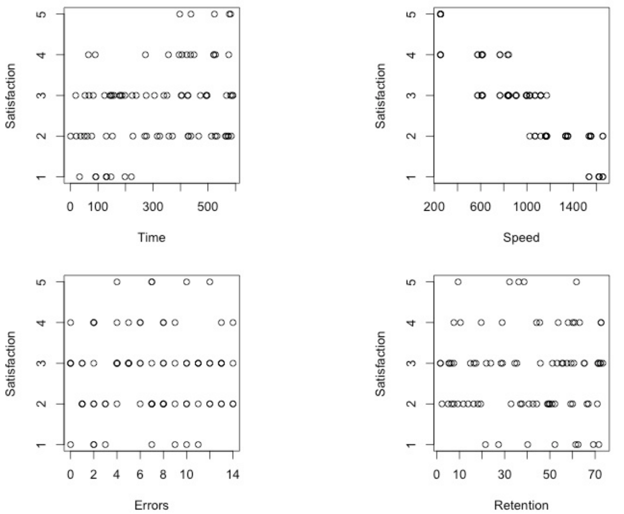

Figura 4. Gráfica de las métricas objetivas con respecto a la métrica subjetiva.

Como la satisfacción es una métrica subjetiva categórica, nuestro objetivo es utilizar el procedimiento propuesto en la Sección 3.2 consistente en aplicar un modelo de RLM al conjunto de datos anterior y luego encontrar los límites adecuados para redondear la variable continua propuesta por el modelo de RLM.

Para ello calculamos el coeficiente de determinación de todos los subconjuntos variables objetivas, seleccionado aquel que mejor explica la satisfacción al tiempo que ofrece un modelo simple. Los resultados del análisis de todos los subconjuntos de variables se proporcionan en la Figura 5. Esta figura representa las posibles combinaciones de las variables objetivas, y el término constante, con respecto al coeficiente de determinación (r2). Podemos observar que cuatro de las combinaciones nos proporcionan un coeficiente de determinación de 0,93 (una vez redondeado a dos decimales). De mayor a menor coeficiente de determinación, estas combinaciones se componen de una combinación de las cuatro métricas, dos combinaciones de tres métricas y una combinación de dos métricas. Seleccionamos la combinación de dos métricas, ya que nos proporciona el modelo más simple que tiene un coeficiente de determinación más alto. Si redondeáramos a cuatro decimales, coeficiente de determinación de esta combinación es 0.9266. Las dos métricas son el tiempo de aprendizaje y la velocidad de ejecución.

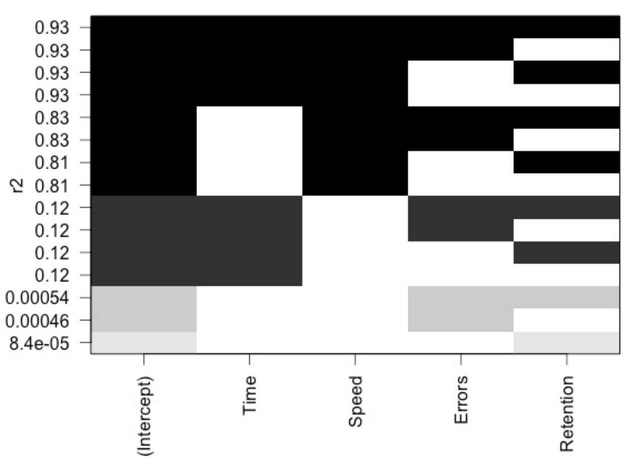

Figura 5. Análisis de todos los subconjuntos de variables en la RLM.

Por lo tanto, un modelo de RLM se aplica al conjunto de datos representado en la Figura 4 utilizando las variables tiempo de aprendizaje y velocidad de ejecución, frente a la satisfacción. La Ecuación 2 incluye la expresión obtenida donde $\widehat{Satisfacción}$ denota la satisfacción estimada no redondeada, Tiempo representa el tiempo de aprendizaje y Velocidad representa la velocidad de ejecución. Por lo tanto, esta ecuación nos proporciona un valor estimado de la satisfacción, dados el tiempo de aprendizaje y la velocidad de ejecución. La satisfacción sólo toma valores en el conjunto {1, 2, 3, 4, 5}, mientras que la satisfacción estimada no redondeada puede tomar valores decimales. Por lo tanto, después de aplicar la Ecuación 2 redondeamos adecuadamente la $\widehat{Satisfacción}$ para obtener la satisfacción estimada.

$$\widehat{Satisfacción} = 1.8559 * 10^{-3} Tiempo - 2.2625 * 10^{-3} Velocidad + 4.4592$$

Ecuación 2. Relación de la satisfacción de los usuarios con el tiempo de aprendizaje y la velocidad de ejecución.

Utilizando el conjunto de datos, representado en la Figura 4, dibujamos en la Figura 6 la satisfacción verdadera frente a la satisfacción estimada. La gráfica de la izquierda de la Figura 6 representa la satisfacción verdadera frente a la satisfacción no redondeada; es decir, representa la satisfacción como se da en el conjunto de datos, representado en la Figura 4, con respecto al resultado de la aplicación de la Ecuación 2 al tiempo de aprendizaje y la velocidad de ejecución dadas en el conjunto de datos. Mientras tanto, la gráfica de la derecha de la Figura 6 representa la satisfacción verdadera frente a la satisfacción redondeada de forma natural; es decir, representa, como antes, la satisfacción como se da en el conjunto de datos pero, aquí, con respecto al resultado de redondear, a los números naturales, la aplicación de la Ecuación 2 al tiempo de aprendizaje y a la velocidad de dadas en los datos.

Debido a que los límites apropiados en el redondeo no están siendo utilizados, hay tres errores de clasificación, que son visibles en Figura 6 de color azul, rojo y verde. Se corresponden con el valor 2 de la satisfacción, medida en el conjunto de datos, y los valores 2.500571, 2.506287 y 1.477177 de $\widehat{Satisfacción}$. Después de realizar el redondeo natural, estos valores corresponden respectivamente a 3, 3, y 1, en lugar de a 2, el valor que toma la medición de la satisfacción en el conjunto de datos.

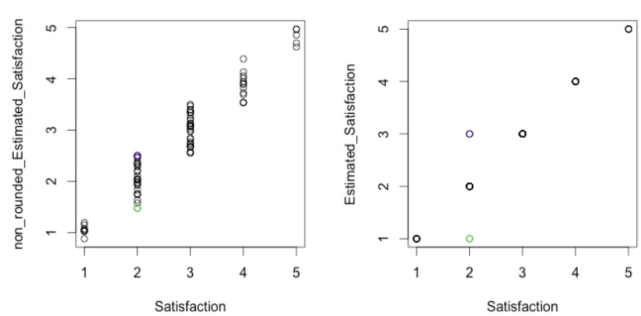

Figura 6. Satisfacción vs. satisfacción estimada, antes de ser redondeada de forma natural (izquierda) y después (derecha).

Como se propone en la Sección 3.2, el siguiente paso es encontrar los límites adecuados para hacer el redondeo. Se obtiene $(lim_2, lim_3, lim_4, lim_5) = (1.336973, 2.529228, 3.516011, 4.505122)$. Como los tres errores de clasificación anteriores pertenecen a (lim_2, lim_3), no hay ninguna clasificación errónea cuando se utilizan los límites apropiados en el redondeo.

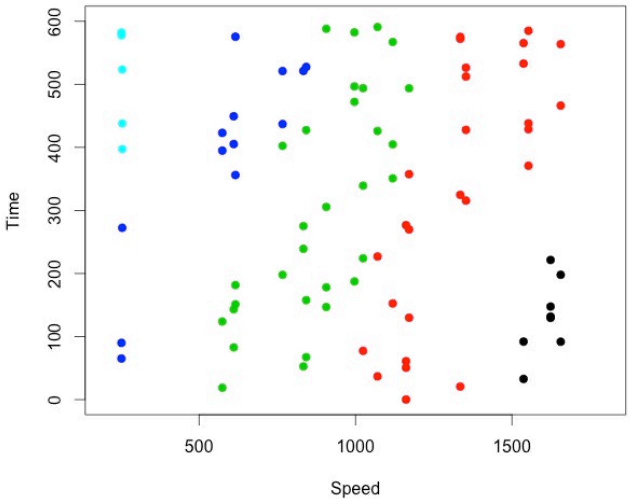

Figura 7. *Velocidad* contra *Tiempo* donde la satisfacción del usuario está coloreada en la gama de negro (1 en la escala de Likert) a azul claro (5 en la escala de Likert), pasando por el rojo (2), verde (3) y azul marino (4).

Del modelo dado por la RLM (Ecuación 2) se deriva que para estimar la satisfacción del usuario es suficiente con tener el tiempo de aprendizaje y la velocidad de ejecución. De hecho, la satisfacción es directamente proporcional al tiempo de aprendizaje e inversamente proporcional a la velocidad de ejecución. Esto se puede observar en la Figura 7, donde se representa la *velocidad* frente al *tiempo*. En esta figura los datos se han coloreado de acuerdo con el valor de la satisfacción, desde el negro (1 en la escala Likert) al azul claro (5 en la escala Likert), pasando por el rojo (2), verde (3) y azul marino (4). Por lo tanto, los 5 grupos pueden ser fácilmente identificables. Se puede deducir que, como muestra la Ecuación 2, una disminución de la *velocidad* y / o un aumento en el *tiempo* produce datos que suben al siguiente punto en la escala. En particular, para los datos con escala Likert 1 se observa que un aumento en el tiempo suficiente para subir a escala Likert 2. Análogamente, para los tres datos con escala Likert 4 y menor velocidad, basta un aumento en el tiempo para actualizar a escala de Likert 5.

4.3 Generando informes

La generación de un informe fue el último paso en este proceso de evaluación. Este informe mostró al evaluador que las métricas de alta prioridad son el *tiempo de aprendizaje* y la *velocidad de ejecución* porque tienen una alta influencia en la satisfacción del usuario. Sin embargo, el *recuerdo en el tiempo* y el *ratio de errores* son métricas de baja prioridad. El informe incluye información sobre el propósito de estas métricas.

La Figura 8 muestra un extracto de este informe, el cual incluye los valores que toman las dos métricas de alta prioridad cuando se maximiza la satisfacción del usuario en las tareas de evaluación. Además, el informe muestra el porcentaje de usuarios satisfechos con la aplicación. Así, el evaluador conoce el grado de satisfacción de los usuarios y qué aspectos deben mejorarse en futuras iteraciones del ciclo de vida de desarrollo del software.

Por último, el informe sugiere a los evaluadores reducir el tiempo necesario para realizar apuestas deportivas con la aplicación y mejorar el tutorial que explica las funcionalidades del sistema. Aunque los usuarios empleen más tiempo con este tutorial, suelen sentirse más satisfechos, ya que podría facilitarles una mejora en la velocidad de ejecución. Por otra parte, el informe muestra los resultados del modelo estadístico con las gráficas y la ecuación para predecir la satisfacción de los usuarios a partir de los valores de las métricas de alta prioridad.

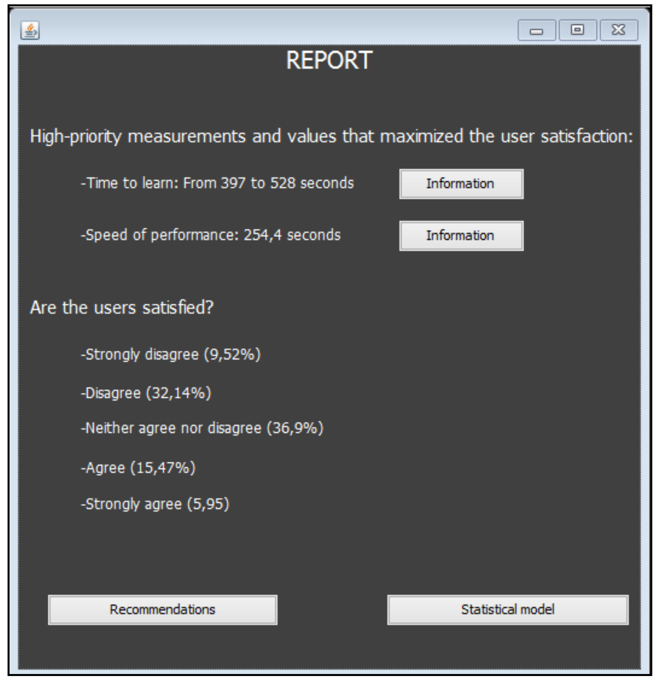

Figura 8. Fragmento del informe.

5. CONCLUSIONES

Las herramientas software pueden ser de utilidad para llevar a cabo procesos de evaluación de la usabilidad en contextos reales de uso como aquellos en los cuales los usuarios de aplicaciones *groupware* interactúan entre sí en cualquier momento y lugar mediante dispositivos móviles. Estas herramientas software pueden observar automáticamente las interacciones de los usuarios y generar un conjunto de métricas con información sobre la usabilidad de la aplicación.

Este artículo ha descrito un entono que, siguiendo un método dirigido por modelos, permite construir soporte computacional que ejecuta automáticamente procesos de evaluación de las usabilidad previamente modelados. El entorno permite a los evaluadores configurar modelos con las interacciones que deben observarse y con las métricas a calcular. De este modo el proceso de evaluación puede adaptarse a las características del sistema y del contexto de uso. Finalmente, el entorno genera el código fuente del soporte computacional que lleva a efecto este proceso de evaluación de la usabilidad y así el esfuerzo de programación se ve reducido.

El proceso de evaluación también analiza las relaciones entre los valores de las métricas y la satisfacción del usuario con la aplicación. Este análisis se realiza con un modelo estadístico que genera una ecuación mediante la cual se puede conocer qué métricas tienen una mayor correlación con la satisfacción del usuario y qué valores deben adoptar las métricas para optimizar esta satisfacción. Como resultado del proceso de evaluación, el entorno genera un informe con los valores que toma cada métrica y un conjunto de recomendaciones para mejorar las debilidades de la aplicación. Estas debilidades se identifican gracias a que los evaluadores incluyen el propósito de cada métrica en los correspondientes modelos y, por tanto, es posible acceder al factor que causa problemas en la usabilidad de la aplicación.

El entorno ha sido puesto en práctica para evaluar la usabilidad de una aplicación *groupware* móvil que soporta la realización colaborativa de apuestas deportivas. Esta evaluación ha proporcionado un informe que muestra cómo los usuarios más satisfechos son aquellos que finalizan sus tareas en un corto periodo de tiempo. Por tanto, la velocidad de ejecución debe ser un atributo de usabilidad prioritario por su impacto en la satisfacción del usuario. Esta evaluación muestra también que aquellos usuarios más satisfechos son aquellos que emplearon mayor tiempo en comprender el sistema con un tutorial. Por tanto, parece que la aplicación necesita un periodo de entrenamiento para ser utilizada con un buen nivel de rapidez y crear un sentimiento de satisfacción en los usuarios. Así, los desarrolladores y evaluadores son conscientes de que deben poner su atención en esos factores durante el proceso de desarrollo.

En el futuro se pretende trabajar en la evaluación de la expresividad del DSL, la posibilidad de utilizar otros dominios de aplicación e integrar los resultados del informe en el DSL para permitir refinar rápidamente los modelos con nuevas métricas.

6. AGRADECIMIENTOS

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Supporting Users Experience in a 3D eCommerce Environment

D.Contreras
Facultad de Ingeniería y Arquitectura, Universidad Arturo Prat, Chile
Dept. Matemàtica Aplicada i Anàlisi, Universitat de Barcelona, Spain.
dcontrag@maia.ub.es

M. Salamó, I. Rodríguez, A. Puig
Dept. Matemàtica Aplicada i Anàlisi, Universitat de Barcelona, Spain.
{maria, inma, anna}@maia.ub.es

A. Yañez
Facultad de Ingeniería y Arquitectura, Universidad Arturo Prat, Chile
alejandra.yanezt@inf.unap.cl

ABSTRACT

3D eCommerce spaces may often be highly populated spaces, with a huge number of users, areas and selling products. Therefore, their design should address different strategies to guide and assist users to locate and to be aware of the most interesting areas, products or users in there. In this paper, we present an approach to enhance and facilitate user buying experience in a large 3D eCommerce space. Specifically, we propose a collaborative recommendation framework which incorporates three types of interactive objects –the User Registration Object (URO), the Interactive Map Object (IMO), and the Recommendation Object (RO)– to guide users along the whole buying experience.

Categories and Subject Descriptors

I.3.6 [**Methodology and Techniques**]: Interaction techniques; H.5.2 [**User Interfaces**]: Interaction styles

General Terms

Theory.

Keywords

3D Virtual Worlds, Recommender Systems, Scalability.

1. INTRODUCTION

3D Virtual Environments are collaborative 3D interfaces which allow multiple users, represented as avatars, interact each other and with the environment to synchronously develop either fun (e.g., gaming) or serious (e.g., learning, shopping) activities. Depending on the domain, these activities are formed either by a controlled set of users, for example a number of learners, or an unknown high number of potential users such as customers in a shop. Specifically, 3D eCommerce spaces may often be highly populated spaces, with a huge number of users, areas and selling products, and therefore their design should address different strategies to guide and assist users to locate the most interesting areas, products, or users in there.

In a previous work, we presented a framework that integrated a recommender[2] in a 3D eCommerce space [1, 2]. The previous work focused on demonstrating the collaboration aspect, whereas this work addresses the scalability of the framework. To do so, we enrich our framework to consider a high number of users interacting in a large 3D eCommerce environment. In this context, this paper contributes with new interaction objects to enhance and facilitate users buying experience.

First of all, when users arrive to our proposed 3D virtual store they find a registration panel, which allow them to provide their current preferences, e.g. camera price or manufacturer. Second, an interactive map helps users to be aware of the whole buying space and thereby find places and/or other users based on given preferences. And finally, during the buying process, they interact with a conversational recommendation panel which helps them to reach their desired product (i.e., using a conversational recommender) and, at the same time, to review two type of suggestions provided by another recommender: (1) suggestions about similar products that have been previously purchased by other users; and (2) suggestions about affine people currently in the virtual store. The first type of suggestions is based on a HOR (History and Opinions based Recommender) and the second one is based on the similarity with other users' preferences specified to the CCR (Collaborative and Conversational Recommender) during the session.

2. FRAMEWORK OVERVIEW

This section presents an overview of our collaborative recommendation framework. As shown in Figure 2, it is divided in three layers.

In the top of Figure 1, the *3D Space Client* is an immersive 3D virtual space where users interact with the following elements: the User Registration Object (URO), the Interactive Map Object (IMO), the Recommendation Objects (RO) to acquire a desired product, and available Rooms in the space. In particular, a Recommendation Object contains two differentiated areas, one for searching products and another for receiving suggestions about similar products and affine users. For each type of interactive object (URO, IMO, RO), this layer triggers user registration, interactive map, and recommendation object events respectively.

[2] Recommender systems are well-known tools which provide the users a personalized assistance when buying a product [3,5].

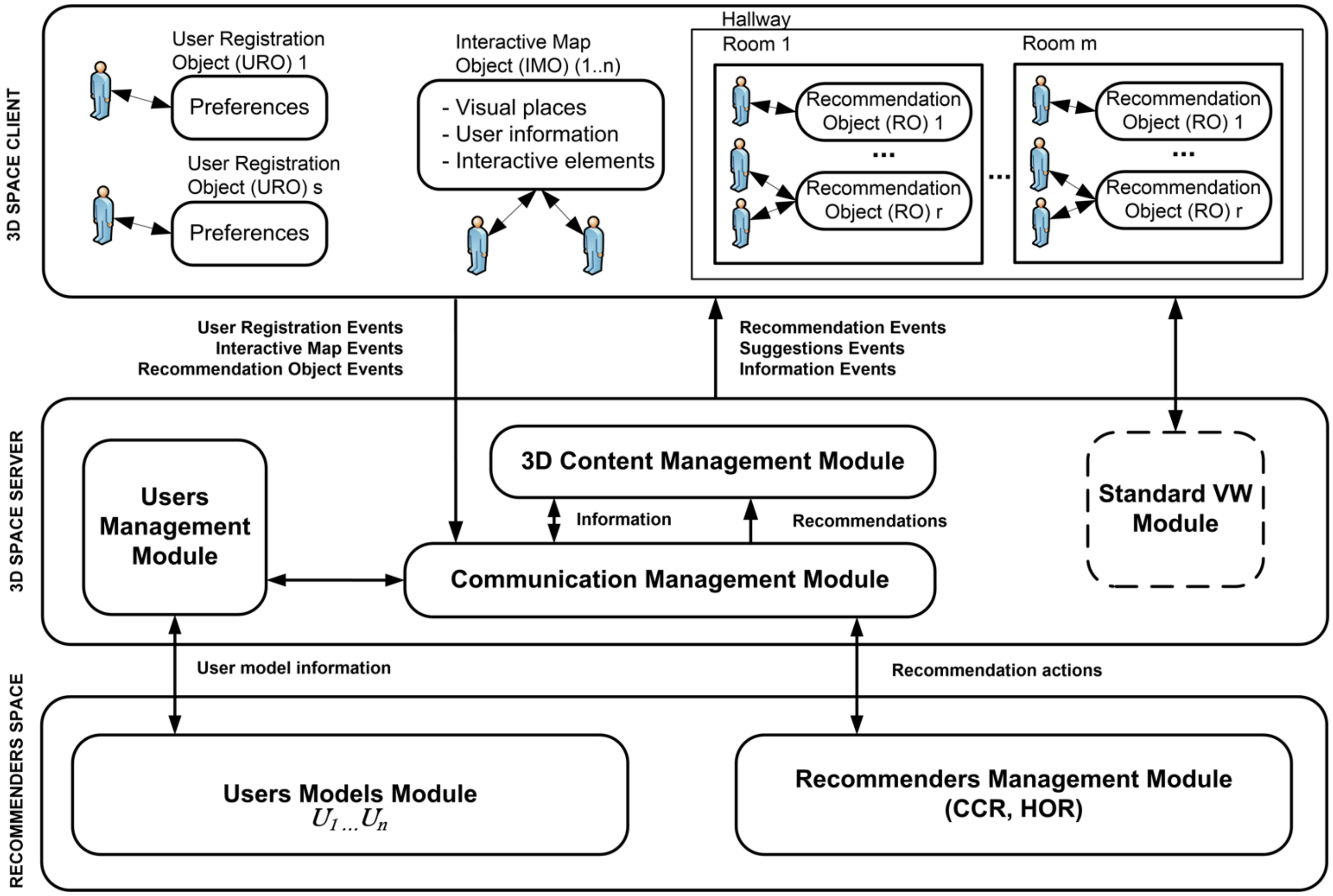

Figure 1. Framework overview.

To facilitate a scalable number of users connected to the system, the 3D store is organized in different spaces (Room, Hallway). Rooms have a limited number of Recomendation Objects and users interacting with them. When a room is full, new users can be located in another room taking into account their preferences. In case all rooms were full, we can dynamically generate new 3D content (rooms and ROs) using the Virtual World Grammar concept proposed in [6]. Note that a group of rooms is usually focused in a particular product domain (e.g., smartphone). Then, hallways would be groups of rooms that allocate different types of products. For example, the 'hallway of Smartphones' or the 'hallway of PCs'.

In the bottom of Figure 1, the *Recommenders Space* layer hosts the User Models Information Module and the Recommenders Management Module. The former is responsible for obtaining the user buying preferences about recommended products from User Models, U_i, and general information about users (i.e., personal information as name, age, gender among others). The latter contains two types of recommendation algorithms, the HOR and the CCR. Both are conversational recommenders, which are content-based recommendation [4]. The History and Opinions Based Recommender (HOR) algorithm receives a recommendation request when users interact with an IMO or the suggestions area in a RO. The Collaborative Conversational Recommender (CCR) algorithm receives a recommendation request when users interact within their searching area in their RO.

In the middle of Figure 1, the *3D Space Server* is the communication layer responsible for the connection through the Communication Management Module between previous layers, interface, and recommenders. The Communication Management Module maps user events triggered in the 3D Space Client to user information or recommendation actions and, in reverse, recommendation actions or user information to user events (i.e., Recommendation Events, Suggestions Events, and Information Events in *3D Space Client*). Furthermore, it is responsible for the management of the 3D content objects (i.e., the 3D Content Management Module), and the users preferences (i.e., the Users Management Module). First, the 3D Content Management Module is in charge of updating the visual components in the *3D Space Client*, the URO, the IMO, and the RO. Second, the Users Management Module interchanges the user information, user buying preferences and personal information, between the *3D Space Client* and the Recommenders Space layers.

3. INTERACTION OBJECTS

In this section we detail the different interaction objects proposed for a 3D eCommerce store with a scalable number of participants. They allow users to get information and to be aware of other users and products locations, by helping them in their shopping decision, and by providing them with relevant information about similar products and users with similar preferences.

The interface layer in the collaborative recommendation framework incorporates three types of interactive objects: the URO, the IMO, and the RO. These objects guide users in each phase of their buying experience: the arriving (URO, IMO) and the buying phase (RO). Next, we describe each of them in the domain of selling smartphone.

The User Registration Object (URO) is represented in the 3D eCommerce store by a terminal machine as shown in Figure 2. This terminal machine implements the metaphor of individual communication between customers and bank systems, this time mediating customer-recommender system communication.

Icons in the terminal machine represent two main preferences needed by the recommender (e.g., mobile phone operating system and price, in the Smartphone domain). Both of them visually represented by the corresponding semantic icons, operating system logo and dollars in the case of price. When the user introduces her preferences, they are highlighted to provide visual feedback, then she confirms them.

Figure 2. Screenshot of the user registration object.

The Interactive Map Object (IMO) is represented by a 3D panel which shows all rooms in the eCommerce space and users that are interacting with Recommendation Objects (RO) (see Figure 3). Note that the recommendation framework allows users to buy products interacting either individually or collaboratively (i.e., with a group of users).

This map displays eCommerce store locations and related information, where a) are rooms of the 3D e-commerce space, b) are users into the rooms which may be green circle (i.e., users interacting individually with a RO) and a red circle (i.e., two or more users interacting collaboratively with a RO), c) are buttons that allow users ask for suggestions about rooms where they should go to find the users or products that matches their preferences, d) is the map legend. Users can require information about another user by pressing the Affine Users button. The information of other users is displayed through a text message and it shows the similarity of preferences among them.

The Recommendation Object (RO) is represented through 3D panels into each room as shown in Figure 4. The 3D eCommerce space now have six rooms with three panels for each room, however our framework allows the scalability and growth of the space.

Each 3D panel (RO) consists of several interactive elements (see Figure 5), where a) are visual affordances representing the features of the current recommended product, b) displays one (<>) or two (+ , −) icons that are used for performing

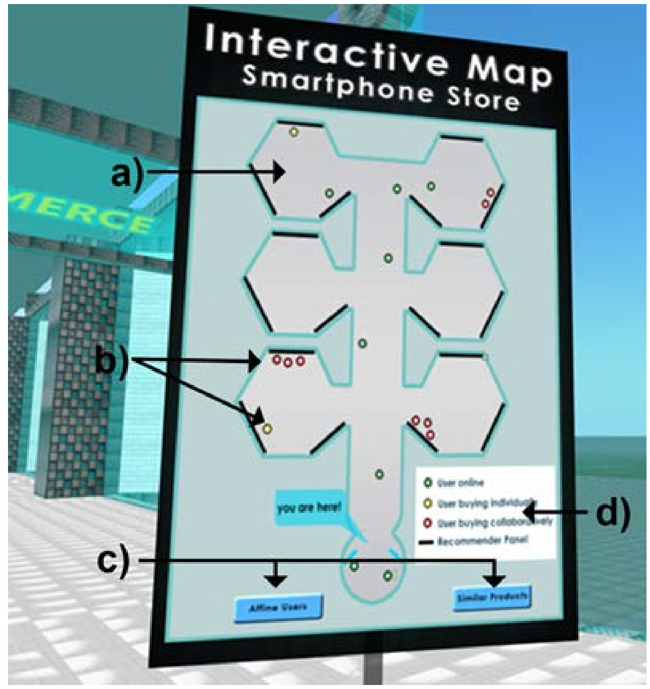

Figure 3. Screenshot of the interactive map.

critiques[3], with the value of the feature on top of it, c) is an image of the current recommended product, d) are buttons for the collaborative actions or for finishing the recommendation process when the target is reached by pressing the Buy it button, e) shows suggestions about people with similar preferences that may be useful for collaborating, and f) displays suggestions about bought products by other users with similar preferences (i.e., recommendation based on off line history information).

Figure 4. Screenshot of 3D recommendation panels.

Therefore, the user interacts with the RO: to critique one feature of the product, for example "I want a less expensive camera

[3] A critique is a directional preference over a feature of the product to determine users' constraints and preferences.

price"; to select a product suggested automatically by the recommender; and to select to collaborate with another user. All these actions are translated to recommendations events that arrive at the Recommenders Management Module in the *Recommenders Space* layer. This module uses two recommendation algorithms (i.e., CCR and HOR) for selecting the next product recommendations to the user. When the Recommenders Management Module returns the recommendation actions the RO is updated to visualise the new recommended product.

Note that the visualisation of both IMO and RO is automatically updated from information coming from the *3D Space Server* and *Recommenders Space* layers.

Figure 5. Screenshot of the recommendation object.

4. USER INTERACTION FLOW

This section describes the interaction flow that users may follow during their buying experience. First, users arrive at the virtual eCommerce space and provide some initial preferences. Next, they locate a room to go or a user for starting collaboration. Finally, they start searching their desired product. Note that this flow is particularly useful for the users that have never been before in the virtual eCommerce space and they need some guidance. However, users have freedom of choice and they may follow a different course of actions.

In detail, when users just arrive to the 3D e-commerce space (i.e., the *3D Space Client*) they may register their initial preferences about the desired product using the User Registration Object (URO). This is the first object they will find at the entrance of the eCommerce space. Note that users are allowed to come back to any URO at any time and change their initial preferences.

Apart from the URO, at the hall users will see an Interactive Map Object (IMO) where they can be aware of the distribution of the space and the location of both rooms and other users. Once users have selected a room in the IMO, they can use the teleporting mechanism or just walk to the room. There, they start a conversational recommendation session (i.e., individual or collaborative recommendations).

A typical session with a conversational recommender consists of a series of recommend-review-revise-update cycles, where both the user and the recommender actively participate. Basically, the recommender suggests a product and the users review the recommended product by doing a critique action. This action generates an event that is revised by the recommender. Moreover, the critique action is first used to update the user model, U, as it contains the preferences of the user, including the initial preferences defined in the URO, and it is also used for recommending another product. The process finishes when the user either find (and buy) the desired product or give up the recommendation process.

5. CONCLUSION

In this paper we present a 3D recommendation framework which provide eCommerce customers a collaborative interface to buy products with the help of recommenders. It is composed by three layers: the 3D interface, the recommendation and a communication layer which allows the connection between the other two. In this paper we focus on the former and advocate for high populated 3D eCommerce Environments designed to facilitate users awareness of locations, products and other users which are also buying in the virtual store.

To do so, we have designed a new framework that enables scalability and we have concentrated on this paper on the front-end. That is, on the interaction mechanisms to enhance and facilitate users buying experience. These mechanisms are facilitated by several interface elements such as a registration (preferences) panel, an interactive map and a recommendation panel. As on-going work we are developing the framework backend and then we plan to evaluate the usability of the proposal with real users.

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La delgada línea roja entre la usabilidad y la experiencia de usuario

Msc. Yuliana Puerta Cruz
Universidad del Cauca
Popayán-Colombia
Corporación Universitaria
Rafael Núñez
Cartagena-Colombia
puertacruz@gmail.com

Phd. Cesar A. Collazos
Universidad del Cauca
Popayán -Colombia
ccollazo@unicauca.edu.co

Phd. Toni Granollers
Universidad de Lleida
Lleida- España
antoni.granollers@udl.cat

RESUMEN

Este artículo busca debatir acerca de dos términos muy habituales en el campo del diseño de sistemas interactivos: la Usabilidad y la Experiencia de Usuario (UX). La necesidad surge de observar (de forma no empírica) que tanto la industria del software, la del diseño de interfaces e incluso en la academia, utilizan dichos términos sin tener total claridad sobre qué se refiere cada uno. Son incluso percibidos como atributos intercambiables "según la moda" del momento. Con la intención de profundizar empíricamente sobre estos conceptos, se estudia la literatura existente y se realiza una encuesta para tener información de primera mano procedente de diferentes actores relacionados con el Diseño Centrado en el Usuario (DCU) y la Interacción Persona-Ordenador (IPO) en general. La principal motivación en la cual reside nuestro interés científico está en verificar si las aproximaciones DCU actuales son adecuadas tanto para el desarrollo de sistemas usables como para sistemas con alto grado de UX.

Categorías y Descriptores Temáticos

H.5.2 [**Interfaces de Usuario**]: Metodologías/Evaluación, Estilos de Interacción, Diseño Centrado en el Usuario.

Términos generales

Diseño, Confiabilidad, Factores Humanos.

Palabras claves

Experiencia de Usuario, Usabilidad, Diseño Centrado en el Usuario, Interacción Humano Computador.

1. INTRODUCCIÓN

Desde hace bastante tiempo, las personas pertenecientes a comunidad relacionada con la IPO vienen utilizando los términos "Experiencia de Usuario" y "Usabilidad" de forma casi sinónima. Lo cierto es que a la hora de definir ambos conceptos existe una confusión generalizada entre aquellas personas que, incluso siendo conocedores del tema, no llegan a profundizar del todo e incluso tratan de enfrentar ambos conceptos [1]. Por esta razón, partiendo de las definiciones más o menos aceptadas, en este artículo se intenta indagar en las diferencias conceptuales entre Usabilidad y UX para explicar algunos detalles que los distinguen, así como aquellos que los relacionan.

La UX es un tópico discutido frecuentemente en la ingeniería de software en los últimos años, pero a pesar de los esfuerzos no se ha logrado un consenso de lo que significa exactamente y permanece como un concepto ambiguo y puede ser difícil de entender la naturaleza de la misma [2]. Diferentes autores proponen similitudes en sus definiciones que dejan pensar que al alcanzar Usabilidad se logra alcanzar cierto nivel de UX [3], considerando algunos a la Usabilidad como una de las diferentes facetas de la UX.

N. Bevan [4] conceptualiza la UX a partir de la comparación entre diferentes métodos de evaluación de Usabilidad, para lo cual define una serie de diferencias a partir de la categorización de métricas de UX y de Usabilidad. En [5] se estudian los efectos de medir la Usabilidad a nivel de interfaz de usuario y a nivel del sistema, sugieren ampliar el concepto de Usabilidad a nivel del sistema para incluir la facilidad de aprendizaje, la accesibilidad y la seguridad, contribuyendo a la experiencia general del usuario.

Durante el desarrollo de este artículo se han revisado diferentes aproximaciones conceptuales y se ha elaborado el estado del arte de algunos trabajos que han intentado conceptualizar y/o establecer similitudes o diferencias entre estos conceptos. También se ha diseñado y aplicado un instrumento de encuesta entre la comunidad de expertos académicos y profesionales con el fin de revisar como son entendidos y aplicados estos conceptos en el diseño de productos interactivos.

Este artículo está organizado de la siguiente forma: en la sección 2 se realiza una revisión del estado del arte de los conceptos de Usabilidad y UX, así como aquellos que consideran cercanía entre estos conceptos. En la sección 3 se presenta el instrumento utilizado para recolectar información en la comunidad de expertos respecto a las diferencias y/o similitudes entre UX y Usabilidad. En la sección 4 se realiza en detalle el análisis de resultados de la encuesta. Finalmente, se presentan las conclusiones y trabajos futuros.

2. EXPERIENCIA DE USUARIO Y USABILIDAD: EL DILEMA

Tomaremos las siguientes definiciones cómo punto de partida:

- La Usabilidad se define como: *"La medida en que un sistema, producto o servicio puede ser usado por usuarios específicos para alcanzar metas con efectividad eficiencia y satisfacción en un contexto de uso específico"* [6] y [7]. En [8] agregan *que se refiere a "la facilidad de uso, sin experimentar frustraciones "*
- Mientras que la UX se define como: *"Las percepciones y o*

respuestas que resultan del uso o anticipado uso de un producto, sistema o servicio" [6] y [7]. En [9] afirman que no es solo un buen diseño o interfaces de lujo, si no de crear experiencias positivas a través del uso del producto.

Estas definiciones resultan ser distintas, pero encierran cierto grado de ambigüedad que, al momento de utilizarlas de forma práctica, generan dudas en relación a lo que realmente abarca cada una de ellas y sobre cuales son los puntos que las diferencian. Actualmente este es tema de discusión entre diferentes autores e investigadores del área de IPO. Como se mencionó anteriormente en este trabajo se pretende abordar esa cercanía, para determinar si a partir de las aproximaciones de DCU se logra alcanzar buenos niveles de UX y no tan solo de Usabilidad.

En [4] y [5] se afirma que la UX y la Usabilidad pueden ser medidos durante o después del uso de un producto o servicio y ponen a consideración la similitud entre la característica de percepciones y/o respuestas de la UX y la satisfacción que abarca el concepto de Usabilidad. Además, también en [5] se deja ver que el disfrute o diversión es un aspecto de la UX que también contribuye significativamente a alcanzar satisfacción de un producto, característica de la Usabilidad. Y para ello la UX debe satisfacer las metas pragmáticas y hedónicas definidas en [10].

Las investigaciones en la comunidad académica han producido diferentes Modelos y Frameworks para la evaluación de UX, pero en la práctica la industria adopta el término de UX para el desarrollo de productos basándose en los métodos de la Usabilidad tradicional [11]. De acuerdo a esto, se hace necesario el desarrollo de métodos prácticos de evaluación de UX para ser usados en la industria y, para ello, es necesario tener claridad del concepto de UX e intentar adaptar otros aspectos de IPO a aspectos particulares de la evaluación de UX [12].

Desde [13] dejan ver que un uso común o definición de UX aún no es definido claramente. Tanto la industria como la academia coinciden en afirmar que la definición de UX incluye más que la definición previa de Usabilidad. En [12] también se busca establecer y definir el alcance y concepto de la UX, para lo cual aplican una encuesta entre académicos y profesionales del área de UX, teniendo en cuenta el creciente interés en el tema y que no ha sido fácil establecer un concepto y un alcance común del significado de la UX.

Actualmente se utilizan diferentes métodos para la evaluación de Usabilidad y UX, pero el mayor grado de subjetividad que encierra la UX no permite que sea evaluada de igual forma que la Usabilidad, es necesario conocer cómo se siente el usuario en la interacción con el producto [14]. La UX llega a cubrir en su totalidad los aspectos de interacción de un producto o servicio, a partir de brindar altos niveles de calidad. Debe ayudar a la persona a acceder al producto con facilidad, para ello el producto debe ser simple, placentero, elegante, además de incluir aspectos culturales [15].

A partir de una revisión de diferentes trabajos, en [16] se logra definir una serie de aspectos de la UX que van más allá de aspectos emocionales, entre los que se destacan: la accesibilidad, la propia Usabilidad, la jugabilidad, la plasticidad, la utilidad o, entre otros, los aspectos contextuales. En [17] también dejan ver la importancia de incluir otros conceptos que van más allá de la Usabilidad, más relacionados con el contexto de uso [7].

A pesar del esfuerzo por encontrar diferencias y o similitudes entre estos conceptos, se observa que todavía no hay un consenso bien establecido y frecuentemente se llega a pensar que, cuando se trata la Usabilidad y la UX, en realidad, se está hablando de lo mismo. Así pues, con la intención de aportar nuevo conocimiento al respecto creemos necesario disponer de datos empíricos que nos aporten algo de luz con la que alumbrar la discusión abierta. Para ello, hemos diseñado un formato de encuesta para aplicar entre los conocedores de estas áreas y desde el cual se pretende aclarar esta ambigüedad a partir de las concepciones de los expertos. Los resultados obtenidos nos permitirán despejar dudas y orientar el curso de nuestra investigación futura (ubicada en la construcción de metodologías orientadas al desarrollo de sistemas interactivos maximizando su UX).

3. ENCUESTA ELABORADA

Con el objetivo de lograr identificar esas similitudes y/o diferencias se elabora una encuesta dirigida a expertos en IPO tanto en el ámbito empresarial como académico a nivel mundial. La encuesta intenta analizar las diferencias y/o similitudes existentes entre la Usabilidad y la UX, a partir de las opiniones de profesionales académicos y empresariales de estas áreas, considerando sus diferentes puntos de vista y opiniones al respecto, con el fin de consensar su definición y definir la línea que separa estos conceptos.

De acuerdo a lo anterior, la hipótesis planteada en el desarrollo de esta encuesta esta centrada en verificar si existen diferencias considerables entre los conceptos de UX y Usabilidad. En la encuesta se formularon preguntas abiertas y cerradas, a partir de las variables definidas, las cuales son: áreas de estudio de preferencia (Usabilidad o UX), rango de diferencia entre UX y Usabilidad (medida como ninguna, mínimas, considerables, totalmente diferentes), relación entre alcance de Usabilidad y UX(evaluada como si, no, no sabe), nivel de importancia de las facetas que componen la UX (de 1-10 según grado de importancia) y metodologías de diseño (esta variable se considero para identificar si se utilizan y cuales se usan).

Considerando una población limitada (alrededor de 600 personas que participan activamente en asociaciones como AIPO[4], UXPA[5], UX Alliance[6]así como miembros de grupos de investigación dedicado a trabajar en temas de IPO con conocimientos suficientes y trayectoria de investigación en estas áreas) se ha estimado un error muestral de 5% (confianza del 95%), lo cual nos permite manejar una muestra adecuada cercana a los 40 participantes. Al contar con 45 participantes en la muestra, los resultados presentados son estadísticamente representativos.

Su distribución se hizo a través de la herramienta gratuita de Google para crear formularios *Google Form* y fue distribuida entre los conocedores. Se obtuvo una muestra de 44 encuestas respondidas, cabe resaltar que su aplicación llego a ser complicada porque a pesar que el contacto a través de la Internet fue rápido, los tiempos de espera en las respuestas fueron lentos, sin embargo se logró con éxito su aplicación.

[4] Asociación Interacción Persona Ordenador (aipo.es)

[5]UserExperienceProfessionalsAssociation (https://uxpa.org)

[6] UX Alliance (www.uxalliance.com)

3.1 Análisis General de la Encuesta

La tendencia de los encuestados estuvo marcada en trabajar sobre ambos conceptos con aceptación de un 93,2% de los encuestados, este comportamiento estuvo determinado así tanto para los académicos como para los profesionales.

En relación a las diferencias entre UX y Usabilidad hubo un 59,1% afirmó que existían diferencias considerables entre estos aspectos, aunque un 22,7% de los encuestados indicó que existían diferencias mínimas. Entre estos datos cabe destacar que, para ninguno de los encuestados son exactamente iguales. A pesar que un pequeño porcentaje de los encuestados indican que no existe ninguna diferencia entre estos conceptos, la mayor tendencia esta concentrada en afirmar que existen diferencias considerables, lo que permite ver que la línea que separa estos conceptos realmente es delgada y que realmente existe ambigüedad, pero no llegan a ser iguales.

Respecto a la relación entre el alcance de Usabilidad NO asegura el alcance de buenos niveles de UX, un 45,5% de los encuestados indica que alcanzar Usabilidad en los productos NO asegura buenos niveles de UX, mientras que un 38,6% piensa que SI se logra. La tendencia de estas opiniones es que al no ser el único aspecto que debe considerarse al evaluar la UX, la Usabilidad permite alcanzar cierto nivel UX, pero no en los niveles deseados, porque es necesario considerar otros aspectos relevantes. Al realizar pruebas de de T-student se logra observar que el "P-value" es 0.685 > 0.25, se concluye que la Usabilidad no asegura el alcance de buenos niveles de UX.

En relación al nivel de importancia de las facetas de UX definidas por [10] y puestas a consideración en este estudio, fueron tenidas en cuenta unas más que otras en el momento de alcanzar buenos niveles de UX. Un 80% de los encuestados considera que la Usabilidad corresponde a una faceta relacionadas con la UX, cuando se busca alcanzar buenos niveles de UX en el diseño de un sistema interactivos. Un 64% considera que el Estado Emocional y la Utilidad son las otras facetas de mayor importancia. La faceta con menos elección es la Plasticidad, pero también considerada importante con un 25,7% de escogencia. Esto deja ver que la Usabilidad es considerada como una faceta de importancia cuando se pretende alcanzar buenos niveles de UX, sin embargo no es la única faceta que debe considerarse.

En la verificación de las metodología de diseño y evaluación de productos de software con buenos niveles de Usabilidad y/o UX, se pudo observar que la mayoría destacaban técnicas para la evaluación de productos, principalmente de evaluación de Usabilidad, pero el uso de metodologías fue casi nulo.

3.2 Comparación de Resultados Sector Profesional y Académico.

La tendencia de los encuestados tanto del campo Académico como Empresarial es a estudiar ambas disciplinas, solo una pequeña muestra de ambos campos coincidió en estudiar exclusivamente la UX. Y un académico indico estudiar exclusivamente la Usabilidad. Las opiniones de los académicos tuvieron mayor tendencia a que la Usabilidad no asegura alcanzar buenos niveles de UX, mientras que las opiniones del sector empresarial estuvieron divididas en esta cuestión. Sin embargo, y a pesar de estas opiniones, ambos estuvieron sectores coincidieron en asegurar que la Usabilidad SI es un aspecto a considerar al momento de alcanzar buenos niveles de UX.

En relación a las opiniones respecto a las diferencias entre UX y Usabilidad, tanto en el área Académica como la Empresarial son parejas: uno y otro afirman una tendencia que las diferencias entre ambos conceptos son considerables, lo que deja ver que, para ellos, son dos áreas distintas; con características en común, pero distintas.

Las respuestas dejan ver que el listado de facetas expuestas es de importancia cuando se quiere alcanzar UX, algunas en mayor proporción que otras. Entre las facetas más destacadas se encuentran la Usabilidad y el estado emocional en mayor proporción tanto para los académicos como los del área empresarial, sin olvidar la importancia de otras facetas como la utilidad, la confianza o el contexto. Tanto los académicos como quienes trabajan en la industria del diseño de sistemas interactivos coincidieron en que la plasticidad es el área de menos importancia.

En cuanto a las facetas propuestas para definir la UX, los académicos consideraron que el Estado Emocional era la faceta más relevante, seguido de la Usabilidad y en menor importancia la Plasticidad. De acuerdo a esto dejan ver que el alcance de buenos niveles de UX va más allá del concepto de Usabilidad, siendo necesarias otras facetas.

De forma general los encuestados del campo empresarial también consideraron que estas facetas, algunas en mayor medida y otras en menor eran de real importancia al momento de alcanzar buenos niveles de UX. Las facetas de más importancia para ellos eran, la Usabilidad, la Utilidad y los aspectos Contextuales. Siendo las áreas de menor importancia la Jugabilidad y la Plasticidad

5. CONCLUSIONES Y TRABAJO FUTURO

La revisión del estado del arte deja ver que existe una gran cercanía entre los conceptos de Usabilidad y UX, coincidiendo en varios trabajos que la definición de los estándares ISO [7] al indicar que una de las facetas de la Usabilidad es Satisfacción se alcanza en diferentes facetas de la UX. Por otro lado esta cercanía se corrobora al considerar la Usabilidad como una faceta de la UX.

En términos generales, se define la Usabilidad como una faceta importante para la UX, no siendo la única que permite alcanzar buenos niveles. Se consideran como importantes otras facetas como el estado emocional, la utilidad, el contexto, utilidad, jugabilidad, accesibilidad, entre otras.

La línea que separa estos conceptos realmente está especialmente manifestada con los aspectos emocionales que definen la UX. Al momento de considerar la Usabilidad como una faceta de UX, se podría afirmar que al lograr Usabilidad se logra un buen nivel de UX, pero no el nivel suficiente, porque es necesario considerar el resto de aspectos emocionales.

Por otro lado, el hecho de realizar un sondeo sobre las metodologías de diseño de Usabilidad y de UX, dejó ver entre los encuestados que actualmente utilizan mayormente técnicas de evaluación de estos conceptos frente al uso de metodologías que aseguren el alcance desde el diseño.

La revisión conceptual de Usabilidad y UX ha permitido verificar la necesidad de considerar las diferentes facetas de la UX en el desarrollo de productos y no solo desde la evaluación, sino desde el diseño mismo. En este sentido, se orientara el desarrollo de esta investigación, hacia el diseño e implementación de una propuesta metodológica para el desarrollo de sistemas interactivos basada en el diseño centrado en el usuario que integre facetas de UX.

Las conclusiones mencionadas nos hacen emerger otras preguntas importantes para ser valoradas en un análisis posterior. Las nuevas preguntas son:

- ¿podemos considerar que teniendo presentes los aspectos emocionales de las personas mientras utilizan un sistema interactivo, es suficiente para garantizar un elevado grado de UX?,
- si coincidimos en que las metodologías de DCU son las más adecuadas para desarrollar sistemas interactivos altamente usables, ¿podemos decir que, reformulando los procesos DCU mediante la inclusión de los mecanismos de diseño y evaluación emocional, estos se transforma en procesos de Diseño Centrado en la UX?

Cuestiones que abordaremos para seguir avanzando en nuestra línea de investigación.

2. AGRADECIMIENTOS

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USABILITY AND USER EXPERIENCE (II)

Effect of Snippets on User Experience in Web Search

Mari-Carmen Marcos
Universitat Pompeu Fabra
Barcelona, Spain
mcarmen.marcos@upf.edu

Ferran Gavin
Softonic Barcelona, Spain
ferran.gavin@softonic.com

Ioannis Arapakis
Yahoo Labs Barcelona, Spain
arapakis@yahoo-inc.com

ABSTRACT

In recent years, the search engine results pages (SERP's) have been augmented with new markup elements that introduce seamlessly additional semantic information. Examples of such elements are the aggregated results disseminated by vertical portals, and the enriched snippets that display meta-information from the landing pages. In this paper, we investigate the gaze behavior of web users who inter- act with SERP's that contain plain and rich snippets, and observe the impact of both types of snippets on the web search experience. For our study, we consider a wide range of snippet types, such as multimedia elements (Google Images, Google Videos), recommendation snippets (Author, Google Plus, Reviews, Google Shopping Product), and geo-location snippets (Google Places). We conduct two controlled user studies that employ eye tracking and mouse tracking, and analyse the search interactions of 213 participants, focusing on three factors: noticeability, interest, and conversion. Our findings indicate that ranking remains the most critical factor in relevance perception, although in certain cases the richness of snippets can capture user attention.

Categories and Subject Descriptors

H.5.m **[Information interfaces and presentation (e.g., HCI)]**: Miscellaneous

General Terms

Measurement, Design, Experimentation, Human Factors

Keywords

Search engines, rich snippets, eye tracking, user experience

1. INTRODUCTION

Information access is an area of research that, among other aspects, deals with the improvement of SERP's, both in terms of the presentation as well as the relevance of the retrieved results.

In the last decades, companies with online presence developed a strong dependence on tracking metrics provided by search engines. As a result, many companies turn to specialists for optimising their web content for search engines and improving their ranking, a process known as Search Engine Optimisation (SEO). At the same time, search engines constantly upgrade their algorithms and interfaces, seeking to facilitate better services in terms of performance, content relevance, and user experience. One such example are the semantic markup elements (multimedia items) introduced in the SERP's, which show aggregated results from vertical portals. If we consider the case of Google, we can identify several other types of similar elements sharing the space with the typical results, composed by title, snippet (defined in [1] as "query-biased search result summaries"), and URL.

This work aims to understand better how the enrichment of snippets with multimedia elements, recommendations, and geo-location information affects user behaviour during interactions with SERP's. More specifically, we investigate the following three dimensions: (i) noticeability, (ii) interest, and (iii) conversion. As noticeability we regard the ability of rich snippets to compete for user attention against other types of elements in a SERP. Interest is the overall engagement and involvement with a given resource, whereas conversion is how this attention translates to click-throughs and, eventually, monetisation. Our experimental approach involves the use of eye tracking technology and click logging, for capturing the effects of rich snippets shown on SERP's. This is a high-value research area, yet poorly understood. We further believe that this work can impact future web search interfaces and interaction techniques for studying UX, as well as complement the common batch evaluations in information retrieval.

2. RELATED WORK

Until recently, the results of a SERP were presented using the same layout, and the relative ranking position of a result was the most determining factor that users considered [14]. This has been demonstrated by previous studies [8] that have altered the original rankings of the results in SERP's and observed that users would still assign more importance to top-ranked results. In the same work [8], the authors introduced additional information to the snippets and found that the performance for informational tasks improved significantly. The reason for that was that users clicked on results while being certain about the relevance of the corresponding landing pages, hence the importance of snippets.

A critical step in designing and building efficient search services is understanding how people interact with SERP's. In promoting such knowledge, past work has proposed techniques ranging from direct observation and user surveys to log analysis, and most recently eye-tracking studies. Eye tracking is a promising technique for the study of user behaviour in web search, since it can register accurately short- term changes in gaze activity that are not measurable by other means. Furthermore, It provides an account of users' unconscious behaviours and cognitive processing that are needed for interpreting their actions, as well as useful for mapping the user experience [6]. Some of the first works that studied user interactions with SERP's with the help of eye tracking hardware, were published in the last decade [12, 13]. Since then, there has been a surge of research [2, 4, 3,

16, 26, 9, 5, 27, 19, 24, 7, 18, 10] that has employed eye tracking and mouse tracking to analyse different aspects of the SERP's.

2.1 Aggregated Search

In addition to web search, the major commercial search portals offer access to specialised search services (e.g., news, local business, online products) or verticals of different in- formation sources (e.g., images, videos, books). Aggregated search attempts to achieve diversity by fusing results from different verticals into one SERP, and complement the standard web results. Arguello and Capra [3] employed several aggregated verticals like images, news, shopping and video, and evaluated whether these verticals can influence user interactions with other components in the SERP. The results from a large-scale crowdsourcing study revealed that the level of influence may depend on the vertical, its surrogate representation, where it is displayed, and how it is distinguished from other components in the SERP. In [2, 4], the authors examined the aggregated search coherence, i.e., the extent to which results from different sources focus on similar senses of an ambiguous or underspecified query. Both studies provided evidence that users are more likely to interact with the web results when the vertical results are more consistent with the users' intended query-sense, e.g., a user searching for information about the planet "Saturn" is more likely to interact with the web results if the blended images contain pictures of the planet versus the car.

2.2 Gaze and Cursor Behaviour in Web Search

Several studies have investigated the gaze and click behaviour in aggregated search. Liu et al. [16] collected eye tracking data, click-through data, and users' feedback on their examinations of SERP's. The findings of this study reveal than a large proportion (45.8%) of the results fixated by users were not recognised as being "read". In addition, the authors of [16] found that before users actually read the results, there is often a skimming step during which they briefly scan the results without reading them, and perform judgments according to different signals.

Wang et al. [26] and Diaz et al. [9] found that different result appearances can create different biases on gaze behaviour for both vertical and other results on SERP's. A number of studies [5, 27] also showed that multimedia components in SERP's and result attractiveness may influence users' gaze and click-through behaviour. Furthermore, Navalpakkam et al. [19] conducted a controlled study where they varied the presence and relevance of a rich informational panel placed to the right of organic search results.

The authors discovered that the information panels contain- ing information relevant to the user's task can attract more attention and facilitate longer mouse cursor hovers.

Sushmita et al. [24] investigated the factors affecting users' click-through behaviour on aggregated search interfaces. Their study led to several findings. Foremost, it revealed that the position of search results was only significant for the blended interface. Secondly, participants' click-through behaviour on videos was different compared to other sources. Finally, capturing a task's orientation towards particular sources was identified as an important factor that warrants further investigation.

Chen et al. [7] studied click behaviour in aggregated SERP's and proposed a novel federated click model, which accounts for the fact that user attention is attracted by vertical results. The study provided evidence which indicates that the visual attention received by the vertical results can increase the chances that other nearby web results are also examined, and that click behaviour on vertical results can lead to more clues of search relevance due to their presentation style.

2.3 Rich Snippets & Social Annotation

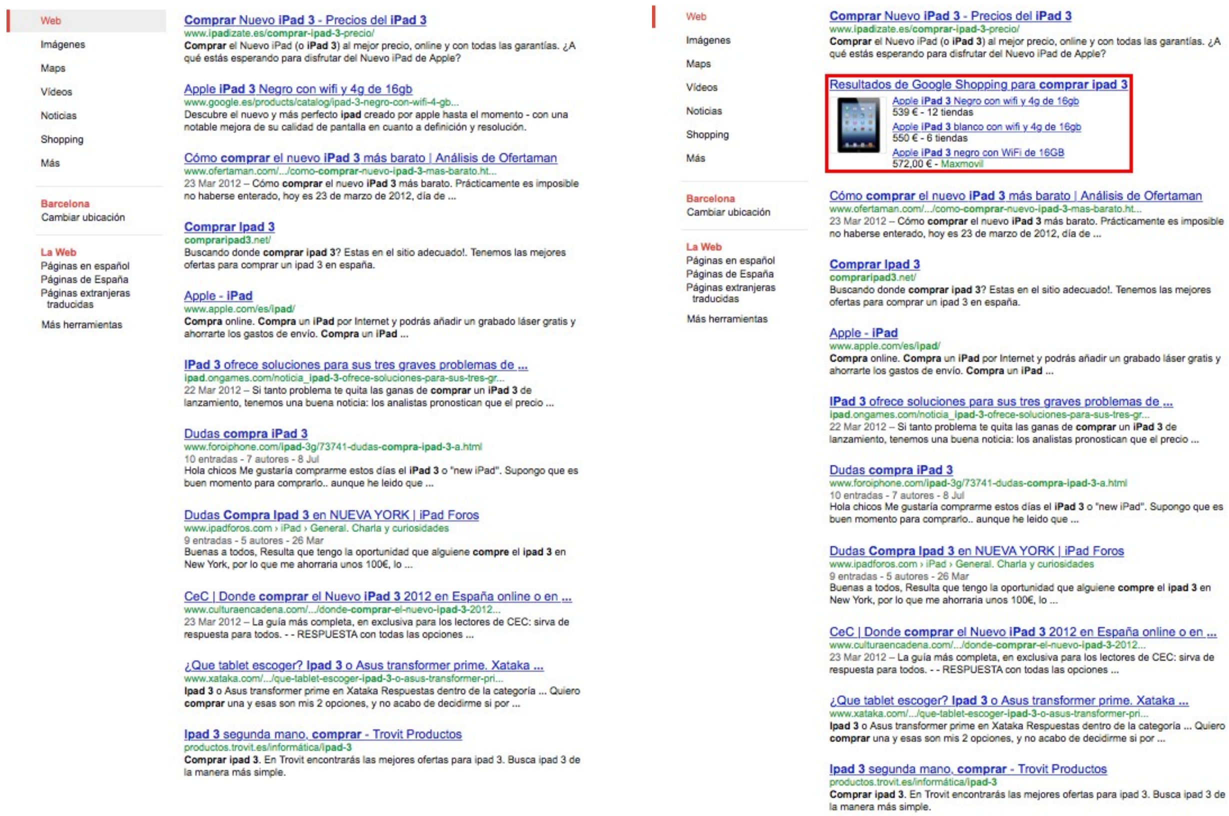
Several works have also examined the interaction between rich snippets and social annotations. A study by Muralidharan, Gyongyi, and Chi [18] demonstrated that placing a social annotation at the bottom of the snippet block reduces the probability of users fixating on it. The same study also revealed that positioning the social annotation at the top of the snippet block can mitigate this issue. The authors attribute this behaviour to the "inattentional blindness effect" [17], which leads people to notice mainly what they are actively looking for. In this study, the tasks were con- ducted using mock-ups and expert searchers, which places the reported effects in an artificial environment rather than a real-life setting.

Fernquist and Chi [10] investigated the impact of enriched elements with social annotation in SERP's. More specifically, the authors conducted an eye-tracking study using a retrospective think-aloud protocol, based on the design guidelines discussed in [18]. The authors blended the users' personal organic search results with regular, live search results, using a personalised ranking function. Their findings reveal that users employ annotations for local and shopping query types more often than fact-finding and news-related query types. Additionally, the authors discovered that users make use of annotations only when the task context and situation fit the need to look for social resources, such as subjective queries like shopping, products, and restaurant reviews.

Despite the above research efforts, there is still little understanding on what constitutes a well-designed, attractive, and engaging aggregated SERP. This paper provides some initial insights by examining the design of aggregated results and their effect on user gaze and click-through behaviour, in the context of web search. In what follows, we provide a description of our experimental method and discuss the main findings.

3. METHODOLOGY

To demonstrate the impact of enriched snippets on user search experience we carried out two controlled experiments, thereof referred to as Study 1 and Study 2.



(a) SERP with plain snippets. **(b) SERP with rich snippet (#2).**

Figure 1: SERP example showing the original plain results (a) and the results with the enriched snippet (b).

Both studies asked a number of participants to complete a series of search tasks using a commercial search engine, and shared a similar objective: investigate to what extent the richness of the snippets can affect user behavior in web search. Study 2 followed Study 1, and aimed at validating the preliminary findings discovered in Study 1.

3.1 Study 1

Study 1 consisted of an offline and an online part. The offline part was conducted in a laboratory setting, where the experimental procedure was followed and eye tracking data were collected. The online part repeated the same experimental design in an online setting, and collected mouse tracking data.

3.1.1 *Design*

The study used a mixed design with three independent variables: snippet richness (with two levels: “plain”, “rich”), snippet position (with two levels: “top-ranked”, “bottom- ranked”), and snippet type (with five levels: “Author”, “Google Plus”, “Google Places”, “Multimedia”, “Review”). To control for snippet richness, we prepared two versions of every SERP shown in the study: one version containing a rich snippet among the organic results (at top-ranked position

#2 or #3, or bottom-ranked position #6 or #7) and an- other version without the rich snippet, showing only plain web results. More specifically, for each task introduced in the study (Section 3.1.3), predefined search queries were sub- mitted to Google Search until obtaining SERP’s that contained at least one of the types of rich snippets shown in Table 1, in the 2nd, 3rd position, 6th, or 7th position. While retaining the original look and feel of the retrieved SERP’s, we edited the HTML code of the pages so that they either contained only one rich snippet or no rich snippets; any additional, unwanted rich snippets were modified to appear as plain snippets instead.

Given that the retrieved SERP’s showed the original top ten results obtained from Google search, we considered them as topically relevant to the associated search query. This assumption was further validated by a manual examination. We also controlled that none of the snippet text (plain or rich) contained directly the answer to the query. The reason for that is because we wanted to study click behaviour (con- version), therefore displaying the answer in a snippet would bias to click on it, or avoid it if its not the correct one

Our dependent variables were noticeability, interesting- ness, and conversion, all aspects of the search experience that can be potentially affected by the richness of the snip- pets. To study the effects of our experimental manipulation on our dependent variables, we obtained several metrics of gaze behaviour and a metric of search task performance [6], as shown bellow:

- Noticeability: Time to First Fixation, Fixations Before
- Interest: Total Fixation Duration, Fixation Count, Visit Duration
- Conversion: Click count

3.1.2 *Apparatus*

The relationship between attention and eye movements has been investigated extensively in the past [11, 20, 21, 22]. When we read, examine a scene, or search for an object, we continuously make eye movements called saccades. Saccades are rapid movements that occur when we change focus, and can reach velocities as high as 500◦ per second. When the visual gaze is maintained on a single location for several milliseconds we have a fixation. The importance of gaze in the assessment of attention focus lies in the fact that, although looking might appear to be a process that is under voluntary control, conscious and deliberate control of fixation happens infrequently. As with other components of voluntary performance, looking is controlled by a general intention, and consciousness plays a minor role in the execution of the intended sequence of fixations [15].

To analyse gaze behaviour, we used a Tobii 1750 eye tracker, integrated into a 17" TFT monitor with a 1280×1024 resolution. When activated, the eye tracker illuminates the user with two infrared projections that generate reflection pat- terns on the corneas of the eyes. A video camera gathers these reflection patterns along with the position of the user and, through digital image processing; the pupil locations are extracted at a rate of 50 Hz. The pupil positions are then mapped to gaze locations on the screen. For the gaze behaviour analysis we used the eye metrics listed in Table 2, which were extracted automatically using the Tobii Studio Statistics application. The metrics were calculated based on defined Areas of Interest (AOIs) and data selection time intervals. We defined as our AOI(s) the results shown in the SERP. In addition to using eye tracking in the offline part of Study 1, we also used the software CrazyEgg to log participants' mouse tracking data for the online part of the study.

Table 1: Types of rich snippets and search tasks used in Study 1

Rich snippet	Search task
Google Places	1. Find a hotel near Sants Station 2. Find a destination management company in Barcelona
Google Plus	3. Find the Fitur events program 4. Find the definition of "revenue management
Author	5. Find statistics of the use of Facebook in companies of the touristic sector 6. Find what actions is taking the Ushuaia Hotel in Facebook
Multimedia	7. Find in what Facebook Places does consist on 8. Find a webpage with reviews of the Ushuaia Hotel
Review	9. Find a webpage with reviews of the Pach´a Hotel 10. Find a good blogs directory about tourism and travel

Table 2: Eye metrics used to analyse gaze behaviour

1	Time to First Fixation: Time taken (in seconds) before a participant fixates on an AOI for the first time.
2	Fixations Before: Number of times a participant fixates on the media before fixating on an AOI for the first time.
3	Total Fixation Duration: Sum of the duration for all fixations within an AOI.
4	Fixation Count: Number of times a participant fixates on an AOI.
5	Visit Duration: Duration of each individual visit within an AOI.

3.1.3 *Search Tasks*

A total of ten tasks (shown in Table 1) were performed by every participant, two for each type of rich snippet. In the context of these search tasks, the participants assumed the role of an expert in social media for the tourism sector and were invited to participate in a panel for a particular city. Examples of the tasks involved finding a hotel near the venue, retrieving the conference program, and other. For each search task, two SERP's were available: one that contained a rich snippet at a top-ranked (#2 or #3) or a low- ranked position (#6 or #7), and one showing only plain snippets.

3.1.4 *Participants*

A total of 60 participants (female=38, male=22), between the ages of 18 to 58 and free from any obvious physical or sensory impairment, were recruited through a campus- wide ad. All participants were frequent users of web search engines. Besides the 60 participants who were involved in the offline study that collected eye tracking data, another 110 participants were involved in the online study that collected mouse tracking data. The participants were mainly locals (i.e., Catalan, Spanish) and had graduated from, were currently studying, or working at the at Pompeu Fabra University, Barcelona. Finally, participants were all proficient with the English and Spanish languages.

3.1.5 *Procedure*

For every search task, participants were presented with an initial search query and the retrieved SERP for this search query. They were instructed to examine the SERP as they would normally do, although they were not able to issue additional search queries. As long as the answer did not appear in the snippet description of the retrieved results, participants were encouraged to click on any of the result links and examine the landing pages, prior to continuing to the next task. Two tracks were designed in order to show the SERP's in an alternating manner (Figure 2).

There- fore, for every type or rich snippet participants were shown a SERP with a rich snippet (at a top- or low-ranked posi- tion) and a SERP containing only plain snippets. Selecting a particular result as the one the participants felt would an- swer the search task question, would conclude the task. To enrich the sample for the conversion measure, 110 partici- pants performed the same search tasks online, while we were logging their mouse tracking data.

3.1.6 *Results*

To choose an appropriate statistical test, we first examine the distribution of our data using the Anderson-Darling and Cramer-von Mises tests. These tests are known to perform better compared to the Kolomorov-Smirnov test [23, 25], al- though in large samples they tend to be significant even for scores that are marginally different from a normal distribution; we thus interpret them in conjunction Q-Q plots, while also accounting for the skew and kurtosis values. Since in all cases we observe a non-normal distribution in the absolute differences of the estimated error, we opt for the Mann- Whitney test and report our results at an α level of .05.

Finally, to take an appropriate control of Type I errors in multiple pair-wise comparisons we apply the Bonferroni correction.

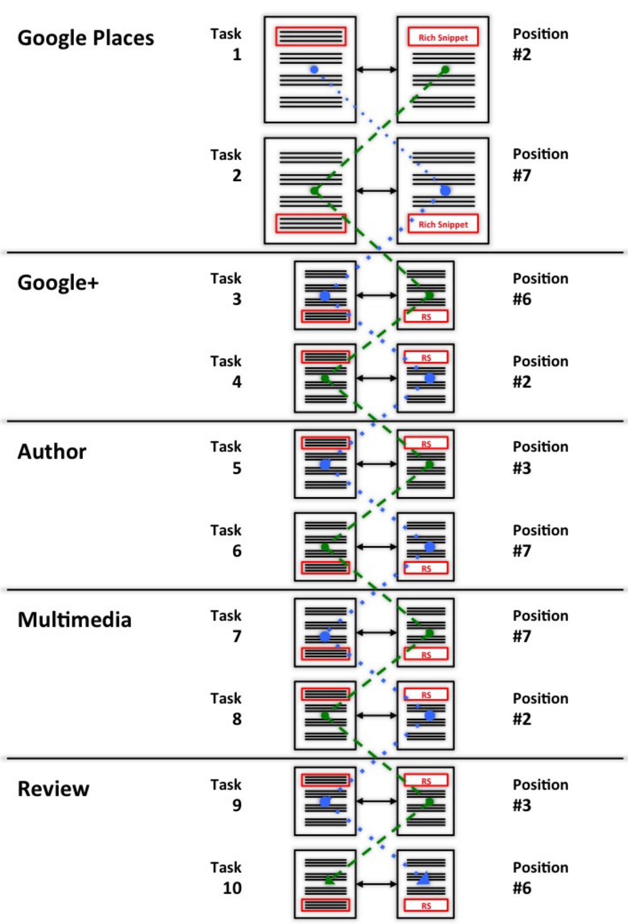
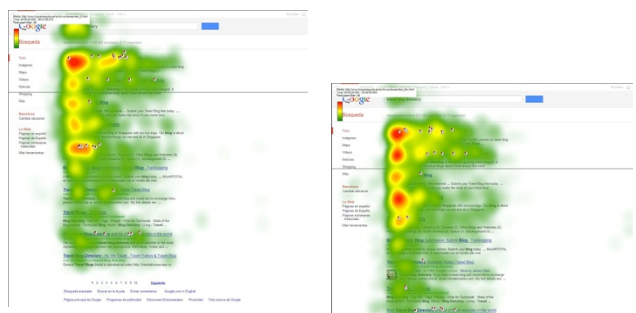


Figure 2: Experimental protocol.

When comparing top-ranked vs. bottom-ranked snippets, we identify several statistically significant differences across our eye metrics, and for both rich and plain snippets, and different snippet types (Author, Google Plus, Google Places, Multimedia, Review). More specifically, for the metric Time to First Fixation, the Mann-Whitney test reveals that top- ranked plain snippets (M dn = 2.88) received their first fixation significantly faster than bottom-ranked plain snippets (M dn = 15.71), U = 1289.50, z = −10.03, p = .000, r =−.48. Similarly, the top-ranked rich snippets (M dn = 3.25) received their first fixation significantly faster than bottom- ranked plain snippets (M dn = 15.30), U = 1135.50, z =−9.71, p = .000, r = −.46. For the metric Fixations Be- fore, the Mann-Whitney test reveals that top-ranked plain snippets (M dn = 9.00) had significantly fewer fixations on other items before being noticed than bottom-ranked plain snippets (M dn = 51.50), U = 1405.50, z = −9.79, p =.1, r = −.46. The same highly significant effect is observed when comparing top-ranked rich snippets (M dn = 9.00) against bottom-ranked rich snippets (M dn = 46.00), U = 1112.50, z = −9.77, p = .000, r = −.46. Additionally, when examining the metric Total Fixation Duration, the Mann-Whitney test reveals that the top-ranked plain snip- pets (M dn = 2.08) received longer fixations than bottom- ranked plain snippets (M dn = 0.81), U = 3644.00, z =−5.08, p = .000, r = −.24. Likewise, participants fixated for longer times on the top-ranked rich snippets (M dn = 2.08) than bottom-ranked rich snippets (M dn = .90), U = 3364.50, z = −4.65, p = .000, r = −.22. For the Fixation



(a)Only plain snippets .(b) With rich snippet (#7).

Figure 3: Heatmaps showing allocation of user attention in web search, on two SERP's.

U= 3364.50, z = −4.65, p = .000, r = −.22. For the Fixation Count metric the Mann-Whitney test reveals that the top-ranked plain snippets (M dn = 10.00) received significantly more fixations than bottom-ranked plain snippets (M dn = 4.00), U = 3422.50, z = −5.56, p = .000, r = −.26.

The same effect, is observed when comparing top-ranked rich snippets (M dn = 10.00) against bottom-ranked rich snippets (M dn = 5.00), although it has a smaller effect size, U = 3550.00, z = −4.23, p = .000, r = −.20. Finally, for the metric Visit Duration, participants spent significantly more time examining the top-ranked plain snip- pets (M dn = .81) than the bottom-ranked plain snippets (M dn = .59), U = 4975.50, z = −2.28, p = .022, r = −.10.

Likewise, participants spent significantly more time examining the top-ranked rich snippets (M dn = .74) against bottom-ranked rich snippets (M dn = .53), U = 4035.00, z =

−3.12, p = .002, r = −.14. These findings provide further evidence that the results shown in top-ranked positions at- tract significantly more attention, and for longer time, com- pared to the results shown in bottom-ranked positions. But does this also hold for plain vs. rich snippets that are dis- played in the same position in a SERP? Does the richness or type of snippet introduce any effect?

To answer the above questions, we perform a comparison between rich and plain snippets that have the same relative position in the layout of the SERP, across all eye metrics. We observe that rich snippets generally tend to attract more attention. For example, rich snippets receive their first fixation faster, have fewer fixations on other elements prior to being noticed, and receive more and longer fixations than plain snippets. However, none of these differences appear to be statistical significant, and even less when comparing snippets in top-ranked positions (Figure 3). Most likely, when a snippet appears in a top-ranked position, this by itself introduces a bias which makes users consider it as topically relevant [1]; thus the absence of significant effects in top-ranked snippets.

Next, we repeat our analysis for each snippet type separately. As before, we observe differences between the rich and plain snippets that span across the different types of snippets, like Google Places, Author, Multimedia, etc., al- though most of them appear not to be statistically significant. As side-findings, we report that participants fixated faster on the top-ranked rich Multimedia snippets (M dn = 1.87) than the top-ranked plain Multimedia snippets (M dn = 2.49), $U = 218.00$, $z = -2.36$, $p = .018$, $r = -.24$. More-

over, the bottom-ranked rich Multimedia snippets (M dn =.45) were observed for less time than the bottom-ranked plain Multimedia snippets (M dn = .71), $U = 104.50$, $z = -1.99$, $p = .045$, $r = -.20$.

Figure 4: Visual representation of the four rich snip- pet types used in Study 2.

When analysing the click-through data of the 110 participants who performed the online part of Study 1, we observe that the top-ranked snippets of type Review, Author, and Google Plus (all recommendation snippets), receive the highest percentage of clicks: 32%, 21%, and 18% respectively. In 4 out of 5 rich snippet typologies, the number of clicks is similar; a statistically significant difference is only found for the Google Plus recommendation snippet ($p = .04$). For this type of rich snippet, the recommended result received eight clicks, while the plain result received only two. However, we cannot conclude that Google Plus recommendations per se had a strong influence on the participants' click behaviour. We need to account for the context as well as the person that recommends the result, as dis- cussed in [18]. In this case, the picture we used as a recommender is a public and acknowledged person. We speculate that the results could have been different if the recommender was someone less popular or unknown to the wide public. Finally, the rich snippet with the least clicks is the Multimedia snippet, most likely because people seeking information do not take so much into consideration multimedia results. An- other possible interpretation is that any deviation from the traditional, textual presentation of he results may lead to "banner blindness", and consequently result in less attention to the enriched snippet. No significant differences in performance are found when we compare enriched results with plain snippets.

3.2 Study 2

The second study is a follow-up to Study 1. It was per- formed to investigate users' behaviour while interacting with a different set of snippets (Figure 4) and also allowed us to replicate the preliminary findings of the first study. More specifically, we introduce the Google Shopping snippet and remove the Google Plus (given recent findings reported in [18]) and Multimedia snippet types. The reason for that was the increasing popularity and visibility of Google's Shop- ping Product snippet. In addition, we now compare only top-ranked rich vs. plain snippets, and exclude from our analysis bottom-ranked results, in the light of the findings provided by Study 1.

Table 3: Types of rich snippets and search tasks used in Study 2

Rich snippet	Search task
Author	1. iPad 3 Vs. iPad 2 comparison
Google Shopping	2. Buy iPad 3
Google Places	3. Apple store Madrid
Review	4. Best moment to sell an iPhone

3.2.1 *Design*

The study used an independent measures design with two independent variables: snippet richness (with two levels: "plain", "rich"), and snippet type (with five levels: "Author", "Google Places", "Google Shopping", "Review"). To control for snippet richness, we prepared two versions of every SERP shown in the study: one version containing a rich snippet among the organic results (at position #2) and another ver- sion without the rich snippet, showing only plain web re- sults. More specifically, for each task introduced in the study (see Section 3.2.3), predefined search queries were submitted to Google Search until obtaining SERP's that contained at least one of the types of rich snippets shown in Table 3 in the 2nd or 3rd position. While retaining the original look and feel of the retrieved SERP's, we edited the HTML code of the pages so that they either contained only one rich snippet or no rich snippets;

any additional, unwanted rich snippets were modified to appear as plain snippets instead.

Given that the retrieved SERP's showed the original top ten results obtained from Google search, we considered them as topically relevant to the associated search query. This assumption was further validated by a manual examination. Similarly to the previous study, we controlled that none of the snippet text (plain or rich) contained directly the answer to the query. Our dependent variables were again noticeability, interestingness, and conversion, all aspects of the search experience that can be potentially affected by the richness of the snippets. To study the effect of our experimental manipulation on the dependent variable, we obtained the same five metrics of gaze behaviour and one metric of search task performance discussed in Section 3.1.1.

3.2.2 *Apparatus*

The study used the setup discussed in Section 3.1.2.

3.2.3 *Search Tasks*

Four search tasks were used in the study, as shown in Table 3. Each search task asked the participants to retrieve relevant information to answer a question, e.g., find information on how to arrive to the AppStore located in Madrid. For each search task, participants were presented with an initial search query and the retrieved SERP for this search query. Participants were instructed to examine the SERP as they would normally do, although they were not able to issue additional search queries. As long as the answer did not appear in the snippet description, the participants were encouraged to click on any of the results and examine the web pages prior continuing to the next task. Selecting a particular result as the one that answered the search task question would conclude the task.

Half of the participants were shown SERP's that contained only plain snippets and the other half SERP's that included a rich snippet at a top- ranked position.

3.2.4 *Participants*

A total of 43 participants (female=26, male=17), between the ages of 18 to 45 and free from any obvious physical or sensory impairment, were recruited through a campus- wide ad. All participants were frequent users of web search engines. The participants were mainly locals (i.e., Catalan, Spanish) and had graduated from, were currently studying, or working at the at Pompeu Fabra University, Barcelona. Finally, participants were all proficient with the English and Spanish languages.

3.2.5 *Procedure*

Two groups were created using an independent measures design. Each group performed four search tasks. The search tasks were part of a larger scenario that instructed the participants as follows: "You want to buy the new iPad 3, but before you do so, you need to know how much it costs, what are the technical pros and cons in comparison with iPad 2, how to arrive to the AppStore in a particular city, and the best moment to sell your iPad 2". Four SERP's were selected and were enriched with four types of rich snippets: Product, Author, Places, and Reviews. For this study, the rich snippets and its respective plain snippet were always placed at a top position (#2).

For each group, half of users would see the SERP's with the plain results and the other half would see the SERP's that contained the rich snippet. As in Study 1, the participants were asked to click on the result that they felt would answer the question presented in the search task. After per- forming the four tasks, the users in the group that saw the enriched SERP's were shown the rich snippet highlighted and were asked to answer the following questions: (i) Did you notice the highlighted result?, (ii) If you noticed it, did you click on it?, (iii) What was the reason behind (not) clicking on it?, and (iv) Did the image (pictures, maps, stars) influence your click decision?

3.2.6 *Results*

To analyse the user behaviour (noticeability, interesting- ness, and conversion,) we use the Mann-Whitney test on all eye metrics. Our analysis does not reveal any statistically significant differences between plain and rich snippets, for any of the SERP's and snippet types (Author, Google Places, Google Shopping, Review). In addition, we apply the Chi-Square test of Association on the click data obtained by the eye tracking software. A significant association between the snippet richness (plain, rich) and the number of participants who clicked on the enriched results is observed for the task that involved the Google Places snippet, ($\chi2(1) = 4.00$, $p = .045$). The reason could be that the map and address shown in the rich snippet were perceived as helpful and topically relevant, and the participants felt inclined to select it.

Furthermore, we apply the Chi-Square Goodness-Of-Fit test on the questionnaire data, and more specifically to questions (i), (ii), (iii), and (iv) presented in Section 3.2.5. The test reveals a consistent effect across all snippet types. More specifically, the Chi-Square Goodness-Of-Fit test indicates that significantly more participants reported having noticed the rich snippet of type Author ($\chi2(1) = 6.00$, $p = .014$), Google Shopping ($\chi2(1) = 8.16$, $p = .004$), Google Places ($\chi2(1) = 8.16$, $p = .004$), and Review ($\chi2(1) = 6.00$, $p =.014$). Finally, significantly more participants reported that the presence of the pictures, images, or stars in rich snippets did not influence their decision of clicking the result, that those who reported that it did. Again, this effect is consistent across all snippet types, i.e., Author ($\chi2(2) = 15.75$, $p =.000$), Google Shopping ($\chi2(2) = 19.00$, $p = .000$), Google Places ($\chi2(2) = 13.00$, $p = .002$), and Review ($\chi2(2) = 7.00$, $p = .030$).

4. DISCUSSION & CONCLUSIONS

In this paper we presented a two-part study of the gaze and mouse behaviour of web users, while interacting with SERP's. Considering our User Experience (UX) context, our goal was to investigate whether the richness of snip- pets can affect user behaviour and introduce a bias to the subjective perception of relevance, i.e., which results people perceive as more useful or relevant in a SERP.

Foremost, the findings of our first study indicate that the relative position of a result in a SERP remains the most influential factor of click behaviour, although snippet rich- ness appears to become a more important variable, especially when examining bottom-ranked results. Our analysis did not indicate an effect of snippet richness on the gaze behaviour for top-ranked positions: none of the eye metrics we examined was found to be statistically significantly different for rich snippets, followed by similar findings in regards to the recorded clicks. Nevertheless, snippet richness is a factor that must be taken into account when considering bottom-ranked results, since they are noticed much earlier than the plain snippets and for longer periods of time. Furthermore, Multimedia snippets were the most noticeable element across the evaluated types of snippets in this study. Also, we demonstrated that the social content in a snippet has a growing importance, as indicated by the higher click count it achieved, compared to the equivalent plain results of the same ranking.

The second study compared rich and plain snippets dis- played at top positions. Our analysis did not provide any evidence that rich snippets attract attention faster or for longer periods of time than their corresponding plain snip- pets. Additionally, the number of clicks did not differ be- tween the rich and plain snippets, apart from the Google Places snippet. The reported answers in the questionnaire suggested that the participants were aware of the presence of these enriched results, but their decision of clicking was not conditioned by their presence in the SERP.

In conclusion, our study provides further evidence, which confirms the importance of ranking in relevance judgments, and also indicates that snippet richness is not as influential as one would originally anticipate. However, this may change in the future, but more work is needed to understand how rich snippets should be presented, and in which position in a SERP they are most effective. We consider that this work can impact future web search interfaces and interaction techniques for studying UX, as a complement to the common batch evaluation that dominates the IR field. Eye-tracking is a suitable method for such research, as it accurately captures a user's initial (low-level) attention, much more accurately than other methods, such as clicks logs for example.

Finally, we acknowledge that the results discussed in this paper are preliminary, and further testing is warranted with additional snippet types and search tasks. We leave for future work search tasks where the scenario is ambiguous: will rich snippets play a more important role when the user cannot provide a definitive search phrase? Nevertheless, we feel that we have raised a main issue for a topic that is largely unexplored and it is of importance to research conducted in human-computer interaction (HCI), information retrieval (IR), as well as SEO practitioners.

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Evaluación de la eficiencia de uso de las versiones de escritorio y tableta de una aplicación

Juan P. Moreno
Statistics, Mathematics and Informatics Department
Miguel Hernandez University of Elche
Elche, Spain
juan.morenom@umh.es

Antonio Peñalver
Center of Operations Research University Institute
Miguel Hernandez University of Elche
Elche, Spain
a.penalver@umh.es

Federico Botella
Center of Operations Research University Institute
Miguel Hernandez University of Elche
Elche, Spain
federico@umh.es

ABSTRACT
Ya es un hecho que el proceso de diseño y creación de productos software se está orientando cada vez más a los dispositivos móviles. Si se habla del entorno web, las grandes compañías emplean ya más esfuerzo de desarrollo en las versiones móviles de sus sitios webs corporativos y de venta que en sus versiones de escritorio. Y lo mismo ocurre con otros productos software. Las aplicaciones móviles, que pueden usarse cómodamente en móviles y tabletas para tareas como banca electrónica, redes sociales, reserva de instalaciones, reproducción de contenidos digitales… etc. están desbancando progresivamente a los programas clásicos que se solían emplear en ordenadores de sobremesa. Llegados a este punto, cabe preguntarse qué ocurre cuando el usuario debe realizar operaciones de cierta complejidad con el software, como gestionar una pequeña o mediana empresa. ¿Realmente es usable y eficiente una aplicación móvil de gestión para una empresa? En este trabajo realizamos un estudio con el fin de medir la eficiencia y la usabilidad percibida de una aplicación de escritorio, enfrentando los resultados a los obtenidos en un estudio de esa misma aplicación en su versión de tableta. De esta forma, se ha obtenido un ratio de eficiencia de una aplicación de escritorio con respecto a su respectiva versión para tableta, que puede resultar relevante para el desarrollo de futuras aplicaciones tanto de escritorio como móviles.

Categories and Subject Descriptors
H.5.2 **[Information Interfaces and Presentation (e.g., HCI)]**: User Interfaces – Evaluation/methodology, Input devices and strategies (e.g., mouse, touchscreen), Screen design (e.g., text, graphics, color).

General Terms
Measurement, Experimentation, Human Factors

Keywords
Mobile usability, screen size, SUS, mobile efficiency, mobile effectiveness

1. INTRODUCCIÓN
Hoy en día podemos encontrar en el mercado una gran variedad de dispositivos móviles con distintas resoluciones y tamaños de pantalla. Desde los smartphones, cuyo tamaño de pantalla oscila entre las 3 y las 6 pulgadas (incluso las 7); a las tabletas, que presentan unos tamaños de pantalla que van desde las 7 pulgadas hasta pantallas de más de 10 pulgadas. Además, las tabletas de última generación, presentan cada vez interfaces más eficientes, incluyendo teclados en pantalla cada vez más intuitivos y versátiles, lo que convierte a estos dispositivos en serias alternativas para poder realizar con ellos tareas complejas, para las cuales, tradicionalmente, se han empleado ordenadores de sobremesa. De esta forma, un usuario debe plantearse para qué tipo de tareas merece la pena emplear una tableta, con las ventajas que supone usar un dispositivo de este tipo (movilidad, ligereza, versatilidad, duración de batería…); frente a emplear un laptop (con sus cómodos teclados y grandes tamaños de pantalla (por encima de 11 pulgadas [1]), o un ordenador de sobremesa tradicional, con pantallas ya por encima de 27 pulgadas [2].

Parece lógico asumir que un smartphone no es lo más adecuado para realizar tareas complejas de forma eficiente. Este tipo de dispositivos son adecuados para tareas simples, tales como consultas de información, introducción de pequeñas cantidades de información, captura de imágenes, etc. Pero si consideramos las tabletas, ¿puede un usuario llegar a ser tan eficiente como lo sería con un ordenador en la realización de tareas complejas, como puede ser la gestión integral de una empresa? O en cambio, ¿existirá algún tipo de tarea que sea difícil de realizar con una tableta? Y si no es posible ser tan productivo con una tableta como con un ordenador, ¿cuánto más productivo se es con un ordenador que con una tableta?

En este artículo se pretende probar la hipótesis de que un usuario es más eficiente realizando tareas de cierta complejidad con un ordenador que con una tableta, así como que la usabilidad percibida por éste es mayor cuando trabaja con el ordenador que cuando lo hace con el dispositivo móvil. Para ello se ha diseñado un experimento destinado a mediar la usabilidad de una aplicación de gestión adaptada tanto para versión escritorio como para la tableta. Dicho experimento se ha llevado a cabo con ocho usuarios que han realizado tareas complejas con ambos dispositivos. Además se recogieron datos cualitativos acerca del uso de la aplicación y la usabilidad percibida por estos usuarios. Este estudio revela la importancia de un buen diseño adaptativo para los distintos dispositivos y tamaños de pantalla, y cuantifica el incremento de tiempo que conlleva realizar una tarea compleja con una tableta en relación con el tiempo necesario para realizarla con un ordenador o laptop.

El resto del artículo se organiza de la siguiente forma: la sección 2 presenta un resumen del estado del arte. En la sección 3 se describe la aplicación empleada en el estudio. La sección 4 presenta una descripción detallada del experimento, así como la metodología empleada. En la siguiente sección se detallan y analizan los resultados obtenidos en el experimento y, finalmente, en la sección 6 se exponen las conclusiones obtenidas y las líneas de trabajo futuro.

2. TRABAJOS RELACIONADOS
Son muchos los estudios centrados en analizar la usabilidad de las tabletas en distintos ámbitos de uso: evaluar el rendimiento de

niños que emplean estos dispositivos en sus tareas escolares [3]; o la usabilidad de distintos tipos de tabletas cuando son usadas por alumnos universitarios con algún tipo de discapacidad [4]; o bien estudiar la influencia del uso de tabletas como una herramienta de ayuda para que personas mayores se familiaricen con las nuevas tecnologías [5]. En [6] se estudia la influencia de factores externos en la percepción de usabilidad de usuarios cuando éstos trabajan con dispositivos móviles, teniendo en cuenta aspectos del movimiento físico, combinado con cualquiera de las necesidades de navegación en el espacio físico, o la división de la atención mientras se emplean dispositivos móviles. Todos ellos hacen hincapié en la importancia de un buen diseño de los menús, pantallas y áreas de navegación cuando se trabaja en pantallas reducidas..En [7] se realiza un estudio que demuestra que los usuarios sufren un déficit en su capacidad de recordar la información que han leído cuando lo han hecho en pantallas pequeñas en relación con lo que recuerdan cuando leen en pantallas de grandes dimensiones. Cuando los usuarios tienen que realizar tareas complejas que implican la escritura de texto en dispositivos móviles, los estudios demuestran que el rendimiento de los usuarios se reduce considerablemente. Si el usuario necesita escribir algo en una aplicación móvil, los problemas de usabilidad se acentúan, ya que se hace necesario mostrar en pantalla un teclado virtual, de manera que la cantidad de información que se puede mostrar en pantalla se hace todavía menor [8]. El teclado virtual (imprescindible para escribir en tabletas) reduce el área visual con información para el usuario, lo que aumenta considerablemente la dificultad de la tarea de escribir pulsando con los dedos (o con un dispositivo señalador) sobre una pequeña pantalla. Adaptar la interfaz de una aplicación tanto a las necesidades del usuario como al tamaño de la pantalla es crucial para mejorar el rendimiento y la eficacia del usuario [9].

En relación a estudios comparativos entre dispositivos de escritorio frente a dispositivos móviles, se han escrito trabajos como [10]., que proporciona una visión general de los estudios de usabilidad de aplicaciones móviles existentes, proponiendo un marco genérico para la realización de pruebas de usabilidad de aplicaciones móviles. En cuanto al diseño adaptativo o "responsive", los usuarios se sienten más satisfechos y, en consecuencia, presentan un mayor rendimiento cuando usan aplicaciones cuyos interfaces presentan un diseño adaptativo [11], en lugar de aplicaciones cuyo interfaz es rígido y normalmente adaptado a versiones de sobremesa o a pantallas de mayor tamaño. Otros trabajos analizan la satisfacción del usuario y sus preferencias en relación al uso de tabletas en comparación con ordenadores portátiles en la realización de tareas comunes [12].

Por último, también existen estudios que enfocan las evaluaciones de usabilidad en función de quién las realiza,, basado en la perspectiva del usuario (que se expresa por la percepción del usuario de la aplicación) y la perspectiva del especialista en interacción persona – ordenador [13].

3. DESCRIPCIÓN DE LA APLICACIÓN

En este trabajo se ha evaluado la usabilidad de una aplicación para la gestión de estudios de fotografía desarrollada en tres versiones: escritorio, tableta y smartphone. Se trata de una versión de prueba de la aplicación Photo Solution Pro[7], de la cual se han empleado ciertos módulos para el diseño de las pruebas con usuarios.

Photo Solution Pro es una aplicación de gestión para estudios de fotografía. Esta aplicación permite llevar el control global de una empresa de este tipo, permitiendo al usuario gestionar todo su flujo de trabajo: citas, presupuestos, sesiones, modelos, facturación, gastos, marketing, beneficios, tesorería etc.

La aplicación está dividida en seis grandes áreas a las que se puede acceder desde su pantalla de inicio:

- TPV: esta sección permite gestionar la caja diaria, permitiendo introducir ventas por caja, crear tickets de venta, imprimirlos, editarlos, eliminarlos, imprimir listados de caja, etc.
- Agenda: desde esta sección se gestiona la agenda del fotógrafo. Permite introducir citas rápidas, citas basadas en trabajos en curso, editar las citas, mostrar la agenda en distintas vistas (día, semana y mes), listar citas o tareas pendientes, etc.
- Clientes: este apartado permite listar clientes, buscarlos a través de distintos filtros, introducir nuevos clientes, editarlos, eliminarlos, etc.
- Contabilidad: esta sección permite gestionar los presupuestos, albaranes y facturas de la empresa. Así como generar multitud de informes de ingresos, gastos, beneficios, gráficas de distintos tipos, etc.
- CRM: apartado para gestionar los aspectos de la relación con los clientes, filtros de clientes según sus compras, fechas de nacimiento, preferencias… Una vez obtenidos los listados de clientes, se les puede enviar e-mails, newsletters, SMS, etc.
- General: gestión de productos, empleados, proveedores y archivo digital. Desde esta sección también se acceder a la personalización y preferencias de la aplicación.

La aplicación ha sido diseñada de manera que se pueda acceder a ella desde tres tipos de dispositivos: ordenadores de escritorio o laptops, tabletas y dispositivos móviles. Para cada una de estas versiones de la aplicación se han empleado técnicas de diseño distintas. Es decir, se ha realizado un diseño adaptativo de la aplicación, siguiendo las directrices de diseño adecuadas para cada versión de la aplicación en cuanto a tamaños de texto, tamaños de los botones, distancia entre los elementos, resoluciones de pantalla, etc.

El diseño de cada una de las pantallas de la aplicación ha sido adaptado a todos los dispositivos desde los cuales se puede acceder a ella: Escritorio, iPad y iPhone. Para el interfaz, se diseñaron cientos de presentaciones con distintos tamaños para adaptarlas de la mejor manera posible a los distintos tamaños y resoluciones de pantalla disponibles. Los tamaños de letra, botones, paneles, etc. fueron diseñados expresamente para cada versión de la app, así como los diferentes menús y pantallas.

[7] http://www.photosolutionpro.com

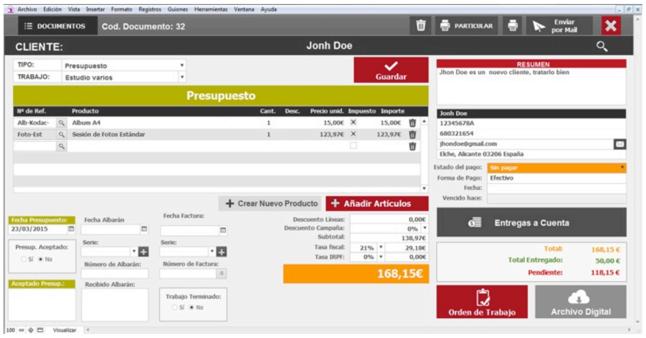

Figura 1. Captura de la versión Desktop.

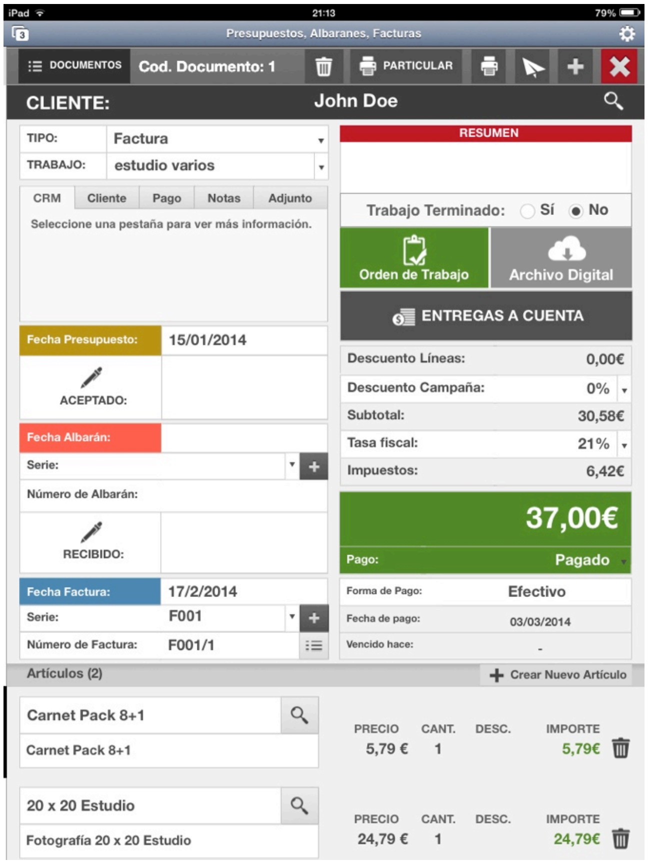

Figura 2. Captura de la versión iPad con los objetos adaptados al tamaño de la pantalla.

4. METODOLOGÍA

En el presente estudio se ha realizado una evaluación de usabilidad de una aplicación de gestión diseñada para dispositivos de escritorio y para tabletas, con diferentes diseños para cada uno, mediante sesiones guiadas con usuarios reales que fueron registradas a través de distintas cámaras y analizadas con posterioridad. El objetivo de este experimento fue comprobar cuánto tiempo lleva a un usuario realizar ciertas tareas complejas en un ordenador de escritorio, para después comprobar cuánto tiempo le lleva realizar esas mismas tareas en una tableta, es decir comprobar la eficiencia de los usuarios al realizar estas tareas en un dispositivo móvil con pantalla de 7,9’’ en comparación con realizarlas en un ordenador de sobremesa con teclado y una pantalla de 15,6’’. Del mismo modo, el estudio pretende analizar la eficacia de los usuarios al realizar las tareas, así como la usabilidad percibida con estos dos dispositivos de tan diferentes características.

Para ello se desarrolló en primer lugar un plan de pruebas donde se definieron una serie de ítems que fueron tenidos en cuenta durante la realización de todo el experimento. Los puntos incluidos en este plan de pruebas fueron los siguientes: objetivos y preguntas de investigación, características de los usuarios, diseño de las pruebas, definición de las tareas, equipo y entorno de pruebas, métricas de evaluación, resultados y conclusiones.

4.1 Objetivos

El objetivo principal de este estudio ha sido medir la caída del rendimiento de los usuarios al realizar varias tareas de cierta dificultad con un dispositivo de reducidas dimensiones como un iPad, en comparación de la realización de esas mismas tareas con un dispositivo de mayores dimensiones, como es un ordenador de escritorio; todo ello con la misma aplicación en ambos dispositivos. Para ello se definieron previamente las siguientes cuestiones a investigar:

a) El rendimiento en la ejecución de una serie de tareas en un ordenador de sobremesa es mayor que en la ejecución de esas mismas tareas en una tableta.

b) La usabilidad percibida por el usuario será distinta dependiendo de con qué dispositivo realice la tareas, ordenador o tableta.

c) El número de problemas de usabilidad detectados por el usuario es menor cuando el usuario realiza las tareas en un ordenador de sobremesa que cuando las realiza en una tableta.

Para dar respuesta científica a estas cuestiones se realizaron pruebas con usuarios reales, con el objetivo de experimentar la influencia de la interacción de un mismo usuario con dos versiones de una misma aplicación diseñada para distintos dispositivos (en este caso Escritorio e iPad).

4.2 Participantes

Para este experimento se han seleccionado ocho usuarios que se ofrecieron voluntariamente para realizar el estudio de usabilidad de la aplicación. Antes de la realización de las pruebas se le facilitó a los usuarios un cuestionario pre-test [14], que debía ser respondido en unos dos minutos aproximadamente. Estas cuestiones tenían una doble utilidad: 1) Hacer que los usuarios se sientan más cómodos rompiendo el hielo antes de comenzar las pruebas y 2) Conseguir la información necesaria para clasificarlos. Así se obtuvieron los siguientes datos demográficos y de experiencia en el uso de dispositivos móviles.

Se realizaron las pruebas a cinco hombres y tres mujeres. Las edades de los usuarios reclutados para las pruebas de la aplicación están comprendidas entre los 24 y los 35 años (Media = 31,50; SD = 4,38). Cada uno de los usuarios es propietario de un ordenador y de una tablet (aunque no todos ellos tienen un iPad como los que se han utilizado en nuestro laboratorio). En general, todos los usuarios hacen un uso intensivo de sus dispositivos móviles, ya sean smartphones o tabletas, durante la semana (Media = 20,38 horas / semana; SD = 14,60); sin embargo, no todos los usuarios tienen demasiada experiencia en el uso de aplicaciones móviles en sus dispositivos móviles, dejando al margen las habituales aplicaciones de mensajería instantánea, redes sociales, mini-juegos, etc. En cuanto al trabajo con ordenadores de escritorio, en general los usuarios también realizan un uso intensivo, con una media semanal de 18,13 horas (SD = 18,46). Uno de los usuarios declara usar programas de gestión en ordenador de sobremesa muy frecuentemente, cuatro usuarios declaran hacerlo de manera frecuente, mientras que los otros tres usuarios dicen no usar programas de gestión en ordenadores. Sin embargo, tres de los ocho usuarios declaran emplear otro tipo de software en sus ordenadores de manera muy frecuente, otros tres usuarios de manera frecuente, un usuario afirma hacerlo de vez en cuando, mientras que sólo un usuario dice usar el ordenador de manera nada frecuente.

Ninguno de los usuarios había trabajado previamente con la aplicación puesta a prueba en este estudio. Como todos los usuarios se encuentran en el mismo rango de edad, se puede afirmar que el efecto de la usabilidad percibida en función de la edad de los participantes ha sido mínima [15].

4.3 Procedimiento

Las pruebas fueron realizadas por ocho usuarios, que realizaron las tareas en ambos dispositivos. Ocho usuarios es un número aceptable de participantes para obtener resultados válidos en estudios de usabilidad [16]. Cada uno de los 8 participantes realizó en primer lugar las tareas en orden secuencial en una tableta iPad. Los resultados de las pruebas con la tableta fueron publicados en nuestro trabajo previo “How efficient can be a user with a tablet versus a smartphone?” [17]. Unos meses más tarde, los mismos ocho participantes realizaron las mismas tareas en el mismo orden secuencial con un ordenador de sobremesa. De esta forma, el tiempo transcurrido entre las pruebas con la tableta y las pruebas con el ordenador hace que el efecto aprendizaje no sea tenido en cuenta en los resultados.

Se evaluaron las dos versiones de la aplicación (versión iPad y versión escritorio) en un diseño de pruebas basado en el modelo ‘Within-Subject Design’, definido por Jeffrey Rubin y Dana Chisnell [18]. El modelo ‘Within-Subject Design’ es un sistema de evaluación basado en que un mismo grupo reducido de usuarios realice todas las tareas a evaluar.

Se instaló la aplicación Filemaker GO 13 en un iPad Mini y en un ordenador Acer Aspire para poder conectar de esta forma con el servidor de Photo Solution Pro y poder ejecutar la aplicación a probar sobre los dos aparatos. Cuando los usuarios llegaron al laboratorio se encontraron con ambos dispositivos preparados con las dos versiones de Photo Solution Pro en perfectas condiciones para comenzar con las pruebas.

Para la duración de las pruebas, se acordó previamente que la duración total estimada de todas las tareas a realizar por un mismo participante, incluidas las tareas con los dispositivos y la realización de todos los cuestionarios, debería ser de 30 minutos como máximo con cada uno de los dispositivos.

Todos los usuarios realizaron las mismas pruebas en el mismo laboratorio y bajo las mismas condiciones. Antes de que los usuarios comenzaran a realizar sus tareas, se preparó una etapa de bienvenida de unos 5 minutos aproximadamente. En esta etapa, el moderador leía un guion escrito en el cual daba la bienvenida al usuario y le explicaba con exactitud al usuario el motivo y objetivos de las pruebas. Además, durante esta fase se invitó a cada participante a firmar un formulario de consentimiento de grabación, donde se le informaba de que su prueba iba a ser grabada en vídeo con el fin analizar las imágenes para detectar problemas de usabilidad de la aplicación. Durante los siguientes 2 minutos, se le realizó al usuario el cuestionario con las preguntas pre-test. A continuación, se emplearon los siguientes 3 minutos en pedir al usuario que navegara por los distintos menús de la aplicación y explicara en voz alta qué sensaciones le transmitía la aplicación y que tratara de definir cuál pensaba que era el propósito final de la aplicación. Ninguno de los usuarios seleccionado conocía esta aplicación antes de comenzar con las pruebas con la tableta, por lo que era importante una primera fase de familiarización con la app y recoger sus impresiones. Tras la etapa de familiarización, los usuarios comenzaron con la realización de las tareas, se les dejó trabajar libremente, sin proporcionar a los participantes ningún tipo de feedback acerca del éxito o fracaso de sus progresos. Sólo en el caso de que un participante tuvo problemas graves en una tarea, el moderador la detuvo e invitó al usuario a continuar con la siguiente tarea. Tras la realización de las tareas, se llevó a cabo una fase de indagación de 5 minutos aproximadamente en la que cada usuario cumplimentó un cuestionario del tipo SUS (System Usability Scale [19]), con el fin de que quedara registrada la usabilidad general de la aplicación que cada participante había percibido.

4.3.1 *Equipo físico para las pruebas*

En nuestro laboratorio empleamos el siguiente equipo: un iPad Mini de 64 Gb. Pantalla Retina, Multi-Touch retroiluminada por LED de 7,9" (en diagonal). Un ordenador Acer Aspire 5741G, con pantalla de 15,6" HD (1366x768) con tecnología LED. Para grabar las pruebas se empleó una camára USB IPEVO Ziggi HD Document Cámara, con 5 Megapixel de resolución con micrófono incorporado. Esta cámara grabó los movimientos de las manos y la voz del usuario mientras realizaba las pruebas con la tableta. Para capturar la cara y movimientos gestuales de los usuarios se empleo una cámara Canon EOS 5D Mark II. 21.1 MegaPixel, con la que se grabaron las pruebas en Full HD (1080, 30 fps). Para el almacenamiento y edición de las grabaciones se empleó un iMac 2,93 GHz Intel Core Duo. 8 GB RAM DDR 3 1067 MHz..

4.3.2 *Tareas realizadas*

A continuación se describen las cinco tareas secuenciales que los participantes realizaron en ambos dispositivos:

- Tarea 1. Dar de alta un nuevo cliente. El usuario debe introducir un nuevo cliente en la aplicación, completando los siguientes datos: nombre, apellidos, empresa, cargo, CIF, fecha de nacimiento, teléfono móvil, teléfono fijo, e-mail, web, dirección, C.P., ciudad, provincia, país y aceptación de publicidad. El tiempo estimado de esta tarea es de 180 segundos para iPad y 150 para Escritorio.
- Tarea 2. Dar de alta un producto. El usuario debe introducir un nuevo producto en la aplicación. Los datos del producto son: artículo, fabricante, número de referencia, categoría, ubicación, peso, foto (que el usuario debe tomar con la cámara de la tableta, o bien insertar desde el disco duro del ordenador), precio coste, margen, precio venta sin IVA, precio venta con IVA, existencias y stock mínimo. Esta tarea tiene un tiempo estimado de 160 segundos para iPad y 140 segundos para Escritorio.
- Tarea 3. Dar una cita a un cliente. El usuario debe asignar una cita al cliente dado de alta en la tarea 1. Los datos de la cita son los siguientes: fecha, hora desde, hora hasta, lugar, fase de trabajo, tipo de trabajo, cliente y notas. La duración

estimada de esta tarea es de 140 segundos para iPad y 120 segundos para Escritorio.

- Tarea 4. Rellenar el presupuesto de la sesión de fotos. En esta tarea el usuario debe confeccionar un presupuesto para una sesión de fotos añadiendo un par productos al presupuesto una entrega a cuenta por parte del cliente. Los datos a cumplimentar son: artículo 1, artículo 2, fecha de entrega a cuenta, importe y forma de pago. El tiempo estimado para esta tarea es de 200 segundos para iPad y 80 para Escritorio.
- Tarea 5. Enviar un newsletter a un cliente. En la última tarea, el usuario debe enviar un newsletter publicitario a un cliente. Los datos del newsletter son cliente, foto (que el usuario debe tomar con la cámara del dispositivo móvil), titular y cuerpo. Esta tarea tiene una duración estimada de 240 segundos para iPad y 150 segundos para Escritorio.

En la Figura 3 se puede observar a un usuario introduciendo un nuevo producto en la aplicación usando el iPad, mientras se graban sus manos realizando la tarea con una cámara situada sobre ellas. Al mismo tiempo se captura y se graba la pantalla mediante el software Reflector en un iMac para registrar con más detalle todos los movimientos y pulsaciones del usuario.

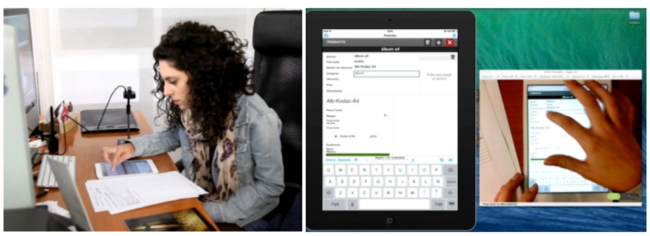

Figura 3. Un usuario realizando la prueba en nuestro laboratorio, en el momento de introducir un nuevo cliente en la aplicación.

4.4 Medidas

4.4.1 *Efectividad en cada dispositivo*

Antes de que las realizaran los usuarios, todas las tareas fueron realizadas por el equipo de desarrollo de la aplicación en el laboratorio de pruebas, con el fin de estimar el tiempo requerido para realizar cada una de las cinco tareas en ambos dispositivos:

Tabla 1. Tiempos estimados para completar cada tarea (en segundos) usando la tableta (columna t) y el ordenador (columna d).

Task1		Task2		Task3		Task4		Task5	
t	d	t	d	t	d	t	d	t	d
180	150	160	140	140	120	200	80	240	150

Todas las actividades de los participantes fueron grabadas en vídeo mientras éstos completaban las tareas en los dos dispositivos. De esta manera se pudo comprobar, a posteriori, si el usuario había finalizado completamente cada una de las tareas y calcular el tiempo empleado. Además, la grabación permite obtener datos cualitativos acerca de las impresiones de los usuarios mientras interactuaban con la aplicación. El moderador no proporcionó a los participantes ningún feedback acerca del éxito o del fracaso del usuario en la realización de las tareas. Se permitió a todos los participantes trabajar libremente hasta que finalizaron todas sus tareas. Sólo un participante, trabajando con la tableta, no consiguió terminar una de las tareas. En este caso el moderador simplemente invitó al participante a continuar con la siguiente tarea.

4.4.2 *Eficiencia en cada dispositivo*

Mediante el análisis de las grabaciones de las pruebas, se calculó el tiempo exacto en segundos que cada participante necesitó para la realización de cada una de las cinco tareas, primero con la tableta y después con el ordenador. Todas las tareas se completaron con éxito, excepto una de ellas. Para esta tarea, se hizo necesario estimar el tiempo de la tarea que el usuario no completó adecuadamente, con el fin de calcular la eficiencia de forma precisa.

4.4.3 *Usabilidad percibida de la aplicación*

Para calcular la usabilidad percibida por cada uno de los participantes, se empleo un cuestionario SUS (System Usability Scale). Tras completar todas las tareas con ambos dispositivos, se le pasó a cada participante dicho cuestionario. El moderador realizó las preguntas del cuestionario a cada participante y les indicó que respondieran lo más rápidamente posible a las preguntas, sin pensar demasiado, ya que está es considerada la forma idónea de realizar el cuestionario. Los participantes puntuaron los 10 items del cuestionario en una escala del 1 (Totalmente en desacuerdo) al 5 (Totalmente de acuerdo). El motivo de seleccionar el cuestionario SUS como herramienta para evaluar la usabilidad percibida fue la gran aceptación de este cuestionario por la comunidad científica que trabaja en temas de usabilidad, y por ser un cuestionario libre, fácil de cumplimentar y de evaluar.

5. RESULTADOS

5.1. Efectividad en tareas

Todos los participantes en el experimento realizaron las cinco tareas propuestas tanto en una tableta iPad Mini como en un ordenador de sobremesa Acer Aspire. Entre las pruebas con el iPad y las pruebas con la versión de escritorio pasaron meses de diferencia. Ningún usuario había empleado la aplicación antes de las pruebas, ni volvió a usarla en el periodo que transcurrió entre ambas pruebas, así que el efecto de aprendizaje de la aplicación, que pudiera haber existido entre pruebas, queda descartado al ser las pruebas distantes en el tiempo. El interfaz de cada una de las versiones de la aplicación (iPad y Escritorio) no fue el mismo; dependiendo del dispositivo y del tamaño de su pantalla, cada versión dispone de distintas presentaciones, tamaños de botones y textos, menús, etc.

En la Tabla 2, podemos ver los resultados de la ejecución de todas las tareas por parte de los ocho participantes. En ella puede observarse que todos los participantes completaron el 100% de cada una de las tareas, excepto el Participante 5, quien completó la Tarea 2 al 45% realizándola con el ordenador de sobremesa. Todos los tiempos mostrados en la Tabla 2 son tiempos reales requeridos por los usuarios para completar sus tareas. El tiempo indicado del Participante 5 corresponde a la anteriormente mencionada tarea que quedó pendiente de completar, así que fue necesario calcular el tiempo estimado que el usuario hubiera necesitado para completar la tarea inconclusa, para de esta forma poder comparar con el resto de tiempos y completar el estudio.

5.1.1 *Medidas de rendimiento de las tareas*

En la Tabla 3, se puede observar la diferencia entre el tiempo empleado por cada usuario para la ejecución de cada tarea en comparación con los tiempos estimados mostrados en la Tabla 1.

Tabla 2. Tiempo (segundos) y porcentaje de finalización de tareas para cada usuario en diferentes dispositivos (t=tablet; d=desktop).

	Task1				Task2				Task3				Task4				Task5			
	t	%	d	%	t	%	d	%	t	%	d	%	t	%	d	%	t	%	d	%
P1	190	100%	165	100%	145	100%	179	100%	134	100%	130	100%	255	100%	105	100%	265	100%	161	100%
P2	180	100%	140	100%	183	100%	129	100%	127	100%	136	100%	167	100%	81	100%	302	100%	156	100%
P3	255	100%	219	100%	233	100%	191	100%	330	100%	118	100%	355	100%	85	100%	375	100%	255	100%
P4	193	100%	172	100%	155	100%	112	100%	181	100%	104	100%	154	100%	72	100%	268	100%	148	100%
P5	168	100%	213	100%	119	100%	268	45%	148	100%	108	100%	135	100%	79	100%	238	100%	190	100%
P6	185	100%	166	100%	124	100%	138	100%	136	100%	109	100%	170	100%	69	100%	137	100%	123	100%
P7	166	100%	190	100%	125	100%	112	100%	90	100%	117	100%	155	100%	85	100%	226	100%	129	100%
P8	116	100%	121	100%	89	100%	148	100%	69	100%	113	100%	95	100%	88	100%	182	100%	127	100%

Se puede comprobar que, trabajando con la tableta, los usuarios necesitaron menos tiempo del estimado en 24 de las 40 tareas. Mientras que trabajando con el ordenador, fueron 19 de las 40 tareas, en las que los usuarios terminaron antes del tiempo estimado. Cabe destacar que el Participante 3 necesitó un tiempo significativamente mayor para realizar sus tareas, sobre todo con la tableta. El motivo de esta mayor diferencia entre el tiempo estimado y el real fue que el Participante 3 no tenía demasiada experiencia en el uso de este tipo de dispositivos, unido al hecho de que el entorno de pruebas y la grabación realizada, le ponían nervioso. Esto contrasta, por ejemplo, con el Participante 8, que fue uno de los usuarios que menos tiempo necesitó para realizar todas las tareas tanto con el iPad como con el ordenador.

Tabla 3. Diferencia de tiempos (en segundos) entre el tiempo real necesario y el estimado para cada tarea.

	Task1		Task2		Task3		Task4		Task5	
	t	d	t	d	t	d	t	d	t	d
P1	10	15	-15	39	-6	10	55	25	25	11
P2	0	-10	23	-11	-13	16	-33	1	62	6
P3	75	69	73	51	190	-2	155	5	135	105
P4	13	22	-5	-28	41	-16	-46	-8	28	-2
P5	-12	63	-41	128	8	-12	-65	-1	-2	40
P6	5	16	-36	-2	-4	-11	-30	-11	-103	-27
P7	-14	40	-35	-28	-50	-3	-45	5	-14	-21
P8	-64	-29	-71	8	-71	-7	-105	8	-58	-23
Mean	1,63	23,25	-13,38	19,63	11,88	-3,13	-14,25	3,00	9,13	11,13
SD	35,94	31,45	41,71	48,97	74,56	10,37	76,49	10,33	67,99	41,07

Para la Tarea 1, los ocho participantes se ajustaron bastante al tiempo estimado trabajando con la tableta. Sin embargo, con el ordenador se obtuvieron tiempos en general por encima de lo estimado. Esto es así porque estimamos que el hecho de escribir los datos del cliente en el teclado del ordenador reduciría considerablemente el tiempo necesario para realizar la tarea, sin embargo las pruebas demostraron que esta diferencia no fue tan acentuada como esperábamos. El Participante 5 no logró terminar la Tarea 2 con éxito trabajando con el ordenador, debido a que no consiguió agregar la imagen a la ficha del producto y no pudo finalizar. No fue el único usuario que tuvo problemas con el proceso de inserción de fotografía para el producto, lo que indica que debe ser mejorado este aspecto de la aplicación. Un aspecto interesante de la Tarea 2 es que resultó ser una de las más complejas de realizar para los usuarios en su versión de escritorio, pero fue también una de las que menos tiempo les llevó realizar con la tableta, este hecho sugiere que el diseño de la pantalla de introducción de los datos del producto debe ser reconsiderado en la versión de escritorio. La Tarea 4, una tarea compleja que precisa una búsqueda previa de información que el usuario ha generado en las Tareas 2 y 3 (debe crear un presupuesto asociado a una cita dada de alta en la Tarea 3, con algunos productos, uno de los cuales lo debe haber creado el usuario en la Tarea 2), resultó ser una tarea sencilla para los participante con el iPad, ya que en general terminaron en menos tiempo de lo esperado. De nuevo los resultados fueron algo peores para esta tarea con la versión escritorio, debido principalmente a un diseño y colocación de botones mejorable en esta versión de la aplicación. Por último, para la Tarea 5, al igual que la Tarea 3, se obtuvieron unos tiempos cercanos a los estimados.

5.2. Eficiencia en la ejecución de tareas

Todos los participantes llevaron a cabo las cinco tareas del experimento tanto en tableta como en ordenador de sobremesa. Mediante el análisis de las grabaciones se calculó la diferencia de tiempo necesitado por el usuario para realizar cada tarea en el iPad con respecto al tiempo que había necesitado para realizar la misma tarea con el ordenador. En la Tabla 4 se puede observar el porcentaje de tiempo que cada participante necesitó para completar todas las tareas en la tableta con respecto al necesitado para completarlas con ayuda del ordenador (los datos de la Tabla aparecen en %).

Tabla 4. Porcentaje de tiempo que cada participante necesitó para completar todas las tareas en la tableta con respecto al ordenador

T-D	Task1	Task2	Task3	Task4	Task5	Mean	SD
P1	13,16%	-23,45%	2,99%	58,82%	39,25%	**18,15%**	**31,96%**
P2	22,22%	29,51%	-7,09%	51,50%	48,34%	**28,90%**	**23,60%**
P3	14,12%	18,03%	64,24%	76,06%	32,00%	**40,89%**	**27,84%**
P4	10,88%	27,74%	42,54%	53,25%	44,78%	**35,84%**	**16,71%**
P5	-26,79%	-26,05%	27,03%	41,48%	20,17%	**7,17%**	**31,61%**
P6	10,27%	-11,29%	19,85%	59,41%	10,22%	**17,69%**	**25,96%**
P7	-14,46%	10,40%	-30,00%	45,16%	42,92%	**10,80%**	**33,60%**
P8	-4,31%	-66,29%	-63,77%	7,37%	30,22%	**-19,36%**	**43,51%**
Mean	**3,14%**	**-5,18%**	**6,97%**	**49,13%**	**33,49%**	**17,51%**	**22,84%**
SD	**16,72%**	**32,97%**	**40,88%**	**19,88%**	**13,10%**	**18,99%**	

Se puede apreciar que, en general, un usuario necesitará de media alrededor de un 17,50% más de tiempo para realizar una tarea en la tableta de lo que necesitaría para realizarla con un ordenador de sobremesa. Los resultados obtenidos parecen indicar que la diferencia de tiempo necesario por los usuarios para realizar una tarea con el iPad con respecto al necesitado para realizarla en un ordenador de sobremesa tiende a incrementarse conforme van transcurriendo las tareas, siendo similar en las primeras tareas y más pronunciada en posteriores tareas. Esto parece indicar que cuando el usuario no conoce una aplicación su rendimiento es semejante en ambos dispositivos, pero conforme va conociendo la aplicación con la que trabaja, se va volviendo más productivo con el ordenador que con el dispositivo móvil. Se puede observar también que cuanto más compleja es la tarea, más se acentúa la diferencia de productividad, como se aprecia en la Tarea 4. Esta tarea es la más compleja de las realizadas por los participantes, ya que es necesaria la búsqueda de información de citas y de productos (información que proviene de otras tareas); y es en esta Tarea 4 donde el incremento del tiempo necesario para realizarla con tableta con respecto al necesario para realizarla con el ordenador es más alto, un 49,13%. Otro factor importante que queda demostrado es que el hecho de tener que escribir texto en la tarea influye notablemente, algo que la lógica parecía indicar a priori dada la naturaleza de los teclados de ambos dispositivos. Si nos fijamos en la Tarea 3, volvemos a tener tiempos parecidos, ya que se trata de una tarea en la que apenas se ha de escribir, se actúa sobre ella con botones, listas desplegables, ruletas de fecha, etc. Sin embargo, la Tarea 5 es de las que más texto requiere ser escrito, ya que se trata de enviar un texto publicitario, por lo que el tiempo necesario para completar la tarea en el iPad con respecto al ordenador es de nuevo elevado, un 33,49%. Por último, cabe destacar los resultados del Participante 8, que obtuvo mejores tiempos con el iPad que con el ordenador de sobremesa. El motivo de este resultado es que este participante es usuario habitual de dispositivos Apple, tanto de iMac como de iPad y iPhone, siendo usuario experto en el manejo de los dispositivos móviles de este fabricante. Esto, unido a su falta de costumbre a trabajar con ordenadores que funcionen bajo el sistema operativo Windows, fue lo que explicaría tiempos mejores con el iPad que con el ordenador.

5.3 Problemas de usabilidad detectados

Todos los participantes en el experimento fueron grabados mientras realizaban sus tareas con ambos dispositivos. Todos los problemas de usabilidad detectados por los usuarios (directa o indirectamente) fueron anotados mientras se examinaban las grabaciones después de que los usuarios completaran sus pruebas. En la Tabla 5, se pueden apreciar el número de problemas de usabilidad detectados por los participantes en ambas versiones de la aplicación.

Tabla 5. Problemas de usabilidad detectados por los usuarios en función del dispositivo.

	Problems detected		
	t	d	Total
P1	9	6	15
P2	4	5	9
P3	10	11	21
P4	13	4	17
P5	5	6	11
P6	4	3	7
P7	2	3	5
P8	3	6	9
Mean	6,25	5,50	11,75
SD	3,92	2,56	5,44

Como indica la tabla, la media de problemas encontrados por los usuarios con la tableta fue de 6,25 (SD = 3,92), mientras que los participantes encontraron una media de 5,50 (SD = 2,56) problemas de usabilidad para la versión escritorio de la aplicación. Es interesante comprobar que la media de errores encontrados en ambos dispositivos es semejante, cuando la lógica parecía indicar que la media de errores encontrados iba a ser mucho mayor con la tableta, al ser un dispositivo menos utilizado tradicionalmente para tareas de gestión.

Los problemas de usabilidad detectados fueron de diversa índole. A modo de resumen, la Tabla 6 muestra los errores que se repitieron más una vez en el transcurso de las pruebas:

Tabla 6. Algunos problemas de usabilidad detectados.

Error	Number of ocurrences
Para introducir un nuevo registro, le da al botón nuevo registro de Filemaker, en lugar de al botón + de la aplicación.	8
Le cuesta insertar la imagen del producto, hace click con el botón derecho encima del mensaje de información en lugar de en el cuadro de la imagen.	7
El usuario tiene problemas al introducir una fecha empleando el calendario desplegable.	5
Tarda en averiguar cómo filtrar la agenda para ir a un día en concreto. El menú inicial de la agenda parece confundir al usuario.	4
Le cuesta encontrar cómo introducir las entregas a cuenta. No ve el botón para acceder a esta sección, tarda mucho en encontrarlo.	3
El menú inicial para filtrar clientes en el CRM parece confundir al usuario, no tiene claro cómo encontrar el cliente.	3
La ventana emergente que ofrece la posibilidad de seleccionar a cliente para darle la cita confunde al usuario. Al principio no la ve, y cuando la ve, la cierra sin usarla.	2
En la lista desplegable de Acepta publicidad, no ve la lista y empieza a escribir el valor.	2
No ve el campo de Resumen para la cita.	2

Cabe destacar en este apartado que los tres primeros errores en cuanto al número de veces que se repiten, vienen derivados de las herramientas que ofrece la plataforma Filemaker (el motor sobre el cual está montada la aplicación). Los calendarios desplegables para introducir fechas, el interfaz de introducción de imágenes en el sistema, así como los botones de introducción de registros que ofrece dicha plataforma parecen confundir al usuario en lugar de ser elementos de ayuda. Por este motivo, este equipo recomienda evitar dichos elementos en aplicaciones tanto móviles como de escritorio, si se trabaja con la plataforma Filemaker como base para su desarrollo. En esta ocasión estamos hablando de problemas con la versión escritorio, pero estos problemas también se dieron en nuestro anterior trabajo, en el que analizábamos las versiones de tableta y smartphone de la aplicación, por ejemplo con las ruletas de introducción de fechas y con las ruletas de introducción de horas.

5.4 Usabilidad percibida

Tras realizar todas las pruebas en ambos dispositivos, cada uno de los usuarios contestó a un cuestionario SUS, cuya finalidad fue definir la usabilidad percibida de la aplicación en su versión de Escritorio. Este formulario arrojó una usabilidad percibida de 89,38 puntos (medidos sobre 100) con una SD = 3,47. Los resultados del cuestionario SUS para cada uno de los participantes pueden verse en la Tabla 6. Es interesante destacar que en nuestro anterior estudio, en el que comparábamos las versiones de tableta y smartphone de la aplicación [17], el resultado obtenido en el cuestionario SUS fue de una usabilidad percibida de 83,44 puntos son una SD de 11,18 puntos. Se puede observar, que la usabilidad percibida por los usuarios al trabajar con la versión de escritorio de la aplicación ha aumentado en 5,94 puntos con respecto a la usabilidad percibida cuando sólo trabajaron con la versión móvil de la aplicación.

Tabla 7. Resultados del cuestionario SUS.

	SUS
P1	90,00
P2	85,00
P3	95,00
P4	92,50
P5	90,00
P6	90,00
P7	85,00
P8	87,50
Mean	**89,38**
SD	**3,47**

6. CONCLUSIONES Y TRABAJO FUTURO

En este trabajo se ha podido comprobar que el uso de ordenadores de sobremesa puede mejorar la eficacia de los usuarios cuando tienen que realizar tareas de cierta complejidad, si comparamos con la eficacia que se pueden obtener al realizar estas mismas tareas en un dispositivo de menores dimensiones y con teclado en pantalla, como una tableta; necesitando de media alrededor de un 17% más de tiempo para realizar una tarea en la tableta que en el ordenador.

En las pruebas que se presentan en este experimento, todos los usuarios fueron capaces de realizar todas las tareas con éxito con la tableta, y sólo un usuario no fue capaz de completar una de las tareas al 100% en la versión escritorio de la aplicación). Así que, de forma general, se podría decir que tareas complejas pueden ser realizadas en un dispositivo de las características de una tableta, aunque las mismas tareas realizadas en un ordenador de sobremesa, con pantalla de mayores dimensiones y teclado tradicional, serán llevadas a cabo de una manera más eficiente.

Queda demostrado con este estudio que, normalmente, a un usuario le llevará más tiempo realizar una tarea en una tableta del tiempo que le llevará realizar esa misma tarea en una ordenador de sobremesa. Este tiempo se puede incrementar considerablemente si el usuario ha de escribir algún tipo de texto o tiene que buscar algún tipo de información en el dispositivo.

Por otro lado el número de problemas de usabilidad detectados es ligeramente mayor cuando los usuarios trabajan con la tableta con respecto a los problemas detectados cuando lo hacen con el ordenador de sobremesa, detectándose una media de 0,75 problemas más (ver Tabla 5). Siendo esta diferencia menor de la esperada a priori por el equipo de investigación. Además se ha podido constatar que algunos de los elementos de interfaz nativos de la plataforma Filemaker, sobre la cual está montada la aplicación, son una fuente de problemas en lugar de una ayuda. Elementos como los calendarios desplegables, los botones de introducción de registros, o el sistema de introducción de imágenes en campos contenedores tienden a confundir al usuario, por lo que se recomienda evitar su uso, sustituyéndolos por elementos de programación propia. En cuanto a la usabilidad percibida por los usuarios, el cuestionario SUS ha arrojado unos resultados de 89,38 puntos sobre 100, siendo esta puntuación 5,94 puntos mayor de la obtenida en un anterior estudio en el que solamente evaluábamos las versiones móviles de la aplicación, de lo que se deduce que el uso de un dispositivo como un ordenador de sobremesa incrementa la usabilidad percibida por el usuario.

Como trabajos futuros, se plantea la posibilidad de analizar las mismas preguntas de investigación de este estudio con un mayor número de usuarios y tareas, con el fin de confirmar la robustez de los resultados obtenidos en el presente estudio. También sería interesante realizar las pruebas de usabilidad con usuarios representativos del sector al que va dirigido la aplicación, con la finalidad de comprobar si profesionales del sector de la fotografía obtendrían mejores resultados.

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Lenguaje Visual de Consulta sobre Grafos de Datos: Un enfoque desde el Diseño Centrado en el Usuario

María Constanza Pabón
Ph.D. student at Universidad del Valle -
Lecturer at Pontificia Universidad Javeriana-Cali
Cali, Colombia
mcpabon@javerianacali.edu.co

César A. Collazos
Universidad del Cauca
Popayán, Colombia
ccollazo@unicauca.edu.co

RESUMEN

Ofrecer a los usuarios finales, expertos en un dominio, la posibilidad de explorar y consultar datos almacenados en los sistemas de información con los que trabajan puede generar grandes beneficios para las organizaciones y la sociedad. Con frecuencia, formular preguntas ad hoc usando un lenguaje de consulta resulta una tarea compleja para un usuario final. Aun, en aquellos casos en los que se usan lenguajes visuales e interfaces gráficas. Generalmente las interfaces gráficas de consulta usan conceptos y elementos de los lenguajes que son poco intuitivos para el usuario final. En este artículo se presenta, desde la perspectiva del Diseño Centrado en el Usuario (DCU), el proceso de diseño de GraphTQL, un lenguaje visual de consulta sobre grafos de datos. El objetivo de GraphTQL es facilitarles a los usuarios finales la formulación de consultas de mediana complejidad. El caso de aplicación de este trabajo es el dominio médico, en particular las consultas sobre datos clínicos. Se presentan los resultados de las entrevistas y pruebas de usabilidad con profesionales de la salud que, desde las primeras etapas del proyecto, se llevaron a cabo como parte de este enfoque de diseño. Y se describe cómo estos resultados, y el enfoque de diseño, influenciaron y enriquecieron las decisiones de diseño de GraphTQL.

Categories and Subject Descriptors

H.5.2 [**Information Interfaces and Presentation**]: User Interfaces; H.2.3 [**Database management**]: Languages.

General Terms

Human Factors, Languages.

Palabras Clave

Lenguajes visuales de consulta, Lenguajes de consulta sobre grafos, Diseño centrado en el usuario.

1. INTRODUCCIÓN

Las organizaciones recopilan grandes cantidades de datos en sus sistemas de información. Sin embargo, generalmente los usuarios expertos en el dominio de las aplicaciones no cuentan con herramientas que les facilite explorar esos datos y proponer consultas ad hoc (no predefinidas, no conocidas con anticipación). Adicionalmente, la información muchas veces está dispersa en diversas fuentes de datos que tienen representaciones y tipos de datos heterogéneos [73]. Un ejemplo en el dominio médico es la información clínica de los pacientes. Ofrecer a estos usuarios, la posibilidad de explorar y consultar datos almacenados en los sistemas de información con los que trabajan podría generar beneficios para las organizaciones y la sociedad.

Nuestro propósito es ofrecer a los usuarios finales un mecanismo que les facilite el acceso a los datos. Para ello se desarrolla GraphTQL, un lenguaje visual de consulta que le permite a los usuarios finales formular consultas ad hoc. El caso de aplicación particular es el dominio médico. Con este propósito, se sigue un proceso de diseño centrado en el usuario (DCU) [75] en el que se ha involucrado un conjunto de profesionales de la salud, con el fin de que nuestra propuesta se adapte a sus necesidades y a las tareas que ellos realizan.

Este artículo describe cómo se ha llevado a cabo el proceso de diseño centrado en el usuario (DCU) [75] y cómo este proceso ha enriquecido el diseño del lenguaje, siendo un factor determinante en las decisiones que se han tomado.

El resto del artículo está organizado en cuatro secciones. En la Sección 2 se describe las principales decisiones de diseño del lenguaje visual y el lenguaje propuesto. La Sección 3 presenta los experimentos realizados como parte del proceso de diseño centrado en el usuario y cómo han impactado el diseño del lenguaje de consulta. La Sección 4 incluye los trabajos relacionados con sistemas visuales de consulta sobre grafos. Finalmente, en la Sección 5 se presentan algunas conclusiones y se proponen líneas de trabajo futuro.

2. GRAPHTQL

En esta sección se presentan algunas decisiones de diseño del lenguaje y una descripción breve del mismo.

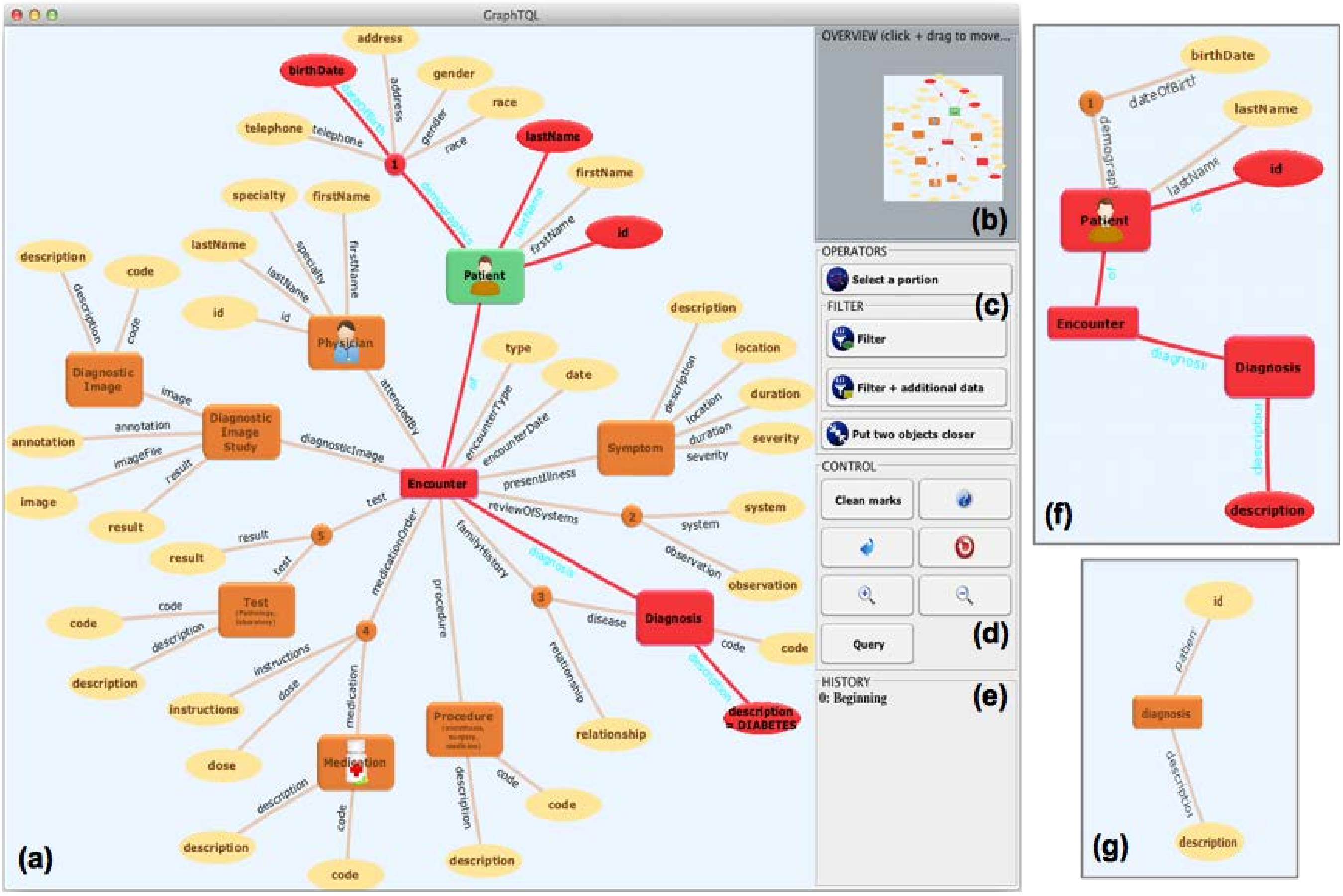

Figura 1. Interfaz de GraphTQL

2.1 El modelo de datos

El modelo de datos que subyace a GraphTQL se caracteriza por: a) Permitir representar la organización de los datos en el nivel conceptual. b) Tener una representación gráfica simple. c) Hacer evidente la relación entre los datos para evitar, por ejemplo, el uso explícito de conceptos como el *join*, necesario en las consultas sobre el modelo relacional. d) Facilitar el mapeo con otros modelos de datos de manera que a través de la vista de nivel conceptual se pueda acceder a los datos de diversas fuentes de datos.

Teniendo en cuenta que los modelos de datos basados en grafos tienen las características mencionadas, permiten modelar de manera natural los datos [66], y que representarlos en un diagrama facilita su entendimiento por parte de los usuarios, GraphTQL está basado en grafos.

El modelo que subyace a GraphTQL distingue entre el grafo esquema y el grafo instancia. El grafo esquema se usa para proveer una representación de los datos en el nivel conceptual, lo cual favorece la interacción con los usuarios finales. Adicionalmente, esta separación (esquema e instancia) evita la complejidad que se añade al modelo cuando la metadata del esquema agrega nodos y arcos a los datos de la instancia, como sucede en RDF [80]. El modelo también se caracteriza por tener nodos y arcos simples (sin atributos). Los atributos de los objetos se representan con nodos de tipo valor básico. Esta característica posibilita definir operaciones de consulta que se aplican de manera uniforme sobre objetos y atributos, ya que ambos se representan en el grafo de manera uniforme, por medio de nodos. Con base en estas características se escogió GDM [77] como modelo subyacente al lenguaje visual de consulta.

En GDM [77] los nodos del grafo esquema (Figura 1-(a)) representan clases y los nodos del grafo instancia (Figura 2), las instancias de esas clases. Los arcos representan atributos en ambos, esquema e instancia. GDM ofrece tres tipos de nodos, nodos clase objeto (los rectángulos grandes), nodos de valor básico (los óvalos) y nodos de valor compuesto. Estos últimos permiten representar relaciones n-arias (los rectángulos pequeños) o agrupar atributos (los círculos pequeños). Las Figura 1-(a) y 2 muestran un ejemplo de esquema e instancia de una base de datos con información clínica de pacientes. Estos incluyen los datos demográficos del paciente y los datos clínicos como descripción de la enfermedad actual, diagnósticos, ordenes médicas, y resultados de exámenes diagnósticos, entre otros.

2.2 Descripción del Lenguaje

Como se mencionó antes, GraphTQL usa el grafo esquema como base para la interacción con el usuario. Por tanto, la interfaz despliega la representación diagramática del grafo esquema (Figura 38-(a)), que a su vez ofrece una vista genérica de todos los datos disponibles para consulta. Los datos se seleccionan por la aplicación sucesiva de operaciones que transforman las vistas de los grafos esquema e instancia. La metáfora que se aplica es la reducción progresiva del grafo esquema y de la instancia respectiva, hasta llegar al subconjunto de datos que el usuario necesita recuperar. Un ejemplo de ello se muestra en la secuencia de Figura 1-(a), 1-(f), y 1-(g).

Los parámetros de entrada de los operadores se definen por manipulación directa del grafo esquema, y cada vez que el usuario elije una operación, recibe retroalimentación, ya que se despliega el grafo esquema modificado, sin ejecutar la operación. Cuando el usuario ha elegido la secuencia de operaciones para su consulta, la ejecuta.

2.2.1 *Operadores de Transformación de Grafos*

Las operaciones que transforman los grafos son:

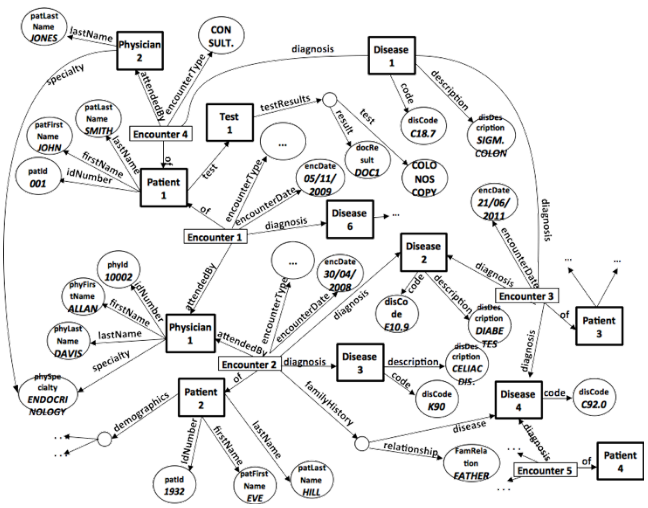

Figura 2. Grafo instancia con información clínica de pacientes.

- *Select a portion*: permite seleccionar una porción del grafo. Por ejemplo, si se requiere la fecha de nacimiento, la raza, el nombre y la identificación de los pacientes, el usuario marca estos nodos y los arcos entre ellos y selecciona esa porción del grafo. La operación no busca la coincidencia exacta de un patrón (no es *pattern matching*), puesto que recupera todos los nodos y los arcos que corresponden con los tipos marcados en el esquema. Por tanto, para el caso de ejemplo, se recuperan pacientes con datos incompletos.
- *GraphTQL* ofrece dos tipos de filtro:
  - *Filter*: Permite seleccionar los objetos de cierto tipo, la clase de interés, que cumplen una condición específica, y algunos datos conectados a ellos. Por ejemplo, si interesa la identificación, el nombre y la fecha de nacimiento de los pacientes que han recibido el diagnóstico de "Diabetes", el usuario marca la clase de interés, Paciente, la condición que deben cumplir las instancias de esa clase, ha recibido un diagnóstico de "Diabetes", y otros datos que se requieren (nombre y fecha de nacimiento) (Figura 1-(a)). Estos últimos son opcionales y aparecen en el resultado, si están disponibles. El esquema del resultado contiene los nodos que se habían marcado (Figura 1-(f)), y la instancia los nodos correspondientes con el esquema y que cumplen la condición (están conectados al diagnóstico con descripción "Diabetes").
  - *Filter + additional data:* Permite seleccionar todos los datos relacionados con un objeto que cumple una condición. Por ejemplo, seleccionar todos los datos de la historia clínica de los pacientes que han tenido un diagnóstico de "Diabetes". A diferencia de *Filter*, "todos los datos" incluyen otros diagnósticos recibidos, además de "Diabetes". El esquema no cambia, se recuperan los pacientes que cumplen la condición y los nodos que están conectados a esos pacientes a través de un camino simple del grafo esquema. Para aplicar este operador basta marcar una clase de interés (en el ejemplo, paciente) y la condición que deben cumplir las instancias de esa clase.
- *Put two objects closer*: esta operación reemplaza un camino que conecta dos nodos por otro camino que crea una relación entre ellos. En este caso no hay interés en los datos del camino reemplazado, por lo tanto no hace parte del grafo respuesta. Por ejemplo, en el resultado del ejemplo de *Filter* se quiere reemplazar el camino que conecta la identificación del paciente con la descripción de los diagnósticos que ha recibido. Para ello, se marcan los nodos y el camino a reemplazar (Figura 1-(f)). El resultado en el esquema se muestra en la Figura 1-(g).

2.2.2 *Mecanismo de Interacción*

GraphTQL tiene una interfaz simple que consta de cinco marcos (Figura 1-(a) a (e)): (a) Vista Principal, donde se despliega el grafo esquema. (b) Vista de referencia del grafo esquema, para facilitar la ubicación y el desplazamiento en el grafo. (c) Operadores. (d) Funciones de control, que incluyen limpiar las marcas, ayuda, retroceder un paso, volver al inicio, zoom, y ejecutar la consulta. (e) Historia de los operadores aplicados durante la formulación de una consulta.

Para seleccionar las entradas de cada operación se tienen 3 notaciones visuales: nodos de valor básico con una condición de filtro, clase de interés, y otros nodos y arcos involucrados en la operación. En el diagrama del grafo, los nodos con condición aparecen en color rojo, con la condición escrita al lado de la etiqueta del nodo; la clase de interés aparece en color verde; y los otros nodos y arcos marcados, en color rojo (Figura 1-a)). El usuario especifica los nodos con condición y la clase de interés haciendo click derecho sobre el nodo, los otros nodos se marcan haciendo click sobre ellos. Cada vez que se marca un nodo, la interfaz se encarga de encontrar y marcar el camino que lo conecta con los nodos previamente marcados. Cuando hay más de un camino, se realiza un diálogo de clarificación que presenta todos los caminos posibles para que el usuario elija uno o varios de ellos.

En el diagrama del grafo, los óvalos representan los nodos de valor básico, de esta manera el usuario puede distinguir fácilmente sobre cuales nodos especificar las condiciones de los filtros.

Con el fin de simplificar la interfaz, los operadores de filtro requieren que el usuario marque solamente una clase de interés y las condiciones que ésta debe cumplir; además, en el caso particular de *Filter*, otros nodos a seleccionar. Sin embargo, la sencillez de esta representación genera dos problemas: el primero, que limita la expresividad de los filtros y el segundo, que cuando se necesita especificar más de una condición, la representación gráfica es ambigua y por tanto, se hace necesario especificar si se trata de una conjunción o de una disyunción de las condiciones. Con el fin de proveer mayor expresividad en los filtros, sin agregar conceptos o notación gráfica que el usuario deba aprender a usar, el lenguaje realiza un diálogo de clarificación del filtro. La interfaz identifica los nodos de bifurcación, es decir aquellos donde se bifurcan los caminos que conectan la clase de interés con las clases de condición. El diálogo de desambiguación consta de una serie de preguntas que se plantean al usuario para que especifique para cada nodo de bifurcación, si se aplica una conjunción o una disyunción a las condiciones que se desprenden de él.

2.2.3 *Características del diseño del lenguaje*

GraphTQL tiene como características distintivas que el usuario: (a) Tiene una vista de nivel conceptual de los datos disponibles, y de los que ha seleccionado en cada paso de la formulación de la consulta. (b) No requiere explorar el esquema de los datos y no requiere construir patrones de consulta desde cero. (c) No necesita definir cuando hay patrones exigidos y patrones opcionales. La herramienta calcula como patrones exigidos aquellos que conectan la clase de interés con los atributos que tienen una condición. Y como patrones opcionales los que conectan los nodos que no hacen parte del patrón exigido. (d) No necesita que definir variables, variables de salida, ni distinguir entre variables y valores literales. (e) Opera solamente sobre grafos. En lenguajes como SPARQL solamente el patrón básico de búsqueda opera sobre el grafo, las otras operaciones se aplican sobre conjuntos de mapeos. Esto hace que la semántica de estas operaciones, cuando hay datos incompletos, pueda resultar engorrosa aun para programadores. (e) Los filtros no son locales, se filtra la clase de interés por la conexión con nodos de otras clases que cumplen cierta condición, lo cual ofrece mayor expresividad que las herramientas de exploración de datos. (f) El diálogo de clarificación de filtros da la posibilidad de combinar conjunción o disyunción en diferentes puntos del grafo, sin necesidad de que el usuario cree un árbol con la expresión lógica.

Adicionalmente, el diseño de la interfaz incluye las características básicas que Nielsen [81] propone para una interfaz desarrollada con principios de usabilidad: (a) Tiene un diseño simple, que contiene solamente la información que el usuario necesita. El grafo se despliega de forma estética, atendiendo a parámetros de simetría y evitando el cruce de arcos y el solapamiento de nodos. (b) Usa el lenguaje del usuario en el modelo conceptual, y los nombres de las operaciones se cambiaron teniendo en cuenta las opiniones que los usuarios aportaron durante las pruebas de usabilidad realizadas. (c) Minimiza la carga de memoria del usuario desplegando elementos de diálogo que lo guían. (d) Es consistente, por ejemplo, en los efectos de los comandos y en la ubicación de la información. (e) El usuario recibe retroalimentación durante la formulación de la consulta. (f) Ofrece, en todo momento, salidas marcadas según las convenciones del sistema operativo. (g) Ofrece un historial de la interacción, el usuario puede deshacer una o varias operaciones o volver al estado inicial. (h) Provee ayuda a través del botón de ayuda y por los *tool tips* que se despliegan cuando el mouse pasa por los botones. Y los mensajes de error ofrecen información que guiar al usuario en la solución del problema.

2.3 Detalles de Implementación

El prototipo de la interfaz se desarrolló en Java. El despliegue y manipulación del grafo se realiza usando Jung8. Los comandos que por defecto provee Jung para manipular el grafo se cambiaron para que no se requirieran combinaciones de teclas y clicks en la interacción del lenguaje.

La interfaz toma como entrada un grafo esquema especificado en GraphML9, que además de los datos de cada nodo, puede incluir la ubicación (coordenadas x e y) del nodo en la ventana principal. Cuando no se proveen las coordenadas se aplica el algoritmo kkLayout [79] para calcular la organización del grafo en la ventana. La opción de aportar las coordenadas de los nodos se implementó porque, a pesar de que kkLayout genera una buena distribución de los nodos en este tipo de grafos, persisten algunos cruces de arcos o agrupaciones de nodos que pueden generar confusión en los usuarios.

La interfaz permite que los objetos puedan tener asociada una imagen, que se pinta en el nodo.

La interfaz captura la secuencia de operaciones que el usuario usa en la formulación de la consulta y genera en XML[10] un árbol que representa esta secuencia de operaciones con los parámetros correspondientes. Este árbol se envía al motor de ejecución para realizar la consulta. El manejo de los datos en el motor se realiza con Neo4j[11].

El código fuente del prototipo de GraphTQL está disponible para ser descargado[12].

3. PROCESO DE DISEÑO

Para el desarrollo de GraphTQL se siguió un proceso de Diseño Centrado en el Usuario estructurado en cuatro fases (Tabla 6). La metodología para la realización de la entrevista preliminar y las evaluaciones siguió las recomendaciones dadas por Rubin [82] y Nielsen [81].

3.1 Entrevista Preliminar

En el primer experimento, la entrevista preliminar, participaron cuatro médicos especialistas. La entrevista se desarrolló en formato libre, sin cuestionario guía, y el moderador guio la conversación para responder a las siguientes preguntas: ¿Cuáles datos se registran en una historia clínica?, ¿Durante la atención a un paciente qué información puede necesitar?, ¿Sería importante relacionar los datos de un paciente y los de las historias clínicas de sus familiares?, y ¿En cuáles procesos (i.e. investigación, enseñanza) puede ser útil una herramienta de consulta de datos clínicos? Cada entrevista tuvo una duración aproximada de una hora.

A partir de la información recolectada se concluyó que las consultas ad hoc sobre la historia clínica de los pacientes son necesarias en los siguientes escenarios: evaluación y vigilancia epidemiológica, consulta externa y citas de control, administración de los servicios de salud, investigación de casos clínicos, seguimiento de la evolución de los pacientes, procesos de enseñanza-aprendizaje, y planeación de programas de prevención.
Dentro de estos escenarios los médicos dieron 31 ejemplos de consultas, entre ellas:

- En consulta externa y citas de control: Revisar los conceptos dados por médicos de otra especialidad al paciente que está en consulta.
- En administración de los servicios de salud: Obtener estadísticas de diagnósticos o de resultados de exámenes. Por ejemplo, ¿Cuántos hemogramas se hicieron en el mes?, ¿Cuáles son las patologías más frecuentes?

[8]http://jung.sourceforge.net
[9]http://graphml.graphdrawing.org/

[10]http://www.w3.org/TR/REC-xml/
[11]http://neo4j.com/
[12]http://labsistemas.javerianacali.edu.co:8000/~mcpabon/GraphTQL-interface.zip

- En investigación de casos clínicos y procesos de enseñanza-aprendizaje: Encontrar grupos de pacientes que cumplen un perfil. Por ejemplo, datos de los pacientes de género femenino que estuvieron hospitalizados en la sala de pediatría general durante los años 2009 y 2010 con diagnóstico de enfermedad por reflujo gastro-esofágico.
- En planeación de programas de prevención y seguimiento de la evolución de los pacientes: Revisar las historias clínicas de recién nacidos cuyas madres tuvieron diagnóstico de hipertensión durante el embarazo.

Tabla 1. Pruebas de usabilidad realizadas durante el desarrollo del proyecto.

Prueba	Objetivo	Momento de aplicación
Entrevista preliminar	Conocer cuál información se registra en una historia clínica, cuál información necesita consultar un médico cuando está atendiendo un paciente, y en que situaciones es útil una herramienta para formular consultas sobre datos clínicos	Antes de iniciar el diseño del lenguaje
Prueba exploratoria	Validar si la representación de los datos en grafos y las operaciones de transformación de grafos son entendibles para el usuario	Punto intermedio en el diseño, antes de iniciar la implementación
1a. prueba de evaluación	Evaluación, sobre dos opciones de la interfaz, de un experto en diseño de interfaces y un grupo de usuarios de diverso perfil	Punto intermedio en la implementación de la interfaz
2a. prueba de evaluación	Evaluar la facilidad de uso del lenguaje visual de consulta	Terminada la primera etapa de implementación de la interfaz
Prueba comparativa	Evaluar la facilidad de uso del lenguaje visual de consulta y compararlo con una interfaz gráfica para formulación de consultas en SPARQL	Terminada la primera etapa de implementación de la interfaz

Las consultas de ejemplo dadas por los médicos se clasificaron en tres tipos: Consultas que recuperan datos de la historia clínica de un paciente, consultas para seleccionar grupos de pacientes que cumplen un perfil, y consultas que incluyen operaciones de agregación. El desarrollo actual del lenguaje visual de consulta se centra en los dos primeros tipos, las operaciones de agregación se incluirán en una etapa posterior.

3.2 Prueba Exploratoria

Con la prueba exploratoria se trató de corroborar si el uso de un grafo como modelo de datos, las operaciones propuestas para el lenguaje, los iconos de las operaciones y los textos explicativos son entendibles. Para esta prueba el perfil de usuario fue más amplio, en esta oportunidad participaron tres profesionales de la salud, entre ellos un epidemiólogo y un enfermero.

La prueba se hizo con prototipos de papel y se dividió en cuatro partes: 1. Presentación de la noción de grafo y su uso como modelo de representación de datos. 2. Presentación del grafo esquema como una representación general de la organización de los datos y el grafo instancia como una representación particular de hechos acorde al esquema. A manera de evaluación, se pidió a los participantes que encontraran en los grafos dos datos particulares.3. Presentación de las operaciones del lenguaje. 4. Actividad de identificación de operaciones aplicadas en cuatro casos.

El moderador de la prueba podía aceptar comentarios y preguntas del usuario en cualquier momento y responder a ellas.

Se obtuvieron los siguientes resultados:

Los participantes identificaron y entendieron la información representada en el esquema y la instancia y respondieron acertadamente a las preguntas de la parte 2. Dos de los participantes tardaron en identificar la relación *Encounter* entre los nodos *Physician* y *Patient*, por la notación que se usó en esos prototipos para ese tipo de nodo. Sus observaciones se tuvieron en cuenta para cambiar la representación de los nodos (Figura 38). Los participantes hicieron comentarios como “Me parece interesante” y “Es un diagrama que permite encontrar y amarrar la relación entre los datos”.

En cuanto a la actividad de la parte 4, el 91,6% de los casos fueron identificados correctamente, y en un 16,6% el moderador intervino para hacer notar alguna parte del grafo. Los participantes comentaron que las operaciones permiten realizar consultas pertinentes para el ejercicio clínico y la investigación. Todos los participantes coincidieron en que los íconos y los textos propuestos son claros.

Como comentarios adicionales, los participantes afirmaron que la primera impresión al ver los grafos es que esta representación (tipo red) es compleja, pero que cuando empezaron a usarlos y responder las preguntas notaron que era fácil encontrar la información y las relaciones entre los datos.

De la prueba exploratoria derivamos las siguientes conclusiones: Para los participantes fue fácil interpretar los grafos esquema e instancia y las operaciones del lenguaje transformación de grafos. Para ellos fueron claros los íconos y textos propuestos para la aplicación. Los participantes opinaron que la herramienta sería útil en su trabajo. Además, durante el desarrollo de la prueba se observó que a los participantes les toma más tiempo (y probablemente esfuerzo) interpretar el grafo instancia, esto confirma que es una buena alternativa usar el esquema para guiar la formulación de las consultas.

3.3 Pruebas de Evaluación

La etapa de evaluación incluye tres pruebas que se describen a continuación.

La primera prueba de evaluación se realizó con un experto en diseño de interfaces y un grupo de usuarios de diverso perfil. El experto es diseñador gráfico, especializado en estética, con experiencia en publicidad, y desarrollo y diseño de estilos y de páginas web. En la prueba se presentaron dos diseños con diferencias en la organización de la pantalla y en los colores usados en el grafo y para marcar las clases de interés, nodos con condición y los otros nodos y arcos. Con base en la opinión recopiladas se eligió la organización de la pantalla, se cambiaron algunos colores, se modificaron los iconos de los botones de operación y de control, y se cambiaron los nombres de los operadores.

En la segunda prueba cuatro participantes, dos profesionales y dos estudiantes de carreras relacionadas con áreas de la salud, evaluaron el prototipo del lenguaje visual de consulta propuesto. El plan de esta pruebas constó de: (a) Apertura: El moderador explica el propósito de la prueba y las partes que incluye. El participante diligencia un cuestionario pre-test, que recoge información de su perfil de formación, y firma el formato de consentimiento para realizar la prueba. (b) Demostración de la herramienta, se hace con una base de datos sobre películas y series de televisión. El moderador explica las opciones, botones y operaciones de la herramienta, y desarrolla tres ejemplos de formulación de consultas. (c) El usuario realiza cuatro actividades. Para este caso se toma una base de datos clínicos. En cada actividad se pide al participante que formule una consulta. La complejidad de las consultas crece de una actividad a la siguiente. Las consultas se eligieron buscando poner a prueba las operaciones de filtro, y los diálogos de clarificación de caminos y de condiciones de filtro del lenguaje de consulta propuesto. Los participantes cuentan con un tiempo máximo de 15minutos para formular la consulta de cada actividad.

Si bien la tasa de respuestas correctas fue baja, estas pruebas permitieron detectar varias oportunidades de mejoramiento de la interfaz. Primero, la versión que se evaluó no incluía el diálogo de clarificación de caminos, la herramienta marcaba todos los caminos posibles entre los nodos marcados, con el fin de hacerlos evidentes al usuario, y se esperaba que el usuario quitara la marca de aquellos que no eran necesarios. Se notó que los usuarios tienden a aceptar por defecto las sugerencias que la herramienta hace. Entonces, el patrón principal de consulta incluía caminos que no se requerían. Segundo los nombres de las operaciones de filtro no ayudaban a que el usuario recordara la diferencia entre los filtros. Por tanto, en algunos casos el usuario aplicaba una operación que no correspondía con lo solicitado en la consulta. Tercero, dado que la operación de filtro con datos adicionales no cambia el esquema, el usuario dudaba sobre si se había o no aplicado una operación. Cuarto, se identificaron varias validaciones que se podían agregar en cada operación, de manera que se prevengan posibles errores. Por ejemplo, si el usuario marca condiciones sobre algunos atributos y luego elige el operador *Select a portion*, las condiciones marcadas no tienen incidencia en la operación, por tanto es posible que el operador esté confundiendo la operación que requiere aplicar. Además de las opiniones relacionadas estos aspectos, los participantes concordaron en que la herramienta sería de gran utilidad en su campo profesional, que es fácil de usar, que se requiere una fase de entrenamiento corta, y que la representación de los datos en el grafo es fácil de entender.

Finalmente, la tercera fue una prueba comparativa que incluyó una interfaz gráfica para la formulación de consultas en SPARQL y GraphTQL. Se realizó con cuatro participantes, tres profesionales de la salud y un estudiante de medicina. Dos participantes evaluaron GraphTQL y otros dos, la interfaz gráfica de consulta. La prueba siguió el mismo plan de la segunda prueba, y adicionalmente se pidió a los usuarios que respondieran un cuestionario SUS (*System Usability Scale*) [67].

Las cuatro actividades de prueba fueron las mismas para la segunda y tercera pruebas. Estas consultas se eligieron a partir de los ejemplos datos por los médicos en la entrevista preliminar, los cuales se clasificaron según su nivel de complejidad. La complejidad se definió en términos de las operaciones necesarias para realizar las consultas sobre un modelo de grafos. Para las actividades se eligieron consultas de diverso nivel de complejidad. También se tuvo en cuenta que la formulación de la consulta en la interfaz gráfica de SPARQL se realiza dibujando el patrón de consulta, nodo por nodo y arco por arco, por lo tanto se limitó la cantidad de nodos que se requieren en las consultas. Adicionalmente, se limitó el número de operaciones necesarias para formular la consulta en la interfaz gráfica (por ejemplo las consultas no requieren *union*), para disminuir la cantidad de elementos de SPARQL que el usuario debía aprender.

Las consultas que se propusieron en las cuatro actividades de la prueba comparativa y la segunda prueba fueron:

- Se requieren las enfermedades (incluyendo su descripción) registradas en la historia familiar del paciente con identificación 723628; incluir la relación familiar si está disponible.
- Se requiere encontrar los diagnósticos (incluyendo su descripción) dados al paciente con identificación 723628 por médicos con especialidad en “ENDOCRINOLOGY” y, si está disponible, las fechas de las consultas y las medicinas que le recetaron en ese momento (incluyendo descripción y dosis).
- De los pacientes que han tenido un diagnóstico de “OSTEOMYELITIS” desde el año 2000 (desde 01-01-2000), se requieren todos los datos de: identificación del paciente, diagnósticos recibidos, y procedimientos que se le han realizado (incluir la descripción de los diagnósticos y procedimientos). Note que estos datos incluyen los otros diagnósticos, además de OSTEOMYELITIS, y todos los datos que se piden son independientes de la fecha en que se registraron.
- Se requiere encontrar los pacientes que han tenido un estudio de imágenes diagnósticas con anotación “GALLSTONES” y se les ha realizado el procedimiento “COLECTOMY”. De estos pacientes se requiere la fecha de nacimiento, género y raza, si están disponibles. Estos resultados pudieron realizarse en encuentros diferentes, pero el paciente cumple con ambas condiciones.

La primera es una consulta sencilla, que incluye una condición (identificación del paciente) y datos opcionales (relación familiar). La segunda consulta incluye la conjunción de dos condiciones de filtro y datos opcionales. La tercera consulta también incluye la conjunción de dos condiciones de filtro y datos opcionales. Adicionalmente, para formular la consulta en SPARQL se requieren dos variables que representen los diagnósticos, y dos para la descripción de los diagnósticos. De esta manera se incluyen otros diagnósticos adicionales a los de la condición de filtro. En GraphTQL esto se logra usando el operador *Filter + additional data*. La cuarta consulta incluye la conjunción de dos condiciones de filtro y datos opcionales. Para formular la consulta en SPARQL el patrón de consulta debe incluir dos variables para los encuentros, uno que se conecte con cada condición. En GraphTQL basta con responder a las preguntas del diálogo de desambiguación. De manera que en el encuentro (nodo *Encounter* en la Figura 38-(a)) se aplica una disyunción, y en el paciente una conjunción.

Tabla 2. Resultados de la prueba comparativa.

Herramienta	Consultas correctas (%)	Errores por consulta (avg.)	Tiempo por consulta (avg.)	Puntaje SUS
Interfaz SPARQL	0,0%	4,5	10min 53sec	51,3
GraphTQL	62,5%	0,9	3min 56sec	72,5

La Tabla 7 muestra los resultados obtenidos. Se nota que la formulación en SPARQL es difícil si no se tiene un entrenamiento prolongado. A pesar de ello, los participantes que evaluaron la interfaz gráfica para consultas en SPARQL se sintieron confiados al usar la herramienta.

También se notan diferencias importantes en el tiempo requerido para la formulación de las consultas y en el número de errores. El número de errores se refiere al número de tipos de error diferente, por ejemplo si una consulta incluye tres datos opcionales y los tres datos se incluyeron dentro del patrón de consulta como obligatorios, se cuenta solamente un error. Todos los participantes coincidieron en que una herramienta que les permita formular este tipo de consultas sería muy útil en la atención a pacientes, la administración y la investigación médica.

La prueba con la interfaz gráfica para SPARQL permitió observar que la necesidad de explorar el grafo de datos para construir el patrón de consulta tiende a introducir errores porque se equivoca la dirección de los arcos o se asume alguna representación de una relación de manera diferente a la que se establece en los datos. Se observó que en general los participantes no tienen en cuenta el concepto de datos opcionales. Y que pueden confundir nodos que representan una variable con nodos que representan un valor literal. Además, aunque los participantes identificaron en cuales consultas requerían definir más de una variable para representar objetos del mismo tipo, no encontraron la forma de especificar los patrones de manera que se diera respuesta a la consulta requerida.

De otra parte la prueba con GraphTQL permitió identificar que era necesario hacer más claridad en la pregunta de desambiguación para el caso en que el usuario necesita elegir diferentes operadores lógicos (conjunción/disyunción) en diferentes puntos de bifurcación del patrón exigido en la consulta.

4. TRABAJOS RELACIONADOS

Batini et al. [70] define los Lenguajes Visuales de Consulta (*Visual Query Language*) como sistemas de consulta de bases de datos que usan una representación visual para describir el dominio de interés y para expresar las solicitudes sobre los datos. Las representaciones visuales son, usualmente, iconos, tablas, diagramas, o una combinación de ellos.

El desarrollo de sistemas visuales de consulta sobre modelos de grafos ha seguido dos vertientes principales: De una parte, se encuentran las herramientas de exploración y análisis de datos, que se concentran principalmente en mecanismos de agrupamiento (*clustering*) y visualización de grandes volúmenes de datos, y el cálculo de propiedades del grafo (i.e. centralidad, índice de influencia). De otra parte están los sistemas que se enfocan en el lenguaje de consulta, entre los cuales se incluyen aquellos que proponen un nuevo lenguaje y las interfaces gráficas para lenguajes existentes. Estas últimas, proveen una representación gráfica de los elementos de un lenguaje de consulta con sintaxis en texto.

Las herramientas de exploración y análisis, entre ellas Gephi [69], GlyphLink [72], CGV [85], y Shamir y Stolpnik [84], ofrecen diferentes mecanismos para explorar los datos. En cuanto a las formas de seleccionar y filtrar la información, se encuentran, en general, operaciones relacionadas con la topología del grafo que permiten explorar, a partir de un nodo particular los nodos vecinos (k-vecinos) y encontrar caminos entre nodos, y filtros que permiten seleccionar nodos y arcos que tienen una propiedad particular o son de cierto tipo, y en algunos casos permiten componer las expresiones de filtro por medio de operadores lógicos, sin embargo los filtros siguen siendo locales (aplican sobre cada nodo o arco).

Barzdins et al. [68], QUBLE [78], Sadanandan et al. [83] y Catarci et al. [71] proponen lenguajes visuales de consulta que usan un grafo como representación visual para soportar la interacción con el usuario en la formulación de la consulta. Por su parte, Aasman y Cheetham [65], Groppe et al. [74], y SparqlFilterFlow [76] proponen interfaces gráficas para SPARQL. Estos sistemas se caracterizan por ofrecer mayor expresividad, pues incluyen más operaciones (i.e. cláusulas *optional* y *union*) y los filtros se definen sobre resultados de patrones de consulta, con lo cual se puede seleccionar nodos conectados a otros nodos que cumplen cierta condición, además, incluyen operaciones lógicas (y/o) y en algunos casos filtros globales. Sin embargo, generalmente no hay manipulación directa sobre el diagrama del grafo, los patrones se deben construir desde cero a partir de listas de objetos y propiedades. Por tanto, requieren que el usuario haga una exploración del grafo de datos para conocer cómo están organizados los datos, lo cual puede resultar engorroso especialmente cuando hay datos incompletos. Adicionalmente, el usuario no tiene retroalimentación durante la formulación de la consulta y debe entender el lenguaje pues las construcciones del mismo se trasladan a una notación visual. Esto genera un mayor nivel de complejidad porque, por ejemplo, pequeñas diferencias en la forma como se agrupan cláusulas como *optional* y *union*, y la ubicación de los filtros dentro de esos grupos puede generar grandes variaciones en el resultado de la consulta.

Finalmente, solamente los sistemas para consulta de ontologías funcionan sobre una representación de nivel conceptual.

En cuanto al enfoque de diseño centrado en el usuario, algunos trabajos [1, 4, 5, 10] no mencionan el uso de una metodología para el desarrollo de un sistema con características de usabilidad, y tampoco reportan resultados de pruebas de usabilidad. En [8, 12, 14, 19, 20] reportan evaluaciones sumativas, realizadas al final del desarrollo de la herramienta. En general estas evaluaciones miden el número de tareas realizadas correctamente, el tiempo requerido para realizar las tareas, y la percepción de los participantes con respecto a algunas características de la usabilidad. Dos trabajos reportan un mayor involucramiento de los usuarios durante el ciclo de desarrollo del proyecto. Tominski et al. [85] reportan que recibieron retroalimentación de los usuarios durante el desarrollo del sistema. Además, que los comentarios sobre la interfaz y los mecanismos de interacción de los usuarios que empezaron a utilizar la herramienta, influenciaron el desarrollo del sistema en varios aspectos, entre otros, el orden de las vistas, el uso de parámetros de visualización, y la forma de realizar el desplazamiento y zoom. Sin embargo, los autores no reportan la realización de pruebas de usabilidad. Por su parte, Catarci et al.

[71] describen los experimentos de evaluación de usabilidad de un sistema que permite el acceso a datos de fuentes heterogéneas, por medio de consultas expresadas sobre una ontología. Los autores reportan que el proyecto siguió la metodología de diseño centrada en el usuario, e involucró a los usuarios desde las primeras etapas. Durante el desarrollo del proyecto aplicaron evaluaciones formativas y sumativas, entre ellas: una encuesta para obtener información base para analizar el contexto de la aplicación; una encuesta y una evaluación observacional sobre el primer y segundo prototipos; y finalmente, una encuesta, una evaluación observacional y un experimento controlado sobre el prototipo final y el producto terminado.

5. CONCLUSIONES Y TRABAJO FUTURO

Este artículo presenta la aplicación del diseño centrado en el usuario (UCD) en el desarrollo de un lenguaje visual de consulta de nivel conceptual. Como parte de este proceso se realizaron un conjunto de experimentos con los usuarios finales, profesionales de la salud. Se presentaron los resultados obtenidos de la aplicación de una entrevista preliminar, una prueba exploratoria, y pruebas de usabilidad y comparación con una interfaz gráfica para formular consultas en SPARQL. Estas últimas, se realizaron sobre un prototipo funcional del lenguaje visual de consulta, desarrollado en Java, usando Jung[13] para el despliegue de los grafos.

Se describieron las principales decisiones de diseño que surgieron a partir del enfoque UCD y de los resultados de estas experiencias. La aplicación del UCD permitió conocer mejor las necesidades del usuario y tomar decisiones de diseño con criterios diferentes, más amplios, de los que se aplican en un proceso de desarrollo tradicional. Estas decisiones reflejan la importancia que tiene la interacción entre el usuario y la aplicación para el resultado que buscamos.

Actualmente se están realizando pruebas de rendimiento de la ejecución de las operaciones para, a futuro, proponer mecanismos de optimización de la ejecución de las consultas. Además, a futuro, se aplicará el DCU para elegir metáforas que se complementen, y ofrecer al usuario alternativas para la visualización de los datos que son resultado de las consultas y para incluir la posibilidad de aplicar funciones agregadas, ya sea sobre la representación de grafo o sobre otras representaciones con que se visualicen los resultados.

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SOFTWARE, ARCHITECTURE AND INTERACTION

An Agile Information-Architecture-Driven Approach for the Development of User-Centered Interactive Software

Luis A. Rojas and José A. Macías

Escuela Politécnica Superior, Universidad Autónoma de Madrid,
Tomás y Valiente 11, 28049 Madrid, España
luisalberto.rojas@estudiante.uam.es, j.macias@uam.es

ABSTRACT

For the most part, Information Architecture processes include sets of activities and techniques to be carried out by the development team to create interactive applications effectively, involving usability concerns at every development step. In fact, plenty of process models have already been proposed to bridge the gap between User-Centered Development and Information Architecture, empowering the development team to build usable applications successfully. However, the combination of User-Centered Development and Information Architecture paradigms sometimes results in cumbersome process models containing lots of phases and activities to be considered, which increases the cycle time to have partial and validated software increments readily. As less effort has been devoted to speed up the usable Information Architecture development, the aim of this paper is to address such problem. To do so, we present Scrum-UIA, an agile and usable development process driven by the Information Architecture. This process is intended to develop web applications by splitting up responsibilities and tasks, and decreasing the time to perform technical activities, in order to readily obtain usable software increments.

Categories and Subject Descriptors

H.1.2 **[Information Systems]**: User/Machine Systems - Human factors; H.5.2 **[Information Interfaces and Presentation]**: User Interfaces – User-Centered Design and Prototyping

General Terms

Management, Design, Human Factors.

Keywords

Information Architecture, Agile Development, User-Centered Design, Usability

1. INTRODUCTION

Today, even though we live immersed in the information society, information in many organizations is still not properly managed, which affects negatively the costs of the organization in terms of errors and inefficiencies, and also the client's perception in terms of service quality [1]. Furthermore, environments move quickly and are constantly evolving in today's world, which is an additional factor that increases the complexity of information management in organizations.

The current scenario is at once an opportunity and an obligation for both researchers and information professionals, allowing to address the different challenges, opportunities and critical aspects of the Information Architecture (IA). Martin et al. [1] reported that one of the critical aspects of IA is the need for methodological proposals to develop it. There are currently several methodologies for the IA development [2,3,4,5,6]. However, these proposals are based on traditional development process models, making it difficult to carry them out in changing environments, where an agile and quick response is often required.

On the other hand, agile methodologies emerge as a response to the need of adapting quickly to changing environments. Nevertheless, this also reports difficulties when incorporating User-Centered Design (UCD) in agile environments [7], which is an overriding factor when developing interactive software. Several studies have addressed the need of involving end-users into the agile development, supplying specific recommendations but without providing a comprehensive or complete vision, which has been reported by [8] as an incentive to develop new methodologies for the integration of the UCD and the agile paradigm.

The aim of this paper is to address such drawbacks by providing an agile methodology, called Scrum-UIA (Scrum driven by Usable Information Architecture), for the user-centered development of interactive applications, also involving IA as a building block to guide and drive the development to make it agilely adaptable to changing environments. Our proposal features the integration of UCD in Scrum to carry through an agile approach. Also, we provide a set of agile AI techniques to support development tasks. In addition, an end-user vision is incorporated and considered throughout the whole process.

This paper is organized as follows: Section 2 presents a comparative analysis of methodologies for IA and a discussion of agile ones. Next, section 3 introduces the practices used in agile and UCD integration, as well as specific recommendations to integrate UCD in the Scrum methodology. Then, section 4 describes our proposed methodology for agile UCD-IA development based on Scrum. Finally, section 5 presents conclusions and future work.

2. ANALYSIS AND DISCUSSION ON RELATED METHODOLOGIES

In this section, a comparative analysis is performed to check the current features of the different methodologies for the IA development (section 2.1). On the other hand, the feasibility of integrating user-centered activities into agile methodologies is also addressed (section 2.2).

2.1 Comparative Analyses of Information Architecture Methodologies

Five IA methodologies [2,3,4,5,6] have been selected according to their popularity and broad usage. In order to have a common framework to analyze and compare the main features of these methodologies for the IA development, the following criteria has been used: *User-Centered criterion, IA Elements Covered, Level of Description, Scope of the Proposal* and *Flexibility and Adaptability*. These will be briefly described below.

Table 1. Comparative analysis of IA methodologies.

Method	User-Centered	IA Elements Covered	Level of Descr.	Scope of the Prop.	Flex. and Adpt.
[2]	Partially	-Navigation -Organization -Labeling -Search and recovery -Information presentation	High	A, D, I (-), M (-)	No
[3]	Partially	-Navigation -Organization -Labeling	Low	A, D	No
[4]	Partially	-Navigation -Organization -Labeling	Low	A,D, E (-)	No
[5]	Yes	-Organization -Labeling	Average	E	No
[6]	Yes	-Navigation -Organization -Labeling -Search and recovery -Information presentation	High	A, D, E, I, M	No

The *User-Centered* criterion is used to identify whether the proposals design their products focused on the needs of end-users. This criterion can take Yes, Partially or No values to indicate that the proposals are fully, partially or not user-centered, respectively. The *IA Elements Covered* criterion is used to identify the aspects of the IA that proposals attempt to cover. According to Erlin et al. [9] the aspects of the IA that are involved in the development of a product correspond to: navigation, organization, labeling, search and recovery, and information presentation. The *Level of Description* criterion is used to identify the level of detail in which methodologies for the IA development are described. This criterion can take High, Average or Low values to indicate that the proposals are described with sufficient, moderate or general detail, respectively. The *Scope of the Proposal* criterion is used to identify the lifecycle phases of IA development that proposals attempt to cover. The considered phases are: analysis (A), design (D), evaluation (E), implementation (I), and management (M). The phases that are incompletely covered (without providing or prescribing the necessary information to carry them out) are pointed out with an (-). Finally, the *Flexibility and Adaptability* criterion is used to identify whether methodologies are able to adapt to changing environments and respond quickly. In order to assess this criterion, IA methodologies are analyzed to know whether they require extensive planning or have a development process model (i.e., waterfall) that needs numerous controls and policies/standards to be implemented.

The results of the comparative analysis are presented in Table 1.

As we can see in Table 1, most of the proposals do not cover all of the lifecycle phases of IA development, focusing primarily on the analysis and design phases. It is important to highlight that proposals [6] and [5] are the only ones that present recommendations of activities and techniques for the IA evaluation (*Scope of the Proposal* criterion: E). The proposal [4] also indicates IA evaluation, but it is only described and shallowly defined (-). It is worth noting that methodologies [5] and [6] are the only ones that provide a user-centered approach to IA development. By contrast, in most of the proposals this aspect is carried out partially, as the end-users are only included in the initial phases and not during the whole process.

Finally, methodologies [6] and [2] are the only ones that have an adequate level of proposal description (*Level of Description* criterion: High) and cover all IA aspects (*IA Elements Covered* criterion) in the different lifecycle phases of IA development (*Scope of the Proposal* criterion). However, none of the analyzed methodologies present flexibility and adaptability characteristics to respond in an agile and flexible way to changing environments, or they require considerable effort to be adapted (as commented before in the description of *Flexibility and Adaptability* criterion).

Such drawback can be addressed through the flexibility and adaptability offered by agile methodologies, which allow to respond quickly to changing environments. However, agile methodologies include specific issues that can prevent against usage in user-centered product design, which is an essential factor to consider for the IA-driven development.

Therefore, it becomes necessary to analyze the feasibility of agile methodologies to integrate user-centered activities, in order to be able to clearly discern which agile methodologies are more suitable for the development of user-centered interactive software.

2.2 Feasibility of Agile Methodologies to Integrate User-Centered Activities

This section presents a study and analysis of several agile methodologies in order to know the extent to which these can integrate user-centered activities. This will enable to find out both the aspects to envision a hypothetical integration support and the strengths that make it impossible.

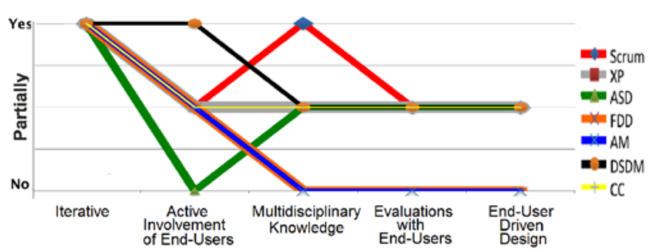

Figure 1. Overview of the feasibility of agile methodologies to integrate user-centered activities.

This way, the seven most-popular agile methodologies were analyzed against a set of reference attributes based on the principles of ISO 9241-210 [10]. The agile methodologies analyzed were Scrum, Extreme Programming (XP), Adaptive Software Development (ASD), Feature-Driven Development (FDD), Agile Modeling (AM), Dynamic Systems Development Method (DSDM) and Crystal Clear (CC).

Figure 1 depicts the result of the analysis in relation to the degree of feasibility of agile methodologies to integrate user-centered activities. Axis X represents the ISO 9241-210 attributes used to evaluate the agile methodologies, whereas axis Y indicates the degree to which the agile methodologies comply with such attributes (Yes, Partially or No).

As shown in the Figure 1, all methodologies comply with the *Iterative* attribute, so that the project is planned and executed iteratively.

Regarding the *Active Involvement of End-Users* attribute, in 5 out of the 7 analyzed methodologies (Scrum, XP, FDD, AM and CC) end-users are partially involved in the process. The DSDM agile methodology is the only one that allows the active participation of end-users by proposing roles that are directly assumed by them. Although 4 out of the 7 analyzed methodologies (Scrum, XP, AM and CC) also describe roles related to end-users, those are more related to aspects concerning functional requirements of the system. It is also important to highlight that Scrum includes a review process (*Sprint Review*), which would facilitate the direct involvement of end-users.

With respect to *Multidisciplinary Knowledge* attribute, 5 out of the 7 analyzed methodologies (Scrum, XP, ASD, DSDM and CC) consider work teams with different skills and knowledge. However, the team building is primarily based on the search of efficiency in the development and maintenance of functionalities from the technical perspective of a software programmer. In the case of Scrum methodology, it explicitly states that the work team formation will be based on all competencies needed to accomplish the work without depending on others being not part of the team.

In relation to *Evaluations with End-Users* attribute, 5 out of the 7 analyzed methodologies (Scrum, XP, ASD, DSDM and CC) accomplish assessments, which are partially focused on end-users. In fact, these methodologies consider specific roles on behalf of end-users, even considering roles as client or expert user with knowledge about the system procedures or functional requirements, which would allow partial involvement of end-users in assessments. Nevertheless, agile assessments are mainly oriented towards unit testing and system integration, as most of the agile approaches are principally focused on the client rather than on the end-user. It is worth noting that Scrum defines a specific event (*Sprint Review*) in order to verify each product increments with the participation of stakeholders. This feature allows the participation of end-users in evaluations.

As for the last evaluated *End-Users-Driven Design* attribute, in 5 out of the 7 analyzed methodologies (Scrum, XP, ASD, DSDM and CC) the design is in part based on understanding end-users, tasks and environments. In 3 out of the 7 analyzed methodologies (Scrum, DSDM and CC) there exists the use of non-functional prototypes and participation of various roles related (directly or partially) to end-users. This facilitates the inclusion of environmental and end-user tasks aspects. However, the priority is set on getting a usable version of the software. In this respect, it is important to stress that in Scrum the requirements are dynamically managed by the *Product Owner* role, which has a profile oriented to the end-user's needs. Hence, this would lead the design based on understanding end-users, tasks and environments.

All in all, DSDM and Scrum are principally the two agile methodologies enabling a better adoption of user-centered activities. These methodologies have in common that both of them involve end-users by considering specific roles and using practices to actively involve end-users. For instance, DSDM presents the user's role descriptions and the use of prototypes. Similarly, Scrum facilitates end-users to prioritize the list of requirements and provides a review process that facilitates end-user involvement. On the other hand, the DSDM methodology has some weaknesses that prevent its application for the stated purpose. To cite a few, DSDM methodology requires a specific institutional framework for software development process, which is neither cheap nor easy to implement, and it also demands significant change of consciousness in any organization. By contrast, Scrum methodology presents a framework that is easy to implement, providing flexibility and adaptation to end-user and business requirements.

On the other hand, AM and FDD methodologies provide less facilities for the UCD integration. These methodologies have in common their orientation towards optimization of coding techniques and modeling for systems development, as well as the use of such methods for technical purposes.

Therefore, the Scrum agile method has been selected as ideally suited to integrate UCD in a development environment that requires agility and end-user focusing.

3. INTEGRATING UCD AND AGILITY

This section describes and analyzes the different practices that are commonly used to integrate UCD in agile methodologies (section 3.1). Furthermore, specific recommendations that enable the integration of UCD in the Scrum methodology are also reviewed (section 3.2).

3.1 Practices and Common Artifacts

Da Silva et al. [11] identified, by means of a systematic review of bibliography, what needs, artifacts and common practices are used to support collaboration between designers and developers in the integration of UCD and agility. Silva da Silva et al. analyzed 58 papers concluding that the most important practices and artifacts correspond to: *little design up front* (LDUF), *low fidelity prototypes, users testing, user stories, inspection methods, one sprint ahead and big picture*. Similarly, Jurca et al. [12] conducted a systematic mapping study to identify relevant research and understand Agile-UCD combination. Some of the recommended practices and artifacts identified were the following: *concept maps, low fidelity prototypes, interviews, scenarios and meetings with users*. Recently, Brhel et al. [13] also conducted a systematic review of the literature on aspects of integration of UCD in agile methodologies. The identified papers were analyzed using a coding system of four levels: process, practices, people and technological dimensions. Thus, the most common practices identified were: *prototypes, scenarios, usability evaluation* (expert), *user objectives* [14], *usability testing* (user) *and user stories*, among others. Finally, Jia et al. [15] conducted a study with the aim of exploring how usability techniques were integrated during the software development in Scrum projects. In this case, the most used usability techniques found in Scrum projects were: *workshops, low fidelity prototypes, interviews and meetings with users*.

Summarizing all, Table 2 identifies correspondences between techniques, reported by [11,12,13], used to integrate UCD in agile methodologies. In addition to this, the correspondence between the techniques mentioned above and the usability techniques used in the Scrum methodology [15] has been identified as well. These correspondences allow to identify matches between usability techniques used in the Scrum and techniques used to integrate UCD in agile methodologies.

As shown in Table 2, *low fidelity prototyping, scenarios, heuristic evaluation, usability testing, people, workshops and interviews* are the most frequent techniques found in the systematic review of the literature regarding UCD and agile integration. This consolidates such techniques as mandatory when integrating aspects of usability in agile projects. Moreover, it is important to note that *user stories* and *guidelines* techniques are not mentioned in [15] as common techniques in Scrum projects because these are mainly associated to XP methodology.

Table 2. Summary, according to reviewed bibliography, describing correspondences between techniques used to integrate UCD in agile methodologies and usability techniques used in the Scrum methodology.

Techniques Used to Integrate UCD in Agile			**Usability Techniques Used in Scrum** [15]
[11]	[12]	[13]	
Low fidelity prototyping	Low fidelity prototyping	Prototyping	Low fidelity prototyping
Scenarios	Scenarios	Scenarios	Scenarios
Inspection methods	Cognitive walkthrough variants	Usability evaluation (expert)	Heuristic evaluation
Users testing		Usability testing (user)	Usability evaluation with users
Personas		Personas	Personas
	Workshops	Focus groups	Workshops
	Interviews	Interviews	Interviews
	Meetings with users		Meetings with users
		Contextual inquiry	Field studies
User stories		User stories	
Guidelines		Guidelines	

Lastly, it can be stated that all these techniques have in common the ability to adapt to changing environments that require a rapid response to the needs of end-users and business value.

3.2 Specific Recommendations to Integrate UCD in Scrum

In this section, the different practices and recommendations used to integrate UCD in the Scrum methodology have been collected and analyzed.

Definition of "Done" for UCD-Related Tasks: Kniberg [16] highlighted the importance of the fact that Product Owner and Development Team should agree on a clear definition of "Done". This would facilitate obtaining a common understanding regarding the scope and demands of the requirements presented by the Product Owner, as well as the tasks that will be carried out by the Development Team. Felker et al. [17] proposed to use a different definition of "Done" for UCD-related tasks. Authors suggested that this strategy would facilitate the monitoring of work in order to know the right moment to move on to the next task.

Product Backlog Management: Singh [18] noticed that one of the key challenges to usability in the Scrum projects is the study of end-user needs and context. Therefore, selected requirements should fit usability concerns and be prioritized accordingly. To address these drawbacks, Budwig et al. [19] proposed the creation of a Product Backlog for issues related to UCD, which helps the UCD team allocate corresponding resources to projects. Similarly, Singh [18] proposed to structurally maintain the Product Backlog but incorporating elements including greater awareness of usability, that is, a higher priority for the requirements that impact on usability, especially regarding potential acceptance criteria for requirements. Furthermore, Kuusinen [20] proposed that UCD specialists were given more influential roles in regard to product level decisions in order to improve managing the *big picture* and understanding and fulfilling end-user needs.

Usability Evaluation Management: Lárusdóttir et al. [21] indicated that it is difficult to find a good moment for UCD evaluation in Scrum. On the one hand, a very early assessment in the project is complicated, because the available features are still insignificant to have a UCD assessment. On the other hand, when characteristics are significant to be evaluated, it is difficult to make important changes because some parts of the product have already been delivered and there is not enough time to evaluate before the next delivery. There have been different proposals attempting to minimize this drawback. Among others, Felker et al. [17] proposed to schedule assessments before knowing what is going to be evaluated, analyze end-user feedback just after UCD assessments, and carry out this at the end of Sprint. Lárusdóttir et al. [22] suggested using informal ways to involve end-users in the evaluation and apply different methods to successfully perform each of the user-centered assessments.

Completing the Contextual Inquiry Beforehand: The contextual inquiry is a method to inspect and understand end-users and their workplace, tasks and preferences. Rannikko [23] recommended the contextual inquiry to be completed before starting the software development. Felker et al. [17] reported on a successful usage of such guideline, so the authors noted that possessing the results of a contextual inquiry was incredibly helpful and it allowed them to focus on the design and implementation, helping establish initial priorities.

Close Collaboration: Lárusdóttir et al. [21] suggested that the UCD specialists should work closely with developers in Scrum Teams. Moreover, Kuusinen [20] stated that it was necessary to identify the right moment for the UCD specialists to work. These issues have been addressed in different ways, among these, it has been suggested that the UCD should occur in parallel tracks to implementation [24], set the UCD teams to work in one or two Sprints ahead of the development teams [19] and design a Sprint ahead of implementation [17,22].

Big Picture of the Project: The term big picture refers to a holistic view of the whole project in Scrum. Lárusdóttir [21] reported that the big picture of user experience is usually missing in Scrum projects. On the one hand, one of the reasons why this happens is that programmers have the responsibility to deliver a small piece of software, but often they do not feel responsible for the user experience or the entire system. On the other hand, it has been reported that the big picture of user experience is not present because the responsibility for particular activities of user experience in Scrum projects is often not clearly defined [21]. To address these difficulties, Budwig et al. [19] proposed to quarterly incorporate, throughout a common Sprint cycle, activities oriented to update the big picture, in order to have a clear vision of the design to be carried out in the proyect and keep up the overall coherence. Another proposal is to use overall quality goals to help deliver the overall design direction [8]. Finally, Lárusdóttir et al. [21] indicated the need for strategic vision and user experience objectives to be defined before starting the current project, that is, before the Sprint. However, the strategic vision should also be considered when defining what will take place in different Sprints [8]. Therefore, different authors recommend that a view of user experience must be considered before starting the implementation, but also it needs to be applied during the iterations of the Scrum project.

Assign Responsibility for End-User Concerns*:* The results of the work of Cajander et al. [8] showed that the responsibility for the end-user's perspective is not clear in Scrum projects, and end-user perspective is often neither discussed nor described in the projects. However, the end-user's perspective is often present through informal feedback used to understand the context of use and report design. Cajander et al. [8] aimed to strengthen the emphasis on the end-user's perspective by clarifying and explicitly communicating the responsibility of working through usability. This includes both who will work with usability and who is responsible for the quality of the final product. However, this proposal does not solve what could be done in the context of Scrum, where there are no formal responsibilities for any quality aspects, such as security, privacy and performance. Cajander et al. [8] provided some examples of the organizational support needed: sufficient mandate, support from the management, organizational competence as well as an adequate position in the team to be able to contribute to better usability.

Systematize the Process of End-User Inclusion*:* Cajander et al. [8] indicated that general agile processes do not support end-user participation. Rather, end-users are informally involved. Often this is done on an ad hoc basis, and mostly based on personal initiative and knowledge of the team members about the end-user's perspective rather than being systematically planned in the Scrum process. Cajander et al. [8] suggested that it could be useful to systematize the process through showing end-user involvement and design feedback as general activities in the development process.

4. PROPOSAL

In order to address commented drawbacks taking also into consideration analyzed proposals to integrate the UCD in the Scrum methodology, an IA-driven approach is proposed with the aim to integrate agility into the user-centered development process of interactive software. The proposal, called Scrum-UIA (Scrum driven by Usable Information Architecture), is based on the Scrum methodology, and it includes roles, events, artifacts and associated rules [25], as well as a combination of practical and specific recommendations, as analyzed before in the literature, to integrate UCD in the Scrum process (see Figure 2).

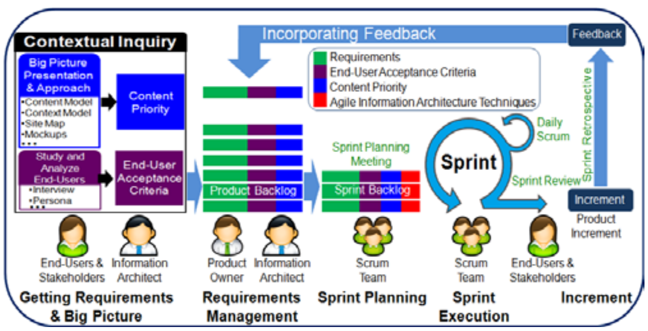

Figure 2. Detail of Scrum-UIA.

The team is composed following the same traditional structure of Scrum (a Product Owner, the Development Team, and a Scrum Master) but the Information Architect is incorporated as a primary role in order to lead the contextual inquiry, support the Product Backlog management, promote the IA-driven incremental development, ensure UCD and encourage end-user involvement.

As shown in Figure 2, our proposal is based on establishing a contextual inquiry as the starting point of the project with the aim of studying and analyzing the needs of end-users and prioritizing the contents, in order for the gained knowledge to provide the basis to set up a big picture of the project. Requirements included in the Product Backlog are improved by incorporating output from the contextual inquiry (end-user and content priorities). This is carried out in coordination between the Product Owner and the Information Architect.

The Sprint planning is carried out after the requirements management through the Sprint Planning Meeting event. In the Sprint planning the work to be done in each Sprint is defined. Thus, the highest prioritized requirements of the Product Backlog are selected for the Sprint Backlog. (This is explained in detail in Section 4.1)

The Product Backlog's items selected for this Sprint together with the plan to carry them out made up the Sprint Backlog. The Development Team splits requirements selected for the Sprint Backlog into specific development tasks, and those are developed during the Sprint execution. Moreover, specific development tasks can be associated to techniques for Agile IA development that are auto-assigned by the Development Team.

Daily Scrum meetings are carried out during the Sprint execution every day in order to inspect and adapt the daily work accomplished by the Development Team, and also to manage individual development tasks so that the visibility and consistency with the big picture can be maintained. The Sprint Review meeting takes place at the end of Sprint and is carried out involving both end-users and other secondary stakeholders, in order to review the potential product Increment generated by the Development Team. Finally, the Scrum Team analyzes the working practices during the iteration and seeks improvement opportunities through the Sprint Retrospective meeting. Overall, our proposal is based on three essential components:

- *Contextual inquiry-driven Product Backlog management.*
- *Information architecture-driven Sprint planning.*
- *End-user-driven inspection and Continuous Improvement processes.*

These essential components are described below in detail.

4.1 Contextual Inquiry-Driven Product Backlog Management

The objective of this component is twofold: first, to ensure that the end-user's perspective can be discussed, described and considered (problem reported by [8]) throughout the Scrum process. And the second is to provide a big picture of the project to help obtain a global and inclusive vision of the product regarding usability priorities, content, business value and end-users.

In order to fulfill the objectives indicated above, we propose to initiate the project with a contextual inquiry (see Figure 3), as recommended in [23] and successfully implemented in [17], with the aim of obtaining knowledge about the priorities of end-users and content. This simultaneously provides the basis to set up the big picture of the project to support the Product Backlog management.

Lárusdóttir et al. [21] reported that Scrum projects do not have a big picture and, according to [26], this is perceived as a problem among UCD professionals. We propose to address this problem by specifying a low fidelity vision of the following artifacts: *content model*, *context model*, *site map* and *mockups*. These artifacts make it possible to report the design of contextual navigation of a site, determine the critical content and visualize relationships between pages and other content components. Thus, these artifacts can be processed to obtain an overview of a site and facilitate discussion of the organization and content management, as well as access priorities desired by end-users [2,27].

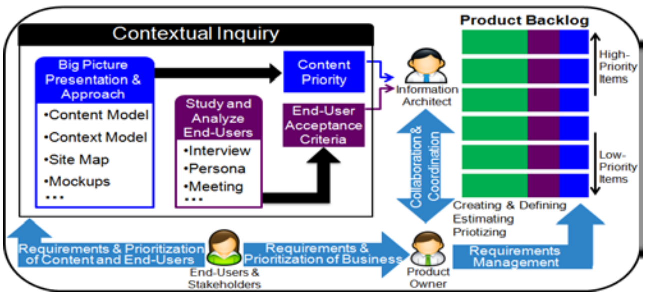

Figure 3. Contextual inquiry-driven Product Backlog management.

As a result, suggested artifacts can support the management of the project's big picture by providing a clear view of the most critical content elements of a site, and also facilitate discussion among the team members on the aspects of end-users and contents related to business needs.

Therefore, it is proposed to develop the suggested artifacts before starting the current project [21] during the contextual inquiry. Moreover, it is suggested to quarterly incorporate work to update the artifacts throughout a common Sprint cycle [19] and use overall quality goals to support the global design management [8]. Furthermore, it is suggested to obtain and specify end-users acceptance criteria through interviews, Personas and meetings techniques that are usually used in Scrum projects [15].

This way, we propose, similarly to Kuusinen's suggestion [20], to provide the Information Architect with the facility for defining, estimating and prioritizing the Product Backlog collaborating in coordination with the Product Owner. In this case, the Information Architect provides the vision of IA and usability obtained from contextual inquiry, and the Product Owner provides business requirements and prioritization.

Finally, we propose, in a similar manner to [18], to maintain the same structure of Product Backlog but incorporating elements to include greater consideration on content priority, end-users acceptance criteria , business value priorities, as well as identification and association of requirements with the big picture's elements. In particular, the Information Architect identifies, among Product Backlog items, high-level conceptual representations of content that evolve towards the solution domain and facilitate the IA-driven incremental development – i.e., *content models* created in the problem domain evolving towards models closer to the solution domain [28]. The results obtained are then used in the Sprint Planning Meeting.

4.2 Information Architecture-Driven Sprint Planning

This component has three main objectives: the first is to ensure (during the Sprint Planning Meeting) that requirements development is driven by IA priorities in an agile and user-centered way. The second is to promote that the development is performed incrementally through the different fidelity levels in evolution with IA deliverables (*blueprints*, *wireframes*, *content mapping*, *inventory* and *content models*). And the third is to provide a common understanding through a clear definition of "Done", as recommended [17], regarding the scope and demands of the requirements set by the Product Owner (in collaboration with the Information Architect) and the tasks that are required to be performed by the Development Team according to specific and selected techniques.

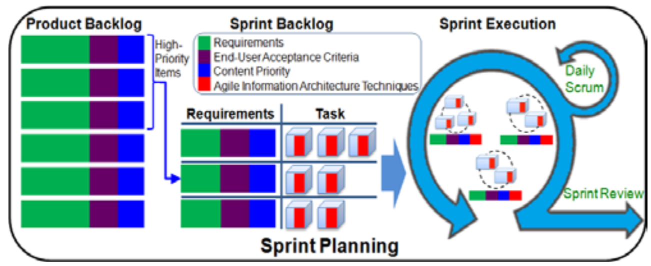

Figure 4. Information Architecture-driven Sprint planning.

As shown in Figure 4, the requirements of the Product Backlog having the higher priority are selected to be included in the Sprint Backlog. Each of the selected requirements (which simultaneously contain elements regarding the priority of end-users, business value and content) is split into specific development tasks by the Development Team. Each requirement priority has an IA-driven weighing provided by the Information Architect during the requirements management, in order to specify IA priorities for the incremental development.

Table 3: Recommended techniques for agile IA development.

Techniques	IA Meth.	A	D	E	I	M
Affinity diagram	[4,6]		X			
Background investigation	[2]	X				
Benchmarking	[2,6]	X	X			X
Card Sorting	[2,4,5,6]	X	X	X		X
Consistency inspection	[6]		X			
Consolidated evaluation	[6]	X	X			
Diagramming	[4]		X			
Entity–relationship model	[6]			X		
Feedback analysis	[2,5,6]			X		X
Field studies*	[6]	X				X
Focus group discussion	[2,6]	X				X
Goodness rating	[5]			X		
Heuristic evaluation*	[2,5,6]	X		X		
Interface design patterns	[6]	X	X		X	
Interviews*	[2,3,6]	X		X		
Low fidelity prototyping*	[6]	X	X			
Meetings*	[2,6]	X			X	
Mock-up prototype	[6]	X	X			
Participatory design	[2,6]		X		X	
Personas*	[2,4,6]	X	X			

Predictability and efficiency evaluation	[5]			X		
Questionnaires*	[4,5]	X		X		
Scenarios*	[2,6]	X	X			
Speeded sentence verification	[5]			X		
Sponsor-driven structure evaluation	[5]			X		
Storyboards	[6]			X		
Structure evaluation	[6]		X			
Usability evaluation*	[6]			X		
Survey	[5]	X		X		
Workshops*	[2,6]	X			X	

A set of agile techniques for IA development (see Table 3) is provided to support the development of specific tasks during the Sprint execution. The agile techniques for IA development are auto-assigned by the Development Team, as well as the tasks to carry out for each of the specific development tasks.

We have obtained the agile techniques for IA development from a second analysis of the five IA development methodologies [2,3,4,5,6]. The second analysis was performed in order to obtain a set of activities, techniques and products for IA development considering an agile and user-centered approach. In addition the coincidences between the resulting techniques and the usability techniques used in Scrum, reported by [15]**,** are identified.

In Table 3, the aforementioned set of agile techniques for IA development is presented, as well as the recommended phases where they can be applied: analysis (A), design (D), evaluation (E), implementation (I) and management (M). Furthermore, the techniques presented by [15] are pointed out with an asterisk (*) in order to demonstrate the high correspondence with the Agile IA techniques. Also, each associated IA methodology is provided denoting its corresponding bibliographical reference.

Finally, the Development Team performs the Sprint execution according to the stated planning and the techniques to ensure usability during the development, having in mind the big picture of the project and a common understanding of the requirements.

4.3 End-User-Driven Inspection and Continuous Improvement Processes

The last issue of our proposal is aimed at enhancing traditional inspection and continuous improvement processes in Scrum (Daily Scrum, Sprint Review and Sprint Retrospective) as a way of encouraging UCD and end-users involvement. On the one hand, individual tasks are inspected to keep up with the big picture and track compliance of end-users acceptance criteria from the early stages during the Sprint (Daily Scrum). On the other hand, the potential product Increment is evaluated through the straight involvement of end-users and other secondary stakeholders (Sprint Review). And last but not least, all team members reflect on the completed Sprint to find out what improvements could be made in the next one – i.e., process improvement (Sprint Retrospective).

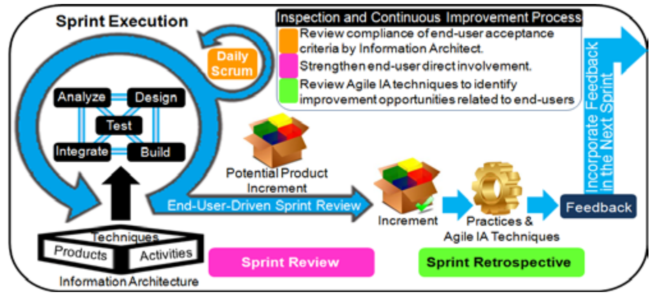

Figure 5. End-user-driven inspection and continuous improvement processes.

During the Sprint execution a "Done", useable, easy-to-use and potentially releasable product Increment is created. As shown in Figure 5, the Sprint execution is supported by a set of activities, techniques and products for IA development in an agile and user-centered way, as commented before.

Every day, the Daily Scrum takes place during the Sprint execution. The Daily Scrum is done by inspecting the work since the last Daily Scrum and forecasting the work that needs to be done before the next one. Moreover, we encourage the Information Architect participation in the Daily Scrum to review individual tasks in order to preserve the big picture and identify, from early stages, the fulfillment of the end-user's acceptance criteria.

A Sprint Review is carried out at the end of the Sprint execution in order to inspect the Increment and sort out the Product Backlog if needed. It is proposed to strengthen end-users involvement through an end-user-driven Sprint Review that, according to [8], could be also beneficial. In this way, the end-user's direct involvement is materialized through formally assigning the prerequisite that end-users must interact with the potential product Increment during Sprint Review. That is to say, the Development Team demonstrates the work that is "Done" through the end-user's direct involvement interacting with the Increment. Moreover, it is suggested to reflect on the results of these ceremonies just after the evaluations [17] and apply different methods to successfully perform each of the user-centered assessments [22].

Finally, the Sprint Retrospective is held with the aim of reviewing aspects concerning the practices and Agile IA techniques used by the Scrum Team during Sprint execution, and also creating a plan for improvements to be enacted during the next Sprint. The Information Architect uses this event as an opportunity to review the performance of the practices and techniques used in the development of the IA, in order to identify improvement opportunities regarding responsiveness to the demands of agility and management of issues related to end-users. The idea is to improve the process, incorporating ideas for next Sprints.

5. CONCLUSIONS

This paper presents an IA-driven approach for the agile development of usable software, which considers the dynamic demands of the environments where organizations operate, as well as the needs of end-users. Concretely our approach, named Scrum-UIA, aims at integrating agility and UCD by contributing the following issues:

- The end-user's perspective is discussed, described and considered during the Scrum process through a *Contextual Inquiry-Driven Product Backlog Management*.

- Development of requirements is driven by IA priorities in an agile and user-centered way through an *Information Architecture-Driven Sprint Planning.* Furthermore, a set of agile techniques for IA development is provided to support the development of specific tasks during the Sprint execution.
- Compliance with the end-user's acceptance criteria is checked from the early stages of the Sprint, and the potential product Increments are evaluated through an *End-User-Driven Inspection and Continuous Improvement Processes.*

In addition, this paper presents different contributions involving analysis and discussion on the following issues:

- A comparative analysis checking the current features of the methodologies for the IA development shows that none of them present flexibility and adaptability characteristics to respond in an agile and flexible way to changing environments, and require considerable effort to be adapted.
- A analysis to know the feasibility of integrating user-centered activities into agile methodologies, showing that the Scrum methodology presents a framework that is easy to implement, providing flexibility and adaptation to end-user and the business requirements.
- A analysis of the practices that are commonly used to integrate UCD in agile methodologies, showing that *low fidelity prototyping, scenarios, heuristic evaluation, usability testing, people, workshops and interviews* are the most frequent techniques used in the UCD and agile integration.

As future work, we expect to build an easy-to-use CASE tool, which can be used to implement Scrum-UIA, in order to automatically provide scheduling, recommendation, activities and techniques to carry out an agile UCD-IA development, also dealing with end-user demands, priorities, usability, business value and content during the agile development process. In addition, we expect to apply the proposal to a real case and thus obtain improvement clues.

6. ACKNOWLEDGMENTS

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Hacia la Caracterización de la Calidad de Interacción

Cristina Roda
Grupo de Investigación LoUISE
Dpto. de Sistemas Informáticos
Universidad of Castilla-La Mancha
02071, Albacete, España
cristina.roda@uclm.es

Víctor López-Jaquero
Grupo de Investigación LoUISE
Dpto. de Sistemas Informáticos
Universidad of Castilla-La Mancha
02071, Albacete, España
victor@dsi.uclm.es

Francisco Montero
Grupo de Investigación LoUISE
Dpto. de Sistemas Informáticos
Universidad of Castilla-La Mancha
02071, Albacete, España
fmontero@dsi.uclm.es

ABSTRACT
La *Calidad de Interacción* es un factor muy a tener en cuenta en cualquier tipo de aplicación y, por supuesto, el diseño de una adaptación a nivel de interfaz de usuario de una aplicación concreta, también debería considerar aspectos relativos a la calidad. Descuidar la evaluación de la calidad puede producir fácilmente aplicaciones que no cumplan con las expectativas de usuarios y desarrolladores. En este sentido, trabajos previos han guiado el camino a seguir hacia la consideración de la calidad en un marco de adaptación de interfaces de usuario. Concretamente, se ha ilustrado cómo se debe contemplar la Calidad de Adaptación en cada etapa del framework ISATINE, analizando las múltiples facetas de este concepto, y proponiendo su descomposición en cuatro tipos de calidad de interacción: *Calidad Esperada* de la adaptación, *Calidad Deseada* de la adaptación, *Calidad Alcanzada* de la adaptación, y *Calidad Percibida* de la adaptación. Además, se han descrito qué tipos de calidad de adaptación están involucrados en cada etapa de ISATINE. Pero, ¿cuál es la idea que tienen, tanto usuarios como desarrolladores, sobre calidad de interacción? ¿Utilizan los mismos términos para referirse a ella? Estas son las preguntas que guían este trabajo, el cual presenta un estudio sobre la caracterización de la Calidad de Interacción, concretamente sobre la Calidad Esperada y la Deseada, con el objetivo de entender mejor las preferencias de calidad de los usuarios que permita a los desarrolladores diseñar productos software mucho más atractivos.

Categorías
H.5.2 [**Interfaces de Información y Presentación**]: Interfaces de Usuario – *evaluación/metodología, diseño de pantalla, diseño centrado en el usuario*.

Términos Generales
Diseño, Factores Humanos, Teoría.

Keywords
Interfaz de Usuario, Calidad de Interacción, Proceso de Adaptación, Calidad de Adaptación, ISATINE, Estudio.

1. INTRODUCCIÓN
En los últimos años, hemos sido testigos del creciente uso de aplicaciones que facilitan las tareas habituales al usuario, como comprar billetes de avión o entradas para un espectáculo, o la variedad de personas que utilizan una misma aplicación. Estos son sólo algunos ejemplos que ilustran la necesidad de crear aplicaciones software adecuadas para cualquier tipo de usuario, cualquier tipo de plataforma, y capaces de trabajar en cualquier situación. Desafortunadamente, es imposible diseñar y prever cada una de las situaciones que puedan surgir durante la interacción, por lo que se hace necesario introducir un mecanismo que permita desarrollar este tipo de aplicaciones sensibles al contexto: *Adaptación.*

La adaptación al contexto de uso de interacción que nos rodea se ha convertido en una rutina diaria cuando interactuamos con nuestros dispositivos, por ejemplo cuando rotamos el dispositivo, la interfaz de usuario se reestructura de nuevo, o cuando un determinado widget nos informa de la previsión meteorológica del lugar en el que nos encontremos, gracias a la geolocalización.

En la literatura clásica sobre adaptación, se describen dos tipos principales de aplicaciones [1]:

- Aplicación *Adaptable*, cuando el *usuario* es el actor encargado de realizar la adaptación de la interfaz de usuario.
- Aplicación *Adaptativa*, cuando la propia *aplicación* es la que realiza la adaptación automáticamente.

De esta forma, existen diversos marcos de adaptación que guían al diseñador en el proceso de crear experiencias de adaptación agradables. El proceso de adaptación más ampliamente aceptado es el propuesto por Dieterich en 1993 [4], aunque, como veremos más adelante, este marco presenta algunas deficiencias. Para solucionar estas limitaciones, se propone el framework ISATINE [17]. Estos y otros marcos de adaptación se describen con más detalle en la sección 2.

Obviamente, estos marcos de adaptación y, en general, el proceso de adaptación, deben proporcionar cierto nivel de *calidad* de interacción, entendida como [10] la capacidad de un producto software de satisfacer necesidades expresadas o implícitas cuando se utiliza bajo condiciones específicas. Esta característica de calidad garantiza una adaptación apropiada y precisa para una situación dada. Del mismo modo que se desarrolla una interfaz de usuario (y una aplicación software) para lograr cierto grado de calidad de interacción, también debe ocurrir lo mismo con las capacidades de adaptación de la aplicación. Este último tipo de calidad está relacionado con la *Calidad de Adaptación* (Quality of Adaptation, QoA) y se refiere a la medida (o incremento) en que un conjunto de adaptaciones produce una interfaz de usuario para alcanzar objetivos específicos con *usabilidad* en un contexto de uso concreto [17].

Sin embargo, como ya se ha visto en trabajos previos [22], actualmente la calidad no se considera de forma apropiada en los procesos de adaptación y, por tanto, no siempre se proporciona una buena experiencia de adaptación al usuario. De esta forma, se ha propuesto integrar la QoA en el marco ISATINE con el objetivo de tener en cuenta la calidad de interacción a través de todas las etapas del marco de adaptación. Esta consideración de la calidad ayudará en la mejora de la experiencia de adaptación en cada paso del proceso de adaptación, y no sólo después de la ejecución de la adaptación, como ocurre habitualmente.

En este sentido, este artículo presenta un resumen del trabajo previo realizado en aras de considerar la integración completa de la QoA en ISATINE, para lo cual se describen los distintos tipos de calidad de interacción y su relación con cada etapa de ISATINE. Este resumen previo permitirá contextualizar mejor el estudio presentado posteriormente.

La justificación de por qué es necesario un estudio para caracterizar la Calidad de Interacción es bien sencilla: entender mejor las preferencias de calidad de los usuarios, es decir, qué factores o atributos son los más importantes para ellos a la hora de determinar si un producto software tiene suficiente calidad o no. Así, disponer de este conocimiento permitirá a los desarrolladores diseñar adecuadamente dichos productos software de acuerdo a las preferencias y necesidades de los usuarios.

Este trabajo se organiza de la siguiente forma: la sección 2 presenta distintos procesos de adaptación propuestos a lo largo de los años y la necesidad de un nuevo proceso de adaptación como ISATINE para abordar las deficiencias encontradas en dichos procesos; la sección 3 presenta los conceptos de calidad y Calidad de Interacción, sus tipos y las relaciones entre ellos, así como el concepto de Calidad de Adaptación y su inclusión en ISATINE. La sección 4 presenta un estudio sobre la primera brecha surgida al caracterizar la calidad de interacción y una discusión al respecto (sección 5). Finalmente, la sección 6 presenta las conclusiones y trabajo futuro.

2. CONTEXTUALIZANDO EL ESTUDIO

Como primer paso para contextualizar este trabajo, a continuación se describen distintos procesos encaminados a guiar un proceso de adaptación.

2.1 Procesos de Adaptación

Una adaptación en sí no tiene por qué ser adecuada y puede, por tanto, causar el rechazo del sistema adaptativo por parte del usuario. Por ejemplo, el brillo de la pantalla de un teléfono móvil se intensifica automáticamente debido a las condiciones de iluminación actuales, lo que conlleva un incremento del consumo de batería. Quizá esta adaptación de IU puede ser rechazada por el usuario si su prioridad es ahorrar energía porque el dispositivo tiene poca carga de batería.

Por consiguiente, se hace necesario un proceso que guíe la adaptación para que ésta sea apropiada, entendiendo como *proceso* [8] una secuencia de tareas que, cuando se ejecuten correctamente, producirán el resultado deseado. Más formalmente, el estándar ISO 9000 [11] define un proceso como un conjunto de actividades interrelacionadas o interactivas que transforman entradas en salidas. Algunos de los beneficios de utilizar un enfoque basado en procesos son [11] la habilidad de centrarse en la efectividad y la eficiencia del proceso; resultados mejorados, consistentes y previsibles; o fomentar la participación activa de los individuos y dejar claras sus responsabilidades dentro del proceso.

A lo largo de los años, se han propuesto diferentes marcos o procesos de adaptación que persiguen el objetivo de guiar a los diseñadores en la definición de las capacidades de adaptación. Por ejemplo, Cockton en 1987 [2] propuso un proceso de adaptación de dos etapas. La primera de ellas es el *diagnóstico*, en la que el sistema imagina las necesidades y habilidades del usuario basándose en información registrada. Seguidamente, en la segunda etapa, se aplica el *tratamiento* encontrado para remediar la situación detectada. Otro proceso de adaptación fue el propuesto por Oppermann en 1994 [19] quien, al igual que Lorenz (2000), dividió el proceso de adaptación en tres fases: *aferencial*, *inferencial* y *eferencial*, es decir, la recogida de la información de contexto (principalmente interacción del usuario), el procesamiento e inferencia de dicha información, y la implementación y presentación de la adaptación al usuario final, respectivamente. Además, este autor destaca la importancia de definir el momento preciso para comenzar y evaluar la adaptación.

Sin embargo, como se mencionó anteriormente, en el contexto de adaptación, el proceso de adaptación más ampliamente aceptado es el que propuso Dieterich en 1993 [4]. Concretamente, los cuatro pasos que conforman este proceso son:

1. *Iniciativa*. Una de las entidades involucradas en la interacción (usualmente el usuario o el sistema) sugiere su intención de realizar una adaptación. Por ejemplo, cuando estamos utilizando Gmail, éste es capaz de detectar si la conexión a Internet es lenta y sugerir una vista mucho más básica.
2. *Propuesta*. Si la aplicación necesita una adaptación, se deben proponer diversas adaptaciones que se puedan aplicar con éxito en el contexto de uso actual. En el ejemplo anterior, Gmail sugiere cambiar desde su interfaz habitual a un modo HTML básico, mitigando la carga y disminuyendo el tiempo de respuesta. Esta propuesta se muestra al usuario por medio de un mensaje de texto que también es un hiperenlace: “Cargar vista básica en HTML (para conexiones lentas)”.
3. *Decisión*. Como puede ser que existan distintas propuestas de adaptación derivadas de la etapa anterior, se debe seleccionar aquella que mejor se ajuste a la necesidad de adaptación detectada. En el ejemplo, el usuario es responsable de cambiar o no el modo de Gmail, haciendo clic en el enlace correspondiente.
4. *Ejecución*. El último paso consiste en la ejecución de la adaptación previamente elegida. En el ejemplo, si el usuario selecciona el modo HTML básico, Gmail proporcionará una vista mucho más simple, eliminando algunas de las características del modo estándar, pero soportando funcionalidades básicas como lectura o escritura de correos.

2.2 Evaluación de la Adaptación por Etapas

Además de estos trabajos que muestran la importancia de utilizar un proceso estructurado que guíe la adaptación de una IU concreta, es interesante también destacar otros trabajos que contribuyen de algún modo a la idea de evaluar un proceso de adaptación con el fin de saber más acerca de su calidad. Por ejemplo, Paramythis et al. [20] están de acuerdo con nosotros en cuanto a realizar una evaluación distinta para cada aspecto que conforma un proceso de adaptación. Proponen un marco para sistemas adaptativos que guía una evaluación por capas de cada fase del proceso de adaptación, así como de todo el proceso en su conjunto, y presentan algunos criterios de evaluación (usabilidad, validez, privacidad, etc.) y métodos (minería de datos, grupos foco, test de usuario, etc.) para evaluar cada etapa por separado. En este sentido, las principales capas de adaptación a ser evaluadas serían: Recogida de datos de entrada, Interpretación de los datos recogidos, Modelado del estado actual del mundo, Decidir sobre la adaptación, y finalmente Aplicar la adaptación. El trabajo presentado por Paramythis et al. es similar a la idea que proponemos en [22], aunque existen ciertas diferencias. Nuestro punto de vista es mucho más formal ya que está centrado en la *calidad*, dando una definición explícita de Calidad de Adaptación y haciendo que este concepto sea el principal foco cuando se evalúa un proceso de adaptación. Por otra parte, estos autores no cubren todo el proceso de adaptación como hacemos nosotros con ISATINE, ya que su framework se centra únicamente en la ejecución de la adaptación, como también ocurre en la propuesta de Dieterich. Además, nuestra propuesta se basa en un proceso de adaptación previamente estudiado y consolidado como es ISATINE, el cual se describe con más detalle en la siguiente sección.

Otro trabajo relevante es el presentado por Gena y Weibelzahl [6] que propone un enfoque de ingeniería de usabilidad para diseñar y evaluar sistemas basados en web adaptativa. En este sentido, estos autores proponen varias técnicas de evaluación de acuerdo a la etapa del ciclo de vida en la que se encuentre, es decir, fase de requisitos, fase de evaluación preliminar, o fase de evaluación final. Además, para cada técnica de evaluación, se especifica la dimensión *importancia para la web adaptativa* con el objetivo de ayudar a los investigadores a elegir la mejor opción para una situación dada, indicando de qué manera dicha técnica puede beneficiar a los sistemas basados en web adaptativa. Estos autores proponen diferentes métodos para dar soporte a la evaluación de un sistema adaptativo, pero centrándose sólo en la evaluación de sistemas basados en web. Nuestro enfoque, por el contrario, es mucho más genérico y flexible y puede ser aplicado a cualquier tipo de sistema. Asimismo, Gena y Weibelzahl proponen métodos para evaluar la adaptación en cada etapa del ciclo de vida, frente a nuestra idea de evaluar cada etapa dentro de un proceso de adaptación como ISATINE. Como se mencionó anteriormente, la siguiente sección presenta una visión general del marco de adaptación ISATINE.

2.3 ISATINE

Como se ha comentado con anterioridad, se propuso un nuevo framework de adaptación, llamado ISATINE [17], que especializa el modelo mental de Norman de interacción de usuario [18]. Este modelo mental descompone cualquier interacción de usuario en siete Etapas de Acción:

1. Formación del *Objetivo*, el usuario da forma a un objetivo en su cabeza.
2. Formación de la *Intención*, para alcanzar el objetivo, el usuario forma alguna intención.
3. *Especificación de una Acción*, la intención se transforma en una serie de acciones.
4. *Ejecución de una Acción*, una acción en un momento determinado es seleccionada y ejecutada.
5. *Percepción del Estado del Mundo*, después de que la acción haya sido ejecutada, se perciben los resultados producidos por la misma.
6. *Interpretación del Estado del Mundo*, los resultados percibidos generan una interpretación en la mente del usuario sobre cómo ha cambiado el Mundo.
7. *Evaluación de la Salida*, dependiendo de esta interpretación, el usuario evalúa si la acción que ejecutó coincide con su objetivo inicial.

En este punto, si intentamos hacer corresponder las cuatro etapas propuestas por Dieterich con el modelo de Norman, se puede ver que la *Iniciativa* corresponde con la *Intención*, la *Propuesta* y la *Decisión* son dos etapas involucradas en la *Especificación de una Acción*, y las etapas de *Ejecución* de ambas propuestas coinciden. Por tanto, es fácil ver que el proceso de adaptación de Dieterich sólo cubre algunas de las etapas del modelo de Norman, creando la necesidad de cubrir el resto de etapas no tenidas en cuenta. Esta idea nos permite expandir la taxonomía de Dieterich, ya que es la más extendida, dando lugar al marco de adaptación ISATINE [17] que tiene en cuenta todas las Etapas de Acción definidas en el modelo de Norman.

Por otro lado, el proceso de Dieterich muestra otras deficiencias, considerando la más relevante para nosotros que la QoA no está contemplada en absoluto, es decir, su proceso de adaptación no permite evaluar la adaptación para saber si ha sido apropiada o no, ya que sólo se centra en la ejecución de la misma. De esta forma, el trabajo presentado en [22] mejora el marco de ISATINE con la integración de la QoA, solucionando estos fallos detectados en el proceso de Dieterich. Nótese que ISATINE considera tres tipos de actores involucrados en el proceso de adaptación: el Usuario (U), el Sistema (S) y un Tercero (T), que puede ser, por ejemplo, un agente externo encargado de actualizar el sistema o un sistema externo que interactúa con el nuestro.

A continuación, se describen las siete etapas de ISATINE, como resultado de la especialización de las siete etapas de acción del modelo de Norman:

1. *Objetivos de la adaptación de la interfaz de usuario.* Cualquier entidad (U, S, o T) puede ser la responsable de definir y mantener actualizados una serie de objetivos que garanticen la adaptación de la interfaz de usuario. Aunque la adaptación debe ser siempre en beneficio del usuario, puede ser realizada con respecto a cualquier aspecto del contexto de uso, es decir, con respecto al propio usuario, la plataforma o el entorno físico en que el usuario está llevando a cabo sus tareas. Los objetivos pueden ser auto-expresados, expresados por la máquina, local o remotamente, dependiendo de su localización: en la mente del usuario (U), en el sistema local (S), o en un sistema remoto (T). Continuando con el ejemplo de Gmail, esta aplicación es responsable de mantener un cierto nivel de funcionalidad dentro de su plataforma (S), como algunas características básicas de lectura y composición de correos a pesar de, por ejemplo, problemas de conexión como conexiones a Internet lentas.
2. ***I**niciativa para la adaptación.* Esta etapa se refina a su vez en formulación de la petición de adaptación, detección de la necesidad de adaptación, y notificación de petición de adaptación, dependiendo de su localización, respectivamente U, S o T. Por ejemplo, T puede ser el responsable de iniciar una adaptación cuando una actualización de la IU está disponible o cuando se produce un cambio en el contexto que no puede ser detectado por el propio sistema, como un evento externo. En el ejemplo, la especificación de esta etapa es muy similar a la etapa *Iniciativa* del proceso de adaptación de Dieterich, es decir, cuando utilizamos Gmail, éste puede detectar si la conexión a Internet es lenta y sugerir una vista básica para su IU.
3. *e**S**pecificación de la adaptación.* Esta etapa puede ser a su vez descompuesta en especificación por demostración, por computación, o por definición, dependiendo de la entidad que produce la adaptación, respectivamente U, S o T. Cuando un usuario desea adaptar la interfaz, debe ser capaz de poder especificar las acciones necesarias para hacer dicha adaptación, como por ejemplo programando por demostración o definiendo las operaciones necesarias. Cuando es el sistema el responsable de esta etapa, debe ser capaz de calcular una o varias propuestas de adaptación dependiendo de la información del contexto disponible. Cuando es un tercero el que especifica la

adaptación, puede enviar al sistema directamente una definición de las operaciones que deben ser aplicadas. En el ejemplo actual, Gmail (S) es responsable de especificar la adaptación, ya que es él el que detecta la conexión lenta, sugiriendo por tanto un cambio en la vista de la aplicación, desde su interfaz estándar a un modo HTML básico.

4. ***A****plicación de la adaptación.* Esta etapa indica qué entidad aplicará la adaptación especificada en la etapa anterior. Como la adaptación se aplica siempre sobre la interfaz de usuario, dicha interfaz debe facilitar siempre un mecanismo que la soporte. Si el U desea aplicar la adaptación, por ejemplo, a través de opciones o personalización, debe ser también posible a través de algún mecanismo de la interfaz de usuario. En el ejemplo, el sistema es responsable de cambiar el modo de Gmail, después de que el usuario decida hacerlo en la etapa anterior, por tanto aquí, S es la entidad que aplica la adaptación.
5. ***T****ransición a la adaptación.* En esta etapa se describe qué entidad garantizará una transición suave desde la interfaz de usuario original a la adaptada. Por ejemplo, si S es el responsable de esta etapa, puede proporcionar algunas técnicas de visualización que mostrarán los pasos ejecutados durante la transición, por ejemplo, a través de animación, morphing o visualización progresiva [23]. En el ejemplo, Gmail es responsable de asegurar una transición suave entre la interfaz estándar y la básica, una vez que se ha hecho clic en el enlace para cambiar la vista.
6. ***IN****terpretación de la adaptación.* Esta etapa especifica qué entidad producirá información significativa suficiente para facilitar la compresión de la adaptación al resto de entidades. Normalmente, cuando S realiza una adaptación sin proporcionar una explicación, U no comprende necesariamente por qué se ha realizado la adaptación. Recíprocamente, cuando U realiza una adaptación, debe indicar al sistema cómo interpretarla. Siguiendo el ejemplo, una vez que la adaptación se ha aplicado y el usuario está visualizando la vista básica en HTML de Gmail, se muestra un mensaje en la parte de arriba de la pantalla que dice “En estos momentos estás utilizando la vista Gmail en modo HTML básico”. El usuario puede también pinchar sobre un enlace para descubrir el porqué del cambio. De esta forma, el usuario está al tanto de por qué ha cambiado la IU.
7. ***E****valuación de la adaptación.* Esta etapa especifica qué entidad tiene la responsabilidad de evaluar la calidad de la adaptación realizada, de forma que sea posible comprobar si se cumplen los objetivos inicialmente especificados. Por ejemplo, si S mantiene una planificación interna de los objetivos, deber ser capaz de actualizar su planificación de acuerdo a las adaptaciones aplicadas hasta el momento. Si los objetivos están en la mente del usuario, pueden ser también evaluados en función de lo acontecido en las etapas anteriores. En este caso, la explicación de la adaptación realizada contribuye además a la actualización de los objetivos. También sería posible la colaboración entre S y U para este propósito. En el ejemplo, Gmail es responsable de evaluar la adaptación de su modo visual, dando la opción al usuario de volver atrás a la vista estándar (el usuario rechaza la adaptación) o dejando la vista básica en HTML como vista por defecto (el usuario aprueba la adaptación).

3. UN VISTAZO A LA CALIDAD

Una vez se ha presentado el marco de adaptación ISATINE, es momento para definir y describir más a fondo y formalmente el concepto de calidad (sección 3.1), concretamente en el contexto de la interacción persona-ordenador, así como sus tipos (sección 3.2), y más específicamente en el ámbito de la adaptación de una interfaz de usuario (sección 3.3). Esto permitirá entender mejor lo que significa dotar de calidad de interacción a un proceso de adaptación como ISATINE (sección 3.4), es decir, entender lo que es realmente la QoA.

3.1 Calidad y Calidad de Interacción

El término *calidad* es bastante ambiguo en su definición, debido principalmente a su uso habitual en múltiples contextos y, por tanto, posee diferentes interpretaciones y definiciones, como las propuestas en [16] y [3]. Éste último define la calidad como “el importantísimo catalizador que marca la diferencia entre el éxito y el fracaso”. Una definición similar fue propuesta en [21].

De manera más formal, la IEEE en su estándar 610.12 [9] define la calidad como “el grado en que un sistema, componente o proceso satisface los requisitos especificados y las necesidades o expectativas del cliente o usuario”. En la familia de estándares ISO 9000 [10], también podemos encontrar otra definición de calidad: “capacidad de un producto software para satisfacer necesidades explícitas o implícitas cuando se utiliza bajo unas condiciones determinadas”.

Sin embargo, la evaluación, el diseño y, especialmente, los procesos de adaptación requieren una definición de lo que determina si un producto es bueno o malo desde la perspectiva del usuario final y, por tanto, se requiere una definición de Calidad de Interacción. Así, el término *Usabilidad* constituye una definición para calidad de interacción ampliamente aceptada hoy día. El estándar ISO 9241-11 [12] define la usabilidad como “el grado en que un producto puede ser utilizado por usuarios concretos para alcanzar objetivos concretos con efectividad, eficiencia y satisfacción, en un contexto de uso específico”. Más recientemente, el estándar ISO/IEC 25010:2011 [13] descompone la calidad en *calidad del producto software* y *calidad de interacción.* Ambos modelos de calidad pueden utilizarse para dar soporte a la especificación y evaluación del software desde diferentes perspectivas [14][13][15], asociadas a la adquisición, los requisitos, el desarrollo, el uso, la evaluación, el soporte, el mantenimiento, la garantía de calidad y la auditoría de software. Así, en este último estándar internacional, la *Calidad de Interacción* se define como “la calidad en uso” de un sistema, es decir, el impacto que dicho producto software tiene sobre los usuarios.

Otro término reciente y alternativo al de usabilidad y que también es muy utilizado por diseñadores y desarrolladores de interfaces de usuario es el de *Experiencia de Usuario* (User eXperience, UX). Este concepto está ligado a las percepciones y respuestas del usuario cuando utiliza un producto, sistema o servicio (ISO/DIS 9241-210:2008).

3.2 Tipos de Calidad de Interacción

Como se ha visto hasta el momento, la calidad y, concretamente, la calidad de interacción dependen de cada usuario y sus objetivos. Por ejemplo (adaptado del ISO/IEC 9126-1:2001):

- Un *usuario* puede identificar la calidad con la idoneidad de un producto software, utilizando criterios asociados a la usabilidad y la calidad en uso. En este contexto, los usuarios con discapacidad pueden asociar la calidad con la accesibilidad de su software.

- Un *adquiridor* reconoce la calidad de un producto software por medio de medidas externas de funcionalidad, fiabilidad, usabilidad y eficiencia, o de calidad en uso.
- Un *mantenedor* generalmente establece una correspondencia entre calidad y mantenibilidad.
- Una *persona responsable de la implementación* del software en diferentes entornos y plataformas, asocia la calidad con la portabilidad.
- Un *desarrollador* puede identificar la calidad de un producto software por medio de medidas internas de cualquier característica de la calidad.
- Un *evaluador* puede asociar la calidad de un producto software con la productividad, la satisfacción y la efectividad de dicho producto.

Además de estos seis puntos de vista de la calidad de interacción, podemos preguntarnos cómo podemos describirla. El trabajo propuesto en [5], sugiere describir la calidad de interacción desde cuatro perspectivas diferentes:

- *Calidad Esperada*, la calidad de interacción que el cliente o usuario necesita, es decir, los elementos o requisitos necesarios en la especificación del sistema.
- *Calidad Deseada*, el grado de calidad que el experto en calidad de interacción quiere conseguir para la versión final del sistema. Este tipo de calidad se deriva de la Calidad Esperada, ya que está relacionada también con la especificación.
- *Calidad Alcanzada*, la calidad obtenida a partir de una implementación dada del sistema. Idealmente, debe satisfacer la Calidad Deseada.
- *Calidad Percibida*, la percepción sobre los resultados que el cliente o usuario tiene, una vez que el sistema ha sido entregado.

En este punto, es interesante establecer relaciones entre los diferentes puntos de vista de la calidad de interacción, y sus cuatro tipos. De esta forma, sabremos qué puntos de vista se asocian con cada tipo de calidad de interacción:

- La *Calidad Esperada* puede ser tratada desde el punto de vista del *usuario*, ya que se refiere a los requisitos del sistema, es decir, satisfacer las necesidades del usuario. Este tipo de calidad de interacción también está relacionado con la vista del *adquiridor* dado que también es adaptable a las necesidades del cliente.
- La *Calidad Deseada* puede ser tratada desde los siguientes puntos de vista: *mantenedor*, *persona responsable de la implementación*, *desarrollador* y *evaluador*, ya que representan a expertos en calidad que quieren alcanzar una calidad de interacción final con respecto a la mantenibilidad, la portabilidad, medidas internas de calidad, y la efectividad del sistema, respectivamente.
- La *Calidad Alcanzada*, como la calidad de interacción deseada, también puede ser tratada desde los puntos de vista del *mantenedor*, *persona responsable de la implementación*, *desarrollador* y *evaluador*, ya que representan a expertos en calidad que finalmente logran cierta calidad de interacción de acuerdo a la mantenibilidad, la portabilidad, medidas internas de calidad, y la efectividad del sistema, respectivamente.
- La *Calidad Percibida*, como la calidad de interacción esperada, también puede ser tratada desde los puntos de vista del *usuario* y el *adquiridor*, dado que está centrada en la calidad de interacción del producto después de su entrega, es decir, la percepción de la calidad que tiene el usuario/adquiridor final. La usabilidad, calidad en uso, funcionalidad o experiencia de usuario son conceptos asociados a este tipo de calidad.

Finalmente, se puede concluir que los tipos de calidad anteriores están relacionados entre sí. Concretamente, la calidad Esperada y la Deseada son complementarias. Así, un producto software será de calidad cuando la calidad Esperada y la Deseada estén altamente solapadas, es decir, su percepción sea similar. De esta forma, este elevado nivel de calidad de interacción será percibido por los usuarios cuando la calidad Deseada y la Alcanzada (competencia de los desarrolladores y diseñadores) se centren en la consecución de las necesidades del usuario. En este sentido, resulta de interés realizar un primer estudio (sección 4) que muestre si existen diferencias significativas entre la calidad Esperada y la Deseada en cuanto a los términos empleados para su caracterización, ya que sospechamos que puede existir un brecha conceptual muy clara entre la percepción de usuarios con y sin experiencia en calidad de interacción.

Los seis puntos de vista de la calidad de interacción pueden reagruparse a su vez en dos puntos de vista más genéricos: *Usuario – Interacción*, y *Desarrollador – Adaptación*. El primero de ellos incluye a los puntos de vista del *usuario* y el *adquiridor*, mientras que el segundo incluye a los puntos de vista del *mantenedor*, *persona responsable de la implementación*, *desarrollador* y *evaluador*. La Tabla 1 muestra las relaciones entre estos dos puntos de vista más genéricos y los distintos tipos de calidad de interacción. En este sentido, la calidad Percibida y la Esperada dependen directamente de las preferencias de los usuarios, sus habilidades y su conocimiento (punto de vista de *Usuario – Interacción*), mientras que la calidad Alcanzada y la Deseada están relacionadas con los distintos entornos, plataformas y contextos en los que se utiliza la aplicación (punto de vista de *Desarrollador – Adaptación*).

Tabla 1. Puntos de vista de la calidad de interacción y tipos

Calidad / *Vistas*	**Esperada**	**Deseada**	**Alcanzada**	**Percibida**
Usuario Interacción	√			√
Desarrollador Adaptación		√	√	

Todas estas relaciones identificadas entre los distintos actores involucrados en un proceso de interacción y las múltiples facetas de la calidad de interacción constituyen un pilar fundamental para comprender adecuadamente lo que significa interacción y QoA, como se verá en las siguientes secciones.

3.3 Calidad de Adaptación

A lo largo de esta sección, se describe cómo se puede considerar a la QoA en las diferentes facetas de la adaptación. Concretamente, las facetas cubiertas son aquellas incluidas en el marco de adaptación ISATINE.

En trabajos previos [17], hemos definido la QoA como *el grado con el que un conjunto de adaptaciones produce interfaces de usuario que permiten al usuario lograr objetivos concretos con usabilidad* (ISO 9241-11 [12]; ISO/IEC 25010 [13]) *en contextos de uso específicos*. Dentro del contexto de uso consideramos las características del usuario, de la plataforma (hardware y software), del entorno físico donde tiene lugar la interacción, y de la tarea que el usuario está realizando.

En este sentido, Gjørven, Eliassen y Aagedal [7] proponen que la QoA se use para valorar cuán diferentes son las salidas de una adaptación real de las salidas de un servicio de adaptación ideal. Así, un *servicio* se define como el trabajo realizado, especificado por un subconjunto de eventos de salida, y aquello que provocó la petición del trabajo, especificado por un conjunto de entradas. De esta forma, un *servicio de adaptación* se define como aquel cuyo evento de entrada es un disparador de la adaptación y cuyos eventos de salida son un conjunto de servicios que potencialmente han sido modificados o producidos durante la adaptación.

Por otro lado, también es posible definir la Calidad de Adaptación retomando el concepto de calidad de interacción definido anteriormente. En este caso, la QoA se define como el cambio en el nivel de calidad de interacción, es decir, la QoA es el incremento *Δ(calidad de interacción)*, el cual se calcula restando el antiguo valor de calidad de interacción, $f(x)$, a su nuevo valor, $f(x + \Delta x)$, donde x hace referencia a la calidad de interacción:

$$\Delta(\text{calidad de interacción}) = f(x + \Delta x) - f(x)$$

Esta expresión matemática sirve como herramienta para calcular la QoA, obteniendo un valor concreto y cuantificable, lo que permite que, aplicada a distintos productos software, éstos puedan ser más fácilmente evaluables y comparables en términos de calidad de interacción. En la siguiente sección, se verá cómo aplicar este concepto de QoA al marco de adaptación ISATINE.

3.4 Calidad de Adaptación en ISATINE

En la sección 3.2, se han presentado cuatro tipos diferentes de calidad de interacción: Esperada, Deseada, Alcanzada y Percibida. Concretamente, en el contexto de adaptación, las distintas perspectivas de la QoA pueden definirse de la siguiente forma:

- *Calidad de Adaptación Esperada*, los objetivos y requisitos de la adaptación que el usuario espera que proporcione una aplicación.
- *Calidad de Adaptación Deseada*, la especificación de la adaptación y las políticas de selección utilizadas para elegir entre las adaptaciones posibles, y así lograr cierto grado de calidad derivado de la QoA Esperada.
- *Calidad de Adaptación Alcanzada*, la calidad realmente obtenida para una implementación dada de una adaptación y su interpretación justificada.
- *Calidad de Adaptación Percibida*, la calidad percibida por el usuario o el sistema, una vez que se ha hecho uso de la IU adaptada.

Una vez definidas las distintas perspectivas de la QoA, es interesante relacionar estos cuatro tipos con las distintas fases del marco de trabajo ISATINE. El objetivo de esto es clarificar qué tipo de QoA debe considerarse en cada momento.

1. *Objetivos de la adaptación* (Objetivos). Esta fase está relacionada con la *Calidad de Adaptación Esperada* ya que representa lo que se espera de la adaptación por parte de un usuario, un sistema o un tercero. Por ejemplo, en una página web que soporte actividades de comercio electrónico es necesario que las ofertas sigan estando presentes, aunque se adapte la interfaz. Cabe destacar que la adaptación no siempre se aplica en beneficio del usuario, dado que puede realizarse, por ejemplo, por motivos de marketing.

2. ***I**niciativa de la adaptación* (Iniciativa). Esta fase también está relacionada con la *Calidad de Adaptación Esperada* dado que el actor encargado de iniciar la adaptación (usuario, sistema o tercero) expresa su voluntad de comenzar el proceso de adaptación, debido a que el estado de la interfaz no le permite alcanzar sus objetivos en el contexto de uso actual.

3. *e**S**pecificación de la adaptación* (Especific.). En esta fase se describen las adaptaciones que pueden llevarse a cabo para lograr la QoA Esperada, por lo que esta etapa está relacionada con la *Calidad de Adaptación Deseada*.

4. ***A**plicación de la adaptación* (Aplicación). La aplicación de las adaptaciones especificadas en la fase previa también debe realizarse de acuerdo a la *Calidad de Adaptación Deseada*.

5. ***T**ransición de la adaptación* (Transición). Es obvio que el cambio de la interfaz de usuario original a la adaptada debe realizarse considerando criterios de calidad alcanzada. En esta fase, el actor encargado de la adaptación debe poder dar cuenta de la calidad lograda con la adaptación y facilitar que se retomen las actividades que venían realizándose antes de la adaptación. El tipo de calidad que se considera en esta fase es la *Calidad de Adaptación Alcanzada*.

6. ***IN**terpretación de la adaptación* (Interpret.). Siguiendo la transición de la adaptación, surge la necesidad de ser capaz de justificar el nivel de calidad logrado, fruto de la realización de la adaptación. Por tanto, esta fase está asociada con la *Calidad de Adaptación Alcanzada*, dado que representa lo que los actores involucrados en la adaptación deberían interpretar o explicar acerca de lo ocurrido.

7. ***E**valuación de la adaptación* (Evaluac.). En esta fase, se comprueba si los objetivos de la adaptación inicialmente especificados se han cubierto o no. Esto puede ser interpretado como la *Calidad de Adaptación Percibida* por el usuario final.

La Tabla 2 resume todas estas relaciones, es decir, qué tipos de QoA se ven involucrados en cada etapa de ISATINE, así como los puntos de vista de calidad relacionados. De esta manera, conocer qué tipo de adaptación debemos soportar en cada etapa del proceso de adaptación resulta crucial para ser capaces de ofrecer QoA en cada etapa de una forma adecuada. Así, el diseñador será capaz posteriormente de proporcionar los medios apropiados para evaluar realmente la QoA de una forma cuantitativa en cada etapa, según el correspondiente tipo de QoA, aplicando distintas técnicas y métricas. La propuesta de esta serie de técnicas y métricas está siendo actualmente objeto de estudio.

Tabla 2. Puntos de vista, tipos de QoA y etapas de ISATINE

QoA / *Vistas*	Esperada	Deseada	Alcanzada	Percibida
Usuario Interacción	1. Objetivos 2. Iniciativa			7. Evaluac.
Desarrollador Adaptación		3. Especific. 4. Aplicación	5. Transición 6. Interpret.	

4. CARACTERIZANDO LA CALIDAD DE INTERACCIÓN: UN ESTUDIO

El objetivo de este estudio es determinar si existen diferencias significativas entre la calidad *Esperada* y *Deseada* en términos de caracterización y denominación. Nuestra esperanza es que los resultados derivados de este análisis ayuden a los desarrolladores a entender mejor las preferencias de calidad de los usuarios con el único propósito de diseñar productos software que resulten atractivos. Este estudio empírico identifica una brecha preliminar entre lo que consideran los usuarios y los desarrolladores sobre calidad de interacción. A continuación, se analizan dos dimensiones de la calidad de interacción en ISATINE, concretamente la calidad *Esperada* y la *Deseada*.

Nótese que no se han incluido por el momento las otras dos dimensiones de la calidad de interacción (Alcanzada y Percibida) ya que forman parte de la evaluación clásica de usabilidad.

4.1 Calidad Esperada

Un total de 31 personas *sin experiencia específica* en interacción completaron este estudio sobre la calidad *Esperada*. Los sujetos eran alumnos de nuevo ingreso cursando el primer curso del grado en Informática. Aproximadamente el 84% de los encuestados eran hombres (n=26) mientras que el resto, un 16%, correspondía a mujeres (n=5). Las edades de dichos sujetos oscilaban entre 19 y 25 años (Media = 19.87, Desviación Estándar = 1.41).

Los resultados fueron analizados en términos de caracterización y preferencias de la calidad de interacción. Se formuló una única pregunta a los participantes. Esta cuestión era: *Por favor, ¿Podrías escribir, al menos, cinco palabras (positivas o negativas) relacionadas con tu idea de calidad de interacción?*

Las respuestas fueron analizadas calculando el porcentaje de palabras repetidas. Estos porcentajes se han representado utilizando un *tag cloud* o nube de etiquetas (véase Figura 1). Estas nubes de etiquetas son representaciones visuales que indican la frecuencia de uso de una determinada palabra dentro de un texto concreto, incluyendo sitios web, artículos, bases de datos, o discursos. Dentro de la nube, la frecuencia de cada palabra se representa incrementando el tamaño de la fuente y la saturación del color asociado a dicha palabra.

Figura 1. Caracterización de la calidad de interacción por sujetos sin experiencia en interacción

4.2 Calidad Deseada

De forma paralela, se llevó a cabo otro estudio sobre la calidad *Deseada*. Un total de 24 personas *con experiencia específica* en interacción persona-ordenador e informática completaron este estudio. Estos sujetos eran expertos en interacción de diferentes universidades españolas. Aproximadamente el 67% de los encuestados eran hombres (n=16) mientras que el resto, un 33%, correspondía a mujeres (n=8). Las edades de estos sujetos oscilaban entre 22 y 52 años (Media = 33.71, Desviación Estándar = 9.06).

De manera similar al estudio anterior sobre calidad Esperada, este estudio estaba enfocado en términos de caracterización y preferencias de la calidad de interacción, pero con la particularidad de que en este caso los participantes poseían un conocimiento específico sobre interacción. Concretamente, los sujetos estaban familiarizados con los distintos estándares internacionales de calidad, y la mayoría de ellos habían desarrollado productos software con diversos requisitos, tanto funcionales como no funcionales.

De nuevo, se formuló una única pregunta a los participantes: *Por favor, ¿Podrías escribir, al menos, cinco palabras (positivas o negativas) relacionadas con tu idea de calidad de interacción?* Como se puede observar, esta cuestión es similar a la planteada en el estudio anterior. De esta forma, es posible realizar fácilmente una comparativa sobre un mismo aspecto, enfocada desde dos puntos de vista distintos. En este caso, ambos estudios se centran en conocer la idea que tienen, tanto usuarios expertos como inexpertos en interacción, sobre la calidad de interacción, es decir, la calidad Esperada frente a la calidad Deseada.

Figura 2. Caracterización de la calidad de interacción por sujetos con experiencia en interacción

Los resultados de este estudio se analizaron y presentaron de la misma forma que en el estudio anterior. La Figura 2 muestra la representación en forma de nube de etiquetas sobre dichos resultados analizados. Como se verá en el siguiente apartado, hay pocas palabras que aparezcan como respuesta en ambos estudios, como *intuitivo*, *eficiente* y *seguro*. A priori, esto nos hace sospechar que la idea de calidad de interacción de un determinado producto software puede venir determinada por el tipo de usuario que utiliza dicho producto, es decir, dependerá de la experiencia concreta que tenga el usuario a la hora de interactuar con aplicaciones software.

5. DISCUSIÓN

Analizando los resultados de ambos estudios, se han observado múltiples diferencias con respecto a la caracterización de la calidad de interacción. Estas diferencias están directamente relacionadas con el conocimiento adquirido sobre interacción persona-ordenador, e informática en general, de los participantes.

Como era de esperar en el caso de expertos en interacción, muchos de los términos encontrados tras analizar sus respuestas corresponden a aquellos empleados en los estándares de calidad, como por ejemplo, *usable*, *eficiente*, *efectivo*, *fácil de aprender*, o *satisfacción*. Por el contrario, los sujetos menos expertos en interacción utilizaban una gran variedad de términos para referirse a la calidad de interacción y no estandarizados, haciendo especial énfasis en *fácil de usar*, *rápido*, *confiable*, *portable* y *eficiente*.

De forma muy preliminar, estos estudios han permitido identificar empíricamente la brecha que existe entre la percepción que tienen individuos con y sin conocimientos sobre calidad de interacción. Por ejemplo, en interesante destacar cómo la palabra *portable* no ha sido uno de los términos utilizados por los expertos, pero sí por los usuarios sin experiencia en interacción. Quizá una de las razones para explicar esto es que hoy en día su uso está ampliamente extendido, a pesar de ser un término bastante técnico.

Por tanto, con respecto a las distintas propuestas sobre marcos de adaptación de interfaces de usuario (véase sección 2), se hace necesaria la implementación de mecanismos que permitan cerrar esta brecha entre la calidad Esperada y la Deseada. Al minimizar esta separación entre ambos tipos de calidad, se conseguirá que, tanto usuarios como desarrolladores, entiendan la calidad de interacción del mismo modo. Esto permitirá crear adaptaciones con menor probabilidad de ser rechazadas finalmente por el usuario, dado que ambas partes, es decir, usuario y desarrollador, estarán de acuerdo en cuanto a los *objetivos* de la adaptación y la *necesidad* de llevarla a cabo (calidad Esperada), lo que se traduce finalmente en una *especificación* y *aplicación* de la adaptación adecuadas (calidad Deseada).

Como es obvio, esta brecha también se encuentra en la calidad Esperada y la calidad Deseada identificadas para el proceso de adaptación ISATINE (véase sección 3.4). Por lo tanto, los resultados derivados de este estudio son extrapolables a ISATINE.

La mayoría de los resultados de este estudio son consistentes con hallazgos previos encontrados en la literatura, relativos a usuarios y desarrolladores. Sin embargo, este estudio proporciona información más detallada sobre la caracterización de la calidad de interacción (criterios).

6. CONCLUSIONES Y TRABAJO FUTURO

A lo largo de este trabajo, se ha visto la importancia de disponer de un proceso que guíe la adaptación con el principal propósito de crear adaptaciones adecuadas que no impliquen el rechazo de la IU. Además, este *proceso de adaptación* debe ir más allá de la simple ejecución de la adaptación e incluir también aspectos relativos a la *evaluación* de la misma. En este sentido, ISATINE es un marco de adaptación que proporciona estas características, cubriendo desde el inicio del proceso en que se crea la adaptación, hasta la evaluación de lo que el usuario obtiene de la aplicación de la adaptación.

También se ha visto cuán importante es considerar la *calidad de interacción* dentro de este proceso de adaptación, de la misma manera en que se considera la usabilidad en el diseño de IUs. Para alcanzar esto, es necesario que el proceso de adaptación tenga en cuenta la QoA en cada una de sus etapas. De esta forma, se ha profundizado en el concepto de calidad de interacción, descomponiéndolo en cuatro tipos de calidad, dependiendo del punto de vista desde el cual se describa.

A partir de esta noción de calidad de interacción, se ha definido y refinado un nuevo concepto llamado *Calidad de Adaptación* (QoA) con el objetivo de entender mejor cómo este término aplica a las distintas etapas de un proceso de adaptación, concretamente a ISATINE. Así, dependiendo de la etapa de ISATINE en la que nos encontremos, podemos hablar de un tipo u otro de QoA, es decir, *Calidad de Adaptación Esperada*, *Calidad de Adaptación Deseada*, *Calidad de Adaptación Alcanzada*, o *Calidad de Adaptación Percibida*. Finalmente, se han establecido relaciones entre los distintos puntos de vista de la calidad, los tipos de QoA y las diferentes fases de ISATINE.

Finalmente, este trabajo se ha centrado en uno de los puntos débiles de ISATINE, concretamente en la brecha encontrada en la definición de calidad Esperada y Deseada. Esta deficiencia se ha identificado, estudiado y analizado por medio de un *estudio* en forma de encuesta, donde los participantes eran sujetos con y sin experiencia previa en interacción. Este estudio identifica los distintos términos que ambos tipos de sujetos han dado para describir la calidad de interacción. Después de llevar a cabo la encuesta, pudimos comprobar que nuestra hipótesis inicial era correcta, ya que existe realmente una diferencia en cuanto a la idea que ambos grupos de individuos tienen respecto a la calidad de interacción, es decir, en cuanto a su manera de expresar verbalmente este concepto. Si consideramos que en ISATINE, dependiendo de la etapa, se puede utilizar un tipo de QoA distinto, unas veces más orientado al usuario, y otras al diseñador o desarrollador, debemos tener en cuenta esta brecha conceptual en cuanto al entendimiento de lo que es la calidad. Considerando esto, se podrá proporcionar información significativa sobre la QoA en cada etapa, dando un completo y buen soporte a la QoA.

Este trabajo sienta las bases de un trabajo futuro centrado en cómo considerar la QoA a través de un proceso de adaptación, detallando qué técnicas y métricas encajan mejor dentro de cada etapa. Al lograr esto, entenderemos mejor qué es la calidad de adaptación y cómo puede ser utilizada realmente en un proceso completo de adaptación, lo que nos permitirá proporcionar un modelo completo de calidad de adaptación que guiará a cualquier diseñador durante el proceso de diseño.

Por otro lado, se propone examinar los diferentes términos utilizados, tanto por usuarios expertos como inexpertos en interacción, para determinar si se refieren a conceptos similares, y así unificar y establecer los términos más utilizados para referirse a la calidad de interacción.

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Extending MOOC ecosystems using web services and software architectures

Juan Cruz-Benito
GRIAL Research Group
Department of Computer and Automatics, University of Salamanca
IUCE, Paseo de Canalejas 169
37008, Salamanca, Spain
juancb@usal.es

Oriol Borrás-Gené
GATE, Technical University of Madrid
Calle Ramiro de Maeztu. 7
1st floor (Rectorado A)
28040 Madrid, Spain
oriol.borras@upm.es

Francisco J. García-Peñalvo
GRIAL Research Group, Department of Computer and Automatics
Research Institute for Educational Sciences (IUCE), University of Salamanca
Paseo de Canalejas 169
37008, Salamanca, Spain
fgarcia@usal.es

Ángel Fidalgo Blanco
Technical University of Madrid
Calle Alenza nº4, office 718
(M Building) 7th floor
28003, Madrid, Spain
afidalgo@dmami.upm.es

Roberto Therón
Department of Computer and Automatics
Faculty of Sciences, University of Salamanca
Plaza de los Caídos s/n
37008, Salamanca, Spain
theron@usal.es

ABSTRACT
This paper present a research project that tries to extend the MOOC ecosystems by integrating external tools like social networks. This integration is developed by using a software architecture that mediate between the different systems and platforms establishing communication workflows and analyzing the information retrieved. This kind of system is applied in a real case, and it allows teachers and managers of the MOOC platform to get enhanced information and insights about users interaction with contents and MOOC tools, as well as some metrics impossible to retrieve or calculate manually in this kind of eLearning platforms with high amounts of users.

Categories and Subject Descriptors
H.3.5 **[Online Information Systems]**: Web-based systems. H.5 **[Information Interfaces and Presentation]**: General K.3.1 **[Computers Uses in Education]**: Collaborative learning.

General Terms
Measurement, Human Factors.

Keywords
iMOOC, MOOC, Moodle, Web Services, Software Architectures, HCI, eLearning.

1. INTRODUCTION
The analysis of interaction among users and systems provide great insights about how users use, understand and take advantage of tools and platforms they utilize to perform any kind of task.

The fact of analyze the interaction and try to extract valuable knowledge from it, have real application in many areas of knowledge and business, as in digital marketing, in education (Learning Analytics), etc. Although in some fields as education, this type of behavior analysis, and interaction analysis is increasingly common, the approaches and tools developed should be updated and adapted to new systems, platforms and paradigms in eLearning. In these new types of learning platforms and paradigms can be highlighted the MOOCs, because they expand the traditional limits in students' interaction with teachers, contents and online learning platforms. Furthermore, MOOCs leverage other platforms (even those that are not purely intended to be applied in education) like the social networks and other online tools, applying by this way multi-platform and multi-context approaches that can improve and upgrade the learning experience [20].

It is because of this use of multiple tools and multiple context that is necessary to design and implement new ways of interaction analysis and platforms that allow to perform it. These new ways and platforms will manage the acquisition of knowledge regarding the learning and interaction with platforms, establishing convergence of knowledge between different learning vectors and context, to finally allow teachers and managers to learn, explore and implement possible improvements that help in the learning process, the design of content and the motivation of students.

The goal of this paper is to explain a modular software architecture implemented to allow teachers and managers of a MOOC retrieve knowledge about how users enrolled in a MOOC course utilize some tools external to the MOOC platform, getting by this way insights about what did users on these external tools, what kind of interaction they perform inside them, and thus, discover possible improvements and solutions for eLearning processes to be applied later in the MOOC platform and its courses.

To explain these contents, the paper is divided into the following sections: section 2 (Aims and goals) presents the main aims and goals of the research presented. Section 3 (iMooc Platform) describes real MOOC platform where is being tested the software architecture proposed and the integration with other online tools. Section 4 (Software Architecture Proposal) explains the software architecture designed to tackle the integration with other tools and gain knowledge about the MOOC users and their interaction with contents inside or outside the MOOC platform. Section 5 (Services and Crawlers) explains how is being developed the software architecture integration with other tools and platforms (eLearning platform and social networks). Section 6 (Results) shows partial results of the application of this software architecture retrieving data from the integrated environments. Finally, the Section 7 (Conclusions) presents several conclusions about the research work and potential work for the future

2. Aims and goals

The MOOC courses are characterized by a high drop out rates primarily due to the heterogeneity of participants is why further information on their activity on the platform will assist meet the shortcomings of course adapted to the student needs.

It aims to create a model to obtain the maximum information from the MOOC platform combining it with the results obtained in the external elements that support the learning of the course, such as social networks, to give a feedback to the educational process, analyze performing users to adapt the content to their interaction, study the behavior to provide the extra functionality MOOC integrating user feedback analysis.

Thus the analysis of interaction in media is emphasized to obtain a deeper comprehension of users or the use of content analysis possible interest. Detecting those topics that interest students while those resources contributed by students for future editions are reused.

It is important to locate the types of learning according to the proposed activities. It is in the non-formal and informal learning where these foster interactions between users

Because of the massiveness of these many interactions resources and resources making it necessary to use tools to filter and collect all the information generated to recover this. This paper is based on the use of hashtags associated with publications to quickly retrieve the generated content. Hashtag is a character string with a topic associated preceded by a # sign and is used to mark tweets [14], part of the text of these. Although their use is widespread in twitter have extended to other social networks such as Google+. A study of hashtags is posed for the types of learning identified in the elements and course activities.

3. iMOOC Platform

3.1 The iMOOC approach

MOOC courses offer new opportunities for learning, features like massiveness of participants, peer-to-peer interactions, free-of-charge, openness or scalability [28]. There are two main types of courses MOOC, the xMOOC with a behavioral approach (occurs in traditional online courses) and cMOOC with a connectivism and networking based approach [17]. Taking advantage of features of both types of MOOC can apply the cooperative model of Fidalgo et. al. [18] which can be defined by three layers: The first one is the "technological layer" linked to the platform where will find the course content and the social network that will support the learning community. The second layer named "training strategy" refers to the instructional design of the course. This layer is divided, according to the two types of MOOC exposed, into a "behavioral strategy" focused on the acquisition of basic common knowledge and into a "connectivist strategy" dedicated to the generation of educational resources by participants. At this point, the resources generated from both strategies need organized. Finally, the "cooperative layer" shows the outcomes and the content generated with the cooperation of instructors and participants of the course [18]. For more connectivist orientation course based on the interaction between participants will require the use of social tools, a good selection of these is a good way to engage students and promote their participation in the course [1] using these tools we can create virtual learning communities (VLC), it is defined as communities of people who share common values and interests, and that are connect via different communication tools that such networks offer, whether synchronous or asynchronous [5]. The incorporation of VLC may provide greater interaction between participants, support and guidance to people with difficulties and may increase collaborative processes between participants.

Over the life of people not only learn in schools or Universities, so do in other situations in life, this idea is called lifelong learning MOOC one of the developments associated with this item. Based on the concept of lifelong learning are identified three types of learning associated with this concept [16]. Their differences [15] are based on the following items: where does the learning take place, in the case of online learning, the platform becomes as the institutional place for learning; if the learning is structured or unstructured; whether the learning is guided or not by faculty; and if there is any certification [2].

Taking these differences the Formal learning is that occurs in an organized and structured environment and leads to validation and certification, it is the most institutionalized [2]. The following types of learning take place in less organized spaces. Then, with opposite sense to the formal is informal learning, which is voluntary and unstructured. It is based on the intrinsic motivation [11] of the student. In this type of learning, the student chooses the way to acquire the knowledge, the learning is given everywhere and applies to any situations in common life [15] and is not evaluated. Finally there is the non-formal learning, which is structured and guided by the faculty, but is generally voluntary and is usually not evaluated. MOOC elements can be associated with the three types of learning, finding the more formal part in the course platform (xMOOC) and the informal part and non-formal community-associated learning (cMOOC).

3.2 Description and main features of the platform

In 2013, because of the agreement between the Technical University of Madrid, the University of Zaragoza and the University of Salamanca, the platform iMOOC or intelligent MOOC [32] emerges. Based on Moodle 2.6.5 platform [27] was chosen for its versatility. The main MOOC platforms such as edX [13], Coursera [6] or MiriadaX [24] focused on Spanish speaking require a single path for the course. Given the heterogeneity of the participants this can be in many cases the abandonment of them to take the part that interests them, one of the main distinguishing features of the iMOOC platform in front those with a more traditional approach is adaptivity of courses for students. This adaptivity is based on three variables: Depending on the user profile, according to an itinerary chosen by the student or for student progress within the course and the knowledge that he is gained. To achieve this functionality is necessary to use Moodle features such as conditionals and groups, as well as external plugins to create groupings. On the other hand iMOOC provides an appropriate environment to an Informal and cooperative learning.

Will make use of the tools offered by the platform such as profiles, forums, workshops and secondly external social networks for informal.

3.3 MOOC course "Social Networking and Learning"

To take advantages of iMOOC platform in early 2015 a course based on a test offered by the faculty version along two editions in the Iberoamerican MOOCs platform Miriada X [4] was launched. The course of one-month duration began January 12 and ended on February 8, leaving an extra week to allow students to finish it. A Total of 793 students were enrolled for the course, more than 400 started it, and 183 students finally accomplish the goal.

The VLC was created using the tool communities of Google +, space where students can interact with each other and with content in the network sharing it. Here they can also discuss, submit questions and publish the result of voluntary exercises throughout the course. To do this has been created 9 default categories (presentations, announcements, discussions, questions, resources, Activities and exercises, application examples, contests and more) with which to classify each publication, besides the possibility to use hashtags.

This course is based on the cooperative model [18] at which has been added a fourth layer called "Gamification layer" that interacts with the other three layers, which aims to improve motivation [3]. Depending on types of learning can be divided the course study into three parts, the first section concerns the iMOOC platform itself, which takes place the more formal or formal part of the course and the other two sections relate to the community of external learning the course where interactions among participants are established and where they are generated and share new resources.

The objective of this course is to provide participants, mostly teachers of basic digital skills in social networks to implement in their classrooms with students creating virtual learning communities. Throughout 4 modules consist of lessons, it is theoretically analyzed in depth the social web and learning communities are studied thoroughly Facebook and Twitter networks and finally reviewed with less detail other valid networks for educational use with and support tools to manage social networks. The modules are divided into small lessons that address a specific topic and the content is based on a short video as well as additional information that complements the video.

As adaptive part participants can choose between five educational itineraries: Full course for teachers (additional lessons are given the keys to implement networks studied), complete course for non-teachers (only the different networks are studied), Twitter (only one module on the network), Facebook (only one module this network) and one special itinerary. The special itinerary was addressed to students who had participated in any of the two previous editions, with an extra module focused on learning communities.

The course consists of a series of directed activities and proposals by the faculty to enhance knowledge of the lessons and interaction between course participants:

- Voluntary exercises along the videos. In both cases this activity takes place in the learning community.
- Discussion proposed and discussed in the community.
- Two videoconferences using Google Hangouts, streamed live, where some course participants could make a brief presentation to other peers about an educational project related to his social networks

Table 1. Relationship of course activities on Google +

Activity	Category	Hashtag
Search examples of social networks	Activities and exercises	#RSEEjemplosRRSS
Bad practices in the use of social networks	Activities and exercises	#RSEMalasPracticas
Measuring influence in social networks using Klout	Activities and exercises	#RSEMiKlout
Using Twitter in education	Activities and exercises	#UsosTwitterEnseñanza
Discussion about the possibility of replacing a learning management system (LMS) through a social network	Discussions	
Discussion on digital identity	Discussions	
Hangout		#RSEHangout

These activities can also be performed on Twitter although the official platform is Google +. Course evaluation is based on four questionnaires one per module that participants must overcome to obtain a certificate of participation offered for free.

So this part can be associated to a non-formal learning, since such courses by not offering an official certifications, for example to allow for recognition of credits, can not be considered as formal learning.

About informal learning this occurs in the community of Google + and is associated with the interactions among participants not addressed by the teaching staff, similar to learning which could result in informal settings outside the classroom such as between colleagues in an office. Three types of interactions:

- Creating new hashtags and subsequent interaction
- Discussion proposed by participants
- Resources contributed

The last two actions are included in the categories created for this publication ("debates" and "resources").

4. Architectural proposal

Following the previous experience of the authors in similar cases, where they apply software architectures to extend the functionality of eLearning ecosystems [7-10; 21], authors decided to use the core of a software architecture they built in 2014.

Several layers compose this core, one to retrieve data from each external platform or tool, other that wipes and stores the information retrieved, another to push analyzed information to other platforms, and others that enable searches and interaction between information and users.

The core of the architecture is a system that acts as a mediator between the different social networks and learning platforms that will be interconnected (Figure 1). This mediator system communicates with each external tool through using web services (REST APIs commonly) and crawlers; retrieving data and information from them and analyzing the information in order to convert the raw data in valuable information for teachers and managers of the iMOOC platform (based on Moodle).

In order to implement this software architecture and its layers, has been used for development several technological components and technologies that are listed below:

- Django Framework [12]: This web framework is used to build the software layers and to coordinate the information workflows between the components and systems of the architecture.
- MongoDB [25]: This NoSQL database is used to store the data without the traditional restrictions of the SQL databases, and allows to adapt the database storage schemas to each kind of content retrieved from external tools and platforms [7].
- REST APIs: these web services are used to serve as communication channels between components and systems involved in the MOOC ecosystem. In case of those tools and systems that do not provide this kind of facilities, will be used crawlers to retrieve information (this will be explained in the following section).

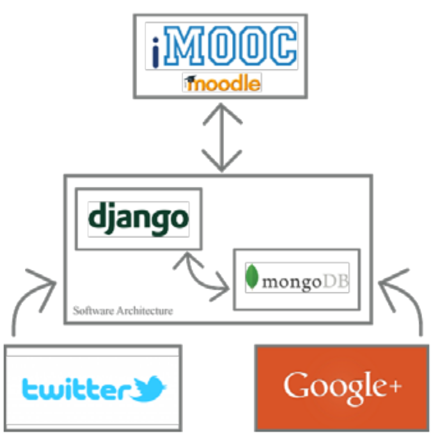

Figure 1. Software architecture proposal

The main idea behind the framework, is that teachers and managers could use the website provided by the architecture to interact with the information and data retrieved from the external tools, so all the assessment and evaluation of the users learning in the MOOC could be centralized in the architecture. The other possible approach, is that the architecture push the analyzed information again to the Moodle platform, allowing teachers and managers to allow them assess and evaluate the learning without leave the MOOC platform, in that case, the data visualization and interaction with the information retrieved depends strictly on the resources Moodle provides.

5. Services and crawlers

In order to implement the information workflows shown in the Figure 1 between the software architecture and the different systems and social networks, researchers need to establish the proper communication channels for the information. These communication channels are based, in this case, in services and crawlers:

- The services are facilities provided by third-party software to facilitate the communication and interconnection with other systems, applications or clients. In this case, researchers have used services for communicating with Moodle and Twitter.
- The crawlers are software applications that find automatically information in third-party systems when they do not provide services for *pull* and *push* information between systems. In this case we are working on crawlers for getting information from Google+ Communities (Google+ does not provide API or other services to get and post activities and other information within the communities).

In the subsections below are explained how have been used these services and crawlers, and how they are implemented within the software architecture.

5.1 Moodle

Moodle provides several API services and API architectures; allowing users and third party applications and systems interact with courses, administration settings, users and configuration information. The API used in this work is based on Representational State Transfer (REST) architecture [19], and it allows several actions in both directions of communication (GET and POST actions, as well as DELETEs, etc.); the full documentation and functionalities of this API can be found at [26].

For example, these API endpoints and functionality allow managers and teachers of the (i)MOOC course to make automatic checks about the tasks completed by users, automatized (and simply) assessment about their participation in the MOOC, etc. In a regular course on Moodle, this usage of the API is not a key aspect, most of these checks and assessment is performed manually by the teachers, but in a MOOC course with more than 700 hundreds (in this case, several thousands in bigger MOOC courses) turns out this resources as a key factor to evaluate the users' interaction with the MOOC and for assessing their learning within the course.

Bellow is presented an example code that allow teachers to retrieve the full list of users enrolled in the course; this result list of users enrolled, for example in the case of the iMOOC course was used to check what users filled their profile with the links to their personal social networks profiles, which was proposed as an activity of the *Twitter in education* lesson. As previously explained, authors implemented the software architecture using Python language, so the code is formatted in the *phytonic* way and includes the main software library used, Requests [30] that allows to implement easily the API consumption.

```
import requests, json
```

```
parameters = {'wsfunction': core_enrol_get_enrolled_users', 'courseid':'id',
              'moodlewsrestformat':'json', 'wstoken':'xxxxxx'}
url = "http://gridlab.upm.es/imooc/"

response = requests.get(url, params=parameters)

if response.status_code == 200:
  results = response.json()
  for result in results:
    print result
else:
  print "Error code %s" % response.status_code
```

5.2 Twitter

Regarding the Twitter data retrieval implementation, the authors have implemented collector that gets tweets on live based on their hashtags. This implementation is possible thanks to the Twitter REST APIs [31] and Tweepy library for Python [29]. Using both facilities (specially the Twitter Streaming API) authors built a software that is able to retrieve in real time tweets tagged [23] with the any of hastaghs proposed in the MOOC course and storing the tweets in the software architecture database (enabling by this way MOOC user matching, etc). As example of how is done this data retrieval, below is attached a simplified version of the code:

```
from __future__ import absolute_import, print_function
from tweepy.streaming import StreamListener
from tweepy import OAuthHandler
from tweepy import Stream

consumer_key="xxxx"
consumer_secret="xxxx"
access_token="xxxxx"
access_token_secret="xxxxx"

class StdOutListener(StreamListener):
  def on_data(self, data):
    try:
      print(data)
      return True
    except:
      pass
  def on_timeout(self):
    sys.stderr.write("Timeout, sleeping for 60 seconds...\n")
    time.sleep(60)
    return

 if __name__ == '__main__':
  l = StdOutListener()
  auth = OAuthHandler(consumer_key, consumer_secret)
  auth.set_access_token(access_token, access_token_secret)
  stream = Stream(auth, l)
  stream.filter(track=['#RSEEjemplosRRSS',#UsosTwitterEnseñanza",
                       "#RSEMiKlout "])
```

About Twitter integration in the system, should be highlighted that the MOOC managers and teachers must get permission of the users about storage their tweets, or simply anonymize the personal data present in each tweet (name and username, location, etc.), because the social network specify in their policy rules this restriction.

5.3 Google+

About Google+, the situation is totally different. This social network provides APIs and methods to retrieve information about users, posts, comments, etc. [22], but it does not allow to retrieve information from the users communities within the social network. This disables the possibility of use the same way to get information about conversation and interactions in the communities, regarding this, teachers and managers from the MOOC course were searching other tools that let them to retrieve the desired information; for example, they use currently the tool AllMyPlus (http://www.allmyplus.com/) that allows them to retrieve information of the learners community related to MOOC. This is not the best solution, because it convert the ideal automatic process indeed in a manual process, so the authors are trying to develop a crawler that enables them to retrieve information directly from Google+ website or AllMyPlus website.

6. RESULTS

By using the software architecture and the other tools (AllMyPlus), was possible to retrieve information about users' posts on social networks, information about their profiles on the iMOOC platform, etc. As example below of the utility of this kind of software architecture supporting and expanding MOOC functionalities, are shown several metrics retrieved from the complete learning ecosystem:

- During the course were recorded in the Google+ community 302 publications belonging to 140 users, 57 of whom have used a hashtag. Table 2 shows the times that have been used hashtags and how many of them are depending on the type of learning.
- During the course were retrieved more than 200 interactions of MOOC users with the content and hashtags in the social network Twitter.
- Also, to evaluate the completion of the MOOC activities, for example as mentioned in previous section, related to the number of users that fill their MOOC profiles with the links to their social networks profiles. In this case, the number of users that accomplish this activity was 275, a 33'86% of the total users.
- Hashtags usage and temporal evolution (Figure 2) of proposed hashtags by the teachers (non-formal) and those used by students initiative (informal).

Table 2. Distribution of posts and contents in Google+ community

	Total #	Different #	# misspelled	Users using #
Non-formal	128	8	8	37
Informal	144	82	-	43
Total	272	90	-	23 (both types)

Table 3. Interactions with MOOC contents and proposed hashtags in Twitter

Total interactions	**Twitter**
Publications	108
Replies	17
Retweets	42
Favorites	45

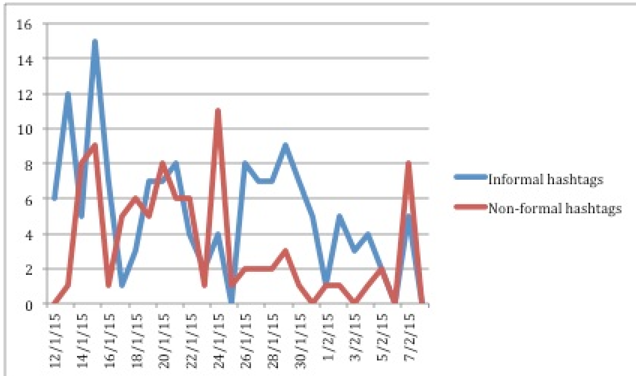

Figure 2. Evolution of informal and non-formal hashtags related to MOOC contents usage

7. CONCLUSIONS

This paper explains a software architecture designed and developed to extend the MOOC ecosystems functionalities and utilities by integrating external tools like social networks. This integration is built by using a software architecture that mediate between the different systems and platforms establishing communication workflows and analyzing the information retrieved. This kind of system is applied in a real case, and it allows teachers and managers of the MOOC platform to get enhanced information and insights about users interaction with contents and MOOC tools, as well as some metrics impossible to retrieve or calculate manually in this kind of eLearning platforms with high amounts of users.

In order to demonstrate the utility of this kind of software architectures, showing also the possibilities and new metrics that could be gathered using it, authors show some data gathered from the iMOOC platform and social networks, showing in these data how the application of this software architecture can help to measure elements difficult to estimate because the vast amount of users enrolled in MOOC courses or because they implicate the usage of external tools like the social networks that teachers can not track without this kind of tools and systems.

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Arquitectura para la interacción en un videojuego para el entrenamiento de la voz de personas con discapacidad intelectual.

Mario Corrales, David Escudero, Valle Flores, Cesar González
Universidad de Valladolid
Campus Miguel Delibes s/n
47011-Valladolid
macoas.5@gmail.com,
descuder@infor.uva.es,vflores@psi.uva.es
cesargf@infor.uva.es

Yurena Gutiérrez
Universitat Autònoma de Barcelona
Campus de la UAB
08193 Cerdanyola, Barcelona
yurenagg@gmail.com

ABSTRACT
En este artículo se presenta una arquitectura software que resuelve aspectos relativos a la interacción persona computador en un videojuego para la mejora de la comunicación oral de personas con discapacidad intelectual. Se describen una serie de aspectos importantes a tener en cuenta en este tipo de aplicaciones como son la falta de memoria de los usuarios, la necesidad de uso concurrente de la aplicación por parte de alumno y de los profesores, la necesidad de guardar registros de la interacción y generación de los correspondientes informes de uso, la adaptación al usuario y la entrada/salida multimodal. La solución es un videojuego basado en la metáfora de historia gráfica, cuya fase de pruebas de usabilidad con usuarios reales se avanza en este trabajo.

Categories and Subject Descriptors
H.5.2 [**Information Interfaces and Presentation (e.g., HCI)**]: User Interfaces; K.8.0 [**Personal Computing**]: Games; J.4 [**Social and Behavioral Sciences**]: Psychology

General Terms
Human Factors, Design

Keywords
Keywords are your own designated keywords.

1. INTRODUCCIÓN
Las personas con discapacidad intelectual presentan una serie de problemas relacionados con la utilización del lenguaje [4].

Existen herramientas con las que los logopedas y maestros en audición trabajan con dichas personas, aunque éstas se reducen a meras actividades individuales en las que se trabajan aspectos concretos del lenguaje [1]. Sin embargo, el uso de las TIC en este contexto está muy poco desarrollado, principalmente por las dificultades que entraña la interacción entre personas con discapacidad intelectual con sistemas informáticos. Por otro lado, en los últimos años, el uso de videojuegos orientados a la educación está sufriendo un incremento muy importante, ya que estas herramientas permiten integrar mecánicas educativas en entornos lúdicos que ayudan a que los alumnos desarrollen dichas dinámicas con una motivación mayor a la que se produce cuando se realizan en contextos estrictamente educativos [8]. El presente trabajo propone un videojuego donde se integran estos aspectos, poniendo especial interés en los problemas que se han detectado en el uso de herramientas informáticas por parte de personas con discapacidad intelectual [5,6] desarrollando una interfaz de usuario acorde con dichas problemáticas.

Debido a que esta herramienta está enfocada principalmente al entrenamiento de aspectos lingüísticos, se hace necesaria la interacción multimodal entre el usuario y el videojuego, utilizando entradas y salidas tanto sonoras como visuales. La interacción multimodal es controvertida porque su uso resulta poco práctico en la mayoría de aplicaciones [9]. Se presenta aquí un caso en el que la interacción vocal es necesaria y donde contribuye además a reforzar la eficacia de la interacción convencional.

Otro aspecto clave a tener en cuenta es el género del videojuego a utilizar. Nos hemos decantado por las aventuras gráficas, ya que este tipo de videojuegos permiten simular un elevado número de situaciones que creen un entorno significativo idóneo para contextualizar los actos de habla o las diferentes producciones lingüísticas. Pero hay que tener en cuenta que algunas personas con discapacidad intelectual, o diversidad funcional cognitiva entre otras dificultades, presentan importantes limitaciones con sus procesos de memoria [3], por lo que hay que evitar que el usuario tenga que recordar gran cantidad de información, algo común en este género de videojuegos. En nuestro enfoque, empleamos recursos de diseño de interfaz que vengan a suplir las limitaciones de memoria de los estudiantes.

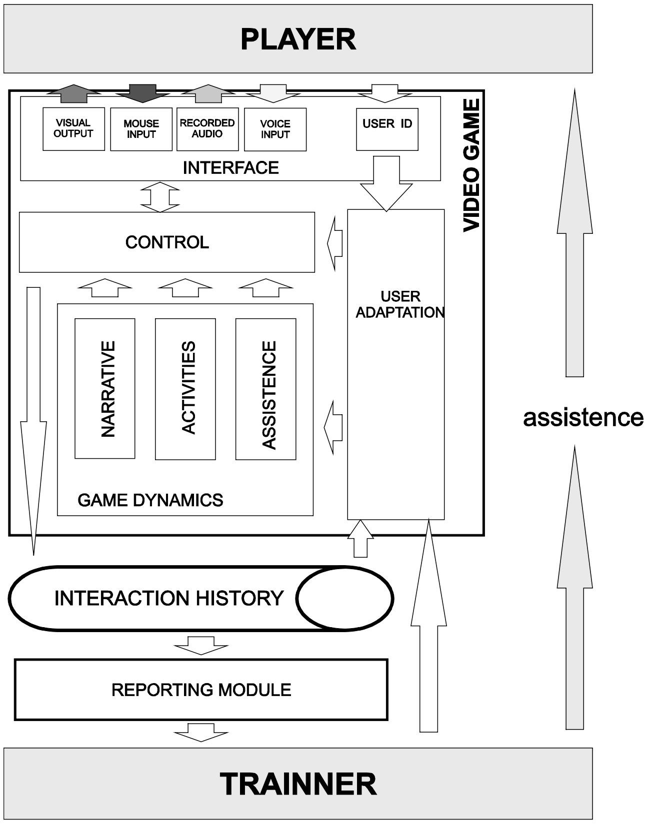

Figura 3: Flujo de entrada/salida de la aplicación

Nuestra aproximación pretende que la herramienta sirva de enlace entre el educador o profesional y el usuario. El educador tendrá capacidad para manejar la aplicación de forma coordinada con usuario, no sólo configurando las actividades de acuerdo al perfil requerido, sino realizando acciones con el interfaz en paralelo al trabajo del alumno. La herramienta dejará registro de la actividad del usuario, y realizará informes que permitan al profesor conocer el aprovechamiento de su uso.

Todos estos condicionantes determinan la definición de la interfaz y la arquitectura de la herramienta. En las siguientes secciones, analizamos la relación entre videojuegos y educación y detallamos la arquitectura del videojuego. Después, explicamos algunas consideraciones de interfaz y desarrollo. Finalizamos realizando una discusión sobre el trabajo futuro que tiene que ver principalmente con la estrategia de pruebas del sistema.

2. ARQUITECTURA DE LA APLICACIÓN

La Figura 1 muestra un esquema funcional del flujo entrada/salida del sistema. Dos usuarios interactúan con el programa: el usuario *player* y el usuario *trainer*. *Player* es típicamente un niño o un joven con necesidades específicas en el ámbito del lenguaje, concretamente en lo que hace referencia a la percepción y producción prosódica. *Trainer* es típicamente un asistente (profesor, logopeda, familiar…) que apoya al player durante la sesión de trabajo. El juego puede utilizarse sin la presencia del *Trainer*. Cuando *Trainer* y *Player* participan juntos en la dinámica del juego, el primero intervendría para asistir al *Player* en el correcto uso de la voz, pero también para configurar la herramienta para adaptar el juego a las necesidades del *Player*. Por último, las dinámicas incluyen opciones especiales para que el *Trainer* pueda hacer que *Player* repita o suspenda determinados ejercicios en función del aprovechamiento del mismo.

El rol de apoyo del profesor es fundamental para explotar al máximo la potencialidad educativa del videojuego. El profesor además de apoyar y guiar al usuario en el proceso, determinará los niveles de dificultad que el usuario puede ir superando, animará a éste a continuar cuando encuentre dificultades en una tarea o actividad, complementará las ayudas proporcionadas en el videojuego para la realización de las actividades y para su avance en el mismo, ayudándole a resolver tanto las dificultades del usuario tanto en el manejo del mismo, como sus dificultades de comprensión de la narrativa o de las actividades.

2.1 Interacción multimodal

A la hora de diseñar el videojuego se han seguido los planteamientos del aprendizaje multimedia, es decir, el aprendizaje utilizando imágenes y sonido [7]. De esta forma, se trata de conseguir que los usuarios no dependan tanto del canal verbal para la recibir la información relevante, sino que se pueda complementar dicha información con imágenes, ya que esta modalidad de información presenta menos problemas de procesamiento para estas personas [3]. De hecho, se ha demostrado que el uso de imágenes para apoyar y complementar la información verbal es una estrategia educativa más eficaz que el uso exclusivo de información verbal [2].

Se trata de una aplicación con un interfaz multimodal, tanto desde el punto de vista de la entrada como el de la salida. La entrada se realiza utilizando voz y también el ratón o el touch si se emplea la versión para móviles y tabletas. En los ejercicios de entrenamiento de la voz, el jugador deberá utilizar la voz de forma obligatoria. La salida del juego emplea los modos visual y sonoro. El videojuego incluye gráficos 2D que describe las escenas donde se desarrolla la acción, los recursos que describen el estado, los avatares que representan al jugador y al asistente virtual. El canal sonoro de salida se dedica a la voz en off que narra la aventura, a los personajes que intervienen en la escena y a los apoyos del asistente virtual. En todo caso, se utiliza voz grabada para incluir un componente de emotividad que la voz sintética aún no alcanza.

2.2 Lógica y control

La arquitectura del juego se muestra en la Figura 2, la cual se estructura en torno a tres componentes separadas. El *módulo de lógica* es el responsable de acceder a los módulos correspondientes para presentar las escenas, actividades y ayudas que corresponden en cada momento. También se encarga de reconocer el nivel del usuario y adaptar las dinámicas a dicho nivel. El *trainer* podrá también acceder a este módulo para corregir las predicciones del mismo.

El *módulo de interfaz* gestiona la presentación de las distintas actividades del juego. Hay actividades de entrenamiento de la voz y otras exclusivamente gráficas. Se incluyen actividades gráficas para hacer más entretenido el juego y para diagnosticar, en tiempo real, el nivel de comprensión del jugador. También es responsable de dar apoyo y realimentación al jugador durante el desarrollo de la partida. En particular es responsable del avatar y del mapa que indica al jugador los pasos que ha cubierto en su aventura.

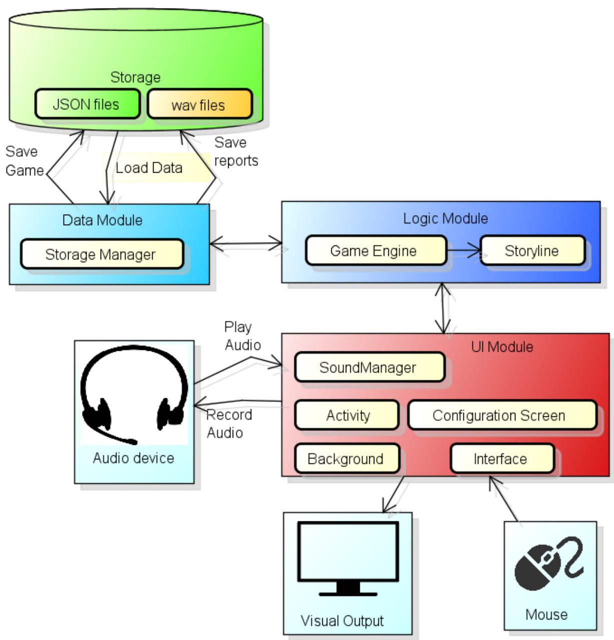

Figura 4: Arquitectura de la aplicación

La interacción del *player* y del *trainer* queda grabada. El histórico de la interacción incluye las muestras de voz. Este banco de datos es monitorizado por un *módulo de datos* que puede ofrecer información filtrada al *trainer* sobre los problemas detectados en el habla del *player* y sobre si se detectan mejorías en su habla a lo largo del uso del sistema. También permite guardar la partida al *player* para continuarla posteriormente.

La arquitectura propuesta pretende desacoplar en la medida de lo posible los distintos elementos que componen el videojuego, a saber: el motor del juego (game engine), el guión de la historia (storyline), las actividades (activity), los escenarios (background), el gestor de datos (storage manager) y la gestión de la interfaz. De esta manera se simplifica el desarrollo del videojuego y la creación de las distintas narrativas por las que discurre el juego. El desarrollo se ha realizado usando Adobe Flash Professional CC. Actualmente el videojuego se puede ejecutar en cualquier dispositivo en el que se pueda instalar Adobe Air: PC, Mac, tableta Android, etc.

3. INTERFAZ Y ACTIVIDADES

3.1 Narrativa e inmersión en el juego

Debido a que la principal función del videojuego es ayudar a las personas con discapacidad intelectual a mejorar el uso del lenguaje, los escenarios, personajes y objetos con los que el jugador interactuará son representaciones del mundo real, para que dichos jugadores puedan identificar situaciones cotidianas y sean capaces de utilizar lo aprendido durante el juego en situaciones reales. Así el jugador pasará durante la aventura por escenarios cotidianos como una biblioteca, un autobús o una tienda de material escolar. Sin embargo, la historia narrada también incluye aspectos imaginarios, ya que ayudan a que el jugador se sienta retado a alcanzar determinados objetivos alejados de las tareas más cotidianas. Por ello, según avanza el juego, los escenarios realistas se irán transformando en escenarios con toques fantásticos.

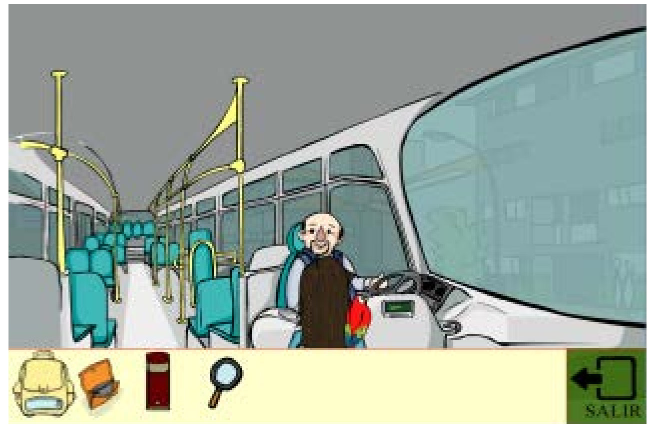

Figura 5: Escenario autobús

Para potenciar la sensación de inmersión dentro del juego, se le ofrece al jugador la oportunidad de seleccionar un avatar al comienzo del juego. Dicho avatar representa la imagen del jugador en el juego, lo que le permite identificarse con el personaje de la historia. Además, se ha incluido un asistente que guía al jugador en el transcurso del juego. Dicho asistente guía al jugador para que sepa a qué escenario debe ir o qué objeto debe conseguir. También recordará el objetivo actual si el jugador se queda atascado en algún punto del juego. Esto último es importante ya que se pretende que el jugador complete el máximo de actividades posibles, por lo que fomentar la permanencia en el juego se vuelve un factor muy importante.

Otro aspecto importante que se ha tenido en cuenta es la inclusión de ayudas visuales sobre los escenarios del juego, para ayudar a los jugadores a identificar el siguiente paso a realizar y evitar que dichos jugadores no consigan avanzar en la historia.

3.2 Tipo de actividades

Como hemos comentado anteriormente, el objetivo principal del videojuego es que el usuario trabaje sus competencias comunicativas. Para ello, se han definido 3 tipos de actividades enfocadas a mejorar algún aspecto relevante en dichas competencias.

- Actividades de comprensión: Dichas actividades están enfocadas tanto a la comprensión léxico-semántica como a la mejora de la percepción prosódica en contextos concretos, como realizar una pregunta o pedir algo educadamente. Para ello se introduce al usuario en diferentes diálogos con personajes del juego, en los que tendrá que elegir entre diferentes opciones con las que continuar el diálogo.
- Actividades de producción: Estas actividades están dirigidas a la producción oral por lo que se les insta a ejercitar el habla teniendo en cuenta aspectos prosódicos, como la entonación, la expresión de emociones o el énfasis silábico. Esto se consigue también realizando diálogos con personajes del videojuego, en los que el usuario tendrá que repetir diferentes frases en adecuación al contexto del diálogo.
- Actividades visuales: Estas actividades tienen 2 objetivos. Por un lado, están las actividades dirigidas a

mejorar aspectos muy concretos de la prosodia, todo acompañado de una respuesta visual a la entrada sonora del usuario. Por otro lado, se introduce actividades diseñadas para añadir diversidad al aspecto jugable, que ayudan a reducir la sensación de monotonía al jugar. Además potencian otras capacidades cognitivas como la percepción espacial, la identificación de formas o la relación entre causa y consecuencia, entre otras.

Cada actividad ofrece en su resolución un feedback positivo o negativo, según los resultados obtenidos por los usuarios en cada actividad. Esto es importante ya que un videojuego debe proponer retos jugables y los jugadores deben ser conscientes de los resultados de su interacción. Sin embargo, debido a las dificultades que presentan los usuarios objetivos, es importante no causarles frustración para que no abandonen el uso del videojuego. Para ello, los errores se tratan de manera positiva. Por un lado, siempre se les permite avanzar independientemente de los resultados, variando únicamente el feedbak mostrado. Por otro lado, a pesar de darles feedback negativo cuando se equivocan para que sean conscientes del error, este feedbak se complementa con un refuerzo positivo que les alienta a seguir jugando y no desmoralizarse, haciéndoles ver que cometer un error es algo totalmente normal.

3.3 Adaptación al usuario

Debido a la variedad de usuarios que se integran dentro de la discapacidad intelectual y sus respectivas capacidades cognitivas, es necesario que el juego se pueda adaptar a las necesidades de los usuarios. Dentro del grupo de usuarios objetivo, se ha diferenciado los perfiles de lector y no lector, ya que la dificultad para la lectura es un aspecto relevante en dichos usuarios. Por lo tanto, las actividades se han complementado con ayudas visuales y sonoras adicionales.

La clasificación de los usuarios en un perfil u otro debe ser determinada actualmente por el personal de apoyo que acompaña a los usuarios al jugar, aunque se pretende que este proceso sea automático en un futuro gracias a las actividades de diagnosis iniciales que se establecerán como parte de la creación del perfil por parte del usuario, es decir, junto a la personalización del avatar.

Otro aspecto de la adaptabilidad del sistema es la capacidad de ajustarse al nivel del usuario. Se han definido 3 niveles de dificultad para cada actividad definida anteriormente. Estos niveles de dificultad no afectan a la mecánica general de las actividades, si no al grado de dificultad de las frases en los diálogos, el número de opciones propuestas por el videojuego en las actividades de comprensión, la ayuda o ausencia de ayuda en las actividades visuales, etc.

4. CONCLUSIONES Y TRABAJO FUTURO

En este artículo se presentan los condicionantes de una interfaz de usuario derivadas de una funcionalidad relacionada con el entrenamiento de la comunicación oral, y de las particularidades del tipo de usuario. El canal visual y el canal sonoro se complementan para reforzar los mensajes y para proponer ejercicios de entrenamiento de la voz. Los refuerzos que se incluyen en la interfaz facilitan el seguimiento de la historia gráfica por parte del usuario. Concurrente con la interacción del usuario, una segunda persona puede interactuar con el sistema para garantizar el aprovechamiento del uso de las dinámicas por parte del jugador.

Un test de usabilidad completará las pruebas heurísticas que se han realizado hasta ahora. El objetivo es evaluar los aspectos de comprensión de la historia, el seguimiento de las directrices para ir superando las distintas actividades, la preferencia de determinadas ilustraciones, la permanencia del jugador con el uso del videojuego, etc. También los profesionales de los centros (logopedas, educadores, profesores, etc.) complementarán formularios de evaluación. Durante la prueba, se anotan todos aquellos aspectos relativos a la actitud del jugador en diferentes momentos, problemas técnicos con el uso de la herramienta, nivel de comprensión de las actividades y otros. Por último, se les pregunta por la experiencia con el videojuego con el objetivo de saber si les ha gustado la historia, las imágenes y las actividades, si lo han encontrado fácil y si se imaginan para qué puede servirles, entre otras cosas.

5. AGRADECIMIENTOS

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Caracterización de las Empresas Desarrolladoras de Software en Panamá en Materia de Usabilidad y Accesibilidad

Ing. Giankaris Moreno, Ing. Vanessa Castillo, Lic. Kaiser Williams, Ing. Nyder Menéndez
Universidad Tecnológica de Panamá
Panamá, Panamá
(507) 560 – 3602
{giankaris.moreno; vanesa.castillo; kaiser.williams; nyder.menéndez}@utp.ac.pa

RESUMEN
En este artículo se muestra un primer acercamiento a las empresas desarrolladoras de software en Panamá en materia de usabilidad y accesibilidad, el principal objetivo era tener una idea de cual es el estado actual de la disciplina conocida como Interacción Humano Máquina (HCI – "*Human Computer Interaction"*) en Panamá. Para ello se llevaron a cabo entrevistas y encuestas a una muestra de empresas dedicadas exclusivamente a desarrollar software en Panamá y otras empresas que poseen internamente un departamento de desarrollo de software para la misma empresa.

Palabras Claves
Accesibilidad; Desarrollo de Software Panamá; Usabilidad

1. INTRODUCCIÓN
Con el pasar del tiempo el desarrollo de software ha realizado importantes cambios en las metodologías empleadas en el desarrollo de procesos y aplicaciones. En sus inicios se hablaba del ciclo de vida del proceso de desarrollo y existían diversos modelos entre los que podemos mencionar el Modelo en Cascada, Modelo Espiral, Desarrollo Iterativo e Incremental entre otros. Actualmente el modelo que está acaparando la atención de los desarrolladores es el Modelo de Desarrollo Ágil (Metodologías Ágiles), el cual está más orientado a las personas que a los procesos.[8]

Al orientar el desarrollo en las personas más que en los procesos, se busca centrar tanto el desarrollo como el diseño, en el usuario; con lo cual se presta especial atención a la usabilidad de la aplicación que se desea desarrollar.

La usabilidad según la norma ISO 9241-11 se define como: "el grado en que un producto puede ser usado por determinados usuarios para conseguir objetivos específicos con efectividad, eficiencia y satisfacción en un contexto de uso específico" [9, 11]. Los factores principales que deben considerarse al hablar de usabilidad son la facilidad de aprendizaje, la efectividad de uso y la satisfacción con las que las personas son capaces de realizar sus tareas [2] gracias al uso del producto con el que están trabajando, factores que descansan en las bases del Diseño Centrado en el Usuario (DCU).[4]

Por otra parte la accesibilidad se puede definir como: "el grado en que un objeto, sitio, servicio, elemento puede ser utilizado por una persona independientemente de sus capacidades físicas o técnicas" [1, 5, 6].

Tomando en consideración las definiciones presentadas previamente acerca de usabilidad y accesibilidad, se procedió a realizar una investigación que nos permita obtener y establecer las primeras evidencias sobre la situación actual de las empresas desarrolladoras de software en la República de Panamá, en cuanto a la utilización de usabilidad y accesibilidad se refiere.

2. METODOLOGÍA
Con el fin de conocer si las empresas panameñas desarrolladoras de software aplican en sus modelos de desarrollo características propias de HCI (específicamente usabilidad y accesibilidad), se procedió a realizar una investigación sobre el proceso de desarrollo de dichas empresas.

Para realizar la investigación mencionada anteriormente, se utilizó una metodología que constaba con una investigación a priori sobre las empresas desarrolladoras de software en la República de Panamá, posteriormente se le aplicó una encuesta a desarrolladores de software pertenecientes a estas empresas y luego se procedió a realizar el análisis de los resultados obtenidos. A continuación se describirán con mayor detalle cada uno de los pasos mencionados con anterioridad:

2.1 Investigación sobre las empresas de desarrollo de software existentes
Para hacer la caracterización de las empresas desarrolladoras de software en Panamá fue necesario realizar una búsqueda de las empresas dedicadas en el país a desarrollar software, fue por ello que se utilizó el directorio de empresas de la Cámara Panameña de Tecnologías de Información, Innovación y Telecomunicaciones (CAPATEC) del año 2013.

CAPATEC es la entidad del país que involucra a empresas que generan conocimiento e innovación, utilizando el valor agregado como base de su negocio, empresas de desarrollo de aplicaciones informáticas, empresas de servicios que utilizan las tecnologías de información y telecomunicaciones como herramienta fundamental para su modelo de negocio, entre las que se incluye a las prestatarias de servicios de telecomunicaciones, llamadas telefónicas, servicios de transmisiones de datos y similares; así como también las empresas dedicadas a la producción de componentes (productores de hardware), usuarios de software, empresas de servicios sustitutos o complementarios (outsourcing, aplicaciones a la medida, integración de sistemas), empresas incubadoras de tecnología (parques tecnológicos, Centros de estudios) [3]. El directorio de empresas de CAPATEC identifica dos categorías de empresas relacionadas con el desarrollo de software: aquellas en las que su actividad principal es el desarrollo de software y las que tienen como principal actividad brindar otros servicios pero poseen un departamento de desarrollo de software para la propia empresa. En total se realizó la investigación a las trece empresas que aparecían registradas como empresas dedicadas al desarrollo de software (diez empresas) y aquellas que poseen un departamento interno de desarrollo de software (tres empresas).

2.2 Encuesta

Para recolectar la información sobre las empresas se confeccionó una encuesta cuyo propósito fue obtener información de aspectos vinculados al desarrollo de software, los mismos están basados en el Modelo de Procesos de la Ingeniería de la Usabilidad y de la Accesibilidad (MPIu+a)[10]. Dichos aspectos son: análisis de requerimientos, diseño, implementación, lanzamiento, prototipado, usabilidad y accesibilidad. A continuación presentamos las preguntas formuladas para evaluar cada aspecto:

2.2.1 Análisis de los Requerimientos

Antes de comenzar a desarrollar el sistema requerido ¿Se lleva a cabo un estudio de la población a la cual va dirigida?

¿Se realizan entrevistas previas a todas las personas involucradas en el uso del sistema?

¿Se clasifican (en roles y/o perfiles) los usuarios del sistema?

2.2.2 Diseño

¿En base a que fuente ustedes determinan las tareas a realizar?

Al momento de diseñar el sistema ¿qué estilo de metodología utilizan?

2.2.3 Implementación

¿Antes de iniciar la codificación se ha definido y realizado un análisis de los requisitos de forma exhaustiva?

2.2.4 Lanzamiento

¿Se practica la retroalimentación de parte del usuario para obtener observaciones de fallos, defectos o virtudes?

De ser sí la respuesta, ¿Esta retroalimentación es utilizada para: implementar mejoras, planificar el mantenimiento, definir fechas para futuras revisiones del producto, otros?

2.2.5 Prototipado

¿Incluyen ustedes la creación de algún prototipo dentro de las fases de desarrollo del sistema?

De ser sí la respuesta, ¿En qué etapa(s) se crea(n)?

¿Qué estilo de prototipado se utiliza?

2.2.6 Usabilidad

¿Aplican ustedes alguna evaluación de la usabilidad del producto en desarrollo?

De ser sí la respuesta, ¿Qué técnicas utiliza para la evaluación de la usabilidad?

2.2.7 Accesibilidad

¿Aplican ustedes algún tipo de evaluación de accesibilidad al producto en desarrollo?

De ser sí la respuesta, ¿Qué herramientas utiliza para la evaluación de la accesibilidad?

2.3 Análisis de Resultados

Luego de recabar la información obtenida con la encuesta realizada, se procedió a catalogar los resultados obtenidos para las características evaluadas.

3. RESULTADOS OBTENIDOS

Una vez aplicada la encuesta se procedió a realizar el análisis de las respuestas obtenidas para cada uno de los aspectos evaluados. A continuación se muestra la evaluación de las entrevistas realizadas.

3.1 Análisis de los Requerimientos

Son pocas las empresas que realizan un estudio a profundidad de la población a la cual va dirigida el sistema. Sólo un 25% de las empresas entrevistadas realiza estudios de la población a la que va dirigido el desarrollo de la aplicación. Algunos expresaron que la falta de tiempo impide este estudio, ya que las empresas piden sus sistemas con carácter de urgencia y estos estudios conllevan mucho tiempo.

Por otra parte un 75% de las empresas realizan entrevistas previas a las personas involucradas en el sistema, más no se les aplicaba a todas las personas involucradas sino a una parte ya que debido al tema de tiempo de entrega del producto no era posible.

En el aspecto de clasificación de los usuarios del sistema, un 87% de las empresas indicaron que sí clasifican los usuarios, ya que eso les facilita el proceso de desarrollo desde el inicio. El otro 13% de las empresas indicaron que no realizan la clasificación de los usuarios ya que solo consideraban el tema de los accesos al sistema y no a un nivel más profundo de roles.

3.2 Diseño

La Figura 1 muestra las Fuentes que emplean las empresas para determinar las tareas; en su mayoría indicaron que aplican entrevistas por ser la más común, sencilla y menos costosa, y le permite a los diseñadores obtener una mayor cantidad de información. Otro aspecto importante que resaltar es que el 47% de las empresas manifestó que utilizan la metodología de diseño apoyada en estándares generales, el 29% emplea la metodologías basadas en estándares aceptables mientras que un 24% indicó que emplean otras metodologías en la que mencionaron RAD (Rapid Application Development), la cual apoya el diseño de sus sistemas, algunas empresas por aspectos relacionados a sus políticas internas no mencionaron cual herramienta emplean.

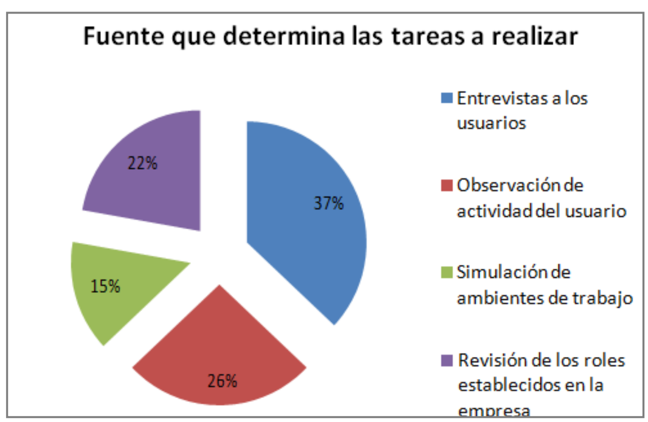

Figura 1 Fuente que determina las tareas a realizar

3.3 Implementación

El 38% de las empresas no define ni realiza un análisis de requerimientos de forma exhaustiva antes de iniciar la codificación. Explicaron que sí lo realizan pero no de manera exhaustiva ya que requiere de mucho tiempo. Solo es presentado los requerimientos primarios y en el desarrollo van definiendo otros requerimientos. Estos es así para minimizar tiempo, alegaban las empresas.

3.4 Lanzamiento

El 100% de las empresas entrevistadas manifestó realizar durante el ciclo de vida del sistema algún tipo de retroalimentación con el usuario. El 65% de estas empresas indicaron que las retroalimentaciones ayuda a proveer mejoras en las futuras versiones del sistema, mientras que a otras les permite planificar mantenimientos.

3.5 Prototipado

Un 87% de las empresas emplean cierto tipo de prototipo en algún punto del desarrollo del sistema. Comentaban que esto les permitía percibir si las ideas de ellos concordaban con la de los usuarios. EL 94% de las empresas concordaron que al inicio y durante el proceso es el mejor momento para crear un prototipo, ya que de esta manera el cliente va observando cómo va a quedar el sistema antes que sea terminado; el 6% restante que mencionó que al final crean el prototipo no están claramente familiarizados con las metodologías utilizadas en HCI, las cuales indican claramente que el prototipado se realiza antes y durante la etapa de desarrollo del sistema.

El 58% de las empresas indicaron que el estilo de prototipo que más se utilizaba (aunque algunas empresas usan varios simultáneamente dependiendo del sistema a diseñar) era el prototipado de software, ya que este permitía que los integrantes se fueran familiarizando con la herramienta a utilizar. Un 21% indicó que empleaban prototipos de papel mientras que el otro 21% emplea los bocetos.

3.6 Usabilidad

En la Figura 2 podemos observar que el 75% de las empresas no aplica ningún tipo de evaluación de usabilidad a sus sistemas creados, algunas expresaron no creer necesario realizarlas y otros que el costo que esto acarrea para las empresas que utilizan el sistema no lo desean costear. El otro 25% indicaron que sí aplicaban evaluación de usabilidad en sus productos de software, emplean combinaciones de técnicas para dar mejor soporte a los resultados, las más utilizadas son el recorrido de usabilidad, observación de campo y entrevistas.

3.7 Accesibilidad

Muy pocas empresas toman en cuenta que tan accesibles son sus sistemas. En esto se percibió que es por falta de expertos que sirvan de apoyo a los programadores. El 19% de las empresas manifestaron que sí evalúan la accesibilidad de sus sistemas e indicaron que solo han utilizado las herramientas W3C CSS Validator y W3C HTML Validator Service. Ellos conocen de otras herramientas pero esa ha sido la que ha resultado más cómoda para ellos trabajar.

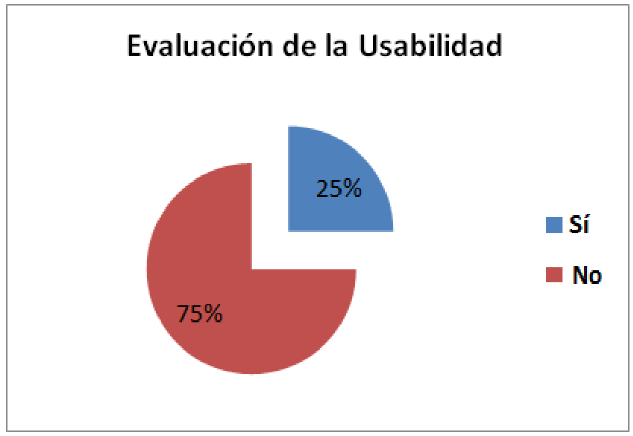

Figura 2 Evaluación de la usabilidad

4. CONCLUSIÓN

En Panamá, actualmente, es muy poco lo que se conoce e implementa en el desarrollo de software en materia de usabilidad y accesibilidad. Una de las principales razones por la cual las empresas desarrolladoras de software en Panamá no aplican pruebas de usabilidad y accesibilidad a sus productos de software es el alto costo en tiempo y recursos que representa aplicar dichas pruebas durante y posterior al desarrollo de los mismos

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ACCESSIBILITY AND SEMANTIC WEB

The Effects of Cross-modal Collaboration on the Stages of Information Seeking

Dena Al-Thani, Tony Stockman, Anastasios Tombros

School of Electronic Engineering and Computer Science
Queen Mary University of London
Mile End road, London, E1 4NA, UK
{d.al-thani, tony.stockman, a.tombros }@ qmul.ac.uk

ABSTRACT

Previous studies of users with visual impairments access to the web have focused on human-web interaction. This study explores the under investigated area of cross-modal collaborative information seeking (CCIS), that is, the challenges and opportunities that exist in supporting visually impaired (VI) users to take an effective part in collaborative web search tasks with sighted peers. We conducted an observational study to investigate the process with fourteen pairs of VI and sighted users in co-located and distributed settings. The study examined the effects of cross-modal collaborative interaction on the stages of the individual Information Seeking (IS) process. The findings showed that the different stages of the process were performed individually most of the time; however it was observed that some collaboration took place in the results exploration and management stages. The accessibility challenges faced by VI users affected their individual and collaborative interaction and also enforced certain points of collaboration. The paper concludes with some recommendations towards improving the accessibility of cross-modal collaborative search.

1.1 Categories and Subject Descriptors

H.5.3 **[Group and Organization Interfaces]:** Collaborative computing; K.4.2 **[Social Issues]:** Assistive technologies for persons with disabilities

1.2 General Terms

Human Factors, Experimentation, Design

1.3 Keywords

Collaborative information seeking; cross-modal interaction, information seeking process; accessibility; web search

1. INTRODUCTION

In the context of Information Seeking (IS), observational studies reveal that group members often collaborate when searching for information, even if they were not explicitly asked to do so [15][12] The activity that involves a group of people searching in a common information seeking task is called Collaborative Information Seeking (CIS). Over the past few years, research in this area has been gaining much interest. This attention on multi-user IS has always assumed all group members are using visual displays. This focus on the visual modality limits the relevance of previous research to users employing other interaction modes for accessing and managing retrieved results. This paper presents the results of an exploratory study conducted to investigate the effect of the presence of two different modalities on the process of CIS. We term the process under investigation cross-modal, collaborative Information Seeking (CCIS). The purpose of this study is to better understand the CCIS process and its effects on stages of the individual IS process presented by Marchionini and White [14].

To date, very few studies [24][26] have examined the process of CIS or attempt to draw a framework and models that describe its processes, therefor in our paper we take the Marchionini and White [14] model of individual information seeking and map its processes to the individual and collaborative IS activities performed. The way their model introduces the IS activity as a process that includes discreet stages will help to inform our understanding of how users employing different modalities go about performing each stage of the IS process both individually and collaboratively. The project is motivated by the observation that many activities in both educational and work settings involve teamwork, and that internet searching often forms an important component of such activities. Specifically, we wish to understand what barriers may exist to visually impaired searchers taking part in CCIS, and what approaches are currently employed by CCIS participants to overcome or work around these barriers.

The paper starts with a brief overview of related work on the accessibility of the single user IS process and a summary of the current research on CIS. We then present our motivation and research questions, before describing the details of the study and results obtained. The effects of cross-modality on the awareness and division of labour in CIS involving VI and sighted collaborators have been reported elsewhere [1], where the patterns of behavior to achieve awareness and strategies to divide labor are described. This paper focuses on examining the effects of cross-modality on the structure of the IS process and identifying the stages in which collaboration occurred and the reasons for it taking place. This paper concludes by discussing the implications of the results to inform the design of a tool that supports CCIS activities.

2. Related Background

2.1. Accessible Information Seeking

Despite the fact that issues surrounding web accessibility have attracted increased attention in research and in the commercial world [3][7], the area of accessible IS is rarely examined. The sequential nature of screen-readers imposes many challenges on visually impaired (VI) web users. These challenges range from the lack of context to overload of short-term memory. Studies have highlighted these challenges and proposed a set of guidelines to be considered when designing an accessible search engine [2][5]. While these studies focused on the usability aspects of the problem, a recent study by Sahib et al. [22] examined the challenges that this problem imposes on the different stages of the IS process and hence on the behavior of the VI information seeker.

In the comparative analysis of Sahib et al. [22] an observational user study was conducted with 15 VI and 15 sighted participants. The participants were asked to perform a complex task which required a high level of cognitive effort (i.e., detailed planning of a vacation). The results of the comparative study identified major differences between the IS behavior of VI and sighted participants. These differences were particularly apparent in the query formulation and results exploration stages. One of the main barriers highlighted was the inaccessibility to screen-reader users of query-level support features provided by search engines at the query formulation phase. Also, In the search exploration stage the number of results viewed by VI participants (mean of 4.27 (SD= 2.15) web search results viewed) was considerably lower than the number of results viewed by sighted participants (mean of 13.40 (SD= 7.39)). These findings led to the development and evaluation of a search interface [23] that aim to tackle the issues identified in their study with special attention to the results exploration and managements stages of the single user IS process.

2.2. Collaborative Information Seeking

Collaborative information seeking is defined as the activity performed by a group of people with a shared information need or 'goal' [15]. A survey by Morris [15] is referred to as one of the earliest studies that encouraged increased attention in this area. Her survey, which she revisited lately [16] did not attempt to examine users' behavior, yet it provided a wealth of data regarding the prevalence of collaborative web search and the tasks motivation and tools involved.

Despite the extensive research in this field in the past few years, there is no consensus over a single model or framework that describes the CIS process. Though there have been a number of research attempts to develop models either to describe the CIS environment [24] or to classify the systems supporting it [6]. Shah [24] proposed a layered model of information seeking. The model contains four layers which are information, tools, users and results. The information layer refers to the different resources and formats of information contained in the entire search space. The tools basically refer to the search engines and the functionality they provide. The user layer includes the users, their profiles and any mechanisms available for personalization. The final layer is the results, ultimately the product of the search process, including all relevant information, users' comments and metadata.

Studies [8][26] examined the applicability of Kuhthau's [11] process of individual information seeking in the context of a group. Hyldegard [8] observed a group of 10 students over 14 weeks when performing information seeking activities and Shah and Gonzalez-Ibanez [26] conducted a laboratory study involving 42 pairs performing a general exploratory search task. Both concluded that though there are evident similarities in the general stages of the process between individual and collaborative behaviours in information seeking, there were also important differences. The differences are related to the contextual aspects associated with social factors. The results of the studies were similar and both concluded that Kuhlthau's process did not completely address the social dimension of CIS.

Golovchinsky et al. [6] proposed a taxonomy of CIS collaboration in which they introduced four dimensions of collaboration. The focus of this taxonomy is on technical models of collaboration rather than social models, they proposed four different dimensions of collaboration, which are intent, depth of mediation, concurrency and location. (1) Intent: Explicit vs. Implicit: When implicit collaboration is supported, the search engine uses data from previous anonymous users with similar information needs or similar behavior to offer recommendations to users. Recommender systems thus support implicit collaboration. In contrast, in systems that support explicit collaboration, users explicitly work together in the query formation and results exploration stages. Microsoft's SearchTogether [17] system is an example of an application that supports explicit collaboration. (2) Depth of Mediation: This dimension refers to the level in which the mediation of information seeking is applied in a system. Pickens et al [20] introduced Cerchiamo, in which CIS is mediated at the algorithmic level. The Cerchiamo collaborative search engine divides the labour between two collaborators. One collaborator is the "preceptor" who investigates new fields of information, while the other collaborator is the "surveyor," who looks at and explores each new field in detail. (3) Concurrency: Synchronous vs. Asynchronous: Concurrency, which does not actually relate to time, means that the system should allow the actions of a user to be conveyed in some way to other team members. In other words, systems should support awareness between collaborative users within a group engaged in different information seeking activities. (4) Location: Co-located vs. Distributed: Distributed collaboration may require additional communication channels such as instant messaging, offline messaging services and voice chat.

3. Research Questions and Motivation

The increased interest in CIS reflects the fact that it is a more frequent activity in our daily lives. However, there has not previously been any attempt to consider the way CIS activities may be different when collaborators use different interface modalities, which is the focus of the current study. The questions we wished to examine are as follows:

Q1: What stages of the information seeking process are done collaboratively and how?

Studies have revealed that though IS stages are typically done individually. Nevertheless collaborators may choose to work together at many points in the process [26][27]. These studies also stressed that collaborative activities are generally ill structured [13]. Hence, very few efforts have been made to define a model of CIS activity [8][26]. In addressing this question, we aim to explore how often collaboration occurs at each stage, how much collaboration takes place and what techniques are used to support it? Furthermore, we wish to examine the effects of cross modality on group performance and techniques employed to address issues arising from the use of different interaction modes. For example, previous research on VI users IS behaviour has highlighted that most challenges are encountered during the results exploration phase [22]. These difficulties arise because examining large search result sets using a screen reader can be a lengthy process, due to the sequential nature of speech and other limitations relating to the navigation of complex information with a speech-based screen reader [19][28].

Q2: What are the strategies and techniques employed to manage search results?
This question also explores the management of search results in the presence of a common goal between group members who use different access modalities. It seeks to identify approaches and techniques used to organize, exchange and manage search results.

4. Observational Study

We observed 14 pairs of users, each pair comprising one sighted and one VI partner, performing two CCIS tasks. For one of the tasks the partners were co-located, while in the other they were located separately. Task order and location were balanced to counter learning effects.

4.1. Participants

We recruited 28 participants, 14 sighted and 14 VI, via mailing lists; table 1 contains their demographic data and the technologies they used. Three VI users employed headphones for speech output, while the other five used speakers. All the VI users used the speech-only version of the Jaws[1] screen-reader. Two pairs were colleagues for more than two years. None of the other pairs had worked together on a regular basis.

Table 1. Demographic and technology information about participants

	Visually Impaired Participants	Sighted Participants
Age	2(21-29), 4 (30-39), 3(40-49), 5 (50-59)	2(18-20), 3(21-29), 3 (40-49), 5 (30-39),1(50-59)
Gender	8 Male,6 Female	8 Male, 6 Female
Browser Used (Multiple Answers)	12 IE, 8 Safari, 5 Firefox	6 IE, 4 Firefox 3 Safari, 1 Chrome
Frequency of CIS Activity	3 Daily , 2 Once a week, 5 once a month 1 Once in the past six months, 3 Never	2 Weekly, 3 once a month , 6 Once in the past six months, 3 Never

4.2. Tasks

Previous CIS research has identified that simple information look-ups and fact finding tasks do not benefit from CIS activity, while multi-facetted and exploratory search tasks are likely to be more appropriate for use in CIS investigations [13][17]. Therefore, participants were asked to collect relevant information for two exploratory tasks that were designed to be realistic work and leisure tasks respectively. The task used in the co-located session was to organize a business trip to the United States (US) while the task in the distributed session was to organize a holiday trip to Australia. They were given dates of engagements in different cities and times when leisure or work activities needed to be identified. Participants were asked to organize the travel, accommodation and activities in these cities. In advance of each study we made sure that participants had not visited the cities before. The complexity of the two tasks was counterbalanced to make them approximately equal in their level of difficulty. They were balanced for subtasks and amount of information retrieved.

4.3. Sessions

Both the co-located and distributed sessions took place at the VI participants' workplace as the intention was to observe the participants in real world settings. For the same reason they were asked to use their own PCs and the web browser and search engines they normally used. In the distributed sessions, participants were seated in remote locations and told that they could use one or more of the following methods to communicate: email, instant messaging, shared documents, or any tool they found suitable. While in the co-located setting, participants were seated in the same room and asked to communicate verbally, though they were free to use additional methods if desired.

During the first session, participants were briefed about the purpose of the study and asked to fill a pre-study questionnaire which collected their demographic data, information about the technologies they use for this type of task and their level of experience with web searching. In each session, they were provided with a brief document giving information about the trip they were required to organise, including dates when they needed to be in different places and details of the types of activities they were required to book.

Following that, participants were asked to perform the tasks and about 35 minutes into their work the principle researcher asked them to stop. We intentionally did not inform them in advance about the amount of time they have to perform the task as we were not interested in examining the influence of time pressure in this study. We concluded each session with a brief semi-structured interview to discuss the participants' experience of the task.

All sessions were videotaped, having obtained the approval of the participants. During the tasks, the screens of both participants were captured using screen recording software. The VI participants' screens were captured using a video camera, as we noticed in a pilot of the experiment that screen recording software sometimes reduced the responsiveness of screen-readers. Additionally the principle researcher made notes of observations during the sessions.

4.4. Data Collection

The main source of data was the video recordings of the interactions between partners and their interactions with the search engines and the post-study interviews. After transcribing the videos, we used the Open and Axial coding phases of grounded theory [4]. Open coding is the process of generating initial concepts from the data while axial coding is when the data is put together to establish connections between the different concepts and categories. The selective coding process includes

[1] http://www.freedomscientific.com/

the formalisation of the data into theoretical frameworks. However, for this study, we stopped our data analysis after open and axial coding as we wanted only to explore the behaviour of the collaborating searchers, as opposed to developing a new theory.

The coding scheme captured indicators of each IS process stage. In relation to the interactions between partners, the coding scheme captured instances of collaborative IS activities and the reasons for these taking place. Semi-structured interviews were conducted individually with each participant to complement the data collected during the study. On the quantitative data, we carried out statistical testing at $p<0.05$ with a two-tailed unpaired t-test.

5. ANALYSIS

5.1. Stages of the Collaborative Process

In general, the process started with a stage in which the pair divided the tasks to be performed. At this stage, usually one of the participants took the lead and assigned tasks to themselves and to their partner. During this process, the other partner might either agree on the task s/he is being given or suggest another task. For instance, visually impaired experienced web users sometimes anticipated that certain tasks were likely to require a longer time for them to complete, therefore they sometimes suggested they performed other tasks. Seven VI participants in the co-located setting and 10 VI participants in the distributed setting preferred searching for a tourism site to booking a hotel room, because the latter task involved filling an online form. In the interviews, VI participants explained that from previous experience of filling web forms they knew that this process can sometimes be lengthy or not feasible due to the presence of inaccessible form elements.

In the co-located sessions, an iterative process was observed. This process mainly involved three stages. In the first stage the pair spent from 2 to 5 minutes looking into and discussing the task. The discussion at this stage mainly related to an initial division of labour. At this stage the task was divided into smaller sub-tasks. However in the majority of cases, partners only decided on who would do each of the first sub-tasks. In stage 2, after each partner had been assigned a sub-task, each participant started to perform the information seeking process individually. Once a piece of information was found (e.g. once a sub-task was completed), the participants usually paused and notified their partner about the completion of this sub-task by discussing the outcome and search results found (Stage 3). The discussion in stage 3 always revolved around three main aspects: division of labour, making sense of the results and reviewing the remaining sub-tasks. Stages 2 and 3 were then repeated until the task is completed. However, in some cases a participant interrupted his/her partner during a task. Two main reasons were noticed for such behaviour. One reason was that the participants would need to browse search results together either to collaboratively make sense of the retrieved information or in some cases VI participants would face difficulties in viewing large volumes of search results, due to the limitations of speech-based screen-readers, and so asked their sighted partners for assistance. The other reason was that some websites were inaccessible and it was impossible for the VI partner to complete the task individually. In the observed sessions, a sum of 17 instances were recorded where the VI participants asked for assistance from their sighted partners in the co-located setting. , 13 of these cases were accessibility issues while four of them were related to navigating large result sets.

In all distributed sessions, a common pattern for the execution of the stages was observed. After the initial division of labour, both participants performed the Information seeking tasks individually and shared the results via email or instant messages. Unlike the process in the co-located session, in the distributed sessions there was no evidence that participants discussed division of labour later in the process. It was observed. However, if one participant completed all the tasks assigned to him/her, they would decide to complete their partner's outstanding tasks. Additionally, there were virtually no interactions between partners relating to making sense of retrieved results. There were only three requests for assistance recorded and all were access related.

5.2. Stages of the Information Seeking Process

For the most part, the separate stages of the information seeking process were done individually. Nevertheless in the co-located sessions, a number of instances were recorded in which query formulation, results exploration, query re-formulation and the search result management stages were accomplished collaboratively.

5.2.1. Query formulation

When a participant is assigned a particular task, he/she immediately opened a search engine and entered a query keyword. Usually the initial query would be broad and once a relevant result set is found, the participant might choose to narrow down the search to a more specific query with more keywords to obtain the information they need. However, this was not the case with VI users, as the average length of the initial query entered by sighted participants was 2.65 (SD: 0.84) in the co-located setting and 2.93 (SD: 0.54) in the distributed setting, while the average length of the initial query entered by the VI participants was 3.37(SD: 0.96) in the co-located setting and 3.31 (SD: 0.95) in the distributed setting. In both settings, the average length of queries by sighted participants is shorter than that of VI users. The result were statistically significant in the co-located setting at ($t(26)$)=2.1058, p=0.045) and not statistically significant in the distributed setting at ($t(26)= 1.2818$, $p= 0.2112$). This result agrees with a previous comparative study [22] of the search behavior of VI and sighted users. In interviews conducted as part of [22], VI users confirmed that they often try to express their complete information need in a long, precise query, in an attempt to reduce the number of results they need to browse to reach the desired result.

Returning to the present study, a number of instances of collaboration were observed at this stage; participants sometimes suggested query keywords for his/her partner. In all co-located experiments, the average of 0.36 (SD: 0.66) instances of suggesting query terms have been recorded, while only one case was recorded in the distributed setting. In situations where the participant was unable to find results that satisfied the information need, his/her partner usually suggested another query keyword. This suggestion was either based on prior knowledge, or based on the context of the task. For instance in the conversation extract below, one participant was finding a hotel in Los Angeles (L.A). This participant suggested the query keyword for her partner, who was looking for a restaurant to dine in L.A. She suggested that the restaurant had to be near the hotel, as shown in the excerpt below:

SP: "I will look for a place to dine in L.A."
VP: "You can Google restaurants near Beverly Hills"

5.2.2. Search Result Exploration

The number of search results explored by sighted users (average 7.14, SD: 3.37) is statistically significantly higher than that for VI participants (average 3.92, SD: 2.12) with ($t(26)= 2.798$, $p=0.009$) in the co-located setting. In the distributed setting, although the difference was smaller, it was still statistically significant ($t(26)= 2.32$, $p= 0.03$). It was recorded that the average number of search results explored by sighted users (average 6.79, SD: 2.38) and by VI users (4.71, SD: 2.64). Collaboratively exploring a set of search results was commonly observed in the co-located setting only. In all sessions, an average of 3.75 (SD: 1.25) instances of exploring results collaboratively were recorded. The average number of search results viewed collaboratively is 0.5(SD: 1.38). All such collaboratively obtained results were triggered by the VI partner needing to explore more results faster. An example of comments taken from two different studies in which the VI partner asked the sighted partner to assist when exploring the search results is shown below

From Study #3 co-located session: VP: "Could you just glance at these results yourself?!"
From Study #2 co-located sessions: VP: "It is listing a number of places, Can you see L.A. there?"

5.2.3. Query Re-formulation

This stage occurs when the user is not satisfied with the initial retrieved set of results and chooses to submit a new query. The new query might be a term from prior knowledge or from information that was just found. Most of the time this stage was done individually with an average of 1.07 (SD: 1.14) in the co-located setting and an average of 0.7 (SD: 1.24) in the distributed setting by VI participants. Re-formulation of queries by sighted participants had an average of 2.93 (SD: 2.47) in the co-located setting and an average of 1.29 (SD: 1.98) in the distributed setting. It was observed that this stage was performed collaboratively in only 3 instances in the co-located setting. In these instances the partner interrupts and suggests a query term when one partner is not satisfied with the set of results. An excerpt of a conversation that captures query re-formulation accomplished collaboratively is shown below:

From Study #4 SP:" I think, perhaps Virgin Atlantic doesn't have direct flights to Las Vegas".
VP: "Yes, this is what I was thinking about".
SP: "Let us try another keyword; perhaps you can Google direct flights to Las Vegas".

5.2.4. Managing Search Results

Since the task was conducted in one session, users did not employ favorites or bookmarks to keep track of required information. Sighted users tended to open multiple tabs within a browser window whereas VI users tended to open multiple windows to keep track of retrieved information. In the co-located setting, the most used note taking tool was Microsoft word. 10 VI participants and 7 sighted participants have used it. The next most used tool by sighted participants was using pen and paper; four sighted users requested a pen and paper to note down retrieved information. Additionally two VI participants and one sighted user used the Microsoft note pad application. One participant established skype communication and added the retrieved information into the Skype session. In most of the conducted sessions, both participants would store the retrieved information in one of the previously mentioned forms. However, in three sessions only one participant noted down the retrieved information and the other participants entirely depended on their partners. In two sessions it was the sighted users who kept track of the retrieved information and stored it, while in one session it was the VI user who organized and stored the retrieved information in a word file.

In the distributed setting, the most used note taking tool was Microsoft word with nine VI participants and five sighted participants. Three sighted participants requested pen and paper to take notes, and two VI participants used the Microsoft notepad application. In the distributed setting, three VI participants and four sighted participants preferred storing their notes and retrieved information using the communication tool, which was either email or chat messaging. In these situations, one team member usually kept track of the information shared in the communication tool by storing them in a word processing application. Four VI participants and three sighted participants kept track of the retrieved in information received from their partners and stored them in a Microsoft word file.

It was observed that the information noted down or exchanged by participants was of five types. These were: a website link, a website link with details, details about the sub-task, simply keywords that refer to the information or copying a part of the webpage. Figure 1 shows the percentage of each identified category in the co-located and the distributed settings.

As shown in Figure 1, the majority of information kept by both sighted and VI users in both settings were either website links with details (52% in the co-located setting and 59% in the distributed setting) or details only (25% in the co-located setting and 16% in the distributed setting). Moreover, the amount of information kept by VI users is nearly half the amount of information kept by sighted users. In fact in the distributed setting, sighted users exchange rate of information to VI users was 2:1. In the post-study interviews, seven VI participants highlighted the difficulties of having to switch between three different applications: the web browser, the email client and the note taking tool during the process.

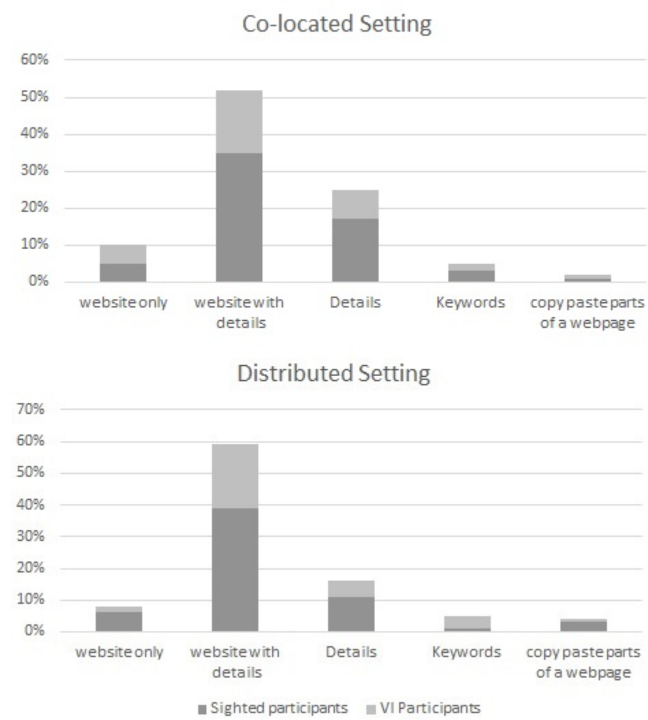

Figure 1. The total percentage occurrence of each type of information kept or exchanged in both co-located and distributed sessions

In the co-located setting the retrieved information was noted down but was not exchanged between the participants by any means. The participants were merely verbally notifying their partners about their progress or asking about their partner's progress as a means of updating their awareness information. Whilst in the distributed setting, partners exchanged information by email or instant messaging as well as using note taking tool.

1.4 5.3 Time intervals

We observe the time spent by participants on each stage. This includes time spent entering a query, times spent viewing search results pages, time spent browsing websites, and time spent managing information. In addition, time spent dealing with an error (whether it's a connection error, interface error or accessibility issue) and time spent switching from one application to another. Table 2 shows the average time interval spent in each stage in both settings. The figures shows that the most apparent differences between the two groups of users were in the results exploration stage, retrieved information management stage, communication stage and switching from one application to another. In the results exploration stage in both settings VI users spent on average a longer time then their sighted partners. Though the differences were not statistically significant with t-test results ($t(13) = 2.05$, $p= 0.06$) in the distributed setting and ($t(13) = 1.95$, $p=0.7$) in the co-located setting. According to our observations the main reason that made the VI participants spend on average more time in this stage is the serial nature of speech that would make the process of going through search results longer.

Table 2. The average time interval spent (in seconds) in each stage in both settings by both groups of users in the study (Mean [standard deviation])

	Co-located		Distributed	
	VI participant	Sighted participant	VI Participant	Sighted Participant
Entering query term	2.38 [1:12]	2.08 [1:59]	2.51 [2:01]	1.37 [0:58]
Exploring search results	3:58 [2:39]	2:11 [1:49]	3:17 [1:52]	2:07 [1:17]
Browsing websites	14:29 [8:48]	14:19 [8:47]	10:44 [6:47]	11:49 [6:08]
Managing information	2:50 [2:25]	5:57 [3:06]	1:59 [1:52]	2:50 [3:52]
Chat	0:00	0:00	06:56 [3:25]	8:36 [4:37]
Encountering error	0:23 [0:43]	0:00	0:20 [0:28]	0:01 [0:02]
Switching applications	1:45 [0:19]	0:35 [0:31]	1:21 [0:34]	0:47 [0:27]

In managing retrieved information, sighted participants spent longer time in both settings. However, the differences are not statistically significant using at ($t(13)=1.95$, $p= 0.72$) in the co-located setting at ($t(13) =2.05$, $p= 0.06$) in the distributed setting. Additionally, it was observed that VI users spent considerably more time switching from one application to another. The applications were internet explorer, the email client or instant chat application in the distributed setting and word processing document or note pad. In the post-study interviews eight VI participants have highlighted the difficulties of having to switch between the three different applications.

The average time consumed browsing web search results by both groups was significantly higher in the co-located setting with t-test results ($t(26)= 2.27$, $p= 0.03$). As in the distributed setting participants spent a considerable about of time using the email client or instant chat messaging service to provide their partners with updates about their progress.

6. Findings and Discussion

6.1. CIS Process

Clearly identifying the stages of the CIS process was not among the formulated research questions; however having an insight of the stages would be of benefit and can help in identifying the phases which are influenced by the presence of two different modalities. According to the literature, the process of CIS is not well-defined and can largely differ according to the task performed. London [13] introduced a general model of collaborative activity. The model comprises three main phases: (1) the problem setting phase in which collaborators spend time understanding the problem and identifying resources required for solving it. (2) A direction setting phase which involves organizing group activities and agreeing on actions, and (3) the implementation phase in which collaborators complete the task assigned to them. He emphasize that this stage can differ according to application area and group size.

We observed a similar structure in the current study. The pairs started by discussing and making sense of the given task. They then assigned different subtasks to each other and started conducting the information seeking task individually. As seen in the analysis section, it was observed that in cases when the partners were colleagues, the VI partner would delegate the task that might contain an inaccessible interaction to the sighted partner. This action contributed to enhancing the performance of the pairs and their efficiency in completing the task.

There was clear evidence of similarities between the stages of the individual IS process and stages of collaborative IS as reported by Hyldegard [8] and Shah and Gonzalez-Ibanez [26]. Even though participants often performed the IS task individually before sharing the results with their partners, as shown in the analysis section, some stages were performed collaboratively for various reasons. The frequency of collaboration largely differed; it occurred mostly in the search results exploration stage in the co-located sessions and in the results management stages in both settings.

6.2. Result Exploration

Collaboration was triggered when the VI participant would ask the sighted participant to assist in going through a large volume of search results. Examination of large sets of search results by Speech-based screen-readers can be time consuming and imposes a number of challenges such as short term memory overload and a lack of contextual information about the data presented [19][22][28]. Additionally, current screen-readers provide almost no mechanism for overviewing a set of search results.

6.3. Results Management

The results management stage was also done collaboratively. The motivation behind users' collaboration in this stage was that they were encouraged to collaboratively work together and produce one outcome at the end of the task. In three of the co-located experiments, only one team member was taking notes, while in seven of the distributed studies only one team member was taking notes.

The observations showed that the amount of information kept and noted down by sighted participants was higher than the amount of retrieved information kept and exchange by VI participants. This is likely to be the result of two factors. The first being that sighted users viewed more results than VI users and hence they kept and exchanged more retrieved information. The second factor is related to the cognitive overhead and time delays that VI users encounter when switching between the web browser and an external application used to take notes. This itself is likely to increase the cognitive load on VI users and hence slow down the process. The effect of this factor was more apparent in the distributed setting where VI users were required to switch between three applications: the email client or instant chat application, the web browser and note taking application. The amount of information kept and exchanged by sighted users was more than double the information kept and exchanged by VI participants reported in the analysis section.

7. Implications and future work

The results and findings of our study clearly indicate that there are a number of ways that the CCIS process could be made more accessible and that the tools used currently do not address the process adequately. The motivation to improve this situation is strengthened by the frequency of team working both in education and employment [15], of which web searching often forms an important part. This section discusses the implications of the current study for the design of technical solutions to support CIS in a cross-modal context, some of which will form future work in this project.

7.1. Providing an Overview of Search Results

The search results exploration was a stage that was done collaboratively in many instances. The reason behind this sort of collaboration is that the VI participants needed help from their sighted partners to navigate through a large volume of search results. This also was highlighted by studies that compared VI individual information seeking behaviour with sighted information seeking behavior [9][22]. These studies have stressed that this stage is the most challenging and time consuming stage for VI users. In fact, this stage is assessed to be two times longer when performed by VI users than sighted users [9]. The sequential nature of speech rendered by screen-readers over loads the user's short-term memory and provides no means of representing spatial layout and contextual information of web pages [19]. Developing a mechanism that provides VI group members with an overview of search results and the ability to zoom in on particular information of interest could help in increasing the VI group members' independence in CCIS activities.

7.2. Improving the Management and Sharing of Search Results

It was observed in the study that managing search results was one of the main obstacles faced by VI users. This was more apparent in the distributed setting where the user is required to switch between three different applications. Moreover, observations in both settings highlighted differences in individual approaches employed by sighted and VI users when managing search results.

A recent publication by Sahib et al. [23] described an integrated tool that allows VI users to keep track of their search progress, and manage their search results. An evaluation of the tool with VI participants resulted in high satisfaction rates as they found it easier to handle search results within the tool as it removed the overhead of switching between a number of applications. Extending this approach to a collaborative context, including tracking the search progress of all collaborating searchers and the management of results at the individual and group levels, appears to be worth investigating, to see if similar or additional advantages accrue. However, a utility that allows collaborators to recall the websites visited and query keywords entered by their partners is clearly not sufficient, as our findings showed the majority of information exchanged regarding search results included website links and details of the information retrieved. Therefore, a tool to support CCIS needs to provide better integration of the whole process as well as supporting the sharing of websites and details of results found. An additional complexity in providing an integrated tool in the context of CIS, as opposed to individual IS, is that this tool will be shared between users employing different interaction modes, and must be accessible through these different modes.

A tool like SearchTeam[2], which is a commercially available website for collaborative search, provides the collaborators with a common place to share details of websites, links and comments. This is similar to a feature that Diigo [10], a collaborative bookmarking website, provides that allows users to share bookmarks.

7.3. Improving Awareness of the Search Query Terms and Search Results

Allowing collaborators to know the query terms entered and results viewed by their partners would certainly inform them about their partner's progress toward the completion of a task. Additionally, having a view of partners search results can allow sighted users to collaborate with their VI partners while going through large amounts of search results. A tool like Coagmento [24] provides a mechanism to allow users to be aware of their team members' activities. This is done by dedicated views that are updated with query terms used and web pages viewed by collaborators. Co-sense is a Microsoft developed CIS system that is aimed to support sensemaking in collaborative web search tasks. It provides different views of the collaborators' activities in terms of query keywords; documents retrieved and shared comments [20]. In the CCIS context, features and views provided by interfaces such as Coagmento and Co-Sense, could be tailored to be screen-reader friendly, by supporting rapid navigation to different views using keystrokes and providing keyword summaries of activities. The WeSearch system [17] allows sharing queries and comments within the group. The queries and comments are colour coded by collaborators. This could be implemented within the context of CCIS by using different screen-reader voices and/or spatially distributing the auditory representations of queries and comments made by different group members.

[2] http://searchteam.com/

8. Conclusions

This paper describes an exploratory study that examines the effect of cross-modal collaboration on the stages of information seeking in co-located and distributed settings. The findings show that there is a clear influence of the different modalities and settings on the different stages of information seeking. The most apparent collaborative issues occurred in the results exploration and management stages. Some of these problems have an underlying accessibility issue caused by to the limitations in the way information is presented and navigated using speech-based screen readers. This paper concludes by proposing some design implications that can be considered when designing a tool that supports CCIS. The results of the study highlight that considerably more work needs to be done to improve the accessibility of both individual and cross-modal information seeking.

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Modelado de perfiles de usuario accesibles para servicios académicos basados en MOOCs

Francisco Iniesto
Departamento de Lenguajes y Sistemas Informáticos
E.T.S. de Ingeniería Informática
Universidad Nacional de Educación a Distancia (UNED)
finiesto@gmail.com

Covadonga Rodrigo
Departamento de Lenguajes y Sistemas Informáticos
E.T.S. de Ingeniería Informática
Universidad Nacional de Educación a Distancia (UNED)
covadonga@lsi.uned.es

RESUMEN

Los MOOCs son un ejemplo de la gran evolución que están viviendo en la actualidad los entornos flexibles de aprendizaje, entornos que facilitan que los estudiantes aprendan desde cualquier lugar, a su propio ritmo y con un acceso abierto a los contenidos. Este escenario está revolucionando el campo de eLearning y provoca la aparición de nuevos tipos de aplicaciones/servicios académicos relacionadas con este sistema de aprendizaje. Este trabajo presenta la estrategia seguida en la definición de un perfil de aplicación basada en una selección concreta de ciertos estándares de metadatos con el objetivo de concretar un perfil de usuario que almacene información acerca de sus preferencias de accesibilidad y que aporte un valor añadido en el diseño de nuevos servicios académicos útiles a personas con diversidad funcional y basados en el uso de los MOOCs.

Categorías y Descriptores

H.1.2 [**Information Systems**]: User/Machine Systems - *human factors, human information processing.* H.5.2 [**Information Interfaces and Presentation**]: User Interfaces - *standardization, prototyping, user-centered design.* K.3.1 [**Computers and Education**]: **Computer Uses in Education** - *Collaborative learning, Distance learning.* K 4.2 [**Computers and Society Issues**]: Social Uses - *assistive technologies for persons with disabilities, handicapped persons/special needs*

Términos Generales

Design, Human Factors, Standardization.

Palabras clave

Accesibilidad, MOOC, estándares, metadatos, perfilado de usuario.

3. INTRODUCCIÓN

Los cursos, en línea, masivos y en abierto (MOOCs - Massive Online Open Courses) han conseguido popularizar los fundamentos de la educación abierta (Open Education) ofreciendo una ventana gratuita de formación a un público globalizado. El impulso está llegando a las instituciones de educación superior, muchas de las cuales están migrando sus plataformas educativas cerradas a nuevos entornos de aprendizaje en abierto demostrando que la evolución de la educación en abierto en Internet es un hecho permitiendo que millones de personas en todo el mundo puedan seguir diferentes iniciativas educativas [1], [2]. Pero también es cierto que el diseño pedagógico y visual desarrollado en los MOOCs junto a aspectos claves de factores relacionados con la arquitectura de la información, usabilidad e interacción entre participantes puede estar teniendo un impacto negativo en la participación de los estudiantes que se demuestra en bajos porcentajes de finalización en este tipo de cursos [3].

En este sentido este nuevo tipo de aprendizaje en abierto y en línea llamado MOOC parece disponer de características especiales que los hacen adecuados para ayudar a la renovación de la educación inclusiva y llegar a todos los ciudadanos: bajo coste, flexibilidad temporal y de ritmo de aprendizaje, completamente en línea,…Por tanto aparecen como un potencial instrumento que ayude a alcanzar la inclusión social, la cual sólo se puede conseguir mediante la incorporación de estrategias que incluyan a los grupos vulnerables en la alfabetización digital completa, entre ellos, las personas con diversidad funcional.

Es cierto que las TIC ofrecen numerosas posibilidades a personas con discapacidad visual, auditiva y de movilidad reducida con el fin de mejorar su bienestar, promover su formación y por lo tanto su potencial para entrar en el mercado laboral [4], [5]. Por lo tanto, una estrategia para hacer los cursos MOOCs más accesibles es la incorporación de los estándares de metadatos relacionados con la accesibilidad, tanto desde el punto de vista de definición del usuario y sus preferencias, como desde la vertiente de los propios recursos educativos y las plataformas que los contienen.

El análisis sobre diferentes estándares de metadatos que contemplan la accesibilidad presentado en el siguiente artículo ofrece ideas para adecuar el modelado de perfiles de usuario en el diseño de nuevos servicios académicos basados en MOOCs de forma que satisfaga sus preferencias de la mejor manera posible y automatizada, siendo el marco general de este trabajo el diseño de un sistema recomendador de cursos MOOC ajustados a las necesidades formativas del usuario y de las adaptaciones relacionadas con sus necesidades especiales. En primer lugar se presenta el estudio concreto de los aspectos de accesibilidad en MOOCs, a continuación se muestran los diferentes estándares sobre los que se ha trabajado y el sub-grupo que se ha seleccionado, mostrando finalmente las principales conclusiones del estudio.

4. CUESTIONES DE ACCESIBILIDAD EN MOOCS

Las plataformas MOOC son básicamente aplicaciones web que: proporcionan herramientas específicas para programar el currículo académico, ofrecen una gran variedad de material multimedia, permiten la comunicación síncrona y asíncrona entre instructores y estudiantes, además enlazan diversos modos de evaluación y retroalimentación con el estudiante. En cuanto a los elementos de la interfaz visual para iniciar o cerrar la sesión, navegar en los cursos y contenidos, los entornos MOOC disponen de múltiples capas a través del las cuales los usuarios con discapacidad deben poder interactuar. También es importante tener en cuenta que los materiales de aprendizaje en línea se utilizan a menudo con una tecnología específica la cual puede hacerlos menos disponibles para las personas que tiene capacidades de acceso limitado o que están utilizando equipos no estandarizados. Estas barreras pueden incluir elementos de la interfaz, de la plataforma en la que los materiales están integrados y la manera en que los usuarios interactúan con estos objetos [6].

Un entorno de eLearning efectivo debe tener en cuenta cada una de las habilidades de los alumnos, junto con los objetivos de aprendizaje, dónde se lleva a cabo el aprendizaje y qué dispositivos específicos utiliza el alumno. En este contexto es estratégico describir las preferencias y necesidades del alumno por medio de un perfil, puesto que la forma en que este perfil interactúa con la plataforma eLearning y los objetos que contiene afectará a la experiencia de aprendizaje de los usuarios con diferentes capacidades funcionales, como por ejemplo se realiza en el proyecto de accesibilidad en educación superior EU4ALL [7]. Con el uso de los estándares los usuarios del sistema pueden especificar qué tipo de adaptación o recurso alternativo prefieren o necesitan, por ejemplo, el usuario puede preferir información textual sobre los recursos visuales o recursos auditivos, sobre el texto o las imágenes, etc.

5. ESTÁNDARES DE ACCESIBILIDAD: PERFIL DE APRENDIZAJE Y RECURSOS EDUCATIVOS

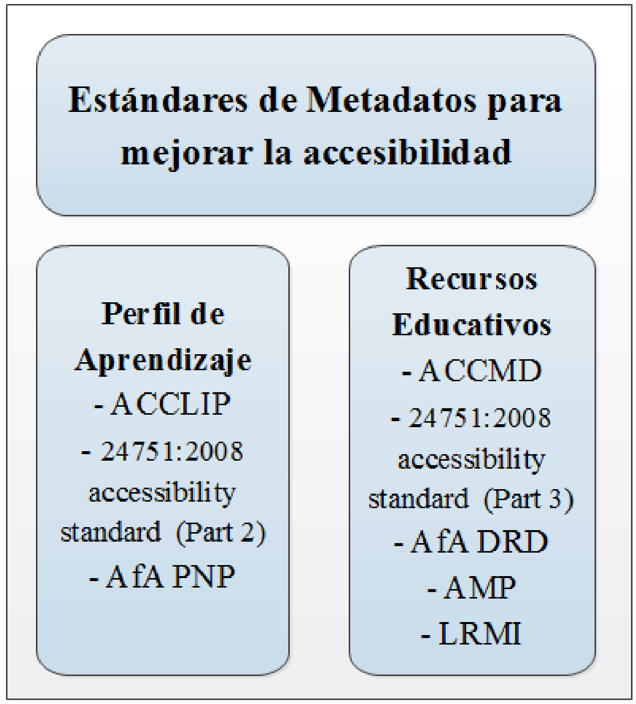

Figura 1. Estándares de metadatos para mejorar la accesibilidad.

Varias estrategias se pueden aplicar para mejorar el nivel de accesibilidad en las plataformas MOOC y servicios en su conjunto, algunas de ellas están relacionadas con la accesibilidad al añadir repositorios de materiales educativos a través del uso de esquemas de metadatos específicos y la definición del perfil de usuario y preferencias [8].

Ante todo hay que distinguir entre dos tipos de normas y estándares: aquellas que se utilizan desde el punto de vista del usuario para definir su perfil, el cual contiene información acerca de sus preferencias de visualización y aquellos estándares dedicados a proveer meta-información a los recursos educativos para que se ajusten a dichas preferencias del usuario, como se muestra en la Figura 1.

5.1 Estándares de perfil de aprendizaje.

Algunos estándares se han definido para determinar las preferencias del estudiante y las necesidades que ayudarán al usuario a personalizar los dispositivos y servicios para estudiantes con diversidad funcional.

El Consorcio IMS (Global Learning Consortium) ha desarrollado una especificación para abordar el desarrollo del perfil del estudiante (IMS LIP) [9], dedicado a describir las características generales del usuario mediante la definición de un conjunto de paquetes que se pueden utilizar para importar y extraer datos desde un servidor de información de estudiantes compatible con IMS. El paquete de información accesible del aprendizaje IMS para el LIP (ACCLIP) [10] es el subconjunto de IMS LIP que permite a los estudiantes especificar sus preferencias de accesibilidad y necesidades en términos gráficos, fonéticos o de dispositivo. Este perfil proporciona un medio para describir cómo los alumnos interactúan con un entorno de eLearning centrándose en los requisitos de accesibilidad. Por lo tanto un conjunto de preferencias de los usuarios puede ser utilizado de acuerdo con los diferentes contextos de uso del entorno de eLearning, pudiendo personalizar la visualización de los contenidos de aprendizaje, seleccionar el dispositivo de entrada o de salida preferido, etc.

Las preferencias del usuario en términos de accesibilidad en los estándares IMS se pueden agrupar de la siguiente manera:

- **Información en pantalla**: este conjunto describe las preferencias de los usuarios para tener información de lo que se muestra o se presenta. Por ejemplo, es posible definir preferencias relacionadas con los textos (fuentes y colores), video (resolución), ratón (puntero, movimiento), etc.
- **La información de control:** este conjunto define las preferencias del usuario para controlar el dispositivo: teclado (virtual), preferencias de zoom y el reconocimiento de voz.
- **Información del contenido:** este conjunto define las preferencias del usuario para visualizar los contenidos de aprendizaje.
- **Privacidad y protección de datos:** cada elemento ACCLIP tiene metadatos relacionados con esta información. La privacidad y la integridad de los datos se considera muy importante ya que la información intercambiada puede estar estrechamente relacionada con la discapacidad del usuario.

Mientras que el estándar IMS se centra en la definición de las características del contenido, la norma ISO relacionada se centra en la diversidad funcional de los usuarios, es decir, especifica los sentidos y la forma a través de los cuales se accede a los contenidos. En este sentido la segunda parte de la norma de accesibilidad ISO/IEC24751:2008 (Tecnología de la información - adaptabilidad individualizada y accesibilidad en eLearning, educación y formación-Parte 2: "Acceso para todos" necesidades personales y preferencias para la entrega digital) [11] está dedicada a la descripción de las necesidades personales y preferencias de los alumnos.

De acuerdo con los estándares, los alumnos pueden declarar explícitamente sólo un modo de acceso alternativo para cada recurso de aprendizaje y no permite cambios: por ejemplo, un usuario ciego puede preferir audio-descripción pero si esas alternativas no están presentes en su perfil no puede elegir una descripción de texto en su lugar. Por ello se ha desarrollado recientemente un nuevo estándar de IMS de acceso para todos (AfA) necesidades personales y preferencias (PNP) 3.0 [12], con el objetivo de resolver este tipo de problemas y dejar que el estudiante pueda especificar múltiples solicitudes de adaptación para cada modo de acceso existente. Sin embargo, IMS PNP tiene algunas restricciones al elegir el tamaño o la calidad de los recursos de vídeo y audio. Por ejemplo, no es posible solicitar una versión anterior de un videoclip o archivo de audio para adaptarse al dispositivo del usuario. Por lo tanto sería deseable un perfil de calidad específico para los recursos de aprendizaje, así como normas de clarificación para describir mejor la lista de opciones alternativas.

5.2 Estándares de recursos educativos.

En el momento de utilizar Internet como medio de comunicación para publicar contenido multimedia en formato audiovisual es necesario tener en cuenta diferentes aspectos:

- **Tecnológico**: los agentes de usuario que deben hacer posible el acceso a la información, la tecnología para desarrollar y editar los recursos, las herramientas de autor para facilitar la producción de materiales accesibles o la adaptación de los ya producidos.
- **Dispositivos de ayuda**: cuando un usuario accede a un recurso disponible en Internet se puede acceder directamente o mediante un dispositivo específico: lector de pantalla, ratón especializado, teclado virtual, lupa, etc.
- **Metodologías inclusivas existentes y estándares educativos:** en este sentido, los lenguajes de marcado XML tienen que ser mencionados junto con el uso de metadatos que proporciona la capacidad de adaptación de los contenidos de acuerdo al perfil del usuario.

Con el fin de mejorar la accesibilidad de los contenidos eLearning la especificación de metadatos Access-For-All (ACCMD) [13] fue desarrollada por IMS en 2004. En ella se describe el contenido de aprendizaje mediante la identificación que se dispone de los tipos de recursos en un objeto de aprendizaje, que puede ser utilizado para presentar el mismo contenido a un estudiante determinado o a través de diferentes medios. Los metadatos se pueden utilizar para describir los tipos y las relaciones entre un recurso original y sus formatos adaptados disponibles. Mediante la interpretación de los perfiles de usuario que permite elegir el contenido apropiado y su combinación con los metadatos de ACCMD se pueden describir las alternativas textuales que están disponibles para las correspondientes imágenes, descripciones de audio para videos, transcripciones o subtítulos para las pistas de audio, alternativas visuales para texto y una variedad de otros formatos alternativos que coincidan con las preferencias del usuario. En base a ACCMD estos recursos alternativos adecuados pueden ser recuperados y presentados al usuario, un alumno con discapacidad visual, por ejemplo, que vea un vídeo que había sido utilizado en el perfil ACCLIP previamente, recibirá automáticamente ese video con descripciones de audio, mientras que un alumno con discapacidad auditiva recibirá el mismo video pero con subtítulos incluidos en la presentación.

Por otra parte, la tercera parte de la norma de accesibilidad ISO/IEC 24751:2008 (Información tecnológica – adaptabilidad individualizada y accesibilidad en eLearning, educación y formación-Parte 3: "Acceso para todos" descripción de recursos digitales) [14] se dedica a describir los recursos que constituyen un contenido eLearning con un enfoque similar a IMS ACCMD, ya que son normas que tienen el mismo objetivo: proporcionar información sobre alternativas a los recursos originales. Cualquier recurso presentado en un contenido de aprendizaje electrónico puede ser identificado con una forma original y una o más formas adaptadas, dependiendo de su tipo de soporte tecnológico.

Una limitación de estas normas surge cuando los autores de contenido eLearning quieren ofrecer alternativas tanto a todo el contenido original como a cada parte que compone el recurso: imágenes incluidas en un documento, los textos formateados, etc. De acuerdo con estas normas no es posible disminuir esa granularidad y declarar esas partes de texto formateado como recursos originales si no están en archivos separados, ni tampoco un subconjunto de recursos adaptados puede ser declarado como una alternativa a un solo recurso. Por ejemplo, una secuencia de archivos de audio no se puede identificar como un único recurso auditivo, un video con lengua de signos no se puede definir como una alternativa a la misma y una secuencia de imágenes no puede ser declarada como una alternativa a un video.

El estándar de IMS acceso para todos (AfA) de descripción de recursos digitales (DRD) 3.0 [15] propone objetivos para resolver estos problemas cambiando radicalmente el punto de vista: ahora es posible declarar uno o más modos de acceso para cada recurso, definir adaptaciones accesibles existentes y determinar si proviene del recurso original específico.

El proyecto de accesibilidad de metadatos (AMP) [16] es un subconjunto de metadatos que surgió con la idea de definir un conjunto de metadatos para permitir la búsqueda y descubrimiento de recursos web que se adapten a las necesidades y preferencias de los usuarios. Se trata de encontrar una solución a la falta de propiedades para identificar el carácter accesible de los recursos que son útiles proponiendo definir la semántica que los describa de manera que se facilite su descubrimiento por conveniencia.

La iniciativa de metadatos de recursos para el aprendizaje (LRMI) [17] es una iniciativa desarrollada para facilitar la publicación, la búsqueda, el descubrimiento y la oferta de recursos educativos en la web, después de haber desarrollado un marco común de metadatos para describir los recursos de aprendizaje. Está enfocada a beneficiar el trabajo automático de los motores de búsqueda de forma que éstos puedan proporcionar resultados más acertados, permitiendo a educadores y estudiantes descubrir los recursos que se ajustan mejor a su particular situación de aprendizaje.

6. ESTÁNDARES DE ACCESIBILIDAD Y MOOCS

Para definir y modelar el perfil de usuario se han escogido los estándares más recientes y más completos de IMS como es acceso para todos (AfA) y sus aspectos de la PNP y DRD, como se ha hecho por ejemplo en el proyecto METALL[3], ya que permiten definir colecciones en lugar de un único valor para cada caso (multiplicidad) [18] como se muestra en la Figura 2. A continuación se detallan los metadatos seleccionados para modelar el perfil de aprendizaje y los recursos educativos, los criterios seleccionados han sido aquellos que tratan el modo de acceso requerido por el usuario, el tipo de adaptación que necesita, aquellos que conllevan información sobre el enriquecimiento del recurso educativo y finalmente los relacionados con el idioma. La selección tiene en cuenta el enfoque de uso en el diseño del sistema recomendador.

6.1 MOOCS y metadatos para perfilar el aprendizaje.

Del conjunto total de dieciséis elementos se han escogido diez elementos que tienen que ver con los aspectos educativos del perfil:

- **AccessModeRequired**, modo de acceso que el usuario busca, ya sea una adaptación o un recurso original como reemplazo para un modo de acceso diferente, se permite el uso del atributo "existingAccessMode" que define el acceso existente, por ejemplo "visual" y el atributo "adaptationRequest " que indica la preferencia en el modo de acceso de los usuarios, por ejemplo" textual ".
- **AdaptationTypeRequired**, la naturaleza o género de la adaptación requerida para un modo de acceso específico, tiene los mismos atributos para permitir el acceso siendo igualmente "visual" el ejemplo de un modo de acceso y un tipo de adaptación que el usuario prefiere podía ser por ejemplo "audio-descripción".
- **AtInteroperable**, el recurso es compatible con las ayudas técnicas, en cumplimiento con las WCAG 2.0. [19]
- **EducationalComplexityOfAdaptation**, identifica si el recurso está simplificado o enriquecido con relación a otro recurso que presenta el mismo contenido intelectual.
- **HazardAvoidance**, recursos que tienen dicha característica por las cuales no deben ser entregados a un usuario, por ejemplo "luces intermitentes".
- **InputRequirements**, sistema de entrada única suficiente para controlar un recurso, por ejemplo, si queremos recursos que son plenamente utilizables con un teclado.
- **LanguageOfAdaptation**, la preferencia por el lenguaje de la adaptación de los recursos educativos.
- **LanguageOfInterface**, la preferencia por el idioma de la interfaz de usuario.
- **AdaptationDetailRequired**, detalle de alguno de los tipos de requisito de adaptación, también contiene "existingAccessMode", podría ser "auditiva", y permite el uso de "ADAP-tationRequest" para expresar la alternativa deseada, si existen, por ejemplo "palabra por palabra".
- **AdaptationTypeRequired**, la naturaleza o género de la adaptación requerida como un re-colocación para un modo de acceso específica, que tiene el valor "existingAccessMode" como un ejemplo "visual" y el "adaptationRequest" podría tener el valor "PDF".

6.2 MOOCs y metadatos de recursos educativos.

Se han escogido trece de un total de diecinueve elementos relacionados con los aspectos educativos de los recursos:

- **AccessMode**, modo de acceso a través del cual se describe el contenido intelectual de un recurso o adaptación, por ejemplo, "visualmente".
- **AccessModeAdapted**, el modo de acceso del contenido intelectual del recurso que está siendo adaptado, por ejemplo "visual".
- **AccessModeOrnamental**, descripción del contenido ornamental del recurso o adaptación.
- **AdaptationDetail**, el detalle de uno o más valores del tipo de adaptación, por ejemplo si el objeto está grabado con voz humana en lugar de voz sintetizada.
- **AdaptationMediaType**, identifica el tipo de medio del recurso descrito.
- **AdaptationType**, la naturaleza o género de la adaptación, por ejemplo "texto alternativo"
- **ApiInteroperable**, indica que el recurso es compatible con la API de accesibilidad que se hace referencia, por ejemplo "ARIAv1".
- **AtInteroperable**, el recurso es compatible con las ayudas técnicas, en cumplimiento con las WCAG 2.0. [19]
- **ControlFlexibility**, identifica un único método de entrada que es suficiente para controlar el recurso descrito, podría ser como ejemplo plenamente utilizable con el teclado.
- **DisplayTransformability**, identifica una característica de visualización del recurso descrito que puede ser modificado mediante programación, por ejemplo si se permite ajustar el tamaño de fuente a petición del usuario.

[3] https://access.ecs.soton.ac.uk/projects/metall

- **EducationalComplexityOfAdaptation**, identifica si el recurso está simplificado o enriquecido con relación a otro recurso que presenta el mismo contenido intelectual.
- **Hazard**, una característica del recurso descrito que no debe ser entregado a algunos usuarios, por ejemplo, "luces intermitentes".
- **LanguageOfAdaptation**, idioma del contenido intelectual del recurso.

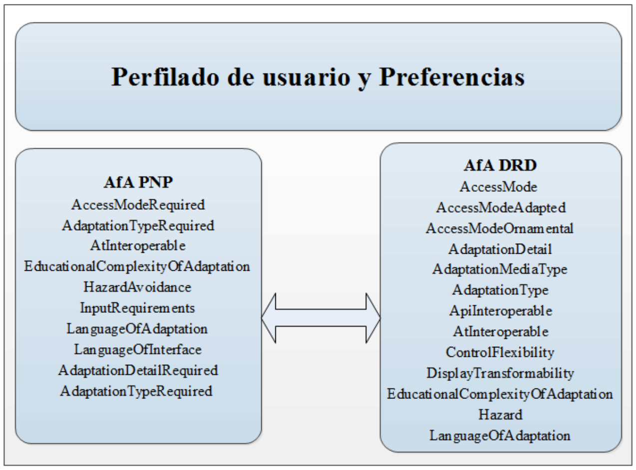

Figura 2. Perfil de usuario y preferencias.

7. CONCLUSIONES

Las plataformas MOOC deben cumplir con las normas de accesibilidad como el resto de las plataformas de eLearning, no sólo con respecto a la interfaz web sino también tener en cuenta las capacidades funcionales de los estudiantes y sus objetivos de aprendizaje. Para lograr la mejor adecuación del entorno al usuario es necesario describir sus preferencias y necesidades por medio de un perfil que atienda a su diversidad funcional y que modele también la experiencia del aprendizaje de usuarios con capacidades diferentes. El “acceso para todos” (AfA) en sus normas PNP y DRD ofrece la posibilidad a los alumnos para que puedan especificar qué tipo de adaptación y/o recurso alternativo prefieren o necesitan.

En el diseño del sistema recomendador los siguientes pasos consisten en refinar el modelado del perfil de usuario y su enriquecimiento para finalmente poder ser cruzado con un vector de características de accesibilidad de los diferentes cursos MOOC.

8. AGRADECIMIENTOS

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Creación de documentos EPUB accesibles por usuarios no técnicos: un largo camino por recorrer

Jordi Roig
Estudiante de la Universitat de Barcelona
c/Melcior de Palau, 140
08010 - Barcelona
+34 934034017
jordi.roig@icloud.com

Mireia Ribera
Universitat de Barcelona
c/Melcior de Palau, 140
08010 - Barcelona
+34 934034017
ribera@ub.edu

ABSTRACT
Este artículo presenta una evaluación cuantitativa de los resultados de conversión de documentos ofimáticos a EPUB. Como conclusión se observa que los resultados de la conversión no cumplen los estándares y no preservan la información de accesibilidad y que las herramientas llevan retraso en la adopción del nuevo formato EPUB3.

Categories and Subject Descriptors
I.7 Document and text processing, I.7.2 Document preparation, I.7.4 Electronic publishing

General Terms
Documentation

Keywords
Transformación de documentos, EPUB3, Calibre, Sigil, accesibilidad digital, ATAG 2.0

10. INTRODUCCIÓN
EPUB es un formato para codificar documentos electrónicos, no sólo libros sino también revistas, artículos, informes… [3] su versión 3, EPUB3 [13], se ha diseñado teniendo en cuenta que las maneras de acceder a la información son diversas y pueden incluir leer, escuchar, visualizar el texto con letra ampliada, visualizar los vídeos con subtítulos… con una visión inclusiva, pensada para todos los públicos [9] [25], a partir de la experiencia del formato DAISY [16]. La adopción por parte de EPUB3 de los lenguajes HTML5, CSS3, junto a las posibilidades que ofrece JavaScript, permiten a los usuarios acceder a auténticas publicaciones electrónicas multimedia e interactivas. Por lo que respecta a la accesibilidad EPUB3 incorpora la nueva estructura semántica de HTML5 (section, article, aside, nav, etc.) con el añadido de la portabilidad y mecanismos más ricos de navegación, permite la incorporación de audio sincronizado con el texto y las especificaciones recomendadas para los lectores facilitan la personalización de la experiencia lectora por parte de los usuarios con algún tipo de discapacidad.

Para crear un documento EPUB 3 en una editorial se suele partir de un contenido estructurado en XML y transformaciones XSL que permiten además crear otras versiones del mismo contenido como PDF, Mobi, etc. Pero para los autores, y en general para el gran público, su creación suele basarse en herramientas de ofimática y conversiones posteriores [17][15]. Grandes proyectos de accesibilidad [12] han potenciado la creación de herramientas de conversión como *DAISY Pipeline* [5], *RoboBraille* [24] u otras; en Internet abundan las guías para crear documentos accesibles a partir de *MS Word* o *MS PowerPoint*. Las directrices ATAG 2.0 (Authoring Tools Accessibility Guidelines) [21] del Consorcio World Wide Web, sobre herramientas de autor, tratan las conversiones en dos únicos criterios de éxito. El criterio B.1.2.1, titulado "Restructuring and Recoding Transformations (WCAG)", pide preservar la información de accesibilidad, o en caso contrario a) avisar a los autores, b) activar un chequeo automático de la accesibilidad, o c) sugerir a los autores realizar este chequeo. El criterio B.1.2.4, titulado "Text alternatives for non-text content are preserved", sólo se ocupa de las alternativas textuales, e implica que si el contenido no-textual se conserva en la transformación también debe conservarse su alternativa. El primer criterio de éxito supondría que en la conversión a EPUB se conserve la accesibilidad o bien se informe a los autores; el segundo criterio supondría que en la transformación de imágenes se conserva su texto alternativo si lo hay.

El artículo se divide en una sección de objetivos (sección 2), metodología (sección 3), resultados (sección 4) con una valoración de las conversiones y finalmente en una sección de reflexión y conclusiones finales (sección 5).

11. OBJETIVOS
En este trabajo hemos querido revisar si es posible generar un libro EPUB según los estándares y buenas prácticas de accesibilidad a partir de la edición desde una herramienta ofimática con una conversión posterior o con herramientas WYSWYG sin conocimientos de código.

Figura 1. El proceso de autoría de un EPUB a partir de herramientas ofimáticas o WYSWYG

12. METODOLOGÍA

Para evaluar la validez de la creación de EPUBs por autores no técnicos en primer lugar hemos hecho una selección de herramientas de autor con una alta adopción, tras ello hemos elegido los elementos a testear y hemos creado un documento para cada uno de ellos con cada una de las herramientas seleccionadas.

12.1 Selección de herramientas de autor

El criterio principal para la elección de las herramientas ha sido su disponibilidad y alta adopción. Así en primera instancia se han seleccionado el editor de texto *MS Word* para la plataforma Windows; el editor de texto *Pages* para la plataforma OS X; y el editor de texto *LibreOffice Writer* disponible tanto en la plataforma Windows, como en OS X como en Linux, y muy extendido en esta última plataforma. Tras revisar diversos fórums sobre el tema y con el deseo de dar una visión global finalmente también se ha añadido el editor EPUB *Sigil*, multiplataforma, por ser uno de los pocos editores EPUB dirigido a una audiencia no profesional que cuenta con una interfaz de texto. *Sigil* tiene ahora mismo una alta adopción, aunque seguramente se discontinuará a favor del editor *Calibre* [23] y cuenta además con la ventaja de ser un programa gratuito traducido a muchos idiomas, hecho que lo hace atractivo a una gran masa de la población.

Tabla 1. Herramientas utilizadas

Editor	**Conversor**	**Versión EPUB**	**Plataforma testeada**
MS Word 15.0.4	Daisy 2.5 + Tobi 2.4	3	Windows
MS Word 14.4.7	Calibre 2.20	2	OS X
Writer 4.3.5	W2E 1.1	2	OSX Windows Linux
Sigil 0.8.1	No requiere	2	OS X Windows Linux
Pages 5.5.2	No requiere	2	OS X

De los editores de texto mencionados, únicamente *Pages* dispone nativamente de un conversor al formato EPUB. Los demás editores, *MS Word* y *LibreOffice Writer*, para publicar un documento como EPUB deben usar un complemento o usar una herramienta externa. En el caso de *LibreOffice Writer* se ha seleccionado el complemento *Writer2epub* (*W2E*) [http://extensions.openoffice.org/en/project/writer2epub]. En el caso de *MS Word* se ha seleccionado una herramienta externa, el programa *Calibre* [http://calibre-ebook.com/], compatible con Windows y OS X y muy popular [11].

Finalmente para este editor se ha evaluado también la conversión en dos pasos: con el complemento *Save as DAISY* [http://www.daisy.org/project/save-as-daisy-ms-word-add-in] de *MS Word* de Windows y con el programa de edición y autoría de EPUBs *Tobi* [http://www.daisy.org/project/tobi] también de Windows, ambos creados desde la comunidad de accesibilidad [6]. Estas herramientas no se han seleccionado por su adopción sino por su especial atención a la codificación semántica. El complemento *Save as Daisy* convierte el documento de texto al formato Digital Talking Books [18] y el programa *Tobi* convierte éste último al formato EPUB. El resultado de todas las combinaciones citadas, con excepción de *Save as DAISY* y *Tobi*, es un documento en formato EPUB2.

12.2 Juego de pruebas

Para testear la conversión se han establecido unos elementos de contenido del documento básicos y se han creado unos juegos de muestra. En esta investigación no se han analizado elementos estructurales como prefacio, prólogo u otros, ni metadatos. Tampoco se han tenido en cuenta aquellos elementos más propios de documentos técnicos como texto a dos columnas, fórmulas matemáticas o gráficos.

12.2.1 Elementos analizados

Para evaluar la conversión de documentos, se han analizado diversas publicaciones (artículos, documentos docentes…) [20] así como guías de creación de documentos ofimáticos accesibles [19] y se han listado los elementos más comunes: encabezados, imágenes, listas y tablas, considerados como elementos básicos; notas, como elemento importante en los libros electrónicos pero secundario; y estilos de texto y enlaces considerados como elementos complementarios.

12.2.1.1 Elementos básicos

Encabezados. Son elementos primordiales para la navegación del documento por parte de los usuarios con discapacidades visuales y motrices, y para obtener una visión global del documento en el caso de los usuarios con discapacidad cognitiva.

Imágenes. La accesibilidad de las imágenes es fundamental para que los usuarios con discapacidades visuales puedan acceder a su contenido.

Listas. Son un elemento estructural del documento, y al igual que en los encabezados, facilitan la navegación para los usuarios con discapacidades visuales y motrices. Por otra parte, para los usuarios con discapacidad cognitiva son un recurso clave para presentar el contenido de una forma clara.

Tablas. A pesar de ser un elemento que no está bien resuelto desde el punto de vista de la accesibilidad, sobre todo por lo que respecta a las tablas complejas, es considerado como un elemento básico ya que es un elemento muy común en los documentos.

12.2.1.2 Elementos secundarios

Notas. Aunque las notas son en sí un contenido secundario, éstas pueden ser muy relevantes para la comprensión del texto y para dar explicaciones complementarias en el caso de las personas con discapacidades cognitivas. Las notas deben estar construidas correctamente a nivel de código para que los usuarios con discapacidades visuales que utilizan lectores de pantalla puedan gestionarlas adecuadamente.

12.2.1.3 Elementos complementarios

Estilos de texto. Resaltar las palabras o enunciados principales facilita la comprensión del texto a los usuarios con discapacidades cognitivas o con dificultades de lectura.

Enlaces. Una correcta formación de los enlaces e incorporación de atributos aportan información sobre el contenido del enlace y su comportamiento a los usuarios con discapacidades visuales que utilizan lectores de pantalla. En oposición al entorno web los enlaces en libros electrónicos son poco usuales pues no se pueden resolver en el mismo programa de lectura.

12.2.2 Ponderación

Inspirados por la evaluación de EPUBTest, [http://epubtest.org/] hemos asignado un valor a cada uno de los elementos en función de la relevancia de la correcta conversión a la accesibilidad usable del resultado. Es decir, a los elementos considerados principales se les asigna un 20% de la calificación global, a los secundarios un 10%, mientras que a los complementarios sólo afectan a un 5% de la nota global cada uno de ellos.

12.2.2.1 Elementos básicos

Encabezados. Se consideran los seis niveles de encabezados del lenguaje HTML, de h1 a h6.
A una correcta conversión de cada nivel le corresponde un 3,3% del 20% asignado a los encabezados.
Imágenes. Se exploran, según las pautas de accesibilidad, cuatro posibles escenarios:

- Imágenes decorativas sin necesidad de descripción
- Imágenes que requieren texto alternativo
- Imágenes con epígrafe que requieren texto alternativo
- Imágenes con que requieren una descripción más detallada

A la correcta conversión de cada tipo de imagen le corresponde un 5% del 20% asignado a las imágenes.

Listas. Se analizan listas ordenadas, no ordenadas y mixtas -combinación de ambas-. Para las viñetas y la numeración únicamente se consideran los símbolos clásicos y nombres arábigos respectivamente.
A la correcta conversión de cada tipo de lista le corresponde un 6,7% del 20% asignado a las listas.

Tablas. Solamente se consideran tablas simples con fila de encabezado, título y resumen de la tabla.
A la correcta conversión de cada elemento (estructura de tabla bien formada, encabezado, título, y resumen) le corresponde 5% del 20% asignado a las tablas.

12.2.2.2 Elementos secundarios

Notas. Se incluyen notas a pie página y notas al final del documento. Hay que tener en cuenta que en el formato EPUB, no existe el pie de página como tal, pues la "página" sólo existe en los EPUB de maquetación fija.
A la correcta conversión de cada tipo de nota le corresponde un 5% del 10% asignado a las notas.

12.2.2.3 Elementos complementarios

Estilos de texto. Se toman en consideración los estilos tipográficos más habituales: la negrita, la cursiva y el subrayado. A la correcta conversión de cada estilo le corresponde un 1,6% del 5% asignado a los estilos de texto.
Enlaces. Se incluyen tanto los enlaces que redirigen a direcciones web como enlaces a correos electrónicos. Hay que tener en cuenta que en el entorno de los EPUBs los enlaces no son muy comunes puesto que representan enlaces externos y a menudo no son gestionados correctamente por los lectores de libros electrónicos.
A la correcta conversión de cada tipo de enlaces le corresponde un 2,5% del 5% asignado a los enlaces.

12.2.3 Documentos de test

Como texto de referencia para hacer el análisis de los elementos se ha escogido el cuento infantil de *Los tres cerditos*, en su versión inglesa, *The three little pigs.*

Figura 2. Muestra de un documento de test de Pages, con una imagen

A partir de este texto se han creado documentos independientes conteniendo un único elemento de los escogidos para la evaluación (ver Tabla 2 y Figura 2). En consecuencia, para cada elemento existen cuatro documentos ofimáticos – la versión *MS Word* básica, la versión *MS Word* editada con la extensión *Save as DAISY*, la versión de *Pages* y la de *LibreOffice Writer* -y un documento EPUB creado directamente con *Sigil*-.

Tabla 2. Documentos de test

Nombre del archivo	Contenido
encabezados_*editor_conversor.ext*	6 niveles de encabezados
enlaces_*editor_conversor.ext*	un fragmento del cuento con una palabra en negrita, otra subrayada y otra en cursiva
estilos_texto_*editor_conversor.ext*	un fragmento del cuento con un enlace a un sitio web y otro enlace a un mail
imagenes_*editor_conversor.ext*	tres imágenes relacionadas con el cuento; una que hace la función de decorativa, otra con texto alternativo y otra con texto alternativo y epígrafe
listas_*editor_conversor.ext*	una lista ordenada, no ordenada y mixta
marca_agua_*editor_conversor.ext* (sólo en MS Word y LibreOffice)	marca de agua
notas_final_*editor_conversor.ext*	un fragmento del cuento con tres notas al final del documento
notas_pie_*editor_conversor.ext*	un fragmento del cuento con tres notas a pie de página
tablas_*editor_conversor.ext*	una tabla que sigue las pautas de accesibilidad

Cada uno de estos documentos se ha creado siguiendo buenas prácticas de creación de documentos accesibles [19], y se ha convertido a EPUB excepto en el caso de *Sigil*, que ya crea un EPUB directamente.

Tanto los documentos de test como el resultado de las conversiones respectivas se ofrecen en abierto en el web del grupo de trabajo Adaptabit [http://bd.ub.edu/grups/adaptabit/Interaccion2015/documents.zip] para su posible reutilización en investigaciones posteriores.

12.3 Evaluación

Para cada contenido de los documentos de muestra, se han creado unos documentos EPUB teóricos según las especificaciones EPUB2 y EPUB3 definidas por el International Digital Publishing Forum.

Los documentos resultantes de la conversión y los documentos EPUB teóricos se han comparado tanto visualmente como a nivel de código para identificar qué atributos se mantenían a través de la conversión. La evaluación, dado el bajo número de documentos, y la falta de investigaciones previas que permitieran automatizar la tarea, se ha realizado manualmente por los autores.

13. RESULTADOS

A continuación se detallan los resultados de las comparaciones entre los documentos convertidos reales y los documentos convertidos ideales elemento por elemento, para hacer finalmente una valoración de las distintas herramientas utilizadas.

13.1 Elementos

Encabezados.

Todas las herramientas convierten correctamente los encabezados a excepción de *Pages* que sólo convierte los encabezados hasta el tercer nivel. Este error es debido a una limitación en el propio editor de texto, que no permite la creación de encabezados superiores al nivel 3.

En la evaluación final cada nivel de encabezado bien convertido se ha ponderado cómo un 1/6 de la conversión de encabezados. Así todas las herramientas obtienen un 100% de ponderación, excepto *Pages* que obtiene un 50%.

Imágenes

Según los cuatro escenarios descritos anteriormente (ver sección 3.2.1.1):

- Imágenes decorativas:

Las imágenes decorativas no deben aparecer en las presentaciones no visuales pues no aportan contenido relevante ni realizan ninguna función de interacción, y por ello no requieren de texto alternativo. Únicamente *MS Word + Save as DAISY + Tobi* puede transformar imágenes con el atributo “alt” vacío, las demás herramientas por defecto añaden el nombre del fichero como texto alternativo si éste no aparece en el documento origen. Como alternativa, los editores de texto *MS Word* y *LibreOffice Writer* permiten añadir imágenes como marcas de agua pero estas desaparecen incluso de la presentación visual tras la transformación.

- Imágenes con texto alternativo

Todos los editores permiten añadir texto alternativo a sus imágenes menos *Sigil* -que automáticamente pone el nombre del fichero como texto alternativo-. Ahora bien, después de la transformación sólo lo preservan *Pages* y *MS Word + Save as DAISY + Tobi*. El conversor *W2E* no incorpora el texto alternativo que se especificó en el editor de texto sino que lo cambia automáticamente por el nombre del fichero. Por su parte, *Calibre* renombra todas la imágenes como “Imagen”, “Imagen1”, etc., por orden de aparición de las imágenes en el documento.

- Imágenes con texto alternativo y epígrafe

En EPUB3 se puede indicar el epígrafe con la etiqueta figcaption (ver Figura 3), y la mayoría de editores de texto ofrece funciones para incluir un epígrafe en las imágenes. Pero en las conversiones *Pages* no convierte el epígrafe como parte de la imagen sino como texto independiente, y únicamente *MS Word + Save as DAISY + Tobi* resuelve esta situación con una buena conversión, pues en la edición con la extensión *Save as DAISY* se ofrece una función adicional para indicar los epígrafes de las figuras.

```
<figure>
  <img alt="the three little pigs dancing" src="../%20Images/5-imatge1.jpg" />

  <figcaption>Image 1</figcaption>
</figure>
```

Image 1

Figura 3 Conversión *Save as DAISY+Tobi* de una imagen con texto alternativo y epígrafe

- Imagen con descripción detallada

Este escenario no está resuelto en los editores origen pero sí en EPUB3, gracias al atributo aria-describedby.

En la evaluación final cada uno de los escenarios planteados se ha puntuado con 1/4 de la conversión de imágenes. Así, *Save as DAISY + Tobi* obtiene un 75% de ponderación, *Pages* un 25% y las otras herramientas obtienen un 0%.

Listas

```
<ul>
  <li>One pig</li>
  <li>Two pigs</li>
  <li>Three pigs</li>
  <li>One wolf</li>
  <li> </li>
</ul>
```

- One pig
- Two pigs
- Three pigs
- One wolf
-

Figura 3. Conversión errónea de listas no ordenadas con W2E.

Sigil y *MS Word + Save as DAISY + Tobi* transforman correctamente los tres tipos de listas analizadas -ordenadas, no ordenadas y mixtas-; *Calibre* transforma correctamente las listas ordenadas y las no ordenadas. En cambio, *Pages* no crea listas verdaderas, sino que las simula mediante estilos CSS. Finalmente, *LibreOffice Writer + W2E* tienen un problema grave de formación de código de listas, pues, generalmente añaden un ítem vacío a la lista y genera un código HTML mal formado con dos etiquetas sin cerrar. Véase como muestra el código de la Figura 3: en el último ítem de lista se puede observar que falta la etiqueta de cierre, así como también falta la etiqueta de cierre de la lista.

En la evaluación final cada tipo de lista bien convertida se ha ponderado con 1/3 de la nota final de listas. Así *Sigil* y *Save as DAISY + Tobi* obtiene el 100% de puntuación y *Calibre* obtienen un 66%.

Tablas

Sigil no ofrece la opción de crear tablas desde la interfaz de texto, las tablas se pueden crear únicamente mediante la interfaz de código. A pesar de que las demás herramientas en el documento en origen permiten indicar encabezado, resumen y epígrafe para las tablas, en la conversión ninguna combinación de herramientas preserva el resumen de la tabla. La combinación *MS Word+ Save as DAISY +Tobi* preserva la estructura, el título y los encabezados en las tablas, pero añade un código superfluo en las celdas y muestra las tablas sin bordes (véanse las etiquetas de párrafo en el código de la Figura 4). *Pages, LibreOffice Writer + W2E* y *MS Word + Calibre* no distinguen entre celdas de encabezado y celdas de datos, y las transforman todas como celdas de datos.

```
<table>
  <caption>
    Houses and pigs table.
  </caption>
  <thead id="d3176e27">
    <tr>
      <th colspan="1" id="d3176e29" rowspan="1">
        <p>Pigs</p>
      </th>
      <th colspan="1" id="d3176e32" rowspan="1">
        <p>Houses</p>
      </th>
    </tr>
  </thead>
  <tbody id="d3176e35">
    <tr>
      <td colspan="1" id="d3176e37"
        <p>One pig</p>
      </td>
      <td colspan="1" id="d3176e40"
        <p>One pig</p>
      </td>
      •••
```

Houses and pigs table.

Pigs	Houses
One pig	One pig
Two pigs	Two houses
Three pigs	Three houses

Figura 4. Conversión de tablas con DAISY

Por lo que respecta al epígrafe, éste desaparece después de la transformación en *Pages* y en *LibreOffice Writer + W2E*, mientras que *MSWord + Calibre* lo presentan como un párrafo independiente de la tabla.

En la ponderación final cada elemento de la tabla bien convertido se ha ponderado con 1/4 de la calificación total de las tablas. *Sigil* se valora pues con un 0%, *Pages, W2E* y *Calibre* con un 25% y sólo *Save as DAISY + Tobi* aprueban con un 75%.

Estilos de texto.

Las combinaciones *LibreOffice + W2E* y *MS Word + Save as DAISY + Tobi* transforman la negrita y la cursiva en etiquetas semánticas (strong y em) mientras que *Calibre* y *Sigil* optan por etiquetas de presentación (b e i).

Por lo que respecta al estilo subrayado, todas las herramientas lo transforman haciendo uso de los estilos CSS, a excepción de *Sigil* que emplea la etiqueta <u> -actualmente obsoleta-. Finalmente, *Pages* codifica estos estilos mediante hojas CSS y no mediante código semántico HTML tal y como muestra la figura 5.

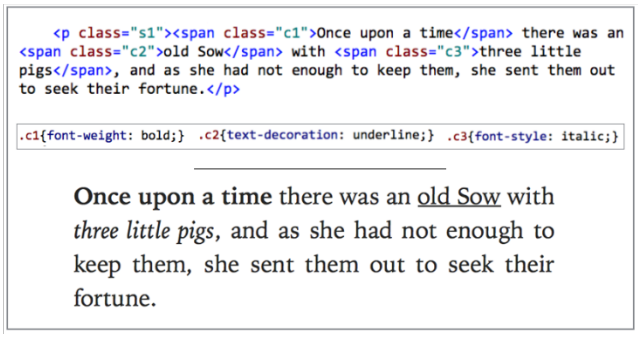

Figura 5. Conversión de estilos de texto con Pages.

Para cada uno de los estilos analizados en la puntuación final se ha asignado 1/6 de la nota total de estilos si en la conversión se utilizan etiquetas de presentación y 1/3 si se utilizan etiquetas semánticas.

Así, *W2E* y *Save as DAISY + Tobi* obtienen la máxima calificación, *Pages* queda con un triste 16%, *Sigil* le sigue con una puntuación de 33% y *Calibre* con un aprobado justo del 50%.

Notas.

Aunque los editores de texto permiten insertar notas a pie de página, en el formato EPUB esta opción no existe. Para dar una solución a las notas originales a pie de página *Pages* y *W2E* generan en el fichero EPUB una página HTML nueva en la que ubican todas las notas que en los editores de texto eran notas a pie de página, en cambio, *Save as DAISY + Tobi* las convierte como notas al final del documento y *Calibre* crea una página HTML nueva para cada una de las notas. Por lo que respecta a las notas al final del documento, *Pages* y *W2E* las transforman del mismo modo que las del pie de página, es decir, ubicándolas en una página aparte, mientras que *Save as DAISY + Tobi* da error en la conversión y únicamente *Calibre* las transforman correctamente al final del cuerpo del texto. El editor *Sigil* no proporciona un modo directo para crear notas desde la interfaz de texto.

La conversión de cada tipo de notas se ha ponderado en la evaluación final con 1/2 de la calificación global de las notas. Así *Calibre* obtienen una calificación de 100%, mientras que *Pages*, *W2E* y *Save as DAISY + Tobi* se quedan en el 50%, y *Sigil* con un 0%.

Enlaces.

Todos los correctores transforman los enlaces correctamente, tanto los que redirigen a un sitio web como los que permiten enviar un correo electrónico. En éstos últimos, las herramientas ofimáticas permiten indicar un campo "Tema" que las herramientas de conversión añaden en el enlace URL del correo electrónico. En el editor WYSWYG de *Sigil* no aparece esta posibilidad, y si se quiere incluir el tema hay que añadirlo manualmente.

Cada tipo de enlace se ha ponderado con un 50% de la nota final, y todas las herramientas obtienen el 100% de la calificación.

En la tabla 3 se pueden consultar los valores agregados.

Tabla 3. Evaluación numérica de la conversión

	Encabezados 20 %	Imágenes 20 %	Listas 20 %	Tablas 20 %	Notas 10 %	Estilos de texto 5 %	Enlaces 5 %	Total 100 %
Pages	10 %	5 %	0 %	5 %	5 %	0,7 %	5 %	30,7 %
W2E	20 %	0 %	0 %	5 %	5 %	5 %	5 %	40 %
Sigil	20 %	0 %	20 %	0 %	0 %	1,5 %	5 %	46,5 %
Calibre	20 %	0 %	13,3 %	5 %	10 %	2,5 %	5 %	55,8 %
Save as DAISY+ Tobi	20 %	15 %	20 %	15 %	5 %	5 %	5 %	85 %

13.2 Valoración de las herramientas

Pages

Aunque es el único editor ofimático analizado que integra la posibilidad de exportar nativamente al formato EPUB es el que peor puntuación obtiene de todos los conversores. En los elementos considerados básicos, esto es, encabezados, imágenes, listas y tablas, está muy lejos de realizar conversiones aceptables. Por lo que respecta a los elementos considerados secundarios, es decir, notas, estilos de texto y enlaces, solamente en el últimos obtiene la máxima puntuación. Dicho esto, en una evaluación únicamente con criterios visuales, es decir, sin tener en cuenta la corrección del código, la mejor conversión sería sin duda la del editor *Pages*, pues sus conversiones son muy fieles al documento ofimático. Las imágenes, tablas, listas, y otros elementos aparecen con mucha fidelidad tras la conversión. Parece que en el conversor de *Pages* los esfuerzos técnicos de transformación se han dirigido al lenguaje CSS, dejando en un segundo plano la corrección del código HTML.

Figura 6. Conversión de listas en Pages

Writer2epub

Este conversor obtiene una puntuación global de 40 sobre 100. De los elementos básicos sólo en los encabezados realiza una buena conversión, mientras que en los demás elementos –imágenes, listas y tablas- las conversiones son absolutamente deficientes hasta tal punto que, en el caso de las listas, los lectores EPUB deben corregir el código (ver Figura 7).

Únicamente las conversiones de los elementos secundarios -notas, estilos de texto y enlaces- son correctas. Cabe esperar que en futuras versiones del conversor [2] estos errores se solucionen.

Sigil

Este editor obtiene una puntación global de 46.5 sobre 100. Ante este resultado cabe recordar que *Sigil* es propiamente un editor EPUB y por lo tanto, con ciertos conocimientos de código –básicamente HTML y CSS- puede conseguirse la máxima puntación. No obstante, en este estudio se han analizado sólo las funcionalidades del editor WYSWYG de *Sigil*, según el uso que podría darle un usuario sin conocimientos de código.

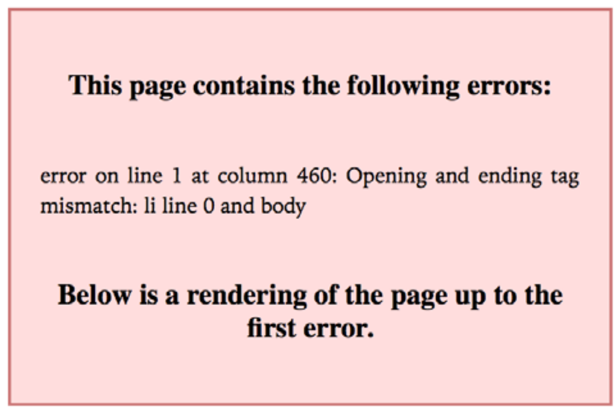

Figura 7. Comentario del lector iBooks. Este tipo de errores pone de manifiesto la necesidad de informar a los usuarios sobre la calidad de las transformaciones.

En su editor de texto, *Sigil* no ofrece la posibilidad de crear tablas ni notas y en las imágenes ofrece pocas posibilidades. Los demás elementos, a excepción de los estilos de texto que no los marca semánticamente, los realiza correctamente.

Si *Sigil* mejorara el gestor de imágenes e incorporara las tablas y las notas a sus funcionalidades WYSWYG sería sin duda la herramienta recomendada para la creación de documentos EPUB accesibles por parte del usuario no técnico. Desgraciadamente el desarrollo de *Sigil* en los últimos tiempos ha tenido altos y bajos [10] y su continuación está en entredicho.

Calibre

Este conversor consigue una puntación global de 55.8 sobre 100. Las conversiones de imágenes y tablas -5 de 40 puntos posibles- penalizan mucho el resultado global. Una mejora en estos elementos beneficiaría muchísimas conversiones pues

Calibre no es solo una de las herramientas más usadas para crear EPUBs, sino que es la base de otras herramientas como RoboBraille [http://www.robobraille.org/], el Convertidor [http://www.elconvertidor.com/ebook-converter.php] Online Converter [http://ebook.online-convert.com/es/convertir-a-epub] u otros. Sorprende que *Calibre* todavía no haya actualizado las conversiones a EPUB3 pues, al contrario que *Sigil*, *Calibre* cuenta con una comunidad de desarrolladores muy activa.

Save as DAISY + Tobi

Como se ha dicho en el apartado 3.1 la elección del complemento *Save as DAISY* y la aplicación *Tobi* no se debe a su alta adopción por parte de los usuarios no técnicos sino por su especial atención a la codificación semántica. No es casualidad entonces que obtengan la puntuación más alta de todos los conversores analizados, 85 sobre 100. No obstante, debe mencionarse que la instalación de estas dos herramientas, sobretodo en el caso de *Tobi*, no es tan sencilla como puede ser la de las otras herramientas analizadas, pues requiere disponer de una máquina virtual Java, instalar Net framework, etc. En el caso del complemento *Save as DAISY* para crear un documento altamente accesible deben seguirse unas recomendaciones adicionales para los pies de figura, notas, etc. que aumentan levemente la dificultad de creación del documento original. Ambas herramientas tienen planificadas actualizaciones [7] y cuentan con una organización sólida tras ellos y financiación.

14. CONCLUSIONES

El formato EPUB, desde su adopción por IDPF como estándar oficial en septiembre de 2007, ha tenido una gran difusión como formato de publicaciones digitales [25], pero esta adopción no ha llegado aún al gran público autor de documentos, pues entre las herramientas ofimáticas más adoptadas, solamente *Pages* puede exportar nativamente a EPUB sus documentos, mientras que tanto *Pages* como los demás editores sí pueden exportar a PDF.

Por otro lado, son escasos los complementos o herramientas externas gratuitas que conviertan documentos ofimáticos al formato EPUB3. La mayoría todavía lo hace al formato EPUB2 [14] a pesar que las especificaciones de EPUB3 fueron aprobadas en octubre de 2011 e incluyen cambios notables respecto su versión anterior. Ello puede ser debido a la dificultad de los pequeños desarrolladores para encontrar los recursos necesarios para mantenerse al día de las nuevas versiones o estándares [22] [1].

Finalmente cabe resaltar, como se muestra en los resultados, que las conversiones de estas herramientas no son aceptables -especialmente en lo que concierne a los criterios de accesibilidad- y hacen inviable la creación de documentos EPUB de calidad por el usuario no técnico. El autor de un documento no conoce de antemano ni recibe ningún tipo de retroacción sobre la calidad de la transformación y las características de accesibilidad introducidas en el documento de origen por norma general se pierden por el camino.

Por otra parte las directrices ATAG 2.0 se quedan muy cortas en sus exigencias y descripción de los problemas de conversión, y se requerirían descripciones más completas, como las propuestas en [16] o [3] para modelizar las conversiones entre diferentes formatos de documentos digitales.

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Exploring language technologies to provide support to WCAG 2.0 and E2R guidelines

Lourdes Moreno
Labda Group, Computer science department
Universidad Carlos III de Madrid
lmoreno@inf.uc3m.es

Paloma Martínez
Labda Group, Computer science department
Universidad Carlos III de Madrid
pmf@inf.uc3m.es

Isabel Segura-Bedmar
Labda Group, Computer science department
Universidad Carlos III de Madrid
isegura@inf.uc3m.es

Ricardo Revert
Labda Group, Computer science department
Universidad Carlos III de Madrid
rrevert@inf.uc3m.es

ABSTRACT

Part of citizenship faces accessibility barriers when they read and understand texts containing long sentences, unusual words, complex linguistic structures, etc. Readability and understanding should be considered when texts are created. In order to make online texts more accessible, there are initiatives as Easy-to-Read (E2R) and Web Content Accessibility Guidelines (WCAG) 2.0, however they do not cover every need that arises in this regard. In addition to accessibility guidelines and E2R rules, technology supporting the authorship of texts is required because the transformation of a text to an easier text to read and understandable is impossible. As a solution to the need to have (semi)automatic support to comply with accessibility and E2R guidelines, the application of Natural Language Processing (NLP) resources and methods is proposed. In this paper, E2R guidelines are introduced and a subset of WCAG guidelines regarding readability and understanding has been obtained. In addition, a review on NLP technology concerning accessibility is given. To illustrate this proposal for improving accessibility using PLN approaches, a use case for simplifying drug package leaflets in Spanish is introduced.

Categories and Subject Descriptors

K.4.2 **[Computers and Society]**: Social Issues -handicapped persons/special needs, I.2.7 **[Natural Language Processing]**: Text Analysis

Keywords

Web accessibility, Easy-to-Read, disability, Natural Language Processing, Text Simplification, Lexical Simplification

1. INTRODUCTION

The problem of readability is under investigation since 1920s, when educators discovered a way to use vocabulary difficulty and sentence length to predict the difficulty level of a text [14]. Reading and understanding texts containing long sentences, unusual words, and complex linguistic structures among others can be very hard for persons with cognitive or learning disabilities [41].

Reading difficulties and the impact of different linguistic deficiencies especially in learning are known [15]. In order to make online texts more accessible and readable to these groups of readers, E2R guidelines [17] were produced. Moreover, the WCAG 2.0 accessibility guidelines [47] created by W3C are concerned as a standard for the industry and many important principles from the standpoint of an E2R are highlighted in these guidelines. However, the capability of the WCAG 2.0 to estimate accessibility of a website for E2R is not complete in all situations [1].

WCAG 2.0 contain some accessibility guidelines regarding the text related to the readability and understanding. Some of these guidelines have the highest conformance level (Level of Conformance AAA). WCAG 2.0 is standard ISO among others and is the work of reference in the most of the regulatory frameworks and laws in the countries. These laws require a Level AA, this can cause these requirements (of Level AAA) are not raised. If these guidelines are not fulfilled, there are user groups affected with accessibility barriers. These user groups are people with any kind of cognitive disability. One of them is older people group [31]. Figures indicate that in the coming decades will be a large number of older citizens and at the same time, active citizens in the use of ICT. Consequently, the age related a disability is a very important factor to keep in mind. If accessibility barriers regarding the text are not stopped, the digital divide will increase in the near future.

WCAG 2.0 documentation provides useful techniques in conjunction with to satisfying these guidelines regarding the text; however, these guidelines are complicated requirements to carry out in web applications and web sites, especially in large-scale web sites. Despite the existence of a complexity to comply with these accessibility requirements related to the accessible text, there are techniques and technologies from different disciplines that can be used to support these requirements of the accessibility standards. Just as there are works of the discipline of Software Engineering and Web Engineering to integrate accessibility in the design process [27] [32], there are important works on the scope of the Natural Language Processing (NLP) that may offer support to comply with the guidelines regarding to the accessible text [39] [5] as proposed in this work. The paper aim is to introduce opportunities to integrate these NLP approaches into authoring tools, as well as possible services to be able to offer to improve accessibility in text content as the readability and understanding.

In this paper, E2R guidelines are introduced in the section 2. In order to help professionals who have an interest to fulfil these guidelines, section 3 an overview of techniques, methods and tools of NLP focused on approaches simplification of text is introduced. In section 4, a set of WCAG 2.0 accessibility requirements related to this issue is presented. In order to clarify this support of NLP methods to improve the accessibility, a proof of concept in the drug package leaflets is presented in the section 5. Finally, conclusions and future work are presented.

2. EASY-TO-READ (E2R) Guidelines

Readers with cognitive disabilities among others often experience difficulties understanding complex words and deriving their meaning from the context [6]. In order to make online texts more accessible to these groups of readers, their content should follow E2R guidelines [17] and thus be uncovered of complex words or phrases that could be replaced with more commonly used words [13]. These adaptations are carried out with the use of text simplification techniques which will be presented in this paper.

In the past decades, in many countries guidelines on E2R have developed [21] [20]. Usage examples of these guidelines are, for example, in Spanish (Discapnet)[4] or in English with (Journal of Inclusion Europe)[5] and news with simple summaries with access 'easy reading' (Simple English Wikipedia)[6]. Highlight the System Simplex project; it is aimed at producing a text simplification system for Spanish[7].

2.1 E2R target groups

The importance of understandable content and accessible information for people with learning difficulties has received increased attention in last decade. People with intellectual and learning disabilities are the main E2R target group. Additionally, pre-lingually deaf persons, deafblind persons, persons with dementia belong to the group [34]. Individual cognitive abilities such as attention span and memory also play a role as can be the case of older people. Good practices in E2R benefit non-alphabetized people and immigrants with a different native language [28]. Furthermore, research with application de E2R based technology with good results for people with aphasia, dyslexia, and autism are found [38] [12].

If authors produced texts that are simple to read and understand, the result is not only more accessible to people with cognitive disabilities, but also for all users [41].

2.2 E2R goals

There is still no overall acceptance on the common linguistic principles of E2R. They vary from detailed and strict standards of Inclusion Europe 2009 to holistic and loose guidelines of IFLA 2010 [25]:

- to the definition of the people needing E2R
- to the definition of text genres that are supposed to be simplified.

Also, E2R goals of both guidelines differ in some fundamental aspects (see Table 1).

From these guidelines and initiatives arise specific guidelines, which can help address the increased demand for E2R content on the Web. In general terms these guidelines are: use the simplest and most common words should, that long words should be avoided, should be avoided use of abbreviations and that the same term should be consistently used to refer to the same concept. Besides, use short sentences, avoid complex sentences with dependent clauses, use active language and avoid passive voice.

Table 1: Main different aspect between E2R guidelines

IFLA guidelines	Inclusion Europe 2009 standard
It mainly concentrates on People with very different linguistic needs as the target groups.	It mainly concentrates on People with intellectual disability.
Not planned to develop detailed guidelines for E2R.	To provide precise and normative rules for producing E2R.

These guidelines help to produce texts E2R, but they are aimed only to text content. According to user studies, the most important principles in addition to E2R guidelines itself are related to page structure and the amount of information on a web page [1]. For this reason, accessibility requirements of WCAG 2.0 must be taken into account such as will indicate in section 4.

3. NLP APPROACHES FOR TEXT SIMPLIFICATION

Natural language processing (NLP) is a discipline devoted to develop technology to understand natural language in a similar way human being does it. It has different applications such as machine translation, information retrieval, information extraction from unstructured data, summarization, question answering and many others. Tokenization, part-of-speech tagging, syntactic parsing, named entity recognition, relation extraction among others processes are integrated in different architectures to analyse texts.

In recent years research has been done in the area of text simplification where NLP processes are applied with the objective of transforming a text in an equivalent one but more accessible to people with any kind of cognitive disability. This section describes related works carried out in the area of text simplification. For the purpose of this work three NLP processes that could be applied to text simplification tasks are described: language detection, abbreviations detection and topic detection

Language detection consists on identifying the language of a text and is useful if language-dependent NLP processes are used. It is also helpful for example, when screen readers are used. A usual method is to find out it is to check if language-specific characters, e.g. Dutch if string “ik” appears, German is “ich” or “β” is used, Polish if “czy” or “ń”, “Ł”, “ź” are included in words. These conditions can be easily implemented as rules in a

[4] www.noticiasfacil.es
[5] http://www.e-include.info/
[6] http://simple.wikipedia.org/
[7] http://www.simplext.es/

text tokenizer[8]. Other approaches, [7], use n-grams[9] frequency distributions. All languages have words that occur more frequently than others (Zipf´s Law[10]), therefore if two texts of a same language are compared then they should have similar n-grams frequency distributions. This method has limited success it is applied to language detection of short texts.

Concerning abbreviations, this is an active area in processing biomedical texts due to the fact that many acronyms and abbreviations in scientific literature, clinical reports, etc. Abbreviation detection and expansion is also a useful technique that contributes to enhance text understanding in the accessibility field. Main approaches to recognized abbreviations and corresponding expansions use pattern-matching methods based on rules and heuristics to detect upper alphanumeric strings with the objective of identify *Long form (short form)* or *Short form (long form)* utterances. For instance, in the utterance *acquired immune deficiency syndrome (AIDS), AIDS* is the short form and *acquired immune deficiency syndrome* is the long for (or definition). [35] describes a method that combines linguistic information (POS tags, noun phrases and stop words) with statistical information (frequency of terms, length of terms, frequency of nested terms) to extract terms that appear frequently next to an abbreviation in a collection of texts. The hypothesis is if a sequence of words co-occurs frequently with an abbreviation and the sequence does not occur with other near words then it is assumed that there is a “abbreviation-definition” relationship.

Third NLP technique is automatic text summarization or topic detection. This technique is of great interest due to the fact that editors of web contents could require tools to create titles of paragraphs and sections that faithfully represent the content they head.

The goal of automatic text summarization is to obtain a set of sentences that reflects its content, A summary could be only a sentence, such as the case of a headline for news or it could be several sentences, as in abstracts of scientific publications. A good definition of a summary is [44]: A reductive transformation of source text through content reduction by selection and/or generalisation on what is important in the so usually, people make summaries by exploring the document, making judgments of relevance and finally, generating the abstract. This is a difficult task to evaluate because there is no a clear idea about what is a good summary.

Automatic text extraction is the most used approach to obtain summaries. One common approach is to use a surface-base methods that considers that relevant sentences of a text have a big amount of important words. The importance of a word is calculated with a TF*IDF measure that relies on how frequent is a word in a document and in how many documents from a collection the word appears. This measure can be enhanced taking into account the position of the sentences (important sentences appear in specific places, for instance in introduction and conclusions sections of a paper) or giving more score to words of headings. Also cue words depending of the type of summary and patterns could be considered..

The algorithm has four steps: (1) score all the words of the document according to the TF*IF measure, (2) score all the sentences in the text by adding the scores of the words from these sentences, (3) take out the sentences with top N scores and (4) display the extracted sentences in the original order. If the objective is to entitle a paragraph the algorithm should extract in step 3 only the top scored sentence. This sentence is the best candidate as title of the paragraph.

The approaches reviewed in this section are useful resources to comply with some WCAG 2.0 guidelines concerning the readability and understandability, some of them and their correspondence with WCAG 2.0 success criteria are shown in Section 4.

3.1 Text Simplification

First works in text simplification started 20 years ago [8]. It is based on transforming a text in an equivalent text that is easier to read and probably easier to understand by a target audience. In automatic text simplification there are different levels of difficulty in texts to be considered.

There is a need of content adaptation to some groups of people with disabilities due to information is not equally accessible to everyone. It is highly unlikely that professionals elaborate adapted texts and NLP techniques could help to simplifying texts by automatizing some tasks. In this way, it is possible to help content editors to generate adapted contents. On the other hand, text simplification is essential in several types of texts: News, Government and administrative information, laws and rights, etc.

There are three subtasks of text simplification, Saggion et al. (2011) [40]: (1) syntactic simplification that divides complex sentences in simplest sentences, (2) lexical simplification whose objective is to replace complex vocabulary by common vocabulary and (3) clarification that provides definitions and explanations. These tasks are not completely automatic, they have to be manually reviewed in some cases.

As it has been previously mentioned, there are authors that distinguish between readability and understandability, these concepts capture different aspects of the complexity of the text. Readability gives an evaluation about the structure of sentences (it concerns syntax and consequently requires syntactic simplification approaches). On the other side, understandability captures the lexical aspects [3] and lexical simplification approaches are required.

Concerning syntactic simplification it consists on transforming complex and long sentences into simplest and independent sentences eliminating coordination (of clauses, verbs, etc.), dropping subordination utterances (relative clauses, gerundive and participle utterances), resolving anaphora and transforming passive into active voice. First a parser is used to obtain a dependency tree that represents the syntactic structure of the sentence (noun, prepositional and verbal phrases and how they

[8] NLP process devoted to identify sentences and tokens of a text (words, punctuation marks, etc.)

[9] A n-gram is a sequence of n characters that are part of a string (including blanks). For instance, bi-grams of the word “book” are _b, bo, oo, ok, k_; tri-grams are _bo, boo, ook, ok_, etc.

[10] Given a corpora of utterances, the frequency of any word is inversely proportional to its rank in the frequency table

are related to). Then, rule-based approaches are used in syntactic simplification. Rules can be automatically learned from annotated corpora of text (syntactic trees of sentences where original sentences are related to their simplified sentences), [49] or handcrafted rules [8] [43]. The rules include *split*, *drop*, *copying* and *reordering* operations over syntactic trees.

Related to lexical simplification, this task consists on replacing words (taking into account the context) and complex utterances by easier words or phrases. A heuristic used is that complex words have a low frequency. Moreover, lexical resources as Wordnet, [16], are used to extract synonyms as candidates to replace a complex or difficult word. Combining a lexical resource and a probabilistic model is an approach that has been tried [11]. Probabilistic models are obtained from lexical simplifications have previously done applying E2R guidelines, as in the Simple Wikipedia. McCarthy and Navigly (2007) [30] introduces work to propose candidates to replace a word using contexts. In Semeval 2012, English Lexical Simplification challenge[11] with ten participant systems, the evaluation results showed that proposals based on frequency give good results comparing to other sophisticated systems.

But before simplifying we have to know le level of readability of a text by using complexity measures. There are simple measures based on frequency of words in texts as well as length of phrases, FOX index [18], Flesch-Kinaid [24] measures are used in English. In Spanish texts, [2] describes several indexes to measure the structural complexity of a text: the number or verbal predicates in subordinate clauses, and the index of sentence recursion (a measure that counts the number of nested clauses in the text). To measure the lexical complexity two indexes are proposed: an index of low frequency words (the number of content words[12] with low frequency[13]/ Total of lexical words) and an index of lexical density (number of distinct content words /total of discourse segments[14]. Finally, other indexes such as the average length of sentences and average length of words (syllables) although they are criticized.

These indexes have to be validated by final users. Knowing the readability level of a document, users have the opportunity to choose the most suitable text, from a collection of documents delivering the same information [41].

This paper describes in section 5 a prototype for lexical simplification of drug package leaflets. In particular, each drug effect is replaced by a simpler synonym. The MedDRA resource is used to obtain the set of synonyms for each effect. The prototype proposes two possible simpler synonyms: the preferred term proposed by MedDRA and the MedDRA synonym with the highest frequency in a collection of documents gathered from the MedLinePlus website.

[11] http://www.cs.york.ac.uk/semeval-2012/task1/

[12] A content word is a word with meaning (nouns, verbs, adjectives and adverbs)

[13] There are several resources/corpora to query the frequency of a word. In Spanish, for instance, there is the CREA corpus, http://corpus.rae.es/creanet.html

[14] A discourse segment is a sentence or a phrase.

Finally, there are specific works to simplify numerical expressions. Bautista and Saggion (2014) [4] propose a rule-based lexical component that simplifies numerical expressions in Spanish texts. This work makes news articles more accessible to certain readers by rewriting difficult numerical expressions in a simpler way.

3.2 Support Technology

The use of tools to assist authors and support the linguistic analysis could be explored further [28]. Implementing E2R asks for research and discussion of automated tools helping with analyses grammar/semantic as well as navigation/interaction in order to support users and authors of web content [33].

Different NLP tools which have been integrated in existing text editor are found in some systems; these tools have the aim of providing support for text simplification experts who prepare easy-to-read texts in English [19]. Other related tool is SPARTA2 [41], a Word plug-in for text simplification in Italian language.

4. WCAG 2.0: READABILITY AND UNDERSTANDABILITY

In this section, Web Content Accessibility Guidelines (WCAG) 2.0 standard is introduced, and a subset of accessibility requirements relating text content of WCAG 2.0 is presented. These accessibility requirements can be supported by NLP methods to achieve compliance.

4.1 Layers of Guidance

WCAG 2.0 defines how to make Web content more accessible to people with disabilities. The professionals that adopt WCAG vary widely and include web designers and developers, policy makers, purchasing agents, teachers, and students. In order to meet the different needs of this audience, several layers of guidance are provided including overall principles, general guidelines and testable success criteria with techniques are provided.

There are four principles to be considered accessing and using Web content. Anyone who wants to use the Web must have content following these principles: Perceivable (Information and user interface components must be presented to users in such a way they can perceive them), Operable (User interface components and navigation must be operable), Understandable (Information and user interface must be understandable), Robust (Content must be robust enough that it can be interpreted reliably by a wide variety of user agents, including assistive technologies).

Under each of the principles there are guidelines and success criteria that help to address these principles for people with disabilities. The guidelines are not testable, but provide the framework and overall objectives to help authors understand the success criteria and better implement the techniques. For each guideline, testable success criteria are provided to allow WCAG 2.0 to be used where requirements and conformance testing are necessary. In order to meet the needs of different groups and different situations, as it has been previously mentioned there are three levels of conformance: A (lowest), AA, and AAA (highest).

4.2 WCAG success criteria concerning text content

After analyzing the WCAG 2.0, we propose a subset of success criteria for the textual content (see Table 2). As indicated above, in E2R guidelines two fundamental concepts are always present: understandable and readability. Some authors treat these concepts in a combined way, but others make a distinction between readability and understandability. These concepts capture different aspects of the complexity of the text: “a text could be highly readable, since the syntax is extremely simple, but extremely hard to understand because of the lexicon used” [41]. In section 3 have been described different NLP strategies to simplify texts depending on whether you want to analyze understandable or readability. One of the guidelines of WCAG 2.0 is 3.1 (*Readable: Make text content readable and understandable*); this guideline comprises various success criteria. Readability concept has a direct correspondence with the success criteria 3.1.5 (*Reading Level*), however, for understandable, several success criteria should be considered as 3.1.3 (*Unusual Words*) and (3.1.4 *Abbreviations*) among others.

As proposed in this work, NLP methods can be used in order to evaluate or detect that a WCAG 2.0 success criteria is not satisfied, besides providing a reparation proposal for the success criteria failure. Works in the accessibility field propose the use NLP techniques in order to help users to better understand web contents as well as the operation of the user interface [29] are found.

For example in the case of following success criteria 2.4.2 (*Page Titled*), 2.4.6 *(Headings and Labels*) and 2.4.10 (*Section Headings*), in the process that follows a person when interpreting a text it is important the existence of well determined titles, because these titles are activated during the processing of a text as help understanding the information through schemes that also eliminate the ambiguity. For web documents that lack these important elements, NLP approaches presented in section 3 as text simplification through the topic detection task can be used in order to repair these documents generating titles and headings.

Similarly could give support to success criteria 3.1.3 (*Unusual Words*), through the combined use of PLN approach and dictionaries with definition, an extension in the users' browsers using a glossary to enhance the original web content with these explanations could to be provided.. Another case is the use of approach text simplification through the abbreviations detection task in order to detect abbreviations/acronyms and obtains their corresponding expansions to be repairing it. The accessibility requirement indicates that the expansion of an abbreviation must be provided to the reader. So, this approach would help comply with the success criterion 3.1.4 (*Abbreviations).*

Finally, for success criteria 3.1.5 (*Reading Level*), as indicated the syntactic simplification approaches are required.

Table 2. WCAG 2.0 success criteria concerning text content (*)

Code (Level Conformance)	**Description**
1.1.1 Non-text Content (Level A).	Every non-text content that is presented to the user has a alternative text that serves the equivalent purpose
2.4.2 Page Titled (Level A).	Web pages have titles that describe topic or purpose.
2.4.4 Link Purpose (In Context): (text type)	The purpose of each link can be determined from the link text alone or from the link text together with its programmatically determined link context
2.4.6 Headings and Labels (Level AA).	Headings and labels describe topic or purpose.
2.4.9 Link Purpose (Link Only) (Level AAA). (text type)	A mechanism is available to allow the purpose of each link to be identified from link text alone, except where the purpose of the link would be ambiguous to users in general.
2.4.10 Section Headings (Level AAA).	Section headings are used to organize the content.
3.1.1 Language of Page (Level A).	The default human language of each Web page can be programmatically determined.
3.1.2 Language of Parts (Level AA).	The human language of each passage or phrase in the content can be programmatically determined.
3.1.3 Unusual Words (Level AAA).	A mechanism is available for identifying specific definitions of words or phrases used in an unusual.
3.1.4 Abbreviations (Level AAA).	A mechanism for identifying the expanded form or meaning of abbreviations is available.
3.1.5 Reading Level (Level AAA).	When text requires reading ability more advanced than the lower secondary education level after removal of proper names and titles, supplemental content, or a version that does not require reading ability more advanced than the lower secondary education level, is available.

(*) Success criteria concerning to captioning (1.2.2, 1.2.4) were not considered because they follow specific standards on how to create captioning for the deaf.

4.3 Additional accessibility requirements

One important issue when E2R content is published in web page is the fact that E2R audience is a very heterogeneous with different needs. For some user groups an easier content is enough but some user groups need a user interface easier to use [1]. So, in addition to the linguistic features of E2R, more accessibility features should be explored [28]. In addition to language itself, the most important factors influencing accessibility of web pages for E2R users are page structure, navigation structures, the amount of information on a webpage and the way elements in a web page are highlighted.

WCAG 2.0 document does not specify guidelines to these matters in a same precision level as it does to matters concerning visual or auditory accessibility, because of that it is more challenging to use WCAG 2.0 with E2R user groups [1].

Although there WAI documentation in this regard [48], the accuracy of E2R criteria for digital information should be reviewed, especially regarding the coverage of E2R in WCAG [28].

Through an analysis carried out, a set of additional WCAG 2.0 success criteria has been obtained. This proposal contains important accessibility requirements regarding the presentation, navigation, structure, cognitive aspects in user task, etc. that must be taken into account in addition to those concerning the textual contents (see Table 2) and E2R guidelines. These additional success criteria are: 1.4.8 (*Visual Presentation*), 2.4.5 (*Multiple Ways*), 3.2.3 (*Consistent Navigation*), 3.2.4 (*Consistent Identification*), 2.2.3 (No Timing), 3.3.1 (*Error Identification*), 3.3.2 (*Labels or Instructions*) and 3.3.5 (*Help*).

4.4 Discussion and conclusions

After the analysis and study conducted, the following main results are obtained:

A confusion of how to use the WCAG 2.0 has been detected. It is due to the lack of correspondence between the two leading concepts in E2R guidelines (readability and understandability) and success criteria of WCAG 2.0. This situation causes the professional closely to the field of the accessibility conformity WCAG does not know how to accomplish requirements E2R.

Aside from WCAG 2.0 success criteria regarding the text, further accessibility features should be considered. These are navigation structures, the amount of information on a web page and visual presentation among others.

Moreover, in WCAG 2.0 support is not provided beyond the list of related resources provided for each WCAG 2.0 success criteria. As the solution, the PLN approaches with a use of E2R resources provide the support needed.

5. PROOF OF CONCEPT: LEXICAL SIMPLIFICATION OF DRUG PACKAGE LEAFLETS

NLP approaches as simplifying the texts have been reviewed. In this section, a proof of concept which shows the adequacy of an NLP approach to make texts more accessible is presented.

The principal text source of information for patients about their medications is package leaflet. This document provides informative details about a medicine, including its appearance, actions, side effects and drug interactions, contraindications, special warnings, etc. Several studies [36][10] have shown that there is an urgent need to improve the quality of drug package leaflets because they are usually too difficult to understand by patients, especially those with low literacy skills as well as elderly people, and could result in misuse of medications. Posology and administration, contraindications and adverse drug reactions seem to be the sections most difficult to understand [26]. The vocabulary used is too specific, too technical. Also, readers usually have trouble understanding long paragraphs, *especially* those containing lists of side effects. Furthermore, drug package leaflets are usually written using a too small font size (9 points), which does not seem to encourage patients to read these documents. Patient misunderstanding could be a potential source of drug related problems, such as medication errors and adverse drug reactions.

We created a system with the objective of simplifying the lexical difficulties that patients may encounter when facing with package leaflets. The main goal of our system is to present the information in an easy and clear way to read. Medical terms (in particular, drug effects) are translated into lay terms, which patients can understand. In this way, accessibility is improved and compliance with WCAG 2.0 success criteria of the guideline 3.1 is supported.

Lexical simplification (which basically consists in replacing complex concepts with simpler synonyms) has been applied to simplify texts from different domains (such as crisis management [45], health information [22], aphasic readers [6] [12], language learners [37], but they have not used to simplify drug package leaflets.

5.1 System architecture

The architecture of the system is a pipeline in GATE[15], in which we can recognize two different modules (see Figure 1): a first module to recognize drug effects and a second one to simply these terms.

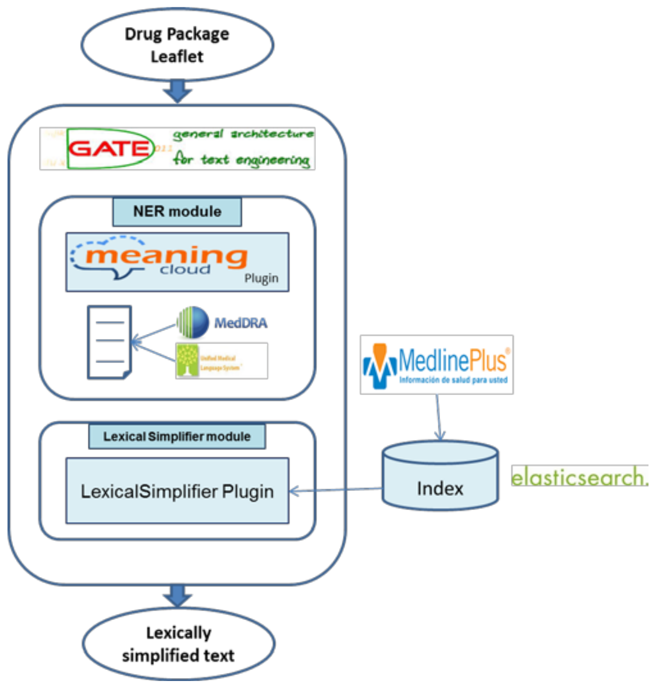

Figure 1 - Architecture of the system

5.1.1 *First module: NER*

The first module performs the Named Entity Recognition (NER) task. Specifically, this module detects the mentions of drug effects in the package leaflets. To do this, we used MeaningCloud[16], a multilingual text analysis engine to extract information from any type of texts. We have previously developed several pipelines basesd on this technology to NER (drugs, diseases, adverse effects among others) [42]. This tool follows a dictionary-based approach to identify named entities. In particular, we used MedDRA[17], a medical multilingual terminology dictionary about events associated with drugs, as dictionary to recognize drug effects. We used a plugin, which integrates MeaningCloud into GATE.

[15] http://gate.ac.uk/
[16] https://www.meaningcloud.com/
[17] http://www.meddra.org/

5.1.2 Second module: Lexical Simplifier

Once the drug effects have been detected in the package leaflets, the second and main module identifies the effects whose names are considered complex with the objective of replacing them by a simpler synonym. Thus, the LexicalSimplifier module is aimed to check whether a given effect is a complex term or not. If it is a complex term, then it is replaced by an easier synonym, following two different strategies: preferred term substitution and most frequent term substitution.

Preferred Term Substitution

The hierarchical structure of MedDRA allows to defining sets of synonyms and providing a preferred term for each set. Therefore, this first strategy consists in substituting an effect for its preferred term as described by MedDRA (if it is not itself). For example, *cefalalgia* (cephalalgia) would be substituted for *cefalea* (headache).

Most Frequent Term Substitution

For this strategy, we take into account the frequency of appearance of all the different effects in a corpus of MedlinePlus documents. A total of 1,536 documents were gathered from the MedLinePlus website[18] using the Java HTML parser jsoup, 939 belonging to drug package leaflets and 597 to general health related articles about diseases, effects and diagnoses. We used Elasticsearch[19] to index the MedLinePlus documents. Elasticsearch is a flexible, powerful, open source, distributed and real-time search and analytics engine, which runs on top of Apache Lucene, offering complex search capabilities, high-performance and being reliable.

In order to calculate the frequency of each effect in the corpus, we lean on the Elasticsearch index, obtaining the number of hits for a particular effect, and then comparing it with the one of its synonyms. In this case, the complexity of the terms will be determined by the number of times they appear in the articles. Our hypothesis is that complex terms should be less frequent than simpler terms in the corpus. Therefore, an effect will be substituted for its synonym with highest frequency (if it is not itself) in the corpus. For instance, *catarro* (nasopharyngitis), *resfriado* (cold), *resfriado común* (common cold) and *síntomas de resfriado* (cold symptoms) can be considered synonyms according to our dictionary built from MedDRA. They appear 12, 48, 7 and 6 times respectively in the MedLinePlus corpus, meaning that if any of them appeared in the text, it would be replaced by *resfriado* (cold), with 48 appearances.

Table 3 shows a passage of the adverse effects section of an Ibuprofen package leaflet.

In the first row we can see the original text from the package leaflet, with the detected effects highlighted in blue. The second row shows the output of the first strategy, Preferred Term Substitution. We can see *dispepsia* (dyspepsia) replaces *indigestión* (indigestion) in the first line. The third row shows the output of the second strategy, Most Frequent Term Substitution. In this case, *pirosis* (pyrosis) (43 hits) stands for *indigestión* (32), *sangrado* (bleeding) (347) for *hemorragia* (hemorrhage) (93) and *gases* (gases) (82) for *flatulencia* (flatulence) (21).

Table 3- Output example

original	Muy frecuentes: diarrea e indigestión. Frecuentes: náuseas, vómitos, dolor abdominal. Poco frecuentes: hemorragia. Raros: perforación gástrica, flatulencia, estreñimiento
PT	Muy frecuentes: diarrea e dispepsia. Frecuentes: náuseas, vómitos, dolor abdominal. Poco frecuentes: hemorragia. Raros: perforación gástrica, flatulencia, estreñimiento
freq	Muy frecuentes: diarrea e pirosis. Frecuentes: náuseas, vómitos, dolor abdominal. Poco frecuentes: sangrado. Raros: perforación gástrica, gases, estreñimiento

At first, we decided to use Wikipedia as corpus to build the index and to calculate the frequencies of effects, nevertheless, it was observed that many of effects were not found in Wikipedia or their frequencies were not statistically significant. For this reason, we finally decided to use a health-related site like MedLinePlus, instead of an open-domain resource like Wikipedia.

6. CONCLUSIONS

For some people, it is difficult to infer the meaning of a word or phrase from context when the word is unusual; for these users the ability to read and understand may depend on the availability of specific definitions or the expanded forms of abbreviations. Also, long sentences and complex linguistic structures can cause barriers in access to text content as indicated in WCAG and E2R guidelines. However, these guidelines despite providing resources and techniques, do not provide precise methods and support (semi) automatic with which to address these accessibility issues concerning to text readable and understandable. In this sense, the application of NLP resources and methods are proposed, which provide support for compliance with WCAG guidelines regarding readability and understanding. A review on this NLP technology has been presented.

With the aim of bringing the paper reader to the text simplification approach, a prototype to simplify drug package leaflet that implements a component for lexical simplification has been shown.

In this system are being included other approaches to providing support for more accessibility issues concerning abbreviations, summaries, definitions of unusual words, etc. In addition, evaluations by experts and users are planned. The combination of using the approaches of text simplification with how to display the content simplified taking into account other important issues as the presentation elements, page structure, navigation structures etc. on the Web interface is a great challenge for us.

7. ACKNOWLEDGMENTS

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[18] http://www.nlm.nih.gov/medlineplus/spanish/
[19] https://www.elastic.co/)

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Building a unified repository of interaction patterns

Alfons Palacios[1,2]
[1]Escola Superior Politècnica
TecnoCampus Mataró-Maresme
(Universitat Pompeu Fabra)
Av. Ernest Lluch 32 (Porta Laietana)
E-08302 Mataró, Spain
FAX +34 169 65 05
palacios@tecnocampus.cat

Roberto García[2]
[2]Universitat de Lleida,
Jaume II 69, E-25001 Lleida, Spain
Fax +34 973 702 702
tonig@diei.udl.cat

Marta Oliva[2]
[2]Universitat de Lleida,
Jaume II 69, E-25001 Lleida, Spain
Fax +34 973 702 702
oliva@diei.udl.cat

Toni Granollers[2]
[2]Universitat de Lleida,
Jaume II 69, E-25001 Lleida, Spain
Fax +34 973 702 702
rgarcia@diei.udl.cat

ABSTRACT

In recent years there have been many proposals of lists of interaction patterns applicable to the design and development of web interfaces. Many of the patterns proposed in different lists are the same, perhaps with different names and different examples. Our purpose is to join these lists in a unified repository.

This requires formalizing the definition of interaction patterns to make them comparable, facilitate their classification or recommend them automatically based on a characterization of user needs, interaction context, etc.

In parallel, Web applications using Semantic Web technologies are starting to proliferate. This implies in many cases a paradigm shift for user interaction that requires questioning which are the more appropriate end user tasks, starting from “traditional” Web interaction tasks but taking into account that they might change or raise new tasks. A good characterization of these tasks is then the starting point to explore what patterns can be used to implement them.

To facilitate this process, we have built a unified repository of interaction patterns classified by Semantic Web end-user tasks. We have built this repository using Semantic Web technologies.

Categories and Subject Descriptors

H.5.2 **[Information Interfaces and Presentation (HCI)]**: User Interfaces – evaluation/methodology, graphical user interfaces (GUI), interaction style, standardization, theory and methods, user-centered design, user interface management systems.

General Terms

Design, experimentation, human factors, standardization.

Keywords

Human computer interaction (HCI), Semantic web, Interaction patterns, Semantic web end-user tasks, Semantic web usability.

1. INTRODUCTION

An Interaction Pattern is the description of a solution to common problems of usability and accessibility in using Graphical User Interfaces (GUI) (Yahoo, 2012) [[1]]. Interaction Patterns model and propose software components to build GUI that are understandable and usable (Tidwell, 2011) [[2]].

We have studied and built a unified repository of interaction patterns from proposals from (Tidwell, 2011),(van Welie, 2007) [[3]],(Toxboe, 2011)[[4]],(Yahoo, 2012),(Crumlish et al., 2009)[[5]] or (Quince from Infragistics, 2012)[[6]]. We have also considered the work of (van Duyne et al., 2006) [[7]]) and (Scott and Neil, 2009) [[8]].

To classify the patterns we have used our proposal of Semantic Web End-User Tasks in (Palacios et al., 2014) [[9]]. In Section 2, a brief description of these tasks is done. Section 3 explains how we have formalized and built the unified repository of interaction patterns and, finally, Section 4 presents the conclusions and the future work.

2. A PROPOSAL OF SEMANTIC WEB END-USER TASKS

Several definitions of sets of end-user tasks for Web and Semantic Web are presented in the work of (Heath et al, 2005) [[10]], (Kellar et al, 2006) [[11]], (Battle, 2006) [[12]], (Mäkelä et al, 2007) [[13]], (Di Maio, 2008) [[14]] and (Sabou et al, 2007) [15]. From the analysis of this existing literature we have synthesized a set of generic end-user tasks that can assist Semantic Web developers:

2.1 Search

This kind of tasks corresponds to those when a user poses a query and obtains a set of results that might be rendered in different ways. We include here when the search might be delayed or repeated in the future, like in monitoring scenarios.

2.2 Browse

This task is performed when the user moves through the information currently displayed. In the context of Web information systems this is usually done by following the links that connect the information to related information pieces.

2.3 Annotate

In this task the user describes a resource by providing properties and values that model its characteristics, its relations to other resources, etc. This task includes providing a completely new description but also complementing an existing one, modifying it or deleting some or all of the attributes currently available.

2.4 Mashup

This task is about the user gathering different pieces of information and combining them in order to get something more than the simple aggregation of those pieces. Specific examples of this task range from simple mashups such as combining a set of resources that are geographically situated in order to, for instance, which are the hotels near a venue, or resources with temporal dimension that are arranged in a calendar or timeline in order to facilitate scheduling.

2.5 Map

This task takes place when the user defines mappings among terms from different vocabularies. It is not constrained to a particular set of resources like in the case of the Mashup task, and it does not operate at the level of particular resource descriptions. On the contrary, in this task, the user is working at the level of the vocabularies. These vocabularies might be used in descriptions for many resources, some of which the user might not be aware of it at the moment.

2.6 Share

This task considers uploading, publishing, updating and deleting pieces of content with the intention of making them available to other users, who can access the content from a place and at a time individually chosen by them. This last statement allows to clearly distinguishing this tasks from the Communicate task, which is presented next.

2.7 Communicate

This task is about sharing information directly with particular users, without the intention of making it available to other users. The process is in this case driven by the user participating in this task as the emitter.

2.8 Transact

This task is associated with user actions that provoke a change in the state of a real-world entity or of a resource in a system outside the scope of the system the user is interacting with.

In a previous study (Palacios et al, 2014) we presented examples of using these tasks in the particular case of the semantic web, as they could be enriched with semantic content and we compared this set of semantic web end user tasks with existing literature:

Table 2. Semantic web end user tasks and previous works

	Heath	Battle	Kellar	Mäkelä	Sabou	Tools
Search	Locating, Monitoring,	Information Seeking	Fact Finding	Semantic Content Consumption		Swoogle, SemSearch, Falcon-S
Browse	Exploring, Grazing	Information Seeking	Browsing	Semantic Content Consumption		Tabulator, Exhibit, mSpace
Annotate	Asserting	Content Update	Maintenance	Content Indexing		Annotea, Faviki
Mashup	Evaluating, Arranging	Information Synthesis	Information Gathering	Semantic Content Consumption		Sigma, Semantic Pipes
Map		Ontology Mapping			Folksonomy Enrichment, Word Sense Disambiguation	Potluck, Snoggle
Share	Sharing	Information Sharing				Semantic MediaWiki, Twine
Communicate	Notifying, Discussing					Haystack, xOperator
Transact	Transacting	Action-oriented				Semantic Web Services
Not end-users				Ontology Maintenance and Publishing	Ontology Matching	

3. BUILDING A UNIFIED REPOSITORY OF INTERACTION PATTERNS

The process of building the repository has been done in the following steps: classification, formalization and implementation.

3.1 Classification

All patterns are classified taking into account the proposed semantic web end-user tasks discussed in the previous section. Many of them might be mapped directly from the Web domain to the Semantic Web, like most of Welie's patterns for Search and Browse for example. In any case, new features in Semantic Web provide new opportunities in some patterns. Our analysis shows that the user tasks where the contribution of Semantic Web technologies might be more important are in Annotate, Mashup and Map user tasks. For these end-user tasks –the newest and closest to the Semantic Web- is difficult to find interaction patterns; new ones for Semantic Web have to study and define.

Furthermore, sometimes different sources explain the pattern giving different names and different shades; we have been grouped identical or similar patterns in a single proposal.

Therefore, the work of classifying includes:

a) Identify patterns proposals from different sources that are inherently the same, despite having different names or descriptions.

b) Assign each interaction pattern to an end user task. Sometimes an interaction pattern can be assigned a more than one task. We have chosen one as primary and leave the rest as secondary.

c) Choose a name and a definition for each set of identical or similar patterns. A definition that can be formally described in the future to enable the implementation of recommendation systems or the automatic generation of GUI.

3.2 Formalization

In order to implement a unified repository is important to define a conceptual model for the inventory of interaction patterns.

The goal is to eventually create one or more ontologies that represent the interaction patterns.

A first proposal of ontology is explained in Figure 1.

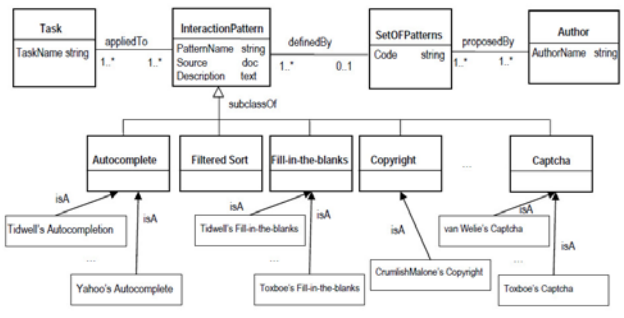

Figure 1 Ontology for an inventory of interaction patterns

The goal is to define a framework to merge the sets of interaction patterns by different authors in a single inventory that allows adding new patterns defined in the future.

Centralization in a single inventory of all sources of interaction patterns makes it easier for the research community on issues of HCI and the Semantic Web, and, in general, the entire developer community.

In the model we relate the concepts of interaction pattern introduced in section 1 and semantic web end user task commented in section 2, defining subclasses for pattern-type consolidated proposal. Specific:

- **Task** represents semantic web end user tasks.
- **InteractionPattern** are the proposed interaction patterns that have been studied (from one or several proposals by one or more authors). The patterns are classified by defining subclasses for equivalent patterns of various proposals. Subclasses are instantiated with patterns from different sources.
- **SetOfPatterns** is each of the sets of interaction patterns proposed by different authors to the developer community of GUI.
- **Author** contains information of all researchers or companies that have made proposals in the field of interaction patterns.

3.3 Implementation

Once we have formalized the unified interaction patterns inventory, the next step is to implement it in a repository.

We implement this repository with semantic web technologies.

We have used Rhizomer for implementing this repository.

Figure 2 Unified repository in Rhizomer

The Rhizomer platform (García et al., 2008) [16] (W3C, 2013) [17] is a Semantic Content Management System (SemCMS) based on a Resource Oriented Approach (RESTful) [18] and Semantic Web technologies. The Rhizomer project constitutes a technological framework that can be used to build up semantic web portals. Rhizomer manages RDF metadata in a user-friendly way. It facilitates not just the common Semantic Web to end-user interaction provided by semantic web browsers, it also provides the reverse interaction path: end-users can create, edit and remove semantic metadata. The whole interaction is performed through a "classical" HTML interface in a usable way, which minimises user efforts and maximises the benefits they obtain from their Semantic Web experiences. The overall intention is to minimise the gap among computers and human beings in the context of Semantic Web. The semantic metadata management part provided by Rhizomer is combined with an easy to use and simple content management system based on a Wiki engine. The wiki provides the means to create and maintain information objects that are described with semantic metadata.

To work with Rhizomer we have to translate the conceptual model to RDF. Once translated the conceptual model to a RDF model, a repository for the inventory of interaction patterns have stayed at Rhizomer.

The repository where is located the inventory of interaction patterns using Rhizomer, can be found in : http://indagus.udl.cat/iPatternsSemWeb/ .

3.4 Results

The core of this unified repository of interaction patterns is built from proposals of (Tidwell, 2011)(94 interaction patterns),(van Welie, 2007)(131 patterns), (Toxboe, 2011)(54 patterns),(Yahoo, 2012)(59 patterns),(Crumlish et al., 2009)(124 patterns).

Our analysis against related work specific for Web information systems shows that the user tasks where the contribution of Semantic Web technologies might be more important, because they a less consider or not considered at all, are Annotate, Mashup and Map.

This is reflected in the number of patterns that we have associated to each semantic web end-user task; while tasks as Search (20 patterns from different sets), Browse (134 patterns), Share (93 pattens), Communicate (12 patterns) or Transact (130 patterns) are the result of years of works to find solutions to the interaction with the web, for end-user tasks newer and closer to the semantic web as Annotate, Mashup or Map, we have only found a few interaction patterns in these sets.

A future work is to define new interaction patterns that are specific for the Semantic Web and can be applied in new end-user tasks and adapt existing ones to new features of the end-user tasks.

4. CONCLUSIONS AND FUTURE WORK

We have proposed a set of semantic web end user tasks is defined (Palacios et al., 2014); the set of tasks includes Search, Browse, Annotate, Mashup, Map, Share, Communicate and Transact and they have been described, and they have been used to classify interaction patterns.

Once the user tasks have been identified, it is really useful to have an inventory of interaction patterns that give support to these user tasks as a guideline. There are many lists of interaction patterns, though most of them focus on Web systems or other interactive systems without adapting their proposal to Semantic Web user tasks.

Our aim has been to build an inventory of Semantic Web interaction patterns starting from existing inventories, e.g. Tidwell's, van Welie's, Toxboe, the Yahoo! Design Pattern Library, or Crumlish & Malone's. This objective has been built on top of these pattern libraries and classified them taking into account the proposed Semantic Web end-user tasks.

Different sets of interaction patterns have different proposals of patterns that are similar or identical although they have different names and definitions. A work has been done for detecting and grouping identical or similar patterns in unified proposals with a single name and a single description.

To build a unified repository a conceptual model has been defined. In this conceptual model interaction patterns have been related to end user tasks and sets of patterns by different authors. Subclasses have been proposed to represent each of the unified interaction patterns. Subclasses have been instantiated by specific patterns of different sets.

The conceptual model has been translated to RDF to build a unified repository using the Rhizomer Platform, a Semantic Content Management System based on Semantic Web technologies.

Our future work is aimed at achieving the following challenges:

a) Find a way to formalize the definition of each interaction pattern with ontologies that allow an analysis in-depth.

b) Check the patterns that have been grouped using these ontologies.

c) Enrich patterns and end user tasks with new features of the Semantic Web, new opportunities should be detected.

d) Study and define new interaction patterns that are specific for the new semantic end user tasks, there is room for novel interaction patterns that the Semantic Web might make possible. Our analysis shows that user tasks where the contribution of Semantic Web technologies might be more important are Annotate, Mashup and Map.

e) Build a model of interaction patterns that automates the process of study, to centralize the proposals of different sets of patterns in a single repository and provide the basis for proposals for self-generation of user interfaces for the semantic web. The model should allow us to validate the classification of patterns and decisions on equivalences between patterns.

f) Model the interaction needs of the semantic web end users to link needs with interaction patterns.

g) Develop a recommender to help the process of design and implementation of interfaces that work with the Semantic Web

5. ACKNOWLEDGEMENTS

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Desarrollo de una herramienta para el diseño y ejecución de actividades enfocadas a ancianos con el tabletop NIKVision

Clara Bonillo Fernández

GIGA Affective Lab
Dep. Informática e Ingeniería de Sistemas Universidad de Zaragoza, España
clarabonfdez@hotmail.com

ABSTRACT

El principal objetivo de este trabajo ha sido desarrollar una herramienta que permita diseñar y ejecutar actividades para personas mayores que aprovechen las ventajas que ofrecen los tabletops, utilizando para ello el tabletop tangible NIKVision, perteneciente al grupo GIGA Affective Lab de la Universidad de Zaragoza

Lo que se ha intentado conseguir es que cualquier persona que necesite crear una actividad para tabletop pueda hacerlo de una manera sencilla con la herramienta realizada, sin necesidad de que esa persona necesite tener conocimientos de programación.

Como objetivo secundario, se han desarrollado también un conjunto de actividades como demostración de la validez de la herramienta junto con una evaluación de la misma.

1. ESTADO DEL ARTE: TABLETOPS Y TERCERA EDAD

Se ha realizado un estudio sobre ejemplos de actividades usadas por personas mayores, con especial énfasis en aquellas que hacen uso de tabletops, concluyéndose que aunque las actividades estudiadas permiten a las personas mayores trabajar sus capacidades cognitivas, no aprovechan todo lo que podrían las ventajas de tener un dispositivo tabletop, puesto que casi todas las actividades se realizan usando la mano o algún dispositivo que podría ser fácilmente sustituido por la mano, y en los casos en los que se utilizan objetos, éstos son pocos y demasiado concretos.

Por esa razón, la principal ventaja de NIKVision reside en la variedad de objetos que permite utilizar, de modo que prácticamente cualquier juguete puede usarse sin necesidad de crear nuevos objetos.

2. ÁREAS COGNITIVAS Y ACTIVIDADES

El envejecimiento trae consigo diversos problemas. Algunas de las áreas cognitivas que se ven más afectadas cuando una persona envejece son: la atención, la memoria, la capacidad de cálculo, el lenguaje, la orientación espacio-temporal y el razonamiento. Por lo tanto, nuestro objetivo ha sido buscar actividades que ayuden a potenciar dichas áreas para ayudar a prevenir, en la medida de lo posible, su deterioro.

Este trabajo se ha centrado en las áreas cognitivas de la atención, la memoria y el razonamiento, puesto que se vio que eran las que más podían aprovechar el uso de objetos sobre el tabletop. Una vez seleccionadas las áreas en las que trabajar, se realizó una propuesta de actividades para cada una de las áreas elegidas, las cuales son explicadas con más detalle en la sección 5.

3. DESCRIPCIÓN DE LA HERRAMIENTA

Tomando como base la propuesta de actividades previamente mencionada, se realizó el análisis de la herramienta extrayendo los requisitos que esta habría de cumplir.

Gracias a dicho análisis de requisitos, se decidió modelar las actividades para tabletop como una secuencia de tareas (ver fig. 1). Cada tarea es un objetivo que el jugador ha de alcanzar para poder avanzar en el juego. Cada tarea está compuesta por:

- Un fondo: el tablero.
- Varias áreas: zonas del tablero o de una pieza de juego en las que posicionar unas determinadas piezas de juego tiene un significado.
- Varias piezas de juego: objetos utilizados en el juego. Se colocan en las áreas; fuera de ellas la pieza no tiene ningún significado para el juego.
- Retroalimentación: elementos gráficos o sonoros que muestran las consecuencias de las acciones del jugador.

La estructura jerárquica de los diferentes elementos hizo que la forma más adecuada de modelar las actividades fuera mediante un lenguaje de marcas como el XML. La herramienta desarrollada es la encargada de cargar y ejecutar los ficheros XML que contienen las actividades en el dispositivo tabletop.

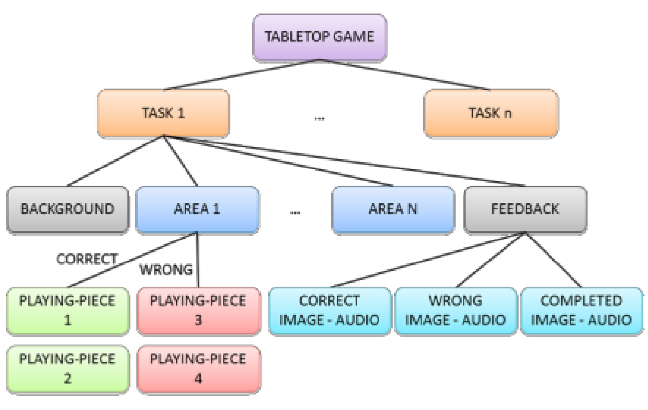

Figura 1: Jerarquía de los elementos

La herramienta ofrece dos opciones para la ejecución de las actividades: la primera opción es ejecutar una actividad concreta indicando la actividad a ejecutar en un fichero de arranque. La segunda opción es mostrar en el propio tabletop un menú en el cuál se muestran todas las actividades desarrolladas, de modo que el usuario puede seleccionar la actividad que desee ejecutar en ese momento de forma táctil sobre el tabletop. Una vez dentro de la actividad, el usuario tiene las opciones de volver al menú, de pausar la actividad y de poder modificar en tiempo de ejecución las actividades.

La herramienta también guarda información sobre las actividades realizadas en un fichero de logs en el que se guarda la fecha y hora de realización de la actividad, el tiempo empleado en su resolución, las acciones correctas e incorrectas realizadas y si la actividad se ha completado hasta el final o no.

4. ACTIVIDADES DESARROLLADAS

A continuación se van a comentar las actividades que se desarrollaron como ejemplo para cada una de las áreas cognitivas.

4.1 Actividades de atención

Como actividades de atención, se desarrollaron las actividades "¿Cuántos hay?" (atención dividida), "Marca los símbolos" (atención selectiva), y "Tangram" (atención sostenida).

En "¿Cuántos hay?" al usuario se le muestra una imagen con números entre el 0 y el 9. Nada más empezar la actividad, suena una grabación que le dice al usuario qué número ha de buscar. El usuario tendrá que ir situando fichas sobre todos los números que encuentre de ese tipo, mientras que a la vez se estará reproduciendo una grabación con una secuencia de golpes, de modo que el usuario, a la vez que marca los números, tendrá que decir cuántos golpes van sonando. Los objetos que se utilizan en esta actividad son fichas que el usuario tendrá que colocar en los números correspondientes (ver fig. 2 izquierda).

En "Marca los símbolos" se presenta un mapa con símbolos de gasolineras, restaurantes, hoteles, farmacias...y se pide al usuario que marque todos los que sean de un tipo concreto. Los objetos que se utilizan en esta actividad son fichas que el usuario tendrá que colocar en los símbolos correspondientes (ver fig. 2 centro).

La actividad "Tangram" tiene dos modos: el fácil, en el que se ve en qué posición está cada una las piezas que conforman la figura, y el difícil, en el que solo se muestra el contorno de la figura. En la modalidad difícil también se trabaja el razonamiento, al tener que deducir dónde va cada pieza. Los objetos con los que trabajamos en esta actividad son las siete piezas del Tangram (ver fig. 2 derecha).

Figura 2: Actividades de atención. Izquierda: ¿Cuántos hay?

Centro: Marca los símbolos. Derecha: Tangram

4.2 Actividades de memoria

Como actividades de memoria se desarrollaron las actividades "Lista de la compra" y "Viajes".

En "Lista de la compra" se muestra en pantalla una imagen con una lista de la compra con alimentos durante cinco segundos. Pasado ese tiempo, se quita la imagen de la lista poniéndose una imagen con una bolsa de la compra y el usuario ha de seleccionar los alimentos correctos y situarlos en la bolsa. Los objetos que se utilizan en esta actividad son diversos juguetes de comidas y bebidas (ver fig 3. izquierda).

En la actividad "Viajes", al usuario se le muestra un mapa de Europa y se reproduce una grabación con un itinerario a seguir con distintos medios de transporte. El usuario ha de recordar el itinerario y situar los transportes correspondientes en los países correctos. Los objetos que se utilizan en esta actividad son tres juguetes de medios de transporte: tren, avión y barco (ver fig 3. derecha).

Figura 3: Actividades de memoria. Izquierda: Lista de la compra. Derecha: Viajes.

5.2 Actividades de razonamiento

Como actividades de memoria, se desarrollaron las actividades "Analogías" y "Completa la secuencia".

En "Analogías" se dispone de un conjunto de fichas con dos imágenes cada una. A cada imagen le corresponde una pareja, que estará en otra ficha diferente. El objetivo de la actividad es que todas las fichas formen una cadena de modo que todos los extremos de las fichas estén con su correspondiente pareja. Los objetos que se utilizan en esta actividad son las diferentes fichas (ver fig 4. izquierda).

En "Completa la secuencia" se usan fichas de dominó para mostrar una secuencia en la que faltan algunas piezas. El usuario ha de seleccionar la pieza que falta para completar la secuencia. Los objetos que se utilizan en esta actividad son las fichas de dominó (ver fig 4. derecha).

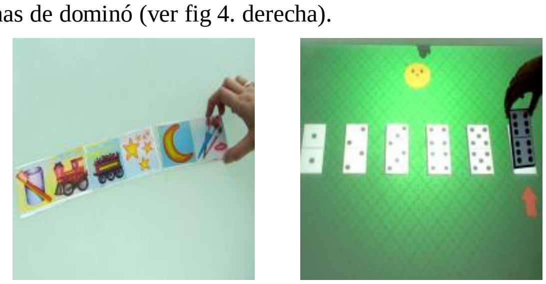

Figura 4: Actividades de razonamiento. Izquierda: Analogías.

Derecha: Completa la secuencia

5. EVALUACIÓN

Una vez que se tuvo un prototipo implementado de la herramienta, alumnos de la asignatura Diseño Centrado en el Usuario de Grado de Ingeniería Informática de la Escuela de Ingeniería y Arquitectura de Zaragoza hicieron, como práctica opcional de la asignatura, el diseño de una actividad para el tabletop NIKVision. El objetivo principal que se buscaba era ver si la herramienta permitía realizar el diseño de actividades de manera sencilla para aquellas personas que no estuvieran familiarizadas ni con el tabletop NIKVision ni con la herramienta mediante una evaluación de su usabilidad, y se obtuvieron buenos resultados que indicaron que el manejo de la herramienta era bastante sencillo.

6. CONCLUSIONES Y TRABAJO FUTURO

La principal línea de trabajo futuro sería implantar la herramienta en un ámbito sanitario para que pueda ser probada por personas mayores y así ver si su uso les permite mejorar sus capacidades cognitivas y evitar su deterioro, así como comprobar la utilidad de los ficheros de logs generados durante la realización de las actividades.

Análisis de requerimientos y prototipado de una aplicación accesible para personas ciegas basada en la API de Google Maps

Rubén Alcaraz Martínez
EINA, Centre Universitari de Disseny i Art de Barcelona
Passeig de Santa Eulàlia, 25
08017 Barcelona
34 93 203 09 23
ralcaraz@eina.cat

ABSTRACT

Objetivos: Explorar las posibilidades ofrecidas por las diferentes plataformas de cartografía digital, así como de otros lenguajes, librerías y estándares actuales del Web, para crear una aplicación accesible para personas ciegas que ofrezca servicios relacionados con información de carácter geográfico.

Metodología: Desarrollo informático de una prueba de concepto consistente en un mapa digital accesible para personas ciegas basado en la API de Google Maps, a partir de los requerimientos derivados del estudio de las características del colectivo objetivo, del análisis de las directrices para la accesibilidad del contenido web (WCAG 2.0) y de la especificación WAI-ARIA 1.0.

Resultados: Se ha obtenido un primer prototipo que permite realizar búsquedas sobre la base de datos de Google Places y obtener rutas entre dos puntos a partir del servicio de rutas de Google Maps, en el que destaca el acceso mayoritario a las funcionalidades de la aplicación mediante una interfaz de teclado, así como la aplicación de la ontología de roles, estados y propiedades de WAI-ARIA para anunciar los cambios en la interfaz provocados por la interacción del usuario con la aplicación.

Keywords

Accesibilidad web, WCAG 2.0, WAI-ARIA, Google Maps API v3, Servicios basados en la localización, Personas ciegas.

1. INTRODUCCIÓN Y JUSTIFICACIÓN

El campo de la información y la comunicación constituye un elemento esencial en la vida social, política, cultural y económica de las personas. Los avances producidos dentro del ámbito de las tecnologías de la información y la comunicación han abierto nuevas posibilidades de acceso a estos aspectos, pero al mismo tiempo también han propiciado, de manera indirecta, la creación de nuevas barreras para las personas con discapacidad. Por lo que respecta al disfrute y uso de todo tipo de bienes, servicios y tecnologías, el marco regulador debería abarcar todas las situaciones en las cuales se ponen a disposición del público en general. Según lo dicho, resulta poco relevante quién proporcione el bien o preste el servicio, ya sea el propio Estado o una empresa privada. Si el bien o servicio se pone a disposición del público en general, resulta lógico que deba adaptarse a unos requisitos de accesibilidad determinados, como recoge la disposición final sexta de la *Ley 51/2003, de 2 de diciembre, de igualdad de oportunidades, no discriminación y accesibilidad universal de las personas con discapacidad*. Los incumplimientos del principio de accesibilidad universal son considerados por esta ley como supuestos de discriminación y de violación del derecho a la igualdad de oportunidades.

Diversos autores (Nielsen, 2000; Romero, 2001; Arch y Letourneau, 2002)[1][2][3] han destacado la importancia de la accesibilidad no sólo como cuestión ética, sino también como factor de competitividad en el entorno empresarial. Teniendo en cuenta tanto el importante porcentaje que representan las personas con algún tipo de discapacidad entre los usuarios o clientes potenciales de cualquier web o aplicación, como el elevado grado de exigencia existente en el entorno web fruto de una competitividad cada vez mayor, la integración de los estándares de accesibilidad en el desarrollo de estos productos puede resultar un rasgo diferencial frente a la competencia. Además, la accesibilidad también resulta de utilidad en otros ámbitos, como en el SEO (Dolson, 2012; Nielsen, 2012; Carreras, 2013)[4][5][6] o en la mejora de las versiones móviles de los portales web, entre otros. El proyecto que nos ocupa beneficia principalmente a las personas ciegas, pero también es aplicable o útil para usuarios con otros tipos de discapacidades. Se trata, además, de mejorar un tipo de contenido que prácticamente todas las administraciones públicas ya han incorporado en sus respectivos portales en Internet, generalmente de una manera no accesible. Algunos ejemplos sobre los que se podría aplicar son los callejeros digitales de las ciudades, los servicios de rutas en transporte público o, incluso, en mapas que se han creado en otros ámbitos públicos o privados, como los directorios de empresas o los portales de búsqueda de hoteles, entre otros.

2. LAS RIA, AJAX Y GOOGLE MAPS

Las RIA (*Rich Internet Applications*) son aplicaciones web ejecutadas desde un navegador, capaces de incorporar la interactividad y dinamismo característico de las aplicaciones de escritorio. En este tipo de aplicaciones, el contenido se añade, modifica o elimina sin intervención del usuario, o como consecuencia de una acción determinada. Una de las tecnologías protagonistas en el desarrollo de las RIA es AJAX (*Asynchronous JavaScript And XML*). La naturaleza dinámica de AJAX es a la vez su gran virtud y su gran inconveniente, si estas aplicaciones no se diseñan desde el punto de vista del usuario con discapacidad. La creación de zonas dinámicas en la interfaz que se actualizan constantemente o a petición del usuario, sin necesidad de actualizar la página, y el uso de todo tipo de controles y botones similares a los que podemos encontrar en cualquier aplicación de escritorio, plantean desafíos adicionales de accesibilidad. Google Maps se enmarca dentro de lo que hemos definido como RIA y se basa en AJAX para ofrecer una buena parte de sus funcionalidades.

3. LAS PERSONAS CIEGAS Y EL ACCESO A LA INFORMACIÓN EN LA WEB

Conocer las características de los diferentes perfiles de discapacidad, así como las estrategias y ayudas técnicas que utilizan al interactuar con el contenido, es imprescindible para poder crear productos accesibles para todos ellos.

El usuario ciego accede al contenido web de una manera muy diferente a la que lo hacen el resto de usuarios. Mientras que los usuarios videntes exploran y toman decisiones en base a la organización visual del contenido, el ciego que accede mediante un lector de pantalla no es capaz de analizar la totalidad de la página con tanta inmediatez. Frente a contenidos organizados jerárquicamente o al uso de zonas destacadas cromáticamente para atraer la atención hacia los elementos más importantes de la página, el contenido al que acceden los discapacitados visuales es lineal y basado en texto. El posicionamiento en la página o el diseño gráfico ni ayudan, ni dificultan de manera inherente el acceso de este colectivo a la información que contiene el sitio web. Simplemente, resultan irrelevantes. Son otros factores, como el orden por programación, una sintaxis correcta o la posibilidad de saltar bloques de información, los que realmente suponen una óptima experiencia de usuario para este colectivo.

4. PROBLEMAS DE ACCESIBILIDAD

Las principales barreras de accesibilidad de las aplicaciones desarrolladas a partir de la API de Google Maps las encontramos en la imposibilidad de acceso a los controles de la interfaz (botones para moverse por el mapa, cambiar de tipo de mapa, pulsar sobre un marcador...) mediante el teclado, y en la posibilidad de que una buena parte de los contenidos (resultados de una búsqueda, indicaciones de una ruta solicitada, errores...), pasen desapercibidos para el usuario ciego al actualizarse de manera dinámica mediante AJAX.

5. SOLUCIONES TÉCNICAS

La API de Google Maps genera de manera automática los diferentes controles de la interfaz como elementos <div> incapaces de recibir el foco y, por lo tanto, no son operables a través del teclado. Para solucionar este problema existen varias alternativas. La primera de ellas consiste en sacar fuera del mapa los diferentes controles de la interfaz, creando nuevos elementos interactivos que sí puedan captar el foco. Otra de las opciones pasa por manipular el DOM de la página mediante JavaScript para insertar en el código HTML generado por Google Maps, es decir, dentro del mismo mapa, elementos que sí capten el foco en lugar de los <div> creados por defecto. La creación de controles accesibles no sólo beneficia a los usuarios ciegos, sino que también resulta de gran ayuda para otros tipos de discapacidades como las motrices o cualquier otra que impida a las personas que la padecen usar el ratón.

En relación a los contenidos que se actualizan automáticamente en la interfaz, la propuesta de solución pasa por utilizar WAI-ARIA, una especificación del W3C que proporciona una ontología de roles, estados y propiedades que se pueden utilizar para mejorar la accesibilidad de los contenidos y aplicaciones web enriquecidas.

Las áreas de una página web que ven modificados sus contenidos de forma automática se conocen con el nombre de *live regions* (zonas vivas). Estos nuevos contenidos pueden pasar desapercibidos para las personas ciegas o con baja visión si no son marcados adecuadamente, al no ser capaz el lector de pantalla de anunciar los cambios producidos. WAI-ARIA propone tres atributos (*aria-live*, *aria-atomic* y *aria-relevant*) que una vez incorporados a nuestro código fuente, nos permiten identificar las zonas vivas y especificar cómo y cuándo queremos que se anuncien al usuario. WAI-ARIA se puede utilizar además para especificar el rol de los elementos de la interfaz, determinando su función en la página. También permite codificar propiedades y estados, por ejemplo, indicando que el elemento de un formulario es obligatorio o que un elemento se encuentra marcado o desmarcado. Información a la que los lectores de pantalla podrán acceder para informar al usuario ciego.

6. TEST DE USUARIOS

Las soluciones técnicas comentadas en el punto anterior se pusieron a prueba en un prototipo funcional. A lo largo del proceso de desarrollo de este prototipo, se realizaron diferentes test con un usuario ciego al que se le propusieron diferentes tareas a realizar. Fruto de estos test, se logró comprender mejor las necesidades de este colectivo, y se corrigieron los diferentes problemas de accesibilidad detectados.

7. CONCLUSIONES

Los test de usuario realizados demostraron la capacidad del usuario ciego para interactuar con los diferentes controles y formularios del prototipo, acceder a los resultados de búsqueda y a las rutas recomendadas por la aplicación. Más allá de algunas funcionalidades pendientes de implementar, uno de los principales problemas de accesibilidad pendientes son las indicaciones proporcionadas por el servicio como resultado de las peticiones de rutas en transporte público. Se trata de un tipo de indicaciones que incluyen tramos a pie y otros en metro, bus, etc. Mientras que las indicaciones de rutas a pie son suficientemente descriptivas para la mayoría de usuarios ciegos, las indicaciones mixtas de las rutas en transporte público resumen demasiado la información del trayecto hasta la estación de origen, y el de la estación de destino hasta el punto final del trayecto, imposibilitando la autonomía del usuario ciego.

8. RECURSOS

El texto completo del trabajo se puede consultar en http://hdl.handle.net/2445/58427.

9. AGRADECIMIENTOS

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Factores importantes para un sistema de recomendacion de una red social educativa

Virginia del Castillo Carrero, Isidoro Hernán-Losada, Estefanía Martín-Barroso
Dept. Lenguajes y Sistemas Informáticos I
Universidad Rey Juan Carlos, URJC
Móstoles, Spain
vdelcastillo.c@gmail.com, isidoro.hernan@urjc.es, estefania.martin@urjc.es

ABSTRACT

Este artículo presenta los factores más importantes a tener en cuenta para realizar un sistema de recomendación basado en contenido para una red social orientada al aprendizaje. Los resultados son obtenidos del proceso del diseño e implementación de un sistema de recomendación basado en contenido, aplicado a una plataforma social para el aprendizaje a través de la creación de vídeos. El sistema ha sido realizado y aplicado en una experiencia real para la enseñanza de conceptos básicos de interacción persona ordenador a través de la creación de videos, dando soporte a las fases de discusión y difusión de los mismos. En la actividad participaron 43 futuros graduados pertenecientes a dos grados diferentes: Ingeniería de Computadores y Comunicación Multimedia.

Sistemas de recomendación; aprendizaje basado en vídeos;redes sociales de aprendizaje.

1. INTRODUCCIÓN

Los sistemas de recomendación (SR) han cobrado una gran importancia, experimentando grandes avances, sobre todo en el campo comercial. De hecho, disponer de un buen SR puede marcar la diferencia entre el éxito y el fracaso de una empresa. Las cantidades ingentes de contenidos a los que los usuarios hacen frente diariamente y la limitación de tiempo para buscar y encontrar productos que se adapten a sus gustos, tiene como consecuencia que los usuarios a veces no puedan encontrar lo que buscan. Una de las principales motivaciones de los SR es justamente ayudar a los usuarios a que encuentren aquello que buscan. Los SR buscan sugerir aquello que pueda resultar relevante para los usuarios, realizando una estimación de lo que puede gustar, interesar o ser de utilidad para ellos. La definición general de SR [1] busca maximizar el valor de utilidad de un contenido para un usuario.

En general, podemos encontrar tres tipos de SR: basado en contenido, filtrado colaborativo y una combinación de los dos anteriores denominado híbrido [1]. Los sistemas de recomendación también han pasado a ser una parte importante en las redes sociales. Como es el caso de Youtube [2], Facebook, Twitter y un largo etcétera.

Dentro del ámbito educativo, existe un creciente interés por las redes sociales enfocadas al aprendizaje. Viendo el gran potencial que aportan en otros contextos los SR, estos pueden ser usados para recomendar materiales docentes a los alumnos. Se debe tener en cuenta que los sistemas de recomendación tienen diferentes objetivos según el contexto en que nos encontremos [3] y por tanto, se debe tener en cuenta distintas informaciones para poder realizar su tarea con éxito. Este trabajo trata de encontrar los factores principales que se han de tener en cuenta para realizar un sistemas de recomendación basado en contenido con un objetivo educativo y marcar diferencias con respecto a sistemas que se crean con objetivos distintos a los de la enseñanza.

2. CONTEXTO: CLIP-IT

Clip-It es una red social desarrollada dentro del proyecto europeo Juxtalearn que persigue el objetivo de fomentar el aprendizaje de thresholds concepts mediante la creación de vídeos [4]. Clip-It está compuesto por diversos plugins, que la dotan de funcionalidad. Esta característica convierte a esta red en un sistema altamente configurable. La plataforma permite al docente plantear una actividad, sobre la que tienen que trabajar los alumnos, produciendo un vídeo sobre la temática planteada. Clip-It permite el trabajo colaborativo a través de grupos, dotando de espacios privados para compartir archivos y foros para la discusión [5]. Además, admite la subida y reproducción de vídeos en distintos formatos así como los comentarios y valoraciones de los vídeos públicos.

Una característica muy importante es que permite el etiquetado de todos los elementos, con lo que se puede realizar una clasificación en base a las opiniones de los usuarios.

Para facilitar el aprendizaje se ha creado un SR basado en contenido con el cuál se facilite a los usuarios encontrar materiales que sean de su interés. De esta forma, los alumnos pueden complementar la información sobre el tema en el que están trabajando. El SR ha sido implementado en forma de plugin, para que el administrador de Clip-It pueda situarlo y usarlo donde y cuando quiera.

La plataforma Clip-It ha sido probada por alumnos de Ingeniería de Computadores y Comunicación Multimedia, los cuáles debían realizar vídeos relacionados con conceptos básicos de la asignatura de Interacción Persona-Ordenador que en ese momento cursaban.

El número total de alumnos que han usado Clip-It en esta actividad han sido 43, algunos con conocimientos previos informáticos (alumnos de Ingeniería de Computadores) y otros sin conocimientos previos (alumnos de Comunicación Multimedia). Todos ellos contribuyeron a determinar los

factores más influyentes en el SR a través de sus opiniones recogidas mediante encuestas.

3. ESTUDIO DE LAS NECESIDADES

Los SR en un contexto educativo tienen objetivos diferentes que los SR comerciales, como ya hemos comentado previamente [3]. Para realizar la captura de requisitos del SR se pasó un cuestionario al grupo de 43 alumnos los cuales ya habían interactuado con la plataforma de Clip-It.

Las principales ideas extraídas a partir de las opiniones de los alumnos son que el SR no debería mostrar más de cinco recomendaciones por pantalla, siendo estas visibles desde la página principal del usuario y más ampliamente en un apartado propio en la plataforma, siempre junto al material que estén visualizando en el momento. Las recomendaciones deben basarse en las exigencias académicas del presente inmediato, dando menos importancia a las asignaturas futuras o incluso aquellas suspensas en el pasado. Dar más importancia a las relaciones de compañeros de clase que a las de amistad (caso contrario en otros tipos de redes sociales). Y tener en cuenta las asignaturas y trabajos con los que están interactuando en ese momento. Así como los contenidos multimedia basados en vídeo tienen una mayor importancia para los alumnos.

4. SISTEMA DE RECOMENDACIÓN

El SR creado es un sistema basado en contenido. Se ha elegido esta opción porque Clip-It hace uso del etiquetado social, con lo cual proporciona una clasificación sin necesidad de un análisis previo del contenido. Es el propio usuario quién clasifica el contenido. El uso del etiquetado social tiene sus ventajas y sus inconvenientes [7]. La ventaja principal es que se obtiene una gran escalabilidad. La desventaja es la tendencia del usuario a utilizar pocas etiquetas (o no etiquetar) para describir contenidos.

Para realizar las recomendaciones utilizamos las votaciones realizadas por los usuarios y además tenemos en cuenta los contenidos que han comentado recientemente, estos datos formaran un perfil lógico del usuario. Este perfil será utilizado por el sistema para encontrar contenidos que se adecuen a los intereses del usuario. La similitud entre contenidos es dada por el número de etiquetas que tienen en común. La comparación entre etiquetas tiene una previa lematización dejando únicamente la raíz de la palabra, antes de realizar las comparaciones entre contenidos.

El sistema puede diferenciar entre tres tipos potenciales de usuario, son los siguientes:

Usuario nuevo: el sistema no tiene información suficiente acerca de su intereses, es decir, no tiene un perfil de los gustos del usuario, ya sea porque no ha interactuado con la plataforma o sus gustos son muy particulares y el sistema no logra captarlos. El sistema hará una recomendación de cinco contenidos aleatorios de los últimos contenidos actualizados o subidos a Clip-It.

Si el sistema puede crear un perfil de usuario con sus gustos, las recomendaciones se crean teniendo en cuenta estos gustos y se da una prioridad mayor a los contenidos que comparten varios intereses. De estos contenidos, los vídeos tienen mayor peso que el resto de materiales, como los alumnos indicaron en el estudio previo. En esta situación el sistema se encuentra con los dos casos

Usuario con pocas recomendaciones: el sistema dispone del perfil de gustos del usuario, sin embargo el número de contenidos que puede sugerir el sistema es escaso. El resultado que muestra el SR está formado los contenidos que se asemejan a sus gustos, más una selección de contenidos actuales que varían de forma aleatoria.

Usuario con muchas recomendaciones: este caso es una variante del anterior, donde el sistema tiene una multitud de contenidos que se adecuan al interés del usuario. Para evitar sobre-especialización de contenidos, efecto típico de SR basados en contenido, el sistema añade algún contenido actual a las recomendaciones realizadas por el usuario y/o modifica periódicamente las recomendaciones para que vayan variando.

5. EVALUACIÓN Y CONCLUSIONES

El SR expuesto en este trabajo ha sido evaluado mediante un estudio posterior con los mismos alumnos que colaboraron en las diferentes fases de este proyecto. Los resultados de la evaluación han sido muy positivos validando las diferentes reglas establecidas a la hora de realizar las recomendaciones. En general, los alumnos mostraron una buena aceptación del SR.

Como principal conclusión, destacar la idea de la necesidad de realizar un estudio previo del entorno de trabajo del SR. De esta forma el SR será una herramienta útil y necesaria que sirva de apoyo a la interacción entre la plataforma y el usuario, evitando que el SR se convierta en una herramienta ineficiente o molesta que impida que los usuarios no aprovechen todas la ventajas que ofrece el SR.

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Case Study on Mobile Applications UX: Effect of the Usage of a Cross-Platform Development Framework

Esteban Angulo
esteban.angulo@gmail.com

ABSTRACT

Cross-platform development frameworks for mobile applications promise important advantages in cost cuttings and easy maintenance, posing as a very good option for organizations interested in the design of mobile applications for several platforms. Given that platform conventions are especially important for the User eXperience (UX) of mobile applications, the usage of a framework where the same code defines the behavior of the app in different platforms could have a negative impact in the UX and in the way the mobile application and user interact.

This work describes a study where two different versions of a mobile application were designed and developed, one using a framework that generates Android and iOS versions automatically, and another team using native tools. The alternative versions for each platform have been evaluated with 37 users with a combination of a laboratory usability test and a longitudinal study. The results show that differences are minimal in the Android platform, but in iOS, even if a reasonably good UX can be obtained with the usage of this framework by an UX-conscious design team, a higher level of UX can be obtained directly developing with a native tool.

Categories and Subject Descriptors

D.2.6 [**Software Engineering**]: Integrated environments.
H.5.2 [**Information Interfaces & Presentation**]: User-centered design.

General Terms

Design, Experimentation, Human Factors.

Keywords

Mobile user experience, cross-platform development, interaction design, mobile applications.

1. INTRODUCTION

The objective of this study is comparing the cross-platform and the native approach for being able to determine if the selected development approach has any impact on the users in terms of UX. To be able to set a base line under this subject, a study on cross-platform frameworks was performed to select the most appropriate one from a UX point of view. Among several options which were evaluated under an established criterion, only one cross-platform framework was selected for developing a prototype of the mobile application which was used in the study.

In recent years, the growth and usage of smartphones and mobile devices has changed the communication habits of the population and the development of mobile applications is supporting their daily life activities. The market offers a great variation of mobile devices and platforms, and the challenge for development teams is being able to create mobile applications that can be used and run seamlessly on different devices and platforms. In order to cover all these potential markets, specific versions of the application need to be developed for each target platform.

Cross-platform development frameworks offer a way of saving resources in the aim of covering different platforms. These tools provide developers the flexibility to create an app than runs across several mobile platforms based on the ideal principle of "write-once-run-everywhere".

UX and Interaction Design must follow specific conventions in order to be consistent with standard or typical interaction strategies for each platform. User eXperience (UX) is the key differentiator aspect in mobile application acceptance.

The rest of this document is structured as follows: next section explores the State of the art on the topic. Section 3 is dedicated to UX considerations for cross-platform development and the usage of cross-platform development frameworks and the selection of one of these frameworks. Section 4 describes the methodological approach for the study carried out, and section 5 details the results and conclusions.

2. STATE OF THE ART

The development of mobile application using cross-platform frameworks is very popular in these days and several studies or researches performed on this subject looking for the most suitable cross-platform framework to develop an application as native as possible but usually from the developer's point of view. However, the information about a comparison of the usability of a mobile application developed using native technologies against one developed with cross-platform frameworks is scarce.

Most of the documentation and bibliographic research found on the topic, evaluates cross-platform frameworks from the point of view of development companies or software development easiness. In this case we were looking for another approach: UX.

3. CROSS-PLATFORM FRAMEWORK SELECTION

Our starting point for studying the possible limitations of cross-platform development frameworks in terms of UX of the developed apps was to select the best one from a mobile UX point of view.

At the beginning we found 19 options of cross-platform framework. We have discarded frameworks for specialized domains, like gaming. We studied the information available for each framework, considering the following criteria:

- To offer support for Android and iOS native app development, to be able to compete with directly-developed native apps.
- To be based in a well-known programming language, to ease adoption by developers.
- Free availability.
- To be compatible with widespread IDEs, to ease development.
- To offer access to device APIs, to be able to offer the same level of functionality than native code.
- To have a high use rate among developers.

After analyzing the characteristics and properties of all the candidates, only the three tools complied with all the requirements. These three tools were evaluated with a case study, consisting on an app to show the bus timetable for a university campus.

Based on other evaluation process and the easiness for the development, the best option for this case study was Titanium Appcelerator.

4. EVALUATION METHODOLOGY

The study designed for evaluating the impact of using a framework into the UX was based in having two design teams working independently: one team designing the Titanium version (which generates Android an iOS versions automatically), and the other one working on the two native versions.

Both sets of versions (cross-platform and native) were used on the usability study of this work.

4.1 Study design

The participants of this study were 37 students of the School of Computer Science at UPM. These students have evaluated the alternative versions of the app for each platform.

The study consisted in the combination of 2 different usability evaluations for each version of the prototype:

- **Laboratory study**: It was a first-impression study in which the participants had to complete a set of tasks while the evaluators were watching their reactions and interaction with the application; once the participant was ready with the tasks, he/she had to complete a usability evaluation survey which addressed different topics and was focused on evaluating the prototype from a UX point of view.
- **Longitudinal study**: It was performed once the participants were ready with the laboratory study, they had five days to use the application in their own context and explore it as much as they want. When the five days were over, the participant had to complete again the set of tasks (now having more experience with the app) and complete the usability evaluation survey.

The same process was followed with both prototypes (native and cross-platform) in a random way. This means, that some users begin the experiment with the native application and others with the cross-platform one. To avoid adaptation times, the participants used their own smartphones where the app was installed.

We choose to perform the study this way in order to have different kinds of experience and try to analyze the impact of the first impression.

When both prototypes have been tested, a final evaluation is completed on which the participants compared their experience with both versions.

A group of usability attributes were selected as the variables to be assessed in this work. The selected variables are: effectiveness, efficiency and satisfaction. We used different usability evaluation methods for each study in order to obtain the necessary information to measure the different values.

For the laboratory test, the methods chosen are: satisfaction questionnaires, performance measurement and interviews. For the longitudinal study, the methods selected are: remote data collection and satisfaction questionnaires.

For the purposes of this study, three different questionnaires were applied to gather the participants' impressions about each version of the application. The questionnaires used were: System Usability Scale (SUS); a customized and reduced version of the User Experience Questionnaire (UEQ) to focus on the only aspects that were applicable to the app context of use; and an ad-hoc questionnaires where participants were asked to compare the version of the app tested with the look and behavior of a typical app in their platform.

Another source of gathering information during the 5-day usage period of the longitudinal study was Google Analytics. This information helped to understand and control de usage of the application during this exploration period and get insights about the troubles and difficulties that users had during their interaction with the applications.

5. CONCLUSIONS

A case study has been presented for evaluating how the decision to develop a mobile app using use a cross-platform framework impacts the UX of the resulting app, against developing with native code for each platform considered.

The advantages of this kind of frameworks from a development point of view are well known, but this time it has been evaluated in terms of the UX of the produced app with a longitudinal study, with an app with enough functionality to be considered a full-scale app, and with a number of test participants to provide a minimum coverage of the two main mobile platforms: Android and iOS.

The results show that a good level of UX can be obtained if the cross-platform development framework is chosen carefully in terms of providing adapted interaction styles for each platform, and the development team has UX expertise. The differences are minimal in the Android version, but in iOS, even if a reasonably good UX can be obtained with the usage of this framework by an UX-conscious design team, a higher level of UX can be obtained directly developing in native code.

Further research is needed to tackle the specific interaction design issues that will be difficult to cover in the framework-generated apps and offer the software engineers and development teams another way to evaluate the advantages and disadvantages of adaption the native or the cross-platform development approach on terms of UX.

INDEX OF AUTHORS

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