Nuevas tecnologías de visualización para la mejora de la representación arquitectónica en educación

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Localización interior por simulación numérica en Casa Batlló.

La simulación numérica se ha implementado con diversos métodos de cálculo que se han probado en varias situaciones: el Polinomio de Taylor, la Ley de Hook, y otros. Se han incluido otros parámetros de tipo "Constrains" para evitar que los resultados variasen dando valores extremos o errores de aproximación. Además se han aplicado filtros y otras técnicas basadas en criterios matemáticos como las curvas de Bezier, el número de Courant, cálculo de condensación, etc.

El resultado de todos los cálculos se ha aplicado para el posicionamiento del proyecto de Casa Batlló para situaciones de extrema dificultad debido a la geometría compleja de los espacios y la gran cantidad de interferencias que se manifestaban en el edificio.

El alumno ha tenido la capacidad de adaptar los métodos de cálculo para la mejora del rendimiento de la aplicación. Es un sistema que, debido a su complejidad, ha requerido de múltiples ensayos y pruebas de campo en el mismo museo.

En el proyecto de EPSON, el desarrollo sólo se ha realizado para adaptar el sistema al dispositivo de las gafas MOVERIO. No ha habido un cambio sustancial en el método de cálculo, pero ha servido para ver la versatilidad del sistema.

El último proyecto para La Seu Vella ha permitido desarrollar una interficie para la configuración más sencilla de la entrada de información para la correcta ejecución de la aplicación Android. Estos datos son la posición de los beacons, la posición y contenido de los POIs (Puntos de Interés) y la configuración de la intensidad de las señales.

Desarrollo de aplicación genérica de localización interior

El principal resultado es una librería de código de programación capaz de integrarse en aplicaciones móviles para la localización de usuarios en espacios interiores y mostrar contenidos multimedia y, por consiguiente, de Realidad Virtual.

Este código se muestra a partir de una aplicación genérica en la que el alumno ha desarrollado una interficie de configuración para la integración de los datos necesarios para su correcto funcionamiento con balizas y otros accesorios como gafas inteligentes.

La visualización de contenidos de Realidad Virtual se produce en cada punto de interés configurado desde la aplicación. Ésta es capaz de incorporar un mapa para su ubicación en el espacio del museo o edificio. Se muestra un gráfico de la planta para posicionar los POIs y a la vez se indica el contenido a mostrar. Generalmente es un contenido guardado en una dirección URL para permitir la gestión on-line de éstos.

Los contenidos son imágenes digitales 3D panorámicas en 360º en el proyecto de Casa Batlló, vídeos en el proyecto con EPSON e imágenes esféricas reales de espacios no visitables de La Seu Vella.

Las funcionalidades principales de la aplicación son:

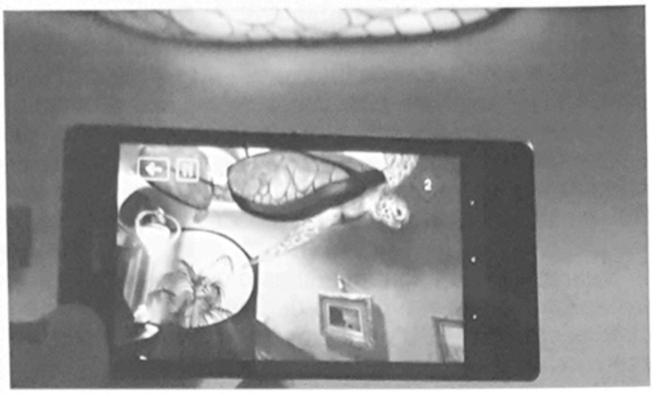
- Ubicación de las balizas sobre un mapa.
- Configuración del tipo de señal para las balizas.
- Ubicación de los Puntos de Interés sobre el mapa.
- Definición de los contenidos de los POI.
- Ubicación del usuario en el mapa y activación de contenidos.
- Integración de visualización esteroscópica para uso de gafas de Realidad Virtual.

Integración en video-guía de Realidad Virtual de Casa Batlló

La casa-museo Casa Batlló dispone actualmente de vídeo-guía que muestra 20 puntos de interés del recorrido de la visita. El dispositivo es un teléfono móvil Sony Xperia T3 con la aplicación instalada de la visita. Incluye un menú con números que corresponde a los lugares en la casa marcados con un rótulo en la pared con el mismo número. Al seleccionar el número correspondiente a la sala, aparece una imagen virtual de 360º mostrando el mismo espacio con el mobiliario de la época y animaciones digitales incrustadas.

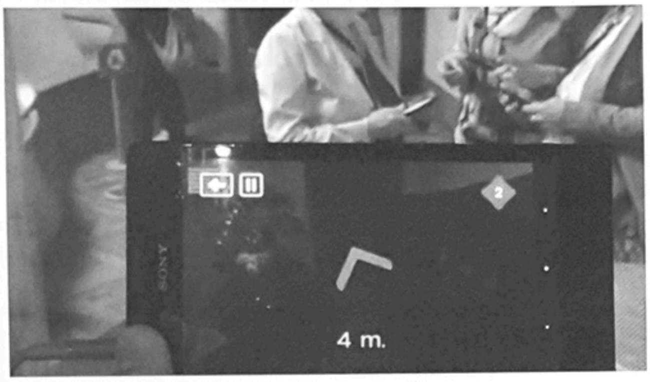
Indicaciones en el menú (núm.4) por localización.

Los responsables del museo detectaron que los visitantes no marcaban los números correctamente, lo que podía generar una experiencia poco satisfactoria. Con intención de mejorar esta situación, desarrollamos la integración del posicionamiento en la vídeo-guía 2.0. El objetivo principal era sugerir el número al visitante y mostrar las imágenes sólo si la posición era la correcta. En caso contrario, la pantalla se mostraría oscurecida y sólo se activaría el audio.

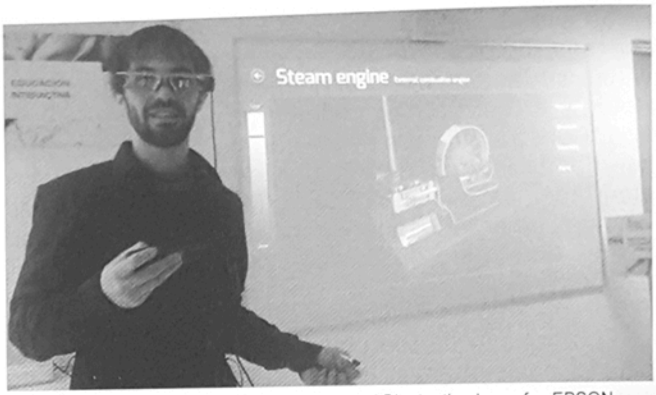


Contenidos de imágenes 360º con animaciones digitales.

Validación de la aplicación con gafas inteligentes con técnicos de EPSON.



Orientación de la aplicación al visitante por localización.



Demostración de Oriol con el conversor de señal Bluetooth y las gafas EPSON.

La aplicación se trabajó conjuntamente con los creadores de la primera versión, miembros de un departamento de la Universidad de Valencia. Esto permitió una colaboración entre dos centros universitarios en una misma investigación para la aplicación en un primer edificio patrimonio de la UNESCO. La responsabilidad era grande y por ello se procuró mantener un contacto permanente entre ambos equipos.

El resultado final fue satisfactorio a nivel de funcionamiento. La dificultad de integrar las balizas en un edificio patrimonial fue un motivo para desestimar la instalación de los dispositivos. No obstante, el código se empleó en los proyectos siguientes aplicando mejoras sustanciales.

Integración de gafas inteligentes EPSON

El siguiente proyecto consiste en la visualización de los contenidos multimedia en un dispositivo de gafas inteligentes. El objetivo consistía en mostrar vídeos en el monitor de las gafas durante el recorrido de un espacio de exposición de productos EPSON. Si el proyecto resultaba con éxito, se planteaba la posibilidad de implementarlo en la Alhambra de Granada, patrimonio de la Humanidad por la UNESCO.

En este caso de estudio, la empresa EPSON brindó la oportunidad de trabajar en su espacio de exposición para evaluar la robustez del sistema de posicionamiento. Es importante que las empresas proveedoras de tecnología también se impliquen en proyectos de investigación. El soporte de los técnicos especialistas de la empresa fue de utilidad para considerar algunos aspectos técnicos de los sensores de las gafas.

El dispositivo de EPSON tiene un sistema de comunicación Bluetooth 3.0. Fue necesario crear un accesorio de comunicación para convertir la señal 4.0 a 3.0. Esto permitió al dispositivo reconocer la señal emitida por las balizas y mantener funcional el sistema de cálculo de posicionamiento.

Tras la evaluación de los resultados, se espera volver a tener ocasión de presentar la propuesta de implementación en la Alhambra de Granada. Este proyecto depende de otros factores ajenos al desarrollo de la investigación que se describe en este artículo.

Integración en gafas low-cost y dispositivos móviles en La Seu Vella

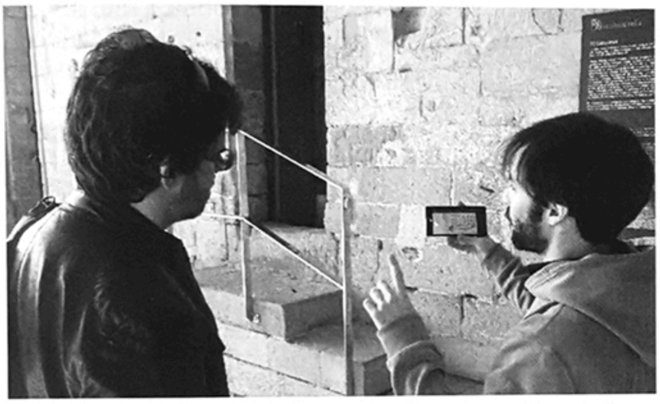
Este proyecto se denominó "Seu Vella para todos" en la jornada para la presentación del monumento de La Seu Vella de Lleida como candidato a Patrimonio de la Humanidad por la UNESCO.

El objetivo es mostrar imágenes reales panorámicas 360º de espacios que, por algún motivo, no es posible visitarlos. Estos espacios no son accesibles a personas con dificultad de movilidad. Por ello, se presentó como una alternativa a la mejora de la accesibilidad de los contenidos del monumento.

Los visitantes pueden descargar unas imágenes desde códigos QR ubicados en puntos de interés. Las imágenes se muestran con sistema estereoscópico y las pueden visualizar con gafas de cartón fabricadas por la empresa LABS4GLASS en colaboración con la empresa de Servicios de Turismo cultural NOMON.

Visualización de imágenes 360º con gafas de Realidad Virtual.

Otra opción presentada fue una aplicación específica para tal evento con el sistema de posicionamiento por balizas que mostraba el mismo contenido que en el sistema descrito anteriormente. Los visitantes podían acceder con sus propios móviles a imágenes de espacios no visitables (torre del campanario, criptas, crucería, etc).



Demostración de Oriol de la aplicación de Realidad Virtual por posicionamiento.

La experiencia con gafas de Realidad Virtual resultó bastante satisfactoria por la idea original de poder mostrar con nuevas tecnologías espacios inaccesibles al público general.

Análisis de resultados y líneas de futuro

Los resultados generales son satisfactorios, tanto en lo académico como en lo profesional. El seguimiento del proceso con aplicación directa en casos reales tiene una repercusión notable en los contenidos del trabajo.

Las tecnologías empleadas sufren una evolución constante, por lo que el proyecto contempla la posibilidad de estos cambios. El código desarrollado permite una adaptación sencilla a las nuevas versiones de sistemas operativos en los dispositivos móviles. Los contenidos son los menos afectados por este cambio.

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Virtual reality using smart-devices in educational frameworks. Case Study: Museum Casa Batlló

Abstract

The main aim of this study is to evaluate the understanding of historical World Heritage buildings through the use of advanced visual technologies during the visit. The main innovative features of the project are focused on the use of mobile and wearable technologies, the indoor location of visitors and their mixed assessment in the context of an educational project. We will use smartphones, virtual reality and indoor positioning systems. Both the devices and the students' experience will be assessed through quantitative and qualitative methods. The proposal seeks to complement, in a contextual way, the real experience of visiting an emblematic space (our case study: the Casa Batlló Museum, 1904-1906, Antonio Gaudí, Barcelona, Spain), by using multimedia contents to understand the complex architectural space and the uses for which it was designed.

Keywords: Mobile indoor content, student mobile usability, user behavior, virtual reality, architectural design education, visualization, indoor location, student motivation.

1 Introduction

Nowadays, the ways we communicate, consult the news, watch television or simply play have changed in order to adapt to new devices and applications, which include characteristics such as mobility, interaction and interconnection. Cultural activities have been a clear example of this revolution; with many interactive screens, multimedia shows and a great variety of performances based on the use of ICTs (Information Communication Technologies). In this regard, and as we will see, it is still easy to find examples of researches and projects aimed at the development and implementation of

ICTs in cultural places, in order to improve the visitors' experience (Grinter, Aoki, Szymanski, Thornton, Woodruff, & Hurst, 2002; Haugstvedt, & Krogstie, 2012).

Any proposal that enhances the spatial understanding of a cultural space does not only have a social utility, but also an educative utility (Sharples, Lonsdale, Meek, Rudman & Vavoula, 2007). One of the inherent objectives of Architecture and Technical Architecture studies aims at the presentation and understanding of architectural space through all kinds of infographic techniques. Often, infographic proposals of singular spaces can be classified into two categories: those placed in a real space (museums, or expositive places), (Chang, 2006), or inside a virtual zone (such as digital environments accessible via mobile devices), (Sundar, Go, Kim, & Zhang, 2015). Both proposals link the visitor's position to the art pieces and cultural heritage sites, giving access to additional information and content (Burigat & Chittaro, 2007).

The motivation behind this article appears with the necessity to evaluate, in an educational context, the way in which architectural space is presented in an interactive form. With this method, students are able to evaluate, not only the configured explanation, but also the implemented working method and to what extent it can be applied to the presentation of their future projects with the current available resources: models, static panels, infographic videos, etc. Casa Batlló Museum (1904-1906, Antonio Gaudí, Barcelona, Spain) was selected after achieving several requirements: it is located in the same city as the faculty (facilitating the transport and visit for the students); it is provided with a multimedia video-guide with 3D contents that explain the singular space; the system locates the user position (using beacons) and his/her position related with the POIs (Points Of Interest) in order to show the virtual content about the constructive process and the house itself into the mobile devices; it is a World Heritage Place; and we have been provided with free access for those architecture students who collaborate in the project.

The main aim of this experiment is to study student-mobile interaction in the position-based process of visualizing virtual reality (VR) data. Our primary objective is to assess the method's usability (indoor location based contents), and our secondary objective is to validate the hypothesis that the use of these methods improves students' understanding of architectural spaces (based on the explanations of architectural elements that students can watch and listen in the virtual video-guide).

In order to analyze the proposed educational method and assess the degree of usability of the system, we adopted a mixed approach. The quantitative approach is based on ISO 9241-11, previously used in other educational cases, (Fonseca, Martí, Redondo, Navarro & Sánchez, 2014, Pérez-Cota, Thomaschewski, Schreep & Gonçalves, 2014), which provides usability assessment guidelines of efficiency and user satisfaction. The qualitative approach is a post-visit interview with a representative sample of the students involved in the project, who will share their experience with the appliance of this new technology into the visit. For this final stage, Bipolar Laddering Assessment (BLA) was used, a technique also previously validated in other educational experiments (Fonseca, Redondo & Villagrasa, 2015; Fonseca, Valls, Redondo & Villagrasa, 2016).

2 Literature Review

2.1 Mobile and wearable technologies for cultural and educational issues

Some ICT-based cultural proposals aim at the visualization of 3D contents, while others focus on the technological improvements of architectural places. In the first case, the accessible on-line platforms already allow interaction between the device and the exhibited objects. It enables a 360-degree view and connects it with systems that have created specific spaces and options for cultural places, such as Sketchfab (https://sketchfab.com/museums, Godin et al, 2002; Wojciechowski, Walczak, White & Cellary, 2004; Younan & Treadaway, 2015). Therefore, the visit can become more engaging, interesting, and generate a better emotional response from both the user (Haywood & Cairns, 2006; Sylaiou, Mania, Karoulis & White, 2010; Alelis, Bobrowicz & Ang, 2015), and the inside educational strategies (Di Blas, Paolini & Hazan, 2003; Bickmore, Pfeifer & Schulman, 2011; Bouta, Retalis & Paraskeva, 2012).

An increasing number of museums are including new technologies in their visits, such as touch screens, interactive projections, new types of video-guides, etc. (Carrozzino & Bergamasco, 2010). With the emergence of mobile technologies, however, some of these experiences mix both elements, giving as a result new proposals where visitors provide the device necessary for the experience. This is known as BYOD ("Bring Your Own Device", Ballagas, Rohs, Sheridan & Borchers, 2004). The approaches are aimed at improving the navigation, interaction and narrative of singular spaces; concepts that students and professionals of architecture need to develop in their projects. In this framework, we can define the use of ubiquitous devices for viewing and interacting with advanced contents and educational proposals as a type of Mobile Learning (ML). ML can go a step further by enabling teaching via wireless networks and mobile devices, allowing the learning process to take place anywhere, and at the same time ensuring teacher-student interaction (Naismith, 2004).

The use of ICTs in learning methods, especially in Architecture, Urban Planning, or Building Engineering degrees are defined in the academic plans (Anthopoulos & Fitsilis, 2010). These teaching methods aim for a quicker and more effective learning process, compared to traditional educational methods. Visual knowledge is one of the most relevant aspects with which the architecture student works, due to the substantial amount of cultural data present (Boeykens, Santana-Quintero & Neuckermans, 2008). Spatial information is represented in a variety of ways, ranging from traditional methods, such as printed plans and physical models (working from 2D to 3D) to modern methods, such as digitally printed plans and tridimensional models, which allow for a greater level of detail and the ability to navigate and consider potential changes instantaneously (Bouchlaghem, Shang, Whyte & Ganah, 2005).

2.2 Indoor positioning: The iBeacons

The multimedia performances in museums and heritage buildings have been mostly aimed at facilitating the explanation of complex contents in an accessible and usable way, adapting their quality to the visualization device, usually panels and fixed screens. The qualitative leap in the process of displaying specific content to visitors is locating their position and providing them with optimal information related to their surroundings. In this regard, we clearly need to differentiate outdoor and indoor locations, both with their problems and particular solutions.

Outdoor positioning systems that allow users to know and share their physical or geographical location are recognized as a key point in the development of mobile applications (Steinfiled, 2004). In order to achieve practical implementations, we can find previous researches focused on several possibilities, ranging from ultrasound to radio transmission systems (Pahl, & Radar, 2000), without forgetting the most extended positioning technology, GPS (Global Position System).

Indoor location has various possible approaches, all of them depending on the type of technology used. Among the technologies that have historically been used for such purposes, we can cite the motion capture, cell triangulation, GPS navigation and the most common cases of Wi-Fi positioning systems and hybrid models. Recently, we can find more implementations using Beacons (Bluetooth Low Energy – BLE). The Beacon based system has two major advantages: it is between 60% and 80% cheaper than the traditional Bluetooth, and it is ideal for applications that require the transfer of small amounts of data on a regular basis (type Broadcast).

In conclusion, the usability of this type of sensors that work with a basic Bluetooth processor, a battery and a firmware is considered satisfactory. It is regarded as an optimal solution to our approach, a system that indicates and guides users through the content by sending messages based on their position.

2.3 Mixed methods applied in educational mobile HCI

In the experimentation and scientific research of working hypotheses based on user's response, a basic issue is the correct design of methods that allow data extraction. If we acquire a large number of samples, the collected data may be treated quantitatively, and the results can be considered as statistically significant. With fewer users, however, the qualitative approach has proven to be equally valid with the ability to obtain a detailed explanation of the variables of the study (Delamont & Atkinson, 2010). In this frontier, a hybrid approach to experimental methodology has emerged, which uses a more holistic view of methodological problems: the mixed-methods research approach. We can define the mixed method research as the natural complement to traditional qualitative and quantitative research. With a great potential to promote a shared responsibility in the quest for attaining accountability for educational quality (Johnson & Onwuegbuzie, 2004), it utilizes the strengths of both qualitative and quantitative research (Creswell, 2013).

On the one hand, quantitative research focuses on analyzing the degree of association between quantified variables, as promulgated by logical positivism. Therefore, this method requires induction to understand the results of the investigation. Because this paradigm considers that phenomena can be reduced to empirical indicators that represent reality, quantitative methods are considered objective (Sale, Lohfeld & Brazil, 2002; Vigo, Aizpurua, Arrue & Abascal, 2011). On the other hand, qualitative research focuses on detecting and processing intentions. Unlike quantitative methods, qualitative methods require deduction to interpret results. The qualitative approach is subjective, as it is assumed that reality is multifaceted and not reducible to a universal indicator (Pfeil & Zaphiris, 2010). Qualitative methods are commonly employed in usability studies and, inspired by experimental psychology and the hypothetical-deductive paradigm, employ samples of users who are relatively limited. Nevertheless, the Socratic paradigm from postmodern psychology is also applicable and useful in these usability studies because it targets details related to the UX with high reliability and uncovers subtle information about the product or technology studied (Pifarré & Tomico, 2007). Starting from the Socratic paradigm basis, the BLA system (Bipolar Laddering) has been designed. BLA method could be defined as a psychological exploration technique, which points out the key factors of user experience. The main goal of this system is to ascertain which concrete characteristic of the product entails users' frustration, confidence or gratitude (amongst many others). The BLA method works on positive and negative poles to define the strengths and weaknesses of the product. Once the element is obtained, the laddering technique is applied in order to define the relevant details of the product. The objective of a laddering interview is to uncover how product attributes, usage consequences and personal values are linked in a person's mind. The characteristics obtained through laddering application will define what specific factors cause the person to consider an element as strength or as a weakness (Fonseca, Redondo & Villagrasa, 2015).

In conclusion, the possibility of working with both types of information in a single study is a great advantage for a research team: multidimensional outcomes make it much easier to propose solutions and further research steps in a given field of study.

3 Project Description

The aim is to propose a wireless system, which offers new 3D virtual content that complements the visit, using a video guide based on the user's position. Batlló House officials detected disorientation problems amongst the users; visitors did not mark the correct POI guide number associated to their position, and therefore missed important content, resulting in an unsatisfactory or poor comprehensive visit experience. Additionally, Batlló House managers did not want these sensors to be located in visible areas, which besides the morphology of the spaces, complicated the positioning of the beacons, and consequently, their response. The main stages of the project are:

- POI definition: Jointly, Batlló House managers and the Company Lab4Glass (start-up led by the authors of this paper and with the participation of La Salle students), defined the POIs and the type of contents to be displayed in the mobile devices.
- 3D modelling: The Polytechnic University of Valencia (UPV) was subcontracted for the production of virtual contents, all under the supervision of Batlló managers.
- Location studies: Parallel to the previous point, the devices (beacons and mobile devices) were programmed with the information detailed in the following section.
- User eXperience (phase described in this paper): A study with architecture students was conducted in order to assess the usability of the system and its possible application in their future projects.

3.1 Indoor positioning

For the current proposal, we have selected the Estimote beacons (with a range of up to 70m), and Batlló House officials chose to work with mobile devices type Sony Xperia T3 (Android OS). The advantages of working with the Estimote beacons are based upon two criteria: their work with Bluetooth 4.0 (type BLE, minimum power consumption with as much data as possible) and its appearance, which recalls the typical forms of Antonio Gaudi's mosaics (Architect, Author of Batlló house). According to the previously described stages, the first step was to the set the location of the POIs. This process was necessary in order to configure digital devices, create the modeling of the additional information shown in them, and to set the position of the beacons, which must locate the visitor's video-guide and indicate him/her to open the information available. Subsequent to the study of the characteristic morphology of the Batlló House, Fig. 1 shows the location of the beacons and the numeric simulation.

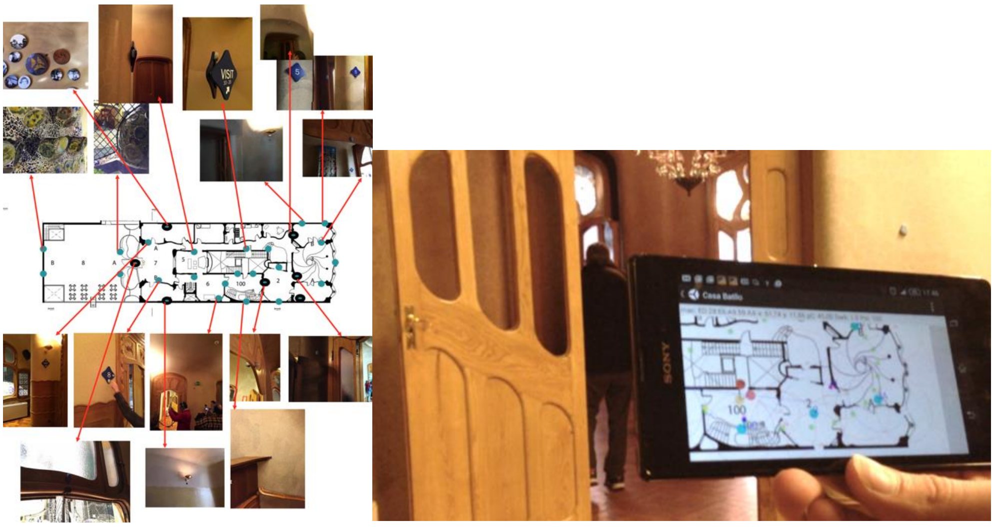

Figure 1. *Location of the beacons and indoor location based on numeric simulation.*

The visual content generated by UPV has been created using AutoCAD, 3DMax and Revit Architecture. Additionally, an Android application was developed using Unity, which interprets the files programmed in C# and JavaScript for the configuration of the positioning. This positioning is determined through the user's triangulation. Because in Batlló House there is a large oscillation of the signal, the RF signal (Bluetooth type) and its power have been studied using a numerical simulation of different variables and filters. These oscillations depend on the user's orientation, the transmitter, the geometry of the spaces, the magnetic interferences, etc., factors that alter the intensity of the signals and therefore shall be taken into account into the calculations (Fig. 1).

3.2 Evaluation Design

The model of the study was quasi-experimental. This method is used to determine the cause and effect relationship between variables, and to identify the reactions of participants under certain conditions. The quasi-experimental method is a design, which involves disregarding random distribution through placing participants in control and experimental groups. This model compares the results without random distribution by interviewing two or more groups. One experimental group will visit the Batlló House using the video-guide with beacon-based indoor location, and another control group will visit the museum using the video-guide without any location system.

Plenty of models can be used to design the responses of implementing new technologies in cultural heritage sites for architecture educational proposes, focusing on the efficiency, effectiveness and level of satisfaction/usability of a proposal (Martín-Gutiérrez, 2010; Navarro et al., 2012; Stanney, Mollaghasemi, Reeves, Breaux, & Graeber, 2003). Our case was based on ISO 9241-11, which provides several usability guidelines. All of the questions were scored on a five-point Likert scale (1 = never or strongly disagree, 5 = always or strongly agree). The model used was based on prior recommendations from Martín-Gutiérrez (2010), and was successfully used in our previous experiments. Finally, some students covering both groups (experimental and control), were interviewed in order to obtain their subjective opinion using the BLA.

4 Results

From the 32 students enrolled, 15 were assigned to the experimental group (G1), and 17 to the control group (G2). The experimental group was composed of 8 females and 7 males, with a average age of 21.5 years (Standard Deviation = 1.8), and the control group was composed of 9 females and 8 males (average age = 20.0 years old, SD = 0.5). We divided them using a random distribution, and after that they passed a user profile test (or Pre-Test), in order to assess their interest and motivation about using mobile technologies in education and in professional architecture work. The aim of this step was to find possible significant differences between the experimental and the control group, an issue that can bias the results. Pre-test mean scores are similar in all groups, and to estimate the probability that groups are significantly similar, we used the Student's t-test (Gosset, 1908), using the null hypothesis (H_0) that there are no differences in scores between groups. Statistical significance (two-tailed) is $p = 0.386$, which exceeds the threshold of $p = 0.05$, meaning that there is a very low probability that the groups are different in their perceptions and motivation. One-way between-group analysis of variance (ANOVA) using pre-test scores as the covariant was conducted to compare personal use: with respect to the use of devices or technologies related to educational use, there are no statistically significant differences between the different groups or between gender ($F = 0.279$, $p = 0.762$).

4.1 Quantitative assessment of usability

After completion of the visit, the post-test was completed. The main purpose of this test was to evaluate student assessments of the visit, the 3D contents, and the technology.

Through the structured test, based on International Organization of Standardization (ISO) 9241-11, it was possible to evaluate the feasibility of using video-guide with 3D contents based on visitor location on mobile devices in architectural environments while focusing on the usability guidelines of: Effectiveness (E1), Efficiency (E2), and Satisfaction (S1). Table 1, shows the student's responses of the usability post-test:

Table 1.- Global usability results.

Usability variables	*G1 (n=15)*		*G2 (n=17)*	
	Mean	*SD*	Mean	*SD*
(E1-1) The (visit) device is suitable for the visit	4.2	0.7	3.8	0.4
(E1-2) It is easy to navigate with the application	4.2	1.0	3.7	0.5
(E1-3) The quality of multimedia content helps the spatial comprehension	4.1	0.9	4.2	0.8
(E1-4) The menu enables a clear and orderly viewing of the contents associated with the visit	4.4	0.5	3.3	0.5
(E1-5) The visualization of contents based on the mark location helps the spatial comprehension of the building	3.6	0.9	4.3	0.5
(E2-1) It was possible to use the device in an autonomous way	4.4	1.0	4.3	0.5
(E2-2) The application was stable	3.1	0.6	3.7	1.4
(E2-3) It was possible to visualize all the multimedia content	3.7	1.1	2.8	0.8
(E2-4) Number of POIs and their content were suitable for the understanding of space at the time of visit	4.0	0.7	2.8	1.2
(E2-5) An ordered visit of the POIs was possible	4.1	0.8	1.3	0.8
(S1-1) Degree of satisfaction with the use of the mobile device to complement the visit	3.4	0.9	2.8	0.8
(S1-2) Degree of satisfaction with the mobile application	3.7	0.7	3.3	0.8
(S1-3) Overall assessment of the multimedia content quality	4.1	0.8	3.8	0.4
(S1-4) The spatial comprehension of the project was satisfactory using the selected POIs	3.9	0.8	3.8	0.4
(S1-5) The guided tour is more satisfactory than an autonomously carried out one	3.9	0.6	3.7	1.2
(S1-6) Mobile tech. and 3D visualization improves the interest, the spatial knowledge and the motivation of the user in heritage sites	4.6	0.5	4.7	0.5
(S1-7) ICTs are useful in other environments such as heritage, tourism, culture, leisure…	4.6	0.9	4.2	0.8
(S1-8) Global Assessment	3.7	0.5	3.5	0.8

Using a null hypothesis (H_0) stating that there are no differences in scores between groups, we find a statistical significance (two-tailed) of p = 0.0457, which does not exceed the threshold of p = 0.05, meaning that there is a high probability that the groups are different in their usability evaluation. The results indicate a significant difference among the G1 (usability average of 3.99, with low variance = 0.15), and the control group (G2 average of 3.56 and with more distributed variance of 0.59). The average responses related to E1 and S1 are very similar for both groups and are not statistically significantly different, as shown in Table 2. On the other hand, the comparison of E2 between groups has a p = 0.051, a value that confirms the difference between our working groups.

Table 2.- Pooled data of usability variables.

Variables	*G1 (n=15)*		*G2 (n=17)*			*Critical*	*p*
	Mean	*SD*	Mean	*SD*	*t-Statistic*	*t-Value*	*(two-tailed)*
Effectiveness (E1)	4.11	0.19	3.87	0.13	1.053	2.306	0.323
Efficiency (E2)	3.89	0.15	3.00	0.34	1.943	1.617	0.051
Satisfaction (S1)	3.99	0.15	3.73	0.27	1.408	2.178	0.184

4.2 Qualitative BLA

Conducting a BLA consists of three steps: Elicitation of the elements, marking of elements, and element definition. From the results obtained, the next step was to polarize the elements based on two criteria:

- Positive (Px)/Negative (Nx): The students must differentiate the elements perceived as strong points that helped them improve the type of work. These elements are classified as useful or satisfactory. On the other side we find the negative aspects that did not facilitate work or simply need to be modified (see Table 3).
- Common Elements (xC) / Particular (xP): The positive and negative elements that were repeated in the students' answers (common elements) and the responses that were given by only one of the students (particular elements) were separated according to the coding scheme shown.

	Positive Common (PC)	**Av Score (Av)**	**Mention Index (MI)**
1PC	The use of VR for viewing additional data	8.42	100%
2PC	Interactivity / Usability	9.00	57%
3PC	The system helps to understand the space	9.00	57%
4PC	The combination of audio and video data	9.50	28%

5PC	Advertisements for near POI	9.50	28%
	Negative Common (NC)	**(Av)**	**(MI)**
1NC	Loss of synchronization in movement	4.33	85%
2NC	A digital map is necessary to navigate	3.66	57%
3NC	Image quality	5.00	42%
4NC	Screen size	4.33	42%
5NC	It is difficult to understand the interface	4.00	36%
6NC	Video details	4.00	28%
7NC	Screen Reliance	3.66	28%

Table 3. Positive and Negative Common (NC) elements

In this type of analysis, the Positive/Negative Common (PC / NC) elements are the most representative because they are the most cited. Depending on the reference rate and its average obtained value, we can identify the most relevant elements.

In the third step (the qualitative stage), students describe and provide solutions or improvements for each of their contributions in the format of an open interview. The common elements that are mentioned more frequently (Table 4) are the most important aspects to use, improve or modify (according to their positive or negative sign). Other elements, especially those identified by a single user only, may be ignored or addressed in later stages of development.

	Description	**Mention Index**
1CI	Adding a visual map of the space. Not a conceptual POI map.	85%
2CI	Adding more details to the videos	85%
3CI	Improving the interaction to adjust it with the navigation	85%
4CI	Viewing the information without losing the reality: use AR	71%
5CI	Using tablets or mobiles with bigger screens	57%
6CI	Improving the quality of the video (images and render)	57%
7CI	Changing the information in depending on the user profile	28%
8CI	Improving the type of information to be more professional	28%

Table 4. Proposed Common Improvements (CI) for both positive and negative elements

5 Discussion

Based on the homogeneity of both groups assessed in the pre-test, we used Student's t-test to review the quantitative data, with the null hypothesis (H_0) that there would be differences in mean scores between the groups. The results show significant differences between the two groups trough five indicators: E1-4 (p = 0.000), E1-5 (p = 0.050), E2-3 (p = 0.0416), E2-4 (p = 0.0322), and E2-5 (p = 0.000). For E1-4, the lack of help on the POI's orderly localization suffered by the control group is settled as the main variable causing the low score obtained in this aspect. This aspect is directly related to the need of incorporating an installation map to orderly orient the user (see the common negative answer from BLA: NC-2). This need is one of the most mentioned aspects at the BLA, by up to a 57%, and it is very negatively scored (Av: 3.66). The low assessment by the experimental group for E1-5 is largely due to the device sync problems (NC-1, Av: 4.33, MI: 85%). The lack of beacons, as well as the excess of them, generates tuning jumps and loss of the multimedia content visualization. In addition, the singularity of casa Batlló's morphology did not help. E2-3 is among the three less scored at the usability test (both in the experimental and control group), being especially negative. Searching its justification from the BLA data, we highlight the following answers: NC-1, with an Av: 4.33 and MI: 85% and the problem of a small screen visualization (NC-4, Av: 4.33, MI: 42%). As it was expected, E2-4 affects negatively to the control group. The lack of indications to localize the defined POI, and the irregular environment like the space at the Casa Batlló, may generate an incomplete experience (NC-2, Av: 3.66, MI: 57%). In order to understand complicated locations, there is a need for more POIs and the possibility of complementary information in every one of them, as it is reflected at the BLA. Finally, for E2-5, the control group's response is the worst from the test and clearly shows how the current guide does not allow for an orderly visit without the help of a location system, (as reflected both in negative at the BLA, NC-2, Av:3.66, MI:57%, as in positive at the experimental group: PC-5, Av: 9.50, MI:28%).

6 Conclusions

In line with our previous experiences, we have demonstrated the usefulness of the mixed method applied. It has demonstrated its usefulness as a system for capturing information related to student's experiences with technological devices and applications.

If we focus on the main objectives of this study, we can conclude that using ICTs with an indoor positioning system improves the guided visit in interesting buildings. This assertion is directly linked to the usability test. The effectiveness, as much as the efficiency, and the satisfaction of the proposed method are better than in a video guide system without indoor positioning (control group), being the difference significant in the case of E2.

On the other hand, and thanks to the BLA, we confirm the effectiveness of the system proposed, and its possible uses in the field of architectural visualization and student understanding of the architectonic space. All students (PC-1, MI: 100%, Av: 8.42) have recognized the use of the VR to visualize additional information on architectural projects as a positive aspect. This answer is linked to the skill of understanding the 3D space.

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