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Experiencing Augmented Reality as an Accessibility Resource in the UNESCO Heritage Site called "La Lonja", Valencia.

Marina Puyuelo[a]*, José Luís Higón[b], Lola Merino[a], Manuel Contero[c]

[a]*Escuela Técnica Superior de Ingeniería del Diseño, Universitat Politècnica de València UPV, Valencia, Spain*
[b]*Escuela Técnica Superior de Arquitectura de Valencia, Universitat Politècnica de València UPV, Valencia, Spain*
[c]*I3BH, Universitat Politècnica de València UPV, Valencia, Spain*

Abstract

This paper presents the design of an augmented reality application for the Gothic Silk Market Building called the "Lonja de la Seda" in Valencia (UNESCO Monument Heritage Site, 1996) and the results of the experiments carried out "in-situ" to observe its usability as an accessibility resource. The objective of this project has been to use and validate augmented reality (AR) as a tool to increase the accessibility to the architectural elements of this monumental setting. The AR application aims to resolve the perception issues derived from poor lighting, the distance in relation to the multiple details, access, etc. 145 individuals of different ages and diverse origin, making the visit to the monument with or without guide used the AR application. When visitors had used the application as they wished, interviews were conducted individually in order to receive their feedback about the AR experience. Users enjoyed identifying and selecting the motifs they were going to visualize with the AR tool. In general, the experience was very positively evaluated by participants, promoting a favourable and renewed image of the monument

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* Corresponding author. Tel.: 34-96-3879501; fax: 34-96-3877509
E-mail address: mapuca@ega.upv.es

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1. Introduction

In view of the fact that modifying certain protected monuments to make them accessible is difficult, as in this case, a notable example of 15th century Gothic architecture (one of the most visited sites in Spain, see Fig. 1), it is useful to investigate other approaches that generate similar experiences for all visitors. From the perspective of inclusive design, it is worth emphasising the importance of promoting and equating the visit for all people in terms of time and content of understanding and enjoying the place. In this regard the gradual integration of technological formats and devices in this type of monuments or heritage sites provides in situ resources that facilitate an expanded visit, thereby promoting intuitive knowledge based on enjoyment of the place

This paper presents an augmented reality (AR) application, based on a graphic substrate, to improve accessibility to this built heritage site. The most significant challenge in the system created is make this technology available to visitors to the monument so they can explore and visualize building details as directly and intuitively as possible. This AR application aims to expand the main features of this building and to promote a new way of communication of this monumental site. The use of virtual 3D models can provide interpretations, stimuli and explanatory references that adapt more closely than others to the discourse of the disciplines to which they refer. In terms of accessibility, both in situ and through virtual experiences, they have an undisputed ability to compensate, by providing perceptions for understanding and enjoyment of such places, and are obviously irreplaceable in certain situations of disability. With augmented reality it is possible to overcome certain limitations in the environment and/or users, and provide new perceptions and understanding of these places. This project proposes the enhancement of an artistic and historical heritage site the Lonja, using an interactive resource to increase visitor interest, participation and experience.

This work is based on two hypotheses: the first highlights the importance of experimenting with this technology in real contexts of interest for the community, thus reaffirming the concept of situated learning [1]. The second aims to verify the viability insofar as it performs a non-intrusive application in a protected monumental context, and it is sufficiently user-friendly and intuitive so that visitors may use and understand it in an autonomous and efficient way [2].

The main focus of the research is constituted by the direct observation of the visitors' interaction with the system in this exceptional real environment. Participants were surveyed once they used the AR application. The used questionnaire evaluated the use of the technology in this architectural setting, the handling of the application, the visitor's interest in the observed details, the contribution of this resource to the accessibility and their general opinion. The first section of this paper describes the methodology, the model selection criteria the design [3] and requirements of the system's components [4], as well as the on-site implementation

The importance of this work consists in the fact that it shows how systematic research makes it possible to confirm the relevant aspects for the implementation of a virtual technology such as AR in a monumental setting. In this case, the use of AR confirms the established hypotheses regarding their contribution in the context of situated learning, which assumes that this process occurs more efficiently in a real context and it becomes a major part of the basic knowledge associated with this learning. It also confirms the need for simplification in the execution of the experience especially if the aim is to promote the accessibility and the autonomy of the user [5]. Accordingly, it highlights the design's role in the aesthetic quality of the marks configuration [6], since they constitute the primary stimulus of the communication with the system and facilitate the active selection of the contents to be viewed. This paper shows the role of this particular technology as mediator of a virtual representation/reality in building new ways of interacting with places and knowledge that can be useful in situations of disability. The research was divided into three stages: the first one related to the visualization of the pieces in handheld devices which will enhance the elements in an augmented environment, the second one related to the process of creating the virtual version of the pieces in 3D, and finally the implementation of the system in the real scenario to be used by the visitors.

Fig. 1. (a) Room of columns at the Silk Exchange, Valencia. (b,c) This room is the most charismatic space in the building with its slender twisted columns; scenery and components of the experience with the system created; (d) using one of the models which represents an element located on the first stage of the building

2. Design requirements and components of this AR system for this monumental site: 3D models and marks

This section describes the developed AR application given to the visitors to improve their visit experience to such as singular/particular place. It is worth noting that, given the characteristics of this protected heritage site, one of the requirements was to perform a non-intrusive application [7] including the minimum number of objects in order not to interfere with the global view of the monument. The used scenario in which the experience was developed consisted of an information panel with a description of the experience to be done and the technical equipment for sampling: two support tables, a 32 inch television screen with web cam, laptop loaded with AR application and, the marks printed in matte finish surface with the elements to be visualised representing the models.

The method for creating this AR application has been developed in two stages. First, the technical design of the 3-D visual models, based on selected elements from the site, and second, the design of the panels which are the basic interfaces for interacting with the chosen motifs. A pilot experience carried out previously, allowed outlining the characteristics of the different components, and fitting the contents to the objective public taking as a criterion the concept of inclusive design [8].

The criteria for selecting the elements to be modelled in this AR application is based on a previous accessibility study [9] which determined the site landmarks which should be available to all visitors for a complete, comprehensive visit. The selected elements and details developed as 3D models correspond to two

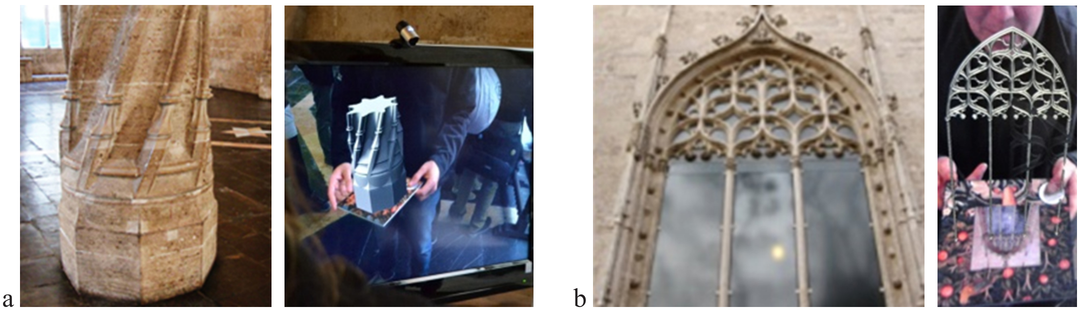

Fig. 2. Two types of elements depending on their volume at the Lonja building that have been enhanced with different models: a. Column, b. Window tracery

different types depending on their shape: the constructive fully three-dimensional elements (Fig 2 a), like columns, capitals and stairs; and those who are related with their almost-plane shape (Fig 2 b), such as doors, ceilings and pavements. The system allows the user to get different approaches in each element that gives more information: points of view, constructive descriptions or historic recreations. The models are controlled by the visitors interacting with a mark in front of the camera.

Often when considering usability of an AR technology, the focus is on observing the handling of the mark which acts as interface in relation to visualization of the volume element on the screen. Usability in this case starts on the initial visual contact with these interfaces that are considered as codifier and de-codifier of the information to be transmitted. Consequently, the piece to be visualized has been represented figuratively in the mark in order to provoke an initial reaction from the moment it is chosen, thus creating specific expectations about the information that is going to be visualized.

2.1. 3D contents

The created AR system provides the user with 9 elements of the building with different impact and complexity, which are handled with easily identified marks or panels, as the sole use interfaces required. These marks make it possible a very simple interaction with the 3D visual contents that appear in the screen. Zoom in or zoom out effect is achieved moving the markers closer or farther to the webcam.

The large quantity of descriptive graphic information on this building, together with general and partial measurements for the elements to be modelled, was considered sufficient. Furthermore, given the constructive characteristics of some of the elements to be modelled (mainly the stairs and coffering) laser scanner technology can only provide data from visible surfaces. However, in some cases the intention is not to show the shape of the surface of the object but to detail its constructive relationship with the elements in the building. Therefore, in this AR application which presents a variety of elements, it was decided to make a geometric modelling based on the available graphic documentation on the building. The models thus obtained have a low triangle load because the geometry representing them clearly defines the edges and apexes of the models.

The appearance of model surfaces was made just mapping the materials on the surface of the model. To represent their textures, shadows were pre-calculated and then mapped on the model as material. The use of photorealistic textures was not recommended in this case, given that many surfaces of the elements modelled are not visually accessible for constructive reasons. This fact would require the use on the same model of textures calculated as material together with textures captured directly from element surfaces, and quality would be conditioned by the poor illumination of some elements. For these reasons it was decided to replace photorealistic textures of the object with material mapping from the pre-calculation of shadows.

The results for model geometry and texture are sufficiently representative to show the relevant aspects of the models on the AR application. In this regard, and considering that the main characteristic in visualisation of the models is dynamic perception, we attempted to compensate for the influence of the two variables with an impact on model visualisation. Firstly, geometric models were obtained with high fidelity to the shape shown in the existing graphic documentation on the monument with a much lower triangular load than that produced by the laser scanner. Secondly, shadow pre-calculation used as element material is not intended to be a faithful imitation of the texture of the represented objects, but to conceptualise the different materials in the constructive definition.

Four of these panels have two or three different models of visualization which allows more detailed information with different purposes:

- Column: two models present the base of this element and the module that generates the column
- Staircase: three scales showing the construction of the staircase does not use any structural support and is constructed from a step
- Window Tracery: description of the curved molding and shapes on the top (Fig 3).

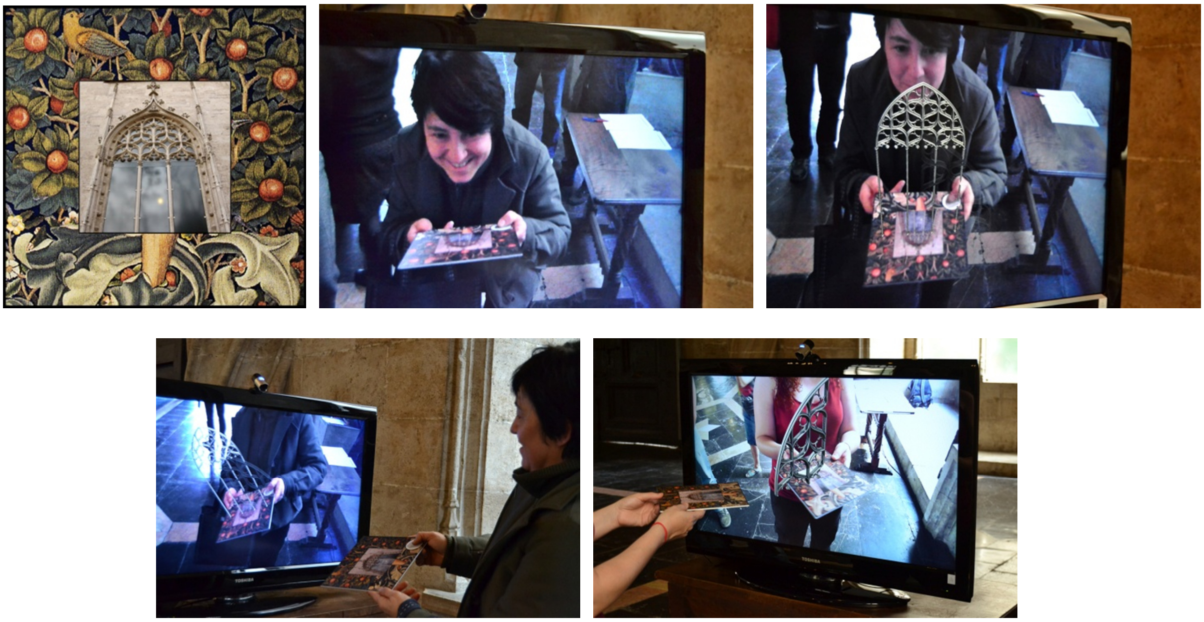

Fig. 3. (a) Mark of the tracery of the windows and use of the same in the two levels of detail (b,c,d,e). The visitor uses the application in a playful and intuitive way just showing it to the video camera, the display image of the 3D model appears on his hands, they can move it freely and get a zoom of other parts of it.

- Capital and the arches of the vault: A second model recreates the color treatment in the fifteenth century

2.2. Marks design

Once we had the virtual pieces we integrated them in the augmented reality system. One important aspect in the creation of any augmented environment is what virtual objects should appear and in what position. In order to simplify this issue we follow a well-known method consisting in placing artificial marks in the scene; the system can identify those marks and associate each virtual object. As we explained before, we consider that these marks have a non-trivial role in the interaction with users and we find important to give a more appropriate image that could help the communication process. So we didn't use commonly binary marks and we design these marks using photographs related directly with the elements to show in the site and from them we extract features that can be used in the tracking process. This choice of graphic metaphors helps users to understand the interface functionality better and improve accessibility providing them with an efficiently constructed network of associations. In these marks we include carefully a black fingerprint in a corner that shows the user how to take the mark and invites him to move it freely in the scene.

These panels provide the necessary texture to be read by the webcam. The proportions, size and format of these marks were pre-tested to ensure robust webcam recognition. The AR application was implemented using the LabHuman markerless AR library which is based on the works of Wagner et al. [10] and Kim et al. [11]. The proposed method works fine with textured planar objects, that is, with planar images which contain a great number of keypoints. This library implemented a method based on image retrieval techniques in order to

Fig. 4. (a) Mark of the explanatory models of column (b) The first level is displayed in the column based startup revolving ribs producing the effect of upward movement toward the vault, (c) The second level of approximation shows the construction module that generates this column

recognize simultaneously a great number of images, specifically, Nister and Stewenius [12] vocabulary tree method was used.

3. Experiences with visitors in the scenery. Discussion

A total number of 145 individuals of different ages and diverse origin have used and evaluated the AR application developed for this study. As with other AR applications in real environments, the presence of users in the same place involves a level of natural and indirect interaction with the information which is highly interesting for the experience. While the user interacts with the marks and visualizes the 3D models, other visitors can observe the scene and learn: the actions of those who are taking part, how they move and see the elements on the screen, the enlarged details in the 3-D models. As noted above, the shape and design of the panels for the marks in the form of graphics helped participants to identify the marks intuitively.

The fact that users see their own hands on the screen means they immediately experience and interpret what has to be done while they direct the mark to the camera. The speed at which users learn to handle the marks and remember and find positions and the shapes they want obeys the concept of “proprioception” [13] and can be observed in these experiments.

Finally, when visitors had used the application as they wished, interviews were conducted individually. It is worth noting that they showed less interest in this conventional participation instrument than in their prior experience with the application. In general, we found that almost all participants felt comfortable using the system, it made an impact on them and they valued the use of AR in real contexts like this one very positively.

The results obtained from the survey offer a users' quantitatively suitable sample (145) to validate the usability of the AR system created and its possibilities to increase the attention, the time dedicated to the visit, the knowledge and, the accessibility to this monument. These results confirm the established hypotheses regarding the contribution in the context of situated learning, the great potential of AR for offering explanatory models that ensure accessibility and communication of heritage and also confirms the need for simplification in the execution of the systems if the aim is to promote the accessibility and the autonomy of the user.

The fact that the experience is carried out in the place of the visit it is valued 'very important' or 'important enough’ for the practical totality of the respondents (94 %), diminishing this appraisal of the context in the youngest sectors (up to 7 %).

About the perception of ease in the managing of the technology, the practical totality of the respondents (92 %) consider it to be 'very easy' or 'easy' the use of the technology showed in this application, decreasing the perception of ease in the sector of people aged 65 and older (up to 16 %). Related to the degree of global satisfaction with the experience, all the sectors of age consider 'satisfactory' or 'very satisfactory' the experience, predominating this response (80 %) in the range of intermediate age.

Regarding the appraisal of relevant details of the building, these are related in most of the cases to the accessibility from the point of view of the user and his mobility. The time invested in the visit also meets clearly influenced by the sector of age polled, increasing in advanced ages.

It has been stated the efficiency of the marks and the appraisal, impact and the interest promoted by their figurative appearance of high aesthetic component. The users enjoyed themselves and delighted with the identification and selection of the motives that "they" wanted "to "augment". It can be affirmed that these aesthetic and figurative qualities increase the cognitive compatibility with regard to these signs and in consequence, turns out to be determinant and improves the process of interaction with the system.

4. Conclusions

This experience with augmented reality at this heritage site shows the effectiveness of the tool as an instrument for accessibility and communication of the specific cultural content of the place by actively supplementing and augmenting its vision. Visitors' experience with this technology has provided a profile of component characteristics for adaptation to the target public from the perspective of inclusive design. Being aware of the impact and usefulness of augmented environments, in this research we developed a prototype of an augmented reality system that seeks as an objective the popularization of this technology not only as an objective itself but as a tool for solving problems of visualization or interaction in monumental environments.

The marks were found to be effective and appreciated. Impact and interest were found linked to their aesthetic and figurative dimension. Users enjoyed identifying and selecting the motifs they were going to visualize with this technological tool. They were able to select what they wish to "augment" from the whole visit. The aesthetic and figurative quality of marks increased cognitive compatibility in relation to these signals and consequently, it was a determining factor for improving the interaction with the system. The fast evolution of consumer technologies in this field, moreover, allows more and more frequently gets used in commercial devices, with accessible costs, instead of expensive ad-hoc appliances [14].

This work is a contribution to the research on new human-computer interaction techniques that present good results in education, but there is yet much work to do to use this technology as an accessibility tool. Further research should be done creating other models and controlling lighting and other conditions to facilitate an intuitive performance in this sort of environments.

Furthermore in this experience the use of AR transcends its own specific functions to favourably create a renewed image of the monument, promoting the active perception of this historic site as well as the receptiveness of user groups who not frequently use these types of technologies.

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