An experimental virtual museum based on augmented reality and navigation [Demo paper]

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ABSTRACT
Indoor environments offer many possibilities for the development of navigation-aided systems and location-based services. This paper introduces an experimental setup that combines navigation facilities with augmented reality, and which is applied to two museums in the city of Mexico. The approach is based on a semantic model of a museum environment that reflects its organization and spatial structure. The experimental setup combines augmented reality, GPS and digital compass devices with smartphones. While several constraints reduce interaction capabilities among exhibitions and visitors, augmented reality offers the possibility of relaxing these constraints by combining real sceneries with digital representations. This enhances interactions between users and objects of interest pointed by the users, where additional multimedia information on the collections presented is available on demand.

Keywords
Augmented Reality, museography, multimedia browsing

1. INTRODUCTION
Augmented Reality (AR) is a computer-based technology that allows a real-world environment to be enriched by virtual images thus enhancing one's current perception of reality [1]. AR technology augments the sense of reality by superimposing virtual objects and cues upon the real world in real time [2], this generating an augmented real-world environment [3]. Most of published AR research has been oriented to enabling technologies in indoor and outdoor environments, and on experimental prototype applications, from AR system design and interfaces [4] to user-based experimentations [5]. AR has been applied to many application domains such as architecture, military and emergency services, navigation in outdoor environments to mention a few examples [6].

Over the past few years, AR has been the object of increasing development in indoor environments like museums, considering that most of them do not have the space and resources required to exhibit their whole collections [7]. In particular, the nature and fragility of some pieces do not make available to the public. AR can be useful in such contexts, providing visualization of 3D digital models of any element of an exhibition, by combining real and digital sceneries, and favoring interactions with these objects in multiple ways. Many museums are progressively applying AR techniques to integrate 3D sceneries in exhibitions [8], but still without a few assistance for navigation tasks. It is worth noting that AR has been also used in combination with other technologies such as pattern recognition for object identification, and in combination with wireless systems [9] [10].

In many museums visitors can be assisted using guided tours or audio guides (hand held devices with headsets) to receive guidance and instructions. However, visitors must carry the headsets along all the way, and when they want to get additional information of an object, they should select a label that identifies the object of the exhibition, and then an audio available in multiple languages is played. Another disadvantage is that these devices have limited memory, this complicating information delivery and updates. Moreover, these audio-guides do not apply for people with impaired hearing. From a different perspective, several virtual museums on the web have been recently developed, and even experimented in conjunction with navigation devices. The Archeoguide is one of the most original experimental systems developed so far [11]. Archeoguide supports exploration of cultural heritage sites by adding virtual information in context through position and orientation tracking. It allows visitors to see virtual reconstructions of ancient buildings. A user is equipped with a see-through head-mounted display and wearable computing equipment. However, this system has not been developed for a mobile device, it does not provide navigation facilities and interaction with these virtual objects is rather limited. The LIFEPLUS project is another related project where real historical sceneries are enhanced with virtual fauna and flora, but the system has not been experimented in real contexts [12].

The experimental prototype presented in this paper introduces an AR setup developed for the museums Bellas Artes and Soumaya in Mexico City. We propose an AR navigation-based solution that provides additional services to these museum visitors for: (1) a visitor navigating by random (2) a user following a given itinerary. The prototype developed takes the form of a mobile application that guides the user to some specific rooms in a given order, and displays additional virtual information derived from external objects of interest along the exhibition. The rest of paper is organized as follows. Section 2 introduces the navigation infrastructure and the experimental interfaces and services developed so far. Section 3 concludes the paper.

2. PROTOTYPE PRINCIPLES

The Augmented Museum (AM) includes three modules: navigation, identification, and exploration. AM allows the users to navigate through a virtual space in order to display multimedia content related to the objects belonging to an exhibition. The application displays a virtual representation of the exhibition space in combination with the real contents found herein. The following sections introduce the principles of the navigation facilities and user route tracking, relationships between virtual and real sceneries and how additional information are associated to objects of interest, and how those objects of interest are identified along a navigation. The experiments have been applied to a recent Greco exhibition in the Palace of Bellas Artes and the museum Soumaya in Mexico city.

2.1 Navigation

Navigation tasks are tracked on top of a spatial model that represents the structural layout, possible routes and the distribution of historical objects in the museum (Figure 1). The spatial model is a hierarchical graph-based representation of the museum where exhibition rooms are nodes and connections between these rooms edges. Exhibition objects are associated to their respective exhibition rooms. A few common itineraries within the museums are modeled as paths.

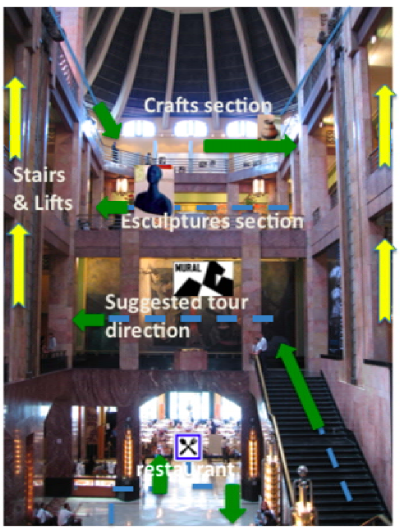

Figure 1. Museum spatial model for an exhibition in Bellas Artes Palace

The museum has three floors. Typically expositions are distributed along these three floors, and organized using specific itineraries that can start in different forms. Navigation tasks are supported by an orientation and location scheme, where GPS locations and coordinates of the main elements of each room are captured and stored into a reference XML database which is locally stored in the mobile phone. One of the goals is that when a user begins to use the AM at the beginning of her/his tour, that user receives a suggested itinerary (i.e., dash lines in Figure 1) and the possibility to browse through a museum map. User positions and displacements are tracked by a compass included in the mobile phone device, and compared to positional information associated to the rooms and objects of the exhibition. The tracking of the visitors is made in this way, and the data associated to each location and orientation is displayed when the camera video is activated from a location within a room of the museum.

2.2 Objects identification

The objects identification module allows to identify an element of a room exhibition based on the user navigation information given by the compass, the GPS and the implementation of a pattern recognition algorithm. A room scenery is captured by a video camera, and analyzed in order to detect patterns previously recognized (called markers). Markers are printed images that can be detected and recognised by the AR application in order to identify exhibition objects and which virtual objects should be displayed. Those are fiduciary markers that contain graphic patterns that allow to define their position and orientation relative to the observer. Markers have the following constraints: they must be square, they must have a continuous border and the area inside the border must not be rotationally symmetric. Figure 2 shows an example of fiducial mark.

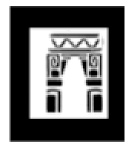

Figure 2. A fiducial marker

Each element of an exhibition room is labeled with a fiducial mark, this fiducial mark is located in front of an exhibition object. In order to be identified, a visitor should point to it with using her/his cell phone and camera. A video is captured and the recognition pattern process is applied when a mark is recognized, then additional information is overlayed on the real scenario captured by the camera on the mobile phone. Figure 3 provides an example of such a functionality.

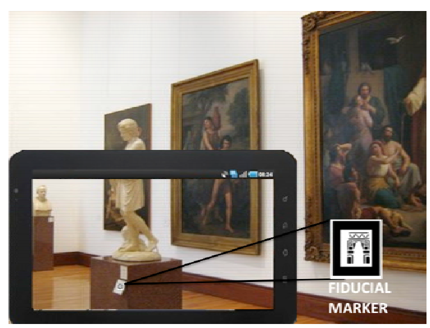

Figure 3. Visitors' museum identifying objects

2.3 Exploration

Let us introduce a brief scenario to illustrate the AM application. Suppose that a visitor located in a room wants to know where is a sculpture presented in this room and to get some information about it. This implies to know (1) the location of the user in that room, (2) toward which cardinal point is oriented the sculpture, and (3) toward which cardinal point the user is pointing to. (1) is given by the navigation module, (2) is derived from the user location and the location of the sculpture given by the XML database, (3) is given by the compass. From the user location, the location and orientation of that scultpure are finally derived. Therefore, a virtual representation is displayed and additional data is shown by means of a wireless communication established with a media server by exchanging media content with the mobile iPhone. This is provided using streaming technology based on Live HTTP Streaming [13]. The design of the network architecture has been made taking into account the characteristics of the environment and using the radiation pattern of a dipole.

Once completed the different views for the virtualization of the exhibition halls, the AR application should recover the content to be associated with the objects exhibited. The exchange of information between the server and the mobile application is performed using XML files. Image retrieval is done over HTTP while the transfer of live audio and video is done using the Live HTTP Streaming Protocol. When a user interacts with the application, any request is sent to the server, and a list of available content is returned. The search for content for an object is done through a unique key that allows it to identify which server XML file must be read. When selecting a particular content, the user is asked once again to display or play the content using the streaming service. Figure 4 shows a typical result of an object identification.

Figure 4. Identifying objects in a room museum

A tabular view integrates the search and displays the results as shown in Figure 5.

Figure 5. Searching contents

When a content type audio or video is selected a new view is shown (Figure 6).

Figure 6. Virtual view of an exhibition object

Moreover, a table view is included to display the contents of the museum classified by type, and to offer the user to select the type of content (i.e., video, audio, image, Figure 7)

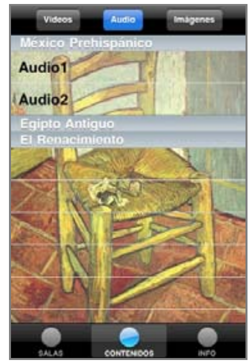

Figure 7. Displaying a multimedia content

A setting option is included where user can choose to browse the environment by using the accelerometer or touch screen. Moreover, the application, intended for use in large and popular museum, is available in four languages (Spanish, English, French and Italian). For the identification objects, when an object is targeted, the user can select one of the results and a detailed view of the object is shown once selected in the selector, as shown in Figure 8.

Figure 8. Detailed view of an object in a scenerie

The AR application provides many possibilities regarding the content to be related to an identified object, which can be videos, audio and images, enriching the way in which current guidelines work in museum exhibitions. The graphics processing and renderization is done using OpenGL graphics libraries (www.opengl.org) and functions provided by accelerometers and touch screen. The iPhone used for the experiment has three accelerometers that measure 3-axes angular tilts. One accelerometer is used for moving closer to a given target, and another for turns into a room. Accelerometer values also allows to process zoom-in or zoom-out functions in a given scenery captured by the iPhone camera. Alternatively, the AM application includes touch screen functions for straight navigation; this provides an easier and more intuitive navigation for inexperienced users. An example of virtualization in a room is shown in Figure 9.

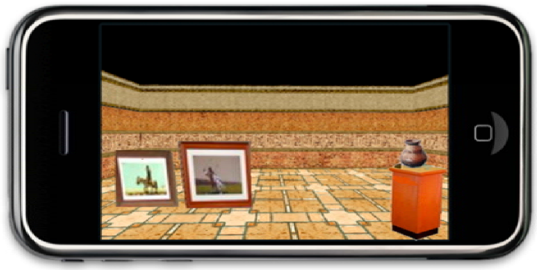

Figure 9. Preview of a virtual room

The complete view of a room is shown below (Figure 10). The AR application also allows navigating through them via the device's accelerometer.

Multiple evaluation tests have been performed during the exhibition. Concurrent content requests to the server from twenty devices have been performed, varying in each test the type of content to download and user locations. Results are encouraging as communications between visitors and the server are performing well. Fiducial markers are easily identified and matched to appropriate virtual objects. Most of the few problems identified so far are rather dependent on the cognitive capabilities of the visitors, particularly interactions between the physical and virtual displays which are not always intuitive for all users.

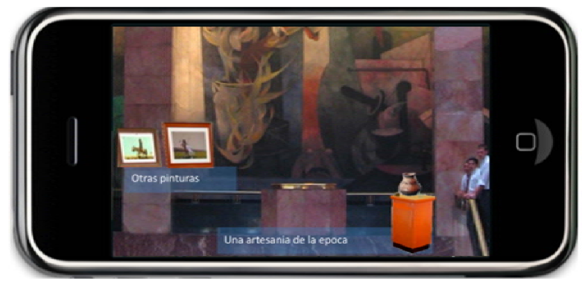

Figure 10. Augmented view of a museum room

3. CONCLUSIONS

This demonstration paper introduces an experimental AM prototype that integrates several real time navigation, exhibition objects identification and exploration functionalities. The prototype enhances interactions between visitors and exhibition objects, thus providing a new form of navigation that combines real and virtual information. The system developed so far has been applied to the Bellas Artes and Soumaya museums in the city of Mexico. Preliminary evaluation results are encouraging as most of the visitors that have tested the developed system are generally rewarding the development. We plan to extend the AM prototype by including voice command assistance, itineraries suggestions and interactions facilities between visitors. Another direction to explore is the extension of the prototype to outdoor environments, to perform navigation and assistance tasks in downtown Mexico.

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