Mobile Augmented Reality for Cultural Heritage

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Abstract. This paper introduces an approach of using mobile Augmented Reality (mobile-AR) in cultural organisations, such as museums and archaeological sites, for information provision and enhancing the visiting experience. We demonstrate our approach by presenting a mobile-AR educational game for iPhones that has been developed for the archaeological site and the exhibition area at Sutton Hoo. This pilot aids visitors' understanding of the site and its history via an engaging and playful game that connects the site with the British Museum where the objects that have been excavated from the site are exhibited. The paper discusses stakeholders' requirements, the system architecture and concludes with lessons learned and future work.

Keywords: Augmented Reality, smartphones, mobile-AR games, cultural heritage, ARToolkit.

1 Introduction

In recent years, mobile phones and particularly smartphones, have developed into an ideal platform for AR applications. This is significant because the widespread adoption of smartphones means that this platform could be one of the dominant platforms for AR applications in the near future. Mobile AR has been named as one of the top 10 emerging technologies by MIT [1]. The potential of AR is huge, particularly in the mobile space where research firm ARCchart forecasts that by 2015 2.2 billion AR-enabled phones will be present in the market [2]. That growth has opened up a plethora of new possibilities in learning, teaching, and the creative sector.

Current technology allows researchers and visual artists to investigate a variety of application possibilities using mobile-AR in domains not commonly associated with computer technologies. Such domains are cultural heritage, and performing arts [3,4,5,6,7]. The current study investigates the possibilities offered by mobile-AR in cultural organisations like museums and archaeological sites without necessarily investing in buying hardware infrastructure, but taking advantage of devices own by the visitors. A survey in Europe showed that 35% of

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museums have already incorporated Virtual Reality (VR) and AR presentations to enhance their exhibitions [5]. While some projects are at an initial stage, the rapidly growing number is an indication that museums start to understand that AR can be an effective way to build user interest in museum collections and exhibits by engaging users and prompting their participation within an exhibit. Studies also, have shown that AR could provide an alternative mean for navigation, interaction and orientation in a museum especially when museums do not have the space and resources required to exhibit their whole collection or the nature of some of the objects prevent the museums to make them available to the public.

While most of the studies in museums have been conducted indoors, there is little literature involving outdoor mobile-AR without the use of fully embodied and wearable systems [8,9]. It is more challenging to move an AR application outdoor, into archaeological places and excavations where interactive storytelling and environmental conditions could play a significant role in the user's experience. Such a system would require an intuitive human-computer interface based on metaphors, hotspots, logical clues, and portable technology. The users should be able to interact with digital content naturally and get augmented information of the excavated objects. Furthermore, the system should provide solutions that enable the comparison and identification of artifacts, in different historical periods, found in the specific archaeological place.

This paper presents an example of a multi-user mobile-AR educational application for the Sutton Hoo site, a group of Anglo-Saxon burial mounds, for SmartPhones. The site combines indoors and outdoors points of interest that need to be connected. The AR tour is delivered in the form of a team-oriented puzzle game. A number of teams of children visitors, age between 11 and 16, are cast into the role of investigators trying to solve a number of puzzles that involve finding specific exhibits from the excavation site. Every real excavated object is augmented by its virtual counterpart in its physical environment with the use of mobile-AR. The information space embeds all exhibits into the game storyline and carries visitors along the Sutton Hoo site in an exciting way.

The remainder of the paper is organised as follows. Section 2 discusses the potential of mobile-AR game-based in learning. Section 3 presents the Sutton-Hoo case study. Section 4 discusses the interface aspects of mobile-AR and the system architecture of the application, before we conclude in Section 5.

2 AR-Mobile in Education

One of the most promising aspects of AR is that it can be used for visual and highly interactive forms of game-based learning as presented in this paper. Learners are provided with a new tool that allows them to enhance the existing environment by augmented it with extended knowledge. Learning activities can follow different pedagogical approaches. The theory of Flow has been introduced in game-based learning approach which addresses the issue of focusing in a learning activity and examines the issue of immersion. The psychologist M. Csikszentmihalyi [10] defined the optimal learning experience in the Flow theory which

aims to achieve clear goals, concentration, a loss of feeling of self-consciousness, distorted sense of time, immediate feedback of the current activity, balancing of ability level against challenge, a sense of personal control, a motivated rewarding activity, and high level of involvement in the proposed activity. This theory has been applied to video games but also to educational activities [11].

The mobile-AR application discussed in this project incorporates: conventional game-play mechanisms including interactive narrative and setting; master goal divided into subtasks; choice and collaboration through which are intended to enhance historical content interpretation; user engagement and inspiration. In addition, novel pervasive game features are introduced to it with three types of expansion: temporal, spatial, and social [12]. Temporal expansion defines game sessions as possibly unlimited actions without explicit start or stop. Spatial expansion reflects the impact of the real world as a 'playground' in the game environment. Social expansion takes into account multi-players that share the playground. By integrating with these game-play features, dynamic simulation, rich media datasets, and augmented content can be brought into a learner's personal space at a scale and in a form easy to understand and work with others at a social level through the mobile platform for communication and collaboration.

Thanks to these innovative features, it is seen that mobile-AR system can be used to enhance various types of learning practices for Technology Enhanced Learning (TEL) in terms of the creation, distribution, and access of learning resources, collaboration and interaction, time and location independency, role changing, and achievement of learning outcomes. In a broader context of education, mobile-AR is appealing because it aligns with pervasive learning by offering the technological innovations to the learner and their learning environment that can support the delivery of flexible, seamless and personalised learning activities to learners.

3 Sutton Hoo Case Study

The Sutton Hoo archaeological site is widely known about the burial ship which is believed to be of an Anglo-Saxon King. However, what the site is really about is a group of Anglo-Saxon burial mounds overlooking the River Deben in south-east Suffolk, England containing artefacts from various periods of time, the most important of which containing a sand-impression of a 27 metres ship which is positioned around the 599 to 625AD and is believed to be the burial ship of an Anglo-Saxon King. In the middle of the ship a burial chamber was found with a deposit containing over 260 artefacts. The treasure includes weapons, symbolic objects, gold and garnet jewellery, Byzantine silver, personal items, and objects associated with music and feasting, a king's helmet. However, when the visitors arrive at the site they do not see a burial ship and any of the aforementioned artefacts. After the completion of the excavation the mounds were closed and only one has been reconstructed to its original 7th century size. Most of the artefacts found at the site are on display in the British Museum and only very limited objects and replicas are on display at an exhibition area at the site.

For the visitor to appreciate the importance of the site, information needs to be provided about various periods of times, such as the medieval period, as well as the early 20th century when the excavation took place. Three places need to be connected: the Tranmer House (Edith Pretty's house the land owner who initiated the excavation); the archaeological site; and the exhibition area that consists of limited original objects found at the site, series of photos that provide information about the excavation, replicas of objects and explanatory material and a reconstruction of the Anglo-Saxon King burial chamber. There are also certain characters that are important for the cultural heritage of the site such as: Mrs Edith Pretty, the owner of the Sutton Hoo Estate; Basil Brown, a local archaeologist who began the excavation of the largest mound on the site; Charles Phillips, the archaeologist that coordinated and completed the excavation. So there is a requirement for connecting the three points of interest and British Museum and augmenting information over the real environment in order to aid the visitors understanding about the site.

The application targets key stage 3 and 4 children ($11-16$ years old) visiting in groups, or with their parents. The application can be downloaded at visitors' iPhones and involves them in a scenario where they have to use the application to explore the site and discover objects that are offerings to the "Dead King". The application consists of two versions: a standalone that can be played by individual ad-hoc visitors and one which is multiplayer and is based on the fact that organised groups of visitors participate at the same time at Sutton Hoo and at British Museum.

In the standalone scenario the navigation starts at the reception area, the visitors take the role of Basil Brown who has been invited by Mrs Edith Pretty to start the excavation of the mounds. The application guides the visitors to the Tranmer House to meet Mrs Pretty. Then Mrs Pretty directs them to the dinning room where by pointing their iPhone on markers placed on the bay window the visitors see the mounds as they used to be before the excavation (see Figure 1). The visitors are then guided to the excavation area and are directed to start the excavation at mound 2. The users are provided with a basic archaeological toolset that contains: a hand shovel; a trowel; a hand brush; and a find bag that plays the role of a repository of objects that have been found. The visitors pick up a tool and start digging. Tapping on the screen indicates the duration of the particular action with the selected tool. After several taps an artefact is partially revealed and the application indicates the user to choose the appropriate tool to fully reveal the object of importance. Markers placed at wooden stitches on a fence that surrounds the archaeological site help superimposing multimedia content on top of a phone's camera feed of the real environment. This content is photographs that show how the site looked during the excavation and after continuing the tapping on the screen with a different tool selected, such as a brush, a $3D$ reconstruction of artefacts is being revealed. Then the application involves the visitors in series of quizzes and puzzles about the objects that have been found in order to help them decide if the objects found could be offerings to the Dead King. Once all the objects of a particular mound have been excavated, then the application guides

Fig. 1. A sample view of superimposed information with location and direction to the next mound. The inventory at the bottom of the screen displays the artefacts found in this mound. Location of next mound is shown on top corner.

the visitors to the next mound to be excavated. Once the visitors have finished the excavation and based on the information they have collected so far they have to decide which of the collected objects are offerings. Then the visitors are guided to the exhibition area with the reconstruction of the burial chamber to offer those to the Dead King. Once the visitors reach the exhibition area they can walk through the reconstruction of the burial chamber and then it is revealed to them if the objects that they found are offerings or not.

The networked version of the application connects with the British Museum and is based on the fact that at least two groups of visitors participate simultaneously at both sites. The visitors are involved in a treasure hunt scenario where the ones at British Museum are more knowledgeable and guide the ones at Sutton Hoo to find the required objects via a list of clues that they give them. The visitors at British Museum use a web based application that provides information about the visitors at Sutton Hoo location, the objects that they have found and feed from their phone's camera. The application allows the remotely located groups to communicate with each other by instant messaging. The visitors at Sutton Hoo use their phones to get instructions, directions and clues. The tools for the excavation and the augmented content are the same for the ones provided by the standalone application.

The winners of the game in both the standalone and the networked versions of the application are the ones that identify correctly the objects that are offerings

to the Dead King in the shortest period of time. To increase competition the application provides some information about the stage of other groups that have started playing the game at the same time.

4 System Architecture

Tracking rectangular fiducial markers is one of the most widely used tracking solutions for mobile-AR applications. In recent years, many researchers have worked towards the development of different APIs for mobile devices with the most widely used the ARToolkit API [15]. Originally, the ARToolkit was designed to run only on standard PCs but AR researchers like Wagner [13] and Henrysson [14] extended the ARToolkit tracking library to different phone platforms.

For the Sutton Hoo mobile-AR project (SHMAR) the iPhone 4 is used, since its wide screen and OpenCL technology for high performance computing, makes it ideal for high resolution object visualisation and real-time game interaction, especially in an outdoor environment. The proposed system uses the ARToolkit for iOS development platform, and the location-based educational game is written in Objective-C. OpenGL ES, which is a subset of OpenGL made for mobile phones and other embedded devices, is used for the $3D$ rendering. For marker tracking and pose estimation, a software development kit called Studierstube Tracker (StbTracker) is used for the creation of multiple markers. Figure 2 presents an example of multiple markers on the left, with virtual objects projected on the markers on the right. The system incorporates a database server for the information space, providing the multimedia content on demand, making it scalable to a large number of visitors. The multimedia database is stored along with attributes that relate each artefact to the geographic position. GPS information extracted from the image tags, allow us to augment the images with navigational

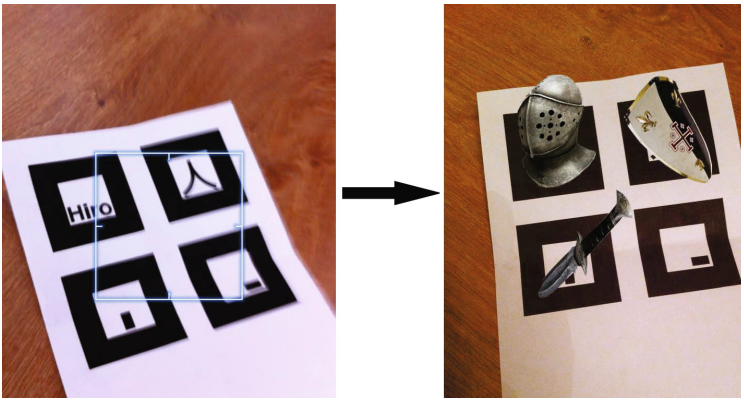

Fig. 2. Virtual objects superimposed on different markers

arrows and direct the visitors to the different mounds. The communication is extended to include different place sharing of information, so that a number of new collaborative interactions are enabled, for example, guiding users to the different mounds and confirming object selection from the excavation site. A basic workflow of the SHMAR project at run-time is outlined in Figure 3.

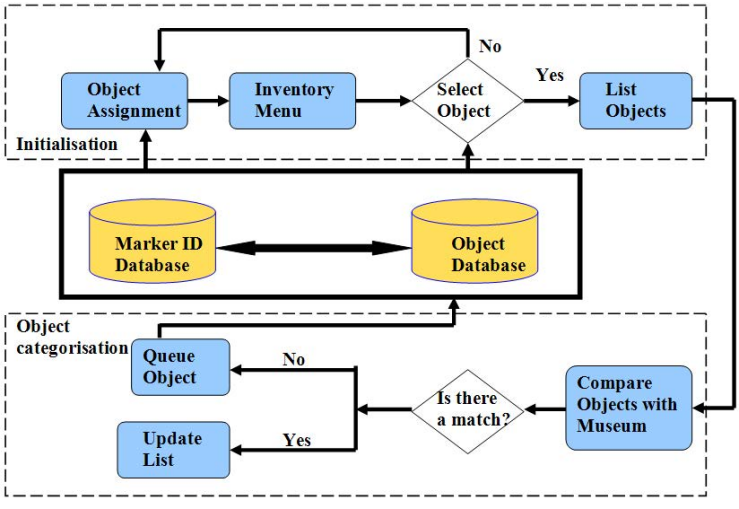

Fig. 3. Architecture of SHMAR visualisation system

5 Conclusions and Future Work

In this paper we present an approach for designing mobile-AR applications to enhance the visiting experience at cultural sites by providing information and interpretations about the sites objects of interest. We demonstrate this by presenting a mobile-AR educational game for iPhones that has been developed for aiding visitor's understanding about the archaeological site and the exhibition area at Sutton Hoo. The paper presents the combination of various technological advances, such as mobile wireless technologies, AR, multimedia and game technologies that have all been brought together in a cultural context to provide meaningful information in a playful and engaging way. The application demonstrates that mobile-AR technology offers great opportunities to cultural organisations for providing added value to their visitors experience by investing in developing applications for hardware owned by their visitors.

Currently the networked version of the project is developed. Once this part of the project is completed a study on site with real users will provide evidence about the effectiveness of the application in improving the visitors understanding about the site, enhancing the visiting experience and addressing the visitors' and the cultural organisations' requirements.

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