Simulating Egyptian Cultural Heritage by Augmented Reality Technologies

Case Study: Pyramids and Giza Plateau cultural heritage site, Egypt

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Abstract

The world is witnessing a great technological progress in the field of applying computational systems in cultural heritage sites. This progress allows many practical marketing applications for such sites like the augmented reality (AR) technology; where the user could acquire a simulated version of the ancient physical world through digital media. On the other hand, there is an absence of using smart technological applications in presenting the Egyptian cultural heritage to the audience to enhance their experience by providing a high degree of realistic interaction. Visitors need means to simulate ruins, buildings, landscapes, or even ancient characters as they formerly existed and the experience could be further enhanced through sensory reactions.

The main objective of the research is to introduce the AR technology as an approach of presenting the Egyptian cultural heritage to the users. When designing augmented reality applications, it’s important to choose the best combination of techniques for presenting the appropriate electronic information to the user which meets their interests and which can also be accepted in the heritage site. By defining that co-relation between “techniques”, “users”, and “site”, the appropriate AR display approach could be determined. The methodology starts with analyzing examples of computational prototypes which used AR applications in cultural heritage, and their AR display approaches. Then, at the end of the research, we would be able to put guidelines to the means of producing a computational model of augmented reality that enables the simulation and visualization of the case study (The Pyramids and Giza plateau).

Keywords: Augmented Reality; technology; smart; simulation; cultural heritage; Egyptian heritage

1. Introduction:

The Augmented Reality (AR) technology is used to enrich the user experience where virtual objects are merging within the real environment. Since reconstruction of cultural heritage through digital technologies has a great significance in preserving, protecting, and interpreting our culture and history, AR applications in heritage have become a platform for learning, motivating, and understanding certain events and historical elements for heritage visitors and researchers.

This paper will present a review on the application of AR technologies in heritage and the approaches used in displaying them. The AR display approaches on heritage will be analyzed in order to classify AR types of requirements: “techniques”, “users”, and “site” and find the co-relations between them which may help in suggesting a proposal for augmenting the case study using the appropriate display method.
2. Difference Between Augmented Reality and Virtual Reality

Augmented Reality (AR) is a technology that allows computer-generated virtual imagery information to be overlaid onto a live direct or indirect real-world environment. AR is different from Virtual Reality (VR). In VR, people are expected to experience a computer-generated virtual environment. In AR, the environment is real, but it is extended with information and imagery from the system. In other words, AR bridges the gap between the real and the virtual in a seamless way (Chang, G. et al, 2010).

The middle ground between real and virtual environments is called Mixed Reality, which also includes Augmented Virtuality; where most of the input including the environment, or background, is computer-generated, see Fig 1. One of the advantages of the AR technology is that there is no need to make an expensive digital version of a scene in the real world when visualizing new objects in an existing environment (Anders Henrysson, 2007).

![Image](image.png)

Fig. 1. Reality - Virtuality continuum and corresponding interaction styles.

3. AR Display approaches

An AR system must be able to provide an output that is a mix of the real and the virtual. The display must hence allow the user to see the real world overlaid with 3D graphics (Anders Henrysson, 2007). Displays can be categorized in numerous ways, one of them is what sense they provide simulation for. The most common display methods provide visual and audio signals, while there are also sensory signals like smell, taste, and touch. Displays can also be categorized by whether they are attached to the participant in some way or not at all (Alan B. Craig, 2013). According to this strategy, AR displays will be categorized as follows:

3.1 Head-worn (Head-Mounted Display HMD)

HMD is a display device paired to a headset such as a harness or helmet. This enables bimanual interaction since both users’ hands are free. In many industrial and military applications, this property makes HMDs the only option (Anders Henrysson, 2007). HMDs place images of both the physical world and the virtual objects over the user’s field of view. It has many problems: (Thomas Vincent, et al. 2013):

- Wearing a salient HMD in public is not socially accepted
- Most systems are expensive
- It hardens the building of wide field-of-view displays
- Eye and video camera parameters differ
- Fitting the HMD with calibrated cameras and tracking sub-systems results in a cumbersome kit

3.2 Handheld display

Handheld display systems, such as mobile phones and tables, allow both direct observation of the physical world un-augmented and an observation of the augmented scene on the screen. It thus allows more design possibilities for modifying the representation of the physical world. There are some advantages for this system:
• Having less social implications and configuration requirements than HMD-based systems
• Having a variety of models unlike the HMD

On other hand, there are some disadvantages:
• A lack of real-time tracking on mobile phones
• No interaction techniques available beyond navigation and simple screen tapping

3.3 Stationary display (optical projection system)

This system acts through "windows" facing the augmented world (Anders Henrysson, 2007). There is no tracking of the display system itself but there is an ability to augment a large area. This system is composed of a projection device and PC monitors or advanced 3D spatial displays.

There are some advantages for this system:
• Providing a large field of view
• There’s no difference between the projected graphics and the place of the real object
• There’s no need to wear any gadgets
• It’s more widely spread than HMD

On other hand, there are some disadvantages:
• It requires a special background to project graphics on it
• A limited range of objects can be augmented

4. AR displays requirements

Many possibilities are available for displaying information in heritage sites through the AR technology. The user can wear a head-mounted helmet and see a video image of the real world mixed with electronic information, a video projector can project information directly onto the heritage objects and the user can hold a small device. Each approach has advantages and disadvantages as explained, so the choice depends upon the application, tracking area, interaction requirements, the needs of the users, and the status of the real site (Wendy E., 2004). To choose the best AR display approach, the following steps must be taken:
• Clearly identify how users interact with physical objects in the real world, and what their interests are (users’ requirements)
• Identify the problems that additional computational support would address (site requirements)
• Identify your needs in the AR application (techniques requirements)

4.1 Users’ requirements

It’s important to specify users’ interests to know how they would want to interact with the AR display. They can see and interact with electronic information - with or without wearing special devices – while having the ability to modify the objects they interact with, see table 1.

Table1: co-relation between users’ interests, and interaction requirements

<table>
<thead>
<tr>
<th>Interaction fulfilled With or Without Using Devices</th>
<th>Heritage reconstruction (watching monuments that no longer exist)</th>
<th>Retrieving Historical events &amp; figures</th>
<th>Interacting with objects without risk of damage (visualizing scenes)</th>
<th>Simulate building materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>Interaction level</td>
<td>With and without</td>
<td>With and without</td>
<td>Without</td>
<td>With</td>
</tr>
</tbody>
</table>
4.2 Site requirements

AR systems must specify the user’s position and orientation in the site to retrieve and present related virtual content. The establishment of position and orientation parameters is known as tracking (Anders Henrysson, 2007). There are AR display systems that support large area tracking and others that don’t, so it’s important to determine the scale of the tracking area in the site and know whether it’s an open or closed area; to choose the appropriate AR display system. On the other hand, the chosen AR display system should be suitable for the status of conservation of the site.

4.3 Techniques requirements

While developing AR techniques, eight requirements have been specified: high geometric accuracy, capturing of all details, photorealism, high automation level, low cost, portability, application flexibility, and model size efficiency (El-Hakim, S. 2004). In every kind of AR display method, some or all of those requirements are fulfilled.

5. Previous experiences of AR applications in cultural heritage

Many projects have used AR technologies for presenting cultural heritage to users. The AR display methods used in several main projects in cultural heritage will be analyzed as follows:

5.1 HMD projects

HMD was used in the ARCHEOGUIDE (Augmented Reality-based Cultural Heritage On-site GUIDE), which was installed at the Olympia archaeological site in Greece, where the site visitors wore AR glasses to see the 3D image display. In the beginning, each visitor provided a user profile showing interest and background. Then, the system provided a set of predefined tours that the visitor should choose from. Based on those choices, the system guided the visitor through the site while wearing special devices. The system depended on a position-orientation tracking component to display AR reconstruction visuals of the temples and other monuments in the site (Vlahakis, V., 2001), see Fig. 2. The experience gained high interaction from users but fitting an HMD with calibrated cameras and tracking sub-systems was a daunting task.

Fig. 2. (a) first picture to the left: Tourist carrying an operating laptop and an AR HMD at viewpoint of Hera temple ruins; (b) second picture to the right: Augmented temple with rendered model on top of live video

5.2 Stationary projects

Peral et al (2005) conducted an example of such implementations, which depended on the projection system. He used projectors and generated images in real time using a computer, which enabled interaction and a sense of taking the leading role in the event, see Fig. 3 (a). This gave exactly the opposite effect of when the display is static. In addition, monuments colours were restored without touching the monument structure, which made the users able to see the different types of polychromes that the monument had throughout the centuries, see Fig. 3 (b). This AR application was available to all the site visitors, there were no special requirements needed to see the virtual objects, a limited range of objects was augmented and the usage of heavy display instruments was accepted in the site.
5.3 Handheld AR projects

An application for using AR handheld display was used in Croatia where a virtual 3D character of the medieval cathedral was created, namely the builder Giorgio da Sebenico. He was performing in real time and at the actual location. Visitors saw him through phones or tablets and received historical information in multi-languages. After the virtual 3D character welcomed them to Sibenik, he began to tell a story about himself, about building up the Cathedral and its uniqueness and significance. If someone passed by or stood next to the virtual character, the device displayed both that person and Giorgio on the screen, as if it were a real situation (Croatia Sibenik tourist board DSP studio, 2013), see Fig. 4. The application was easy to use and entertaining. There were no costs to using it except having your own smart phone or tablet.

Another project was Reggia Venaria Reale’s Palazzo di Diana of which the architecture was modified several times over the years. Each status of the buildings was documented through drawings. These drawings were overlaid on the current facade of the main building through a handheld device. While listening to the story about the Palazzo through an audio guide, the buildings appearance switched through the centuries while seamlessly integrating into the environment, see Fig. 5 (a). Finally, the whole scene looked like a real time ancient drawing, where visitors standing in the large courtyard were watching the fountain and the previous up to the current restoration statues of the Palazzo rendered like drawings on the device, see Fig. 5 (b), (Stricker, D. et al. 2009). This application worked as a virtual tour guide, involving the user into the story in a better way.
6. Case study (The Pyramids and Giza plateau)

There is a bad need for using smart technological applications in presenting Egyptian cultural heritage to the visitors in order to enhance their experience and turn it into a high level of realistic immersion, while giving them the possibility to simulate ruins, buildings, landscapes, or even ancient characters as they formerly existed. This paper intends to produce a computational model of augmented reality after choosing the appropriate AR display approach to simulate and visualize one of the most important Egyptian cultural heritages: The Pyramids and Giza plateau.

6.1 Overview of the plateau

The Giza plateau is perhaps the most studied and world-renown archaeological site on earth (Giulio Magli, 2014). It is among the world’s greatest treasures and dates back to three rules of the 4th Dynasty. Covering an area of 2x2 km, the plateau includes the three pyramids of Khufu, Chephren and Menkaure, as well as private tombs and the Sphinx. It offers much more as it contains mastabas of the nobles of the Old Kingdom and the city of the pyramid builders, see Fig. 6.

Visitors’ common interests are summarized in exploring mystery chambers, clues, and facts about the pharaohs; like how they built the pyramids and their beliefs about the afterlife. As for the site status, the Giza plateau site is generally considered to be in a good state of conservation.

![Plan of the Giza Plateau showing the pyramids, mastabas, the Sphinx, and other structures](image)
6.2 Proposed AR display approach to the heritage site

Based on the classification of AR display types of requirements into those of users, site, and techniques, we can formulate an AR display matrix that enables us to choose the appropriate AR display system to simulate Giza plateau with respect to its visitors’ common interests, state of conservation, and area size. The appropriate AR display will be that which meets the best combination of techniques for presenting the electronic information that suits the users’ interests while being acceptable in the site.

<table>
<thead>
<tr>
<th>AR display requirements</th>
<th>Head mounted display</th>
<th>Handheld</th>
<th>Stationary</th>
</tr>
</thead>
<tbody>
<tr>
<td>users’ interests</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>monument reconstruction</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>retrieving people &amp; events</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>interacting with objects</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>simulating building materials</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>interaction level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high level</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>medium level</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>low level</td>
<td></td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>site requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>tracking area (large area)</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>augmented space (outdoor)</td>
<td>✓</td>
<td>✓</td>
<td></td>
</tr>
<tr>
<td>state of conservation (good)</td>
<td>✓</td>
<td></td>
<td>✓</td>
</tr>
<tr>
<td>techniques requirements</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>high geometric accuracy</td>
<td>✓</td>
<td></td>
<td></td>
</tr>
<tr>
<td>capturing of all details</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>photorealism</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>high automation level</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>low cost</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>portability</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>application flexibility</td>
<td></td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>model size efficiency</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Table 3: matrix of AR requirements and displays

6.3 Deciding on the appropriate AR display system

From the previous table, we found that the Hand-held system was the most suitable AR display approach for using in the case study site (Giza plateau) with respect to its percentage of satisfying the AR requirements of users, site, and techniques, see Fig.7.

![Graph showing the percentage of AR display systems with respect to fulfilling the three main AR requirements](image-url)

Fig. 7. Percentage of AR display systems with respect to fulfilling the three main AR requirements (users, site, and techniques)
6.4 Experiment

The author created augmented information in the form of videos and images that were taken in reality and at the actual location using the Aurasma application, which is available for both android and iOS devices. The application can display augmented 3D models too, which the users can take pictures of. The AR technology has been implemented at the three following locations:

- First location: The main side of the Khufu pyramid where the entrance to Khufu’s tomb is located
- Second location: The Guards’ tomb which is located to the north from Khufu’s mastaba on The Modern Road
- Third location: In front of the statues of sphinx sons

The result was a unique “open air AR tour”. Visitors downloaded and ran the application (following the instructions provided on the wall next to the monuments), see Fig. 8. By pointing their phones or tablets towards the monuments, they were able to watch AR videos.

Fig. 8. The proposed instructions panel to be provided on the front of the great pyramid for the first location

In this experiment, each location was given its own special video as follows:

- The first location plays a video on the construction of The Great Pyramid which presents a lot of useful information about its construction process\(^2\), see Fig 9.

Fig. 9: Virtual video of the first location is playing while the users could take and share pictures with it

- The second location plays a video about the ancient Egyptian afterlife\(^3\), see Fig 10.

![Fig. 10](image1.png) (a) first picture to the left: The second location in real time; (b) second picture in the middle: image as seen on the device showing the augmented video playing while the user takes a picture with it; (c) third picture to the right: the augmented video while playing on the user’s mobile phone.

- The third location plays a video about the construction of the Sphinx\(^4\), see Fig. 11.

![Fig. 11](image2.png) (a) first picture to the left: the third location in real time; (b) second picture to the right: image saved from the application showing the augmented video playing on the device with the user’s presence in the picture.

There is now a public channel on the Aurasma application page with the name “Giza plateau” where the user could find all of the pervious implementations. When users open the application on site, they will be able to receive detailed information in English about the pharaohs’ rituals for the afterlife and their looks, dress code, and behaviors, as well as information about the construction history of the pyramids.

### 6.5 Discussion

Today people are used to receive information in an easier and more fun way through a variety of channels, such as the television, internet, and multimedia content hyperlinks. Though the average user has a very large amount of information in digital form already available, including audiovisual materials, electronic texts, multimedia applications, and geographic information systems, he is still quite far placed from the actual environment. This means that people would have to leave their current locations in order to find additional or desired information.

In general, many visitors have a weak or no knowledge about the site clues and stories, although they are highly interested to gain this kind of knowledge in order to be able to get around with a target in mind while visiting their desired locations. On the other hand, traditional means of presenting knowledge impede the visitors from being free and having fun in the site.

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\(^4\) [https://www.youtube.com/watch?v=9X45QthznQ](https://www.youtube.com/watch?v=9X45QthznQ)
Therefore, the main aim of the proposed AR experiment is to meet users’ need for accurate and timely - while also being entertaining - information. It creates a new, innovative, and recognizable high-tech service that is free for every user. The experiment improves the connection between users and the real world. It is a means of communicating ideas and information in 2D and/or 3D content, which helps enrich the users’ understanding and appreciation of the site.

The experiment has demonstrated that the AR technology is easy to use and that the service can be customized for all groups regardless of age, gender, educational level, and cultural or religious identity. After the installation is made, there is no special maintenance required; therefore, there are no additional costs, so the financial aspect of sustainability allows full long-term viability of the application.

While making this experiment, the author faced the complex task of creating a service that meets the requirements of all user groups regardless of their backgrounds and, of equal importance, that which should fulfil aspects of ease of use and technological and cultural accessibility.

Ease of use and technological accessibility aspects were fulfilled by using a simple downloadable application for Android and iOS devices, which can be run in just a few steps that are explained in a clear and simple way through a panel displayed next to the augmented locations on site. On other hand, the cultural aspect required an intercultural approach and the participation of experts from various fields (history, art history, sociology, textile technology), while applying a system of coordination and implementation for their instructions.

The author recommends future researches to improve the experiment by adding an AR dynamic 3D model of an Egyptian pharaoh that greets the visitors; telling them stories about the site. This may give the visitors a deeper sense of insight and connectivity with the culture of Egyptian pharaohs.

**Results:**

- Implementing AR applications in cultural heritage sites for the goal of presenting knowledge can support and promote the tourism potential and touristic services in general.
- Using handheld AR display in the Giza plateau for presenting the information proved to be better than other AR display systems, as it got the highest percentage in fulfilling AR requirements of users, site, and techniques.
- The experiment has demonstrated that the handheld AR display approach matches with users’ interests and site constraints. It also does not harm the site monuments or cause any damage.

**Conclusion**

The main aim of providing much AR content in cultural heritage is to meet users’ interests for accurate, timely, and entertaining information. The AR technology provides personalized and multimodal interactive information in real time and in the actual location with the actual monuments and historic buildings. Through the various AR display systems, the most appropriate is that which achieves the requirements of “users”, “site”, and “techniques” by using the best combination of techniques for presenting the electronic information which suit the users’ interests, while being accepted in the site.

Overall, there is a need for using high-technology applications in presenting Egyptian cultural heritage to visitors. In this research, the experiment provided only an augmented 2D content in the form of videos. A similar research can improve the experiment by building a dynamic AR 3D model for the ancient Egyptian pharaoh. This will simulate not just the tangible but also the intangible elements of the Egyptian cultural heritage, keeping it accessible as a living part of today’s culture.

**References**

Giulio Magli, 2014. The Giza “written” landscape and the double project of King Khufu, Faculty of Civil Architecture, Politecnico di Milano, p. 2.


