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Augmented Reality Applications for Urban Cultural Heritage Sites: An Overview

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***Abstract*— Augmented Reality applications have become the newest technology used in the Cultural Heritage domain. These applications can be used in education and tourism. Various methods and software tools provide the means of designing such applications. This study provides an overview of the most recent Augmented Reality projects in Cultural Heritage sites in urban environments, comparing tracking methods, devices, themes, and settings used in each project. The most frequently used tracking method is camera-based, with handheld devices being almost entirely preferred in such projects. There is an even distribution of themes, while outdoor scenarios are the preferred setting.**

Keywords*— *Applications, Augmented Reality, Cultural Heritage, Education, Exhibition, Exploration

I. Introduction

Augmented Reality (AR) systems are being actively developed and used in Cultural Heritage (CH) sites worldwide. They offer many advantages to the end users, such as access to multimodal information, visualizations and reconstructions of the past, interaction with modeled objects with no risk to the object or to the human, and much more. While they are currently costly, the demand is getting higher, and technological advances will eventually result in more, cheaper entry-level systems of increasingly better quality. It seems that AR will become one of the most popular technologies in the coming years [1].

The methodology and practices involved in the creation of such systems are still varied. There is no specific set of guidelines regarding the creation of AR applications, nor a set of standard procedures and practices. While this variation can offer stakeholders more options when creating such systems, it can also be a drawback, since each method and approach has different advantages and disadvantages. This literature review focuses on AR application design methodologies. The reviewed applications were almost entirely created specifically for use in urban environments.

II. Main Aspects of AR Applications

All AR applications have the same similar aspects at their core [2]. They use some form of tracking and registration, they require environment modelling, and computers, displays and devices for tracking and recording, and they all have an interaction interface. They can also be categorized according to content and goal (theme) [2]: Educational applications aim to help the user learn the historical aspects of a CH site; Exhibition applications focus on increasing immersion and the quality of the overall experience; Exploration applications help the user visualize and explore historical and current views of a site; Reconstruction applications enable the user to visualize and interact with historical views of the site; and Virtual Museums present CH information and objects in a museum environment.

III. Previous Literature Reviews

In a review of AR and VR in tourism research [3], out of a total of 46 reviewed cases, only 8 cases were AR applications, the rest being VR applications. 7 of the reviewed cases were aimed at tourism experience enhancement, all of these being AR, while 9 were focused at education.

In an important review of AR, VR and MR applications in CH [2], a total of forty AR applications were reviewed and compared with respect to their purpose, tracking method, display used, interface type, and overall setting. 21 of those were found to be exhibition focused, even if not exclusively, with the second most common type being reconstruction. As far as tracking methods were concerned, hybrid tracking was the most often used method. Display types varied a lot, with mobile being the most common, and interfaces were mostly tangible. Most of the applications were made for indoor environments. Apart from the variation in applications, [2] also identified some of the problems in using such technologies in the CH domain, those being the technological limitations, the complexity of the content and human factors. Out of all types of applications reviewed, AR was identified as the most preferable method for exhibition enhancement.

In another review on AR applications for history education and heritage visualization [4], the main concern was how AR is being used to enhance history education, how much does it assist the users, and how do users appreciate the use of this technology. The degree of photorealism in the reviewed cases was mentioned, where out of a total of 35 cases, 3 were determined to have a high degree, 4 of medium, and 4 of low degree, with the rest having no visuals or not being available to review. Most of these applications were created for mobile devices while 4 were mentioned as being marker less and 1 as marker based. They were generally found to have positive impact on student performance [4].

IV. Methodology

In order to find articles that describe AR applications in the CH domain, an exhaustive search was performed on Google Scholar and Scopus. We searched the string (((Augmented AND Reality) OR AR) AND (Cultural AND Heritage)) in the article titles in Google Scholar and in the titles, abstract and keywords of documents in Scopus. Looking at the abstracts of these documents, we tried to identify articles that analyze AR applications that were implemented in urban environments. This study reviews such articles and presents the findings.

V. Case Studies

The reviewed cases were categorized according to the type of tracking method used. The theme of each application is taken into account, as well as the type of display device used.

There were a few cases of marker-based AR implementations. A project implemented in Jeju island was implemented in an attempt to promote the island's CH, and included a printed map with QR codes, a virtual assistant, 3d models and other features [5]. TinajAR was an educational project, that attempted to reinvent and reimagine the ancient Spanish cellars called *calados,* as ceramic exhibition areas [6]. DinofelisAR was a project implemented in the Roman ruins of Conimbriga, and presented a recreated 3d model over the ruins, that the users could explore [7]. Another interesting case was the exploratory study performed in Dr Jenner's House Museum and Garden, and the Forum of Augustus, which compared AR and VR applications that included the same content [8]. All applications mentioned used handheld devices as displays, with the exception of TinajAR which also used a monitor and the Dr. Jenner's House Museum, where a VR HMD was used for comparison.

There also were some image- and feature-based tracking cases. The Parliament Hill project in Ottawa used feature-based recognition, using natural features as points, which also investigated the difficulties in feature-based tracking in outdoor environments due to weather and lighting conditions [9]. The Aurelian Wall at Castra Praetoria in Rome was another image-based tracking project, that recreated part of the ancient wall over the ruins in the AR application [10]. In Aotearoa, New Zealand, an AR project that aimed to help preserve and promote oral Maori traditions was implemented, which used specific landscape features as markers and offered visual and audio information according to the feature currently viewed [11]. Yet another application was designed for rock art visualization in the Cova dels Cavalls rock-shelter in Spain, which used features extracted from images of rock-art and was matched to features the users' camera could detect, in order to display information [12]. Again, all applications used smartphones as displays.

Certain of the reviewed projects employed different approaches from those mentioned above. The ARTS project was implemented in Lukang, Taiwan, which was partly scanned and reconstructed by Unmanned Aerial Vehicle (UAV) images, using photogrammetry, and a 3d scanner [13]. Again, it was designed to work with a handheld device, although it was very processor intensive. TouristicAR presented the Rapid Application Development methodology for creating a complete AR application [14]. For localization, it uses GPS and the Google Play Services location API. It is worth mentioning that it was designed to work on smart glasses. Another project, Footsteps of Ovid [15], was deployed in 3 different locations in Italy, with device tracking being performed by the devices' inertial sensors and the display used was again a smartphone. The Aapravasi Ghat project used a different approach, and took advantage of the pre-existing Wi-Fi coverage over the entire CH site, using the Wi-Fi access points as beacons [16].

VI. Discussion and Conclusions

The technical features of all reviewed cases can be seen in Table I below.

TABLE I: Technical Features of reviewed cases.

Case	Technical Features		
	Tracking	***Display***	***Framework***
Aapravasi Ghat [16]	Wi-Fi, Camera	Handheld	
Aotearoa [11]	Image, Feature	Handheld	
ARTS [13]	Markerless	Handheld	ARKit
Aurelian Wall [10]	Image	Handheld	Augment
Cova dels Cavalls [12]	Feature	Handheld	Unity with AR Toolkit
Dinofelis AR [7]	Marker	Handheld	Unity, Vuforia extension
Dr. Jenner's House & Trajan's Market [8]	Marker	Handheld	Unity
Footsteps of Ovid [15]	Inertial, Depth Perception	Handheld	Tango
Jeju Dol Harubang [5]	Marker	Handheld	JavaScript libraries
Parliament Hill [9]	Image	Handheld	Vuforia
TinajAR [6]	Marker	Handheld	Unity
Touristic AR [14]	GPS, Location API	Smart glass	BeyondAR

Most of the applications reviewed were outdoor scenarios, with only one being both indoors and outdoors and 3 indoors only. Their themes were mostly related to education, exploration and exhibition, with 3 exploration applications, 4 educational, 4 exhibitions and 3 reconstructions. As for location, only 3 were for an Indoors setting and only 1 for both Indoors and Outdoors. A combination of themes seems logical. In fact, quite a few of the applications reviewed could be said to belong in more than one of the overall theme categories. Reconstruction also seems to be more in use in recent years, compared to older cases, probably due to the technological advancements both in computing in general, which allows for faster and more accurate rendering, and handheld display devices.

Considering the above data, along with the results of previous surveys mentioned, we can come to certain conclusions. There seems to be a clear shift towards marker-based tracking, whether that is through the use of actual markers like QR codes or beacons, Wi-Fi or Bluetooth, or feature- and image-based tracking. The devices used in AR are almost entirely smartphones, as it was expected considering the availability and low entry cost. Smart glasses have started to appear in such projects, though the cost is still high. There is also a clear shift towards a more even distribution of themes in the applications, which shows how AR can be effective in many subdomains of the CH domain.

Guidelines for AR application development can go a long way into creating a taxonomy of applications to work with. An AR tour for a museum exhibit can be entirely different from a similar tour of a city that includes CH sites. A set of guidelines that separates and distinguishes various methods, frameworks and practices will make it easier both for developers and stakeholders to choose and create the application that best suits them, with the tools best suited to that particular task. At the very least, applications should be made to work with both ARCore and ARKit, as these two frameworks currently represent the two highest smartphone market shares. Quality is also a major attraction in an application that relies heavily on visuals, therefore some standards need to be set.

Two major issues still remain, the inaccuracy of GPS sensors (which is within 10 meters approximately) and the issue of power consumption. The sensor issue could potentially be solved by using beacons, since Wi-Fi coverage is easy to have in most CH sites, or even image or feature based tracking. This could be inaccurate at times, depending on weather conditions for example, and imposes a heavy toll on the smartphones' battery, which leads directly to the second issue. While the more powerful devices can easily use current AR applications, not all users have access to them. An application that is quite detailed and of high quality, might be slow on an average smartphone. This will potentially be solved as technology advances and the average devices become even more powerful, processor-wise, which will also alleviate power consumption.

Future research needs to focus on how to create a set of guidelines or practices, in order to make AR applications widely available, with more accurate tracking and of above average quality.

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