Envisioning Ambiances of the Past

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Abstract. Outdoor museums of archaeological excavations function as sites of both scientific research and public display. Often, long–term archaeological research means postponing the preparation of the site for visitors. This paper focuses on digital tools for the representation of architectural reconstructions, i.e. possibilities for representing a range of hypotheses regarding the past ambiances of the ancient city. It proposes an augmented immersive revisit of the cultural heritage through mobile devices. Based on mobile phones' current technical capacities, which enables rendering of 3D content combined with camera input, we developed the proposed mobile AR application for mobile Android devices. TeosAR offers a real-time, in-situ 3D depiction and visualization of architectural artifacts of the ancient city implementing model-based tracking methods.

1 Introduction

Heritage developed from the concern of a small group of professionals into a key interest of the wider society. With the introduction of "World Heritage List" by UNESCO, there is a heterogeneous piling up of monumental, iconic, intangible, and quotidian heritage entities, representing a "crisis of accumulation" [1]. Due to the heritage boom in global tourism and the memory crisis of late-modernity, doubt has arisen over our ability to create collective memories and cultural identity. At this point, digitization of heritage helped to resolve the issue of the valorization of the heritage boom. Digitization turns the cultural resources into an important pillar of the digital economy. Digital heritage is "created digitally, or converted into digital form, from existing analog resources" [2].

Studies on digital heritage offer an interdisciplinary approach to historical sites, buildings, and artifacts, incorporating archaeology, restoration, and architecture. Recent developments in emerging technologies have led to 3D archaeology, in which digital tools provide a new perspective on the archaeological excavations in regard to the collection, analysis, and visualization of data. Among these technologies, augmented reality (AR) has great potential for investigating archaeological objects as it provides a non-destructive way for archaeologists, art historians, and other scholars to analyze objects through high-resolution images, with no risk of damage, and also allows visitors to envision the 3D reconstructions of the ancient sites.

Digital and computational tools, combined with applications of Augmented Reality (AR), are changing archaeological practices in the areas of presentation and visualization. Through an interdisciplinary approach, this paper and its pilot application, known as TeosAR, applies augmented reality to the archaeological site, the ancient city of Teos. The project is designed to support the ongoing visualization efforts. Teos, within the present-day borders of the Izmir province, was an important city in Ionia in terms of military, politics, and commerce connections, due to its geographical features, particularly its two sheltered harbors. As of 2010, Prof. Kadıoğlu, supported by emerging technologies in archaeology, has led the excavation and restoration work in the ancient city. The Digital Teos Project, conducted under his supervision, is an interdisciplinary research project aiming to investigate and digitally animate the architectural heritage of Teos. The project consisted of a static public setup at the excavation site, a virtual revisit through VR devices, and a mobile game application. The Digital Teos Project, finalized in February 2018, features a repository of 3D virtual reconstructions of the ancient city.

The Digital Teos project was the first step in an interdisciplinary investigation that enquires into, and digitally animates the archaeological site – one of the most important cities of Ionia. The realization of this project involved close coordination between the fields of archaeology and informatics in design and visualization. In this study, the TeosAR is conceptualized as a digital medium that converts archaeological knowledge into interactions, focusing on a case study in the ancient city of Teos. Our focus is on real-time recognition, visualization, and dissemination of archaeological information. TeosAR is a digital platform that allows the interested general public to explore current archeological findings, and to experience the ancient urban setup without disturbing the progress of the archaeological work. The spatial configuration of the immersive reality presents the architectural information with archaeological accuracy.

This study aims to develop a mobile AR application based on model-based AR tracking methods to present findings from previous studies combined with 3D virtual archeological objects and data from the most recent site research through an interactive mobile interface (for visualization and dissemination the information). Augmented reality in open-air museums is mainly achieved by GPS tracking or image-based marking; however, our project is different in that it explores the use of model-based AR tracking technology to superimpose information on the artifacts themselves. Using model-based tracking technology within augmented reality environments, we aim to develop a mobile application that provides information to expert archaeologists, and non-expert end users alike. The information pertains to artifacts found in the field, and is conveyed by means of mobile devices, and thus to provide a new layer of overall archaeological site experience.

2 Literature Review

Augmented Reality (AR) is the process of simultaneous viewing and interacting with 3D virtual objects in the real world [3]. Milgram and Kishino defined the virtuality continuum as extending from the completely real through to the completely virtual environment, with the area between consisting of augmented reality and augmented virtuality. Virtual Reality (VR) environment is the total immersion in a synthetic world; Mixed Reality (MR) environment is the merging of real and virtual worlds to produce a new environment, and AR completes reality without completely replacing it [4]. Since the 1960s, AR technology allowed the development of series of applications in various fields, including culture, archaeology, tourism, sports, entertainment, architecture, art, defense, education, health, commerce, design and task support. Regardless of the research field, the essential aspects of augmented, virtual, mixed reality applications are: tracking and registration of the user's viewpoint, virtual environment modeling, the key devices required for AR systems (computers, display, and devices for input and tracking), and the interaction interfaces between user and the virtual information [5].

In the field of cultural heritage, AR technology has been used for presentation and dissemination through informative or educational apps for indoor and outdoor museum visitors [6]. AR is more commonly applied in an indoor museum context, however, applications to the broader suite of tourism experiences at outdoor destinations are rapidly emerging [7]. According to Dieck and Jung, AR will be increasingly valuable for the presentation of outdoor historic and enlisted sites, as it eliminates the requirement for numerous information boards and other interpretive panels (including photographs, drawings, reconstructions, 3D views, models, maps, audio materials, etc.). The interaction between visitors of a cultural heritage site and AR systems will contribute to a richer experience [8]. Currently, there are two main AR methods to enrich the visitor experience and subsequent engagement with history: these are georeferenced/location-based, and marker-based AR applications.

Currently, in outdoor cultural heritage, georeferenced and/or hybrid AR applications are more common than solely marker-based AR applications. A prominent example of location-based AR application for archaeological sites is Archeoguide for the ancient city and ruins of Olympia, which is based on user’s position and orientation in the cultural site, together with real-time rendering [9]. Archeoguide uses three basic subsystems, a site information server, mobile units and the network infrastructure. While carrying the mobile units, the visitors’ positions, and other parameters are calculated by GPS. The system corrects the calculations’ accuracy using a Differential GPS. As a georeferenced study, AR application on Pisa Monuments by Duguleana et. al [10] co-locates additional information about existing cultural heritage entities of interest located nearby. This study combines a non-optical tracking algorithm through GPS technology with optical tracking using simultaneous localization and mapping (SLAM) based markerless methods. This system allows identifying not only the location points near the visitors but also it displays additional contextual historical information co-located in the real environment. KnossosAR is an outdoor mobile augmented reality (MAR) guide implemented for the archaeological site of Knossos in Crete, which is on the UNESCO World Heritage List. This guide integrates AR projections of interpretive information with a non-linear storytelling [11]. KnossosAR focuses on the occlusion problem, which is the main issue for location-based AR applications. In order to eliminate this problem, KnossosAR employs a method for estimating the field of view (FoV), when physical obstacles (e.g. buildings, monuments) occludes users' own FOV.

Difficulties in enabling controlled outdoor environments are caused by issues such as changing light conditions, moving objects and possible changes in the defined target. To overcome these problems, georeferenced AR applications are widely used for large-scale outdoor environments. However, location-based AR applications have disadvantages of juxtaposition/overlaying of virtual objects over real objects. With small-scale objects, in particular, the juxtaposition of the tracked object and the virtual reconstruction become crucial. In this situation, researchers and developer prefer the more precise registration of marker-based AR applications. However, marker-based outdoor AR applications introduce new challenges due to the uncontrolled access by the public, and environmental conditions. Thus in this study, we focused on the use of archaeological artifacts as targets in the construction of an outdoor AR application. We used the model-based tracking method to reach the AR environment, and develop mobile AR guide for Teos.

3 Methodology

Archaeological research often fails to go beyond the systematic collection of data, site conservation/restoration, and limited/delayed dissemination to the public. In order to define, interpret, and categorize multi-layered data, assistive technologies must be produced for both archaeologists and visitors alike. This study allows interested visitors to experience the archaeological site by using model-based tracking methods for detection and overlaying created 3D reconstructions through an AR environment. Using a model-based augmented reality mobile, actual architectural artifacts become informed objects without disturbing the archaeological site.

3.1 Model-based Augmented Reality

Image-based target and GPS are traditional methods for applying AR environments to archeological sites in digital heritage [5]. However, the mobility of the visitor in an unrestricted and unprepared environment makes the localization of process more difficult. Fortunately, the emerging technology of model-based tracking method makes it possible to track any object in the physical world. The system requires pre-defined 3D models to track real objects in the environment and to superimpose virtual annotations. Recent personal mobile device technology allows model-based tracking methods to be used on site. The potential of this tracking system has been highlighted in several studies (e.g., [12]).

Among various augmented reality software development kits, Vuforia [13] combined with Unity Game Engine, is one of the most popular AR developer portal. The recent release of the Vuforia Object Scanner App (see Figure 1) helps to create Object Data (OD) files to collect feature points of model (object targets). Developers can generate, test and edit OD files by scanning a physical 3D object through the App. The App also provides a visualization of the object's features, as well as their coverage across the object.

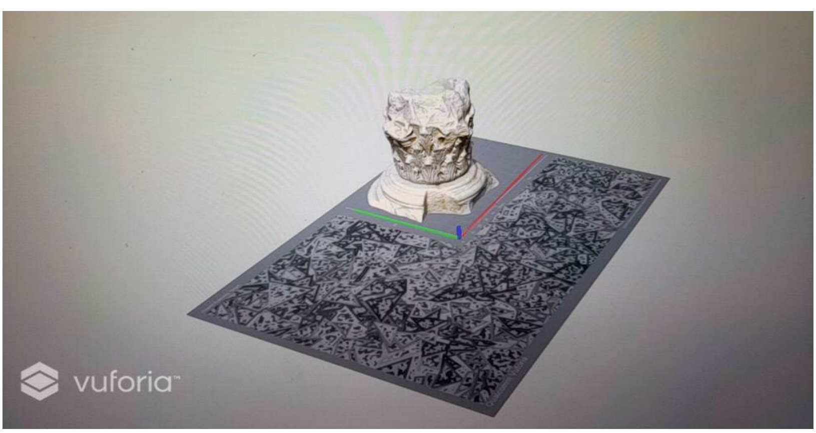

Fig. 1. The screen view of Vuforia Object Scanner application.

In the Vuforia Developer Portal, we defined a target database by uploading scanned objects. The target database is then extracted from Vuforia Developer Portal for uploading into Unity, a cross-platform engine developed by Unity Technologies to develop video games for PCs, mobile devices, and websites. Subsequently, the target database is used for developing the proposed app by combining real objects and virtual reconstruction through the mobile device's display. The model-based tracking allows the user to interact with the virtual objects in real-time through a mobile device's screen. The system architecture of TeosAR application consists of five steps: the image capturing, object detection, tracking, overlaying virtual data, and display (see Figure 2).

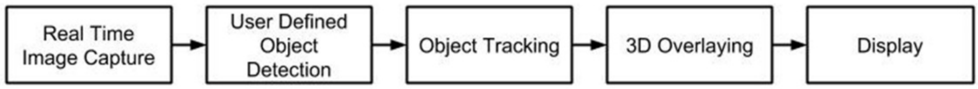

Fig. 2. The system architecture of TeosAR application.

3.2 Case Study

The pilot study aims to develop an augmented reality mobile application to provide information for archaeologists or visitors to an archaeological area, by using model-based tracking technology. Augmented reality is a platform where three-dimensional virtual entities can be presented interactively in real space images. In the past, archaeological sites were only able to present the actual appearance of historical remains; however, now virtual animation and information screens, experienced with the help of mobile devices, can be overlaid on this real space. Thus, it is possible to utilize technology to produce visually rich, interactive products for users. Previously, the cultural heritage community were restricted to sharing 2D data such as plan, section, elevation, etc.; subsequently, 3D data became possible through interactive digital tools, allowing for the addition of a time dimension, namely 4D [14]. The transformation brought by digital heritage representations has enabled virtual heritage to spread rapidly through this extensive, well-established field, which has generally embraced the new technologies in recognition of their obvious superiority over previous approaches [15].

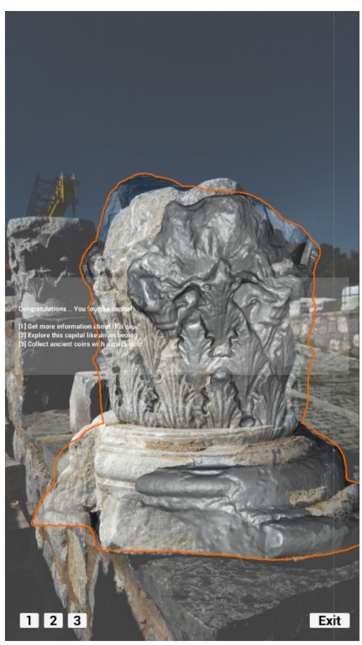

Fig. 3. Detection of artifact through TeosAR application.

According to Bekele et al. [5], AR in cultural heritage has three main research focuses: enhancing visitors' experience, heritage reconstruction, and heritage data management and exploration. Also, the essential aspects of augmented reality applications are: (1) tracking and registration of the user's viewpoint, (2) virtual environment modeling, (3) the key devices required for AR systems, and (4) the interaction interfaces between user and the virtual information [5]. Model-based targets helped us to track and register the user's viewpoint in an outdoor environment. Model-based tracking, which is a tracking phase of lines, edges, or shapes, uses a model of the features of tracked objects based on distinguishable features. For virtual environment modeling, we utilized the restitution models and juxtaposed them onto the tracked object while integrating updated and related information from other excavated objects on site. This also allowed us to convey archaeological excavation progress information with visitors and archaeologists in terms of the fourth dimension. In the developed application featured two Corinthian capitals of Teos, located near to the archaeological site entrance. The key devices required for AR systems are mobile phones or PDAs. Users direct their mobile device cameras to detect one of these capitals. When detected, archaeological reconstructions, i.e. possibilities for representing a range of hypotheses for the capital are shown. For the Interaction interfaces between users and virtual information, each archaeological artifact has its own text information, interactive 3D contents (see Figure 3), and maps other locations if similar artifacts are on site (see Figure 4). These features allow users to be more engaged and informed about the detected objects. By using this method, we can integrate audio-visual content and interactive games.

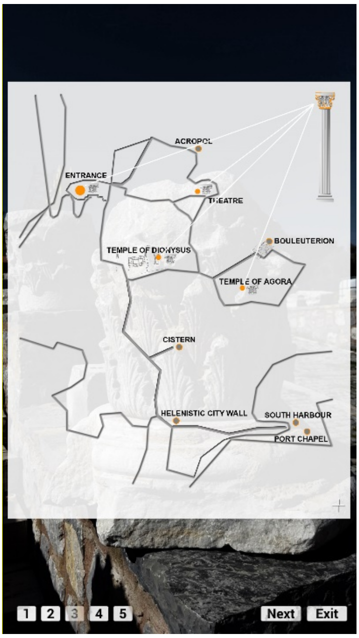

Fig. 4. Pinned locations of similar artifacts on the site map of Teos.

Conclusion and Future Studies

The progress of archaeology is now inextricably linked to applied modern technologies. It is no longer possible to conceive of research projects that do not support informatics; or an excavation that does not extensively use electronic or computerized survey. While all these tools are now accepted as standard, access to data for the site visitor has generally been a low priority. However, computer science and communication networks have become tools for scientists of humanistic science, which offers variety of principles, techniques, systems, and tools for creating effective digital libraries accessible to all end users. New applications of AR have provided opportunities for producing innovative tools for documenting, managing and visiting cultural heritage. As a result of the model-based tracking system developed for TeosAR, both visitors and archaeologists will have access to real-time information on the artifacts they encounter.

In this study, a low-budget augmented reality application is tested and implemented to the archaeological site of Teos. Common computing devices, e.g. Vuforia Scanner App, allow cost-efficient solutions for creating semi-automated guided tours in the outdoor environment. This is an efficient solution for outdoor applications in unrestricted and unprepared environment (with varying light conditions, uncontrolled weather conditions, uncontrolled access of the visitors). The initial results of our pilot application of TeosAR indicated that Vuforia Scanner App was successful in detecting and tracking the targets in various light conditions. In sharp and direct sunlight, as well as incomplete features of the targets, the App successfully detected the target. Comparing with an image-based marker, model-based AR gives an opportunity to look at the artifact in different viewpoints and view-angles which offers users better mobility around the artifacts.

In other words, cultural heritage objects become a smart heritage for a total participation in the promotion of cultural heritage. The study highlights an approach to the smart enhancement of cultural heritage experiences of curious visitors. In this way, archaeologists can use digital technologies to improve the dissemination of information resulting from their research into ancient architecture. Future studies will focus on the visualization of uncertainty in archaeological reconstructions, i.e. possibilities for representing a range of hypotheses regarding the past ambiances of the ancient city. In our virtual system, sliders will allow the user to move from physical to extrapolated data and have instant access to different solutions. As this is an excavation site with limited restitution data, the research will offer a 3D display system proposal, allowing the incorporation of archeologists' observations and interpretations. Thus, this multi-layered information should reflect the past together with a range of hypotheses on the ambiances of the ancient city.

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