Augmented Reality to Reconstruct Sri Lankan Cultural Heritage in Prime State: HeladivaAR

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***Abstract*— Sri Lanka is one of the few countries in the world with a great history and cultural heritage which has been a spotlight in the tourism industry. These places attract many of the local as well as foreign visitors because of their historical value. They try to create an imaginary picture of how it could have been all those years back which could be a false image or a much less correct image than the actual image. Which is why this project is unique in the way it represents the ancient historical sites of Sri Lanka as they were at the time where they were in full structure. "HeladivaAR" is mobile phone application offers personalized augmented reality tours of archaeological sites. It uses image processing, 3D modeling, tracker identification using Android platform, historical books and views from historians and augmented reality techniques to enhance information presentation, reconstruct ruined sites, as it was on top of the existing ruins. By means of Augmented Reality, the real scene is enhanced by multimedia personalized interactive information to increase the experience of the user, who can retrieve this information by a user-friendly interface through their mobile phone. In education, virtual heritage becomes a platform for learning, motivating and understanding of certain events and historical elements for the students and researchers. This application provides a better understanding of Sri Lankan cultural heritage and lets users gain interactive knowledge on archeological facts of ancient kingdoms.**

Keywords; Augmented Reality, Image Processing, 3D modelling, Sri Lankan heritage

I. INTRODUCTION

Sri Lanka is having a rich heritage with artifacts, ancient palaces, kingdoms, statues, pagodas etc. This heritage has been protected for over hundreds of years with the careful observation and preservation of various archeologists as well as Department of Archeology in Sri Lanka. This precious heritage is one of the many reasons for the gain of attention to the country from the world. An overwhelming amount of tourists visit these places and the number increases rapidly.

Unfortunately, the remaining heritage in Sri Lanka is mostly in ruins. The constructions and other artifacts were destroyed, decayed or buried throughout a long period of time. Even though these places are not in their prime state the ruins are of great value and people want to learn and discover about these ruins about how they were in their glorious days.

"HeladivaAR" is an application that has the ability to show a reconstructed 3D model of these ancient ruins as they were in their prime state. With the use of Augmented Reality (AR) technology, this application uses the mobile phone camera to identify and track the remaining ruins of the place and reconstructs the 3D model on it and displays on the application interface.

The rest of the paper is organized as follows. Section II includes an analysis of the existing applications which is similar to this project. Section III includes the methodology followed by the research team in carrying out this research. Section IV contains the results of the application after testing it on site. Section V contains achieved goals, limitations discovered when testing and future works of "HeladivaAR".

II. BACKGROUND

This section presents the major work in literature that has been published which are related to Augmented Reality and 3D reconstruction of archeological sites.

A. Archeoguide: An Augmented Reality Guide for Archaeological Sites

Archeoguide uses outdoor tracking, mobile computing, 3D visualization, and augmented reality techniques to enhance information presentation, reconstruct ruined sites, and simulate ancient life [1].

B. Mixing virtual and real scenes in the site of ancient Pompeii

In this project, video-see-through HMD is used to capture the real scene. After that, this scene was blended by precise real-time registration and 3D modeling of realistic complete simulation of virtual humans and plants in a real-time storytelling scenario based on the environment [2].

C. Meta-Museum: A Supportive Augmented-Reality Environment for Knowledge Sharing

The Meta-Museum is a newly coined concept which seeks to enhance people's knowledge exploration experience in museums. The Meta-Museum blends virtual reality and artificial intelligence technologies with conventional museums to maximize the utilization of a museum's archives and knowledge base and to provide an interactive, exciting and educational experience for visitors [3].

D. The House of Olbrich — An Augmented Reality tour through architectural history

In this research, they present an iPhone Augmented Reality (AR) app that visualizes the compelling history of Darmstadt's unique Jugendstil (Art Nouveau) quarter with video-see through Augmented Reality [4].

E. Virtual and augmented reality for cultural computing and heritage: a case study of virtual exploration of underwater archaeological sites

The paper presents different issues dealing with both the preservation of cultural heritage using virtual reality (VR) and augmented reality (AR) technologies in a cultural context [5].

F. A review on augmented reality for virtual heritage system

This paper will present an overview of augmented reality in Virtual Heritage system and also consists of the explanation of techniques to reconstruct the historical sites [6].

G. A Framework for Mixed Reality Application Development: A Case Study on Yapahuwa Archaeological Site

This paper presents a framework for augmented reality and virtual reality mixed application. The researchers have reconstructed the Yapahuwa Kingdom and created a framework to display it through AR and VR using gyroscope controller, GPS controller, Google Cardboard Visualizer, normal visualizer and custom modules for multiplatform support. [7]

H. Comparison

With the increase of computational speed and advancement of specific computer technology, virtual and augmented reality mobile applications become feasible in multidisciplinary areas. “HeladivaAR” application lets the users experience archeological sites as they were at the beginning.

Previous researches based on augmented reality and archaeology were developed to use in laptops and they were not user friendly. Some of the researches were prototypes and never built because of the cost. “HeladivaAR” has been developed for Android platform and even a non-technical person can easily get used of the application. Earlier researchers were developed using advanced mathematical algorithms such as Furrier and Laplace transformations. Because of the complexity of the mathematical algorithms most off the applications could not give the real time preview of the scene also the output was in low quality. In previous developments, users have to ware separate devices such as HMDs’ (Head Mounted Displays) to get the experience of the scene. The initial cost of development of the previous systems was very high because of the external devices used to create the link between the server and the user. In “HeladivaAR” users do not want to wear a separate device. The user has to only use their mobile phone. Also, the development cost of the system is low. Polonnaruva Royal Palace was used as a stepping stone in order to expand this application throughout Sri Lanka also providing additional information has not been addressed in the similar researches, but included and implemented in this application. The comparison is further elaborated in Table I.

III. METHODOLOGY

The development of “HeladivaAR” followed the Prototype Methodology which allowed the research team to create portions of the solution to demonstrate functionality and make needed refinements before developing the final solution. This helped in ensuring the final application was consistent with expected outcomes.

A. Planning

As the initial step, the research team conducted a feasibility study on locations to be selected as the most suitable place to apply the research solution. In this study, constraints such as the scale of the location, weather conditions, availability of the building structures, etc. were considered. After this study few places such as Thiwanka Pilimaya (Polonnaruwa), Yapahuwa Kingdom, Watadagaya (Polonnaruwa), Royal Palace of King Parakramabahu (Polonnaruwa). Out of these Royal Palace of King Parakramabahu was selected as an ideal place to conduct this research.

B. Analysis

After selecting the suitable place as the Royal Palace of King Parakramabahu, the research team carried out a thorough analysis of this place by collecting data from various sources. The initial step was gathering information from history books

such as Mahavamsa. With this, the research team was able to get a brief idea of the place and the background and history of the place. This analysis included gathering information from travel guides that are presented to tourists and other visitors as well as official documents from Department of Archeology of Sri Lanka. The next step was visiting the actual place. After visiting the place full photographic documentation was conducted. Also, the Polonnaruwa museum was also included in this analysis and most important information was gathered as a result of this analysis.

TABLE I. COMPARISON TABLE

Projects	**Smart phone Application**	**Display Additional Information**	**Interactive 3D Models**
Archeoguide: An Augmented Reality Guide for Archaeological Sites	X	X	X
Mixing virtual and real scenes in the site of ancient Pompeii	X	X	X
Meta-Museum: A Supportive Augmented-Reality Environment for Knowledge Sharing	X	V	X
The House of Olbrich — An Augmented Reality tour through architectural history	V	V	X
Virtual and augmented reality for cultural computing and heritage: a case study of virtual exploration of underwater archaeological sites	X	X	X
A review on augmented reality for virtual heritage system	X	X	X
A Framework for Mixed Reality Application Development: A Case Study on Yapahuwa Archaeological Site	V	X	V
Heladiva : Augmented Reality application to view Sri Lankan cultural heritage in prime state	V	V	V

C. Design

In this stage the research team prepared what should be the basic functionalities of the application and the interfaces were been sketched in order to use as a reference when implementing the actual interfaces. HeladivaAR android application was designed to give a better user experience when providing the given functionalities. These interfaces include – splash screen (Figure 1), main interface, Augmented Reality interface (Figure 2), 3D interface (Figure 3), information interface (Figure 4), settings interface (Figure 5) and the side button panel (Figure 6).

Figure 1. Splash Screen

Figure 2. Augmented Reality Interface'

Figure 3. Information Interface

Figure 4. 3D Interface

Figure 5. Settings

Figure 6. Sidebar Buttons

D. Implementation

After the previous stages have been completed all the resources to implement the system has been set. Each requirement has been addressed and implemented as components.

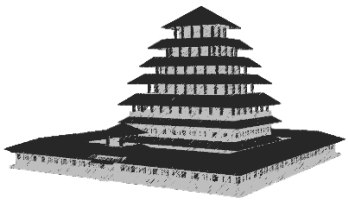

Figure 7. 3D Model (Polonnaruva Royal Palace)

The 3D model was constructed using Autodesk Maya by referencing the physical model displayed at the Polonnaruwa Museum as well as by referencing history books and drone-captured image data of the remains of the Royal Palace of King Parkramabahu. The first version of the model only contained basic material and very low detail. The second version had advanced material but lacked a few details. The third and final version of the 3D model has advanced material and high level of detail and an accurate representation of the Royal Palace in the prime state.

The mobile interfaces were created with the use of Unity3D. The 3D model was integrated into the 3D interface as proposed. The augmented reality interface and the tracking procedure was created with the use of Qualcomm Vuforia architecture. The images of the existing ruins of the Royal Palace were used as 3D image trackers and using Vuforia it was made trackable. Then the 3D model was placed within the field of view of the the augmented reality camera inside the interface. All the relevant functions were written in C# and embedded into Unity gameobjects.

E. Testing

As the final stage of the development, the research team visited Polonnaruwa Royal Palace to conduct a testing procedure for the implemented application. The functionalities that were tested are as follows:

- Augmented Reality feature
- 3D view feature
- Information displays feature

This was majorly white box testing and the research team thoroughly analyzed these functions and their performance.

In the black box testing, the application was run on an Android mobile phone and shown to the visitors at Polonnaruwa Royal Palace. The visitors were satisfied with the outcome because it was a new experience for them and they commented that they always wanted to know how these ancient sites were before they became ruins.

IV. RESULTS

The initial results of the application were the interfaces as shown below. The functionalities that were implemented worked as expected. Below are the screenshots of the working functionalities of the application.

Figure 8. Main Interface

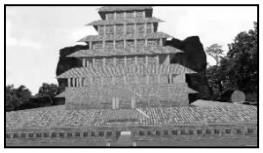

Figure 9. AR Interface

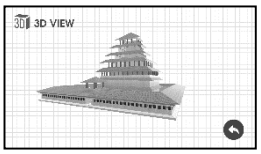

Figure 10. 3D Interface

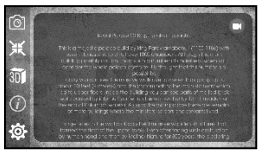

Figure 11. Information Interface

V. CONCLUSION

The goal of this research was to implement an Android application that allows users to use their mobile phone cameras and visualize how the ruined ancient heritage in Sri Lanka used to be in their glory days. As the stepping stone, Polonnaruwa Royal Palace was selected to be digitally reconstructed. Additionally, highly accurate information about the selected place would be displayed in the application.

"HeladivaAR" application was tested on the actual site and the main goal was achieved. The application was run on an Android mobile phone and once the AR interface was loaded the 3D model constructed by the research team was displayed with the camera footage. The information interface displayed information about the Royal Palace and contained a video tour of the ruins. The 3D interface was touch gesture compatible and we could use zoom the 3D model with two fingers and could rotate the 3D model.

In the Augmented Reality interface, the model was slightly glitched due to the environment disruptions such as people walking, dust and overexposure because of sunlight. Due to these reasons, the application could not place the 3D model over the tracker at some points. But this was

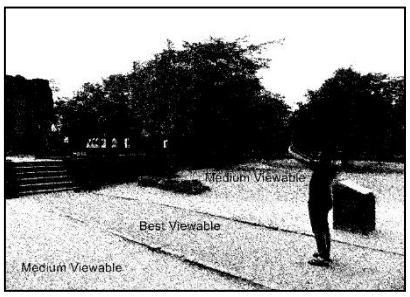

Figure 12. Viewing Guide

an expected outcome and it was almost unnoticeable. In the Royal Palace, the main viewpoint was the front side of the ruins. The sides and the back were heavily covered with trees but people could go within the ruins. Therefore we identified optimum viewing positions for the "HeladivaAR" application to achieve the most accurate result. Figure 12 displays the viewing guide.

The camera of the mobile phone is the main component to be considered in the AR feature. Higher the quality of the camera, higher the accuracy of the tracking procedure.

In the 3D interface, the automatic rotation of the 3D model was added and it could not be stopped even when zooming. This was inconvenient when thoroughly trying to examine the 3D model.

There are several limitations of this software. HeladivaAR is an android based augmented reality application then it can't be used other operating systems such as Windows, IOS based operating systems. Developed application is not the desktop application and preferred rendered quality is based on the mobile device. This application is optimized for Android 3.0 or above. Below versions would experience rendering problems when running. This is an offline application and additionally, databases and everything should be downloaded and taking more data to compare other applications which are except rich applications. To get the view of the model every angle is not giving the correct 100% accurate output is one of the limitations of this application. The current accuracy levels of the HeladivaAR is as follows.

3D Model Accuracy – 65% (in relation to historical books and existing predicted models)

Augmented Reality Accuracy – 40% (according to tests done in sunny and low light weather + tests done within 180 degree curve in the front end of the ruins + tests done using Samsung Galaxy S5, HTC One M8 and Sony Xperia Z2 cameras)

As the main objectives of the system have been achieved, "HeladivaAR" can be improved in many ways. Virtual Reality (VR) tour of the Royal Palace has already been implemented and it will be part of the main application in future. Users can wear a VR headset and take a tour inside the 3D constructed Royal Palace for the maximum user experience. The AR feature will be implemented to other ancient cultural sites in Sri Lanka. The AR feature will be available in any viewable direction in the future implementations to reduce the viewing limitations of the current application. Research on ruins will be conducted accompanying more sources to get the best possible 3D reconstruction.

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