2019 IEEE International Conference on Artificial Intelligence and Virtual Reality (AIVR)

Civil War Battlefield Experience: Historical event simulation using Augmented Reality Technology

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***Abstract*—In recent years, with the development of modern technology, Virtual Reality (VR) has been proven as an effective means for entertaining and encouraging learning processes. Users immerse themselves in a 3D environment to experience situations that are very difficult or impossible to encounter in real life, such as volcanoes, ancient buildings, or events on a battlefield. Augmented Reality (AR), on the other hand, takes a different approach by allowing users to remain in their physical world while virtual objects are overlaid on physical ones. In education and tourism, VR and AR are becoming platforms for student learning and tourist attractions. Although several studies have been conducted to promote cultural preservation, they are mostly focused on VR for historical building visualization. The use of AR for simulating an event is relatively uncommon, especially for a battlefield simulation. This paper presents a work-in-progress, specifically a web-based AR application that enables both students and tourists to witness a series of battlefield events occurring at the Battle of Palmito Ranch, located near Brownsville, Texas. With markers embedded directly into the printed map, users can experience the last battle of the Civil War in the US.**

***Index Terms*—Palmito Ranch, Augmented Reality, AFrame, Simulation, Animations**

I. Introduction

Cultural preservation plays an important role in maintaining our identity. A lot of effort has been devoted to preserving history through formal education or exhibiting artifacts in museums. However, artifacts positioned at the site, lost historical buildings that cannot be reconstructed, or battlefield events that cannot be recreated, make it difficult for the majority of interested viewers to experience them. To alleviate this obstacle and to promote cultural values, a wide range of modern technologies have been adapted to bring people closer to their historical identity. One of the most popular approaches is to create a virtual museum using virtual artifacts [16], and make them available via social communication channels such as a website where viewers can access them using a link.

A rich history unfolding over hundreds or even millions of years is always prone to gaps in learning and understanding a country's culture, especially when considering an individual state within that country. Palmito Ranch Battlefield in Cameron County, Texas, for example, is one of the most significant historical sites in the American Civil War, but few people are aware of it. The historic battle of Palmito Ranch occurred on May 12th to 13th, 1865 as a Union campaign of expedition from Brazos Santiago, Texas. It is the site of the last land battle fought in the Civil War and actually occurred after the war had officially ended with the Confederate Army (South) surrendering to the Union Army (North). Several programs administered by agencies including the National Park Service (e.g., Battlefield Planning Grants, Battlefield Land Acquisition Grants, Palmito Ranch Battlefield Preservation Plan (PRBPP)) [12] have been set up to promote the preservation, management, and interpretation of significant historical battlefields as cultural landscapes.

To the best of our knowledge, no other studies exist exploiting the use of Augmented Reality to simulate this battle. This paper tries to fill this gap by proposing a web-based Augmented Reality Application that helps promote cultural identity by enabling students and tourists to experience a historically significant Civil War site in Texas. The architectural model of this application was taken from [9] with a slight modification by using A-Frame [7] instead of deploying the application in iOS or Android.

Consequently, this paper contributes to current research as it: (1) provides an approach to reconstruct a series of battlefield events in the Palmito Ranch Battlefield, (2) illustrates its approaches through an open-source Web-based Augmented Reality application called *PalmitoAR*.

The remainder of the paper is organized as follows: Sect. II summarizes similar work. We present our system design and

This study was supported by U.S. Department of the Interior-National Park Service and the Korea Creative Content Agency's 2017 Culture Technology R&D program (R2017030023).

978-1-7281-5604-0/19/$31.00 ©2019 IEEE
DOI 10.1109/AIVR.2019.00068

Fig. 1. Main AR scene of Palmito Ranch Battlefield. QR code located at the bottom right allows users to access the AR application. Stage 3 is being simulated (red color button), the annotated text described the event as the Union took the Palmito Ranch and burned the supplies

simulation in Sect. III. User study on the AR application is presented in Sect. IV. We conclude our paper with future work in Sect. V.

II. Related Work

Rafal et al. [16] presented the Augmented Representation of Cultural Objects (ARCO) project which allows designers to create, manipulate and present virtual 3D cultural objects in both VR and AR environments. The proposed system consists of three main components, including content production, content management, and visualization. The content acquisition components include object creation and manipulation. These digitized virtual objects are stored in the repository where the application layer will query and render to the 3D environment or superimpose them onto a marker. Papagiannakis et al. [5] reconstructed ancient Pompeii using mixed virtual reality to recreate and promote the civilization's cultural values. The dramatic stories were revived through a complete simulation of animated virtual human actors (i.e., clothes, body, skin, face) superimposed in the real world. This work provides an outstanding experience for museum visitors in both indoor and outdoor activities. ARCHEOGUIDE [14] is an interesting project that helps visitors explore and experience ancient artifacts based on their interests or needs. The application was embedded in a personalized electronic device and worked as a tour assistant. Enthusiasts select the site of interest, then the system guides them through the site. The position-orientation tracking component is used as an indicator to display in AR the reconstruction of the ancient buildings. Another interesting project using Augmented Reality was developed by Fritz et al. [3] through a project called PRISMA. Similar to the above projects, it employs an AR 3D visualization device capable of working as a tourist guide.

There is further similar research in the field of cultural heritage, with each contribution dedicated to a particular site. Following this stream, the present study makes an effort to contribute to Palmito Ranch Battlefield.

III. System Design

PalmitoAR is developed using JavaScript libraries and in particular the A-Frame [7] and AR.js [2]. Unlike many modern AR applications that are installed directly to smart devices and rely on the deployed operation systems such as iOS or Android, our effort tried to bring AR experience to a more general audience (e.g., tourists, visitors, students) with just a browser-supported device. The use of A-Frame has been shown to be an effective means of creating and sharing VR/AR experience in [10], [15]. The primary goal of *PalmitoAR* is to create an AR application that presents students and visitors a high-level view of the historical event at the Palmito Ranch Battlefield. To meet this goal, this paper proposes several features that are implemented in the *PalmitoAR* based on the application design approach suggested by Shneiderman [13] for an application:

- **Overview Display (F1)**. Display overview of the AR environment.
- **Details on demand (F2)**. Present details of a particular battle event.
- **Automated Simulation (F3)**. Automatically simulate a series of battle events.
- **Semi-Automated Simulation (F4)**. Simulate a particular battle event with user selection.
- **Marker recognition (F5)**. Detect different markers on the printed map.

A. The PalmitoAR components

Based on the outlined features, *PalmitoAR* is designed with two main components: 1) the main component and 2) the marker component.

1) The main component: This component represents the AR environment in which 3d objects (e.g., soldiers, flags, fire) are superimposed onto the real physical map (**Feature F1**). Since the proposed AR was implemented in the web environment, the computational expense should be taken into consideration. To improve performance, we used low poly 3D models with a minimum number of vertices and avoided using too many images as texture. Instead, we used basic neutral colors for filling the faces (i.e., soldier's hat, boots) except for the flags.

Fig. 2 illustrates the process of converting free 3D models into 3D models for Web AR. Most free 3D models are not an ideal model for Web application due to its size and information encoding. To alleviate this problem, The Khronos Group developed the runtime asset delivery format GL Transmission Format (glTF) to minimize both the size of 3D assets, and the runtime processing needed to unpack and use those assets. To apply animations to the downloaded models, we used the free online animation tool Mixamo. Unfortunately, the current version of this tool does not allow us to embed multiple animations into a single 3d model. Thus, Blender 3D software was used to combine all animations (i.e., walking, running, standing and idle). This model was then exported in GLB format. The main component also includes seven

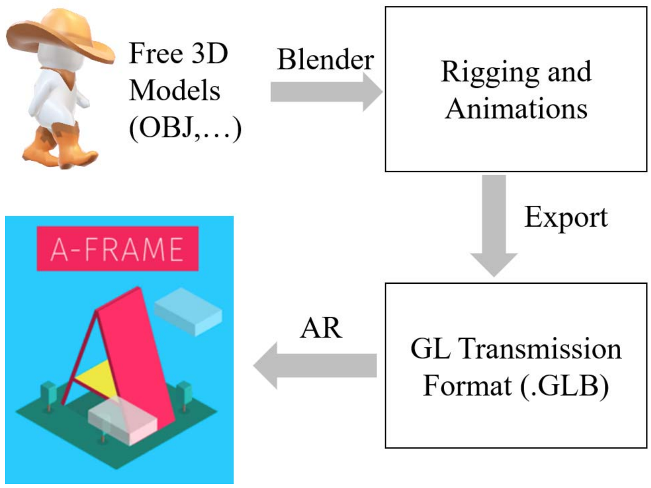

Fig. 2. Converting free 3D models into Web AR binary 3D models

buttons positioned on top of the screen as depicted in Fig. 1. Buttons Stage (denoted as S) 1-8 represent each historical battlefield event (**Feature F2, F4**) where users can simulate them individually. For each stage, a short description of the event is provided as the caption of the scene (**Feature F2**) posited at the bottom of the screen. By default, the next stage will be automatically triggered and simulated once the previous stage is finished (**Feature F3**) with a transition time of three seconds. By clicking or tapping on a particular button, visitors will be able to experience the corresponding stage (**Feature F4**). Animation for each 3D model is applied based on (e.g., running for retreat, idle for resting). The Full screen button allows user to view the AR app in full screen mode. The Print Map button enables viewers to download the map with embedded markers.

2) The marker component: To correctly present 3D objects in a real-world context, the system needs to calculate the location and orientation of the camera (or *pose*). Several tracking methods have been studied in the field of computer vision, robotics or photogrammetry such as sensor tracking methods, visual tracking methods, and hybrid methods [11]. Each method relies on a special sensor. There are two popular approaches in the visual tracking method to superimpose 3D models onto the real physical world, including *marker-based* and *markerless*. In the markerless approach, the AR application has no prior knowledge of the user's surrounding environment to overlay 3D contents. These objects are often positioned to a fixed point in space. Markerless AR uses a combination of complex camera systems, sensors, and specialized maths to accurately detect and map the real-world environments. The main advantage of this approach is the possibility to place virtual objects into a real context without having a tracking image. However, our proposed AR application relies on the printed map of the battlefield and the contextual location of the battle event is more meaningful than a fixed point in space.The marker-based approach, on the other hand, provides a system with an easily detectable predefined sign in the environment (e.g., object, image). The system can detect this sign by applying image processing, pattern recognition and computer vision techniques. Once the sign is detected, a 3D object would be correctly positioned. There are two main types of markers used in typical AR applications, including *template markers* and *2D bar-code markers*. The former identifies the marker, while the latter deciphers the data encoded in the marker. In the current stage of development, the location of the marker is our main interest, so we devised a template marker as a sign to position the soldiers (**Feature F5**). The intuitive idea of using a template marker is to have a database that contains sample images of a marker. The system will compare these sample images against segmented images extracted from the camera, then the best match can be retrieved.

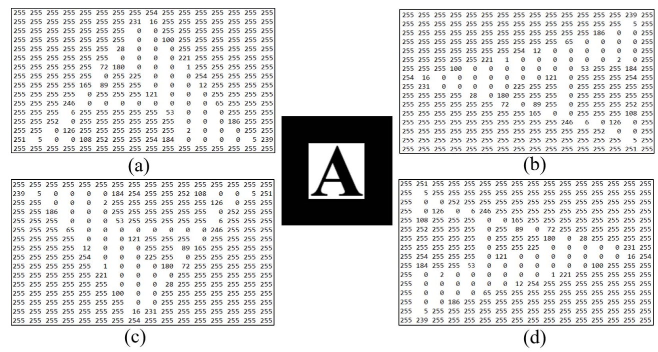

Fig. 3. A marker (letter A) with four sample templates: (a) normal position, (b) rotate left, (c) rotate upside down, and (d) rotate right

Fig. 3 illustrates a sample template marker (i.e., letter A) with four matching templates (a,b,c and d) corresponding to four different orientations (normal, rotate left, rotate upside down, and rotate right respectively). Each pixel on the image is encoded by a number (in grayscale) using 0 for black and 255 for white color. The template that gives the best match (highest similarity or smallest dissimilarity values) within a certain threshold is the correct marker. Building on the procedure for the template marker, our approach makes a slight variation by using an area on the map as a sign for detection instead of using regular letters. As shown in Fig. 4, we capture the base location of the troop Fig. 4(a), this image is then sampled (or converted into templates Fig. 4(b)) by using the training image tool [4]. The cropped image (which is augmented by a black square box Fig. 4(c)) will be overlaid on the existing map at the exact location Fig. 4(d). Hence, a 3D object is superimposed on the desired position Fig. 4(e)

IV. User Study

We conducted a user study with seven participants to evaluate the proposed AR application in terms of perceived ease of use, an essential element of the technology acceptance model [1]. The main goals of this study was to (1) investigate whether the users could learn and operate the simulated AR with

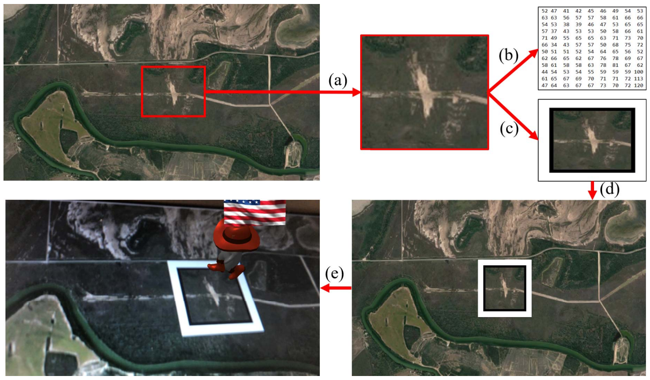

Fig. 4. Process of creating marker and embedded onto existing map: (a) cropping region of interest, (b) extract sample templates, (c) augmented black square box, (d) append image back to the map and (e) superimpose 3D model on the map

ease, (2) assess the degree of ease or difficulty experienced by users with the AR simulator and (3) gather feedback from users to improve the usability of *PalmitoAR*. Before accessing *PalmitoAR*, its basic functionality was introduced to the participants either with direct communication or the pre-recorded video available on YouTube [8].

Results: Overall, all users were excited about the AR application with positive feedback. However, there were some issues with *PalmitoAR* to be addressed as follows: (1) the 3D models did not look realistic, (2) the text descriptions were not aligned well on some mobile devices, (3) audio service was not supported, (4) less information on the troops was provided (e.g., number of soldiers, casualties of each battle), (5) a full screen mode was not supported for some devices, (6) there was a flickering issue with the 3D models.

Discussion: In this preliminary phase of aligning augmented reality to the real-world, we encountered some technical challenges with the AR application. Based on the users' feedback, we tried to mitigate the issues. The issues of (2) and (5) were completely fixed. The issue (3) was handled by using IBM Watson Text To Speech (TTS) to convert written text into natural-sounding audio. However, playing audio as a narrator on iOS device led to another issue since *'Playing sound on iOS — in any browser — requires a physical user interaction'* [6] meaning that users need to explicitly click on the stage button. The issue (6) was related to marker detection and recognition. The current template markers only use small sample images for template matching. As such, the pattern can be lost at some frames. To overcome this problem, the Kalman Filter method can be used to keep track of the position of the marker from the beginning. That is, the position will be detected and maintained within a certain time frame. Another approach is to train more template images for each marker with varying noise levels and/or lighting conditions. Thus, the markers will be more reliable and stable. The issues of (1) and (4) are needed to be further addressed.

V. Conclusion and Future Work

This paper presented a Web-based Augmented Reality application that enables both students and tourists to witness a series of battlefield events occurring at the Battle of Palmito Ranch. The user-friendly interface was evaluated to improve the simulator. This paper is a work-in-progress with several limitations indicated by users in addition to no quantitative method to obtain insights of the user study. To overcome this issue, we are planning to improve *PalmitoAR* based on user feedback and perform a full study using the Technology Acceptance Model on task technology, perceived visual design, perceived usefulness, perceived ease of use, self-efficacy, and intention to use for the extended version of this paper in the future.

Acknowledgement

This work was supported in part by a grant from National Park Service (A17-0245-003).

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