The Augmented Museum: A Multimodal, Game-Based, Augmented Reality Narrative for Cultural Heritage

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ABSTRACT

As digitization has transformed media and Augmented Reality (AR) is evolving from a research area to a commodity, museums are creating interactive AR experiences to digitally enhance their collection and increase audience engagement. Head-worn AR experiences, though, face interaction challenges as they are often employed in busy spaces and are in need of intuitive multimodal interfaces for users on the move. This paper presents an innovative, work-in-progress, multimodal AR experience integrating non-obtrusive dialogue, music, and sound as well as gesture and gaze-based interaction, while a user is wearing a head-worn AR display. Users are motivated to explore and interact with digital cultural artefacts superimposed onto the real-world museum setting and physical artefacts, while moving around in a museum setting. We initially analyze interactive AR experiences to identify specific user requirements related to head-worn AR experiences. We deploy these requirements for the design of interactive, multimodal AR in a museum setting.

CCS CONCEPTS

• **General and reference** → *Design*; • **Human-centered computing** → **Mixed / augmented reality**; • **Applied computing** → **Interactive learning environments**.

KEYWORDS

Augmented Reality, Multimodal, Digital Storytelling, Serious Games, Spatial Audio, Cultural Heritage

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1 INTRODUCTION

Augmented Reality (AR) adds layers of digital content to a real-world environment [7]. Virtual 3D objects as well as 2D information or digital media appear in real-time, superimposed onto the real world enhancing reality with digital information [3], [16]. AR is being used in education, marketing, simulation and other fields, deployed on mobile devices and head-worn displays [8]. Recently, AR technologies have offered digital awareness of cultural content, for the promotion of cultural heritage [17]. AR is vital for cultural heritage's sustainability, promotion and dissemination, increasing accessibility to cultural heritage resources and interpretation, otherwise hidden. In contrast to Virtual Reality (VR) which excludes real-world surroundings, the role of AR is to digitally fill in the 'missing' pieces of multimodal information without replacing or obstructing the real-world, forming a narrative between reality and virtuality [6], [1], [12]. In this way, AR experiences could be transposed to interactive media experiences presented to a museum's audience in ways that would not otherwise be possible [17]. As digitization has transformed media and AR is slowly evolving from research to commodity, digital media content creators are experimenting with head-worn AR technology to share meaningful stories. Similarly to VR, AR has proven to be a powerful tool for the realization of truthful experiences [18]. However, head-worn AR as a new medium is usually prone to usability issues inherent to the technology, inhibiting confusing interaction interfaces and Field of View (FoV) restrictions, especially when dealing with multimodal content [4], [10], [2].

In this paper, we present a work-in-progress multimodal AR experience related to the prehistorical events in Ancient Kydonia, in Crete, Greece from 1650 BC to 1350 BC, to be deployed in an archaeological museum setting. The proposed AR exprerience aims to tackle interaction issues by introducing intuitive hand and gaze-based interaction and will form part of the newly built Archaeological Museum of Chania, one of the landmark museums in Greece. Users are motivated to explore the cultural content while moving around in a museum setting. Our specific contributions include:

- Users interact with the AR interactive experience by hand gestures, voice commands and gaze-based interaction. An initial tutorial scene will introduce the functionality of the head-worn AR display (Hololens 2).

- The experience incorporates gamified elements. Digital content is superimposed on real-scale physical reconstructions of archaeological artefacts and sites in the museum environment.
- A narration system as well as an original musical composition guides the user around the museum, relevant to the historical context. Spatial audio soundscapes are incorporated in the experience.

2 RELATED WORK

In this section, a brief overview of interactive AR experiences for cultural heritage is included. Research challenges related to AR usability and technical development are identified.

2.1 Interacting with Cultural Heritage in AR

Head Mounted Displays (HMDs) have been recently employed to display interactive entertainment experiences in Virtual Reality (VR), communicating a strong sense of immersion [9]. Head-worn AR displays have been installed in museums, interactively communicating cultural narratives with visitors [17], [5], [19]. Digital information such as 3D replicas of archaeological artefacts have been integrated and manipulated in AR, superimposed onto the real-world [6], [20]. Users wearing AR displays either compare real-world sculptures with replicas existing in remote locations [6], interact with cultural artefacts [17], explore excavations [20] or even extract individual elements of 3D buildings such as a pillar or a floor, modifying their size and position [19].

AR has been deployed in the form of virtual guides helping users to explore cultural information in a museum [5]. In the Museum of Relief Maps in Paris, dedicated to 3D military maps dating back to the years of Napoleon and Louis XIV, visitors learn historical facts through a head-worn AR display [14]. For instance, users can interact with the 3D reconstruction of the cathedral of a monastery as well as view digital text, photographs and listen to audio narratives. AR is also deployed for the simulation of a telegraph training exercise in 1942, during World War II, at the Porthcurno Telegraph Museum [11]. The user is trained as a British telegraph assistant, part of an international telecommunication mission during wartime. AR is employed for interactive media experiences transporting audiences in past eras. In "Ancient Olympia: Common Place", digital AR creators have reconstructed the monuments of Ancient Olympia in 3D [15]. The user can walk in the Athens Olympic Games Museum and be transported back to 173 AD, surrounded by sights, sounds and 3D reconstructions of monuments. AR experiences including playful elements are shown to be effective and engaging [17], [19].

Multimodal AR most commonly employs simple hand tracking for interaction and depth sensors for spatial mapping. The AR experiences analyzed above have demonstrated that this is a novel and engaging technology as viewers are seeing a digitally enhanced version of the real-world, immersed in a story by acting, not just following events. Viewer-controlled AR interaction creates a personalized experience of potentially great training and emotional impact. However, interacting with AR digital content displayed on a head-worn AR display is challenging since the user is moving, disrupted by the real-world and digital media. Intuitive user interfaces are required such as automatic tracking of hands, real-time recognition of gestures and eye tracking for immediate input based on gaze-based interaction [13].

2.2 User Requirements

We now list the most essential user requirements for head-worn AR. We follow these requirements for the development of an AR multimodal narrative in a museum setting, addressing interaction challenges and deploying interaction affordances developed for head-worn AR displays. An AR interactive experience for cultural heritage should meet the following requirements:

- Deploying voice commands, hand interaction, spatial audio, gaze-based interaction, scripting for interaction according to context and containing playful features according to goals.
- Promoting learning by experience based on cultural narratives and providing a scenario leading users to specific points of interest into the museum.
- Containing a user guide based on sound narration and, according to context, musical elements that aid users complete missions and navigate through wide real-world areas.

3 IMPLEMENTATION

3.1 Designing the AR Experience

This paper proposes a work-in-progress multimodal AR experience implemented for Microsoft's Hololens 2 head-worn AR display. This AR experience will form part of the exhibition of the Archaeological Museum of Chania temporarily operating within its newly built space in the city of Chania in Crete, Greece, promoting Ancient Kydonia's cultural content.

The visitor wears a head-worn AR display, required to find and move 3D replicas of exhibits to museum's physical locations based on historical events in order to assist in the preparation of ancient rituals. The AR experience is based on a multimodal narrative that guides visitors while they search and collect exhibits necessary for ancient rituals. The museum visitor interacts with the narration through voice commands, detects exhibits via instructions and the musical sounds they produce, employing hand and gaze-based interactions. The goal of the experience is to transfer digital exhibits superimposed onto the real-world museum setting to the real-world physical reconstructions of specific ancient sites located in the museum (Figures 1, 2, 3). As a reward for completing each mission, the visitor activates the next narration as well as views 3D artefacts and listens to a musical composition based on sounds derived by the collected exhibits.

3.2 Ancient Kydonia and Points of Interest

A significant part of the museum's exhibition includes exhibits concerning the period when the city of Ancient Kydonia existed and flourished during the Minoan years. In the museum, there are artefacts located in excavations and representations of physical parts of actual ancient sites, excavated in Chania, Crete, Greece and still standing. Kydonia was a Minoan palatial installation on the northwest coast of the island of Crete. It is at the site of the modern-day Greek city of Chania. According to the legend, Kydonia was founded by King Kydon, the son of Tegeati from Arcadia. Kydon together with his brothers came to Crete and establish Kydonia,

Gortyn and Katri. Among Minoan sites of the era found in the city of Chania are the Lustral Basin, the Minoan Tombs and the large house in the excavation of Saint Aikaterini Square (Figures 1, 2, 3). These are three sites of which representations of specific spots are physically reconstructed inside the new Archaeological Museum of Chania.

Site 1: Lustral Basin

Figure 1: Lustral Basin

In the lowland area to the southeast of Kastelli hill, an extensive building complex was discovered of a sacred and ritual character that had been constructed during the 17th century B.C. Today, only a small part of the Neopalatial building complex is visible at the site, in the basement of the building plot named Papadopoulos. Parts of eight rooms can be seen, including the well known adyton or Lustral Basin (left part of Figure 1). The Lustral Basin functioned throughout the Neopalatial period (1650-1450 B.C.), intended for the performance of religious acts and its exact purpose remains unknown. The Lustral basin is physically reconstructed, as a representation of the past, in the Archaeological Museum of Chania (right part of Figure 1) including the original frescoes that covered the walls conserved and exhibited as they were.

Site 2: Kitchen

Figure 2: Kitchen at Saint Aikaterini

At Saint Aikaterini Square, most of the visible ancient remains are dated at 1450 BC. In an area of 600 sq.m. and at a depth of 2 m., the ground plan of a building and parts of three others are preserved (left part of Figure 2). One of its rooms was the kitchen as documented by the type of kitchen-related artefacts unearthed. A large concentration of clay textile weights testify the existence of a loom located next to the hearth. This room, therefore, functioned as both a kitchen and a space for household activities. The kitchen is reconstructed as a representation of the past, in the Archaeological Museum of Chania (right part of Figure 2).

Site 3: Minoan Tombs

Towards the end of 2003, during a trial excavation, one of the most important discoveries in the history of the city of Chania came to light. These were 60 tombs, cut into an area of 1680 sq.m. (left part of Figure 3). Of great importance was a cluster of warrior

Figure 3: Minoan Tombs

tombs dated from 1450 till 1300 BC. A variety of significant offerings were found inside these tombs, i.e. objects that were buried with the deceased. Three of these Minoan tombs are reconstructed as physical copies of the tombs, located in the Archaeological Museum of Chania (right part of Figure 3)).

3.3 Narration and Perceptual Cues

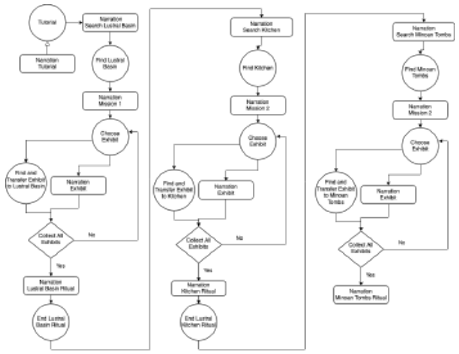

Figure 4: Game Scenario Diagram

As shown in Figure 4, the game begins with a tutorial that trains visitors to use advanced interaction interfaces implemented such as voice commands as well as hand and gaze-based interaction. After the visitor completes the training, a narrative is activated that informs users about the game scenario and invites them to locate the Lustral Basin in the museum's settings (1st physical reconstruction). During the active detection of the Lustral Basin in the real-world museum setting, the narrative explains the history of the Lustral Basin, assigns the visitor the first mission and asks the visitor to select the first exhibit or melody to search. By selecting the exhibit and appropriate melody using a voice command, the 3D reconstruction and sound source of the exhibit is activated and the narrative describes the exhibit's history. Meanwhile, the visitor searches for the exhibit's 3D reconstruction in the museum in order to move it to the Lustral Basin. The process is repeated until the exhibits required to begin the ritual in the Lustral Basin are collected. Following, a narrative describes the ritual and additional 3D reconstructions of exhibits are activated, integrating the musical sounds related to the exhibits into one coherent musical composition. The ritual ends with a voice command. The narration, then, invites the visitor to repeat this process related to the other sites, e.g., the Kitchen and the Minoan tombs, collecting exhibits and activating the ancient rituals.

Each exhibit contains a 3D audio source that reproduces a spatially-aware melody when activated, played by a specific musical instrument, helping the player to locate it by its varying volume based on the user's position and direction (high volume when near, diminishing when afar). When the visitor collects the exhibits and melodies, a ritual is activated and the exhibits and melodies are combined to create a music track resulting to a musical soundscape.

3.4 AR System Architecture

The developed AR platform, developed for the Hololens 2 display, employs the Unity Game Engine and the Mixed Reality Toolkit (MRTK). In a Unity scene, a 3D object is imported resulting from mesh capture of the museum space. Using a Local Spatial Anchor, a 3D object is stored in museum space at the actual location. In this way, it is possible to modify the application outside the museum space. As a result, any 3D object added to a scene automatically takes its place in the real world. Then the Manager Script created activates or deactivates 3D objects of the scene and MRTK functions depending on the point of the AR narrative that the player is experiencing. The functions of MRTK integrated into the application are the following:

- A Local Spatial Anchor allows a 3D object to be stored in a real-world spatial location, used to store 3D reconstructions and objects at specific locations in the museum.
- Hand interactions allow the user to move a 3D object from its initial location to the reconstructed location, so that the ritual is performed.
- Voice commands are used so that the user can activate or de-activate exhibits and specific stages of the AR narrative and receive information based on the narration.
- Gaze interactions are deployed to activate or de-activate labels over 3D exhibits.
- Spatial audio allows the creation of 3D audio sources in the scene; their volume signifying the distance of the user from the audio source and its direction signifying the orientation of the user in relation to the audio source.

4 CONCLUSION AND FUTURE WORK

This paper proposes a work-in-progress multimodal AR experience following a cultural narrative to operate within the newly built space in the city of Chania in Crete, Greece, promoting Ancient Kydonia's cultural heritage. The AR experience incorporates visual and musical elements and deploys advanced interaction interfaces such as hand and gaze-based interaction as well as voice commands,spatial audio, narration and accurate spatial mapping. The narrative guides the player to locate and collect 3D artefacts which contribute to the performance of ancient rituals. Currently, the final background sound, musical components and 3D models of ancient artefacts are created. The current implementation includes primitive 3D objects signifying just location in the museum. The game's mechanics, functionality, spatial mapping and advanced hand and gaze-based interaction have been completed. Future work will include a concrete evaluation of the experience on-site. The utilization of the Azure Spatial Anchors to test collaboration on-site by multiple players between the Hololens 2 and mobile devices is planned. The AR framework could be customised to fit any space. A corresponding AR game, outdoors, around the city of Chania is also being developed. 3D animated characters could be added on-site for human-centred cultural scenarios.

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