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Short Paper

Audio Augmented Reality for Cultural Heritage Outdoors

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Abstract

Audio Augmented Reality (AAR) is a novel area of AR representing the augmentation of reality with auditory input. The way auditory input is combined with 3D superimposed information in AAR is challenging, especially in noisy and busy environments outdoors. This paper presents a novel, work-in-progress, mobile AAR experience that is deployed in a city environment while walking past seven archaeological excavation sites in the city of Chania, Crete, Greece. The proposed AAR experience embeds 3D graphics and audio related to the cultural content while a visitor walks around the city, offering a non-linear narrative. Visual and audio digital elements are accurately geo-located while a personalized AAR SoundScape Generator boosts audience creativity. AAR design is optimized for outdoor use.

CCS Concepts

• ***Human-centered computing*** → ***Mixed / augmented reality;*** • ***Applied computing*** → ***Interactive learning environments;***

1. Introduction

Cultural Heritage (CH) organizations around the world are currently seeking novel ways to promote their content by introducing interactive technologies in their institutions in order to engage their audience [RESLW21], [PCVS20]. Serious Games(SGs) are digital games offered by museums to enhance, complement and enliven the museum's unique features, promote audience engagement and augment the museum's characteristics [PS16]. Recently, Augmented Reality (AR) is progressively employed for interactive entertainment providing meaningful multimodal experiences [KAS*19], [KDMM21]. Digitally revealing 'missing' historical facts without obstructing the real-world is vital for CH's sustainability, forming a narrative between reality and virtuality [Kru91], [CC13], [GKP*22]. Audio Augmented Reality (AAR) is an emergent area representing the augmentation of reality with auditory input [Bed95]. Designing how auditory input is to be combined with 3D superimposed elements in AAR is challenging, especially in noisy and busy environments outdoors.

This paper presents a novel, work-in-progress, mobile AAR experience deployed in the city of Chania, Crete, Greece while walking past seven archaeological excavation sites representing seven Points Of Interest (POIs) of Ancient Kydonia. These are dated from 1650 BC to the 3rd c. BC. The proposed AAR experience aims to motivate visitors to explore the historical sites of a busy city embedding SG elements, 3D graphics and audio while a visitor walks around the city. Our specific contributions include:

- A methodology of spatial integration of sound, music and 3D graphics, promoting historical documentation based on a non-linear experience, e.g. the visitor can start the experience from any POI selected.
- Playful city navigation outdoors, in the form of a musical narrative and production of an audio footprint in a noisy setting.
- 3D digital content of real-scale reconstructions superimposed on archaeological excavation sites, visible under challenging sunlight conditions in the city.
- AAR for audiences digitally visiting underground burial archaeological sites not open to the public, hidden from public view under modern buildings, accessed via 3D portals.
- An AAR SoundScape Generator; an innovative tool boosting audience creativity by allowing creative musical compositions.

2. AR & AAR in Cultural Heritage

As digitization transforms media and Augmented Reality (AR) is evolving, museums and heritage organizations seek sustainable ways to enhance audience engagement [PCVS20]. The research community has developed vast digital content for cultural heritage [PS16], [VDP16]. Serious Games often employ such digital content, providing audiences with gamified experiences which promote interest in cultural heritage on and off-site [BRR*19], [GKP*22]. AR has in itially been deployed in the CH domain in the form of autonomous virtual guides replacing audio guides, to help audiences navigate around a museum collection indoors or an archaeological site outdoors [MMT*08], [VDP16]. 3D visualization of reconstructed artefacts is often included [KS16], [PRDM18], [MGS18]. Audiences navigate around archaeological sites and through AR markers and geo-positioning, observe 3D reconstructed buildings at specific locations. Information about cultural heritage monu-

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ments and art paintings can also be presented to the audiences' mobile screens [WPAA21], [LCMO21]. A prototype application for the Art Museum of Brașov, Transylvania was created with which the audiences could scan art paintings and receive information [LCMO21]. The AR graphic overlay was accompanied by a collaborative chat section that enabled the audience to provide feedback related to the information received. An application was developed to help visitors with informal learning at the historic site of Jakarta's Old Town by providing augmented information enhancing visitors' experience [WPAA21]. A multisensory AR system named SensiMAR represented a custom 360 degree smell-dispenser to further enhance the 3D reconstructed visualizations of the remains of a wealthy Roman house, in Conimbriga Ruins, part of the Monographic Museum of Conimbriga-National Museum in Portugal [MMGB21]. Notably, AR research experiences are still heavily dependent on black-and-white image markers which are not applicable outdoors, in busy and bright city environments while the user moves. AR experiences are mainly designed for indoor use [LCMO21], [GKP*22]. Those designed for outdoor use require the audience to view them from a specific angle and face technical as well location-specific challenges such as operating under extreme light and noise [WPAA21], [MGS18].

Audio Augmented Reality (AAR) is an emerging field based on digital audio augmentation of real-world surroundings [Bed95]. AAR prototypes have been presented in museums and city-based SGs as well as for training [MBWF97], [SWC*03], [CGM16], [LCC20]. An AAR city-based SG deployed sound as the primary interface for conveying game information to the audience based on their GPS location [CGM16]. Electroencephalography sensors where used to monitor the brain activity of participants. The effective use of 3D sound increased participants' alertness. A soundscape of nature integrated in AAR was shown to contribute to reduction of stress and promotion of calmness, while enhancing participants' ability to identify bird calls [LCC20]. A prototype AAR tour guide was created that enabled the audience to move independently inside a museum [Bed95]. A system was designed with which analog tapes were replaced with random-access digital audio and a microcomputer. An invisible spatial locating device was added to provide freedom of movement and exploration for the participant. Previous works described emphasize in audio augmentation and lack AR visualization content. Past work re-imagined and re-created the soundscape of the Crkvina archaeological site, one of the most important early medieval settlements in the Kingdom of Croatia [SRĐJ18]. Audiences' experience was enhanced by the carefully created historical soundscape. Yet, it had precision issues as the audio sources were placed relying on GPS accuracy of 3-5m. It is challenging to combine accurate placement of both augmented audio and 3D content while a participant is outdoors, due to GPS low accuracy. In our work, we achieved higher accuracy by generating 3D sound after scanning the physical environment and placing 3D AR anchors in specific locations based on feature points of the scan.

3. System and User Requirements

We put forward a mobile AAR experience enriched with SG elements for CH, operating outdoors, in noisy and sunny cityscapes while a participant is on the move. AAR gamified applications for mobile devices and tablets for CH, related to Ancient Kydonia and operating within the city of Chania, in an outdoors and busy environment, must meet the following criteria:

- Contain playful and creative elements of AR graphical content formed into a digital narrative, instead of 3D elements simply superimposed on real-world surroundings.
- Contain soundscapes for a complete audiovisual experience promoting novel AAR, recorded to be perceptible but also adhering to safety requirements while walking outdoors.
- Have a non linear SG script that leads the audience to specific POIs with varied starting points.
- Provide a map to help audiences navigate between POIs.
- Have a simple and functional graphical user interface that explains to the audience their role and tasks in the game while being visible under direct sunlight.

4. Implementation

4.1. Ancient Kydonia's Points of Interest

The city of Kydonia in Crete was founded by King Kydon, the son of Tegeati from Arcadia. Kydon together with his brothers came to Crete and established Kydonia. Our AAR experience takes place in the modern part of Ancient Kydonia, in the city of Chania in Crete, Greece while the user walks by seven excavation sites, holding a mobile device. The selection of POIs represents seven locations which include excavation artefacts, parts of the settlement of Ancient Kydonia and burial monuments. The POIs are divided into two chapters, those of Life and Death. The Life's chapter POIs are archaeological excavation sites visible from the street [Fig.1 (a)-(c)]. The Death's chapter POIs are mostly subterranean archaeological monuments, not open to the public [Fig.1 (d)-(g)]. The audience may explore these POIs in a non-linear path, thus, the decision where to start the experience is theirs.

Figure 1: *Ancient Kydonia's Points of Interest.*

4.2. Designing the Interactive AAR Experience

This paper proposes a novel work-in-progress multimodal AAR experience for handheld mobile devices. The AAR experience will extend the permanent indoor exhibition of the Archaeological Museum of Chania, by providing its visitors an exploration pervasive game through the city of Chania outdoors, while visiting real-world archaeological sites, promoting Ancient Kydonia's cultural content. The experience proposed will enable audiences to explore city areas beyond the touristic zones of central Chania.

Our gamified AAR Experience aims to provoke audiences to explore the city of Chania in order to collect digital CH artefacts from Ancient Kydonia. Audiences are provided with a playful map to navigate through the city. As soon as they approach the desired Life's chapter POI, they are prompted to scan the archaeological excavation site with their mobile device. After scanning, the visualization of the reconstructed historical building appears together with sounds of objects and music related to the era. For the Death's Chapter POIs, the audience is informed of the existence of the subterranean burial excavation site. Our system superimposes a 3D scan of each burial site, above the physical ground on specific locations. The 3D model represents a 3D portal the audience can enter and explore. For each visualization of the POIs, the audience navigates around the specific spatial coordinates, experiences the generated AAR spatial soundscape and collects the digital CH artefacts. By collecting the digital CH artefacts, the audience can learn about them through a GUI and use them in the AAR SoundScape Generator to create their own spatial soundscapes. The sound is spatialized, offering clues to the narrative and the user interface may dynamically adjust its colours to suit the level of outdoor luminance.

5. System Architecture

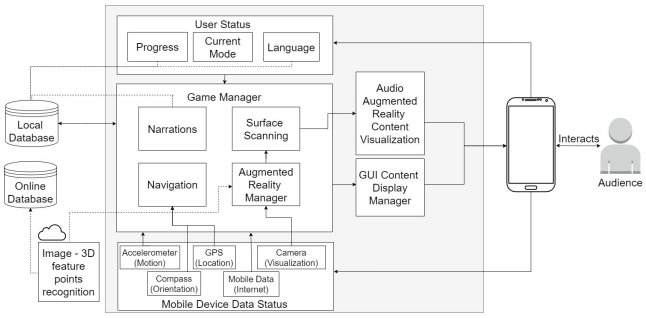

Figure 2: *System Architecture.*

The software architecture of the system [Fig.2] includes playful navigation and narration scripts as well as advanced AR features that enhance user experience while the audience walks around the POIs. The AAR experience has been developed in Unity both for Android and iOS devices with the use of the ARFoundation SDK. Unity's native Audio plug-in and its Audio Spatializer was used for the spatialized sound system. The audience interacts with the system through the mobile interface and by moving in the physical world outdoors. Our system requests the following data from the device; the Accelerometer for Motion, the Compass for Orientation, the GPS for Location, Mobile Data for Internet and the Camera for Visualization. The central manager is called Game Manager, responsible for passing the correct data to each module. The Game Manager also receives as input the user's status data including Progress, Current Mode and Language. The Current Modes are the following; the Navigation Map mode, the AAR visualization at POI mode and the AAR SoundScape Generator. Depending on the Current Mode the audience has selected, the Game Manager will either enable the Navigation Manager or the AR Manager. The Navigation Manager is responsible for combining the compass and the GPS data of the device and guides the user to the desired POI through a map GUI. The AR Manager has two modes. If the AAR visualization at POI mode is enabled, then the AR manager will request the audience to use the camera and search for the desired location, which is presented to them with a 2D image. As soon as they arrive at that location, the AR Manager triggers an image and the 3D feature points recognition process through the network. These will return a precise 3D anchor for the precise placement of the 3D model. The device internally scans the physical environment recreating the feature points and places the received anchor to the physical environment for the final AAR content visualization. In AAR SoundScape Generator mode, the Game Manager will prompt the audience to select an artefact from the collected CH artefacts and sends a signal to the AR Manager to initiate the local placement mode. The AR manager will scan the physical environment for available surfaces and feature points so that the AAR content, both audio and visual, is accurately placed.

6. AAR SoundScape Generator

Figure 3: *SoundScape Generator. The sound range of each CH artefact are identified via different colours.*

Our AAR SoundScape Generator (SSG) is an innovative tool boosting the creativity of the audience. When the audience has navigated through the POIs and has collected all or part of the CH artefacts, then this feature can be deployed. The AAR SSG uses AR technology in order to place CH artefacts in the physical world. Each artefact encompasses a melody based on its material properties and historical knowledge provided by the Ephorate of Antiquities in Chania, Greece, related to the music and melodies of Ancient Kydonia. The audience can enable the SSG mode from the central menu of the experience. As soon as they enter the experience, a GUI will prompt them to select an artefact from the available ones and place it on the physical world to their desired location. The audience may repeat the process and add or remove as many artefacts as they wish from the scene. Because of the AR technology used, the spatialized sound works without any accuracy issues. Audiences move close to the CH artefacts to examine them and enjoy their melodies, navigating through their own soundscape [Fig.3].

7. Conclusion

We propose a novel work-in-progress multimodal AAR experience following a cultural non-linear narrative to operate within the city

of Chania in Crete, Greece, promoting Ancient Kydonia's CH. The AAR experience incorporates visual and musical soundscape elements and deploys advanced gamification components, spatial audio, non linear narration and precise AR visualization outdoors, in busy and bright city POIs. The audience explores the city of Chania through non-linear narration to locate and collect 3D CH artefacts related to Ancient Kydonia. Our research contributes to the broader understanding of AAR in order to create meaningful interactive experiences outdoors. Future work will finalize an adaptive GUI enabling a clear view of digital content under direct sunlight as well as a formal evaluation of the experience on-site.

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