Keynote

Virtual and Augmented Reality for Maritime Archaeology

A Case Study from the iMARECULTURE Project

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Abstract: Underwater cultural heritage sites are widely spread into the Mediterranean Sea and are not accessible to the public due to their environment and depth. Digital technologies have been used in the past, but they are very limited in terms of what visitors can see and how they can interact. Recent advances in virtual reality and augmented reality provide a unique opportunity for digital accessibility to both scholars and public, interested in having a better grasp of underwater sites and maritime archaeology. The project iMARECULTURE (Advanced VR, iMmersive Serious Games and Augmented REality as Tools to Raise Awareness and Access to European Underwater CULTURal heritage) focused in raising European identity awareness using maritime and underwater cultural interaction and exchange in Mediterranean Sea. This paper presents results from iMARECULTURE project in respect to virtual and augmented reality applications for underwater environments. In terms of virtual reality, a serious game that aims in teaching maritime and archaeologist students the main principles of 'site formation', 'surveying' and 'excavation'. Moreover, a novel augmented reality underwater application is presented which can detect square markers in poor visibility conditions as well as serve as virtual guide for divers that visit underwater archaeological sites.

Keywords: *Virtual Reality—Augmented Reality—Maritime Archaeology*

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Introduction

Underwater cultural heritage sites are widely spread into the Mediterranean Sea and are not accessible to the public due to their environment and depth. Photos and surfaced artefacts exhibited in maritime museums provide fragmented aspects of such sites, but this is all visitors can see (Liarokapis et al., 2017). Digital technologies have also been, randomly used, in museum exhibitions, as a supplementary information source, but not always very successfully (Skarlatos et al., 2016; Bruno et al., 2017). Recent advances in virtual reality (VR) and augmented reality (AR) provide a unique opportunity for digital accessibility to both scholars and public, interested in having a better grasp of underwater sites and maritime archaeology.

The project iMARECULTURE (Advanced VR, iMmersive Serious Games and Augmented REality as Tools to Raise Awareness and Access to European Underwater CULTURal heritage) focused in raising European identity awareness using maritime and underwater cultural interaction and exchange in Mediterranean Sea. The aim of the project was to bring inherently unreachable underwater cultural heritage within digital reach of the wide public using virtual visits and immersive technologies (Skarlatos et al., 2016; Bruno et al., 2017).

This paper presents results from two distinctive applications in underwater VR and AR for maritime archaeology. In terms of VR, a serious game that aims in teaching maritime and archaeologist students the main principles of 'site formation', 'surveying' and 'excavation'. Moreover, a novel AR underwater application is presented which can detect square markers in poor visibility conditions as well as serve as virtual guide for divers that visit underwater archaeological sites.

Background

Underwater Virtual Reality

In 2017, an immersive virtual underwater visit in Mazotos shipwreck site was presented allowing for an interactive exploration of the shipwreck and its environment such as plants, fish, stones, and artefacts (Liarokapis et al., 2017). In 2018, a diving simulation in VR was proposed allowing users to experience a historical–cultural context with information regarding the flora and fauna of the underwater site (Bruno et al., 2018). The same year, an immersive VR learning application for teaching the essentials of the underwater excavation based on a realistic sand simulation was proposed (Kouřil and Liarokapis, 2018). In 2019, an educational VR application aiming to aid the future marine archaeologists with the basics of photogrammetry was developed showing that the gamification techniques allowed the creation of accurate measurements to be made (Doležal et al., 2019).

A marine ranch visualization application for the tourism industry simulated the behavioral characteristics and environment of fish swarm in virtual marine ranch to shorten the distance between users and marine ecology (Liu et al., 2020). Moreover, search techniques for discovering artefacts in underwater environments were proposed in the form of a serious game and a VR game (Liarokapis et al., 2020). Recently, a very simple underwater museum using VR was proposed based on point cloud and rig animation (Manju et al., 2021). However, the work seems to be preliminary, and it was not evaluated with users. Another study compared three important elements of VR such as presence, vection and visually induced motion sickness among 30 participants experiencing VR while standing on the ground or floating in water (Fauville et al., 2021). Vection was significantly enhanced for the participants in the water condition, but no differences in visually induced motion sickness or presence were found between conditions.

Underwater Augmented Reality

In terms of underwater AR, two systems were proposed in 2009. The UWAR system provided visual aids to increase commercial divers' capability to detect, perceive, and understand elements in underwater environments (Morales et al., 2009). In another approach, AR was experimentally demonstrated in a swimming pool where it generates visual representations of virtual 3D scenes (Blum et al., 2009). AR was also developed for remotely operated underwater vehicles (ROV) and could be used as navigational and manoeuvring aid as well as prior mission training (Toal et al., 2010). In

2012, an underwater-computerized display system with various sensors and devices conceived for existing swimming pools and for beach shores, associating computer functions, video gaming and multisensory simulations was proposed (Bellarbi et al., 2012).

A year later, an underwater AR system focused on both recreational and commercial divers during navigation providing a fish identification scheme (Brown and Wang, 2013). The first multi-player underwater AR experience for swimming pools focusing for recreational and educational purposes was presented in 2013. In 2016, an evaluation of the same application with 36 kids was presented (Oppermann et al., 2016). In 2018, a new method for AR tracking was introduced based on white balancing (Čejka et al., 2018). The method enhances underwater images to improve the results of detection of markers for AR. Recently, two novel solutions for underwater AR were presented: a compact marker-based system for small areas, and a complex acoustic system for large areas (Čejka et al., 2021).

Virtual Reality Excavation Game

The VR excavation game consists of three components including: search and discovery (Liarokapis et al., 2020), protogrammetry (Doležal et al., 2019) and excavation (Kouřil and Liarokapis, 2018). The architecture of the VR serious game including the controllers is presented in Figure 1. The game is controlled through a menu and VR controllers. It has two models of operation. In the first one, each component must be completed in a sequential manner. However, in case that a player wants to skip a component can jump directly to a particular component through the menu.

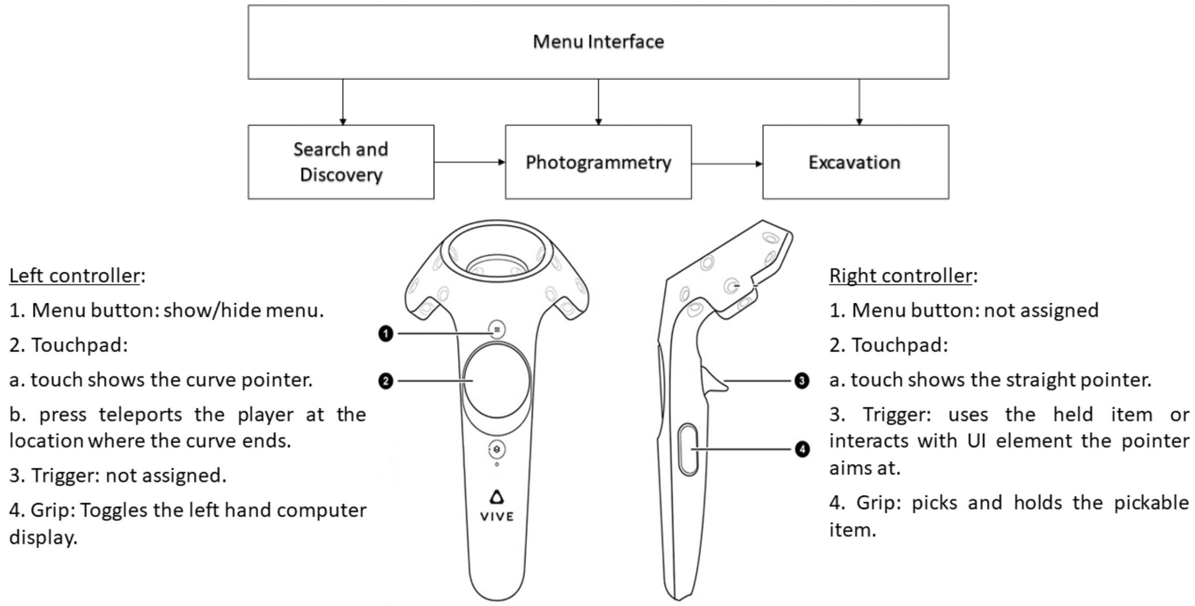

Fig. 1. Architecture of the VR serious game including the dedicated controllers (© iMareCulture)

An overview of the virtual reality serious game is shown in Figure 2. When the player enters the main game in the unified environment, the first task is to search the area and find scattered amphoras and a shipwreck. The search and discovery game assessed two maritime archaeological methods for search and discovering artefacts including circular and compass search. Evaluation results with 30 participants showed that the circular search method is the most preferred and was implemented in VR (Liarokapis et al., 2020). Amphora is found when the user aims at it with the straight pointer and presses the trigger button and thus tags the amphora. Amphoras are also connected to a short video which starts playing above the left hand and it unlocks in the mother base scene in the central panel. The user can either watch the video or interact with the UI element to skip it. Around the area are also scattered objects other than amphoras, which can also be tagged, but no video is played since these objects are not important. When the player finds all amphoras or wants to move to the next task (photogrammetry).

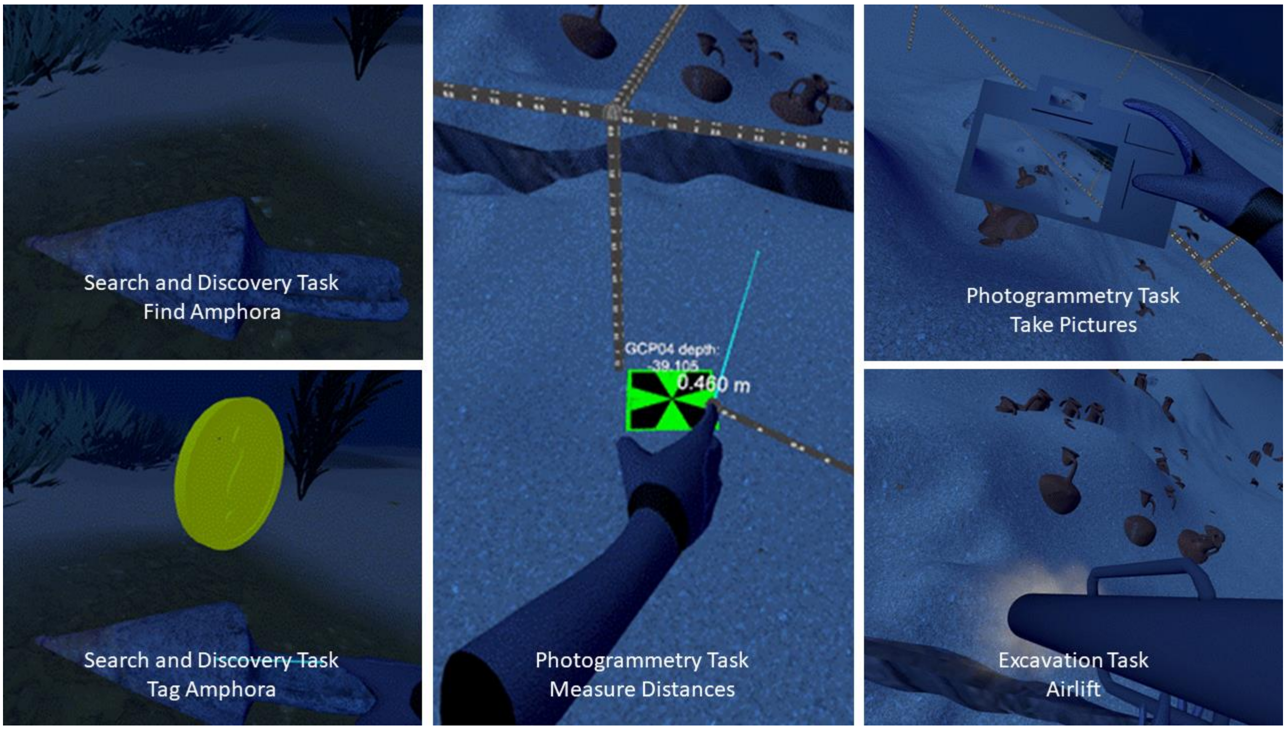

Fig. 2. Overview of the three tasks in the VR serious game (© iMareCulture)

The purpose of the photogrammetry task is to document an underwater site (Doležal et al., 2019). It consists of taking photos in VR that will be used for post-processing photogrammetry analysis. At the start of activity, user places around 4 ground control points (GCP) markers in the site by pressing the left trigger button. Then they need to measure distances between all the markers by pressing and holding the right touchpad. When the measurements are completed, the user must pick up the digital camera and systematically cover the whole area of interest with photos. It is recommended to use swim locomotion mode instead of teleportation. For the photo to be valid in photogrammetry processing, it needs to overlap at least by 30 % with another photo. There are two ways of taking photos. First, the spiral method – the user takes photos from the center in the spiral. The second method, which is recommended in this scenario, is by taking photos in lines perpendicular to the ground. The task is finished after taking at least hundreds of photos. Though taking more photos will provide more accurate result, but it will take more time to process the scan. All photos are stored in the installation folder and can be later used to calculate the 3D scan in any photogrammetry software.

The final activity is the shipwreck excavation (Bruno et al., 2017; Kouřil and Liarokapis, 2018). User can experience the process of underwater excavation by removing sand from the seabed. Similarly, to the previous task, user must grab the airlift device and they can use the device to slowly dredge sand from the seabed and look for objects buried in sand. The player should uncover as much of the shipwreck as possible. Two different approaches were implemented. The first one was based on realistic sand simulation and although it provided a more accurate simulation, it was not effective for large areas (Kouřil and Liarokapis, 2018). The second method, which was preferred and used in the final version was not so computationally expensive and provided reasonable simulation results (Bruno et al., 2017).

AR Guide

The Augmented Reality (AR) within the underwater navigation is intended to enable the diver a new and more immersive experience compared to a classic recreational dive. The site used is the underwater Archaeological Park of Baiae which is located off the north-western coasts of the bay of Puteoli in Naples. The AR allows the diver to view the hypothetical reconstruction of the structures and artifacts that are superimposed on the present status of the underwater archaeological site. The diver-visitor is equipped with an AR enabled underwater smartphone which estimates the diver's position and orientation. To enhance the underwater experience of diver visitors, a hybrid AR application was developed. An overview of the architecture of the system is presented in Figure 3.

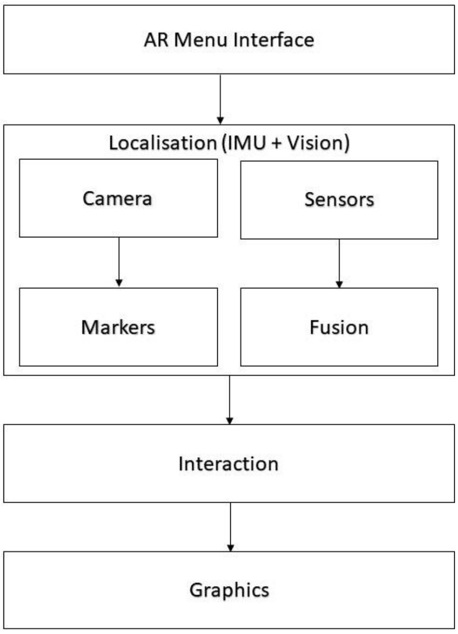

Fig. 3. Architecture of the AR guide (© iMareCulture)

Vision underwater is degraded by several factors such as absorption of light and turbidity, which creates a problem for vision. It is also problematic in terms of localization when computer vision is employed for localisation. To enhance the quality of underwater images, a real-time dehazing algorithm was proposed and implemented (Čejka et al., 2018; Čejka et al., 2019). To further improve accuracy and increase the robustness, data coming from inertial sensors located in the device are used. The AR application records the data from the camera and sensors, detects markers, computes the position of the camera, and renders the virtual model at the proper position. Additionally, it presents interesting information about the site, and records the data from the camera and sensors for further optimization of the application.

Fig. 4. Underwater AR mobile phone with housing (© iMareCulture)

The system is implemented and tested on a Samsung S8 smartphone and a Diveshot housing (Fig. 4). It also contains five optical buttons that divers press by covering the corresponding sensor with a finger and sends the click events to the smartphone using Bluetooth, behaving like an external Bluetooth keyboard. The user interface of the application is designed to use only with the five buttons of the housing because the housing prevents divers from controlling the smartphone directly by touching its surface. It was optimized for smartphones, because their screen is much smaller than the screen of tablets and require less controls so as not to overload the user. It is divided into two parts, a left part dedicated for the application and a right part containing a visual representation of the buttons of the housing. The function and labels of the buttons change according to the needs of the application. Additionally, the screen contains a small clock in the upper left corner.

Fig. 5. AR view of "Villa con ingresso a protiro" (© iMareCulture)

The application provides a 3D hypothetical reconstruction of "Villa con ingresso a protiro" which is located at approximately 6 meters' depth. The user interface is shown in Figure 5. Most of its screen is taken by the AR view, which maintains 16:9 aspect ratio of the camera. The right part with buttons automatically shrinks to fit the missing space of the screen. The clock and the information text about the site are displayed over the AR view. The status of saving camera and sensors streams is depicted in lower right corner.

User experience was evaluated with 10 professional divers and the complete results were recently published (Čejka et al., 2021). Divers reported that they expect that the system will be used in practice for touristic purposes soon. They could see the virtual scene very clearly and agreed that they felt completely immersed in the virtual environment and stopped paying attention to their surroundings. Some divers complained that due to their complete immersion, they lost the feeling of actual diving, which was substituted by their impression of the virtual experience.

Conclusions

This paper has presented two different applications for maritime archaeology. The first application was implemented in immersive VR and aimed in educating the public about the process teaching maritime and archaeologist students the main principles of ‘site formation’, ‘surveying’ and ‘excavation’. Although the final version of the VR application was not evaluated, the individual components were evaluated prior to the integration. The second application is an underwater AR touristic guide for divers. This application was formally evaluated, and results showed that it was very successful as an underwater touristic guide. In the future, results from both applications will be used to design and implement new underwater applications for maritime archaeology.

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