Underwater Search and Discovery: From Serious Games to Virtual Reality

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Abstract. There are different ways of discovering underwater archaeological sites. This paper presents search techniques for discovering artefacts in the form of two different educational games. The first one is a classical serious game that assesses two maritime archaeological methods for search and discovering artefacts including circular and compass search. Evaluation results with 30 participants indicated that the circular search method is the most appropriate one. Based on these results, an immersive virtual reality search and discovery simulation was implemented. To educate the users about underwater site formation process digital storytelling videos were used when an artefact is discovered.

Keywords: Serious games · Virtual reality · Underwater archaeology

1 Introduction

Underwater archaeological sites are discovered mainly by two different ways. The first one is from an archaeological survey that typically includes remote sensing approaches (i.e. optical, sonar, magnetic devices). The second one is focused on reports by sport-divers or fishermen. In any of the above-mentioned cases, ground-truths dives must be produced in order to verify the reports or the acquired images of the seafloor (remote sensing). In the case of remote sensing, where the site is accurately located by means of a GPS mounted on board the boat, the search may be easier and focused on a specific and limited area. In the other cases, the site needs to be precisely located as the reports may not offer

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any accurate location, or there is no precedent knowledge of an existing site. In these cases the search would cover larger areas and be accordingly planned.

Past research has shown that the more types of objects a diver is asked to include in the search, the lower the efficacy is for any single type of object [9]. However, in a typical archaeological search, divers are searching for all available artefacts in the area of interest. There are several techniques that can be used to search for archaeological sites, or to locate a site whose rough location is known. These techniques differ, depending on the type of seafloor and the expected accuracy of the provided location. These are often called search and discovery techniques, and are employed in different fields of expertise, such as archaeology, forensics, law enforcement, search and rescue etc. The concept behind these techniques is to provide the largest coverage of the chosen area with the less time and effort, considering that as with many other underwater activities, time and diver safety are paramount.

The motivation of this research originates from the iMareCulture EU project which focused in raising European identity awareness using maritime and underwater cultural interaction and exchange in Mediterranean Sea [5, 19]. This paper presents first a novel serious game that assesses two maritime archaeological methods for search and discovering artefacts including circular and compass search. Evaluation results with 30 participants indicated that the circular search method is the most appropriate one. Based on these results, an immersive virtual reality search and discovery simulation was created. To educate the users about underwater site formation process digital storytelling videos were used when an artefact is discovered. To our knowledge this is the first time that a maritime search and discovery assessment is performed. Also, it is the first time that an immersive VR simulation with digital storytelling for learning and understanding the site formation process is presented.

The rest of the paper is structured as follows. Section 2 presents related work in terms of underwater serious games and VR environments. Section 3, describes the design and implementation of the serious game. Section 4, illustrates the evaluation methodology as well as the experimental results. Section 5, presents the scenarios used for digital storytelling in order to describe the site formation process. Section 6, presents an overview of the VR application and Sect. 7 concludes the paper.

2 Related Work

The field of serious games for archaeological purposes has been previously documented [1]. An early approach was the integration of artificial life simulations with serious games focusing on the behavioural representation of species in fragile or long-vanished landscapes and ecosystems [20]. Another approach was the Dolphyn system [4], which consisted of 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. More recently, a serious game was developed for seafaring [16] and

incorporated probabilistic geospatial analysis of possible ship routes through the re-use and spatial analysis from open Geographical Information System (GIS) maritime, ocean, and weather data. These routes, along with naval engineering and sailing techniques from the period, are used as underlying information for the seafaring game.

In terms of underwater serious games and immersive virtual reality (VR) simulations, there are not a lot of relevant papers. One of the first attempts was the VENUS project [6] that aimed at providing scientific methodologies and technological tools for the virtual exploration of deep underwater archaeology sites. Amphibian presented an immersive SCUBA diving experience through a terrestrial simulator that mimicked buoyancy, drag, and temperature changes through various sensors [10]. Moreover, immersive VR simulator focused on exploration of the Mazotos shipwreck site in Cyprus [12] for raising archaeological knowledge and cultural awareness. Recently, an underwater excavation VR serious game focused on tagging and dredging procedures was presented [11] by implementing and extending an existing voxel-based sand simulation approach and rasterizing it using the marching cubes algorithm on the GPU. Recently, a VR serious game that introduces maritime archaeology students to photogrammetry techniques was presented [7]. Experimental results showed that the system is useful for understanding the basics of underwater photogrammetry and that could be used for learning purposes.

3 Design and Implementation of the Serious Game

In this section, firstly the features that were used to create an underwater digital environment, are described. After consultation with maritime archaeologists two techniques were selected for implementation. The circular search is one of the most effective ways for divers to search areas of seabed and to position any objects found during the search. The method does not require any complicated equipment, is easy to learn, is very quick to set up and can be used in poor visibility on any type of seabed. The basic principle of a circular search is for divers to carefully search the seabed in a circular pattern at a known distance around a shot weight that marks the centre of the search area. There are a number of other search methods that have been tried such as a jackstay and swim-line searches but they are best avoided. These other methods require ropes and weights to be set up on the seabed or co-ordination between many divers underwater, both of which are time-consuming and prone to failure in all but the most ideal conditions (<http://www.3hconsulting.com/techniques/TechCircularSearch.html>). The second technique that we selected is the compass search, which is also very popular (Fig. 1).

The terrain has width and length set to 1000 units. Boundaries are defined by a transparent wall, to indicate the end of the current game field. All these walls were created from cube game objects with suitably set scales and positions. The color of the wall was set to grey with RGB values equal to (189, 189, 189) and transparency set to 90. A diver model was used as the player's avatar and

Fig. 1. The two search and discovery techniques selected, compass search (left image) and circular search (right image) [22]

animations were used for modeling the swimming of the diver. To achieve the effect of swimming underwater, the diver model was rotated to face the ground and an animation for walking forward was used on it. The scene consists of objects, that the player can interact with, and objects that can't interact with. The objects that the player could pick up and read information about were randomly positioned. The player was able to pick up an object only when was close enough to it. Once, the player is close enough, the name of the object appears above it. This serves as an indicator that the object can be picked up. Figure 2 shows an example of an amphora including some description (<https://en.wikipedia.org/wiki/Amphora>).

One of the two objectives of the game was to find and collect objects including: five statues, three amphora, three ship wheels, one coin, one axe, and one compass. On the other hand, the objects, that the player couldn't interact with had aesthetic significance and were placed statically in the scene [22]. Many instances of these objects were present in the scene with different scales, positions and rotations. The only exceptions were the objects which were randomly positioned such as: four ships, three different types of rock, five types of shells, fourteen types of plants, four types of wood, a plank, a barrel, two different types of anchors, and one type of fish.

To make the underwater environment more realistic, animated models of fish were added to the scene [22]. The behaviour of the fish is implemented by a flocking algorithm, which is commonly used to model flocking behaviour of animals (e.g. the behaviour of flocks of birds, schools of fishes or herds of mammals). This algorithm is based on three rules: (a) each fish from the group tends to move towards the centre of the group, (b) the whole group is heading towards the same direction, and (c) each fish tries to avoid the other fish, so it will not bump into them. Schools of fish were created according to these rules

and were enclosed in an imaginary box, preventing them from swimming too far away. Several of these boxes were placed on different positions on the game field, creating a few smaller schools of fish.

Fig. 2. Example of a scene, that provided information about amphora (<https://en.wikipedia.org/wiki/Amphora>)

Fog was set in each level to model an underwater environment more realistically [22]. It's color was set to dark blue, with the RGB values set to (14, 113, 172). The fog mode was set to exponential squared and the density of the fog was set to different values in each level. In the first level the density was set to 0.015, in the second level it was set to 0.03 and in the third level to 0.02. To make the underwater environment more realistic, the effect of caustics was added to the game. Initially, 16 images of caustic patterns were created and looped through with the frame-per-second (FPS) set to 30.

A mini-map was also created to help the players orient themselves in the scene. In each level, the mini-map shows: (a) the position of the ship, which is represented by a green picture of the ship, (b) the beginning point of the search, which is represented by a yellow dot, and (c) the position of the player represented by a red oval. In the first two levels, the positions of the searched amphora are showed on the mini-map as well. The amphora are represented by green dots. The representation of the maps were created from blurred screenshots of the terrain. An example of the game in action including the mini-map is shown in Fig. 3.

When the game starts an introductory menu is provided containing information about the game and the controllers. After pressing the “Play” button, a screen, that asks the player to enter his name, is shown. This name is used in the following parts to address the player. If the player chooses not to enter any name, the game will address him as a default name (i.e. “Mike”). The game consists of three levels. The first two levels are similar in structure, with the third level being slightly different. A diagrammatic overview of the game is illustrated in Fig. 4.

Fig. 3. Example of the game in action as well as the mini-map [22] (Color figure online)

Fig. 4. Diagram of the game structure [22]

Each level consists of two parts: (a) dialogue and (b) Collecting or marking of amphora. The dialogue is led between 3 people: the player, another diver (called John) and the captain of the ship. This dialogue is written as a friendly conversation between these three people, where they are discussing the upcoming expedition. In the first two levels, information about the search techniques are provided. The first level provides information about the circular search technique, while the second level provides information about the compass search technique. The dialogues in the first two levels include a part, where the other diver dives and the player, together with the captain, are following him on the monitor of their computer.

During this process, they see a blue circle (which represents the other diver) moving in the direction of the discussed pattern. When the player is close to an amphora, it is also shown on the map as a green dot. The yellow dot represents the point, where the other diver started his dive and the position of the ship is displayed using a green picture of a ship. This map is later used as a mini-map for the player to orient himself at the next part of the level. In the third level, one, of three possible dialogues, is generated. Since the third level is randomized, the dialogue is chosen to match the used technique. These dialogues inform the player about the next steps and are displayed in word bubbles. To differentiate between the characters, each character has his bubble shown on a different position on the screen. An example of the dialogues used in the serious game is shown in Fig. 5.

Fig. 5. Dialogue example in the serious game [22] (Color figure online)

In the first two levels, the task is to collect as much amphora as the player can in the given time, which is set to 6 min. The player is shown a mini-map in the bottom right corner of the screen to help him orient himself. In the third level, the player does not have the positions of the amphora (which are randomised).

The task is to find them and mark their positions on the map within 10 min. The task is randomly chosen from 3 possible scenarios. These scenarios differ in the technique used to do the exploration. The player should use either the circular or compass search technique, which were explained to him in the previous two levels. In these cases, there is a helping path created at the seafloor as a hint to preserve the pattern. The last possible scenario does not follow any prescribed pattern. The player was allowed to move freely and search. After the third level ends, the player is shown a score.

4 Evaluation

4.1 Participants and Procedure

33 healthy volunteers took part in the evaluation but three of them were discarded because they did not complete the serious game. The remaining 30 participants (20 male and 10 female) were testing the game in three separate parts. Since the third level in the game is randomized, three separate versions of the game were built, without the randomization of the third level, and each version was tested by an equal number of participants (10 participants). When a participant arrived, was asked to take a seat at any place in the laboratory and fill in a Consent form. After this, a brief description of the experiment was provided, mainly about the structure of the game (number of levels and description of their structure). Participants, who played the versions of the serious game with circular or compass search as the last level, were also asked to adhere the provided path, which served as a hint to preserve the desired pattern. They were also told to freely ask any questions about the game during playing.

4.2 Data Collection

Data collection consisted of both questionnaires and log data. The questionnaire consisted of 4 parts. In the first part, demographics were collected. This information was gathered before playing, the rest of the questionnaires were filled in after the game and concerned information about the participants experience with the game. The second part of the questionnaire included 10 custom-made questions about the game. In the third part, participants were asked to sum up their experience using a written open-ended questionnaire. The feedback may serve as an indicator for possible future improvement of the game. The last part included the NASA Task Load Index questionnaire [8] which measures cognitive workload.

During the process of playing the game, log data were collected (see Fig. 6). During one game, 4 text files were created. Three of them contained information about the movement of the players. One text file was created for each level. The last text file contained information about the collected amphora. As soon as the player picked up an amphora, a record about this was made. In the result a list of all collected amphora was created, where they were sorted according to the

order, when they were picked up. At the end of the level, the remaining time (in seconds) and a total sum of the collected amphora in that level were recorded as well. The aim was to compare the third level for each of its version. Specifically, the number of amphora collected using each of the 3 methods (circular, compass, free search). In case of circular or compass search, the players were asked to follow the path on the floor, which served as a hint to preserve the pattern. From observing their playing, it was noticeable, that they mostly started their search the correct way, i.e. by following the path and looking around for objects. But many of the participants, who got to the end of the path and saw, that they do not have all the objects, started to search randomly.

Fig. 6. Comparison of search and discovery techniques

4.3 Results

Mann-Whitney analysis [14] was used to analyse the collected data. In terms of interaction, the serious game was considered as easy to get used to. It was reported that it was easy to concentrate on the assigned tasks (i.e. collecting objects and navigating). Overall, participants did not find controlling of the movement of the diver very difficult. Most answers, regarding this question, fell

between the values of “not difficult at all” and “somewhat difficult”. Only 3 participants found the movement to be rather on the difficult side. This could be explained by the fact, that some of them do not play much games in their free time or not used in playing games in general.

One of the aims of the serious game was to educate players about underwater search and discovery techniques. This was done by the dialogues at the beginnings of each level. Not being sure about the suitability of the length of the dialogues, the players were asked to provide their opinion about this length. With most participants choosing values between 3 and 5, the expected result was met. This result justified the assumption, that the dialogues should be slightly shortened, or made more interactive, for example by giving the player an opportunity to choose his answer and making him this way paying more attention and increase his feeling of being involved in the story (Fig. 7).

Attribute	What do you think about the length of the dialogues? ²²	How much have you learned about underwater search and discovery techniques? ²³	How interested are you in learning more about underwater exploration techniques? ²⁴
Mean	4,133333	3,700000	2,300000
Std. Deviation	1,136642	1,178836	1,512021

Fig. 7. Results of the educational part of the serious game [22]

Another question checked whether these participants, who had free search as their final level, really used the mini-map more often than players, who had the other two versions of the level. Although the average values are not very different, it can be seen on Fig. 8, that participants with free search at the end indeed agreed on using the mini-map more often than the rest of the participants. Because the playing part of the game in the first two levels was mainly for fun and for getting the player used to the handling of the game, results of these levels are not going to be analyses in this chapter. The focus is going to be on the third level, which was different in the used techniques.

Furthermore there were observations on whether there were significant differences in success between players of each group. As shown in Fig. 9 the most successful was the group, which had the free search as the final level and the least successful were players with compass search at the end. To find out the significance of these result, the U-Test was performed. This showed that the difference between players, who tried circular search and player who tried the free search is not significant ($p = 0,2052$). Difference between players, who tried the circular search and player who tried compass search is significant ($p = 0,0067$). The difference between players with compass search at the end and players with free search at the end was also found to be significant ($p = 0,0055$).

Attribute	Circular search	Compass search	Free search
Mean	1,6000	1,2000	0,6000
Std. Deviation	1,3499	1,3166	0,8433

Fig. 8. Results of the mini-map usage [22]

	Circular search	Compass search	Free search
Mean of relevant objects found	7,9000	5,6000	8,4000
Std. Deviation of relevant objects found	1,1001	1.95551	1.8974

Fig. 9. Comparison of search and discovery techniques [22]

During the process of playing the game, the log data were collected. During one game, 4 text files were created. Three of them contained information about the movement of the players. One text file was created for each level. The last text file contained information about the collected amphora. As soon as the player picked up an amphora, a record about this was made. At the end of the game, a list of all collected amphora is created, where they were sorted according to the order, when they were picked up. At the end of the level, the remaining time (in seconds) and a total sum of the collected amphora in that level were recorded as well. To assess the different search and discovery techniques a third level of the game was specified.

Specifically, the number of amphora collected using each of the 3 different methods (circular, compass, free search). In case of circular, or compass search, the players were asked to follow the path on the floor, which served as a hint to preserve the pattern. Illustrative results from all the log data from all participants are illustrated in Fig. 6. Moreover, the log data of the game showed that there are significant differences between players who tried the circular search and compass search ($p = 0,0067$). The difference between players with compass search at the end and players with free search at the end is also significant ($p = 0,0055$).

5 Site Formation Process Storytelling Scenarios

Digital storytelling is considered to be the narrative entertainment that approaches the audience via media and digital technology [15]. There is a lot of literature that argues in favour of emergent narratives [2, 13, 21]. Another challenge for digital storytelling is to present the information on immersive VR where the audience can choose their view inside the virtual environment. This includes many challenges [18] and one of them is the Narrative Paradox challenge is specified as a struggle between a user's freedom of choice and the control of the main storyline [3]. Guidelines for introducing the motivation factor as a solution for narrative paradox has been recently presented [17] and followed in this research.

Fig. 10. Screenshots from the interactive story about site formation process

After assessing the most appropriate technique for search and discovery (i.e. the circular search), storytelling videos for the VR application were created. They consist of description of the site formation process, which as mentioned before are very important for underwater archaeologists as well as for educating the public. Examples of the storytelling videos are shown at Fig. 10. An interactive story was created using computer animation and voice of the narrator, according to the following scenario illustrated in the next sub-sections.

5.1 Sinkage and Impact

Once the ship starts to go down into the water column, the ship itself and the cargo will behave in different ways. These ways will depend on the previous processes (The Wrecking Event), and will end up with different disposition of the ship and cargo on the seafloor. The ship hits a rocky seafloor and brakes apart. Due to the inability to be covered by sand, the ship will remain exposed to eventual currents and wave actions and to the marine wood borers (teredo navalis) which will feast over the wood structure of the ship, slowly eating all the wood. The ship breaks into pieces and the cargo spills out of the hull following different routes to the seafloor ending up spread over a large area on the seafloor.

This creates a ‘discontinuous site’ or even a ‘scattered site’. The ship arrives on a sandy seafloor, bounces slightly up, and falls back hitting the seafloor again. It is possible that this process will break an unbroken hull, and the cargo will spill on one or both sides of the hull. It is also likely that the impacts will produce the breakage of previously intact amphora, particularly those on the top layers of the stacking pile. The ship sinks but the structure remains coherent. The cargo may move into the ship’s hull and the stowage position may slightly alter. This scenario will create a ‘continuous site’.

5.2 Wreck Site Formation Processes

Once the ship has reached the seafloor and has slightly settled, the shipwreck site starts to form. The processes of formation of a shipwreck site over time are various and they are affected by several factors and processes.

Natural Site Formation Processes or n-transforms are the environmental agents that cause the deterioration (or in few cases the preservation) of the site and/or the artefacts. Unlike in the case of cultural site formation processes, in natural ones the human factor plays no part. The primary environmental agents which cause n-transforms to underwater archaeological sites are the waves, bottom currents, the sediment, (micro)-organisms and the water itself (i.e. its chemical properties). The Seafloor type is the type of seafloor will influence the chances of preservation of the wooden structures. A rocky seafloor will prevent the preservation of wood, while a sandy seafloor will facilitate the preservation of wood, as the latter will be covered by the sandy sediment and safeguarded in an anoxic environment (low-oxygen environment).

The action of waves and currents can accelerate the process of deterioration of the ship’s hull and by oxygenating the water, speed up the decay of wood and the proliferation of wood borers (*teredo navalis*). Shallow water sites and those close to the shore are the ones most affected by wave actions; not only because of the wave strength, but also because the waves move sediment on the site, constantly exposing and reburying artefacts. Similarly, currents have an effect on the formation of a shipwreck site. Apart from surface currents that may displace floating artefacts at large distances from the wrecking site. Underwater currents move sediment around provoking not only the mechanical deterioration of the wood and fragile organic artefacts, but also by constantly exposing and reburying artefacts. Sand ripples are a testimony of the strength and direction of the currents patterns in the area.

The type of sediment and the bio-chemical composition of the sediment play a role in the preservation or decay of the artefacts (particularly organic materials). The buried, semi-buried or exposed artefacts bear evidence of the site formation processes. On a theoretical base, following the image below, exposed amphora will have traces of marine concretions. Conversely, the semi-buried will have traces only in the exposed portion, while the buried amphora, would not have any concretion. Obviously, on the basis of the effects of wave and currents on the

sediments that we have described above, this is not a static and/or unidirectional process, instead it often represents a dynamic process where exposure and burial alternate, leaving evident traces on the artefacts.

Chemical properties of the water Factors influencing survival and condition. The environmental conditions include: Dissolved Oxygen, pH, Temperature, Water Movement, Salinity, Sulphate Reducing Bacteria and Galvanic Coupling. High temperature usually nurture the growth of bacteria and wood borers, while cold waters, low oxygen or high salinity usually limit the growth of these organisms. That's why shipwrecks in the warm Mediterranean waters are more likely to be attached by *teredo navalis*, while for instance Baltic Sea shipwrecks are usually more well preserved. This is also one of the main reasons why ships sunk in the Black Sea have been preserved to the extent seen here.

The Cultural Transform are those processes that involve the intervention of human activity and are developed in the modern Cultural Transformation times, long after the wreckage of the ship. There exists an extensive literature regarding modern salvage activities. With this term archaeologists usually indicate the activities produced in Modern times, before underwater archaeology was established as a discipline. The examples are numerous.

The Nemi shipwrecks in the lake of Nemi (Central Italy) were for example made the subject to several salvage attempts by Leon Battista Alberti in 1446, by the military engineer Francesco De Marchi in 1535 and by Annesio Fusconi in 1827. It is clear how activities intervening long after the shipwreck and long after the wreck has reached an equilibrium with the surrounding environment will create hazards for the preservation of the archaeological remains. Not only these activities have disturbed the equilibrium of the site, they have also disturbed the "coherency" of the archaeological site. Objects may have been removed, while others moved to other positions in order to reach object laying below them and more interesting for the salvage purposes.

Similar to other actions and processes, the salvage operations (ancient or modern) act as both extracting mechanisms, but also scrambling devices, since they move artefacts in order to search underneath them. Trawling (trawl fishing) is a technique that has been criticized from both an environmental and cultural point of view. Trawls are huge nets being dragged by a trawler ship over the seafloor. Clearly the net dragging the seafloor, not only damages the ecosystem but also any eventual cultural heritage site (i.e. shipwreck) encountered on its path. Trawling can not only destroy piles of amphora on the seafloor, but also scatter them over large areas, even far away from their original location and position. This obviously jeopardizes the ability of understanding the site location, the processes of formation and in the last analysis, understand the site.

Another Cultural Formation process to take into account when assessing an underwater site is the possibility of the site being pillaged by divers. For a long time, and still present nowadays although some International measures have been put in place, a common stance among divers has been to believe that what is found underwater is free to anyone to take; what is often called the "Finders

Keepers” attitude. Many sites have been disturbed by divers pillaging artefacts or taking “souvenirs”. In terms of its impact, one of the most relevant Cultural Site Formation process is the activity of Treasure Hunters.

The activity is based on private people/companies investing money on enterprises for the discovery, location and recovery of shipwreck cargoes deemed to have high economic value. The investors put their money in this endeavors expecting profit from the selling of artefacts. Their activity is extremely impacting as they usually can employ the most advanced technologies, they do not care much on archaeologically excavating or recording the site, and they tend to use any convenient method to reach the valuable they are aiming at. Clearly this produces several bad outcomes: the disappearance of the archaeological information without proper recording and documentation, the selling of archaeological artefacts into the private market and therefore the complete disappearance of the site and artefacts from the archaeological record.

6 Virtual Reality Search and Discovery

The final version of the application contains single VR, where the user can perform search and discovery techniques using the circular search method (Fig. 11). Our goal was to create immersive, believable underwater environment with a light condition and sounds that resembles real diving experience. Therefore, the environment is filled with various static and moving objects, including flocks of fish, seaweed, stones, shipwreck and various small debris - e.g. wooden planks, air bottles, chests, etc. In total, the final environment covers an area of $500 \times 600 \times 50$ m where player can freely move. The environment is “populated” with approximately 200 moving objects and around 1000 static objects.

6.1 Scenario

When the player enters the main game underwater environment, the first task is to search the area and find scattered amphora and a shipwreck. When user finds the amphora, they should “tag” this finding. This could be done by pointing at amphora by straight pointer (using the touch-pad on right controller) and pressing the trigger button. The tag with a number appears on amphora. The task of finding and tagging amphora is connected to education videos regarding the site formation process. When user tags the amphora for the first time, a storytelling video is unlocked and starts playing on the panel above the left hand. The video can be replayed later on in the mother base scene. The task is successfully finished when user finds at least 10 amphora out of total 17. After fulfilling the task, it appears green on the task list screen in the base scene. Each amphora also unlock a video. Finding all amphora unlocks all videos in the base scene. Other objects, such as treasure chests or air bottles, are also scattered in the area. User can tag these objects, but this plays no role in finishing the task.

6.2 Controls and Interface

Basic control scheme is derived from a common practice of VR applications. Handheld controllers used by users to interact with virtual environment contains only several buttons. The developed application and activities contain a lot of different actions and possible interactions. Therefore, one button can have different meaning based on current environment and activity. In the base scene, the player can get familiarized with the controls. By touching the touch-pad on the left hand, curved pointer appears. When the user presses the touch-pad, can teleport to the point where the end of the curved pointer ends, but only if the target point is in a valid space.

Fig. 11. VR application

Figure 12 shows that the left hand is a user interface (UI) menu that can be used to start the VR simulation. The right hand is used for interaction. By pressing the touch-pad, a straight laser pointer appears. Using the laser pointer, the user can interact with the UI on the left hand or objects in the world (i.e. tagging found artefacts). The UI also allows to toggle the locomotion mode between teleportation and swimming. Users who are more likely to get motion sick should use teleportation for more comfortable experience. Swim mode is better for users experience with VR.

6.3 Scoring

To engage the player in further exploration of the environment and finish the game, they are motivated by specific task defined in the base scene. The “classic” high score system did not motivate players sufficiently, therefore the “completion” system was developed. The storytelling videos are locked at start and player needs to find all amphora first to unlock them. Each amphora unlocks one video. Although not all videos are needed to fulfil the task.

6.4 Desktop and Mobile VR

The VR application is supported by both desktop and mobile configurations. Instead of developing two separate versions of the environment, it was decided

Fig. 12. Interface of the VR application

to keep single version usable on both platforms. This approach saves a lot of time otherwise spent by developing separate versions, but also brings a new technological challenges. The mobile VR platforms dispose with much lower computation power compared to desktop computers. Therefore, a scope of the environment, a number of moving objects and a level of detail of individual objects have to be adjusted to avoid overloading of mobile VR platforms. During the development, we continuously tested the application on both desktop and mobile platforms and adjusted technical complexity of environment to ensure smooth user experience on both platforms.

7 Conclusions

The focus of this paper was two-fold. First to examine two of the most prominent search techniques for maritime archaeology. This was accomplished by implementing an underwater search and discovery serious game that would assess which of the search techniques is the most appropriate. Log data and questionnaires from 30 participants were used for the analysis. The game consists of 3 levels, with educational dialogues at the beginning of the first two levels. These dialogues serve to educate players about circular and compass search techniques. Results showed that the circular search is the most appropriate maritime method, which also is in line with the feedback from archaeologists.

In the second part of the paper, the most effective technique (the circular search) was ported into an immersive VR environment. Our goal was to create immersive, believable underwater environment with a light condition and sounds that resembles real diving experience. To increase the level of learning, digital

storytelling scenarios about the site formation process were used as a motivation for the players. This was used as a reward to the players instead of providing just a numeric score of discovered artefacts.

The main limitation of the paper is that the immersive VR environment was not formally evaluated. Obviously, the evaluation of such environment would be very different than the one performed in the serious game. In the future, we plan to perform a large scale evaluation of the immersive VR simulation and examine typical aspects of VR such as immersion, presence and motion sickness. Another aspect that will be assessed is the player satisfaction as well as the learning aspects of the site formation process.

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