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Blending WW2 history with the present in an interactive virtual heritage experience

Eike Falk Anderson and Thomas Cousins

Abstract: We have developed 'Exercise Smash', a virtual heritage experience which allows audiences to take part in a 1944 military exercise originally held in preparation of the D-Day landings in Normandy. Several participating amphibious tanks sank during the exercise, and our experience allows audiences to explore the present-day tank wrecks in a virtual dive to the seafloor.

The interpretation and presentation of archaeological artefacts frequently revolves around the two fundamental questions: 'what happened here?', and 'who did it happen to?'. Addressing these, we propose a mode of cultural heritage presentation using an interactive virtual environment, our 'Snapshot in History' time-travel paradigm for Virtual Heritage, which provides an innovative synthesis of tangible and intangible cultural heritage.

Audiences engage in a two-step interactive virtual experience which is ideally suited for the public presentation and dissemination of maritime archaeology, *e.g*. as an interactive museum exhibit. First, they experience the snapshot in history, taking part in the historical event which resulted in the submerged archaeology. The underlying story is conveyed through an interactive narrative, after which the audience are given the opportunity to explore the present-day archaeological site in an extension of the virtual dive trail concept.

'Exercise Smash' proves our concept, engaging audiences with this WW2 heritage. The audience first experience the story, then they are tasked with landing one of the swimming tanks on the beach without sinking it, and finally they explore the present-day wrecks within a detailed virtual environment populated with simulations of local marine life, which in the real world would be accessible only to divers.

Introduction

The public presentation of archaeology is a complex issue (Moshenka 2017) and of increasing importance, not the least because engagement with the public plays a major role in the dissemination of the results of research findings. With the rise of digital media over the past three decades, in recent years Virtual Heritage approaches—the use of interactive virtual environments for the presentation of cultural heritage—have become a popular medium for engaging the public.

The presentation of archaeology can involve different types of cultural heritage. Obvious among these is the 'tangible cultural heritage' which consist of archaeological finds and remains or their reconstructions; these tend to be (more or less) visible, and approaches to their presentation—after preservation—can be straightforwards, *e.g*. in museums. Requiring a much more complex approach for public presentation is the far less obvious and often invisible 'intangible cultural heritage' (UNESCO 2003), which encompasses oral traditions, performing arts, rituals and social practices but can also include personal stories such as memories of war (Jansen-Verbeke and George 2012) or memories by witnesses or survivors of a—potentially traumatic—historical event. Intangible cultural heritage frequently requires a means for interaction of the audience with dynamic objects in the virtual environment and sometimes also with virtual characters.

Our proposed approach towards the public presentation of archaeology aims to combine both tangible and intangible heritage to create a more holistic virtual heritage experience with the intention of improving audience engagement with the archaeology.

Related work

There exist many different types of Virtual Heritage applications for the presentation of cultural heritage, each providing their own sets of challenges. They are often concerned with the interactive visualisation of heritage sites which provide a means for exploration of digital reconstruction of lost or decayed objects and places, sometimes in museums (Deggim *et al*. 2017), requiring the provision of necessary infrastructure or hardware, or online (Firth *et al*. 2019), which can limit the extent of user interaction with the heritage artefacts. Sometimes

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these Virtual Heritage applications employ VR (virtual reality) to immerse users in the heritage sites (Duer *et al*. 2020), or they are enhanced with additional informative or educational content and more extensive user interaction. The latter can include serious games for cultural heritage (Anderson *et al*. 2010; Champion 2015). These can take the form of exploration games which take place in historical settings, such as 'Roma Nova' (Panzoli *et al*. 2010), or games set among the archaeological remains of historical settings, such as the virtual 'Priory Undercroft' game (Petridis *et al*. 2013).

The 3D reconstruction of archaeological or historical sites is often accompanied by the notion of time travel as a means to experience the past. This can take the shape of the virtual and interactive exploration of historical settlements as they existed in the past, such as the previously mentioned 'Roma Nova' (Panzoli *et al*. 2010) or 'Virtual Segeberg 1600' (Deggim *et al*. 2017). Sometimes they take the shape of a simulation which shows how an archaeological site or a historical building evolves and changes over time (El-Hakim *et al*. 2006, Laycock *et al*. 2008), although this type of visualisation is usually non-interactive, merely presenting the changes to a passive audience. One reason for this non-interactivity is the potential problem of role-playing 'time travel' in interactive scenarios, which could affect history in ways which could result in an alternative, counterfactual history (Champion 2015). The challenge which arises from this is to prevent the time-travelling user from making changes to the past without obviously restricting the user's interaction with the virtual world.

Public outreach in maritime archaeology

In recent years, the utilisation of interactive computer graphics, such as those employed by digital games, has become a frequently chosen approach for engaging the public with maritime archaeology (Beavis *et al*. 2021), utilising modern home computer technology to create new avenues for communicating archaeological finds to existing audiences and reaching out to new ones. There are now so-called 'Virtual Dive Trails' (James 2018), which allow for the exploration of submerged archaeology, such as protected wreck sites, either by members of the public who cannot dive, or in cases where sites are inaccessible to scuba divers. While originally in the form of labelled but static 3D models within an interactive viewer application, more recently such dive trails have also been implemented within fully interactive virtual environments (Bruno *et al*. 2017) or as VR experiences (Liarokapis *et al*. 2017), which can provide comprehensive virtual tours of maritime archaeology which can incorporate immersive diving experiences (Bruno *et al*. 2019) or which can be integrated with kiosk-style exhibits in museums (Sundén *et al*. 2017). Perez-Reverte *et al*. (2021) noted the development of virtual heritage experiences based on the 'virtual dive trail' concept can also be achieved by the use of 360 (panoramic) video, providing an alternative to employing a fully computer-generated virtual environment.

Lately, these fully computer-generated virtual dives have also included the simulation of marine life, including both marine fauna and flora, such as plants on the sea-bed or fish moving around the virtual environment. This can increase the perceived realism of the virtual environments (Stone *et al*. 2009; Kouřil 2017; Liarokapis *et al*. 2017), as was demonstrated by Costa *et al*. (2020) in an immersive VR virtual dive experience which allowed users to explore the wrecks of transport ships which had carried Sicilian marble blocks. In support of the creation of such immersive VR virtual dive tours, Plecher *et al*. (2022) explored the user interaction elements which are required to convey a diving experience in VR which is perceived as realistic, resulting in a modular conceptual framework which simplifies the adaptation of the VR diving experience to different maritime archaeology sites, speeding up the creation of virtual dive trails in VR. VR has been shown to be suitable not just for the public presentation of maritime archaeology, but also for the presentation of maritime history. An example of the latter is the VR simulation of the restored four-masted barque 'Peking' (Kersten *et al*. 2020).

One approach to engaging the public which has been popular in recent years is the development of so-called 'serious games' for promoting underwater cultural heritage. Serious games are computer games which not only provide entertainment but have a secondary purpose (Zyda 2005) such as education or public information. Cozza *et al*. (2021) explain the design and development of a serious game, 'Dive in the Past', for promoting underwater cultural heritage in the Mediterranean Sea. 'Dive in the Past' allows users to dive virtually to and then virtually explore underwater archaeological sites. Cozza *et al*. (2021) provide a detailed rationale for the design decisions they made during the development of their game.

Yamafune *et al*. (2017) detail the process of recording and processing underwater archaeology for use in virtual heritage experiences for public outreach, and they describe a methodology for recording and reconstructing maritime archaeological sites. Similarly, Tousant and Fai (2019) developed a detailed workflow for digitally recording (scanning) underwater archaeology and preparing the resulting 3D information for deployment in interactive virtual environments. Such digital recording and processing of underwater archaeology provides the basis for creating VR diving experiences, for which the integration of such processed maritime archaeology into interactive, immersive virtual environments has been comprehensively explained and demonstrated by Plecher *et al*. (2022).

The enhancement of virtual heritage experiences with a narrative, conveyed through interactive digital storytelling and facilitated by the integration of live-action recordings of real actors who provide information about the depicted heritage to users of VR heritage experiences, was explored by Škola *et al*. (2020). These authors created

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a virtual dive trail of a submerged Roman villa which allows users to visit a scenario in the past, during which they can tour the reconstructed villa at a time when it was above the surface and inhabited, where they can then interact with its inhabitants. The effectiveness of the user experience created by this approach in terms of user 'engagement', 'presence' and 'immersion', all of which feed into the perception of realism, was verified not only by employing a user questionnaire but also by recording neurophysiological brain activity as an objective measure. Related to the notion of perceived realism and immersion, it should be noted any type of virtual heritage experience depicting submerged archaeology must try to overcome the various issues identified by McAllister (2021), particularly in regards to the perceived realism of scanned 3D objects placed in an underwater virtual environment. To address issues of realism, McAllister provides a comprehensive set of guidelines for planning and executing photogrammetric surveys, the subsequent processing and evaluation of the resulting 3D data and the final dissemination of results.

A snapshot in history

One difference between many land-based archaeological finds and those discovered through maritime archaeology is that in the latter, the remains are often the result of a single identifiable event in history (*e.g.* such as a ship sinking in a storm). In some cases, there are official reports or recorded eyewitness accounts of the event, and in other cases—for example, among coastal communities—there are stories about these incidents which have been passed down through the generations, being memorialised and becoming intangible heritage (Kempe 2006).

Such instances of intangible cultural heritage which have resulted in tangible cultural heritage are not usually shown in virtual reconstructions of archaeological or culturally relevant sites. These omissions occur despite the potential for a virtual reconstruction within interactive virtual environments to provide the necessary infrastructure to create a view of a snapshot in time of an archaeological site which would allow audiences to experience the event creating the archaeological site, as well as the archaeological remains as they exist today.

One attempt at providing such a link between the past and the present is the 'HMS *Falmouth* dive trail' (Firth *et al*. 2019), which superimposes an annotated photogrammetric scan of the original shipbuilder's model over a recent and annotated 3D survey of the wreck on the seabed, allowing a direct comparison of the wreck site with how the ship would have looked when it was new. We propose to take this link between the past and present much further by splitting the presentation of the archaeological finds into two distinct parts. First, we emphasise the notion of time travel, which allows audiences to experience a snapshot in history depicting the specific event creating the archaeological remains being presented to the public, while simultaneously allowing the public to take part in history interactively without changing it. Second, we allow the audience to explore the archaeological site—which has been fully annotated with information derived from the archaeological investigation—as it exists today.

Our proposed approach is not limited to maritime archaeology but could also be used to depict archaeological sites which are the result of a single cataclysmic event (*e.g*. a battle or a natural catastrophe such as the eruption of Vesuvius which destroyed the Roman towns Pompeii and Herculaneum; Cooley and Cooley 2013).

Using this paradigm for the public presentation of archaeology and the results of archaeological evaluation, we have created 'Exercise Smash' as a proof of concept, providing audiences with an engaging virtual experience which allows the interactive exploration of the archaeological remains of the 1944 'Exercise Smash I' military training exercise by diving to the wrecks of the amphibious tanks. Our virtual heritage experience also presents the archaeological artefacts in their historical context in form of a serious game which allows the audience to take part in the military training exercise (Figure 18.1), using a screen-based virtual environment to immerse the 'visitors' to the past within the event in a similar manner to the immersive VR exhibit by Duer *et al*. (2020), who demonstrated that simple presence within a virtual representation of the past can facilitate the illusion of 'walking in the footsteps of others'.

Historical background

Lessons learnt from other amphibious operations such as Gallipoli in World War One and Dieppe in 1942 highlighted the need for armoured support when assaulting fortified positions. The allied solution was to establish the 79th Armoured Divisions, who developed a series of specialised fighting and support vehicles now commonly known as 'Hobart's funnies'. One of these vehicles was the Duplex Drive or DD Tank.

Originally Valentine, but later Sherman tanks were fitted with a watertight canvas skirt which displaced enough water to allow the vehicle to float. The drive of the tank was also modified so it could power a propeller at the stern of the vehicle, allowing them to sail under their own steam. The tanks could then be launched at sea to land on the beaches without risk to the landing craft, where the skirt would be dropped and the vehicle would operate as any other land tank of its class (Fletcher and Bryan 2006).

A series of live-fire rehearsals were held by allied forces in preparation for the D-Day landings in Normandy. One of these, 'Smash I', took place on 4 April 1944 in Studland Bay, Dorset (South West England, UK), where it was observed by VIPs from a specially built bunker—National Heritage List entry 1411809 (Historic England 2012). Although the beach and hinterland were not ideal in terms of geography, the site was relatively isolated for the South

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Figure 18.1. Top: landing craft approaching Studland Bay during the Exercise Smash virtual experience; bottom: Swimming Valentine DD tanks trying to reach the beach. Image created by the Exercise Smash Development Team.

Coast of England, and it was therefore chosen to practise a full-scale multi-service beach assault.

The exercise plan was for the initial assault to be led by two squadrons of 4th/7th Dragoon Guards in their Valentine DD tanks. These were to launch 5,000 yards out from the beach, landing five minutes before the infantry. However, for reasons unknown, the tanks seem to have been launched in the wrong place and in unsuitable conditions, leading to the loss of six tanks and the deaths of six members of the crew. A seventh tank was also wrecked within Poole Bay; it was long thought to have been scuttled after the exercise, having run aground and drifted off at the next tide (Cousins *et al*. 2020), but new research is shedding doubt on this. In 1944, to avoid drawing attention to what was then a secret weapon, no efforts were made to recover the sunk tanks, and they remain on the seabed today.

In the post-war years, with the advent of scuba diving, the tanks soon became a popular and interesting dive site, and the majority of the non-ferrous metals and loose artefacts were salvaged by sports divers. The latter often included HE (High Explosive) ammunition, which were regularly left on Poole Quay. As a result, the MoD (Ministry of Defence) made the decision to render the wrecks 'safe' by blowing up the submerged tanks in 1987 (Philpott 2015). Two tanks were missed in this endeavour, but one was hit by a trawler in the 1980s, and the other was vandalised by unknown agents in 2022, leaving no complete tanks on the seabed today.

Poole's D-Day heritage–maritime archaeology

Without accurate navigation systems, the actual positions of most of the tanks were lost over time. In 2014, Bournemouth University's Maritime Archaeology department began a student project to locate and survey the remains of these vessels (Manousos 2014).

The first step for this project was to gather all of the reported positions for each tank (40 in total; BU Maritime Archaeology 2014) and input these into a geographic information system (GIS) for correlation with an accurate map of the seabed by the UKHO (UK Hydrology Office). This would enable an assessment of the known obstructions in the area, with the goal of reducing the number of potential targets.

Once a list of targets was produced, divers were sent down to survey the seabed and locate the obstructions, and for any found to be tanks, new confirmed positions were marked along with a basic record of the remains (MAST 2014).

The project resulted in the rediscovery of all of the tank wrecks (Cousins *et al*. 2020), and in 2018, during routine monitoring of the various wreck sites in Poole Bay, it was decided to create rapid photogrammetric models of the sites to act as a baseline for future surveys. As the sunk Duplex Drive tanks are among these heritage assets, Bournemouth University maritime archaeologists also returned to the tank wrecks and created photogrammetric models of the tanks (http://bumaritime.org/projects/duplex-drive-tanks/archaeology-of-dd-tanks/; also see Figure 18.2).

On 31 May 2019, Historic England—England's agency for the management and protection of historic sites, buildings and monuments—placed the sunk 'Valentine Tank Assemblage' (*i.e*. the remains of the Valentine tanks) on the National Heritage List for England as a scheduled monument (Historic England 2019), granting them protection by the state. Unfortunately, though, since the initial surveys in 2018, significant damage occurred to 'Tank 7' in 2019 and 'Tank 1' in 2022. This means the photogrammetric surveys from 2018 are now the most complete record of the sites which exist. As McAllister (2021) notes, an accurate photogrammetric record of an archaeological site can provide a valuable backup in cases where the original site has changed or been destroyed.

Exercise Smash virtual experience

We wanted to make these data available to audiences in a manner which improves on the traditional 'virtual dive trail' by employing our 'Snapshot in History' paradigm. Accordingly, in 2019, we initiated a student project (Anderson and Sloan 2020) to create the virtual heritage experience 'Exercise Smash'. This is organised as two scenarios presented to the audience/players. Implemented using the game engine Unreal Engine 4 (https://www.unrealengine.com), in the first scenario, the virtual heritage experience places audiences at the centre of the action of Exercise Smash I, challenging 'players' to launch a Valentine DD tank from a landing craft into Studland Bay and then 'swim' the tank to the beach, literally stepping into the shoes of the participants of the training exercise. In the second scenario, an immersive 3D virtual dive trail, audiences dive to the tank wrecks, where they can then explore the archaeological remains on the seabed. This is intangible-heritage-in-place (Kaufman 2013), which links places to intangible heritage such as memories of an event or oral histories. In the case of our virtual heritage experience, these are Studland Bay with the sites of the tank wrecks (place) and the story of the events of Exercise Smash (intangible heritage).

First scenario–a snapshot of 1944

As stated above, in the first scenario, 'players' taking part in the virtual experience find themselves in control of a Valentine DD tank on a landing craft in Studland Bay off Studland Beach, taking on the role of a soldier participating in Exercise Smash I. Their tasks are to launch the tank off the landing craft without damaging the canvas which keeps the tank afloat (DD tanks risked tearing their canvas if they hit the sides of the landing craft during launch) and then steer the tank towards the beach without it being swamped by waves and sinking (Figure 18.1).

Figure 18.2. Underwater Photogrammetry of the complete (before the damage that occurred during 2022) 'Tank 1' (Valentine MK-IX DD) at the bottom of Studland Bay (3D model of 3.3 million vertices in 6.6 million triangles). Without a fixed survey grid on the tanks, the 'rapid fire technique' developed by Daniel Pascoe (Pascoe Archaeology Services) and Bournemouth University was used, employing a goPro6 camera with a 105 degree fisheye lens. Four one-meter scale bars were placed around the site, and then with the goPro's time-lapse function, photos were automatically taken every second, with the diver slowly swimming over the site. The resulting photos were colour corrected using Adobe Photoshop and loaded into Agisoft Metashape where the images were further processed to mask out any undesirable features, such as the water column and fish, and to calibrate the lens to compensate for the wide angle which can cause issues with alignment. After processing and filtering with Metashape, the original photos were then used to create the texture-map. Finally, the model was scaled using the bars placed around the site during image acquisition before it was exported as a 3D object. Image created by the Exercise Smash Development Team.

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Success or failure are not pre-determined, and depend on the interaction between the swimming tank, which a player controls, and the simulated waves of Studland Bay. Around the players, other tanks are being launched from landing craft and trying to make their way to the beach, with some of them sinking within the players' view; above them, fighter planes fly past, providing air cover for the exercise. The players see what the participants of Exercise Smash I would have seen; they experience what many participants of Exercise Smash I would have experienced, and, immersed in the scenario through this virtually shared experience, they gain an awareness of what happened back then and who this happened to.

To reconstruct the exercise as faithfully as possible, the construction of the scenario was guided by accounts of eyewitnesses to and participants of Exercise Smash, including oral histories, some of which have been previously reported (Cousins *et al*. 2020). The Valentine tank was modelled after reference drawings, blueprints and period photographs (Fletcher and Bryan 2006), as well as recent photographs of the only surviving Valentine DD in working condition (Figure 18.3), from which engine sounds were also recorded. The integration of the engine noise of a real Valentine DD tank facilitates a more authentic experience, one that is not just limited to 'sight' but which also includes 'sound' for greater immersion in the virtual scenario. Information about the landing craft involved in Exercise Smash—especially the tank transports—was taken from contemporary official documentation (ONI 1944).

For the creation of the interactive virtual environment, Studland Bay itself was modelled after maps, nautical charts and from visual references. The sea was added in-engine by applying an ocean shader which implements 'Gerstner Waves' (Williams 2017), allowing fine control over the roughness of the waves. For the interaction of the swimming tanks with the sea—*e.g*. splashes, as well as water breaching a tank's canvas and flooding the tank—a position-based fluid simulation (Macklin and Müller 2013) was used to pre-calculate cached animation sequences which are interpreted in-engine as geometry caches. These are instantiated in the scene, relative to the user-controlled tank, by triggers placed around the perimeter of the tank's canvas which detect collision with the ocean.

Second scenario–a virtual dive to the Valentine DD wrecks

In the second part of the virtual experience, users take a dive boat out into Studland Bay to dive to the tank wrecks, which they can then investigate (Figure 18.4). The navigation of the virtual underwater environment is not restricted, and players can freely explore it at their own pace. The wrecks are annotated with information about the archaeological remains, as well as historical facts about the use of DD tanks; this information is displayed to the user when an object in the virtual environment is selected. For this, the photogrammetric scans of the tank wrecks made in 2018 (Figure 18.2), as were mentioned in the section on 'Poole's D-Day heritage' above, were integrated into the virtual environment.

The photogrammetric scans of the tank models were of an extremely high resolution, so in order to integrate the archaeology into the virtual heritage experience, the 3D scans needed to be reduced to a more manageable topology for use in the virtual environment. To preserve visual fidelity, detail from the high-resolution tank models was baked into normal maps for in-engine use with these lower-resolution tank models. Distance field blending was used to create a smooth and unnoticeable transition between the scanned seafloor area around the tank wrecks

Figure 18.3. Top left: the last complete and working Valentine DD tank on Studland Beach in April 2019; top right: Valentine tank model (without canvas skirt); bottom right: Valentine DD model with deployed and fully raised canvas skirt. Image created by the Exercise Smash Development Team.

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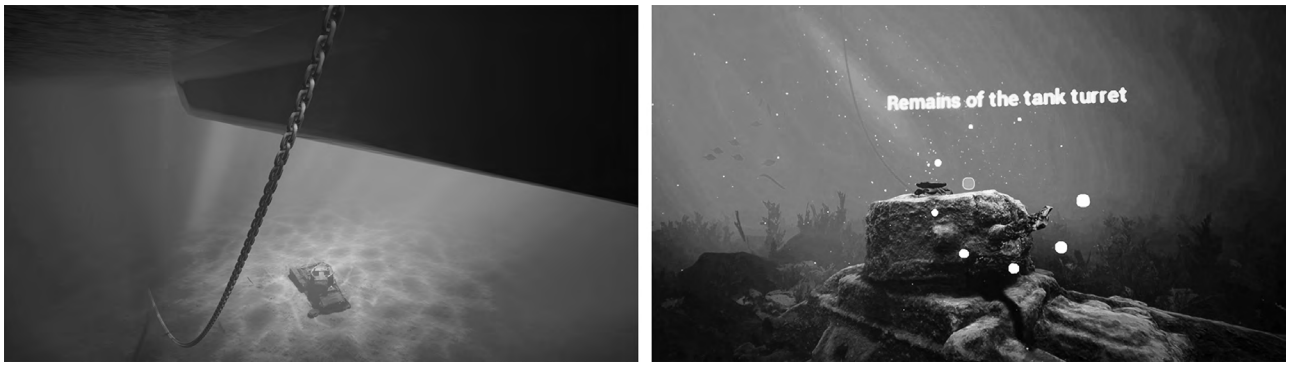

Figure 18.4. Left: view from the diving boat with the tank at on the sea floor below; right: investigating the wreck on the sea floor. Image created by the Exercise Smash Development Team.

and the remainder of the virtual seabed, where rocks and seaweed were placed to add realism to the environment using a simple procedural method based on pseudo-random number generation.

As the sea around the sunk tanks is rich in marine life and many of the species found in the neighbouring Poole Rocks Marine Conservation Zone (DEFRA 2019) are found around the tank wrecks, many of the marine species which inhabit the area around the tank wrecks were identified and modelled to provide a realistic impression of the virtual dive trail to players (Poole Rocks 2017). This made them a major feature of the underwater environment in the dive-trail scenario of our virtual heritage experience (Figure 18.5). To implement schools of these fish, similar to Liarokapis *et al*. (2017), we employed a Boids-style flocking algorithm (Reynolds 1987), with which we extended the Unreal Engine. Within the flocking system, fish models are animated as a looped swim-cycle using a motion path with a spine rig, with the fish models deforming by following this curve.

Discussion

While the project exists as a fully working prototype, it should be considered work in progress, as there are still a number of open questions and unresolved issues. The 'Exercise Smash' proof of concept was built without a specific means of deployment in mind, and with different possibilities kept open for future consideration, which use of the Unreal Engine 4 allows. This could be as a standalone computer game or even a VR experience—possibly set up as a kiosk-style system in a museum (Bruno *et al*. 2017, Deggim *et al*. 2017)—and deployment through a website, either as an online museum or as a virtual dive trail, is a distinct possibility. The virtual experience—especially the second part concerned with the virtual dive to the tank wrecks—was designed and built to present audiences with a rich and detailed virtual environment. This tends to require a fairly large display area, so typical screen size alone—not even taking into account the required GPU capabilities—would most likely be unsuitable for deployment of Exercise Smash as a mobile app for smartphones and tablet computers. The best mode of deployment may be determined by a future user study. Finally, since the development of our initial prototype, the more capable Unreal Engine 5 has been released, and porting the project to the newer engine might result in greater visual fidelity.

One benefit of choosing Exercise Smash as the content for our proof-of-concept prototype was the wealth of

Figure 18.5. Left: some of the distinctive marine animals that populate the sea around the tank wrecks: a) Black seabream (one of the most important species in the region), b) pouting fish / bib (found shoaling in large groups in the area), c) cuckoo wrasse, d) Dover sole, e) Baillon's wrasse, f) brown crab; right: several schools of fish, populating the virtual dive environment. Image created by the Exercise Smash Development Team.

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information and documentation available on Valentine DD tanks, as technical drawings, photographs and moving images of Valentine DD tanks are available. Various military museums house intact Valentine tanks, and there even exists a Valentine DD tank in working condition (Figure 18.3), and some of the developers were able to take reference photographs of it, so there were no issues of reconstruction uncertainty when the submerged wrecks were reconstructed for the first part of the experience, presenting the snapshot in history. This circumstance was a luxury, when compared to many archaeological surveys such as marine excavations of unknown vessels which are hundreds of years old.

The choice of scenario was also fortuitous, as the subsequent damage to the wrecks in 2019/2020 and 2022 resulted in the photogrammetric surveys which were used as the basis for our virtual heritage experience. These provide the most complete archaeological record of the site, and they also now provide the only means for the public to experience the site in its original state—albeit virtually.

We presented the prototype of the 'Exercise Smash' virtual heritage experience at 'Tankfest 2019', a three-day event held at the Tank Museum (https://www.tankmuseum.org) in Bovington (Dorset, UK), where it was demonstrated to a large audience of museum visitors. The prototype generated a lot of interest among these visitors, especially the children, who were particularly fascinated by the first scenario (landing the tank on the beach). The positive reception the prototype received, along with the evident enjoyment of the people who engaged the virtual experience, was encouraging and inspiring for the development team. A further opportunity to demonstrate our prototype virtual heritage experience was the CAA-UK symposium (Anderson and Cousins 2019), where our prototype was experienced by other archaeologists.

The public demonstration was very useful, as—apart from the bugs which were discovered by the audience—it highlighted a number of issues for future consideration. For example, we quickly noticed the playtime was far too long for use in a public installation, as several children who were determined to drive the tank to the beach and `win the game' had to be convinced by their parents to leave before their tank reached the beach. The younger audience were particularly helpful in discovering bugs and game-play issues which should be addressed before the virtual heritage experience is finalised, such as player actions which had not been anticipated during development. For example, a bug which occurred when players tried to turn a tank on the landing craft before it had cast off the landing ramp was discovered by multiple children who tried out the prototype.

To provide an immersive experience of time travel, we believe, it is important to avoid mechanisms which obviously restrict the user's actions. This meant predetermined events had to be reduced to a minimum or their nature hidden. To achieve this in Exercise Smash, the determination of whether a user-controlled tank sinks or reaches the beach depends solely on the simulation of the sea in its interplay with the user's steering actions. By not specifying which historical tank is being controlled (*i.e*. a tank which sank or a tank which succeeded in reaching the beach), the problem of possibly altering history, as mentioned above, is avoided.

Conclusions and future work

We have proposed what we believe to be a novel mode of cultural heritage presentation using an interactive virtual environment which creates a strong synthesis of tangible and intangible cultural heritage, combining stories about and memories of a historical event with archaeological finds which are directly linked to the event. To prove the concept, we created 'Exercise Smash', providing audiences with the experience of taking part in the virtual recreation of the historical Exercise Smash I, a Second World War landing exercise with amphibious tanks, several of which sank during the exercise. The experience of actively participating in the (virtual) exercise keeps the memories of the event 'alive' by immersing audiences in it; they do not just passively witness it, but literally 'live' through it, thus virtually sharing the experiences of the soldiers who were there. The site of the present-day archaeological remains resulting from this event can then be virtually visited and explored during a virtual dive. As these archaeological remains have been damaged since the 3D data we used were recorded, the significance of our virtual heritage experience has increased, as it is based on data which provide the most complete record of the site.

Our approach extends beyond existing 'time travel' paradigms and has the potential to immerse audiences not only in history but in the resulting archaeology itself, creating a much richer virtual heritage experience. This type of 'Snapshot in History' makes use of and combines existing Virtual Heritage approaches in a similar manner to Duer *et al*. (2020), facilitating the experience of intangible-heritage-in-place (Kaufman 2013). Audiences are immersed in the past to convey the intangible heritage of a historical event, and in the present, they virtually explore a fully interactive related location, such as an archaeological site. We believe this approach can create new avenues for the public presentation, as well as dissemination of archaeology, and should be particularly suitable for maritime archaeology. Through this, we believe our 'Snapshot in History' paradigm can provide opportunities for advancing the field of maritime archaeology by explicitly linking the tangible heritage of the archaeological finds with intangible heritage of the history which created them. By experiencing the intangible heritage first hand—literally 'living' it—and actively engaging with the historical event, public audiences are given the opportunity to gain a better understanding of the history and the resulting archaeology, which, by extension, should lead to a better understanding of human life.

Future work on the 'Exercise Smash' project will, in its first step, consist of improvements to the virtual heritage

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experience by fixing the bugs and addressing the gameplay issues identified during the presentation of our prototype at 'Tankfest 2019'. For instance, during the public presentation of the virtual heritage experience, we noticed some interesting user behaviours when players engaged in the diving scenario, which suggested some form of disorientation, possibly due to the accurately simulated low-visibility underwater and a lack of kinaesthesia in terms of the viewer's position and orientation in the virtual environment. This warrants further investigation, as it has implications for scenarios dealing with virtual maritime archaeology, and might require a reduction of the simulated realism, sacrificing visual fidelity for the sake of 'playability' of the scenario. After this first step has been completed, we plan to conduct a set of focussed user studies to help decide the best possible form of deployment of our virtual heritage experience for public engagement, and to determine the efficacy of our 'Snapshot in History' approach on the public presentation of archaeology.

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19

Blue Growth meets Maritime and Underwater Cultural Heritage (MCH / UCH): overview of the situation of preventive archaeology in France

Nicolas Bigourdan

Abstract: This chapter presents an overview of how France has managed the protection of Maritime and Underwater Cultural Heritage (MCH / UCH) over the last three decades, in relation to the Marine Spatial Planning (MSP) and Blue Growth programmes, through developments in the field of maritime preventive archaeology.

In 2001, the National Assembly adopted a legal framework which defined the application of preventive archaeology on land and under water throughout the French territories. Initial cases were few, isolated and relatively unstructured; but some 10 years later, complex processes had been set in place, and the first official preventive maritime archaeology operation had been launched.

The implementation of MCH and UCH protection in a MSP and Blue Growth context has benefited from the contributions of operational teams, fieldwork means, procedures, technological advances and experience. Effective support of the mission of MCH and UCH protection in a MSP and Blue Growth context is a central objective of the programme in France, but increasing the cooperation, organisation, consideration and interaction among stakeholders is also crucial.

Introduction

The European Union (EU) defines Marine Spatial Planning (MSP) as *'*a public process of analysing and allocating the spatial and temporal distribution of human activities in marine areas to achieve ecological, economic, and social objectives which are usually specified through a political process*'* (Ehler and Douvere 2007: 13). This definition has created the framework within which Maritime Cultural Heritage (MCH) has developed its relationship with MSP. In this context, this chapter provides an overview of the path taken nationally by France over the last 30 years to develop the link between MSP and MCH through its preventive archaeology system and capabilities (within the maritime environment), which is also known as rescue archaeology or development-led archaeology.

The origin and definition of 'Blue Growth'

The term *'*Blue Growth*'* has never had an agreed-upon definition, despite its extensive use, because it has gathered a large and diverse set of meanings and approaches which vary according to context (Eikeset *et al.* 2018: 177). However, the origin of the concept is related to the idea of sustainable development which emerged internationally in the 1960s (Eikeset *et al.* 2018: 177). Following a series of major international conferences centred around this idea since the 1970s, in 2012 after the development of the concept of Green Growth, a similar term focussing on the ocean (Blue Growth) emerged. This term (which was derived from the larger concept of Blue Economy, an umbrella term for economic activities involving ocean resources) was initially used in Europe as part of the Europe 2020 strategy. The Blue Growth initiative began in 2014 when a directive from the European Parliament and the Council of the European Union established a framework which emphasized the importance of marine areas for innovation and growth in specific sectors and increased the focus on MSP and coastal protection (Legat *et al.* 2015: 13).

General context and limitation

In order to contextualise the activities under consideration, the European Commission identifies five main maritime sectors within the realm of Blue Economy or Blue Growth. These five sectors are renewable energy, mineral resources, aquaculture, tourism and biotechnology.

Unfortunately, from a heritage perspective, these large categories, as defined, make very little-to-no direct reference to the role and contribution of MCH to European Blue Growth (Firth 2015: 10). Indeed, in associating heritage with tourism, the European Commission has not positioned it with sufficient strategic importance. However, the diversity, nature and level of relationship between marine industries and MCH long predates the Blue Growth concept, and accordingly, it has been the subject of multiple mitigation strategies in many EU countries. This includes France, which has created a dense and centralised network with multiple diverse layers of stakeholders. Further, these

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