Interactive Virtual Archaeology

Constructing the prehistoric past at Avebury henge

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Abstract— **Avebury Henge is situated approximately 20 miles north of Stonehenge in Wiltshire, U.K. and contains the largest known Neolithic stone circle in Europe. It is part of the Avebury, Stonehenge and Associated Sites World Heritage Site but is less well-known than Stonehenge, despite being an impressive monument with a ditch and bank system more than 400m in diameter. In the past 20 years or so many computer-based simulations of archaeological sites around the world have been created, but many of these digital reconstructions lack both the ability to enable personal presence of the user in the virtual landscape itself, and the facility for users to interact with others and the virtual environment around them in real time. The project described in this paper aims to research the issues of presence and interaction in virtually reconstructed ancient landscapes through a reconstruction of Avebury Henge in a virtual world environment, as it might have been circa 2,300 BCE. This paper describes and evaluates the construction phase of the project in a virtual world environment.**

Keywords — interaction, virtual environments, history, heritage, virtual archaeology, Avebury

I. INTRODUCTION

This paper discusses work in progress to construct a simulation of a Late Neolithic/Bronze Age (circa 2,800 – 2,000 BCE) monument in SW Britain in a virtual world environment. The overall aim of the project is to investigate the affordances of virtual simulations of ancient sites as a means to enhance the engagement of young people with history and heritage. In particular, the interactive qualities of virtual environments, where users can interact with the environment itself and with others, are the specific focus. There are two elements planned for this project: firstly the construction of the simulation, taking account of the evidence upon which it is based, how that evidence has been interpreted in a virtual environment and the benefits and challenges posed by the virtual construction. This element is the subject of this paper. Secondly, the completed construction will form part of the undergraduate curriculum in history and heritage studies at the University of the West of England in the Spring of the 2016/17 academic year, when students will undertake social and construction activities in the simulation and will also take part in an evaluation study. As this paper is concerned with the construction and reflection element of the project, it begins with a brief discussion of interactive technologies in archaeology, a description of present day Avebury, and the archaeological evidence for the virtual reconstruction. The paper then moves onto the main discussion of the approach used to construct the landscape and soundscape in an interactive environment and the reflection of the author on constructing virtual Avebury.

II. VIRTUAL ARCHAEOLOGY

The term 'virtual archaeology' was first coined by Reilly [1] and originally referred to the promise of information technologies in creating 3D computer models of buildings and artifacts. The notion of 'cyber-archaeology' was subsequently discussed by Jones [2] as a means to encourage a wider use of technology to facilitate interaction through the formation of virtual communities and virtual settlements, and thereby to enhance our understanding of the social aspects of archaeological sites and landscapes. Since then, both information technology and its use in the study of archaeology have developed considerably to include the use of virtual reality (VR) techniques [3] [4], reconstructed 3D virtual world environments [5] and augmented reality [6]. In the past 20 years or so many computer-based simulations of archaeological sites around the world have been created, such as Catalhoyuk in Turkey [7] and Stonehenge in the U.K. [8]. The recent Seeing Beneath Stonehenge project [9] uses the Google Under-the-Earth app for Google Maps and a wide variety of photographic and digital resources to create an online virtual landscape that can be explored by the user, including views that are not possible in the physical environment such as overlays of geophysics data and pictures of excavations in situ.

These detailed and evocative reconstructions demonstrate ways in which computer technologies can enhance our understanding of how ancient sites might have been constructed, and how they might have been used at various points in their history. However, whilst these digital reconstructions can be impressive and highly informative, they lack the ability to enable personal presence of public users in the virtual landscape itself, and the ability for those users to interact with others and the virtual environment around them in real time. Virtual worlds and similar virtual reality platforms are environments where participants can meet others and communicate, collaborate and participate in activities together. They are also spaces where the environment can be a place of experimentation in ways which are not possible in the physical world. There is evidence that social participation in

constructions of past environments in virtual worlds can help us to understand the physical world of the present [28]. UK Government statistics [29] show that the levels of engagement with heritage sites in the 16-24 age group are more than ten percentage points lower than for other adult age groups under the age of 75, and research into the reasons for this dip in engagement [30] suggests that online offerings of heritage sites are not sufficiently collaborative, participatory or communicative to attract this age group. This project is therefore investigating the affordances of virtual worlds in encouraging engagement with heritage sites by young people by offering a collaborative, social environment in which to experiment, communicate and participate with others.

Virtual reconstructions are essentially forms of reconstructed space, which draw upon aspects of the physical space of the present and the imagined space of the past. They can illuminate what is now imperceptible, contextualise what is now isolated and incongruous and can give us a means of connecting with people and cultures from which we are separated by thousands of years. As Pietroni [10] states, the aim of virtual reconstructions of ancient sites is to "…multiply the communicative potentialities of cultural heritage, re-activating … relations in space, time and meaning". In his work on modern urban spaces, Soja [11] argued that ideas about space have tended to concentrate upon a binary opposition of what he termed 'first space' and 'second space'. First space is understood to mean space as a material environment, i.e. the space we experience physically in the present. Second space refers to the feelings that humans experience during their interaction with first space and also how we conceptualise and conceive space psychologically, including how we might imagine landscapes that existed in the past. Soja argued that this binary opposition was overly reductionist and in response he created the notion of 'third space', where aspects of the real and the imagined are combined to create a richer understanding of the meaning ascribed to spaces and landscapes. So although Soja's work was primarily focussed on the study of modern urban landscapes, there is a strong resonance between the notion of combining real and imagined aspects of space, and spaces constructed in virtual interactive environments.

Online virtual world technologies such as Second Life™ and OpenSim™ and gaming technologies such as World of Warcraft™ and Unreal Tournament™, all of which enable participation of users in virtual environments through the agency of an avatar, provide online environments which have been recognised as effective third spaces in sociological research [12]. Ward & Sonneborn [13] introduce the construct of "individualized collaboration" in these environments, where "…Unlike face to face group activities in real world settings, in which the ambient conditions are largely the same for all participants, virtual worlds have properties that make it possible, in principle, for individuals to personalize their experience even while interacting with others in collaborative groups."

Virtual worlds have also begun to ignite interest as technologies that might provide enhanced opportunities to produce archaeological third spaces; i.e., spaces where the social aspects of spatial and landscape representations can be experienced, as well as the physical and conceptual aspects. For example, in their review paper, Sequeira & Morgado [14] identified four different approaches to virtual archaeology and virtual heritage that utilise virtual world platforms, viz:

- virtual world cyber archaeology, where the environments, landscapes and communities created within the virtual world take on their own value over time and become 'historical' sites that are imbued with their own cultural significance [15],

- reconstructive virtual archaeology, where physical world heritage sites are simulated within the virtual world to inform both the builders about the construction of these sites and the users about their physical configuration,

- virtual museums, in which replicas of artefacts and/or visual images of real world artefacts are displayed and visitors can view them and interact with curators and other visitors in the museum space, and

- interactive virtual archaeology where users interact with the environment and each other. Sequeira & Morgado characterise this approach as using a virtual world as an archaeological "…laboratory, where hypotheses can be put to the test and visually confirmed by having avatars interacting with the reconstructed space."

This project is intended to develop the fourth approach of interactive virtual, focusing upon the potential affordances of the socialisation facilities of online virtual worlds in helping us to understand some of the affective dimensions of Avebury henge and its surrounding ritual landscape.

It is important to recognize that using virtual technologies to create visualisations of cultural heritage sites has been a debated topic since the mid 1990s [16]. Many archaeologists, historians and heritage professionals expressed concern regarding the dangers of hyper-realism, of reconstructions being based upon unclear evidence and the lack of an agreed protocol for demonstrating 'intellectual transparency' in the design, construction and use of virtual reconstructions. This led to the development of The London Charter for the Computer-Based Visualisation of Cultural Heritage [17] which is now recognised as the de facto benchmark to which heritage visualization processes and outputs should be held accountable. The specific objectives of this project are therefore inspired by those of The London Charter, and are to:

- Provide a benchmark for the use of immersive 3D virtual reconstructions of prehistoric sites in the UK that is widely recognised by stakeholders;

- Promote intellectual and technical rigour in the interpretation and construction of these virtual reconstructions, particularly with regard to the archaeological evidence base, techniques of visualisation and the creation of soundscapes;

- Ensure that the processes and outcomes of the project are properly understood and evaluated by users through the use of an appropriate research methodology;

- Enable the results of the project to contribute authoritatively to the study, interpretation and management of prehistoric heritage sites in the UK through academically rigorous processes and employing both wide and targeted techniques of dissemination, and

- Ensure access and sustainability strategies are an integral part of the project design.

III. AVEBURY HENGE

Fig. 1. Avebury Henge today – NE quadrant looking towards the northern entrance

Avebury Henge is situated approximately 20 miles north of Stonehenge in Wiltshire, U.K. and contains the largest known Neolithic stone circle in Europe (see Figure 1). Its construction is estimated to have taken place in different phases and spanned approximately 2,800 – 2,000 BCE, although actual dating of the phases of construction is unclear. It is part of the Avebury, Stonehenge and Associated Sites World Heritage Site and is protected as a Scheduled Ancient Monument under U.K. legislation. The henge is a roughly circular earthwork with a ditch on the inside and a bank on the outside, measuring approximately 420m in diameter. The earthwork is broken into four quadrants by interruptions in the ditch and bank system that have been interpreted as entrances to the inner area. Even today the depth of the ditches and the height of the banks are impressive, but when first dug the ditch was approximately 10m deep and the banks were likely to have been as much as 5m high. The construction would have been carried out using animal and stone tools such as deer antler picks and flint axes.

The earthwork enclosed 3 monumental sarsen (silicified sandstone) stone circles; one outer circle around the inside of the ditch which contained approximately 100 stones, with a further 150 or so stones that constitute 2 inner circles surrounding large megaliths which may pre-date the construction of the henge. These megaliths, known as The Obelisk and The Cove, may have been the original focus of the henge construction. Fewer than 10% of the original stones now remain at present-day Avebury, the majority having been broken up and used for building materials over the past 500 years. At least 2 avenues lead from the henge, originally marked by standing stones along their length. These avenues are approximately 2km long and lead to other monuments such as the sites of wooden circles, standing stones and long barrows, making the henge part of a much larger ritual landscape.

Large ritual landscapes such as those around Avebury have been the subject of historical and archaeological research since the work of Dr William Stukeley in 1743. Our understanding and interpretation of ancient sites has changed significantly since Stukeley's time and we now have excavation, survey, photographic and electronic data that enables the creation of imagined constructions of the Avebury monument and its surroundings at various phases of its history [18]. But the meaning of monuments such as the henge and stone circles of Avebury to the people who created them, and the meaning of the associated monuments and landscape in which the main monument sits, is much harder to ascertain [19]. Indeed, it may not be possible for members of modern societies to fully understand the meaning of ancient sites such as Avebury as we lack the context in which that meaning developed, and our own values and social structures affect our perspectives.

This research is focusing upon the experiences of participants in social activities in a virtual representation of Avebury and its landscape as it might have been circa 2,300 BCE as a means to investigate how interacting with and in such a virtual landscape affects the participants' understanding of, and feelings about, Avebury today. Whilst this has to be carried out with care regarding the generalisation of the meaning of virtual experiences back into the physical world, this does not mean that there is no connection between the virtual and the real. On the contrary, in his seminal ethnographic study on communities and social interaction in online, 3D virtual worlds, Boellstorff [20] discusses the importance of recognising what it means to be "virtually human", i.e. experiencing human activities in virtual environments and with people who represent themselves as avatars. He argues that virtual world cultures are profoundly human and that, in actual fact, "…It is not only that virtual worlds borrow assumptions from real life; virtual worlds show us how, under our very noses, our 'real' lives have been 'virtual' all along…. since it is human 'nature' to experience life through the prism of culture, human being has always been virtual being. Culture is our 'killer app': we are virtually human."

IV. CONSTRUCTING VIRTUAL AVEBURY

It can be tempting to see a monument such as Avebury as a single construction that was conceived, planned and built in the same manner as a construction project in the present day, leading to a "finished" structure. But this is unlikely to be the case. Evidence appears to show that sites such as Avebury continually changed as beliefs, practices and cultures changed. Archaeologists suggest that acts of constructing monuments like Avebury were likely to be of significant importance to the communities that built them, possibly more so than any sense of completing the monument. It may be that the sense of community and shared effort that resulted from creating them, along with the stories of the struggles with particular stones that could have been handed down across generations, bound the community together. So questions such as "what did Avebury originally look like?" are essentially meaningless. There is no "originally". Also, such questions are intended to explore what Avebury looked like at the time of a particular interpretation but, of course, interpretations may not be

accurate; Avebury may never have looked the way it is now imagined.

In one sense the changing nature of Avebury is problematic, as there is no fixed instance against which to measure accuracy of a simulation. But on the other hand this uncertainty provides the opportunity to try different interpretations and to build fluid versions and timelines, rather than attempt a single fixed reconstruction. Virtual reality technologies are well suited for this approach, as they facilitate creating a series of constructions that can be run as alternative timelines, rather than searching for a fixed view of the past. Whilst taking this into account, for the purposes of this project the construction is focusing upon the ditch and bank system and the 3 circles and megaliths within it. But this is one imagined past, and is not being reconstructed as a "true" version of Avebury, but rather as an imagined point in time when the ditch and bank system was at its greatest dimension and the majority of the stones were standing.

A. Visual aspects

Fig. 2. Virtual Avebury - NE quadrant looking towards northern entrance (cf. Figure 1)

The reconstruction is being built in a virtual world based upon the OpenSim™ platform, which enables terraforming and model construction in the sim itself and the importing of mesh objects created externally. The ditch and bank system have been created using both the terraforming tools for the main part of the henge and a mesh model for the false horizon at the edges of the sim. The simulated stones are made in 3D modeling software (Blender) as mesh objects which are then textured with photographs of the Avebury stones today and imported into the sim. Figure 2 shows a view of virtual Avebury from the same vantage point as the picture in Figure 1. The positions of stones that are yet to be placed are marked by small pyramids. To model the stones, the 40 or so that are still standing in the henge today were individually photographed with a person of known height standing alongside for scale checking. Whilst true scale measurements can be replicated in the virtual platform, the perspective and camera angles can affect apparent scale and so final finishing of sizes is carried out by reference to photographs of people in

present-day Avebury. Textures of each of the remaining stones were also photographed and used as the texture wrapping for the 3D models.

Fig. 3. The Obelisk

Today the majority of stones at Avebury are missing, but there are clues as to their likely size and shape from excavation of some of the sockets into which they were placed and because there seems to have been a similarity in shape and size amongst the stones in each quadrant. The missing stones have therefore been modeled using recent interpretations of their likely size and shape [18] and by reference to the records of antiquarians such as Stukeley, who was writing in the 18th century when some of the missing stones were still extant. An example of one of the stones described by Stukeley is The Obelisk, a pillar of sarsen approximately 2.5m in diameter and which may have stood as much as 6m high in the centre of the southern inner circle. Figure 3 is a photograph of the simulated Obelisk at virtual Avebury, and demonstrates how the stone would have been an important focal point when the henge complex was in use. The photograph also demonstrates how different weather conditions, seasons and times of day can be simulated in virtual platforms; environmental features such as these, together with sounds and soundscapes, are vital elements in interactive virtual environments as they change the immersive sense from just walking through a static picture to the sense of immersion in, and interaction with, an environment. As discussed earlier, the opportunity for participants to choose their own environmental conditions and some aspects of soundscapes whilst still collaborating with others, gives virtual reconstructions the ability to be personalized by the user. Soundscapes are a particular feature of virtual Avebury and are therefore discussed in more detail in the following section.

B. Sounds and soundscapes

Falconer & Green [21] comment that sound is often under-used in virtual world simulations as the visual aspects of interactive environments can dominate simulations. For example, Duncan et al [22] developed a taxonomy of virtual world usage in education from scrutiny of over 100 published academic papers and classified the finding into 6 categories, the first 5 of which largely map onto who, what, where, how and why questions. The 6th category maps onto research case studies and specific learning research. Whilst the visual and

communication affordances of these environments featured prominently in the literature in all categories, there was no mention of ambient soundscapes, nor indeed the wider issue of acoustic design.

Sound in some virtual world platforms, including OpenSim™, is subject to technical restrictions of file size and play length that can require looping of short sound clips resulting in repetitions that affect the realism of a particular sound or a soundscape. Despite these drawbacks, research has shown that sound has a significant effect on participants' sense of immersion, particularly on the emotional and affective dimensions. Studies over the past 15 years have demonstrated that audio cues in virtual environments can increase a user's sense of presence and recall of objects and their locations in the spatial environment. For example, Dinh et al [23] found that increasing the modalities of sensory input, particularly auditory cues, can increase both the user's sense of presence and memory for objects in a virtual environment. It is particularly noteworthy that in their study, increasing the level of visual detail did not result in the same increases in sense of presence or recall of objects, demonstrating that virtual environments are not all about the visual. More recent studies have begun to focus upon the effects of different types of soundscape on aspects of recall and memory relating to awareness of detail in virtual environments. For example, Schmidt et al [24] found that spatial audio cues in a 3D virtual environment can be constructed to guide a user's attention. As this project seeks to investigate the interaction of participants with virtual Avebury, the affective dimension of that interaction is of particular interest, addressing the question of how sharing the experience of being "at" virtual Avebury with others makes the participants feel.

Sounds in interactive virtual environments can be ambient, e.g. evoking weather, animals, other people and things which are not visible, or can emanate from co-participants or specific artifacts, e.g. people's voices or the sound of flowing water coming from a stream. The sound architecture in virtual Avebury includes both of these types; the ambient sound forms the base layer for the overall soundscape and is audible wherever the avatar is, whereas attached sounds and the voices of co-participants are only audible if the participant is close enough, and the sounds become louder or quieter depending upon the proximity of the avatar to the object or person.

Sounds and soundscapes in virtual Avebury are diegetic, i.e. they are contextualized within the story space. Therefore the sounds of virtual Avebury create an imagined soundscape whose constituent parts would have been audible around 2,300 BCE. The creation of a soundscape requires the same attention to detail as the creation of visual features of the simulation, and is informed by questions regarding what could be heard at that time. Unlike the present day in the U.K., wolves were plentiful and metal was unknown, or at least probably little-used as Avebury appears to span the end of the Late Neolithic period and the beginning of the Bronze Age. One of the most common sounds of the time is likely to have been flint knapping – the process of forming tools from blocks of flint by knocking off chips and flakes with deer antlers or stones. These sounds would be likely to be ubiquitous in domestic or work settings, but would be less likely in or near a sacred place such as Avebury. Indeed, there is no archaeological evidence of flint working or any domestic processes in the henge, nor evidence of cooking, eating or drinking within the henge. Apart from some small deposits of deer antler picks, bone fragments and potsherds, many of which appear to be offerings of materials that were already old at the time of the henge construction, the henge is relatively clean. This lends credence to the view that the henge was a sacred or reserved place, and so the ambient sounds that make up the base layer of the soundscape concentrate upon sounds of the weather and distant animal and bird calls.

One aspect of sound that is worthy of consideration in ceremonial sites is music. There are long human traditions of music being a part of ceremony, and although poor preservation of organic material means that few examples of musical instruments have been discovered that are dated to the Late Neolithic period in Britain, there is significant evidence of musical instruments being associated with Neolithic cultures across Europe. These tend to be pipes, flutes, drums and whistles; tantalizingly a hollow deer bone "flute" with three holes was found in 1849 in a Bronze Age burial mound a mile away from Avebury henge [25]. Sadly this has been lost, but replicas based upon the sketch of the excavator, John Merewether, have been recreated and played [26]. Recent acoustics research amongst the remaining stones has shown that the close arrangement of the original stones in The Cove would have been likely to act as an amplifier for sounds created within it [27]. Replica Neolithic music is therefore planned to be a constituent part of the overall soundscape at virtual Avebury in the near future.

V. PERSONAL REFLECTION

The next phase of this project, which will take place in Spring 2017, will use a participatory action research methodology that involves students of heritage and history in a range of activities in virtual Avebury, including working as a community to choose and erect stones and experimenting with possible ritual uses of the environment. Before this evaluation element of the project, it is important for me to reflect upon the process of creating a virtual simulation of Avebury and what I have learned as a result. The construction has required consideration of a wide range of factors; indeed the discussion in this paper demonstrates that virtual reconstructions are not simply pictorial renditions of past landscapes. The underlying theoretical approach in this project is one of abduction, i.e. inferring to the best explanation, to understand archaeological findings and the interpretations of specialists to create a virtual simulation of Avebury. But this can only be one imagined past; virtual Avebury is not a "true" rendition of Avebury at any particular point in time. I would argue that this does not devalue learning from the process of its construction or its role as a catalyst for engagement with the distant past. However, I recognize that some of the concerns that resulted in the London Charter were of virtual reconstructions being presented as true pictures of the past, or that the strength of the experience of visitors to these reconstructions would fix them as their view of the past even if the creators did not claim this. Visualisation and interaction in virtual environments are powerful aids to understanding, but that very power can also distort our

understanding by becoming the dominant perspective; an apparent "truth". How we might best balance the positive and negative factors of virtual reconstructions of the past has no simple solution, but I would argue that more research is needed into how to maximize the positive potential for learning and engagement through virtual reconstruction, whilst also enabling understanding of the interpretative and changing nature of our view of history.

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