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Short Paper

Visualising Dudsbury Hillfort: Using Immersive Virtual Reality to Engage the Public with Cultural Heritage

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Abstract

Whilst computer visualisation is an established method of presenting cultural heritage, the use of game engines to provide a full immersive virtual reality experience is less well developed. This research documents the development of a visualisation of an Iron Age hillfort using Unreal Engine together with LiDAR terrain data to create a fully immersive experience for the virtual visitor. The visualisation was evaluated by 36 members of the public. The results show a high degree of satisfaction with the visualisation and agreement with the results of other studies demonstrating significant differences between those new to and those familiar with virtual reality applications. The conclusion is that in combination, game engines and LiDAR are effective tools for creating engaging virtual heritage visualisations.

CCS Concepts

•***Software and its engineering*** → *Interactive games;* •***Human-centered computing*** → *Virtual reality;*

1. Introduction

The use of virtual reality (VR) is now an established method of engaging the public to raise awareness about heritage sites within virtual heritage (VH) applications [CHA16] [BPF*18]. The number of VH applications that take advantage of the visualisation capabilities and functionality possibilities of games engines is rapidly increasing [DHD18] [MC18]. This paper reports on the initial findings from a project that used a game engine to produce a visualisation of Dudsbury hillfort (a prehistoric earthwork enclosure to the north of Bournemouth, Dorset, UK) as it may have appeared in the British Iron Age (650BC-50AD). The visualisation was created as part of Heritage Lottery funded project and was intended to be viewed as part of a wider set of activities designed to raise awareness of the heritage of the site and to promote conservation. The application also been used within public engagement events to evaluate the immersive experience of VR using the Oculus Rift.

This paper first briefly explores the background issues including the use of VR for VH applications, the use of game engines and immersive technologies. Secondly the development of the virtual environment is discussed including the creation of the landscape terrain using LiDAR data, the optimisation of the 3D assets, and the design of the interaction. Thirdly the preliminary results of the analysis of a survey conducted during public engagement events are presented. Finally the conclusions are drawn from the experience of the development and the results of the survey.

2. Virtual Heritage Projects

2.1. Virtual Reality in Cultural Heritage Projects

VR has long been used within Cultural Heritage with one of the earliest examples being a reconstruction of Dudley Castle (UK) which was launched to the public in 1994 [BJ96] [CHA15]. As VR technology has developed the number and variation of VH applications has expanded to make use of the new opportunities [AML*10] [BPF*18]. Today there are many examples of VR applications used within both physical and virtual museums, and the identification and promotion of aspects of excellence within these applications is an active research activity [PES14] [ABD17] and [BPF*18].

2.2. Game Engines

The potential for game engines, such as Unreal Engine and Unity, to be used for VH projects was identified in the early 2000s [FK04]. The use of game engines can rapidly speed up the creation of VH applications because developers can make use of the existing functions without having to create their own [AML*10] [OIK15]. As computer graphics technology has advanced, the functionality of game engines has developed to take advantage of these new capabilities, which has made them even more attractive for VH projects [ABD17] [HSG*17] [KPKK17]. Their use, however, has drawbacks. For example, for their full potential to be achieved development has to be performed on high-performance computers with 3D objects and textures optimised in order to be able to render them in real-time [RAM17] [KBT*17]. Furthermore, advanced use of game engines requires developers to have programming exper-

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tise and 3D modelling skills [OIK15]. Despite these drawbacks, it is possible to create high quality historic visualisations, such as the Viking village of Midgard [PEN12], and the series of visualisations of Flint Town [VIS18].

2.3. Point Clouds and LiDAR Data

There has been increasing interest in the use of laser scanning, multi-image photogrammetry (or Structure from Motion) and remote sensing techniques like LiDAR for the automatic creation of 3D models to be used in VH projects [ROS*14] [HSG*17] [SAC18]. The creation of point clouds of objects, buildings or landscapes can greatly speed up the development of accurate detailed 3D models and textures but the data files that hold the points can be massive which makes them too large to be directly imported into game engines without further processing. The automatic conversion from point clouds to polygonal models is still in early stages of development and requires considerable modelling effort [MDC18] [AMSM18]. An increasing number of VH projects have used LiDAR data with a reduced number of points to create accurate virtual landscape without a prohibitive use of memory [ROS*14] [OIK15] [ABD17] [HSG*17] [JSC*17].

2.4. Immersion and presence

The essential characteristic of VR as defined by [DBS18] is the enhancement of the user experience by immersing them in the virtual world to the extent that they perceive they are actually present in the virtual environment. For the experience to be immersive a number of factors have to present i.e. the experience has to be believable, interactive, explorable and enjoyable [DBS18]. Game engines are able to provide the required interaction that allows the users to explore the environment with the potential to make the experience enjoyable [FM17]. [STO15] warns that people who are inexperienced with VR will experience a "wow" effect at first, but this will wear off as they start to recognise the limitations of the display and input devices, whilst [KPKK17] highlights the higher expectations that the younger generation may have due to their experience in computer gaming.

A variety of factors contribute to making the VR experience believable especially the realism of the visual presentation, along with other factors such as the use of sound, haptic feedback, and interaction with humans [KPKK17] [FAL17] [MDC18]. The realism of the visual presentation has been increased with advances in graphics libraries, game engines and graphic cards [MC18] and the development of visual effects such as fog and particle systems [KPKK17]. Visual immersion has been provided by the development of relatively affordable VR headsets that track the wearers head movements, such as the Oculus Rift and HTC VIVE headsets that were both launched commercially in 2016 aimed at home gamers who possess a high specification gaming computers or consoles. Since then there has been an explosion of VH projects that are designed to use these headsets [RAM17] [BPF*18] [SAC18]. Both headsets have proprietary controllers, but also work with a variety of input devices including keyboard, Wii, Kinect, Leap Motion or smartphones for gestures recognition [BCM*15] [GT115] [FPMR17] [BPF*18] [SAC18], although it is possible to navigate just using head movements [DHD18].

The use of sound has also been found to be important for the sense of immersion by researchers, for instance [GRW16] found that the Oculus Rift immersive set up with ambient sound gave an immediate sense of presence of being somewhere, but the interpretation of the location was deeply personal to the individuals' memories and experience. Similarly [FAL17] highlighted the importance of ambient sound to provide an evocative effect that increases the sense of immersion, while the effect of sound located in the landscape had a more subtle affect. Additionally [FAL17] found that individuals' responses were complex and personal, and developed perceptions that were not intended by the creators of the visualisation. The availability of haptic devices to give tactile feedback has not yet caught up the visual experience but research into creating new wearable devices is increasing [GCWG17] [SMB*18]. [MDC18] highlighted human presence as an important factor that has often been missing in many VH projects but virtual humans are increasingly being used. The creation of virtual humans is a complex task including designing both it's appearance and interaction, but [MDC18] emphasised that it is vital for the virtual humans to exhibit believable behaviour. Another important issue relating to immersion is the requirement of historical accuracy [MC18]. [KOU17] emphasised the need for input from professionals and experts within VH projects for content validation.

3. Dudsbury Historic Virtual Reality visualisation

3.1. Dudsbury Guide Camp

Since the 1930s Dudsbury hillfort has been used as a camp site by Bournemouth Guide Camp Association. The camp is located in an Iron Age hillfort or enclosure at West Parley to the North of Bournemouth. In 2016 Dudsbury Guides Camp was awarded funding for a project entitled "Interpreting and conserving Dudsbury Ancient Hillfort and the history of Girlguiding on it" by the Heritage Lottery Fund. The project detailed a number of activities designed to investigate the heritage of the site and to promote awareness of conservation issues in order to reduce deterioration of the environment. Bournemouth University was a partner to the project with the task of creating a VR tour of the hillfort as it may have appeared in the Iron Age.

The hillfort is sub-circular enclosure containing about 3 hectares, with a maximum width of about 350m. The site rises to height of 30m above sea level and the land falls sharply 21m down to the River Stour in the south [SW21] [Off75]. Figure 1 shows a plan of the site with the deep red representing the banks and light grey representing the ditches of the enclosure ramparts [RS17]. Today there are four entrances to the enclosure and while the entrances to the east and north are considered to be modern there is some debate about whether the entrances to the west and south west are the original ones [SW21] [Off75]. A limited excavation was carried out in 1921 that was able to confirm the Iron Age date of the enclosure, and also indicated that the western entrance was a more recent alteration to the earthworks [Ano22]. For the visualisation it was decided to show only the south west entrance to re-enforce the importance of the river as the main transport route at the time.

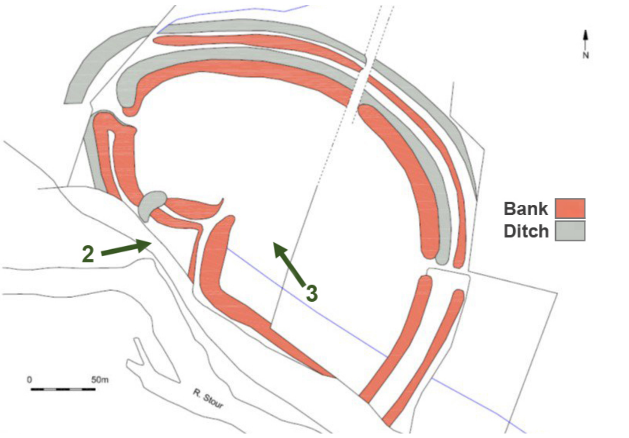

Figure 1: *Plan of Dudsbury Hillfort [RS17] p.147, with arrows showing the viewpoints for Figures 2 and 3.*

3.2. Development of the virtual environment

The aim of the VR development was to produce an interactive VR visualisation of Dudsbury hillfort as it may have appeared during the Iron Age. The visualisation was to be created using a game engine to allow people to explore the site at a human scale and to control their own route while exploring the environment. A limited amount of interactive features were envisioned as it was not intended to be a stand-alone application but would be part of a wider set of activities scheduled within the Heritage Lottery Project. The funding was used to employ Bournemouth University students as 3D developers and geophysical surveyors. A geomagnetic survey was carried out to determine whether archaeological remains beneath the ground, such as the foundations of round houses, pits or fence posts, could be identified. This information would provide the visualisation greater authenticity by identifying structures and types of activities that occurred within the hillfort, and placing them in their correct position. The survey indicated that many of the interior features appear to have been degraded by agricultural ploughing and the results were seriously affected by the presence of modern tent pegs and camp fire sites.

Unreal Engine 4 was used to build the environment to make use of the visual effects. The heightmap for the landscape was prepared using publically available LiDAR data from which trees were stripped away by filtering out the primary returns (often the upper surface of a vegetation canopy) from the last returns (the lower vegetation layers or ground surface) of individual LiDAR pulses [CW11]. The dimensions of the landscape had to be adjusted to match human scale represented in the game environment. The x and y axes were calibrated by placing a modern map texture on the landscape and adjusting the size until the scale matched. The z-axis had to be adjusted independently until the distance between top of the hillfort and the river was 21m. When the landscape was the correct size the banks and ditches had to be sculpted to correct the height of eroded banks and filled in ditches. The landscape was then textured to show areas of grass and, mud and rocks. In order to help optimise the environment as much of the landscape that was not needed was deleted, e.g. parts of the landscape that would not be seen in the north and west were deleted but a large area to the south and west that could be seen from the main gate had to remain. A fog effect was added to soften the horizon and to hide missing features such as distant hills that could not be represented because they were outside of the area of the heightmap. Figure 2 shows the visualisation view looking up to main gate fort from the level of the river and also one of the virtual information boards.

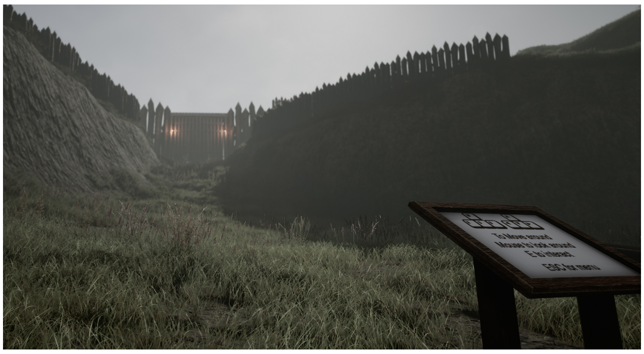

Figure 2: *The main gate at the south west entrance.*

To inform the creation of the 3D assets reference material was gathered during visits to Dudsbury, the Museum of the Iron Age in Andover, Danebury Iron Age Hillfort, Butser Ancient Farm, and the Ancient Technology Centre at Cranborne. 3D models that were created for the environment were optimised wherever possible to reduce the number of polygons and the size of texture files, e.g. a roundhouse was created with 1200 polygons, while a shed was created with 50,000 polygons because of the geometry needed to represent the individual wicker branches that make up the shed walls. The palisade fence took a large amount of resources: it was created with a section of six posts that were only 2,821 polygons but this had to be repeated 1395 times to create the whole palisade and used almost 4 million polygons in total.

Additional effects were added to improve the visual appearance including the use of water surfaces, fog and post process volumes. Ambient sounds were applied with additional sound effects located near specific objects such as the river, trees and fires. The use of foliage is very useful to enhance the appearance of an environment, but this can be use a large amount of the computer resources, therefore a feature was added that allows the user to change the amount of foliage, and post process effects that are displayed. This enables the application to be run on computers with fewer resources than the development computer, by reducing the display quality from within the built level without having to edit the project.

One of the objectives was to create a high quality visualisation to show the appearance of the environment with less emphasis on interaction. However some dynamic and interactive features were implemented including an introductory cinematic, a menu, triggers for opening the gate, a day and night cycle that slowly changes the lighting effects, and the option to show a burning torch inside roundhouses or when the night lighting is displayed. Figure 3 shows a screen shot of the finished environment. The visualisation was used as a basis for a painting that is placed on information

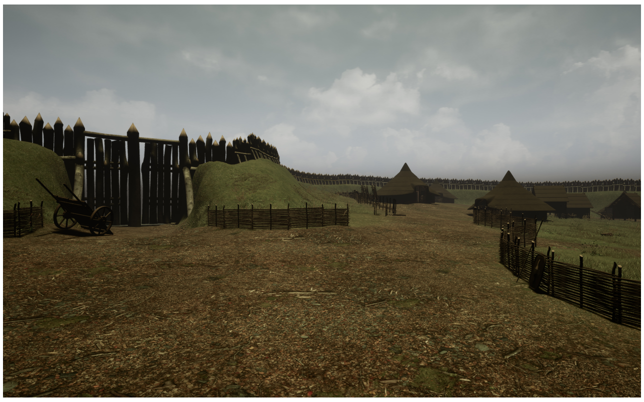

Figure 3: *Interior view of the finished visualisation.*

Table 1: *Comparison of the ratings of participants based on their knowledge of Dudsbury.*

	Fidelity	Navigability	Completeness
Familiar	4.44	4.11	4.22
Unfamiliar	4.41	4.67	4.48

boards in Dudsbury, and videos and screen shots of the finished visualisation are available to be viewed at Dudsbury via a local wifi Vix box system. A video of the visualisation can be viewed online at https://www.youtube.com/watch?v=kkeFrTUpykM.

4. Survey results

The visualisation has also been presented as an immersive VR experience at public engagement events using an Oculus Rift. A human guide was present to oversee the activity and point out areas of interest. After finishing the activity the participants were asked to fill in a short questionnaire about their perception of the experience. The questionnaire recorded whether they were familiar with the location and how much experience they have using VR and their rating of three statements relating to how realistic the environment was (fidelity), how easy it was to navigate and how ready the VR environment is to be used as an on-line exhibit. A 5-point Likert-scale was used to rate the statements from "Strongly Disagree" at 1 to "Strongly Agree" at 5.

Thirty six participants completed the questionnaire. The results of the questionnaire were analysed to compare the responses of participants who know Dudsbury against those who do not and also to compare the results of the participants who were experienced using VR against those that were not. Nine of the participants who knew Dudsbury well were also asked an additional question of how well the visualisation looks like Dudsbury. Their average rating of 4.22 was within the positive "agree" section, but this was one of their least positive ratings for all the questions which could indicate that they may have had different individual expectations, agreeing with the results of [FAL17].

The comparison of the ratings of the participants who knew Dudsbury against those who did not are shown in Table 1. As shown

Table 2: *Comparison of the ratings of participants based on their experience of Virtual Reality.*

	Fidelity	Navigability	Completeness
Experienced	4.30	4.48	4.35
Inexperienced	4.62	4.62	4.54

in Table 1 the average rating of both groups were similar, and all were rated in the positive "agree" section. There were slight differences between the participants who knew Dudsbury compared to those who did not but t-tests that did not find any significant differences between the ratings of the two groups ($p>0.05$) which indicates a strong agreement between them.

Table 2 shows the results of the comparison of the 23 participants who were experienced with VR against the 13 participants who were less experienced. As shown in Table 2 the average ratings of all the participants are positive (in the "agree" section), but the participants who are more experienced using VR are slightly more critical for all three statements. T-tests detected a significant difference between the groups for the statement relating to how lifelike the model was ($p=0.04$) with the inexperienced participants rating the environment more lifelike than the experienced participants. This result conforms to the expectation of [STO15] who predicted that people will experience a "wow" phase when they first use a virtual reality headset, while more experienced user will be more critical. This result is reinforced looking at the participants' comments: many inexperienced participants gave comments like "Excellent" and "I really liked it", while the more experienced participants gave comments like "It was really cool to look around but there should be purpose/make it game" or "Maybe add information when people reach certain points".

5. Conclusions

This research demonstrates the utility of freely available LiDAR based terrain models and popular game engines for the creation of highly effective virtual heritage applications, notwithstanding a few technical issues such as landscape scaling and extent and delivery platform capabilities. An evaluation of the environment produced in this project showed a high degree of user satisfaction. The public survey data shows familiarity with the site did not affect the users' satisfaction with the visualisation whilst familiarity with virtual reality did. These results agree with the results of other studies that found different reactions from users depending on their experience. Possible further work includes the expansion of the number of participants to be able to perform more statistical analysis. Also there are many suggestions from participants that could be implemented to make the experience more interactive and engaging.

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