The 13th International Symposium on Virtual Reality, Archaeology and Cultural Heritage VAST (2012)
D. Arnold, J. Kaminski, F. Niccolucci, and A. Stork (Editors)

Short and Project Papers

Visualising Stonehenge: A virtual archaeology

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Abstract

This paper summarises the results of a virtual archaeological analysis on the stones at Stonehenge. Based on laser scan survey, all observations and discoveries were made in the virtual world. The results of this project are significant to all heritage sites that have been preserved by digital record. The study focuses on evaluating and developing techniques for revealing new information on heritage sites that have extensive laser scan archives. In examining the complete laser scan data archive for Stonehenge, ground-breaking numbers of prehistoric features have been discovered in the survey data. The creation of a virtual archaeological methodology has enormous potential to contribute to the future study of these digital archives.

Categories and Subject Descriptors (according to ACM CCS): I.3.3 [Computer Graphics]: Picture/Image Generation

1. Introduction

Over the past decade laser scanning has become a popular way to record cultural heritage sites. CyArk (a non profit organisation based in the USA engaged in digitally preserving heritage sites) have recorded many endangered heritage sites across the world with the intention of preservation by digital record. Additionally in the UK the Scottish Ten project continues to record key world heritage sites and Historic Scotland has indicated that it is considering recording all of its monuments by laser scan survey. Whilst there are obvious benefits to the 3D digitisation of these Important heritage sites significantly less attention is paid to the use of these scans.

CyArk's mission statement is "Preserving cultural heritage sites through collecting, archiving and providing open access to data created by 3D laser scanning, digital modelling, and other state-of-the-art technologies." CyArk are planning to record 500 heritage sites in five years, this work will amount to an impressive data resource on some of the world's finest and important heritage sites. Many more sites have been and will be recorded in this way, creating a valuable data resource. This project set out to address a number of topics concerning the study of digital data in the virtual environment, the amount of information that could be extracted from a digital archive and the techniques that were transferable from real world archaeology to virtual archaeology.

2. Virtual Stonehenge

Stonehenge is arguably one of the world's greatest and most important cultural heritage sites and it too has an extensive laser scan archive. This data was created in 2011 by English Heritage, the custodians of Stonehenge. English Heritage commissioned Greenhatch Group (a commercial survey company) to laser scan the entire monument and the surrounding landscape known as 'the triangle'. The laser scan of the stones was conducted at a 0.5mm resolution with a Z + F 5010 imager scanner. The Z + F scanner has a range noise of 0.5mm at 10 metres making 0.5mm the finest resolution possible for this phase-based laser scan survey. A 1mm resolution survey was also conducted.

In March 2012 ArcHeritage were commissioned by English Heritage to examine and visualise this digital data in a manner that both confirms existing discoveries and reveals new information about the faces of stones. Any new discoveries would be integrated with the wider context of the monument and its landscape [FiP10]. The full results of this research are available in an English Heritage research report [AAW12], English Heritage intend to use this work to in-

DOI: 10.2312/PE/VAST/VAST12S/001-004

form the interpretation design for the new visitor centre, the construction of which is due for completion in autumn 2013. Because of the timing this project has the potential to influence the way Stonehenge is presented to the public for the next decade and beyond. It can also be used to understand the examination potential of other heritage sites which have a laser scan survey archive.

3. Digital data

English Heritage supplied ArcHeritage with geo-referenced point cloud data at a spacing of 1mm and 0.5mm for every stone face. They also supplied mesh model data in the form of .OBJ files. These meshes were at 1mm resolution for the entire site, with areas of known rock art meshed at full 0.5mm resolution. The meshes were created in Geomagic by the original survey company, Greenhatch Group and are based on a 1mm resolution laser scan. The 0.5mm resolution meshes are based on the 0.5mm resolution laser scan. (Figure 1)

4. Methods of examination.

The first step in visualising any of the data sets required the creation of a visual template to which additional information could later be added. A basic visual catalogue of the stones was created from the 1mm mesh, providing a reference image of each individual stones elevation that could later be plotted with features, creating an atlas of the monument.

Initially we set about examining the 1mm mesh model data. It was a complete archive; every stone had a 1mm resolution mesh model. In the real world the stones at Stonehenge weigh up to 50 tons, but in the virtual environment we can manipulate them without concern for their size. Consequently our methodology to examine these virtual megaliths was similar in nature to the way a lithics specialist might examine a hand axe. We created the ideal lighting situation to highlight surface features using the interplay of light and shadow to define marks on the surfaces of the stones. Combining this functionality with the ability to apply sophisticated shaders like 'Radiance shading' [VRP10] to clarify surface details, the potential for discovering new information was high.

5. Discovering Neolithic archaeology in the virtual model

As each stone was examined in real time in the virtual world, we were able to visualise many archaeological features. We identified tool marks from the original shaping of the stones, Neolithic stone working practices that have survived five millennia of weathering and erosion were present in the data.

On closer inspection we could even identify layers of tooling, which provided a glimpse into the various stages of the Neolithic stone masons work. As we continued the examination of the data it became clear that the majority of this tooling was previously unrecorded information. In the real world the details of the tooling are camouflaged by the surface texture of the Stones. Without this texture it becomes much easier to identify the micro-topography of the surface of the stones. Together with the functionality and ease at which the virtual stones can be manipulated and the surface detail enhanced, many new features could be identified on the surface of the stones. This information was recorded and discovered in the 1mm data set, and provides an indication of the type of features we might expect to find in similar resolution datasets on other heritage sites.

6. Limitations of the 1mm data

Since this project is concerned with the viability of analysing virtual heritage sites, it is also important to note the limitations of the 1mm data set. Our examination of the 1mm resolution data whilst successful in identifying Neolithic tooling, failed to identify, many known areas of graffiti, the 1mm data was not sufficiently dense to record or display fine incised marks as a result were unable to catalogue all of the known graffiti on the site. This is particularly relevant to the analysis of sites with rock art, a higher resolution data set is needed to study such features in a digital archive.

Figure 1: *Virtual Stonehenge, the 1mm mesh model.*

6. Rock Art

Forty-four Bronze Age axe carvings are known on four stones at Stonehenge. In the 1mm data we had been able to identify a limited number of these carvings. Fortunately our research was not limited to the 1mm data set and we were able to use the 0.5mm meshes of selected stones where rock art was known as a target for virtual analysis.

There are a number of ways we approached the examination of the 0.5mm data. Firstly we visualised the 0.5mm mesh in the same way as the 1mm mesh examining the surface with the interplay of light and shadow in a manner akin to a virtual RTI. We also used detail enhancing shaders such as ‘Radiance Shading’. The results of this examination were tantalising and indicated that prehistoric carvings were present in the data, although none of the techniques provided definitive outlines to the carvings. ‘Radiance Shading’ proved excellent at defining incised marks and pick dressing (individual hammer strikes) but all of this detail seemed to mask the overall design of subsequent carvings that formed broad sculpted areas of less than a 1mm deep. These techniques did not prove effective in the visualisation of this type of artwork. It therefore became necessary to develop a specific shading technique that would allow us to visualise the axe carvings in the Stonehenge data.

‘Luminance Lensing’ was a creative idea developed independently in-house that combines real-time visualisation with surface topographical enhancement. The luminance value for each polygon is determined based on its relationship to a hypothetical intersecting 3-D shape. Polygons emit more or less light based on their proximity to the 3-D shape. Rock art features are revealed as areas of increasing or diminishing brightness. (Figure 2)

7. Results

By utilising a combination of the above techniques, in total, 722 surface features were identified and recorded on the stones of Stonehenge. These features include areas of stone-working, prehistoric carvings, graffiti, damage, weathering and conservation. Of these 722 features, 448 are discrete areas of stone-working, most of which had never been recorded until this study. This new information has had a profound influence on our understanding of the construction of Stonehenge. We were able confirm the existence of the 44 known Bronze Age Axe carvings and discover a further 71 previously unrecorded examples of these rare Bronze Age artworks, (Figure 4) this study has doubled the number known in the entire country. Digitally reconstructing broken stones provided calculations on the quantities of missing stone fragments. This provided new evidence suggesting the monument was once complete. (Figure 3)

8. Conclusion

This project has added significantly to the understanding of the benefits and limitations of working with digital data to analyse monuments like Stonehenge. It has demonstrated that the data set provided by English Heritage contains a wealth of valuable digital information. Perhaps the most encouraging and exciting aspect to this project is our ability to look at one of the most studied monuments in the country in a new way. Even though Stonehenge has been subject to decades of extensive study, the application of a virtual study has brought about significant new discoveries concerning the construction, chronology and past significance of the monument. These discoveries stand as a testament to the benefits technological advancements can bring to heritage projects.

High resolution surveys utilising laser scanning are regularly being conducted on important heritage monuments and this project has demonstrated the potential for the examination of those archives. If new discoveries can be made at one of the most studied monuments in the country, the possibilities from implementing these techniques on other laser scan recorded monuments are extremely promising. Advances in digital technology have redefined the way archaeologists engage with the past, and the activities of groups like CyArk provide a virtual archaeological record which has the potential to not only preserve, but also generate significant new knowledge.

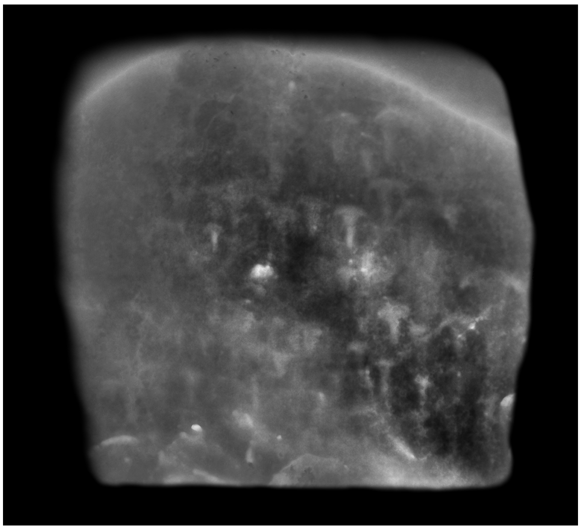

Figure 2: ‘*Luminance Lens’ shading revealing the extent of Bronze Age axe carvings in the 0.5mm data for stone 4*

Figure 3: *Reconstructing Digital elements. Using the digital model we were able to virtually reconstruct broken elements of Stonehenge; this exercise enabled us to identify the amount of stone that had been removed from Stonehenge providing new evidence to support a completion theory for the monument.*

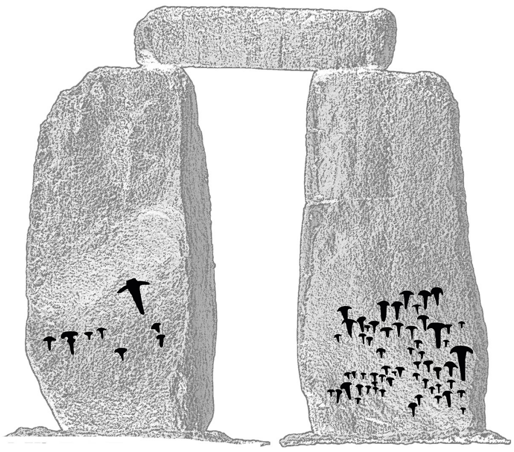

Figure 4: *Bronze Age rock art plotted on stones 4 & 5*

Acknowledgements

This project was funded by English Heritage. Hugo Anderson-Whymark is co-author of the research report and worked with ArcHeritage throughout this project. The project is also grateful for the input from Mike Parker Pearson Colin Richards and Rob Ixer.

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