Battlefield Interpretation: The creation of a Program Design Document utilising 3D Visualisation techniques for use in the investigation and exploration of historic conflict

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Abstract

With the often cited vast increases in computing power seen over the last few decades and, as a result, increasing complexity in the rendering and simulation of virtual environments it could be argued that archaeology has not fully embraced these new powerful digital tools, instead limiting the use of digital visualisation to an extension of presentation and communication. This paper illustrates that archaeology has shared its long and distinguished history with the engaging power of visualisation and how the expression and interpretation of imagery has served archaeology well, igniting the imaginations and interests of the broader public whilst communicating culturally and historically significant findings. In this paper the relationship between archaeological investigation and visualisation is examined and its strengths and weaknesses identified. From this examination it is observed that GIS falls short of meeting the requirements of recent developments and directions in archaeology and that the modern technology found in Video game development can provide viable pathways forward in the creation of virtual environments for archaeological interpretation. A number of these technologies are then assessed within the context of an on-going archaeological investigation into the Battle at Bosworth. It is observed that these technologies hold a great deal of promise with regards to the subjectivity involved with examining the past whilst being able to include the primary features that have made Geographical information Systems (GIS) so useful to archaeology. Extrapolating the findings of this investigation a Program Design Document has been created in order to better define a framework through which current games technology and fields of investigation in archaeology can work together.

Copyright

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Chapter One: Introduction

3D Computer Visualisation has developed rapidly over the past two decades, cementing itself as a powerful and flexible set of tools in the presentation and dissemination of archaeological knowledge (Barcelo et al., 2000). Whilst this relationship, moving into the 21st century has flourished, the ground work of virtual archaeological interpretation and analysis remains primarily in the domain of Geographical Information Systems or GIS for short (Wheatley, & Gillings, 2002; Witcher, 1999; Barcelo et al., 1996). Firstly it could be argued that these hard analytical tools lack a theoretical framework to be so intimately incorporated into archaeological analysis. Secondly they have changed very little since their incorporation into archaeological processes whilst other areas of digital visualisation and simulation such as physics, animation and rendering techniques, have taken giant leaps forward in terms of visual fidelity, speed and flexibility in particular with regards to video games technology. It is the aim of this project to investigate these developing aspects of the virtual world, what they have to offer archaeology, and how they may benefit experimental research being carried out at Cranfield University into the firing and simulation of historic battlefield artillery. From this investigation a design and specification document will then lay the ground work for the development of a simulation environment incorporating some of the tools discussed. This document will illustrate some of the ways in which 3D Visualisation can move beyond the role of presentation and become part of the analytical and investigative process of archaeology.

1.1 Project Background

On August the 22nd 1485 in an unassuming corner of rural Leicestershire a triumphant, battle worn, Henry Tudor places his newly won crown atop his head, assuming his place as king of England and ushering in a dynasty that would last 122 years. He had just defeated Richard III at the Battle of Bosworth, serving as the conclusion to the War of the Roses and the last battle in English history to see a King killed in action. Widely regarded as a defining moment in English History Bosworth battlefield has found itself a source of contention amongst archaeologists (Foard, 2004; Foss, 1998; Wheeler et al, 2010) and whilst seen to be a well-documented event for medieval times its location has until recently (Foard, 2010) existed across a number of possible locations.

After an extensive 5 year investigation led by Glenn Foard and commissioned by Leicestershire county council a viable candidate for the location of the actual battle has been pinpointed within a field straddling Fen lane in the Parish of Upton. The evidence giving the site away (some two miles from what had once been considered the staging of the battle) includes sword mounts, badges, coins and, perhaps most surprising to the archaeologists, a large scattering of round shot. This thin scattering of lead, above anything else, aids archaeologists in the interpretation of the battles flow and direction. Currently it is the charge of experimental research (Allsop, & Foard, 2007) being undertaken at Cranfield University, into the simulation of artillery fire relevant to the period in order to gain a greater understanding of how these weapons changed the way in which battles, such as Bosworth, were fought. The highly practical nature of this project means that a large amount of data will eventually be collected relating to the physical properties of cannon fire. It is expected that this data can lead to a digital simulation with forensic potential; however complex computation of this type is beyond the scope of this project which instead will use the research as a basis for a comprehensive investigation into old, and new, relationships between Visualisation and archaeology.

1.2 Structure and limitations of this report

This paper will firstly discuss the present state of Visualisation in archaeology along with examples from recent projects. It will then move into a detailed review of the relationship between archaeology and Virtual visualisation including its history, current uses, inherent issues and possible avenues for future development. The report with conclude with a section analysing the state of current technology with regards to the development of a virtual simulation and visualisation environment for the purposes of archaeological investigation utilising the latest in real-time rendering and simulation technology.

Due to the expansive and intricate nature of archaeology and the investigation of history this report will use Glenn Foard's work into the introduction of artillery to civil war England as a focal point. This confines the investigation to 15th century warfare with an emphasis on the introduction of heavy artillery to European battlefields and the related practical cannon firing being carried out by Cranfield University, representing the cutting edge in investigative archaeology, and is generating data that can be used in future program developments. This will allow for a structured discussion of visualisation and simulation technologies whilst keeping the report to a manageable size, however there is no reason to suggest that the technologies and processes being discussed cannot be expanded and utilised to encompass other historical periods or areas of landscape and battlefield archaeology.

Chapter Two: Current Trends in Virtual Archaeology

Although the relationship between archaeology and digital visualisation has never been stronger as (Barcelo, 2000) indicates there appears to be very little work moving 3D visualisation into the realm of interpretation and analysis. There has however been a steady push forward in the use of digital environments for representing cultural heritage in a pedagogical and presentational context (Anderson, 2010). What this report does highlight however is the increasing sophistication of computer games technology and its robust and malleable application to the reconstruction of history. This can already be seen in the use of Computer game technology in places such as the BBC series *Time Commanders* (Ansell, 2003) were the technology can be trusted to create a quasi-reliable simulation of historic engagements that are also open to interpretation.

Current archaeological investigation has only recently begun to reap the benefits of Geographical information systems and the analytical tools they have to offer (McCoy, & Ladefoged, 2009). Computer Games technology may very well already be in a position to supplant these benefits with its own developments. (Shepherd, & Bleasdale-Shepherd, 2009) investigates current trends in video games technology and the advantages it holds over current GIS tools. The paper suggests that games technology may have the ability to enhance and perhaps even replace GIS and the tools it has to offer owing to video games ability to simulate spatio-temporal processes as well as handle spatial data. The use of 3D visualisation for archaeological reconstruction is already being taken into serious consideration (Allen, et al, 2004) with academic teams exploring the integration of these technologies into live digs and the kinds of work "pipeline" this would require (Figure 1).

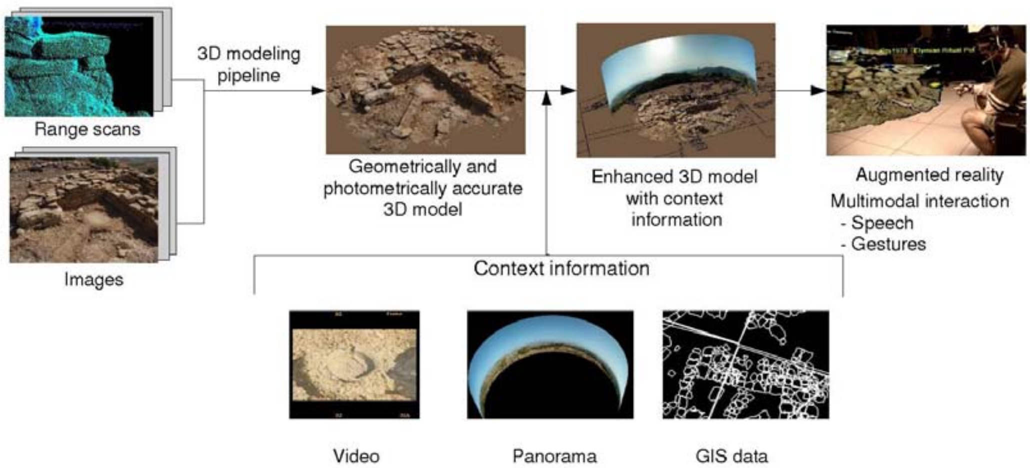


Figure 1. 3D Modelling and Visualisation Pipeline, Allen, et al, 2004

A number of other projects have also approached archaeology with the intention of enhancing areas of the field through digital visualisation techniques. One such project (Rajapakse, Tokuyama, & Somadeva, 2011) explores a wide array of tools for the creation of 3D visuals from reconstruction landscapes with GIS data to the detailing of a human skull with digital sculpting software. In the recreation and simulation of an ancient landscape that is now under water Eugene Ch'ng addresses many of the issues that relate to a project of this type (Ch'ng, et al, 2007). Most notably he champions game engines as a suitable means of "*life-like atmospheric effects and Shader capabilities*" he also notes the online abilities of modern day game engines such as the *CryEngine* (Crytech, 2010) as holding great promise for future collaborative archaeological projects. In a later paper Ch'ng (2009, p. 458) coins the phrase Virtual Time Travel (VTT) to encompass all the elements that contribute towards a digitally simulated virtual environment and puts forward a review of where current technology sits in relation to its uses in virtual archaeology (Figure 2). It is clear from this investigation that technology is now at a point where simulated historic environments for the purpose of archaeological investigation are now a viable proposition. Computer games technology is appearing as a frontrunner for the facilitation of these environments, although more immersive sensory devices such as haptic feedback and augmented reality have yet to mature (Ch'ng, 2009).

	Primitive	**Developing**	**Advanced**	**Established**
Computer Graphics				
Reconstruction Techniques				
Rendering				
Animation				
Interactive Environment				
Selective				
Participatory				
Contributory				
Causative				
enhanced VE (eVE)				
Artificial Intelligence				
Artificial Life				
Climate System				
Multiuser VE				
Computer Networks				
Communications Technology				
Mixed-Reality Technology				
Vision (Head-Mounted Displays)				
Olfactory				
Auditory				
Haptic Feedback				
Augmented Reality				
Global Positioning System				

Environment Sensors				

Figure 2. Diagram depicting the current state of technology for Application in Virtual Time Travel, Ch'ng, 2009

Chapter Three: Literature Review

3.1 Modern developments in Archaeology

Although the genesis of archaeology may be found in the narrow investigations and categorisations of antiquarian societies in the early 19th century it has since exploded into a vast and varied set of disciplines that, although tumultuous in nature, can readily capture the interest and ignite the imaginations of peoples and cultures around the world (Green, 1995). Archaeology's rapid and on-going transformation throughout the last century shows through in the clashing of successive theoretical frameworks. These competing ideas have been developed in an attempt to quantify archaeology's purpose and its application to examining the past. Most prominent was the clash between hard scientific Processualism (Phillips & Willey, 1953) of the fifties and the sociological reflexivity of Post-Processualism succeeding it in the latter half of the 20th century. Both of these frameworks can be viewed as an indication of the discourse that has been playing out between scientific discipline and its relation to the practice of archaeology. Processualism was developed with the aim of marrying archaeology to scientific methodology in its entirety, in particular anthropological study. It took an objective stance of interpretation through the study of artefacts and the effects of environmental change on cultures. Conversely Post-Processualism or as it's recently being referred to "Interpretive Archaeology" partly inspired by the Post-Modernist movement takes a much broader approach to the interpretation of the past recognising the need for a more malleable framework in archaeological study. Perhaps most importantly the Post-Processualist takes a subjective approach arguing that an archaeologist's interpretation of the past will always, and should always be, intertwined with their individual viewpoint. The dispute between archaeology and its relationship to science is on-going, even as we move into the early 21st century (Huffman, 2004; Bednarik, 2005) and is unlikely to conclude any time soon. It is clear however that archaeology and its relationship to science is of great importance when approaching investigations of the past. One place this has been illustrated is in forensic science and archaeology working together on the exhumation of mass graves (Skinner, Alempijevic, & Djuric-Srejic, 2003).

Another direction that has emerged in the social sciences over the past 30 years, countering deterministic models of the past, is that of Agency theory. Essentially this approach promotes an interpretation of the past that accounts for the actions of the individual with relation to their cultural and social bindings along with environmental influences. As (Dornan, 2002) argues agency is still at a stage where its application to archaeology does not possess a consistent framework however this notion of framing the past through a subjective interpretation may lend itself well to an archaeologist immersing themselves in the past with an aim of fostering understanding. Agency theory is part of a post-processual shift towards Phenomelogical archaeology where by emphasis is based on an individual's sensory experience within a given environment, providing qualitative information, rather than a quantitive data set accumulated through experimentation. Phenomenology is however not without criticism (Fleming, 2006) and has been said to rely heavily on subjectivity and lack practical methodologies (Eve, 2012).

(Eve, 2012) explores ways in which phenomenology can be applied to archaeological research and a path forward for its use is beginning to emerge. Eve most interestingly identifies the potential virtual and augmented reality systems hold in making a Phenomelogical approach viable along with addressing issues of methodology by attempting to focus on the "structure" rather than the "content" of any given virtual experience.

As we can begin to see Archaeology as a discipline has always found itself a great beneficiary of the strong forward momentum of scientific endeavour. Take for example the leap forward historic dating techniques took with the introduction of Radiocarbon dating and later techniques such as potassium dating for the identification of further archaeological materials of interest (Figure 3).

	Wood, Plants, Seeds etc.	Bone, Antler, Ivory, Teeth	Tooth enamel	Shells	Stalag Calcite	Pottery, Baked Earth	Slag	Burnt Flint & Stone	Un-burnt Sediment	Obsidian	Glass	Volcanic
Magnetism												
Hydration												
Amino acid												
ESR												
Luminescence												
Fission tracks												
Uranium-series												
Potassium-argon												
Radiocarbon												
Dendrochronology												

Figure 3. Summery Chart of Materials that can be examined by different Scientific dating Techniques, Sandra Hooper, after Aitken, 1990

(Greene, 1995, p.130) discusses how these dating techniques typify archaeology's relationship with science, its development having been reliant on Nuclear Physics and the archaeological applications representing a minor diversion from the central issue. Equally advancements in pathology, in particular X-Ray technology, has allowed for the examination of exhumed historical remains with an unprecedented level of detail. With these examples it can be seen that archaeology benefits much more from the use of science as a tool for specific uses, with an outlined aim, rather than a framework for archaeological endeavour in its entirety.

Far from being a comprehensive review of archaeology's position in modernity this section at least touches on a number of the theoretical approaches being taken in the subject and its malleable nature with regards to these ideas. It also highlights archaeology's innate ability to embrace new ideas and developments, across the entire spectrum of science and modern technology, along with its willingness to improve upon and develop itself. While archaeological theory is itself a tumultuous and constantly evolving area it at least allows us to acknowledge the fact that it is impossible to separate the subjectivity of the investigator, including their cultural bias, and the supposed objectivity of an investigation (Flynn, 2007).

3.2 Archaeological visualisation

Throughout its evolution the processes of archaeological discovery and analysis have been intimately intertwined with representation through images. Whilst archaeology's long standing relationship with imagery brings history to life in ways that stir the imagination it can also be said that these representations contain major issues of subjectivity and interpretation. Firstly and perhaps the largest consideration is, as (Barcelo, 2000) indicates, that we are in fact seeing the past through the eyes of an artist. An artist can only create an interpretation from the information that has been handed to him and it's no secret that more often than not this information will form a fragmented and incomplete story of the past as (James, 2007, p. 25) states *"the only certain thing about any reconstruction drawing is that it is wrong".* Often working anonymously, illustrators of antiquity in the 20th century were the first people to tackle such issues of interpretation. One artist did not work anonymously however and with such a large collection of work (Papadopoulos, 2007) the antiquarian illustrator Piet De Jong and his prominent legacy may help to highlight these problems. (Papadopoulos, 2007, p. 17) discusses De Jong's recreation of a large Fresco featuring two women on the side. As the Fresco was in pieces, most of them missing, De Jong had to interpretively recreate the picture and, as Papadopoulos notes, gives both women hairstyles more reminiscent of the early 20th century rather than the Helladic period that the Fresco had originated from (Figure 4).

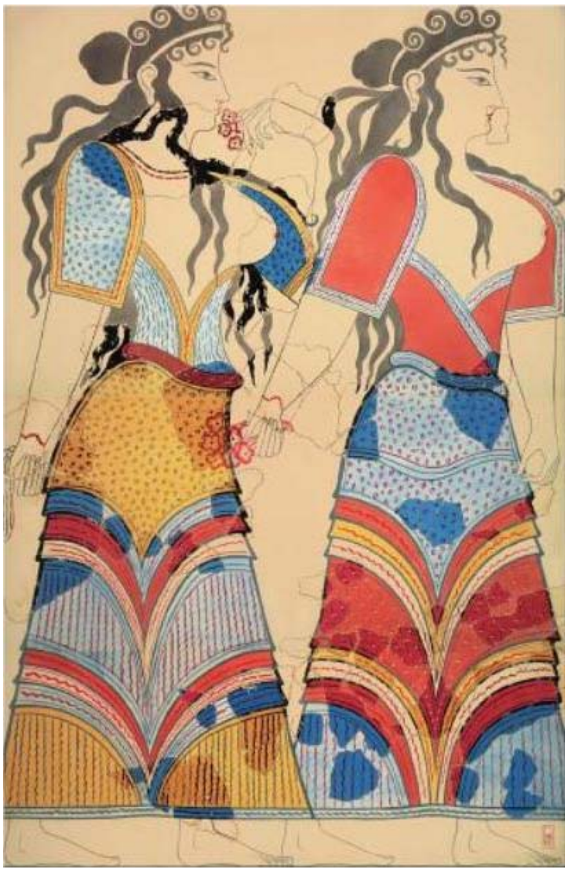


Figure 4. Water Colour by Peit De Jong of the two life-size women from the north west slope plaster dump at the Palace of Nestor Pylos, Lang, 1969

De Jong could have just as easily left the hair out but he has broken no rule as far as archaeological reconstruction is concerned by drawing upon what he knows to interpret the past even if evidence is slim to non-existent. The major concern however is in the audiences interpretation of this illustration and weather that audience now understands 20th century hairstyles to have had existed in the Helladic period as fact. This is also where the intricate detail present in the illustration work against the viewers own reading of the image as (James, 1997, p. 26) indicates that "*people often subconsciously assume that the more impressively finished something is, the greater the authority it carries*". This is a powerful concept that must be understood in order to mitigate and redirect the negative effects of misrepresentation and interpretation.

With the introduction of photography to archaeological (Figure 5) presentation this issue of perceived truth through visual density became of greater importance, having Verisimilitude on its side photography was able to engage with the public on a seemingly much more truthful level. However as (Shanks, 1997, p. 101) indicates photographs are far from "innocent analogues". They are in fact made, and as with the illustrations of De Jong, are subject to the same issues of subjectivity and interpretation through the photographers use of artistic tools such as MISE EN SCENE to construct the image. Furthermore with the use of photographic manipulation software such as *Photoshop* (Adobe, 2011) the idea of the photograph as a Proxy of truth is further thrown into disrepute.

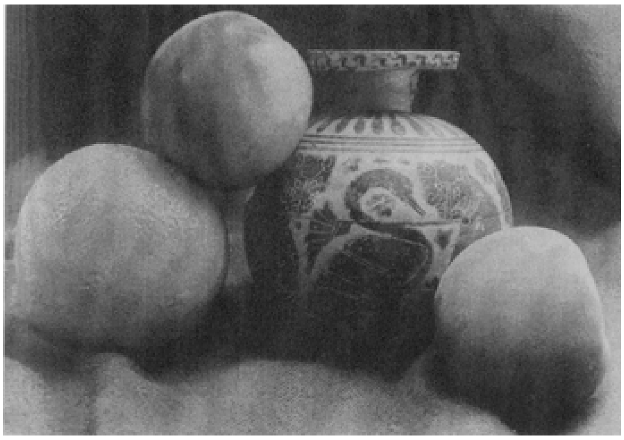


Figure 5. Surrealist still-life: 'Nature morte' Shanks, 1997

This engagement with the public, whilst serving as an end goal for archaeological expedition, brings its own levels of unwanted influence on presentation as the consideration of target audiences is of paramount importance. By presenting history to the public considerations have to be made as to the cultural “baggage” the intended audience may bring and the kinds of prejudices; preoccupations and stereotypes that might promote misinterpretation (James, 1997) with these considerations transcending all methods of informative visualisation.

As Archaeology has developed throughout the 20th and early 21st century it has consistently and openly embraced new forms of media technology such as previously mentioned photographic developments, detailed, special effect laden representations and real-time rendering techniques. Continually augmenting and implementing these new areas of development with the same zeal and enthusiasm it has for aforementioned scientific advancements. Whilst it can however be argued that due to the speed and enthusiasm with which these new forms of visualisation have been embraced a viable framework of implementation for digital reproduction has been side-lined and is only now beginning to be explored (Foni, et al, 2010) the benefits of such technology are clear to see. Visitors to modern day museums, now enjoy a level of interaction with exhibits never before seen (Lepouras & Vassilakis, 2004), exploring the past at their own pace through the use of touch sensitive displays and large scale video projection a primary example being the virtual Egyptian temple (Jeffrey Jacobson, School Of Information Sciences, & Holden, 2005). Equally audiences of archaeology based television programs experience historic reconstructions that draw them into the past in ways that a photograph or illustration cannot.

Whilst emerging visual media has mainly been used to support the communication and interpretation of new discoveries to the broader public it can also serve as a reflexive tool through which the construction, representation and dissemination of archaeological knowledge itself can be questioned (Dyke, 2006). The excavation and reconstruction of a complex timber building by Simon James (James, 1997, p. 29-33) highlights how, when used properly, interpretive illustration can aid in the excavation of a site, helping generate hypothesis that fed questions back into the strategy of the dig itself (Figure 6). Although not a 3D virtual reconstruction this example shows that, even with pen and paper, the power of visualisation in aiding on site archaeological processes. From this on site engagement James was also able to produce three separate illustrative reconstructions to present in the findings, helping to communicate archaeology as a discipline of contrast, comparison and interpretation.

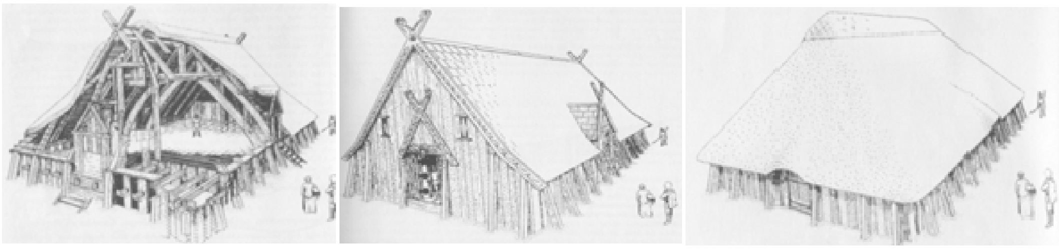


Figure 6. variations on the reconstruction of structure C12 at Cowdery's Down, Hampshire, England from left to right the 'preferred option' the 'Heorot option' and the 'barn option' James, 1997

The presentation of archaeology for public consumption has more than the influences and irregularities of an individual artist to contend with as (Baram, 2008) investigation into archaeologies use within the state of Israel indicates. Baram points to a politicisation of historic representation to serve a nationalist agenda and, with Israel in particular, a need to create a sense of national identity has led to the portrayal of a historical narrative to support this identity. Tours of the biblical city of Jerusalem are constructed around a visitor's particular faith and the omission of sites that contradict that faith. Indeed not the only country to realise archaeology's potential as a tool of propaganda this is by no means a surprising development as the investigation into a country's past will naturally enjoy a level of state funding and, as a result, state influence.

It’s clear to see that archaeology’s relationship with the visual is in rude health with no reason to suggest this will change. Throughout this relationship however lays a veritable minefield of issues regarding misrepresentation, misinterpretation and manipulation. Given this it can be stated that the benefits of archaeological visualisation greatly outweigh the shortcomings, the effects of which can be mitigate through a framework of contextualisation, multidisciplinary communication and audience appropriation.

3.2.1 Archaeological visualisation on TV

Archaeology has always thrived on its relationship with the wider public’s interest and curiosity in the past. Perhaps the biggest contributor to this important relationship has been the universal acceptance of Television into modern life. (Taylor, p. 188) indicates that it is TV’s banal nature that gives it such strength in the presentation of archaeology, arguing that the passive nature by which an audience engages with programs allows for an immediate reflection on their lives. Connecting the minute and the mundane of history with that of the modern world allows immediate comparative access for audiences. Perhaps it is this realisation that leads program makers to use digital visualisation in order to augment rather than override or supplant footage shot in the real world. Examples of this can be seen in a current documentary by the BBC, *City beneath the Waves: Pavlopetri* (Olding, 2011), following a team of underwater archaeologists excavating the ancient port town of Pavlopetri. Great care has been taken to render the Computer Graphics in a way that brings the ancient city back to life in its current underwater state as the city procedurally rebuilds itself bubbles emanate from the bricks and caustics dance across the surface of buildings (Figure 7). This contextual style of digital visualisation extends to micro level artefacts, a diver picks up the shard of a bowl and a 3D model grows around the artefact moving around as if the archaeologist was holding it. Using visualisation in this way may also be seen as an attempt to take the viewers hand, guiding them through the complex archaeological process that are being undertaken at Pavlopetri and allowing for passive consumption of those processes.

Figure 7. [Still from City Beneath the waves: Pavlopetri] Olding, 2011 [image online] available at: http://www.historyextra.com/pavlopetri [Accessed September 22, 2011]

By bringing a team of Hollywood special effects artists on site the program also highlights the importance of a synergy between the archaeologists gathering data and digital artists creating reconstructions. One of the most popular archaeological programs of the past two decades, *Time Team* (Taylor, 1994), although to a lesser extent, has also employed the use of visual artists on site to immediately begin visualising the data being uncovered and the practice of having this on hand method of reproduction stretches back to the days of pen and paper based visualisation (Blegen, 1956). This link between expert and reconstruction is greatly important in the legitimisation of historic recreation and presentation and has also been noted by (Barcelo, 2000). In the BBC Series *Time commanders* (Ansell, 2003) we see historic battles being re-enacted in a digital game environment with members of the public assuming the rolls of general and captain (Figure 8). Throughout each episode the participants, and public, are given guidance through each scenario by two Military experts who asses the outcome of the contestants efforts and then offer the historically excepted sequence of events at the end of the program. This ability to present two scenarios side by side is a powerful one, especially as one has been enacted by the real-time involvement of modern day members of the public. The benefits of using simulated models of the past to allow for interactive user praxis and interpretation have been explored by (Flynn, 2007).

Figure 8. [Time Commanders] PlayGen, 2011 [Image online] Available at: http://playgen.com/portfolio/time-commanders/ [Accessed September 22, 2011]

"They're not watching a Movie, they're in a movie and they can influence that movie" – Time Commanders Military Expert.

The fact that Time Commanders not only demonstrates the power of an interactive simulation environment but the ability of everyday members of the public to interact with that environment, crafting the outcomes, takes the idea of television as presentation and consumption of the banal and adds an entirely new dimension. Unlike programs such as *Time Team* and *City beneath the Waves: Pavlopetri,* where engagement with the past unfolds along a linier path *Time Commanders* presents the viewer with a more tangible and dynamic engagement with the past. Hear we can begin to see the utilisation of interactive visualisation technologies shifting the use of television in an archaeological context away from passive consumption towards a more involving and consequently rewarding experience.

3.3 ParaData and the London Charter

From De Jong's early pen and paper analogue reconstructions to the digital real-time interaction of Time Commanders the power of paring cultural heritage with vivid visualisation is clear to see. With this power however comes a need to appropriate the use and presentation of these fantastic visuals and curb the very real dangers of misrepresentation that comes along with them. The need for an intellectually transparent method of developing virtual cultural heritage has become a central topic in the field and something that has attempted to be addressed a number of times by groups such as the *Virtual Archaeology Special Interest Group* (VASIG),*Cultural Virtual Reality Organisation* (CVRO)and the Virtual Heritage Network (VHN) with the latter providing a large repository of news, information and conference proceedings relating to heritage and technology the existence of these organisations highlights the subjects importance. Recently *The London Charter* (Beacham, et al, 2006) has taken up this task drawing upon the foundations laid out by these groups and consisting of a document that outlines a fundamental set of practices with regards to the creation and presentation of digital visualisation with a view to promote a standard of intellectual integrity and methodological rigour (Figure 9).

Principal 1 – Implementation	The principles of the London Charter are valid wherever computer-based visualisation is applied to the research or dissemination of cultural heritage.
Principle 2 – Aims and Methods	A computer-based visualisation method should normally be used only when it is the most appropriate available method for that purpose.
Principle 3 – Research Sources	In order to ensure the intellectual integrity of computer-based visualisation methods and outcomes, relevant research sources should be identified and evaluated in a structured and documented way.
Principle 4 – Documentation	Sufficient information should be documented and disseminated to allow computer-based visualisation methods and outcomes to be understood and evaluated in relation to the contexts and purposes for which they are deployed.
Principle 5 – Sustainability	Strategies should be planned and implemented to ensure the long-term sustainability of cultural heritage-related computer-based visualisation outcomes and documentation, in order to avoid loss of this growing part of human intellectual, social, economic and cultural heritage.
Principle 6 – Access	The creation and dissemination of computer-based visualisation should be planned in such a way as to ensure that maximum possible benefits are achieved for the study, understanding, interpretation, preservation and management of cultural heritage.

Figure 9. The London Charter as Set out by Beacham, et al, 2006

The London charter essentially provides 3D visualisation a great advantage over archaeological reconstructions of the past where there was no uniform way to authenticate an artistic reconstruction. The primary tool through which this can be accomplished is “ParaData” (Baker, 2010) a term referring to the collection of information gathered through the research methodology and methods of interpretation that went into the creation of a particular digital artefact. During the processes of reconstruction most of this information is lost or simply not represented in the final work and a tool for logging and saving it may bring us closer to a level of intellectual transparency in digital reconstruction. Work has also been done by Nick Ryan (2001) on the technological aspects of applying data aggregation tools for the purposes of logging the creation of peace of virtual archaeology. Recognising the problems of how to represent this type of tool within a program (Niccolucci, & Hermon, 2004) identifies the need to present digital artefacts as “scientific tools” rather than “pieces of art” and puts forward the use of fuzzy logic in asserting a confidence level for a digitally reconstructed object and, in an earlier paper, presents its application to GIS in a visual manner (Niccolucci, et al, 2001). Using a probability scale from 0 to 1 (1 representing an archaeologists complete confidence in the object) it may be possible to implement a tool whereby confidence levels and information on a digital artefacts reconstruction are recorded by a user as the simulation environment is being built.

3.4 GIS and Archaeology

One of the biggest impacts the digital world has had on the archaeological process can be found in the use of Geographical Information Systems (GIS). Over the last 20 years these computer programs have made their way into the toolbox of archaeology as indispensable methods of logging and categorising Geospatial data relevant to sites of interest. GIS is in many ways simply an extension of traditional cartography moving into the digital age and it has made the aggregation and hard analysis of relevant archaeological site data easier than ever (Ebert, & Singer, 2004)(Figure 10). However the fact that these new and powerful tools are essentially being retrofitted onto current archaeological processes raises issues about the nature of these tools and their use. (Witcher, 1999) argues that the novelty and gloss of GIS is a contributing factor to its early uptake in the archaeological community and that the lack of a clear theoretical standpoint has led to the use of GIS in a way that promotes economic rationality and environmental determinism. Witcher is not alone in his criticism of GIS in Archaeology and in particular the fact GIS is not being employed to solve specific problems is a major sticking point for academics (Barcelo et al, 1996; Katsianis, 2005). If we look at the evolution of new-archaeology and the development of processual theory in the late 50's it could be argued that modern day GIS and the hard scientific analysis these types of programs offer have been incorporated into an ideological framework of archaeology that has become many decades out of date. If we are to label current and past GIS as tools of objectivity that help to promote determinism then a way forward may be a digital environment that works in the context of modern day theory's incorporating elements of post-processualism and promoting subjective analysis.

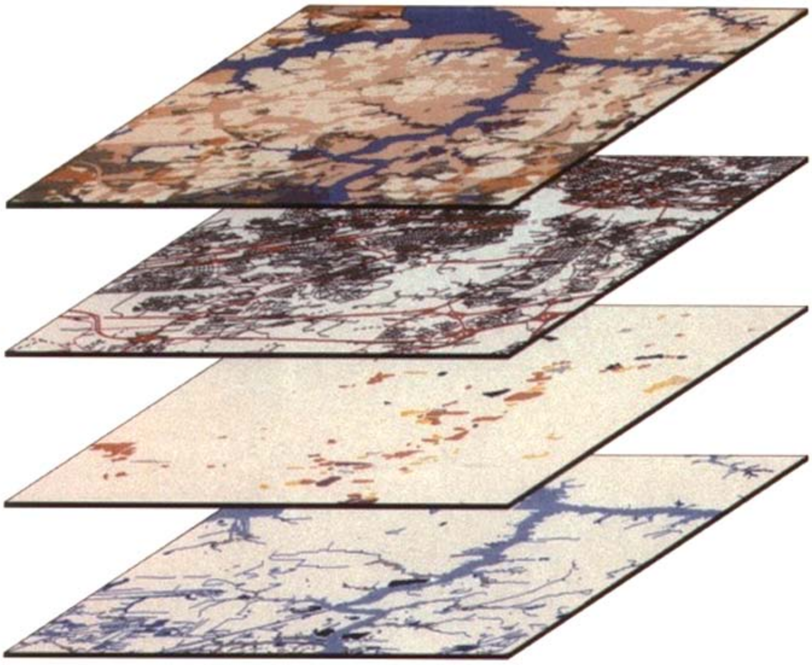


Figure 10. [GIS Layer Cake] n.d. [image online] Available at: http://www.informatics.org/france/gis.html [Accessed October 15, 2011]

"To proceed we need a set of terms to describe the geometry not of abstract, isotropic space, but of the substantial environment in which humans and other animals move, perceive and behave. Thus following Gibson… we speak of surfaces rather than planes, paths rather than lines and places rather than points. (Ingold 1986, p. 147)"

Although writing in the context of society and evolution hear Ingold succinctly describes one of the largest hurdles to face the application of GIS systems to current archaeological processes. While GIS consistently concerns itself with the abstraction and simplification of time and space (through the utilisation of Cartesian points, lines and grids) the simple fact is that archaeology entails the analysis of people, places, environments and all the complex entropy therein. These contrasting theoretical standpoints are outlined by (Tilley, 1994 cited in Witcher, 1999, p. 2) who separates them into Abstract/Scientific and Humanised notions of space although he stresses that neither group are mutually exclusive (Figure 11). Furthermore GIS systems are unsuited to the temporal analysis of people places and environments (Ebert, & Singer, 2004) and, as the report notes, this makes it very difficult for archaeologists to analyse cultural change.

Abstract/Scientific	Humanized
Decentred	centred
Geometry	Context
Surfaces	Density’s
Universal	Specific
Objective	Subjective
Substantial	Relational
Totalized	Detotalized
External	Internal
System	Strategy
Neutral	Empowered
Coherence	Contradiction
Atemporal	Temporal
Absolute	Relative
Static	Dynamic

Figure 11. Abstract Scientific and humanized notions of space, Tilley, 1994 cited in Witcher 1999

Ingold was however writing at a time when the limitations inherent to GIS and archaeology lay not only in the design of the software but also in the raw processing power of the computers they were running on. However even in recent years the incorporation of more 3D oriented features, while promising, has been slow and non-standardised (Zlatanova, et al, 2002) and as (Cross, 2003) notes still cannot accurately account for volumetric data as in points below or above terrain surface. (Brooks & Whalley, 2008) also Explores expanding standard GIS techniques into a three dimensional environment and the possibilities and pitfalls this transition entails. Most notably a need to retain the option for a two dimensional perspective has been identified.

Whilst GIS does not present a viable path forward for visualisation and archaeology in and of itself it has however incorporated a number of tools over the years that have a great deal of potential for archaeology, most notably the application of visibility and view shed analysis to archaeological exploration. Furthermore as (Wheatley, 2000, p. 2) notes the incorporation of visibility studies has not taken place in a disciplinary vacuum as the methods through which these tools are being utilised in a GIS framework are analogous to the manual methods of archaeologists who quantified and represented visibility in the early 1970’s. Wheatley does however level a number of what he describes as “pragmatic criticisms” against the use of visibility studies. These are mainly shortcomings relating to the simplistic graphical nature of most GIS. For example there is great difficulty in accounting for archaeological obstructions such as hedgerows; tree-lines etc. and the simulation of diminished clarity over large distances including the effects environmental variables such as fog might have on vision. Also noted by (Fyfe, 2005, P. 491) in his paper on the simulation of Pollen deposition and dispersal across landscapes the lack of visual fidelity with regards to GIS, whilst being a limitation, is far from an indictment of the software, rather an indication that these systems have not been constructed with subjective archaeological analysis and complex open ended simulation in mind. (Shepherd, et al, 2009) analyses these shortcoming and highlights the extensive abilities of Video Games technology to “out-visualise” the digital environments represented in GIS. Perhaps most importantly Shepherd Pinpoints the contrast between Video Games simulation of synthetic outcomes from synthetic inputs and GIS displaying models of real world processes generated from recorded, real world occurrences (Figure 12). This may be where the two systems can learn from one another and move forward in a mutually beneficial relationship.

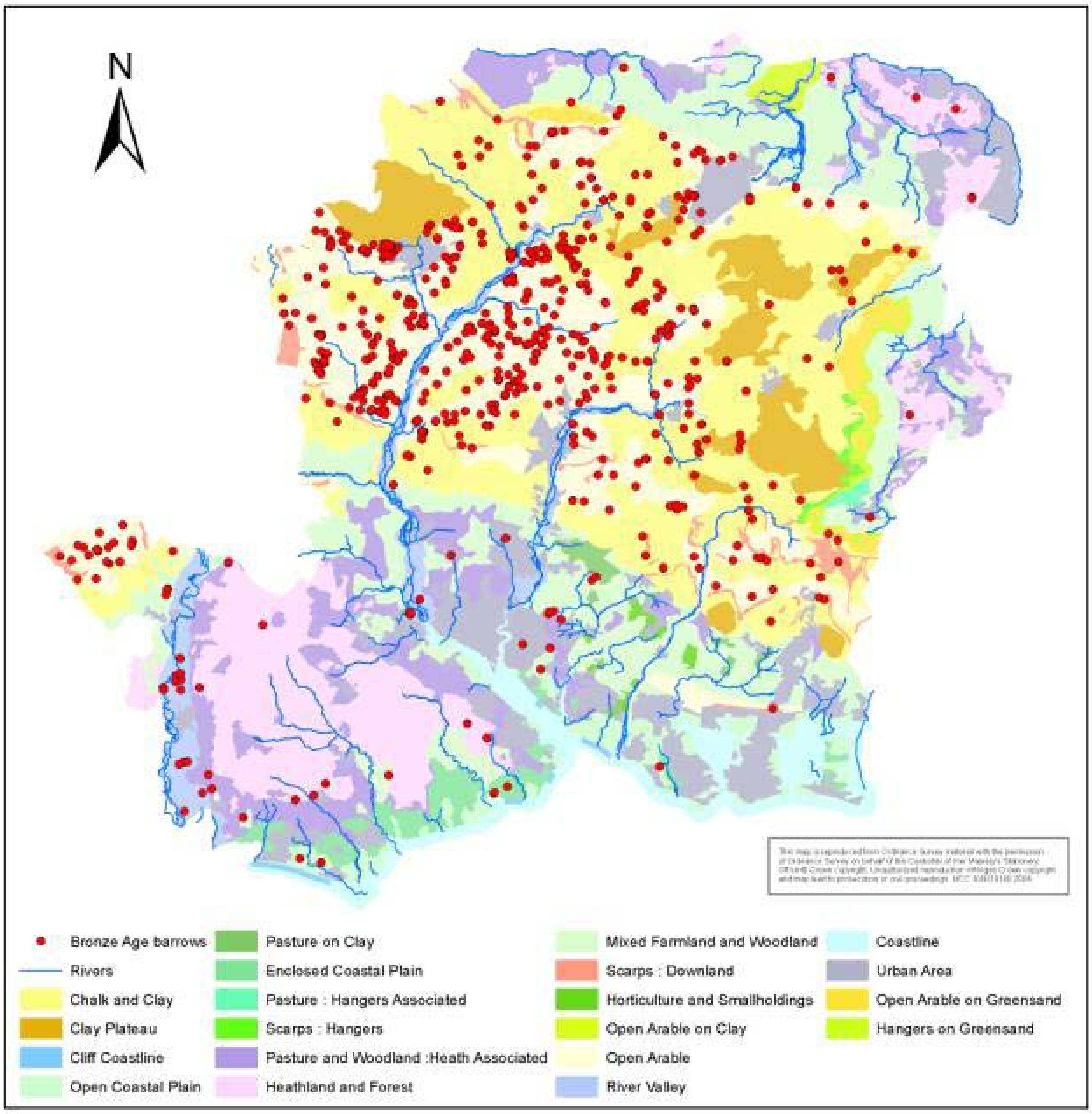


Figure 12. [A GIS generated map showing Bronze Age barrows over Landscape Types and rivers in Hampshire, Hampshire County Council] 2007 [Image online] Available at: http://www.ifp-plus.info/Part_E.htm [Accessed October 20, 2011]

Given the vast increases in computing power and complexity of graphical output over the last two decades and the stagnant nature GIS holds in relation to archaeological discipline it may be time to explore new areas in which the virtual world can begin to emulate the subjective and humanistic approaches archaeological examination now employs . It would however be short-sighted not to take lessons learned and systems developed within GIS and bring them forward into a more contextually productive environment.

3.5 What do Video Games have to offer?

With cultural heritage and archaeological investigations relatively recent engagement with virtual simulation and visualisation perhaps the area of virtual entertainment which has spent the past three decades evolving and refining these tools can aid in defining this new relationship. As (Anderson et al, 2010 p. 256) notes it has been the ever increasing popularity of video games amongst the public that has driven the development of rendering and simulation technology to a point where virtual environments can be taken as a serious proposition for historical investigation. The opening level to *Crysis* (CryTek, 2008) a recent first person "shoot-em-up" sees the player parachute onto a tropical island in the dead of night. Beginning in the bluish hue of a moonlit night the player makes their way to the first objective. As they do the sun slowly rises in the sky, revealing the wide expanse of terrain and meticulous attention to detail that can be found in the environment. Light shafts break through the canopy of semi-translucent palm leaves and volumetric waves lap against the beach as caustics and chromatic aberration play along the water's surface. Incorporating high levels of cutting edge rendering and simulation technologies, Crysis has shown that game environments are now able to reach an uncanny level of realism *"The Crysis environments are so naturalistic, so close to realism, that you find yourself thinking: "of course, because that's how things are supposed to look."* (Rossignol, 2007). Up until a few years ago video games relied on pre-rendered cut scenes in order to ascribe more detail to the game world and draw a player in. It was simply unthinkable to visualise a real-time virtual environment with the same depth of detail you would ascribe to the real world however with faster processors, graphics cards and programming frameworks such as *Direct X11* (Microsoft, 2009) this is the level at which virtual environments have reached. Graphical powerhouses such as *Crysis* can give us important clues as to how a virtual world is able to portray reality to an audience in a manner that suitably mimics it (Figure 13). Furthermore we can begin to understand how representations of spatiality are handled in a virtual environment (Aarseth, 2001), something video games have to consider on a higher level in comparison to the "matter of fact" analogue space of GIS.

Figure 13. [Real Life vs Crysis, Anonymous] 2010 [image online] Available at: http://www.geekstir.com/real-life-vs-crysis [Accessed February 5, 2012]

The question of what spatiality means in a virtual world is one explored by (McGregor, 2007) and through this exploration it is posited that video game space utilises a number of "patterns" that have arisen from society's interaction with real world space. These patterns essentially outline what we "do" in the real world and most prominent to this investigation is that of contested space, Codified space and Creation space (McGregor, 2007, p. 3). Contested space refers to an area as a place for conflict with codified and creation space describing the interface & information given to a space and the creation & alteration of game space respectively. With loosely defined patterns such as these video game designers have been able to construct virtual worlds that users can interact and exist within in a manner analogues to that of real world space, only constricting and refining these patterns to serve the benefit of playability and user entertainment.

Once a virtual space has been created it follows that a system for spatial navigation must be successfully incorporated in order to promote an intuitive and naturalistic engagement between user and program. This user engagement is something that video games must excel at in order to succeed in a competitive market and, as Aarseth points out, games design should prove a rich area in the exploration of this topic (Aarseth, 2001). One of the major limitations of GIS is its inability to utilise viewpoints in order to develop a sense of immersion (Shepherd, 2009, p. 22), this being mainly due to their two dimensional cartographic nature. Video games however make expansive use of viewpoint and camera positioning in order to engage a user, for example *Black & White* (EA Games, 2001) a "god game" in the most literal sense makes use of a gods point of view, far above the game environment affording the user a high level of situation awareness. *Rome: Total war* (The Creative Assembly, 2004) also engages the user in this way giving them a "generals" overview of the battle-space aiding in tactical decision making (Figure 14). Conversely a game such as *DOOM 3* (ID Software, 2004) takes full advantage of the first person perspective in order to subjectively draw the user into an environment of threat and danger, increasing tension and creating a more believable experience (Figure 15).

Figure 14. [Rome: Total War (PC)] Gamespot, 2004 [image online] Available at: http://uk.gamespot.com/rome-total-war/images/341821/ [Accessed March 12, 2012]

Figure 15. [Doom 3 (PC)] Gamespot, 2004 [image online] Available at: http://uk.gamespot.com/doom-3/images/337138/ [Accessed March 12, 2012]

Shepherd (2009) goes on to note that camera placement, whether "egocentric" or "exocentric" has a measurable impact on users performing varied tasks at different levels of difficulty and that it may be necessary to include a method for switching between these viewpoints. A similar set up can be found in *Google Earths* (Google, Inc. 2005) recent *street view* tool whereby a user can move from a 2D cartographic space to a street level first person perspective with the aim of enhancing spatial awareness and navigation. VG's expansive and varied utilization of camera placement/control and user interface highlights the importance of these features to a virtual environment and the impact they have on a users experience and engagement with that environment. If a virtual world is to be created in order to supplant the use of GIS and maximise the potential of open world 3D space then these aspects of virtual user interaction need to be understood and implemented correctly.

3.5.1 Serious Games

With the ever increasing popularity of video games and the rapid increases in sophistication of the virtual environments created around them there potential for novel academic application has not gone unnoticed. The use of interactive entertainment tools to instruct or inform is given the term serious games (Abt, 1987) and a simulation environment for the purposes of archaeological investigation falls within this definition. Given the notion of games as powerful tools for education Clark Aldrich posits that video games and simulation environments represent "Points along a continuum" (Aldrich, 2009). Both examples of Highly Interactive Virtual Environments (HIVE's) and although he discusses HIVE's in the context of learning tools a number of important points are highlighted including, most prominently, how a user may be expected to approach a new virtual environment. He goes on to compare this learning stage to a child learning to swim, firstly getting acclimatised in the water and their new environment, beginning to play, and finally moving on to games that have increasingly complex structure to them. In this instance an Archaeologist represents the child and, as Aldrich illustrates, a level of user competency has to be reached in order to take full advantage of the new environment. In Virtual worlds these take the form of introductory levels or "tutorials" in which a basic set of skills is established to create a familiarity within the environment and promote faster and more productive interaction. Almost all video games employ a learning stage in order to introduce the user to that particular HIVE. For example *Rome: Total War* (The Creative Assembly, 2004) begins with a tutorial level in which a very simplistic battle takes place, it unfolds at the players own pace and introduces navigation, interaction, and game mechanics one at a time until the player can begin using them in conjunction with one-another to become an effective general. Throughout this process contextualised text appears on screen aiding the user and easing unfamiliarity as they ease into this new world. This ties in with Aldrich's swimming pool analogy and is a powerful concept in order to initiate a relationship between a user and Virtual environment, especially one as complex as a reconstructed battlefield.

3.5.2 Criticism

Whilst video games have been tackling the virtual representation of historic events for a greater period of time than most academic ventures it has however been noted (Waring, 2007) that due to the developers need to maximise entertainment value, recouping loses from the production process, factual accuracy of historical elements is often heavily curtailed. Whilst it simply isn't possible for video game developers to accommodate the minute accuracies of particular time periods they're portraying it raises the very real problem that these massively popular forms of media are being consumed by younger generations that have no contextual framework to take what's being presented with an appropriate level of scepticism. This is a prime example of how the visually attractive nature of games, such as *Rome: Total war* (The Creative Assembly, 2004), can work against the portrayal of historical knowledge in popular media.

3.6 Conclusions from Literature

Through an examination of current literature it appears as though archaeology, throughout its theoretical evolution, possesses a restless and conflicting nature. Far from hindering the processes of archaeological endeavour we are in fact experiencing an exciting and fruitful growth in dialectic engagement with the underpinnings of archaeological thought and, what a healthy and vibrant understanding of our history may mean to the modern world. We can also begin to see how archaeology's engagement with the visual is becoming more self-aware in turn informing further use of visualisation and presentational mediums and that directions forward are slowly emerging from this praxis. This self awareness has also lead to the recognition of a more solid set of rules to govern the creation of digital archaeological spaces and artefacts.

With a gradual move towards virtual environments taking place it is also clear that archaeological investigation can benefit from taking on-board lessons learnt about how users perceive and interact with these environments in the games industry and how this interaction may offer a perspective on the past that GIS cannot compete with. Now that theoretical developments in archaeology clearly favour a more subjective approach to the past perhaps an interactive computer visualisation that shares this stance would prove more useful, whilst maintaining intellectual rigor by following rules such as those found in the London Charter. A marriage between the processualist advancements of experimental archaeology and GIS with the subjective interaction and interpretation offered by today’s real-time virtual environments and visualisation techniques may provide a suitable framework for the development of a simulation environment for archaeological investigation.

Chapter Four: Design & Specification

In this section the feasibility of creating a program for archaeological investigation given the state of current technology will be discussed including possible roadblocks and paths forward. The section also examines a number of these existing technologies and how they may contribute to the creation of a digital environment for the purposes of archaeological investigation and interpretation. Their suitability will be critiqued and assessed for the purposes of applying them to a workflow for the creation of such an environment. In the interest of scope the investigation will centre on the environment of Bosworth Battlefield and the needs of an archaeologist as defined by Glenn Foard (2004) and also the physics based simulation of cannon shot, and what that entails (Allsop, & Foard, 2007) in order to help interpret the direction and nature of a battle.

4.1 Affordability

While there is a need for specific problems to be solved in order to take better advantage of new digital analysis methods, developing a simulation environment from scratch is prohibitively expensive. A number of projects concerned with the development of virtual environments for research highlight the considerations that need to be made with regards to cost effectiveness in the development process (Oleggini, et al, 2009; Fritsch, & Kada, 2004). This creates a conflict of interest between the specific questions of an archaeologist and the resources available to build an environment in which those questions can be investigated. It is clear that the ground up development of a virtual environment is untenable. One solution may be the savvy employment of open source software or the licensing of a highly versatile game engine coupled with the design of a versatile environment that can be expanded upon and applied to many other areas archaeological investigations.

4.2 Modern Game Engines

A computer game engine essentially forms the top level abstraction layer that ties together the myriad of components making up a complex virtual environment such as rendering, physics and artificial intelligence (Al-Najdawi, 2007). With many companies today either providing the full engine and source code or a suite of scaled back design tools enabling custom content creation they are becoming an increasingly popular option in the development of interactive environments for the purposes of scientific and academic research (Baker, S. 2008). As baker points out game engines, due to the needs of the developer, come in a wide variety with varying strengths and weaknesses reflecting the design goals of the game they were created for. This point has not gone unnoticed by other academics that see the quantification of these differences as greatly important in exploring their application to “serious games” (Andreoli, De Chiara, Erra, & Scarano, 2005; Anderson, Engel, Comninos, & McLoughlin, 2008).

With a simulation environment that is purpose built to facilitate the needs of somebody exploring large areas of land it would be logical to assume that an engine built to handle the Real Time Strategy (RTS) genre of game would present a promising starting point. Baker points out however that engines designed around the First Person Shooter (FPS) genre of games represent the pinnacle of current technology. It can be argued that this results from the highly subjective nature of an FPS, with a push towards a gamers’ complete submersion in the virtual world and, as a result hyper realism, and forms a major design goal for the genre. Furthermore if we look at the typical example of a real time strategy game like *Civilization V* (2K Games, 2011) the environment is rendered in a “chunky” style favouring a more iconic design (Figure 16). This can be attributed to the large amount of action that takes place on screen and that the player has to deal with, however even with the most recent instalments of the more historically oriented *Total War* series the level of “up-close” detail simply cannot compete with that found in FPS games such as *Crysis* (Crytek, 2008) or *Gears of War* (Epic Games, 2006). This contrast between the “experiential” and “symbolic” nature of game worlds is noted by McGregor (2007, p. 4) when looking at design differences between *Word of Warcraft* (Blizzard, 2011) and *Battle for Middle Earth 2* (EA Games, 2006). In recent years the FPS genre has seen a marked shift from claustrophobic corridor shooters on rails i.e. *Doom 3* (ID software, 2004) to expansive streaming open world environments such as those found in *Crysis*. With this in mind it may be prudent to look at design tools developed for the creation of these kinds of games in order to take full advantage of the subjective immersion they have to offer and that interpretive archaeology appears to be moving towards.

Figure 16. [Civilization 5] Anonymous, 2005, [image online] Available at: http://www.pcgameshardware.com/&menu=browser&mode=article&image_id=1436697&article_id=794274&page=1 [Accessed March 12, 2012]

Crytek's *CryEngine*, Id*Tech 5* and Epic Games *Unreal Engine* represent three of the most prolific and cutting edge engines on the market today, each with its own advantages and disadvantages. The *CryEngine*, in its third iteration, developed originally for the first person shooter *Far Cry* (Crytek, 2004) features vast open world terrain capabilities (Figure 17) a multi-threaded physics engine, *DirectX 11* (Microsoft, 2009) rendering features such as sub surface scattering, Hardware tessellation, Depth of Field and volumetric lighting and has recently released a free Software Development Kit (SDK) for non commercial use (Crytek | MyCryENGINE, n.d.). Having already made its way into serious games the engine has found use in projects such as a training simulation for the Australian Department of Defence ("Australian Government, Department of Defence - Stephen Smith MP," 2011). (Germanchis, Cartwright, & Pettit, 2005) also identifying the potential of video game environments over GIS uses an earlier version of the *CryEngine* to drive a large scale recreation of Queenscliff Victoria. Currently on its fifth iteration the *ID tech* engine has, unlike the two other examples, undergone major changes to its design orientation as it has progressed through versions. Due to a new environment painting process known as "Mega-textures" the engine boasts support for textures at 128,000 x 128,000 pixels in size allowing for giant detailed streaming environments (Figure 18). Previous releases of the engine have supported user creation with the "radiant" editor the latest version appears to pursue a more developer friendly orientation with the proprietary "mega-texture" technology streamlining multiplatform development. Although an open source SDK is due to be released later in the year of writing *ID tech 5* has very little in the way of modification support and is relatively light on robust rendering and physics technology.

Figure 17. [Screenshot of a forest map included with the CryENGINE 3 SDK, KRYPTON SPARTAN] n.d. [image online] Available at: http://crysis.wikia.com/wiki/CryENGINE_3 [Accessed March 12, 2012]

Figure 18. [RAGE (PC)] BigTnaples, 2011, [image online] Available at: http://www.neogaf.com/forum/showthread.php?t=440026&page=7 [Accessed March 12, 2012]

Finally Epics *UnrealEngine* has become the most popular choice amongst game modification enthusiasts and academics alike (Lepouras, & Vassilakis, 2004). Having been first released in 2009 the Unreal Development Kit (UDK) now boasts a vast set of flexible development tools, online support community and documentation (udn.epicgames.com). Currently in its third variation the engines core interface and toolset has changed little since its first release in 1998 owing to its efficiency and intuitiveness (Gatzidis, Brujic-Okretic, & Baker, 2008). The major changes that have been made are primarily to the rendering and Physics pipeline with the engine now able to handle post-processing effects such as depth of field, volumetric lighting, HDR lighting (Figure 19), a highly customizable particle engine and open environments of up to 10 kilometres squared with support for further expansion. Perhaps most importantly the unreal engine comes with versatile, powerful physics computation in the form of the *PhysX engine* (Nvidia, 2012). In terms of processing cost the *Unreal Engine* is incredibly versatile, running with a high level of visual fidelity even on systems of a modest configuration, this can be seen in the UDK's ability to develop for ISO devices such as modern smart phones, setting it apart from the *CryEngine*.

Figure 19. [Unreal Engine 3 DirectX 11 Features] Anonymous, n.d. [image online] Available at: http://games.softpedia.com/progScreenshots/Unreal-Engine-3-DirectX-11-Features-Trailer-Screenshot-87943.html [Accessed March 15, 2012]

Each engine offers its own strengths and weaknesses and a large number of game engines available today are capable of contributing to the archaeological community (Anderson, et al, 2010; Gatzidis, & Okretic, 2008). However given its versatility with regards to hardware requirements, in depth support documentation and *PhysX* integration the *UnrealEngine* would make a suitable option for the development of a virtual environment for battlefield interpretation.

4.3 Three Dimensional Modelling

Whilst there are a number of procedural and easy to use tools i.e. *SpeedTree* (IDV, 2011) that can aid in the population of a large scale outdoor environment there are many objects, such as artefacts, that still need to be modelled by hand. For example the artillery component must be hand crafted taking into consideration historical documentation, expert opinion and existing discoveries. Modelling of an artefact as complex as a cannon and carriage must take place in a specialised program such as *3D Studio Max* (Autodesk, 2011) (Figure 20) where the object can be constructed textured and exported, using appropriate files, to the Game Engine.

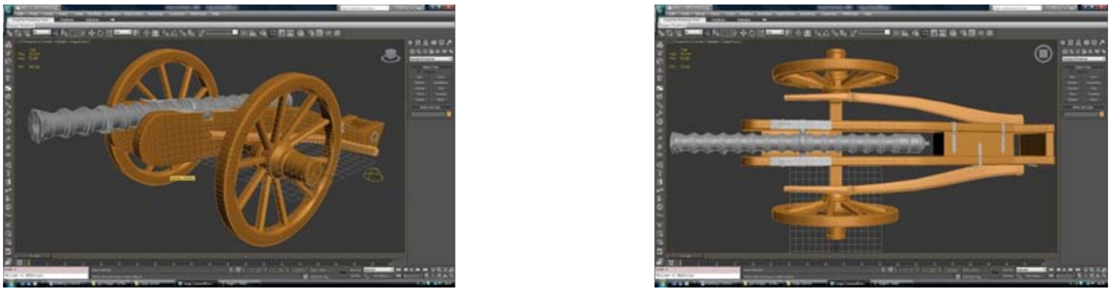


Figure 20. Darlington, J., 2012, Cannon Model in 3D Studio Max [Screen Capture]

Traditionally to model an object in a 3D environment it is better to have a larger set of pictures (usually Top, Side, Front shot straight on) but in the instance of artillery for Bosworth this wasn't possible. Beyond being a large setback to the modelling process this shortcoming in reference imagery is a problem that is all too common in the work done between archaeology and the reproduction of history. Sometimes it is a lack of understanding between two completely different skill sets that can cause setbacks or that the procurement of sufficient reference material is impractical or that such material simply does not exist. As with many cross discipline endeavours of this nature strong communication between the people with historical knowledge and the people with modelling knowledge is paramount (Lepouras & Vassilakis, 2004, p. 97). In particular there must be an understanding of exactly what the archaeologist needs in terms of detail and end result, conversely what the artist needs in terms of resources and reference material. As an example If the artefact being reconstructed is to be used in an interactive display/environment then the model will need to be constructed with constraints on the number of polygons and the size/detail of textures created although with the increasing power of real-time rendering these constraints are being reduced every year.

4.3.1 Photogrammetry

One of the major problems to threaten a productive workflow between the archaeology world and 3D environments is the modelling process, namely the accurate reconstruction of artefacts and objects of interest in a 3D environment. As mentioned there is a lack of cohesion between historical expert and software expert and whilst in the 21st century, through the introduction of GIS, archaeologists have had to become more computer literate the fact remains that computer modelling programs such as *3D Studio Max* (Autodesk, 2011) are very specialised pieces of software requiring a particular set of skills. A possible remedy for this may be the use of a technique called Photogrammetry. This is a process through which three dimensional virtual models are reconstructed automatically from a series of photographs taken at intervals around an object of interest or historical artefact (Figures 21 & 22). In conjunction with other techniques, such as laser scanning, it has already began making its way into heritage preservation and presentation (earl G, et al, 2010; Escarcena, et al, 2011). Laser Scanning involves the Volumetric Capture of 3D data and colour information through the use of Laser Light. This method offers highly detailed scans of surfaces and objects. The data is however provided as point clouds where hundreds of thousands of individual points in space make up the object (Archaeological Data Service, 2012). Whilst it has been noted that high detail volumetric surface data may be of use in educational displays (Ch'ng, 2012, P-146) this format would not be well suited to a large scale interactive battlfield environment. Perhaps by creating a pipeline that can re-appropriate this large amount of data, utilising tools such as the re-topology software TopoGun (PIXELMACHINE, 2009), Laser Scanning can become a viable option for capturing 3D information. If applied correctly processes such as these may also aid in maintaining transparency in a pipeline that could go towards developing an environment whereby academic conclusions are able to be drawn from its use.

Figure 21. Darlington, J., 2012, Elephant Ornament [Photograph]

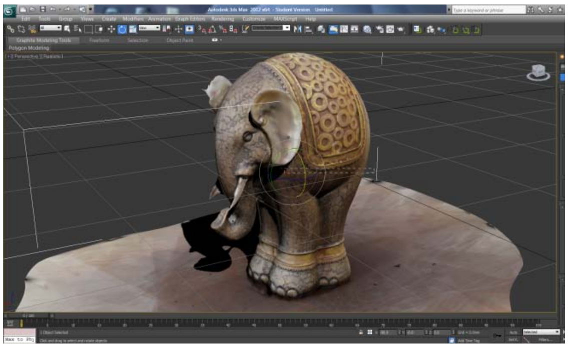


Figure 22. Darlington, J., 2012, Elephant Reconstruction [Screen Capture]

With relation to the work being carried out into the engagement at Bosworth it may offer a new streamlined workflow between the archaeologist's requirements and artist. The guns being investigated for Bosworth are situated in a museum in La Neuveville, Switzerland. This distance raises issues of impracticality whether the guns were to be moved or artists/modellers were to be transported across the continent. A more viable option would be an archaeologist, equipped with a digital stills camera and a tape measure sending the necessary information instantaneously. Whilst photogrammetry seems like the perfect solution for this it is in fact an imperfect process and there are a number of programs available that do the job of digital reconstruction with varying degrees of accuracy and speed. *123DCatch* (Autodesk 2011) is one of the most promising tools, using cloud computing to calculate 3D information with speed, and exporting objects in a wide variety of useful file formats such as .OBJ and .FBX however, depending on the number of photos taken, lighting, angles etc. the objects are processed and reconstructed with often unpredictable results. Even the best set of photos, when analysed by the program, create models made up of a dense tessellation of irregular polygons making them more suited to visual and spatial reference rather than an end product (Figure 23). With every release of real-time rendering software we are seeing giant increases in poly-counts (the number of polygons that can be rendered simultaneously on screen) for example when the *Unreal engines* second iteration (Epic Games, 2002) was released in late 2002 it ran well with a poly-count up to around 50,000 whilst *unreal engine 3* (Epic Games, 2004) can be pushed far beyond this with individual meshes supporting polygon counts up to 32,000 however with support for "Real-time bump mapping" extremely high detailed meshes can now be used to provide proxy normal map information for lower detail meshes that run in real time, further lifting restrictions on detail (Epic Games, 2012).

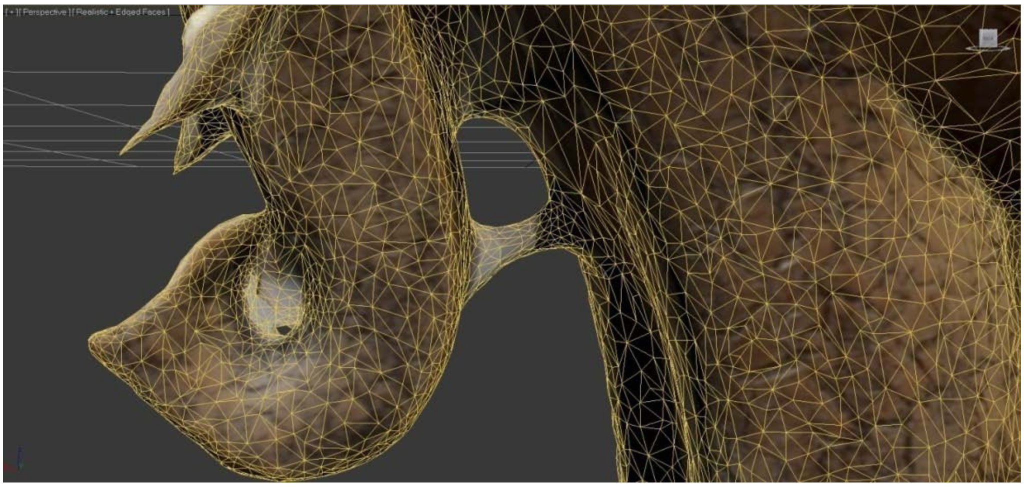


Figure 23. Darlington, J., 2012, Reconstructed Model Tessellation [Screen Capture]

(Devlin, et al, 2002) notes the preferred use of digital visualisation for presentation over research and analysis in there paper investigating the usability of lighting models in experimental archaeology. The paper goes on to highlight the concern for a contextual framework for archaeologists familiar with 3D concepts. Due to the fact that research of this kind only requires polygonal surfaces for light to fall on perhaps this is an area where photogrammetry can provide a strong presence in an experimental environment whilst simultaneously addressing issues of context, as the archaeologists are essentially creating the visual reference data themselves.

Whilst photogrammetry is at a stage to offer great gains in the presentation and representation of historic objects with promise for certain areas of experimental archaeology, the methods available for processing photographs into digital models do not yet yield results refined enough to implement into the workflow of an interactive virtual world based in a game engine. A more precise and controlled method of digital reconstruction is still required utilising the skills of 3D artists although photogrammetry may still provide these artists with a much more tactile and accessible form of reference to begin the reconstruction process.

4.3.2 Detailing a virtual environment

As previously discussed the rendering power of modern day game engines is bringing virtual worlds to a point where reality can be mirrored in a very influential manner. The power of the photograph, with its ability for complete verisimilitude, illustrates the effect perceived reality has on the human subconscious (James, 1997, p. 26). Although this power can potentially be harnessed in the virtual world it requires a much great magnitude of work to do so. In order to impart a sense of reality into a virtual 3D model it must be given the necessary level of detail. With a higher level of detail at one point required a higher number of polygons, however, by taking advantage of current generation rendering techniques along with content creation tools such as *Photoshop* (Adobe, 2011) and *Mudbox* (Autodesk, 2011) a perception of reality, and the power that comes with it can be harnessed. The use of these programs has already made its way into archaeological reconstruction for presentation (Rajapakse, et al, 2011, p. 200) with this paper highlighting the visual impact that the correct use of these technologies can have.

MudBox is known as a “Digital Sculpting” tool and can work in tandem with 3D polygonal modelling software allowing a user to sculpt micro level details into a heavily subdivided polygonal mesh (Figure 24). The user can then paint the object in an intuitive manner using a similar set of brush based tools, exporting the finished detail as a selection of texture maps using algorithms built into the program when they’re done. These maps such as Bump, Normal, specular, Ambient Occlusion etc. can then be utilised in a game engine to give the impression of a higher level of physical detail than is actually contained within the base polygonal mesh.

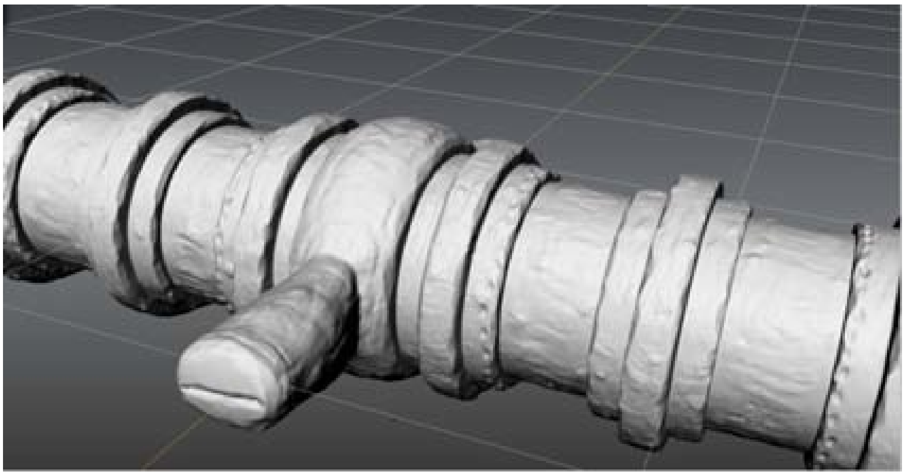


Figure 24. Darlington, J., 2012, Detailed Cannon Barrel in MudBox [Screen Capture]

Although programs such as *Mudbox* and Pixologic's *Zbrush* (2012) allow artists an extreme level of control over the detail of virtual worlds they still require skilled artists with solid lines of communication to archaeologists in order to have an impact.

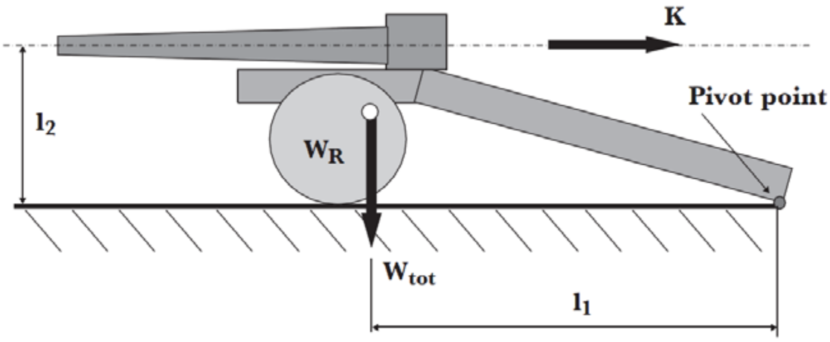
One process whereby an archaeologist may be able to equip themselves with the tools for necessary for digital content creation and offering the ability to capture precise surface detail on archaeological objects is Structured Light Scanning. By projecting vertical stripes of light onto an objects surface a camera can then take pictures of the protrusions in the stripes, a piece of software then analyses this and assigns X, Y, Z coordinates to each pixel in the picture. Whilst this method can capture high levels of detail, along with colour information, there are limitations due to a cumbersome set up and a need for controlled lighting conditions in order to accurately capture 3D data (McPherron et al., 2009).

4.4 Creating a Physical world

One of the most important indicators of Bosworth Battles flow and direction is Lead cannon shot that has been excavated from site. Initially the idea of creating an environment solely for the purpose of replicating this historic cannon fire in an accurate a manner as possible was proposed. However, due to the number of variables involved in firing artillery and that was fired hundreds of years ago during the heat and confusion of battle the idea of utilizing a real time physics engine in order to produce quantitive results is simply untenable. Applications such as *Istrelok* (Borisov, 2012), a ballistics trajectory calculation tool illustrate the number of variables involved with simulation of this nature without accounting for ancillary environmental variables. Instead the reverse engineering of real world data such as that being generated at Cranfield (Allsop, & Foard, 2007) may provide a much more sustainable solution. From this method of reverse engineering real world data, the virtual simulation of cannon fire would serve as a signifier to the action in much the same way as the lead shot found at Bosworth rather than a process through which new insight into the methods of cannon fire can be found. However a simulation environment still requires the ability to understand Newtonian physics with relation to objects in the world and secondly how those objects interact upon collision with each other. Traditionally physics simulation has been a vastly CPU intensive exercise requiring large amounts of time to calculate. Although in recent years, owing largely to the influence of video game development and the vast processing power of modern day multicore CPU's, physics calculation has become a much cheaper and more robust processing task. Real time physics engines have become common place in modern day video games although they are not necessarily designed for precision or scientific accuracy, rather creating the illusion of a physical environment. With a focus on fast visualisation and intuitive interactivity the use of a real-time physics engine would be a more appropriate choice however, as mentioned, this will not form an accuracy oriented solution. (Boeing & Bräunl, 2007) points to the complexity involved in selecting a physics engine although as the report indicates *PhysX* performs uniformly well across a number of tests and as it is already fully integrated into the *UnrealEngine* will form a suitable option.

(Weitnauer, Haschke, & Ritter, 2010) in assessing the application of physics simulation to aid in robotic physical reasoning pinpoint some major problems inherent in physics simulation including stability. Mainly the "limited numerical accuracy of floating-point operations" can cause a decrease in simulation accuracy. By identifying a number of factors that had a significant effect on the stability of simulation precision Weitnauer, Haschke, & Ritter were able to mediate discrepancies between real world physical interaction and virtual simulation. This work was however aimed at a flat object moving across a flat surface although it does show the ability to augment an engine designed for use in games entertainment to fit a more specific purpose.

From the Report published by Glean Foard and Derek Allsop (2007) into the replication of artillery case shot of the 17th century a number of potentially important requirements for the physics engine component begin to emerge. In order for the simulation environment to complement the work being done in the real world it needs to have the ability to imitate a number of variables outlined in the experiment in particular relating to cannon construction (Figure25). Firstly the report describes case shot packed with a varying number of bullets (up to 100) which straight away raises issues of collision stability and friction. The second variable to take into account is the propellant of the gun although impulse actuators are included with most physics packages including *PhysX* and would prove an adequate analogue in imitating the forces exerted by gunpowder ignition.



K = recoil force
$W_{tot} = m_{tot} \cdot g$ = total weight
l_1 = distance from CofG of gun to end of trail arms
l_2 = Height of bore axis

Figure 25. Turning Moment on a Gun Mount caused by the recoil forces, Allsop, & Foard, 2007

The report goes on to discuss a number of other variables that where only found to be a factor once the initial stages of experimentation had begun, principal among them is the effects of “Gun Jump” and soil consistency on the scatter of lead shot. Gun Jump is simply the variable defining how far the barrel lifts off the ground and changes angle at the point of firing (Allsop, & Foard, 2007). With further field work the effects of this phenomenon can be assessed and reverse engineered to form part of the simulation options either as a dynamic result of the firing weapon or an independent variable that can be set by a user. With the unreal Engines PhAT (Physics Authoring Tool), key-framed animation can be blended with physics simulation to achieve the desired results (Unreal Physics, 2012). Using the same method of reverse engineering results from field work soil consistency can be superficially mimicked by altering the level of friction and bounce (both features included in the *PhysX* engine) that the virtual lead shot experiences when it interacts with the terrain, for example areas of softer geology absorbing more energy from the bounce than a firm surface. These examples show that a physics engine should be able to meet the needs of a program aiming to “mimic” if not simulate historic cannon fire and, although relative accuracy would need to be assessed, when used in conjunction with other interpretive and subjective features physics simulation poses a viable path forward as a tool for interpretation.

4.5 Landscape Interpretation

By drawing upon a number of techniques used in landscape study Glenn Foard (2003) demonstrates how the interpretation of a historic engagement can be refined and understood much more clearly by approaching the geography with a subjective mind-set. As we are beginning to see, subjectivity plays a major role in the newer forms of interpretive archaeology and it is hear that video games technology, working in tandem with some of the most recent tools and developments from GIS and Landscape archaeology, can take full advantage of subjective forms of investigation and interpretation.

Taking this approach to interpretation further and extrapolating it to cover the entire theatre of a conflict (Bleed & Scott, 2011) examine how modern day models of war can be applied to sites on the great plains of North America in order to develop "*a synthetic archaeological interpretation of conflict".* Whilst it is noted in the report's conclusion that much more work needs to be done in order to define the impact of this method of approach it does highlight the growing interest in utilizing modern day interpretive models in order to subjectively place ourselves in the landscapes of past conflict. This drive to view the landscape in a subjective manner has led to the use of GIS tools such as Viewshed and terrain analysis (Figure 26) that has allowed archaeologists to understand the terrain in a way that's analogous to the soldiers view of the landscape hundreds of years ago (Scott & McFeaters, 2011, p. 111). Whilst only currently employed in GIS systems there is no reason to suggest that there use cannot be adapted to a more intricate virtual environment where a more robust, real-time approach can be taken to their use.

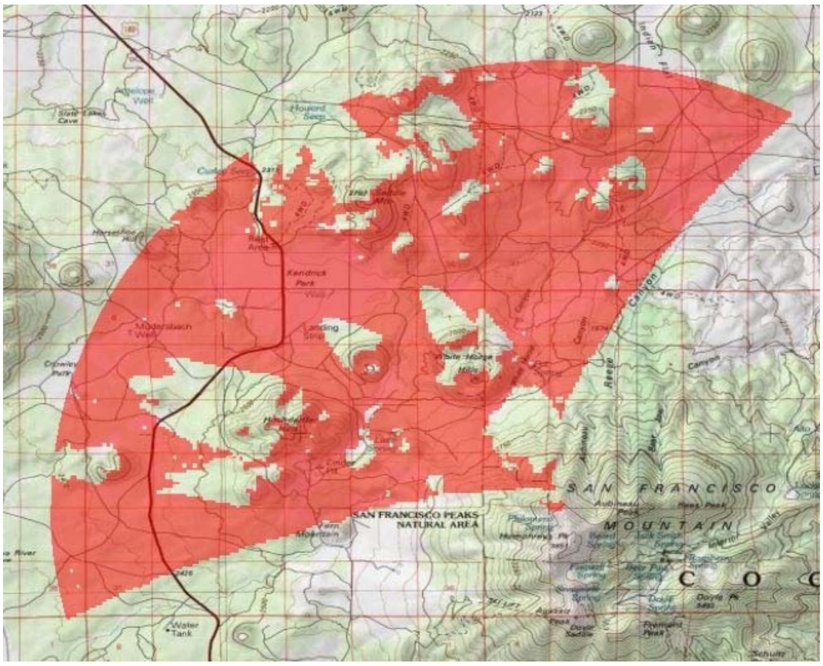


Figure 26. [Viewshed] Anonymous, n.d. [image online] Available at: http://freegeographytools.com/2011/useful-arcgis-explorer-add-ins-i [Accessed March 15, 2012]

Terrain Analysis or as it's known in its more formal military role KOCOA (Key terrain, Observation and fields of fire, Cover and concealment, Obstacles, and Avenues of approach) is a prime example of how a military force can assign meaning to a landscape. By including this type of analysis as a tool within a virtual environment the user would be able to conduct a parallel train of interpretation, informing not only their investigation but how they can continue constructing an environment from documented accounts and geospatial data. (Foard, 2004, p. 51) in his re-assessment of Bosworth identifies the old roman road as a key feature of tactical importance with regards to the armies approach. This road could be sculpted into the environment by a user whilst a colour coded KOCOA visualisation runs in real time allowing them to fine tune the most likely positioning for the road. If we refer back to McGregor (2007) and the idea of "codified space" wherein the landscape of a game world is codified to serve narrative importance in the same manner an archaeologist can codify the virtual analogue of battlefield terrain such as Bosworth in order to bring them closer to a meaningful narrative of the historic battle. Where a games designer might introduce a resource rich area to the landscape, giving it strategic importance to the player, an archaeologist can identify an area for cover and concealment, highlighting that particular area of the virtual landscape as being of strategic importance to any given faction at Bosworth.

4.5.1 Creating Terrain

One of the greatest limitations to experimental research being carried out into historic firepower is the inability to factor in a practical replication of the terrain and its features at the time of the battle. Variables such as tree lines, soil types and surface discrepancies are simply unable to be controlled during a practical live firing. Within a digital simulation environment however terrain variables such as these may be easily factored in starting with the use of a Digital terrain Model or (DTM). DTM's have had a use in geological analysis for quite some time and essentially consist of a data spread sheet with three tables representing easting, northings and elevation. GIS applications can then interpret that data to create visual representations of the terrain e.g. height maps, contour maps and elevation models. Although there is no straightforward workflow for turning DTM data into workable geometry for a virtual environment files can be provided in Autodesk's proprietary .DWG format for 3D viewing and there are ways in which the data can be exported in a manner accessible to 3D applications (Rajapakse, et al, 2011, P. 199). For example the GIS Program *MapInfo Professional* (Pitney Bowes, 2011) contains a feature that allows the user to generate black and white "height-map" images from the elevation data contained within a DTM. This map can then be saved out into a suitable image format and utilized in a game engine or 3D Modelling Package (Figure 27). Whilst a height-Map image can be very robust in its use limitations such as texture resolution in game engines and image file format compression algorithms further limit the detail contained within the data.

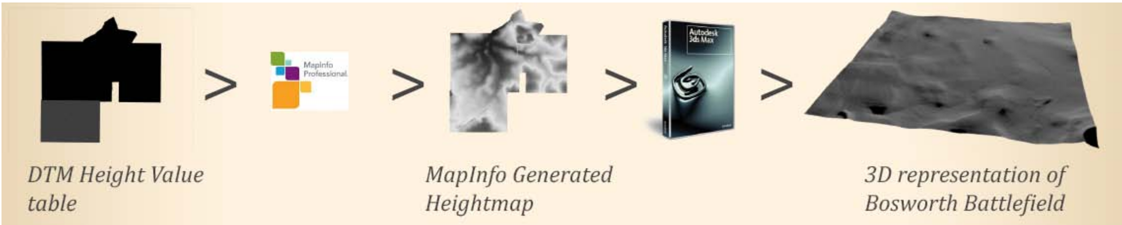


Figure 27. Darlington, J., 2012 Process for turning DTM data into 3D Terrain [Screen Capture]

The use of a Digital Terrain Model does in many ways help bring us closer to a virtual representation of the real world battlefield. However the benefits of a DTM only exist on a macro scale with even the most detailed of survey data only accounting for discrepancies of around five meters (NEXTMap, n.d.). Furthermore these scans do not take into account "soft" surface features such as vegetation, woodland or bodies of water. Whilst other topographical recording techniques are available such as Orthorectified Radar Image (ORI) and digital surface modelling (DSM), both of which have a much greater level of accuracy in determining surface features large and small. The nature of the simulation environment would make these formats unwieldy in a game engine and perhaps starting with a base level representation that can be modified and built upon would be a more suitable approach. As we are dealing with a landscape that has changed considerably in the last 500 years only the large scale features provided by a DTM are of any real significance with regards to tangible geometry. Perhaps a suite of tools for manipulating that geometry, building in micro level detail as required, would provide a more suitable workflow.

The first major issue that arises is the level of detail that can be expected from the terrains surface geometry and, from a physical perspective, would directly impact the accuracy of a simulation model. In recent years game engines have been primarily concerned with the illusion of detail, imitating visually rich and detailed environments through the use of bump and Normal texture maps. With the introduction of *DirectX 11* and hardware tessellation (a process for creating highly detailed volumetric geometry in real time environments) these micro level terrain details can be taken into consideration with a much smaller impact on processing resources. For example at the time of the engagement at Bosworth agricultural techniques were being employed for tending the land and these techniques created an archaeological phenomenon across the terrain known as "Ridge and Furrow" (Figure 28). These mounds of earth would, at their time of use, have been over six feet high in places making these irregularities an important variable to consider in the interpretation of lead shot distribution.

Figure 28. [Medieval Ridge and Furrow above Wood Stanway] Harding, P., 2007 [image online] Available at: http://www.geograph.org.uk/photo/640050 [Accessed October 15, 2011]

Unlike DTM data that can be converted to height map information for export from GIS Ridge & Furrow variation is too small to be represented in this manner. Even with high detail LIDAR scans of the area modern striations that are recorded would bear very little resemblance to what existed in the 15th century. Work done by Glenn Foard does show how R&F information derived from aerial photography can be converted in to polygonal data in MapInfo (Foard, 2004 p. 47). This, when exported into a virtual environment, would contain the necessary measurement information for a user to "calve" the R&F themselves using a set of tools and pre-sets.

4.6 Vegetation

One area in which GIS severely lacks ability as noted by (Shepherd, & Bleasdale-Shepherd, 2009) is in the effects of vegetation and micro level obstacles on sight lines, owing mainly to the resolution of the majority of modern day terrain model scans. Even higher detail LIDAR scans cannot account for flora that may only be evident in historical documentation and this is an area wherein the advantages video games technology possesses are clearly visible. Aside from sight lines Glenn Foard's reassessment of Bosworth battlefield also indicates (Foard, 2004, p. 45) the effects vegetation has on troop movements and deployment further making the inclusion of plant life a priority in order to increase the accuracy of interpretation. In virtual environments vegetation has traditionally been represented as two dimensional textured "cards" that rotate with the users perspective to give the illusion of dense 3D flora. In a simulation environment where physical interaction takes place and analysis is being conducted with solid geometry this form of visualisation is inadequate.

With the ever increasing size of outdoor virtual environment comes the need to model complex groups of dense vegetation and as a result specialised software packages such as *SpeedTree* (IDV, 2011) have been developed whereby trees are created as physical geometry. *SpeedTree* allows for the fast and intuitive generation of Trees and plant life with integration into game engines it can populate an environment with literally thousands of trees. This program has been utilised with great success in games such as the *Elder Scrolls IV: Oblivion* (Bethesda Game Studios, 2007) and is already noted as a possibility for academic applications (Fritsch, & Kada, 2004); a scaled back CAD application is also included with the *UnrealEditor* streamlining the modelling workflow (Figure 29).

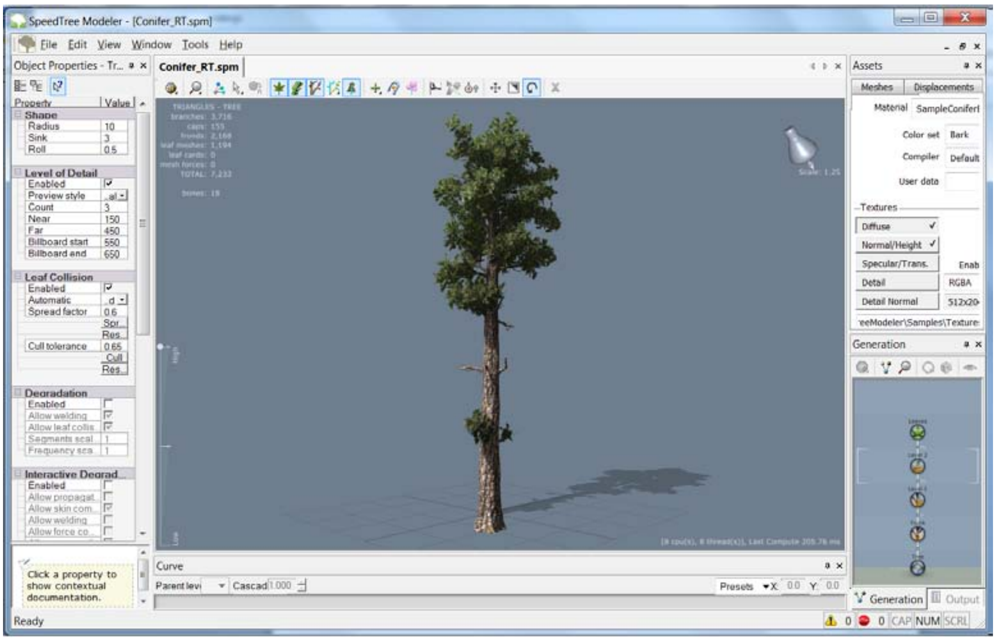


Figure 29. Darlington, J., 2012. SpeedTree UI [screen capture]

This system does have its limitations with the tree canopy/leaves still being rendered using the traditional two dimensional card systems. Whilst this limits the potential of physical interaction between cannon shot and woodland canopy it will still have the potential to suitably facilitate site line calculation and the interpretation of troop movements. As geometry is volumetrically represented with *SpeedTree* there are contact surfaces for Ray-tracing algorithms and Viewshed's can be generated from this type of virtual foliage representation.

4.7 Rendering a Virtual Environment

Aside from highly detailed models and physically responsive environments, one of the biggest features offered by modern day game engines is the level of visual fidelity (*Unreal Engine 3 - GDC 2011*, 2011). Every year video games developers release tech-demos showcasing their newest rendering technology and what can be achieved with it. A large number of these features only contribute to the verisimilitude of an environment such as Ambient Occlusion or Sub Surface Scattering however the ability to render Volumetric Fog or the blinding light of the sun can allow an archaeologist to interpret the direct effects of a battlefield environment on the ocular senses.

4.7.1 High Dynamic Range lighting (HDR)

Modern day computer monitors and Television Screens have advanced very little in terms of the range of light that can be displayed on them which can be prohibitive in the representation of changing light conditions. The human visual System (HVS) has a great capacity for adjusting to different lighting conditions (Figure 30) and the way in which the eye, adjusts/exposes itself to changes in light levels has only recently been developed for inclusion in virtual environments (Debevec & Malik, 2008). Most game engines including the *unrealEngine* do now include it and a feature such as this will allow archaeologists to push even closer to a visually accurate representation of history aiding in subjective interpretation (Gonçalves, Magalhães, Moura, & Chalmers, 2009). Time of Day and position of the sun in the sky played a large role in the staging of any conflict and by mimicking light conditions as accurately as possible the user can acquire a much greater sense of how Bosworth was experienced by the soldiers as the time.

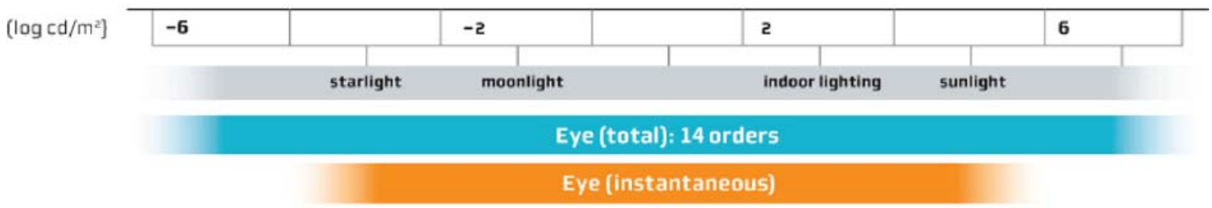


Figure 30. Dynamic Range Aquired by the HVS, Gonçalves, Magalhães, Moura, & Chalmers, 2009

4.8 Visualising Data

From the research conducted It's clear that video games technology is capable of offering highly realistic environments in order to present a world subjectively that no longer exists, however with the potential to include and generate sets of data such as those currently dealt within GIS i.e. Lead shot scatter maps, the possibility that this data becomes mired in its 3D surroundings, rather than helped, should not be overlooked. The benefits afforded to subjective interpretation by a visually engaging world may not be so evident when dealing with the kinds of hard data that come with archaeological exploration and as David McCandless demonstrates in his speech at TED (2010) the identification of patterns and connections in data is only sometimes observable through simplified visual presentation. (Shepherd, 2007, p. 1) points out the tendency of new technologies to be taken up for their own sake with a "*technology first*" attitude that undermines the usefulness that technology may have, this reflecting the criticism levelled at the uptake of GIS in the archaeological community by Witcher (1999). Indeed the impartial use of 3D data visualisation may add unneeded layers of complexity where 2D representation may suffice. For example the hard analysis of cannon fire undertaken by Cranfield University (Allsop, &, Foard 2007) takes place on scatter maps and trajectory graphs and not live video taken from the cannon firing. As (Shepherd, 2007) concludes 3D space proves better at providing a general overview of objects relationship in space whilst Euclidean distance and shapes are needed in order for analysts to discover important patterns in the data. With a virtual environment there is no reason to suggest that the two approaches to visualisation cannot coexist in a mutually beneficial relationship combining the subjective immersion of 3D with the Euclidean analysis of 2D, an example of this symbiotic relationship can been seen with Brooks and Whalley's "Multilayer Hybrid Visualisation" system for GIS (2008) (Figure 31).

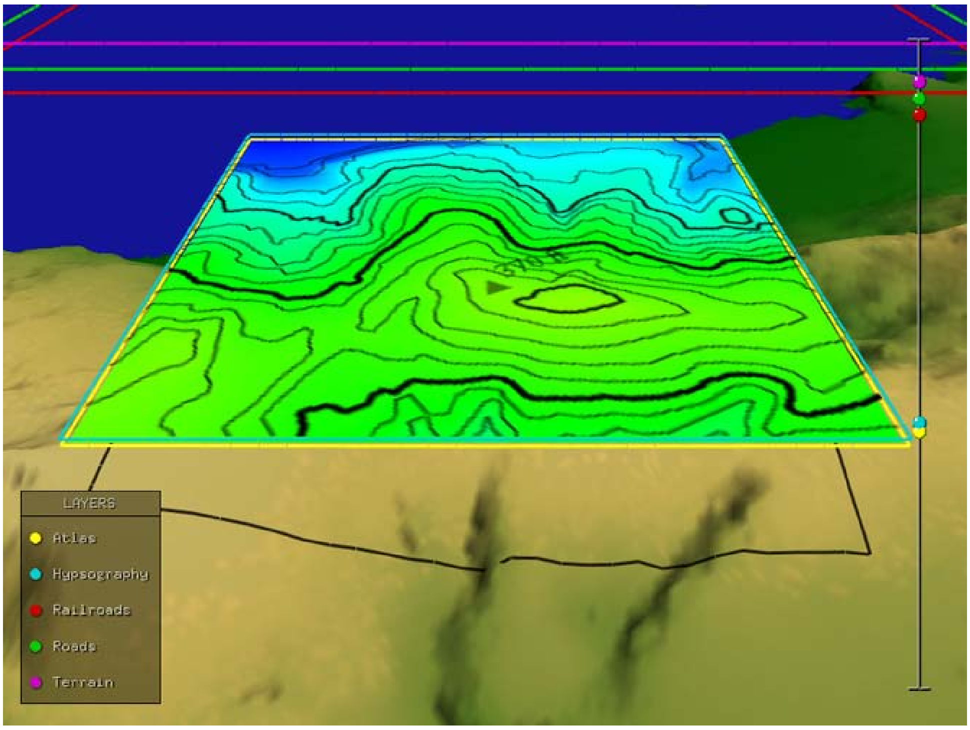


Figure 31. Five Layers over a DEM Terrain, Brooks & Whalley, 2008

4.9 Sound

Archaeology and the communication of history's appeal to the Ocular senses is clear and rendering the past visually holds great potential for the exploration of past events, however, with visualisation now occurring digitally they can be supplemented by sound for a multimedia experience. The idea that a multimodal approach to virtual worlds is beneficial to a user's sense of "presence" in an environment and, conversely their interaction with that environment, has been explored by a number of academics (Nordahl, 2010; Serafin, 2004; Chueng, & Marsden, 2002). The research indicates a higher level of engagement with virtual scenarios and a greater suspension of disbelief in the virtual events that are taking place. With a program that aims to stimulate a user's subjective mind set the ability to enhance perceived presence in the virtual environment through sound is a powerful one.

Television programs and video games already take full advantage of this multimodal presentation and whilst television is able to fully control the auditory experience of the viewer a video game with its virtual world must take a broader approach in matching the visual to the audible. For example whilst a program such a *Battlefield Britain* (Peck, 2004) can depict a battle scene with carefully crafted linier audio that fits the on screen action a virtual environment must account for the movements and interactions of a sentient user. In *Rome: Total War* (The Creative Assembly, 2004) the diegetic sounds of cavalry rumbling across the terrain and soldiers clashing fade in and out as the user moves around the environment, the further out they go soundscapes begin to take over such as ambient environmental noise i.e. wind blowing. Whilst a virtual environment dealing in the exploration of a historic battlefield and the events that unfolded would be dealing primarily in the visual, by not taking advantage of a multimodal approach to presentation the program would be doing a great disservice to a user's interactions and, deny a heightened level of user engagement by not realising the full potential of archaeologies new found place in the digital age.

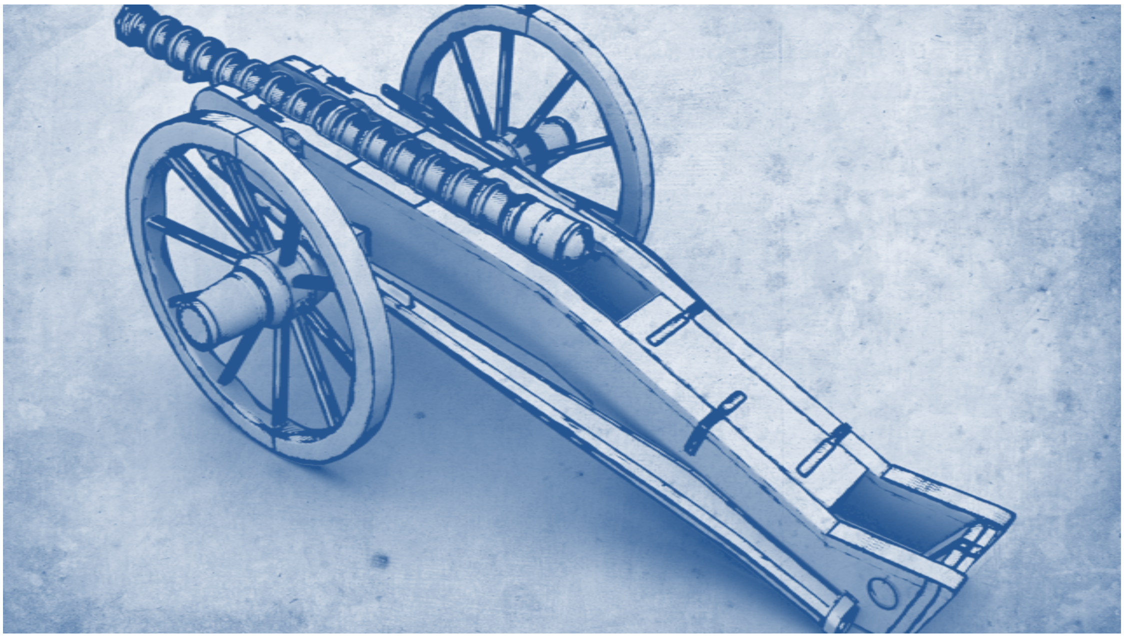
4.10 Design Document

Owing to the resource and time constraints of this investigation a prototype demonstration simulation environment for battlefield investigation was unable to be developed. However from the research conducted a program design document (PDD) was able to be created (Appendix A) aimed at describing the programs specifications and functionality with the possibility of a working prototype being developed in the future with a team of programmers and designers. While this is by no means a complete document; it does aim to illustrate certain design possibilities given current technology and fields of thought in modern archaeological investigation. Once it became apparent that a scientifically accurate simulation of cannon fire would be unfeasible it became more logical to explore other areas in which visualisation and simulation could contribute to the field of conflict archaeology. By presenting a design document it is hoped that the theories and technologies explored in this investigation can be incorporated into a practical and viable format for continued study.

In his guide to creating a computer games design document (GDD) Tim Ryan highlights the importance of laying out a solid and clear set of guidelines before undertaking the development process of any kind of program (Ryan, 1999). The first being, as Ryan puts it, "*the elimination of hype*" more commonly referred to as "*feature creep*" whereby overzealous designers overload the program with a large number of features and elements making the actual programming and development stages an insurmountable task. In order to address this issue a MoSCoW list was created early on in the project when discussions with Glenn Foard were taking place. The MoSCoW (Must, Could, Should, Won't have) prioritisation method allows for the categorisation of features that would be of most importance to a program of this nature, followed by those of less importance. There is also the promotion of clarity with regard to the programs features and proposed capabilities that comes with laying out a design document. This being of great importance considering the myriad of approaches and processes involved in conflict archaeology and battlefield investigation. The document also went through a number of iterations as new features and design goals appeared such as the introduction of a KOKOA landscape interpretation feature and a more streamlined use of information layering which should help to highlight the documents changing direction throughout the research process.

Battlefield Simulation

An Environment for Interpretive Archaeology



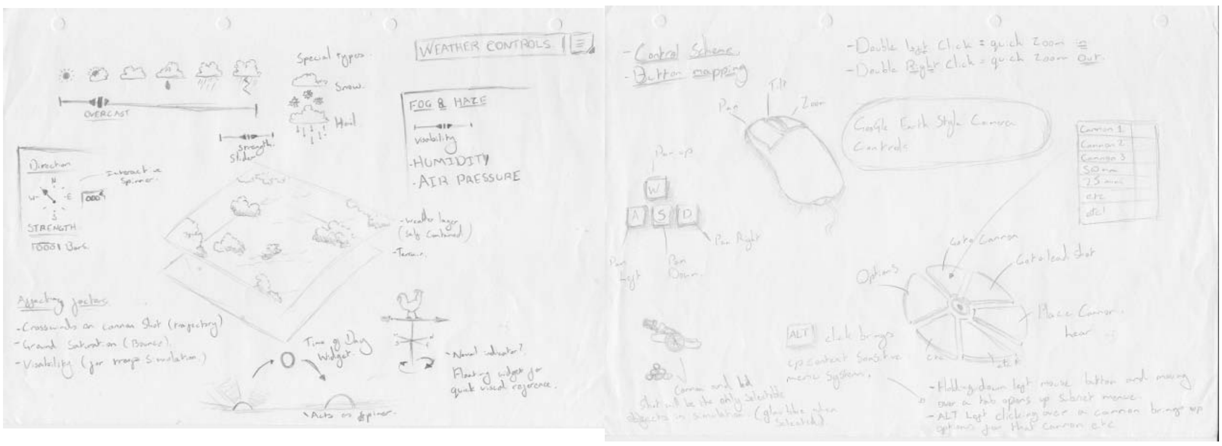
Design Document by James Darlington April 2012

-Version 1.3 –

1. Document History

Version 1.1

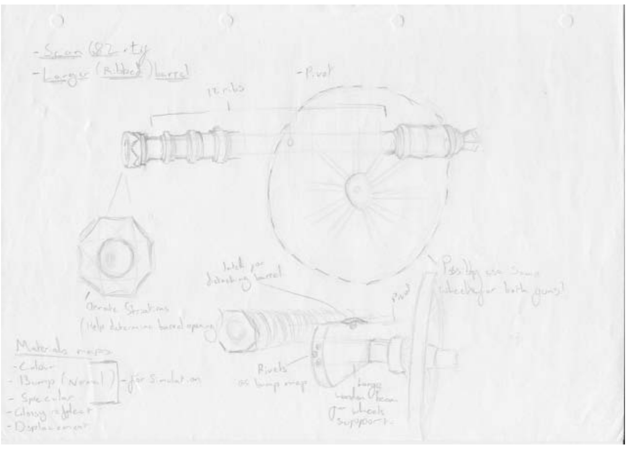
1.) Changed Run simulation format to Record events adding the <u>record</u> function and <u>events sheet</u> as the program is much more akin to real time interaction than one off calculation.
2.) Added <u>Paint tools</u> interaction for terrain sculpting giving the user a much more intuitive method for creating the simulations base layer.
3.) Added orthographic/perspective option into viewport tools allowing the user more control over how they view the environment.
4.) Added Key Features List to give better overview of the program.
5.) Added KOKOA analysis tool begin allowing the user to layer in their analysis and compare and contrast the results visually in real time.

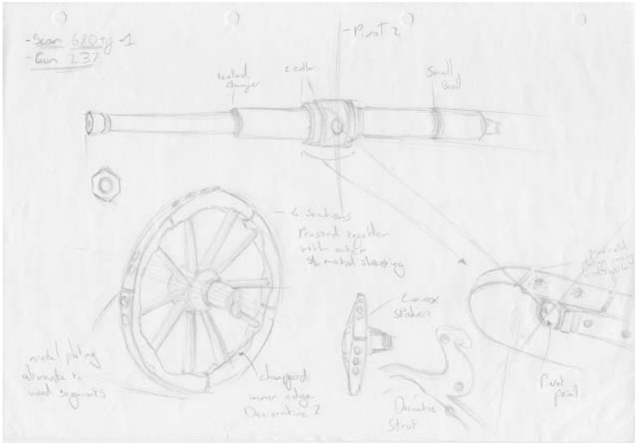


Version 1.2

1.) Included option for logging <u>Paradata</u> giving the user the ability to log research methodology and how data was acquired.
2.) Added the use of SpeedTree (IDV, 2011) CAD system for easy and intuitive foliage creation.
3.) Included <u>Fly-Mode</u> for the camera controls allowing the user to move around with the intuitive ease found in the Unreal Level editor.
4.) Added a “contextual” story to the workflow section illustrating the kind of scenario where the tools of the program would be utilized.
5.) Added Concept Sketches to Appendix.
6.) Reorganised a number of sections to better represent the programs workflow as the document now reads Create – Layers – Analysis.
7.) Moved Foliage/Vegetation paint tool to the simulation layer as this feature involved physical objects relating to the physics.

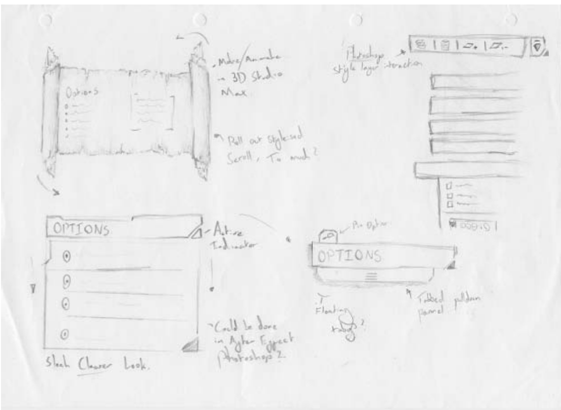
8.) Moved the <u>layer attributes</u> to within the Layers description best representing their role in the program.





Version 1.3

1.) Added visual workflow examples including menu system table
2.) Reorganised document for easier reading
3.) Inserted artwork to help visualise some of the more complex features and systems.
4.) Added referencing section to bottom of document
5.) Moved concept artwork into respective sections



2. Program Summary

2.1Focus Statement

"This simulation environment is a representation of the current best practice in archaeological analysis and the world of 3D visualisation. The environment will utilize GIS data, already found in modern archaeological analysis in conjunction with Physics simulation and Real-time 3D Visualisation found in modern computer game environments. With regards to usability focus will be put on intuitive interactivity with the myriad of tools that will allow a user to build and define a world in which physics based artillery fire can be simulated. At any point during the investigative process the user will have the choice between functional (clean) and presentation friendly (realistic) visual aesthetics. This will allow the user to work in a visually simplified environment more akin to GIS applications and at the press of a button have a demonstrational presentation ready for audience consumption."

2.2 Overview

This design document provides the specifications for a 3D simulation program which will allow a user/archaeologist to replicate the firing of historic artillery pieces in a physically realistic environment of which every aspect is controllable. This program represents an attempt to push the use of 3D Visualisation in archaeological endeavour beyond superficial presentations and fancy interpretation. Putting the benefits of modern day virtual simulation squarely in the hands of archaeologists as they attempt to test out theories and develop interpretations.

When starting the program the user is met with a blank void in which there is a temporal and physical element already provided. Using GIS information such as Digital Terrain Models and geological data the user can build a terrain with contextual relevance to whichever site is under investigation. Utilizing a suite of tools for painting micro irregularities of archaeological interest such as Ridge and Furrow or ancient irrigation channels the user is able to sculpt the terrain to fit historical accounts and interpretations they may be taking into consideration.

The program will utilize a Photoshop (Abobe, 2011) style layers system that not only encapsulates the stratigraphic nature of archaeological investigation but also allows for fast and intuitive control over all aspects of the virtual environment from the terrain to dynamic weather systems.

With two unique visualisation options for the 3D viewport the user is able to switch between two rendering styles. Firstly there is the intuitive "clean" view for manipulation and analysis and the second being a graphically rich “realistic” render for presentation and interpretation purposes.

Using the latest in Physics technology with the PhysX engine (NVIDIA, 2012) lead shot scatter patterns can be created with environmental forces analogous to those in the real world.

Support for the import and export of lead shot scatter maps using GIS compatible files users can closely incorporate and disseminate information generated by the simulation with work already being undertaken in popular programs such as ArcView (esri, 2012) and MapInfo (Pitney Bowes, 2012).

2.3 Target Users

Primarily this program is aimed at archaeologists working in the field of experimental archaeology and who require an intuitive environment with which to investigate certain aspects of a battlefield. The program also facilitates those who are looking to present their findings/interpretations in an impressive and engaging manner utilizing the latest rendering effects helping to shorten the gap between archaeological interpretation and presentation.

2.4 Key Features

- Integration of spatial analysis techniques such as those found in GIS
- Fully interactive and layered environmental influences allowing the user to build a complex physics based virtual world
- Built in visual confidence rating system promotion intellectual transparency
- Simulation of historic artillery fire utilizing data created from the latest experimental archaeology
- Import/Export of spatial analysis formats for integration with GIS programs
- Contextual Authoring system for the inclusion of ParaData and academic referencing of objects used in simulation

3. Game Engine

The battlefield environment simulation will utilize the Unreal Engine 3 (Epic, 2004) designed for computer game development due to its high level of scalability with regards to current hardware and its intuitive purpose built editing system the Unreal UDK. Possibly the engines most important feature is its support for large scale outdoor environments and complex terrain models with the ability to implement Level of Detail scaling and geometry sculpting. With the inclusion of Scale Form Gfx (Flash, 2011) a highly intuitive in engine User Interface (UI) can be created with ease.

OS	Windows XP SP3 (32-bit only)
CPU	2.0 GHz
RAM	2 GB
GRAPHICS CARD	Card with Shader Model 3.0 Support

These are the minimum requirements for a user who is simply building a simulation environment and does not intend to take full advantage of the visual presentation and publishing features of the program. Recommended system specifications (in order to utilize all aspects of the presentation layer) are as follows.

OS	Windows 7 (64 bit)
CPU	2.0 GHz or Higher
RAM	4 GB
GRAPHICS CARD	GeForce 7800 or equivalent

3.1 Physics

The PhysX Engine (Nvidia 2012) provided with the Unreal UDK will be utilized in simulating object interaction and with support for hard body dynamics, fluid simulation, static and Kinetic Friction it is more than suitable. Whilst the physics while not be 100% accurate with regards to the real world PhysX abilities to simulate large numbers of primitive objects interacting in a complex environment make it suitable to aid in interpretive investigation. Through the Unreal visual Physics modelling tool (PhAT) complex physical objects such as cannon carriages can be created with relative speed and ease.

3.2 Rendering

The rendering capabilities of the Unreal engine 3 are highly scalable allowing for the culling of more superfluous visuals on older systems whilst having support for DirectX11 (Microsoft 2011) to allow for cutting edge realism and effects. The engine also supports volumetric environment effects such as fog and day/night cycle lighting along with an advanced particle system for weather effects allowing the user to see a landscape closer to what may have been seen in the real world.

4. Mechanics

The mechanics of the program are designed to provide a simple and intuitive workflow for what can become a complex and cluttered 3D environment. A layered system provides parcelled out control over all aspects of the environment whilst intuitive camera controls should make navigation around (what can potentially become a complex environment) second nature to the user.

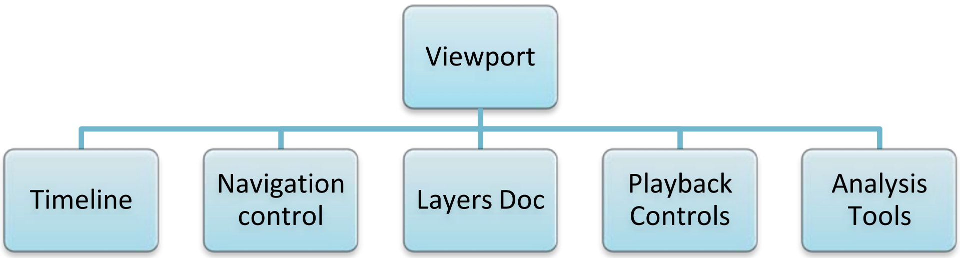
4.1 GUI

The layout of the program is designed to be as simple as possible with the layering system to the right and a standard contextualised windows bar across the top. The rest of the GUI is made up of the 3D environment window where floating widgets for the camera, timeline and analysis controls can be moved around or hidden at the user's discretion.

4.2 3D Viewport

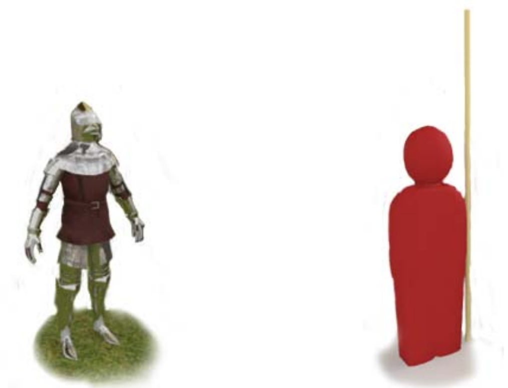
This forms the centrepiece for the program where all the interactive layers come together to form the simulation environment that the user has specified. Using the 3D contextual menu the user has full control of all elements from within this window.

A number of important elements also form a Heads up Display (HUD) around the 3D viewport allowing the user quick access to important control elements.



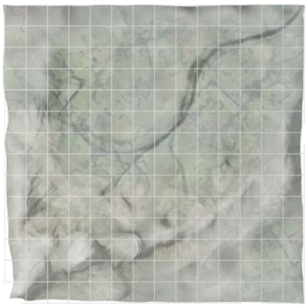
4.2.1 Clean/Realistic render options

This viewport option allows the user to toggle between two viewport rendering options. Clean simplifies the way in which the 3D environment is displayed allowing for easier interaction and a higher frame rate for complex environments also an option for when the program is running on a computer with minimal graphics features. When realistic rendering is toggled on the environment is fully textured and takes advantage of DirectX 10/11 features and effects.



4.2.2 Orthographic/Perspective options

The second viewport toggle allows the user to switch between a 3D perspective style view and a 2D orthographic projection. Orthographic view allows the user to work in away analogous to GIS software and is useful when working with the terrain analysis tools. 3D perspective allows for more intuitive and subjective interpretations of the environment.

4.3 Camera

The user will have complete control over the camera in the 3D viewport with tools for zooming, panning, tilting and rotating. Further options are also available for centring the camera on objects of interest and how the user navigates the world.

4.3.1 Grab and Pan Mode

This option relates directly to the terrain layer and is analogous to how navigation works in GIS programs. The user Left clicks on the terrain to grab and pan across and Right clicks to tilt and rotate the camera around that pivot point.

4.3.2 Focus Mode

This option is for quick and easy manipulation of objects in the world meaning whatever is selected becomes the centre of the cameras orbit. Clicking the Left mouse button and moving the mouse rotates around the object and clicking and holding the middle mouse button to zoom in and out.

4.3.3 Fly Mode

This option allows the user to navigate the environment as if they were piloting a virtual aircraft meaning easy access to awkward or novel viewing angles. W,A,S,D for Forwards, Left, Backwards and Right movement respectively and the mouse for Euler rotation with Left mouse button pressed.

4.3.4 Magnifying Glass

Allows the user to quickly zoom in and out of the environment, essentially altering altitude in perspective mode this tool can also be used to drag a box across a portion of the environment to be focused on.

4.4 Playback
The Playback tool allows for quick access to the temporal aspects of the simulation. Anyone familiar with the playback features of a media player or DVD recorder will understand how to use the playback tool. Pressing play will simply run the setup in real time for preview purposes while other features such as rewind are not available until an event has been recorded.

4.4.1 Record
Part of the playback widget the record tool is essentially where the user captures the events that make up their simulation. Having set up the environment systems and placed artillery along with any obstructions the user can press the record button and log the interactions taking place into the timeline as events.

4.5 Timeline
When the user records an event it is keyed into the timeline allowing the user to scrub back and forth throughout their simulation. All the timeline options are contained within a widget that can be hidden or snapped to the edge of the 3D window.

4.5.1 Event Sheet
This tabbed display under the timeline provides a visual diagram of all events logged into the simulation. It provides a display of each influential component (Artillery pieces, units, weather systems) along with their start time and end time. Each event is also recorded with a dialogue of all variables/ParaData affecting the cannon shot at the moment of firing.

4.6 3D Contextual Menu

This menu appears when the user right clicks on an object or features in the 3D viewport and allows for quick access to options only relevant to the object being clicked on. For example clicking on a previously set and placed cannon will reveal options for reloading, reorientation, copy, delete etc.

4.7 ParaData Input & confidence function

Within the dialogue for every component that makes up the simulation there is an input box for the author to list any research information/data pertinent to their choice of options when setting up that element. This gives any future user of that particular simulation scenario to look back at how much information is based on real-world findings and how much is simply speculation.

Along with the ParaData dialogue the user is able to assign a confidence factor to any object they create (from 0 to 1) with 1 representing complete confidence in the factual accuracy of a particular object. If the user is consistent in the use of this mechanic then the entire environment can be rendered to indicate varying levels of interpretation and fact.

4.8 Import/Export

The program features a number of import and export options allowing the user to firstly bring in Geospatial data from GIS that's relevant to the investigation and secondly publish lead shot scatter maps and vector charts that can be read by GIS. Using the presentation layers a user can render out a high detail matinee for presenting a timeline of events resulting from their investigation. They can also export contour maps of modified terrain data.

5. Create

Before any layers are specified the user should begin creating the objects that they intend to populate the simulation environment with and they have a number of choices when doing this. By going to the Create menu the user has access to a number of dialogues for creating objects and obstacles relevant to the simulation. The create options can also be accessed by right clicking on the appropriate layer in the layers dock or from the 3D contextual menu in the viewport.

5.1 Cannon

Artillery pieces can be created and saved at any point but only placed into the environment once a terrain layer has been specified. The cannon creation dialog contains a large number of options analogous to the real world set up of an artillery peace. While the physical simulation cannot be 100% accurate the user has complete control over the setup of the cannon from the specification of the barrel and ordinance to the dimensions of the carriage. The user can also define and set pre-sets to be saved and used at a later date.
The cannon creation dialogue can also be contextually opened by right clicking on the terrain and selecting it from the 3D spinner. The options for the cannon can also be re-assigned at any point by clicking on the cannon, bringing up the contextual 3D spinner menu for it.

5.2 Vegetation

Utilizing the Speed Tree (IDV, 2011) vegetation generation program the user is able to quickly and intuitively create a number of Woodland and plant Species. The user is then able to group different combinations of Flora together for fast application to the simulation environment.

5.3 Weather System

This dialogue allows the user to specify a number of environmental changes that will occur throughout the duration of the simulation. For example the user can specify effects such as heavy fog/rain, strong winds, snow and air pressure observing their effects on the environment.

5.4 Formation

This is where the user can specify different types of troop formation to place into the landscape. There are also options for the height of each individual in the formation, if they’re wearing body armour etc. effecting the interaction with led shot.

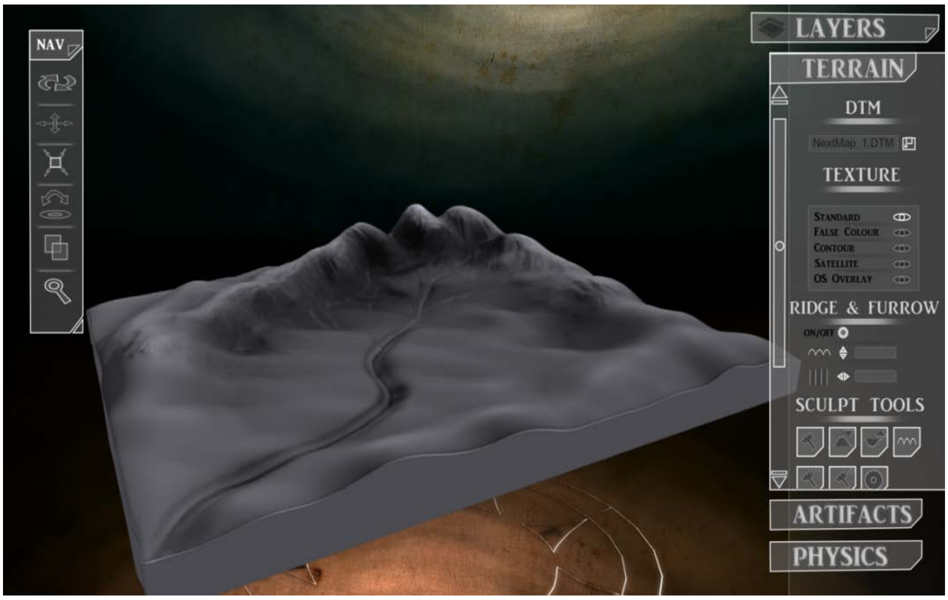
5.5 Primitive
This dialogue allows the user to introduce a simplified object into the scene that can be scaled into any obstacle the user deems necessary. From this option the user is also able to import .OBJ files of more complex polygonal meshes.

6. Layers
The layers system is where the building blocks of the simulation world are ordered and specified. Hear the user can stack data that they want to explore in the simulation, save interpretations and bring new ones in provided by other archaeologists. Using an opacity slider the user can directly compare events and interpretations in a visually intuitive manner. Layer locking and hiding options allow users full control over what is being simulated and seen/interacted with in the 3D viewport. Each layer also has a set of specific attributes provided for it adding further control to the user over how a layer effects the simulation. More than one of each layer can be created for more complex interpretations for example more than one simulation layer can run separate physics simulations that do not interact across layers.

Contained within each layer there is a number of unique tools and options for working with that layers properties. This allows the user to set up their environment in a modular fashion avoiding unnecessary complexity.

6.1 Terrain
This is essentially the base layer of the simulation and forms the canter of which everything else is built around. The terrain can be anything from a default blank plane, a full Digital Terrain Model containing sub-layers of plotted site data or a custom “theoretical” terrain sculpted by the user with the provided tools.

Once a terrain layer has been established sub-layers made up of geospatial data created in GIS systems can be brought in. for example scatter maps and archaeological plots from real dig sites can aid in comparison and interpretation.



6.1.1 Attributes

Due to the possible size of land a user may be dealing with the program provides a Brush Toolset to effectively “paint” the terrain features. The size and falloff of the brush can then be changed on the fly allowing for a fast setup of the environment.

Sculpt tool – this is essentially a paint brush allowing the user to heighten and lower the terrain geometry. The user can also choose to paint micro level details onto the terrain such as Ridge and Furrow irregularities. There also includes options for strength and circumference of the brush.
Soil consistency – another brush tool that allows the user to paint areas of harder and softer geology which directly affects the way in which lead shot will bounce across the surface at simulation time.

Ridge & Furrow - this tool allows the user to paint micro detail irregularities of historic land cultivation onto the terrain. They can also set options for the height and length of this patterning or load in a data set from a GIS application for the layer to interpret.

6.2 Simulation

This layer contains all objects that will be physically interacting with each other on the surface of the terrain including cannons, foliage, unit formations and any other object the user wishes to import into the environment as a physical presence.

6.2.1 Attributes
As with the terrain layer simulation contains an instance of the brush toolset however it is utilized exclusively to apply pre-created vegetation to the terrain.

Vegetation/foliage – Allows the user to paint Vegetation (individually or in groups) directly onto the terrain. Features tools for randomisation, dispersion and grouping properties and can only be used when at least one vegetation group has been created.

6.3 Environment
This layer contains any weather systems that have been created and placed into the simulation and attributes for controlling the suns position in the sky.

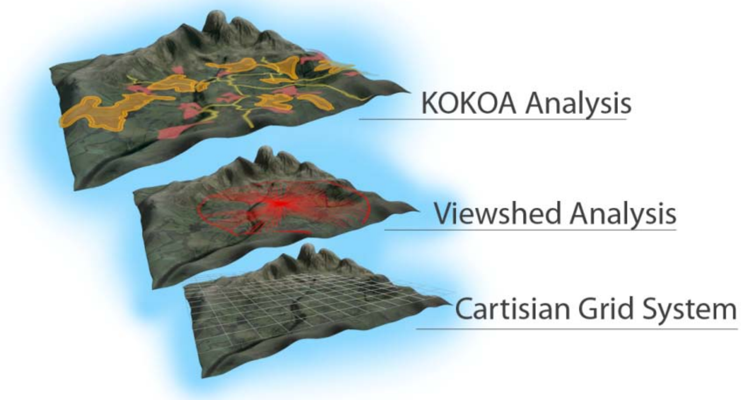
6.3.1 Attributes
Wind speed - this attribute allows the user to add a cross wind to the environment effecting the vector of projectiles and direction of weather effects such as rain and hail (for example by creating snow and a fast cross wind the user can introduce blizzard conditions). A turbulence option also allows the user to give the wind non uniformity.

The environment layer also includes options for controlling a day and night cycle meaning the user can subjectively assess the effects of the suns position in the sky. Using the appropriate inputs the user can set the sun position relative to time of year.

6.4 Presentation
When the user decides that they are happy with a simulation they can compress the component layers and save them out as a single presentation layer. This layer can then serve as a visual aid to compare and contrast different scenarios and interpretations over new ones being created.

6.4.1 Attributes
Camera – this essentially functions as a presentation tool for the user who can set up a camera (or cameras) around the presentation layer to record the sequence of events they have created. By using the camera in conjunction with the Fly-Mode navigation and Record tool the user can create a key-framed matinee of the action as it unfolds.

Graphics Options – the presentation layer also contains a number of options for high level graphics features that are not accessible



through the normal UI. These include such capabilities as Ambient Occlusion, Motion Blur and Depth of field and require DirectX 10 and 11 (Microsoft, 2011). The user can create a battle simulation on a computer with mid-range capabilities, save the presentation layer out, and record a matinee on a more powerful system using these options.

7. Analysis

Once the user has a suitably detailed environment, whether created with thoroughly accurate outside data or full/partial speculation they can apply a number of tools that allow for a subjective interpretation of the virtual environment.

7.1 Measurement tool

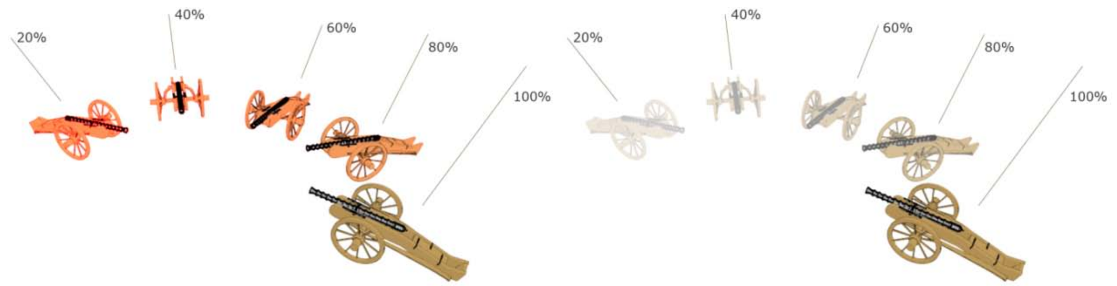
The simplest of the tools this is a simple line based measurement tool. The user can calculate distance easily and intuitively by clicking from point to point or drawing a polygon on the terrain surface and calculating the area squared.

7.2 Vector Lines

This analysis tool is contained within the cannon options and serves as a visual aid to determine the scatter pattern of lead shot from the end of the barrel to rest position. These are shown the first time a cannon has been fired and can be switched on and off.

7.3 Confidence Visualisation

Provided that the user has been rating the objects populating their environment they can use this tool to assign visual gradients that will render a visual aid as to the factual accuracy of what has been created. The user can assign their own colour scheme with this tool from a two toned gradient to an opacity function causing completely speculative elements of the scene to disappear. This variable is also represented as a percentile.



7.4 View-shed/Weapons Fan Analysis

View Shed or in terms of artillery “weapons fan analysis” utilizes the height information from a DTM and the ballistic properties of a placed weapon to calculate its range and effectiveness. This tool only becomes active once there is a terrain and at least one cannon/unit formation placed in the environment. The user specifies which cannon to asses and then a colour coded ring of influence appears around that cannon indicating its orbit of influence relative to the terrain it is on.

When the user selects a unit formation or an individual solider within that unit this tool becomes a simple View-Shed analysis, similar to Weapons Fan although not taking into account any ballistic properties. This tool can also be accessed from the 3D contextual menu of any given cannon/unit.

Once a view-shed has been applied it updates in real-time as the object is moved or atmospheric elements that can impact on visibility are applied i.e. Fog.

7.5 KOCOA Analysis

"Key Terrain Observation and Fields of Fire, Cover and Concealment, Obstacles, Avenues of Approach"

This tool is similar to view shed analysis although it simulates a military assessment of the environment, colour coding the terrain with regards to the five categories above. The user outlines an area with which to apply this type of analysis and specifies the colour coding for each category. This tool is primarily useful in attempting to validate the placement of artillery and unit formations for a given interpretation although it can be redrawn and specified at any time. Access to this tool is also available from the 3D contextual menu by clicking on the terrain layer.

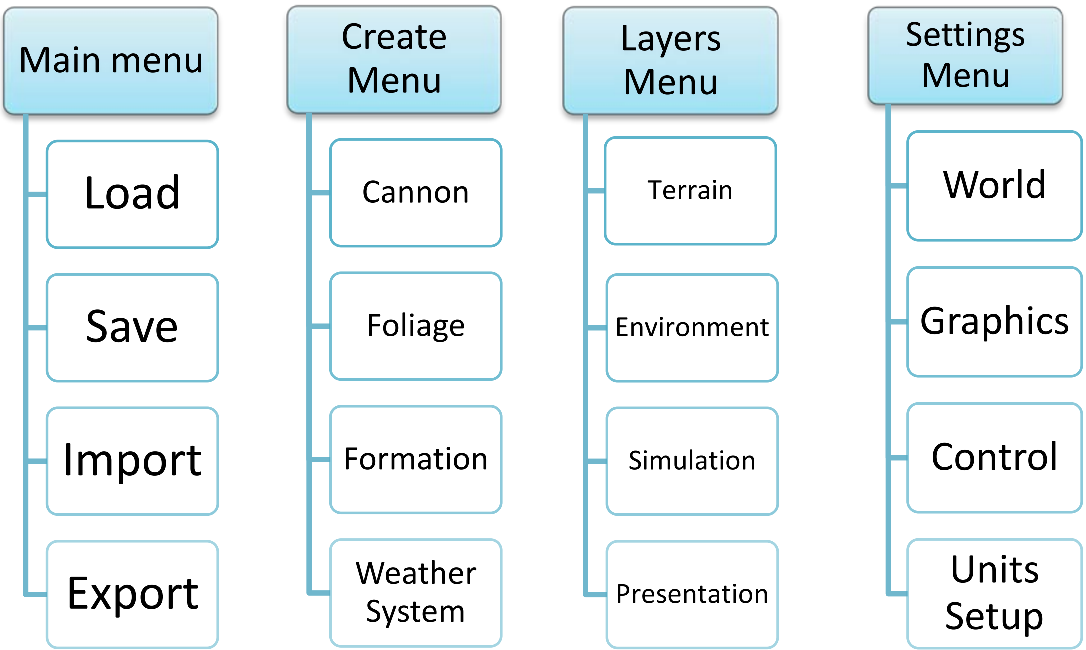
Battlefield Element	Definition	Examples
Key Terrain	A portion of the battlefield, possession of which gives an advantage to the possessor.	Road junctions, bridges, high ground.
Observation and Fields of Fire	Any point on the landscape that allows observation of the movements, deployments, and activity of the enemy that is not necessarily key terrain, offers opportunity to see over an area and acquire targets, and allows flat-trajectory weapons to be brought to bear on the enemy.	High ground, sloping approaches to entrenched positions.
Cover and Concealment	Landforms or landscape elements that provide protection from fire and hide troop positions from observation.	Walls, structures, forests, ravines, riverbanks, entrenchments, ditches.
Obstacles	Landscape elements that hinder movement and affect	Rivers, walls, dense vegetation, fortifications,

	the ultimate course of the battle.	ravines, ditches.
Avenues of Approach	Corridors used to transfer troops between the core battle area and outer logistical areas.	Roads, paths, creek beds, railroads.

Source - Stephen. F, (2008). A Documentary and Landscape Analysis of the Buckland Mills Battlefield. Buckland Preservation Society: Gainesville, Virginia, 29 February.

8. Menu System

Access to the full functionality of the program can be found in the bar across the top of the screen. Whilst similar options can be found within the layers of the simulation they are contextual to that part of the program, for example if you were to click the import function on a terrain layer it would only allow you to import data pertinent to the terrain layer.



9. Workflow Examples

9.1 Your First Simulation

1.) Having opened the program you are greeted with an empty void representing 3D space containing a Cartesian grid system for reference.

2.) In order to start building an environment you need a plain representing the geography of the area under investigation. Right clicking on the empty pain on the right of the UI opens a context menu giving the option of adding a number of layer variants. Choose Add Terrain Layer.

3.) The Terrain Layer Dialogue now appears prompting you to set a number of parameters relating to the geography. Having done this and clicking add you now have a blank plain to begin building a simulation upon.

4.) Before you can begin populating the geometry with interacting objects you need to create some. By clicking on the create tab you are given a list of objects that can be defined and dropped into the scene. Select Cannon Creation.

5.) The dialogue that appears is analogous to the set-up of a real world cannon and contains a large number of features. After you define the features appropriate to your investigation you can save out those preferences to a named pre-set. If your set up is related to broader research then any ParaData can be logged in the appropriate dialogue box for if the simulation scenario is published.

6.) Once your cannon set-up has been created you can right click on the terrain and place an instance of the cannon into the environment from the 3D contextual menu. When an interactive object is added into the environment a simulation layer is created containing that object and any others that function in the physics engine.

7.) A simulation layer is created on the fly like this because the artillery peace is a physical object and requires the layer however an empty layer can be created and then populated later on. The simulation layer attributes simply consist of a gravity setting and once this is set most interaction with the layer consists of dropping objects in and moving them around.

8.) By right clicking on the cannon you placed in the scene and choosing load you access the fire controls. From this menu you can essentially “load” the cannon for firing and once your happy with the settings you can click fire (from the dialogue or the contextual menu) and let the physics engine calculate the direction, speed ,bounce, friction and roll of the shot.

Note – Once your cannon is placed you can access the analysis tools (a major feature of the program) for example you can pick the View-shed tool and from the dialogue pick the cannon to calculate a firing range for it.

9.) When an artillery piece is fired like this it essentially serves as a preview and does not get recorded as an event for playback. The vector lines of the shot can be displayed by ticking the appropriate box in the cannon settings dialogue. They are recalculated the next time the artillery piece is fired and can be saved to the presentation layer by the user and also colour coded for visual differentiation.

10.) Going back into the create panel and clicking on Weather System you have access to options enabling you to create environment effects (rain, hail, fog, snow etc.) and also queue up multiple weather patterns that play out over the course of the timeline. By selecting rain from the dropdown menu you are given a number of options relating to precipitation, once you have set these to your preference name the system and save it.

11.) Back in the main UI right click on the layers dock and select environment. When this is done your simulation is rendered with a sun and background horizon. With this layer you can now right click on it and add the weather system you previously created and named.

12.) With the environment layer extended go to the Wind attribute and set a preferred direction and speed, the rain in the environment now begins reacting with this choice.

13.) Go to the UI camera controls and select <u>Focus Mode</u> from the drop down menu and click on the cannon you'd placed in the environment to re-orient the camera around it. By clicking fire again you can re-simulate the lead shots trajectory whilst assessing the effects of the new environmental conditions.

14.) You now have the beginning of a simulation environment. Taking things further you could import GIS information and a Digital Terrain Model into the Terrain layer or use the sculpt/paint tool box to form your own landscape interpretation.

9.2 A Contextual Example

You're sat in the office and an e-mail notification appears. It's a file containing geographical and spatial information for a set of historic streams including the alluvial soils that boarder them. You think to yourself what could this mean to the battle that was fought hear five hundred years ago? As you open up the simulation environment.

The program loads and a number of windows snap into place surrounding an infinite void containing nothing more than a coordinate grid and a compass tool. You move to the menu bar at the top of the screen clicking OPEN you scroll down to the file SCENARIO_5B and click LOAD. The empty void is now filled with the 3D Dioramic representation of an historic battlefield. Two opposing forces stand in their respective formations atop a DTM/DEM model derived from the real world location. Your artillery positions sit primed and ready as you left them on last saving your work. The layers pallet to the right mow adorned with each separate factor you have chosen to include in this environment, ready to begin their influential role the minute you click RUN.

Moving your cursor to the layers pallet on the right you click the TERRAIN layer activating a table of customisable attributes. You move down to the geological composition attribute and load in the alluvial soils table sent to you. Now the friction and dampening effects that occur when cannon shot comes into contact with the terrain are altered at the appropriate coordinates. Closing the terrain attributes window you mouse over the navigation tools on the left negotiating your way through the diorama to a key cannon placement. A contextual click later and the attributes for the cannon appear along with the faint red vector trails indicating a previous firing solution arching over and into the newly established soft soils of the terrain. With your previous simulation saved and packaged into its own layer you double check your settings press RECORD and fire the cannon, anticipating a marked change in the bounce and roll of the shot.

Chapter Five: Conclusions and Suggestions for Future Research

5.1 Summary and Conclusions

By examining the literature that is outlining current trends and theory's in archaeology it is clear that the gradual move towards a more subjective dissection of history and the utilisation of virtual environments, such as GIS, has been taking place for some time. The potential for interpreting the different kinds of digitised archaeological records and data in a virtual environment has yet to be fully realised however, owing mainly to the limitations of GIS and the current tendency to utilise virtual environments only for presentational purposes. The recent development of a framework for handling the intellectual rigor, so important to archaeological investigation with The London Charter highlights an interest being taken within the archaeological community and also the importance of tackling misrepresentation and misinterpretation, something not unfamiliar to the visualisation of archaeology.

From the literature came a number of investigative tools and concepts that have been shown to be compatible with a 3D interactive environment and, with the example of viewsheds and 3D foliage creation hold greater potential than they might in a GIS context. Through the creation of a design document a number of these concepts have been presented in a more accessible manner in order to be built upon and expanded in the future. This by no means represents a finished product and a great deal of testing and development would need to take place in order for the full potential of a program of this kind to be realised. Many of the features and their proposed function can only be accurately assessed through rigorous development and usability testing whilst the application of a layered approach to historical landscape creation would need to be assessed with regards to archaeological investigations other than Bosworth.

In conclusion it appears as though, when coupled with the newer more subjective strands of archaeological theory, virtual reconstruction and simulation technology has a great deal to offer the processes of examining and interpreting the past. It's also evident that in order for further exploration of this field to be viable, video games technology should be employed in the creation of these digital environments offering increases in subjective representation, intuitive interaction and manipulation of site data such as DTM's along with the curtailing of prohibitive development costs associated with creating virtual interactive worlds. The coupling of video game visuals and archaeological processes with a foundation in intellectual rigor may also hold potential to aid in presenting the past to younger generations in a more realistic capacity, counteracting the misrepresentation of history that occurs in video games for entertainment.

5.2 Future Research

Whilst this report has attempted to approach the design and specification of a battlefield simulation from a number of avenues there are many ways in which the research can be expanded and improved upon owing to the time and resources constraints of this project. Firstly the technologies and methods explored could be explored with regards to archaeological investigations of an earlier or later period, wherein collected data and historical accounts would change in detail and accuracy for example what the impact of approaching a battle such as Edge Hill, with a far more detailed set of accounts than Bosworth, would have on the interpretation of that historic event. The application of these technologies to other areas of archaeological investigation could also be explored for example how a detailed virtual landscape could work in tandem with landscape analysis such as those discussed to investigate historic town planning, or even siege tactics. The following sections examine a number of emerging technologies that have yet to see a measured impact on the archaeological discipline although they do show potential in contributing to further integration of archaeology and the virtual world.

5.2.1 Interactive Surfaces

Battlefield Britain (Peck, 2004) contains a number of visual effects used to aid in the viewers understanding of how particular battles where staged and unfolded. A number of times we see the main presenter unfolding a table to reveal a 3D digital overview of the battle space. Terrain is clearly outlined and textured with environmental features such as rivers and woodland rendered in detail. As the battle unfolds the presenter is able to gesture to the key movements of forces presenting a clear and intuitive overview of the action. Four years after the broadcast of this program Microsoft releases the *Microsoft "Surface"* computer interface (2008). Essentially a real world version of *Battlefield Britain's* "virtual table" this piece of technology allows users to intuitively and tactically interact with whatever program is displayed on the table top. The device uses multi-touch interaction and recognition of real world objects in order to create a natural user interface (NUI) and its benefits to interaction with a virtual environment have been proven with the release of the real-time strategy game *RUSE* (Eugen systems, 2010). Players are able to zoom in and out of a virtual battlefield environment with the pinch of their fingers and pan across the world with the wave of a hand (Figure 32).

Figure 32. [RUSE running on Microsoft Surface] Costa, C., 2009 [image online] Available at: http://www.gadgetreview.com/2009/06/e3-09-microsoft-surfaces-first-real-3d-video-game-ruse-video.html [Accessed 25 March, 2012]

These kinds of developing interactive technology may also facilitate more collaborative learning and research experiences for users. Recognising the potential of multiuser interfaces in heritage exploration, including their possible application to public exhibition, Eugene Ch'ng (2012) develops two systems that utilize a multi-touch interface whereby users are able to undertake historic tasks with analogues hand gestures. The paper also identifies a possibility for the use of above surface sensors such as Microsoft's Kinect (Microsoft, 2010) motion sensing device opening up the possibility that in the future users may not need to make physical contact with an instillation in order to interact with it.

With the release of Apples *Ipad* (2010) and increases in smart-phone technology with their use of Multi-touch surfaces and NUI innovation is prompting software developers to rethink the ways in which we interact with our applications and broadening the approachability of those applications to varying demographics. In terms of a battlefield simulation environment platforms such as the *Ipad* would allow a faster and more productive workflow for a user who may find it difficult to learn a new program from scratch. As of 2008 the uptake of more portable platforms such as laptops has been accelerating whilst the purchase of static PC systems has been in decline owing to the hunger for portable technology (mintel, 2008). (Ch'ng, 2006, P-145) also notes this paradigm shift and this coupled with the highly mobile nature of an archaeologist may see portable devices with NUI capabilities a sought-after platform for the development of a virtual battlefield simulation and interpretation environment.

5.2.2 Haptic Feedback

Carrying on the theme of Natural User interfaces haptic feedback takes things a step further by simulating the sensation of the mechanical properties of virtual objects such as mass, shape and surface texture. Whilst this technology is not as matured as touch sensitive surfaces their potential has been explored with regards to enhancing presence in a virtual environment (Sallnäs, et al, 2000). The results show a significant increase in perceived subjective presence in a virtual environment and increased efficiency in interface interaction and productivity. The use of haptic feedback has moved on very little since this report was published and although commercial haptic devices now exist (Figure 33) they are prohibitively expensive and only offer a specific set of interactions.

Figure 33. [Haptic Feedback Device] Golden, E., 2008 [image online] Available at: http://www.djtechtools.com/2008/04/07/digital-dj-super-joystick/ [Accessed 25 March, 2012]

5.2.3 Augmented Reality

Augmented reality (AR) is a relatively new system that allows for virtual elements to be superimposed onto real time video. Using motion sensing the movements of the camera are tracked and the 3D objects appear “planted” in the real world. The technology essential bridges the gap between real and virtual worlds and has recently began making its way into commercial products such as smart phones, Nintendo’s 3Ds (Nintendo, 2011) and most recently a prototype released by Google shows how a user can wear glasses upon which AR applications are projected (Google, 2012). The collaborative implications of AR is an area being explored by academics (Benko, Ishak, & Feiner, 2004) and due to the nature of Conflict archaeology, requiring many expert archaeologists working on a single site, AR technology promises improvements in the way these experts communicate and engage with history.

5.2.4 Agent Based Modelling

Agent Based Modelling (ABM) is currently gaining interest in the archaeological community as a process whereby virtual environment are populated with simulated life (Murgatroyd, 2012). These "Agents" can be assigned individual attributes and parameters in order to simulate individual characteristics such as battle tactics, stamina and mobility, within the simulation an agent can represent a group of entities such as an army unit or a heterogeneous entity such as an individual soldier. Their interaction with a landscape or environment are then able to be explored and perhaps more importantly their reaction to, and impact on changes in that environment can be examined.

By populating virtual worlds with simulated life and exploring archaeological questions with these complex systems there are a great many advantages to be found (Miller, & Page, 2007) most notably the ability to combine precise definable and controllable inputs with open ended dynamic interactions. Through investigating the distribution of vegetation across a now submerged section of the United Kingdom (Ch'ng, & Stone, 2006) demonstrates the viability of ABM in taking virtual reconstructions, moving them away from visually pleasing backgrounds, towards dynamic systems that can provide useful and comparable results. Perhaps with systems such as these we can begin to see where the hugely complex questions offered up by archaeology can be explored and played out in academically valid virtual environments.

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