

The Shotton River and Mesolithic Dwellings: Recreating the Past from Geo-Seismic Data Sources

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Abstract

The Mesolithic Period in Europe has been a much-discussed area in archaeological research. As far as is known, the project reported herein represents the first attempt to visualise an otherwise inaccessible Mesolithic site with Virtual Reality (VR) technology, exploiting real geo-seismic data sources of the Southern North Sea. This paper presents the techniques and technology used in reconstructing an ancient river valley discovered while gathering seismic data for petroleum in the North Sea. The virtual landscape reconstruction is populated with vegetation types based on pollen records of the same period in nearby region, and 3D models of Mesolithic dwellings have been grouped into villages and positioned near possible settlement areas. The final VR environment has been “brought to life” via real-time interactive walkthroughs, complete with environmental and spatial sound effects. This paper also describes the various software applications and hardware used for implementing the high-quality static models and the high-performance interactive world, the latter intended for delivery via the WWW and multimedia for educational purposes.

Categories and Subject Descriptors (according to ACM CCS): I.3.7 Three-Dimensional Graphics and Realism Animation, color, shading, shadowing and texture; Virtual Reality

1. Introduction

The North Sea is currently a highly strategic location for both defence and petrochemical reasons, but from a historical point of view, there are tremendous opportunities for exploration. Recently, seismic datasets of the southern North Sea have been acquired by Petroleum Geo-Services (PGS) [PGS04]. Together with advances in 3D seismic visualisation technologies, the true morphology of Quaternary features has been revealed. Initial investigation of the northern segment of this seabed feature highlighted a large river valley from an ancient landscape existing 10,000 to 7,000 years ago referred to as the *Shotton River* (after Prof. F. Shotton - see *Acknowledgements* section at the end of this paper). At 600 metres wide with an observed length of 27.5km, the river valley displays a trend of North West to South West. From an archaeological perspective, questions naturally arise as to the possible climate, ancient settlements and migration patterns 10,000 to 7,000 years ago. What species of plants would have populated this landscape? How would vegetation spread across the landscape around the river valley district? Would plant growth alter the way living organisms inhabit

these areas just as geological transformations alter plant growth?

As early as 1913, the experienced geologist Clement Reid laid down his perception of the North Sea plain as a landscape, which was originally “available” for human habitation [Rei13]. In 1936, Clark’s work on the Mesolithic Settlement of Northern Europe [Cla36] provided evidence of dry land in the North Sea, based on archaeological findings and pollen records. Wymer [Wym91] highlighted that the North Sea plain was both a land corridor and a place in which to live. In 1998, B.J. Coles [Col98] in the Doggerland project [DOG04] reflected on the now-submerged North Sea landscape with human settlements before the ice-sheets retreated further and sea levels rose to the final separation of the British Peninsula from the mainland. Recent archaeological exploration discovered Mesolithic dwellings in the Northumberland and Dunbar regions of the British Isles [Wad03], [HOW04]. These ancient dwellings, together with the submerged Shotton River - the focus of eager exploration desires of archaeologists, geologists, and a “concerned” British population [Ric03][Sam04] - certainly is not readily accessible for investigation. However, *Virtual*

<h1>The Quaternary</h1>				
Pleistocene 1.8million-10,000bp		Holocene 10,000-present		
Palaeolithic	Mesolithic 10,000-7500bp	Neolithic	Calcolithic (Bronze Age)	... To Present
	Pre-Boreal 10,000-9500bp Boreal 9500-7500bp	Atlantic 6000bp...	Sub-Boreal 3000bp...	Sub-Atlantic 1500bp...

Figure 1: Timescale showing the division of the Quaternary Period.

Heritage has made this seemingly impossible task a possibility. As two researchers of the NYNEX Worldwide Communications & Media Group – Roy Stuart and John Thomas – said in the early 1990s, VR can give the general public access to places and things not normally accessible, to explore objects and experience events that could not normally be explored without ‘alterations of scale or time’. “Technology is solving one of the largest problematic issues concerning cultural heritage – non-destructive public access. For the first time we can not only look more wholly into the past, we can interact with it, discovering its hidden treasures.” [ROAS00].

Virtual Heritage research is expanding, finding new heights in terms of visualization, simulation, preservation, and exploration. From ‘virtualised’ or ‘theorised’ architecture [AG98][dLB00], to artworks [BBC00], [LLP00] and artefacts [Zhe00], [Sto98], entire villages [HOK00], cities [Thw98], [EL00], [CS01], even caves [MC98]. All have been reconstructed as part of the virtual conservation “movement”.

The space and time span for virtual heritage preservation is limited only by our knowledge and imagination. Large-scale landscapes of the present such as the interactive Virtual Florida Everglades [dLB98] and Virtual Snowshoe [ROB02] have been modelled and preservation solutions as far back in time as the Bronze Age [Maz98] have also been studied. The goal of the present project is to reconstruct large-scale interactive, virtual landscapes inaccessible due to geological limitations, populating them with vegetation and possible locations of human settlements as far back as the Mesolithic Age (10,000 – 7,000 years before the present). Successful implementations will provide meaningful virtual sites for archaeological studies. Knowledge acquired from the landscapes will be presented as an educational tool for the general public and children via interactive multimedia systems and interactive, feature-rich Web applications.

The paper begins with information on the location and discovery of the Shotton River and the processing of the

relevant seismic data sources. This is then followed by the integration of archaeological knowledge of the Mesolithic period in the regions of the Southern North Sea. The virtual reconstructions of the landscape are described, as is preliminary work on vegetation dispersion techniques. The paper concludes with discussions on early findings and future work plans.

2. Archaeological Evidence of the Mesolithic Period

Reconstructing the ancient landscape of the Mesolithic age requires a multidisciplinary understanding of a range of details specific to this period, including climatic settings, geological formations, flora and fauna. In combination, these are the details that will lead to theories of human settlements that existed 10,000 to 7,000 years ago. Collection of data and obtaining knowledge of the Mesolithic landscape in the regions of the Shotton River is a lengthy process as different viewpoints are expressed by different archaeologists.

The history of the Earth is divided into four main divisions called periods consisting of Epochs. At present, humans exist in the Quaternary period following the Tertiary. The Quaternary period is a major Geo-Chronological subdivision, which includes the Pleistocene (1.8 to 2.45 million years ago) and Holocene (c. 10,000 years ago to present). The Holocene is the present geological epoch and is marked by rising temperatures throughout the world and the retreat of the ice sheets, which originally led to the flooding of the North Sea. The cultures in existence during the Holocene, in archaeological terms, are classed as Mesolithic (Middle Stone Age), followed by the Neolithic (New Stone Age), Bronze Age, and so on [Kip00]. Around 10,000 before the present day, the last Ice Age was drawing to its close. The population of Europe was expanding into land newly abandoned by the glaciers. This population consisted of hunter-gatherers [Cla00], also known as ‘foragers’, with no knowledge of agriculture or animal husbandry. This period is called the

Mesolithic, which begins with the invention of geometric *microliths* (small stone blades, around 1 cm in length) and the whole of this culture is characterised by the presence of microlithic industries. The Mesolithic economy was supported by the use of plant foods such as hazelnuts and acorns [Cla32], [Dav63], [Cla72], [SDG81].

The climatic period under consideration for the reconstruction of the Mesolithic falls between the Pre-Boreal and Boreal climatic intervals based on Godwin's [God40] scheme of pollen assemblage zones. The Pre-boreal period began about 10,000 years ago, ending some 9,000 years ago and was a time of increasing climatic moderation in which birch-pine forests and tundra were dominant. Radio carbon dating showed that the Boreal period, beginning about 9,500 years ago and ending about 7,500 years ago, was warm and dry. The early Boreal was characterised by hazel pine forest assemblages and lowering sea levels. In the Late Boreal, hazel-oak forest assemblages were dominant but seas were rising. Figure 1 shows the timescale and climatic periods within the Quaternary period. Pollen samples of nearby regions of the same latitude have been used for identifying vegetation types that flourished during the Mesolithic period (as acquiring pollen core samples from the bottom of the North Sea is an impossible task at present). These vegetation types are similar to those of Mesolithic Northern England [Spi99] and Holderness [Twe00], [Twe01]. Tweddle [Twe00] mentioned that, 'during the earliest Holocene, pollen records from all sites within central Holderness are broadly similar.' The woodland types identified include Pine, Ash, Oak, Lime, Elm, Hazel, Alder, and Willow.

Various authorities [Tan65], [God75], [Ing95] have contributed to British plants and ecology and the preferences of individual species of plants in relation to soil types and temperatures for growth. Preferences of the woodland types on landscape features of Shotton River would be similar to Allen's [All99] studies on the vegetation and land use in the Stonehenge landscape in the Mesolithic, although environmental preferences of past woodland types may have been subtly different from those of today according to Spikins [Spi99].

3. Geo-Seismic Datasets and the Conversion Process

Researchers such as Reid and Clark [*op cit.*] in their days were able only to produce a speculative map of the landscape features now submerged under the North Sea due to geological limitations. Advances in seismic technologies and 3D visualisation technologies have since made acquiring submerged datasets reasonably straightforward for accurate reconstructions. The spatial resolutions of seismic datasets are typically 12.5 or 25m, providing adequate detail for three-dimensional topography. The dataset originally gathered for oil prospecting is derived from PGS's 3D Mega Survey data [PGS04] sampled at

25m spacing with the seismic source being a bolt airgun. Initial investigation of the data revealed an interesting river valley to the north thought to possess archaeological importance. The data also revealed hints of ancient lakes and marshes. The seismic dataset was then added into a Geographical Information System and TGS Amira for processing with the output as contours and 3D voxel volume for analysis. Confirmation of the significant riverbed finding prompted the initiation of this project. From the processed dataset, height fields were generated and ported into an Intel XEON 2.6GHz Dual Processor System with 1GB of RAM and an nVidia Quadro4 980 XGL 8X AGP Video Card. 3DS Max 6.0 was installed for the construction and editing of 3D environments as polygonal models. Due to the nature of the height fields, certain protruding faces and vertices of the polygon were edited to prevent a landscape with unnatural spikes. The landscape polygon mesh was also optimised to reduce polygon count and to prevent time and resource bottlenecks when vegetation or other artefacts were added later. Figure 2 shows the process.

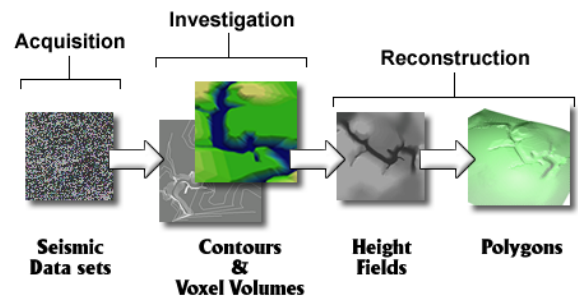


Figure 2: Process of converting seismic datasets into polygon models.

Figure 3 identifies the region from which the seismic data were acquired for the landscape reconstruction in relation to the British Isles and mainland Europe. The coordinates of the river in the UTM zone is 31N as given in the seismic dataset. The river is 600 meters in width with an observed length of 27.5km running North West to South West.

The point in the image from which the arrow originates shows the approximate location of the river valley. The image on the right shows an early version of the virtual reconstruction of the landscape.

4. Virtual Reconstructions and Visualisation

In order to explore and visualise the landscape in its natural form rather than from seismic 3D voxel volumes, it was decided to adopt 3D Studio Max 6.0 as the main content generation tool for the 3D reconstruction of the Shotton River. Optimisation techniques were used to reduce the polygon count to a level manageable by a standard personal

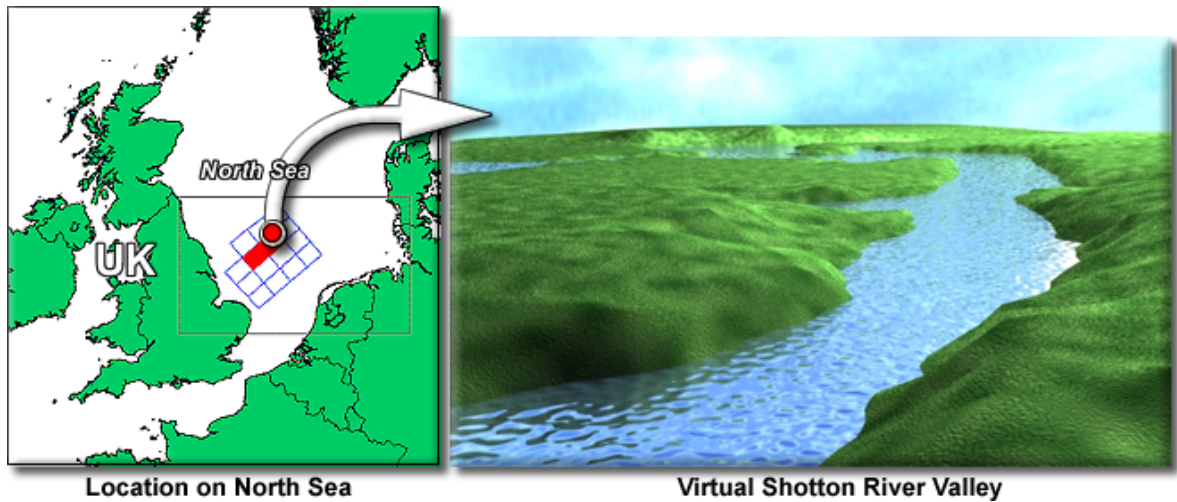


Figure 3: Location of the Shotton River in relation to the British Isles and Mainland Europe. Image on the right shows the virtual reconstruction of the landscape.

computer for real-time interactive modelling and renderings of the vegetation in the later part of the visual reconstruction process. Reducing polygon count in the initial stages of the terrain visualisation work not only conserves resources for reconstruction works but also does much to enable subsequent real-time visualisation via the Internet.

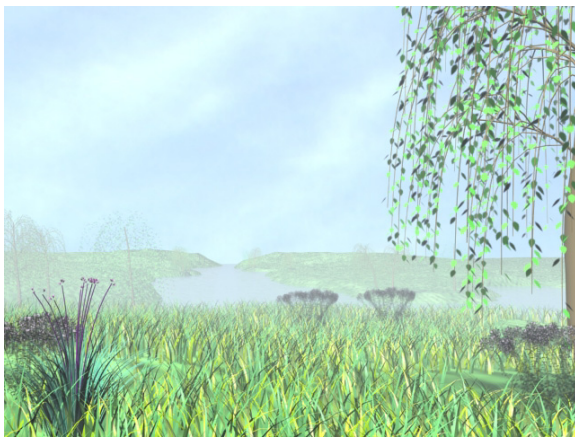


Figure 4: A Scene of the Shotton River Valley from the animation sequence.

Various techniques were investigated in simulating artificial nature such as the vast open grassland in the distance and vegetation in the foreground without compromising on computing resources. As seen in Figure 4, one scene from an animation sequence, rendered images of objects in the near-field landscape appear in greater detail compared to objects appearing in the distance. These different levels of rendering details were accomplished by positioning polygon-based trees with texture mapping in the detailed viewing regions, whereas distant trees were placed using a standard billboarding technique.

Billboarding is a common technique that gives 3D illusion to an otherwise 2D plane by adjusting an object's orientation in relation to the camera angle so that the 2D plane always faces the camera. These techniques reduce computational resources in support of open landscapes.

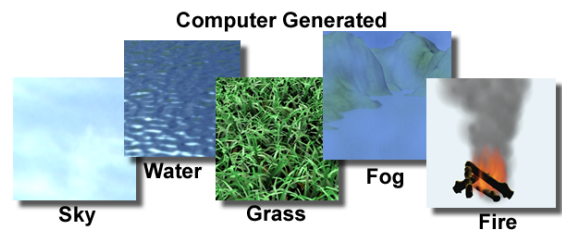


Figure 5: Experimental effects for virtual reconstructions.

Representations of trees in polygonal models and billboards corresponding to the Mesolithic period were added to their respective regions and flowering herbs and grasses were scattered across the landscape. Atmospheric effects such as sky, water reflection, fog and fire were experimented with and added as part of the scene for realism and distance perception (*aerial perspective*) effects (Figure 5). To create a mood for the landscape an animated fly-through was prepared, with water reflection effects, rustling leaves and ambient sound effects of chirping birds and running streams.

Modelling the virtual Mesolithic dwellings required delicate work in order to create a realistic representation, credible in the eyes of the archaeological community [Wad03]. "Construction" began by manipulating a cylinder primitive with 12 segments into a variation of wooden poles and applying wood textures onto it. The

poles were then scaled into variable lengths and positioned onto a pit with an earth mound 6 metres in diameter with an entrance. Straw patches were created and placed around the frames and doorway as covering. Two techniques were experimented with for the straw effects. The first technique scatters a polygon with 3 facets in random orientations to populate the cover of the hut with virtual straws.

The second technique applies straw textures and opacity mapping for protruding straws in the loose end of each patch. Figure 6 illustrates the process of reconstructing the virtual Mesolithic dwelling and Figures 7a and 7b are two variations of the techniques.

Although the first technique was more realistic, the second technique was used eventually, as the polygon count is much smaller. Finally, the completed Mesolithic dwelling was duplicated and placed appropriately around various features, such as the animated campfire with particle smoke and items of pottery scattered around the site (Figure 7c). Based on models of the most probable locations of the dwellings – near the curve of a river valley for example – they were sited and blended into the surroundings with grass patches and trees and animated together with the Shotton River Landscape (Figure 8).

The polygon count for the original high-quality reconstructions amounted to 444,408. The landscape

polygon count reached 32,768 and each Mesolithic house comprised 36,549 polygons. The high-performance model for real-time rendering, as described below, has a greatly reduced total amount of 26,194 polygons with the landscape at 4,718 polygons, with each house comprising 3,098 polygons.

5. Interactive Virtual World and Immersive Environment

As an initial development towards a full VR educational experience (real-time exploration), a suite of VR file format and applications for the web such as VRML and Shockwave 3D, and a real-time VR viewer for standard PCs, such as VR4MAX, were tested. For additional immersive VR implementations, WorldViz's *Vizard*, an OpenGL-based VR programmable development interface that communicates with common VR hardware was utilised. High-quality renderings shown earlier in the paper and real-time interactive environments described here required different computing resources, with the latter placing considerable demands upon performance and visual/interactive quality. To meet these demands, the landscape was further optimised and the Mesolithic dwellings remodelled with significantly fewer polygons (as described above). Billboards with genuine digital images of plants as texture mapping replaced polygon vegetation. An Alpha Channel was added to each of the RGB plant

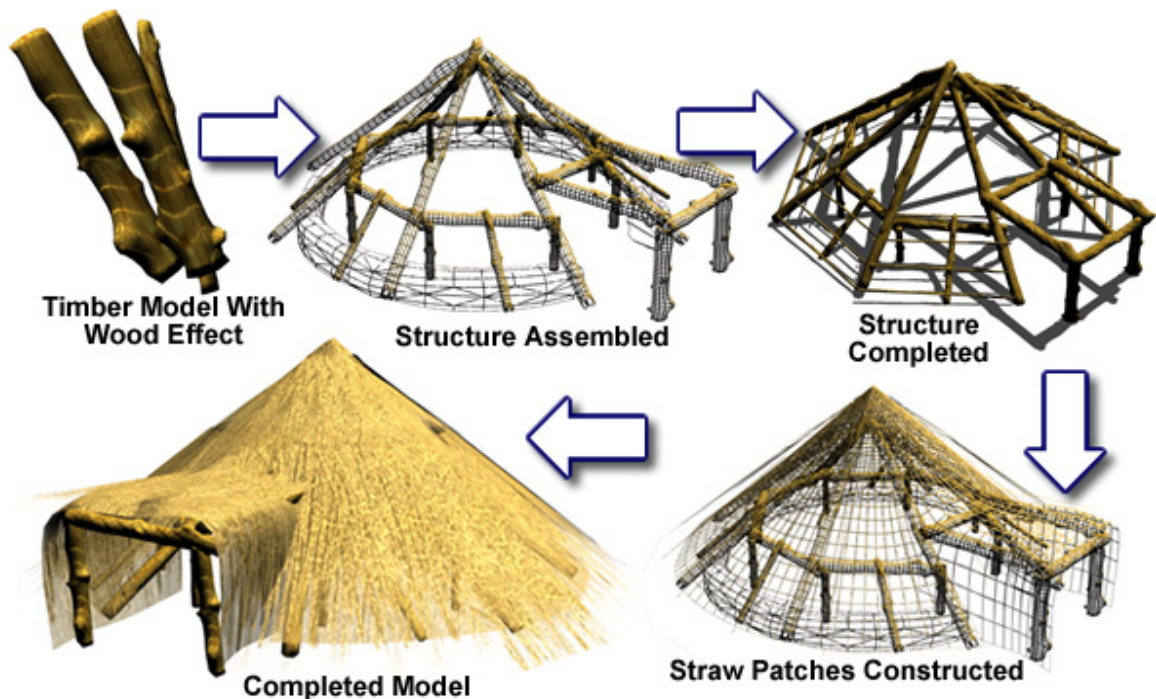


Figure 6: *Virtual reconstruction of the Mesolithic dwelling.*

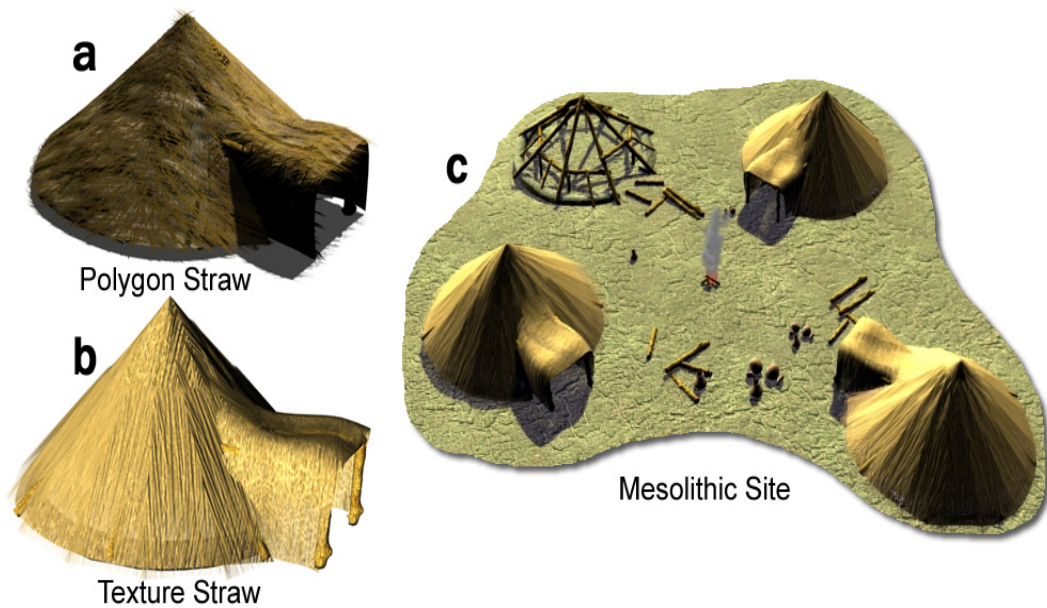


Figure 7: Two techniques for recreating the straw covering and a completed site with Mesolithic dwellings.

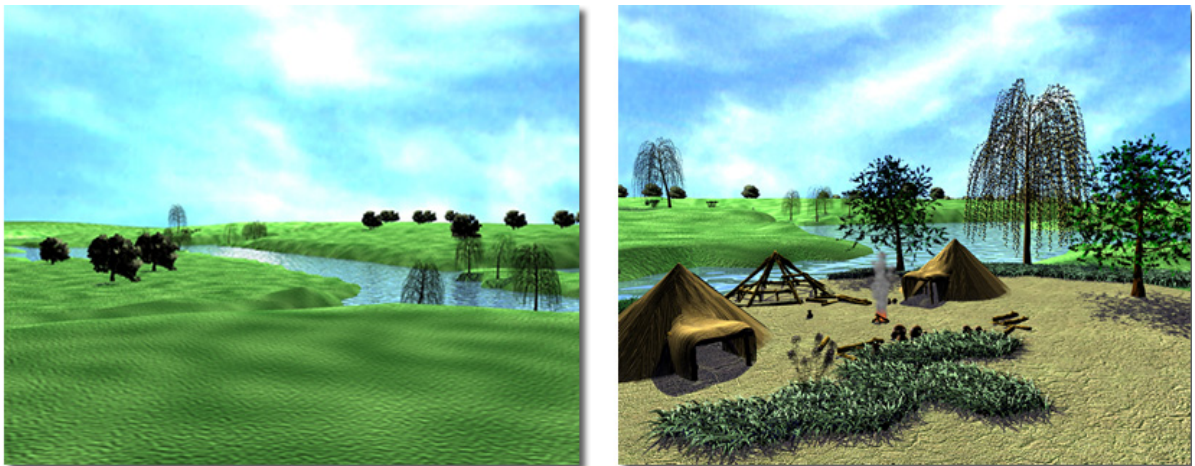


Figure 8: Two scenes from the animation of the Mesolithic landscape on the Shotton River Valley.

images for transparency and exported in PNG or GIF format. Finally, the reconstructed 3D models and textures were customised for each of the test applications as each consisted of different features and limitations, in particular, the different standards in the loading of 3D models, the coordinates of texture mapping, digital images supported, navigation interfaces, and programming capabilities. Figure 9 summarises the process and output.

At the completion of the detailed and lengthy process of customisation, the virtual environments and 3D models in VRML and Shockwave 3D were published for viewing with Web browsers (e.g. ParallelGraphics' *Cortona*) at a significant real-time rendering speed. Ambient and spatial

sound effects of running streams and chirping birds were added into the VRML environment. The spatial sound effects emit sounds in increasingly higher volume as the roaming user approaches the sound source and decreases with further distance. Exponential fog was added for aerial perspective effects. Both the high-polygon model and the optimised model performed very well on the target dual-processor PC system with VR4MAX, a powerful VR runtime system that is capable of taking huge volumes of polygons for real-time walkthroughs. VR4MAX was used for a higher resolution representation and the Magellan SpaceMouse was used as a navigational device.

For simple, semi-immersive explorations, the 3 degree-of-freedom (3-dof) Intersense *Intertrax2* angular (rotational) motion tracker and *CyVisor* Head-Mounted Display (HMD) capable of 1.44 million pixels were used, together with *Vizard* on a Dell Precision M60 Mobile VR laptop. The mobile workstation is equipped with a 128MB nVidia Quadro FX Go1000 Graphics engine with 1GB of RAM and a 1.7GHz Pentium M Processor. Customised 3D models built in 3DStudio Max were exported as VRML and the Wingware *Python* programming language was used to load as well as script parts of the immersive environment such as exponential fog, gravity, collision detection, ground based texture mapping, navigation with mouse, keyboard interaction, and 3D sound effects.

The sound effects such as running streams and bird sounds were attached to transparent objects and placed strategically around river regions and tree groupings across the landscape. The user was initially placed in the centre of the world and two Mesolithic villages were positioned in credible locations on the two sides of the river valley for the user to find and explore.

By using 3D visualisation technologies and recreating a virtual representation of the Shotton River Valley and porting it to various VR runtimes for interactive explorations, the system has already proved itself of benefit in assisting the interpretation of issues related to the Mesolithic landscape.

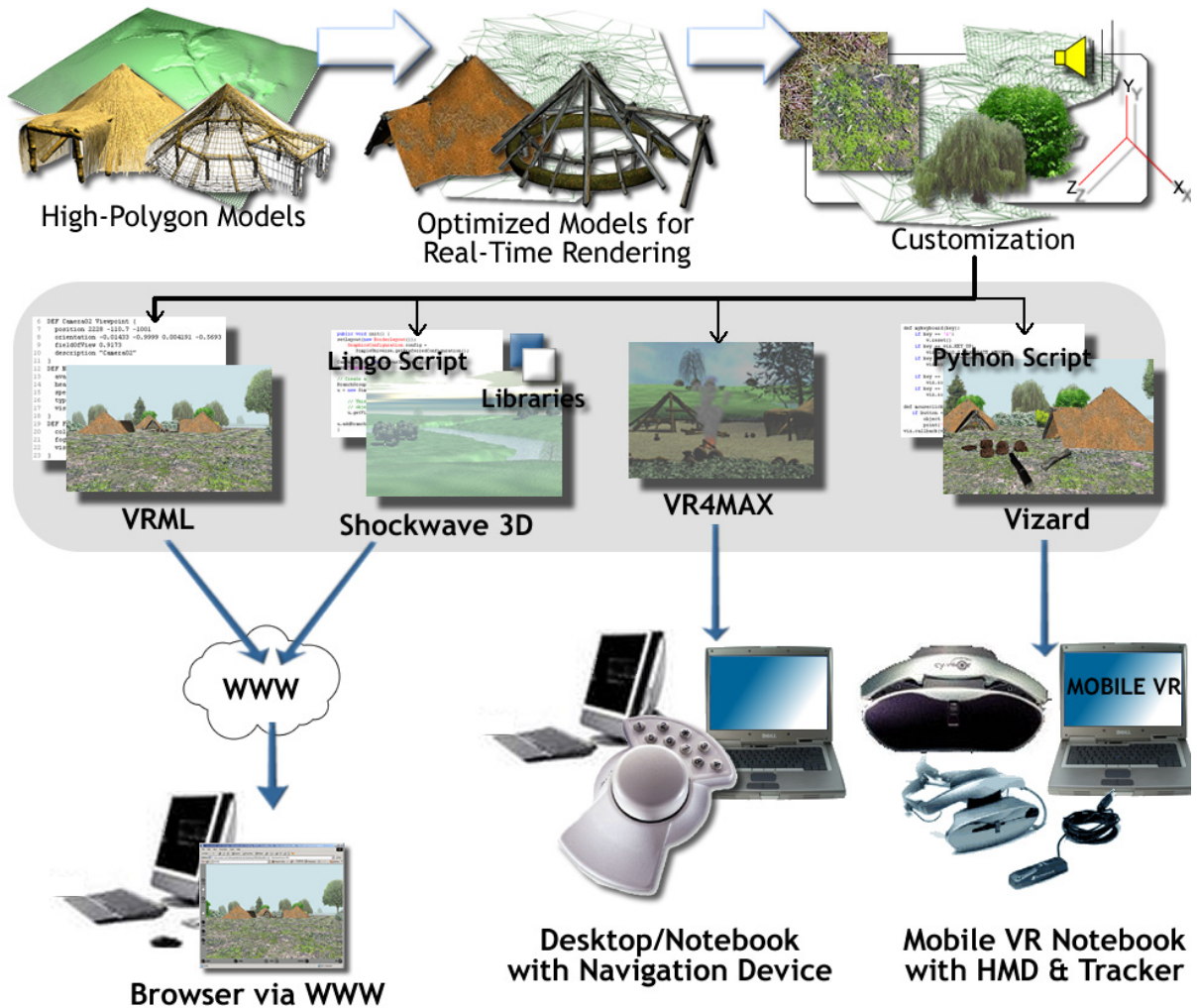


Figure 9: Process of recreating the interactive 3D environment and its output for viewing on the web, desktop, and VR devices.

6. Conclusions and Future Work

This project attempted to visualise the Shotton River Valley in the Mesolithic period with geo-seismic datasets gathered from the Southern North Sea. Initial work on various aspects from data conversion and optimisation to high-quality reconstruction and interactive environments has already taken place. However, a great deal of work is needed to enhance the existing model (and, in particular, the real-time interactive environment). Methods of "seeding" the landscape with vegetation that will eventually disperse on its own based on natural laws are under investigation. Work is in progress using artificial life algorithms to describe vegetation data and behaviours in relation to growth limit and environmental "persuasion" in the Mesolithic settings. The project will eventually be published via multimedia systems and the World Wide Web for educational purposes.

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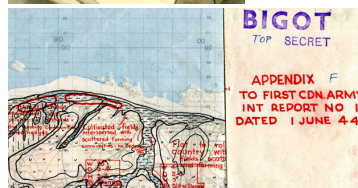
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Acknowledgements

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Prof. Frederick William Shotton MBE FRS (1906-1990)



Prof. Fred Shotton was a renowned geologist who specialised in the study of Ice Age (Pleistocene) geology. A First Class Honours graduate from the University of Cambridge, he taught there and at the University of Birmingham between 1928 and 1940. During the Second World War, Shotton specialised in military geology, initially helping to locate water supplies for troops in North Africa and the Middle East.

One of his most famous contributions to the War involved the generation of geological maps of the D-Day landing sites, pinpointing those regions that might be problematic for military vehicles. Following the war, Shotton became Professor of Geology at University of Sheffield, and from 1949 until his retirement in 1974 he was Lapworth Professor of Geology at the University of Birmingham. In the same spirit as present-day VR endeavours, Shotton pioneered *multidisciplinary* approaches to Pleistocene research, combining geology with archaeology and the study of the remains of flora and fauna mammals to create a multifaceted and information-rich reconstruction of past environments.