The Arminghall Henge in Space and Time:
How Virtual Reality Contributes to Research on its Orientation

Willem Beex
ARC-BV and National Museum for Antiquities,
The Netherlands

John Peterson
School of Information Systems,
University of East Anglia, Norwich NR4 7TJ, UK

ABSTRACT

Neolithic and Bronze Age henges may be related to particular solar events, but confirmation of this requires an accurate determination of relative orientations. In the case of the Arminghall henge in Norfolk, England, the direction of midwinter sunset at that time was thought to have had an important influence, but our computer based methods reveal flaws in this proposal. A spreadsheet relating archaeo-astronomical data to a horizon profile (created manually) and the orientation of the henge (derived from rectified aerial photography) allowed us to plot a simplified view of the sunset, but a virtual reconstruction, based on a digital terrain model and the excavation plan, gives a more accurate, useful and convincing visualisation. From this we can suggest that the henge is positioned so that from it the setting sun is visible "rolling down" the side of the most prominent nearby hill. However, it is clear that the axis of symmetry of the central wooden structure never pointed to this setting point, but towards the top of the hill. Virtual reality reconstruction thus allows alternative theories to be explored, and it may also provide a stimulus to further investigation of the landscape setting of similar structures.

The Arminghall Henge and its Environment

The Arminghall Henge is one of East Anglia's most significant prehistoric field monuments (Ashwin and Bates 2000:230). It lies near the junction of the rivers Yare and Tas, less than 4km south of the centre of Norwich (Fig.1). It is the focus of a large group of monuments, mainly dated to the Bronze Age (Fig.2). Itwas discovered from the air in 1928 and partially excavated in 1935. Two almost circular ditches define it. The inner is larger and has an gap opening towards the south-west. The outer ditch may have had a similar gap. The excavator suggested that there was a bank, about 2m high, between the two ditches. Within the inner ditch there was a setting of large wooden posts arranged in a horseshoe also opening to the south-west.

The contours of the local landscape are not very pronounced, with relative elevations of up to only 40m. Nevertheless, because the Henge is so low, one can see hills from it. The most prominent of these is Chapel Hill, which lies on the end of a spur between the two rivers. This hill lies, again, south-west of the monument. Trevor Ashwin suggests (Ashwin and Bates 2000:233) that the alignment of the Henge might be directed towards both midwinter sunset and the summit of Chapel Hill, although they are only approximately in the same direction. John North (1996:Fig.154) gives us a reconstruction which also shows the axis of symmetry of the horseshoe pointing to the gap in the inner ditch but, because of a miscalculation, it is not reliable and does not suggest a link with Chapel Hill.

An accurate figure for the Henge orientation, agreed among independent observers, was needed. So the first aerial photograph (published in 1935) was rectified to the Ordnance Survey base map by staff of Norfolk Landscape archaeology. One of the staff, Martin Horlock, and one of the authors then independently used drawing software to place a line on the rectified photograph which corresponded, in their judgment, to the axis of the horseshoe post setting (Fig.3). The difference between these estimates of orientation was 0.15°. Accordingly we may conclude that the Henge axis defined by the mirror symmetry is at 40.5° to OS north (to the nearest 0.5°). Since geographic north is 2.63° west of OS north at the Henge, this is equivalent to an azimuth of about 223° in relation to geographic north.
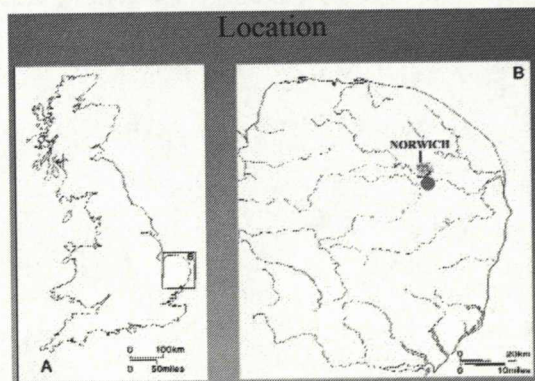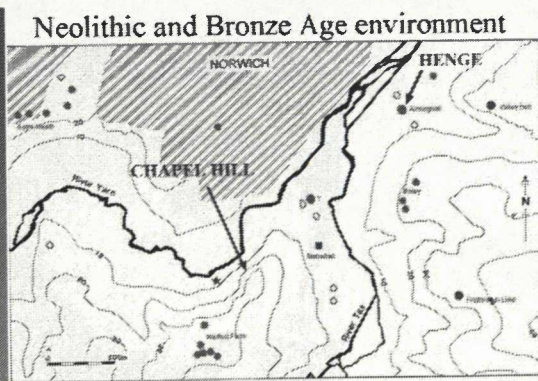
The relationship of the Henge to Midwinter Sunset in 4,000 BP

In the period 5,000 to 4,000 BP the last flash of the setting sun, making allowance for a horizon altitude of 0.8°, was at about 228°. This is 5° from the henge orientation

Figure 1 Location of the Arminghall Henge   Figure 2 Bronze Age environment

so it is difficult to see a connection between the two unless we consider features of wider landscape, adopting the approach taken by (Freeman and Freeman 2001) in the case of Stonehenge. Using their approach, horizon profiles were constructed by drawing rays on the OS map from the centre of the henge and measuring the heights of points along those rays. Calculation then gave the (angular) altitudes, and hence the maximum altitude, along those rays.
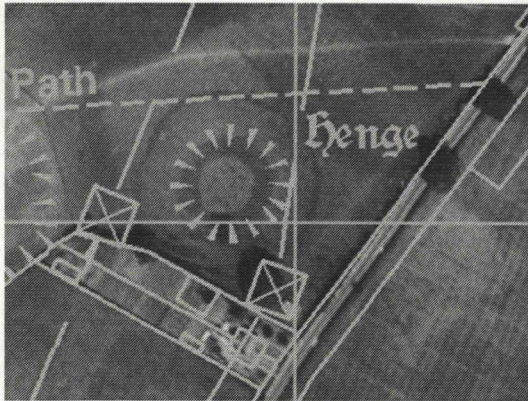
well known case of Croagh Patrick (see http://www.carrow-keel.com/sites/croaghpatrick/reek2.html).

This suggests that the site of the Henge was chosen, perhaps many years before the Henge was built, because it was a place from which such a thing could be seen. It may be one reason why this Henge is so low lying. Only from such positions can hills be seen.

Figure 3 Rectified Aerial Photograph and base map

Figure 4 Orientations compared

VIRTUAL RECONSTRUCTION OF THE LANDSCAPE

A more accurate model of the environment of the Henge required sufficiently accurate data on the elevation of the land surface within a radius of about five kilometres. Modern techniques such as photogrammetry were of little use, even if detailed aerial photographs had been available; half of the surrounding landscape is covered by modern day Norwich. Therefore the data had to come from contour lines at five-metre interval on 1:10, 000 OS maps. These maps have some disadvantage for areas with small differences in altitude, such as the flood plain of the rivers[1], but provide enough information for the reconstruction of Chapel Hill, whose prominence as seen from the henge is a key feature of the landscape.
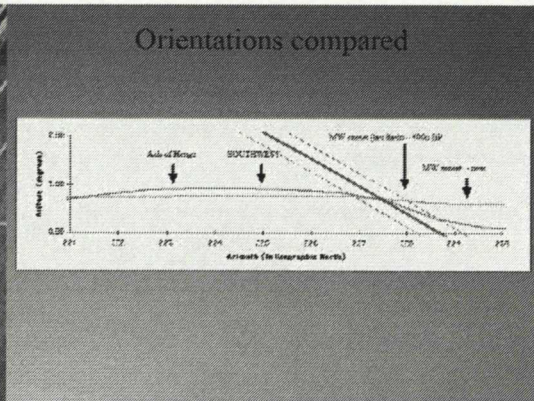
A modified form of the Freemans' calculations gives, for midwinter sunset, a relationship between the apparent altitude of the sun's centre, h (for h < 4°) , and its azimuth. They are approximately related by a straight line

$$h = \frac{\text{Cos Q Cos l} + \text{Sin e}}{\text{Sin l}} + r$$

Where
Q   is the azimuth of the sun's centre,
l   is the observer's latitude,
e   is the obliquity of the ecliptic and
r   is the increase in apparent altitude due to refraction.

A spreadsheet performing these calculations was validated by checking its results against those for Stonehenge given by John North. By trial and error it was established that a value for the refraction of 0.0081 radians gave the best fit of spreadsheet values to those published.

The spreadsheet values for the sun's path were drawn as a graph; the horizon profiles were also included. The date could be altered to affect the obliquity of the ecliptic and hence the sun's path. This showed that in 5,000 BP disc of the setting midwinter sun would have seemed to pass down the right hand (northern) side of Chapel Hill and be "eaten" by the angle between it and the far horizon (Fig.4). Like the Freemans, we tried to observe this on the ground, making an allowance for the change of about 1.5° in sunset azimuth over 5,000 years. This could not be done from the monument itself because a high hedge obscured the view. However, a line was drawn on the map from the Henge centre, at the appropriate angle. From the point where this line intersects a road, nearer to Chapel Hill, the "roll down" of the sun could be observed near midwinter, 2002. Such an effect can be compared to the

The maps were digitised in a CAD-application including their attribute data. The accuracy of this digitising was somewhat less than three metres which, for our purpose, is well within the maximum allowed tolerance[2]. The spatial data was then transferred to Surfer[3], which is probably the best software for creating a Digital Terrain Model (DTM). Its algorithms and parameters allowing for controlled and detailed processing of contour lines. They can be input as exact data and smoothed. For this the search radius, the distance over which data points are allowed to influence each other, is important. For example, the valley of the river Yare must not be smoothed because of measurements taken from a hill two kilometres away. Anisotropy, the irregularity of the landscape, must also be considered. In simple terms, there are two rivers cutting through the hills, which have generated the overall shape of the hillsides.

Experience showed which methods and parameters were most appropriate in this case. The commonly used Triangulation with Linear Interpolation (TIN) approach is not well suited for interpreting this type of data. A DTM produced in this way for the Arminghall Henge area produces a rather terrace-shaped landscape which does not convincingly reproduce the actual shape of the one significant hill. It gives it a flat top, even if smoothing is allowed for. Kriging seems more appropriate. The default application of this algorithm in
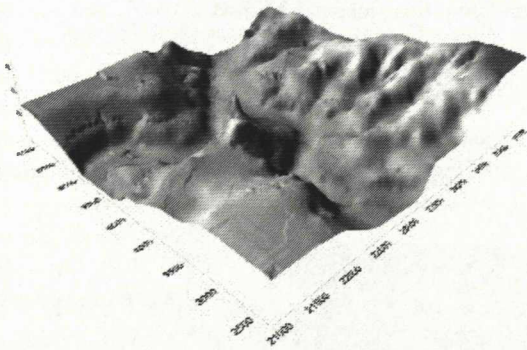
Figure 5 DEM created in Surfer 8

Figure 6 Building the henge

The most significant part of creating the animation involved adjustment of the background sky and the overall lighting. This took some trial and error - reducing ambient light and smoothly inserting a dusk background sky and other effects - to obtain a convincing view of sunset (Fig.8).

Surfer produces a model of the environment of Arminghall Henge which compares favourably with visual observation and photographs of the actual landscape. However, contour lines at five metre interval still lacked some detail needed to give a true profile to Chapel Hill. Adding valid additional data rectified this. The other problem was the tendency of the Kriging method to insert irregularities if the distance between two contour lines is more than ten times the size of the DTM mesh. This problem could be solved by using a custom-made variogram, despite the problems associated with creating this, about which the Surfer manual is quite explicit. The DTM of the Arminghall Henge environment was then prepared for modelling and animation (Fig.5). This required a custom-made LISP-routine in AutoCAD, capable of reading Surfer grid-files.

Meanwhile, using a CAD-program, the henge itself was reconstructed from the excavation plans, while correcting the north to the real world situation (Fig.6). When the basic model was considered to be correct, it was imported into the rendering and animation program. The trajectory of the sun 4,000 years ago was then recreated. Using positions calculated by astronomical software[4], a series of sightlines was plotted, identifying vertices of an arc from pre-sunrise till a few hours after sunset. A bezier-curve through these vertices, allowed for a smooth path for a virtual sun to follow.

With all the different elements available in the 3d-modelling application, textures,

The appearance of the sun itself was done by adding lens-flare effects and the midwinter 2002 photograph provided good reference information, especially for the apparent size of the sun in relation to the horizon. Changing the background from a blue into a dusk-coloured sky was done by using a gradient bitmap, a few times larger than the intended area of the background. This bitmap was then slowly moved upward during the animation, giving the impression of an atmosphere turning from blue into pink/orange.

THE VALUE OF VR RECONSTRUCTION

The VR reconstruction provides confirmation of the phenomenon modelled by the spreadsheet approach, but it has the great advantage that additional information can be presented that is not easily available in graphics and plans . This makes the results of the research on the orientation of the Henge much more understandable. Those to whom we are trying to communicate our ideas can be more confident that they are soundly based.

Figure 7 Adding textures and shades
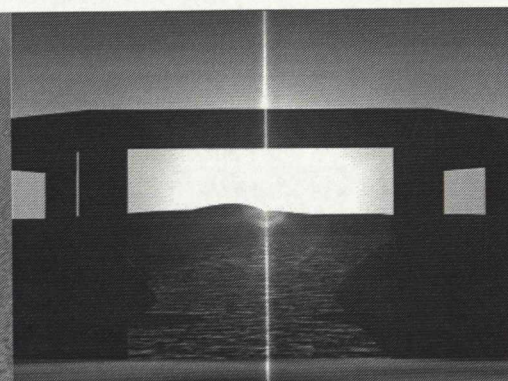
Figure 8 Creating the sunset

daylight effects, animation and post-production were added. Since midwinter sunset was to be simulated no summer textures had to be added to the ground surface and we could assume that at this particular midwinter it had snowed. An appropriate texture, onto which a "bump-map" was placed with a fractal algorithm, produced a snowy landscape (Fig.7).
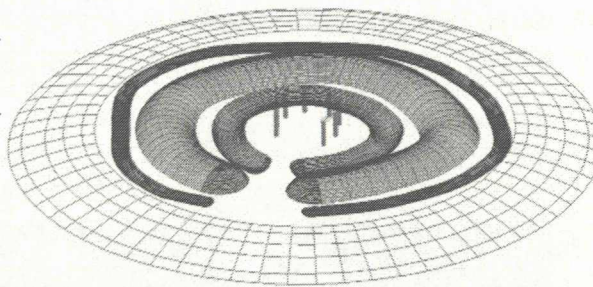
The DTM also provides data which could can be used for further research. For example, there is another feature with a double circular ditch lying at the foot of Chapel Hill on its northern side. This may be another henge. Was it positioned so that a midsummer sunrise event was visible to the Northeast, over the hill on the south side of the Yare valley?

The situation of other similar monuments might also be explored in the same way. The so-called "Seahenge", which is so low that it is now in the tidal zone, may be just part of a group of monuments which lay north-east of the most prominent headland in north-west Norfolk. From this site the headland may have been visible in the direction of the setting midwinter sun, just as at Arminghall.

[1] The floodplains of rivers in the area are now flat, but we expect that 4,000 years BP sea level would have been lower. Our model does not attempt to take account of this, since it has no influence on sunset positions.

[2] When using a puck to digitise, accuracy in calibration of a map should be within 0.05 %.

[3] Surfer is product of Golden Software, Colorado. For the reconstruction of the landscape around Arminghall Henge, the newest version 8 was used.

[4] "Cartes du ciel" was used in this case.

REFERENCES

ASHWIN, T., and BATES, S., 2000. Excavations on the Norwich Southern Bypass, 1989, Part 1. East Anglian Archaeology 91. Norfolk Museums Service, Gressenhall.

FREEMAN, G. R., and FREEMAN, P. J., 2001. Observational Archaeoastronomy at Stonehenge: Winter Solstice Sun Rise and Set Lines Accurate to 0.2° in 4000 BP. In Pilon, J-L., Kirby, M. W. and Thériault, C. (eds.), A Collection of Papers Presented at the 33rd Annual Meeting of the Canadian Archaeological Association:200-219. (The Ontario Archaeological Society Inc., http://collection.nlc-bnc.ca/100/200/300/ont_archaeol_soc/annual_meeting_caa/33rd/freeman1.pdf).

NORTH, J., 1996. Stonehenge: Neolithic Man and the Cosmos. HarperCollins, London.