Very Realistic Graphics for Visualising Archaeological Site Reconstructions

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Abstract

Recent developments in computer graphics are providing powerful tools for modelling multi-dimensional aspects of data gathered by archaeologists. Computer graphics techniques can now be used to reconstruct and visualise features of a site which may otherwise be difficult to appreciate. This new perspective may enhance our understanding of the environments in which our ancestors lived. However, if we are to avoid misleading impressions of a site then we need to be able to evaluate the "realism" of the resultant reconstructions.

This paper investigates the problems associated with reconstructing archaeological and heritage sites on computer.

Keywords: Very Realistic Rendering, Archaeology, Global Illumination, Visual Perception.

1 Introduction

Computer graphics techniques are increasingly being used to reconstruct and visualize features of archaeological sites [1]. While this new perspective may enhance our understanding of the environments in which our ancestors lived, if we are to avoid misleading impressions of a site, then the computer generated images should not only look "real", but must simulate accurately all the physical evidence for the site being modeled. The aim of realistic image synthesis is the creation of such accurate, high quality imagery which faithfully represents a physical environment, the ultimate goal being to create images which are perceptually indistinguishable from an actual scene.

Before the advent of modern lighting, illumination within ancient environments was dependent on daylight and flame. The lack of windows in ancient environments(certainly the case in caves) and later, glass if available was expensive, windows were inappropriate for defense etc, meant that even during daylight hours, some form of firelight was necessary for interior illumination. The fuel used for the fire directly affects the visual appearance of the scene. Furthermore, flames are not static and their flicker may create patterns and moving shadows that further affect how objects lit by these flames might look. Thus any realistic reconstruction of an archaeological site must take into account that these would have been flame-lit environments and thus the reconstructions should not only incorporate the accurate spectral profile of the fuel being burnt, but also the manner in which the flame may move over time.

2 Luminaires

"Command the Israelites to bring you clear oil of pressed olives for the light so that the lamps may be kept burning"
[Exodus 27:20]

The luminosity of flame is due to glowing particles of solids in laminar flux, the colour of which is primarily related to the emission from incandescent carbon particles. In this paper we are interested in the perception of objects illuminated only by the flame from candles made using different fuel types and the impact moving the candle to different positions in an environment has on visual perception. We have built upon the simplified candle flame model of Inakage [5], which Raczkowski extended to include the dynamic nature of the flame[10].

2.1 Building the Luminaires

The acquisition of valid experimental data is of vital importance to realism as the fuel burnt may have had a significant influence on the perception of the ancient environment. The first stage was to build a variety of reconstruction candles in collaboration with our archaeology department. Figure 1 (a) shows a selection of the candles. From top left they are:

- Two processed beeswax candles (such as might be used today), tallow candle (of vegetable origin), unrefined beeswax candle, and a selection of reeds coated in vegetable tallow

- We also used a rendered animal fat lamp, 1(b) and an olive oil lamp, 1(c).

Figure 1: Experimental archaeology: to reconstruct ancient light sources

Detailed spectral data was gathered using a spectoradiometer. This device is able to measure the emission spectrum of a light source from 380nm to 760nm, in 5nm wavelength increments. This gives an accurate breakdown of the emission lines generated by the combustion of a particular fuel. This data can be used to create an RGB colour model for use in rendering the scene.

2.1.1 Converting Luminaire Data

It is essential, when converting the detailed spectrum data from the spectroradiometer into values representing the red,[1] green and blue portions of the spectrum, that this conversion is calculated in a perceptually valid way, as defined by the CIE (Commission International de l'Eclairage) 1931 1-degree standard observer[1].

Figure 2 shows the functions for the X, Y and Z channels. The Y channel measures the luminance of a source, and the X and Z channels measure the chromaticity. This information is more useful when broken down as follows:

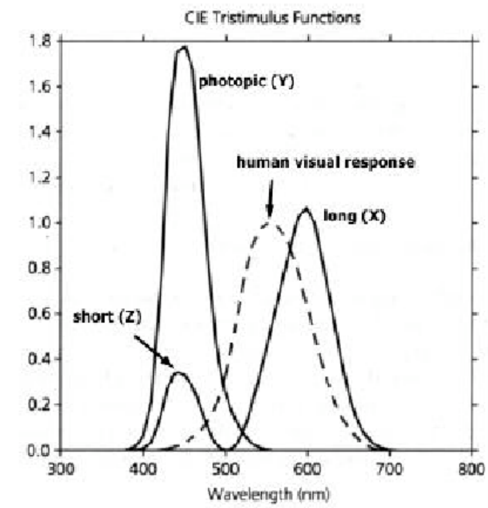

Figure 2: CIE Tristimulus functions

If we let $x = \dfrac{X}{(X+Y+Z)}$ and $y = \dfrac{Y}{(X+Y+Z)}$

Then we can calculate the exact colour values for the red, green and blue sections of the spectrum, disregarding luminance. For a canonical set of VDU phosphors;

RED(x,y)	= (0.64, 0.33)	
GREEN(x,y)	= (0.29, 0.60)	
BLUE(x,y)	= (0.15, 0.06)	(Ward98)

2.1.2 Modelling the flame

Candle flame may be defined as diffusion wick flames, in which heat transfer from the flame cause a steady production of flammable vapour [4, 7]. Observations from the reconstructed light sources showed that all of the flames were small and (ignoring the effect of air turbulence for now [13]) fairly steady.

Rather than attempting to model the shape of the flame mathematically, video footage of the real reconstructed flames was processed using computer vision techniques, the shape of the flame extracted and the real flame incorporated in the virtual scene which was rendered using Radiance [14]. The illumination of the flame in the environment was achieved by approximating the shape of the flame by a series of *illum* spheres [14], as shown in figure 3 (a) and included in the virtual scene 3(b). The number and size of the spheres can of course be varied to achieve a better "fit" to the shape of the flame for each frame of the video sequence.

[1] This system specifies a perceived colour as a tristimulus value (i.e. three coordinates) indicating the luminance and chromaticity of a stimulus as it is perceived in a 1-degree field around the foveal centre.

Figure 3: (a) Simple luminaire model (b) real flame in virtual environment

Conversion of the spectral data to RGB does of course lead to an approximation of the colours present. In future, for more accuracy we will need to consider calculating the convolution of the emission spectrum of the light source with the reflectance curve of the material under examination. However, even with the approximation, significant perceptual differences related to fuel type are achieved. These simulations can be validated with real scenes [8, 9]. Figure 4 shows a test scene including a Macbeth colour chart illuminated with (a) a 55W electric bulb, (b) an olive oil candle and (c) a candle made from animal fat.

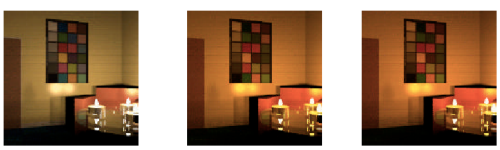

Figure 4: The effect of different fuel types (a) modern (b) olive oil (c) animal fat

3 Example applications

Validated flame lighting has now been applied to a number of archaeological sites to investigate the perception of objects within these sites.

3.1 Cap Blanc

The rock shelter site of Cap Blanc, overlooking the Beaune valley in the Dordogne, contains perhaps the most dramatic and impressive example of Upper Palaeolithic haut relief carving. A frieze of horses, bison and deer, some overlain on other images, was carved some 25,000 years ago into the limestone as deeply as 45cms, covers 13m of the wall of the shelter. Since its discovery in 1909 by Raymond Peyrille several descriptions, sketches, and surveys of the frieze have been published, but they appear to be variable in their detail and accuracy In 1999, a laser scan of was taken of part of the frieze, figure 5, at 20mm precision [12]. It was obviously of utmost importance that an "eye safe" laser was used to ensure there was no damage at all to the site.

Figure 5: Part of the frieze from Cap Blanc

Some 55,000 points were obtained in two scans of the upper and lower part of the selected area, figure 5 (the MDL laser scanner used did not have sufficient memory to store all the points in a single scan). These points were stitched together and converted into a triangular mesh.

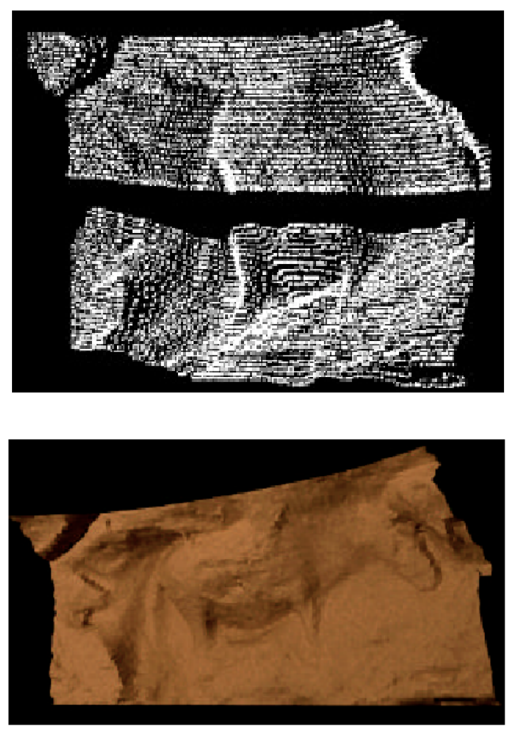

Figure 6: (a) Clouds of points from the scan (b) The reconstructed horse

Detailed photographs of the frieze were taken, each one of which included a standard "rock art colour chart", just visible in figure 5. As the exact spectral data for the colour chart is known, this enabled us to compensate for the lighting in the photograph and thus obtain approximate "illumination free" textures to include with the wire-frame model.

3.1 Results

Images were rendered using Radiance. Figure 7(a) shows the horse illuminated by a simulated 55W incandescent bulb (as in a low-power floodlight), which is how visitors view the actual site today. In figure 7(b) the horse is now illuminated by an animal fat tallow candle as it may have been viewed 25,000 years ago. As can be seen the difference between the two images is significant with the candle illumination giving a "warmer glow" to the scene as well as more shadows.

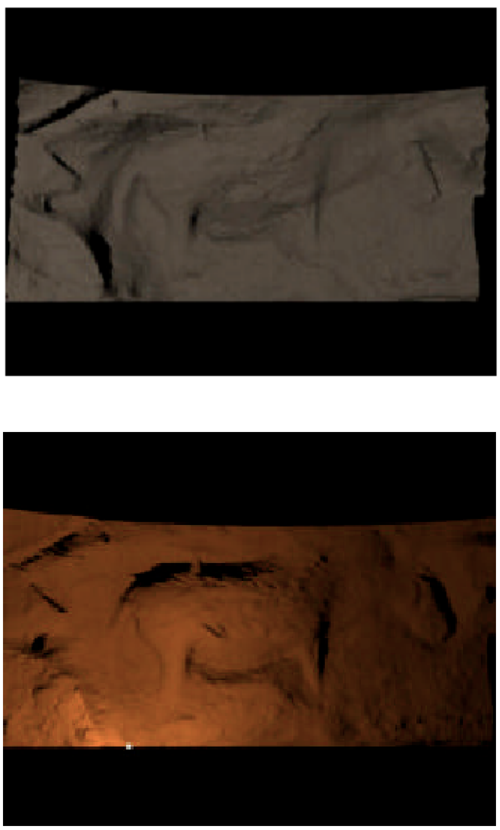

Figure 7: Frieze lit by (a) 55W incandescent bulb (b) animal fat candle

This shows that it is important for archaeologists to view such art work under (simulated) original conditions rather than under modern lighting. (It is of course impossible to investigate these sensitive sites with real flame sources).

For this site, we wanted to investigate whether the dynamic nature of flame, coupled with the careful use of three-dimensional structure, may have been used by our prehistoric ancestors to create animations in the cave art sites of France, 25,000 years ago.

To investigate this hypothesis, images were rendered with the simulated flame in a number of different positions relative to the carving of the horse. Figure 8 shows some stills of the animation that was created [2].

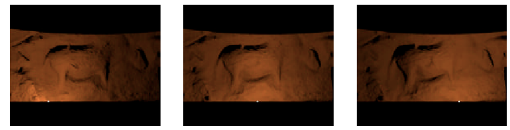

Figure 8: Stills from the animation: *Firelight: Graphics and Archaeology*

The video which illustrates this work can be seen at:

www.cs.bris.ac.uk/~alan/capblanc.html

The shadows created by the moving flame do indeed appear to give the horse motion.

3.2 The House of Vettii, Pompeii

The House of the Vettii in Pompeii is one of the best-preserved and decorated buildings in this World Heritage site, and is the most frequently visited building in Pompeii [9]. The rich colours and extensive use of artistic techniques such as *trompe l'oeil*, along with its magnificent state of preservation draws millions of visitors through its rooms each year. However, the impact of time and tourism on such a site has led to serious deterioration. A very realistic computer reconstruction of the House of the Vettii allows us to view the site as it might have been when it was in use before the eruption of Vesuvius in AD 79 [3].

The room chosen for the study was a reception room, which opens onto a colonnaded garden. The room's three walls are richly decorated by intricate frescoes, figure 2.

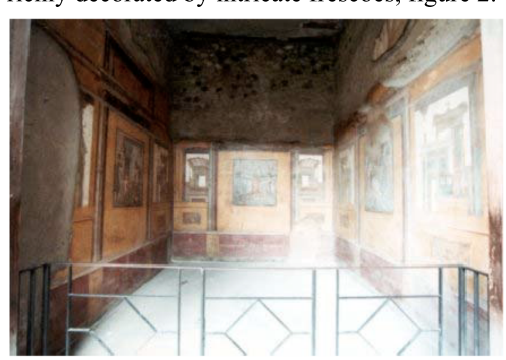

Figure 2. The room as it appears today

The frescoes in the room were recorded photographically. Once again, a colour chart was included at either side of each photo to permit calibration, identify illumination levels and allow us to obtain illumination free textures to incorporate into the computer model.

Figure 7 shows a visualisation of the frescoes using simulated modern and olive oil lighting. It is noticeable that the lamp-lit scenes (Figures 7b – 7d) can be perceived as warmer in appearance when compared to the modern light (Fig. 7a), with the yellow and red pigments particularly well emphasised. The appearance of the three-dimensional *trompe l'oeil* art is also influenced.

Figure 7. Clockwise from top left: (a) modern lighting (b) olive oil lamp (c) olive oil lamp with salt (d) olive oil lamp with water

4 Conclusions

We will of course never know for certain whether the artists of the Upper Palaeolithic were in fact creating animations 25,000 years ago, however the reconstructions does show that it certainly is possible. There is other intriguing evidence to support this hypothesis. As can be seen in the figures, the legs of the horse are not present in any detail. This has long been believed by archaeologists to be due to erosion, but if this is the case, why is the rest of the horse not equally eroded? Could it be that the legs were *deliberately* not carved in any detail to *accentuate* any motion? Furthermore traces of red ochre have been found on the carvings. It is interesting to speculate again whether the application of red ochre at key points on the horse's anatomy may also have been used to enhance any motion effects.

Future work will investigate these possibilities as well as considering reconstructions of other painted (rather than carved) sites in the region to see if a similar hypothesis could apply equally to the use of painting on complex three-dimensional rock surfaces.

Work on the House of Vettii is also only in its preliminary stages. Current work involves the addition of models of appropriate Roman furniture and artefacts to the scene. This will not only create a more realistic scene, but will allow archaeologists to investigate the appearance of these objects under their original lighting conditions. It is important to remember that a reconstruction is only one glimpse of many valid interpretations. Various configurations of lamps are also being modelled to provide a number of possible scenarios.

Very realistic computer reconstructions of past environments provides a safe and controlled manner in which the archaeologist can test hypotheses regarding perception and purpose of colour in decoration and artefacts. Computer generated imagery indistinguishable from the real physical environment will be of substantial benefit to the archaeological community, and this research is one method of moving beyond the current trend of photo-realistic graphics into physically and perceptually realistic scenes which are ultimately of greater use to those investigating our past.

Acknowledgements

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