THE "TRUTHLIKENESS" OF VIRTUAL REALITY RECONSTRUCTIONS OF ARCHITECTURAL HERITAGE: CONCEPTS AND METADATA.

C.L. Ogleby

Department of Geomatics, The University of Melbourne, 3010, Australia. clogleby@unimelb.edu.au

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ABSTRACT:

The more recent trend in using computer graphics technology to visualize and re-create historic monuments and sites has encouraged a proliferation of imagery, both still and animated. Desktop computers give users enormous power to create photo-realistic reconstructions of famous and less well known buildings and landscapes. So photorealistic that the human visual cognitive system, along with centuries of conditioning, accept these as being 'truthful'. They become part of the plethora of visual images that surround us and vie for our attention. The more photo-realistic, the more likely we are to perceive the image as being a 'true' image of the object.

Archaeological illustration and reconstruction is not new, but the advent of high-speed affordable computers and the associated graphics capability gives people the opportunity to create better looking imagery. The imagery, however, is often the result of the technology, not archaeological or historical research. When this imagery is distributed without the accompanying research that explains the decisions made in the reconstruction, it is open to a variety interpretations. This problem is compounded when the imagery is posted on the WWW, as the image can be extracted from the surrounding text and interpreted as an artifact rather than as a diagram.

This paper will illustrate the problem of 'truthlikeness' in the visualization of heritage monuments, and will present and discuss a possible metadata approach to the qualification and quantification of veracity. Whilst researchers working in the field of measurement science are able to quantify geometric accuracy, it is a bigger challenge to quantify 'visual accuracy' as some understanding of the viewer's cognitive processes needs to be included.

1. INTRODUCTION

1.1 Virtual Heritage

Archaeological illustration and reconstruction/recreation is neither new or unusual. Stuart Piggott in his book Antiquity Depicted (1978) has collected images of a rebuilt Stonehenge dating back centuries, whilst participants in the BBC Television program *Time Team* have produced recent books on the process (Ambrus, 2001). There has always been a fascination with both the extant ruins and the impression of what they may have been like before decay. Watercolour paintings of imagined reconstructions, or a physical diorama in a museum were easily understood to be the work of an individual and therefore subject to a variety of interpretive processes

Advances in computer graphics systems over the last decade or so now puts very powerful visualisation tools in the hands of even the most novice user. This has led to the creation of some stunning and innovative computer generated artwork and installations, as well as motion pictures that allow the wildest imagination to become visual 'reality'. This advanced graphics capability has also aided (and sometimes instigated) the production of photo-realistic, computer-based reconstructions and visualisations of cultural heritage monuments and events, sometimes known as *virtual heritage*.

In association with the advances in computer graphics are developments in the transmission and distribution of images. The present environment is increasingly visual, images are everywhere from clothing, to the media, to mobile telephones. An image can now exist simultaneously within a scholarly publication as well as on a student assignment web page, as a desktop theme or a souvenir T-shirt.

The technology now allows incredibly photo-realistic images to be prepared of reconstructed monuments and structures, and these can exist as artefacts in their own right instead of merely being elaborate diagrams. They can exist outside the established discourse of literature, where the reasoning behind an image was contained in the associated text, where the archaeological evidence of a tile being made from terracotta was part of the information available to a reader.

What is lacking presently is both an ontology for visual literacy in the area of virtual heritage, and some method of adding to the viewer's understanding through the supply of supporting information.

1.2 Photography

Before the advent of digital imaging, a photograph was understood to show an actual event or scene as the photographer was evidently present at the time of the photograph. Light reflected off the surfaces in the image and was captured in an instant by the camera. Ignoring the approaches taken to compose the photograph to either stress or diminish the information contained, if it was a photograph it then represented a real 'instant' (more truthfully, a very small period) in time and place. (The manipulation of images by manual cutting and pasting elements was not unknown, but was not widely practiced except for propaganda purposes).

However the advent of digital imaging, both camera based and computer generated, has created dissent within the discourse of photographic realism. William Mitchell, in his book The Photographic Eye: Visual Truth in the Post-photographic Era summarises this well:

> *Photographs appeared to be reliably manufactured commodities, readily distinguishable from other types of images. They were comfortably regarded as casually generated truthful reports about things in the real world…The visual discourses of recorded fact and imaginative construction were conveniently segregated. But the emergence of digital imaging has irrevocable subverted these certainties, forcing us to adopt a far more wary and vigilant interpretive stance…An interlude of false innocence has passed.* Mitchell, 1992, p225

This statement is relevant to those who study the meaning of images, but does this new wariness apply to all viewers of images? Whilst there may be a new scepticism in the 'enlightened' interpretation of visual truth, many people will still tend to 'see' a photo-like image to be more like a photograph, and therefore a record of a real place in time.

1.3 An Illustration of the Problem: The Mausoleum at Halicarnassus

Shown below is a selection of images of a reconstruction of the Mausoleum at Halicarnassus, obtained from a Google Image search. The search returned 4000 hits, these 2 reconstructions were chosen because they appear on multiple web pages, in different forms, with or without any explanatory text. The image marked ©Larrinaga also appears on several student assignment pages. The copyright symbol does not appear on all instances of the image.

Figure 1: http://www.crystalinks.com/mausoleumhal.html

Figure 2: http://www.unmuseum.org/maus.htm
Copyright Lee Krystek, 1998

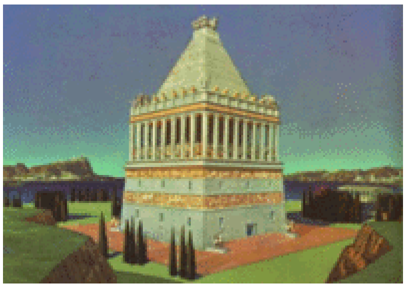


Figure 3:
www.allaboutturkey.com/ita/bodrum.htmpic/halikarnas_mozole.jpg

http://www.moyak.com/researcher/resume/papers/
definitions_ancient.html

Figure 4: library.thinkquest.org/. ../ancient_5.htm

Figure 5: http://www.waltm.net/wonder1.htm
This appears to be a reversed version of the Larrinaga image which has been modified (badly)

There are a multitude of 'reconstructions' of the Mausoleum (as there is for most of the Ancient Seven Wonders), and the book by John and Elizabeth Romer (2005) has also published a collection of these. The Larrinaga images above are not computer based reconstructions, whereas the other is such an image. These examples are not meant to be exhaustive, but serve to indicate the proliferation of images of reconstructions on the web often without any qualification as to their providence, veracity, or authorship.

The problem becomes compounded if, for example, the images or models are displayed in something like Google Earth or Second Life. They indeed have a second life, and a whole new type of audience.

Figure 6: Watsa DaCosta visits a museum in Second Life

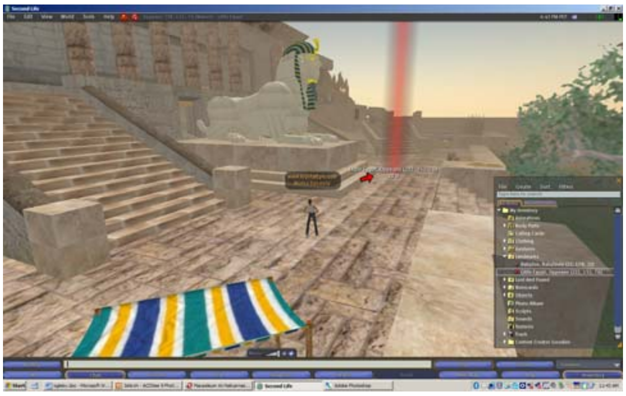


Figure 7: Watsa DaCosta visits Little Egypt in Second Life

1.4 Photo-Realism

The primary advance in virtual heritage is the high level of graphics processing and enhancement available to computer users. One of the main manifestations of this is the ability to produce incredibly 'photorealistic' imagery – images that appear to be photographs of the object. As discussed previously, there was an inherent 'trust' attached to a photograph.

So what is photorealism? Originally the term was used to describe paintings that exhibited all the aspects of a photograph, and is recognised as a distinct art movement. More commonly nowadays it is used to describe computer generated imagery that resembles a photograph. A simple definition may well just be that if it looks like a photograph, then it is photorealistic.

In an early book on photorealism for computer graphics, Fleming (1998) proposed the following 10 elements:

1. clutter and chaos
2. personality and expectations
3. believability
4. surface texture
5. specularity
6. dirt, dust, rust
7. flaws, scratches and dents
8. bevelled edges
9. object material depth
10. radiosity

The 'real' world, or one's interpretation of the real world, is dirty, cluttered and imperfect and illuminated by complex light sources. If a computer generated image exhibits this, then perhaps it resembles a photograph?

2. THE RECONSTRUCTION PROCESS

There are several 'conventional' stages in the graphical reconstruction of an antiquity. These include the gathering of source information, the interpretation of this information, the use of contemporaneous example and parallels, the development of a basic geometric 'wireframe', the addition of detail to this framework and finally the rendering (artistic or otherwise) of the result. This process is common (or should be common) to the generation of imagery regardless of whether a computer is involved.

The thrust of this paper is the production of reconstructions using computer graphics, so this particular process will be detailed.

The process may occur this way:

- Collect all available material relating to the monument. This would include plans, sections, elevations, topography, surveys, measurements, photographs, geographic location, published descriptions, scholarly analysis…
- Determine the shape and relative (if not absolute) dimensions, and orientation and position if needed
- Commence the computer model construction
    - Either using CAD procedures
    - Or using a mesh based approach
    - Or using the source data directly
- Create graphical elements capable of having surfaces and/or texture maps applied
- Create a library of real or derived materials, apply these to the objects
- Place the monument in its correct environment
- Determine lighting parameters, create virtual cameras
- Generate imagery
- Finalise in post-production

Each of these steps will be discussed in a little more detail, as an understanding of these processes is essential to understanding the final visual product.

2.1 *A Priori* Information

As this paper is being published by the ISPRS, most readers will be very familiar with the gathering of *a priori* measured data relating to cultural monuments and sites. The size, shape, orientation and location of both intact and ruined monuments can be determined by field survey, photogrammetry, GPS surveys, 3d laser scanning, 3d coordinate measurement systems, archaeological geophysical exploration techniques, and airborne and satellite sensing and imaging systems. There is a large body of knowledge behind these measurement techniques, with an associated understanding of the accuracies and precisions of the measurements. The thrust of this paper is not concerned with metric accuracy, but more how the measurements truly represent the object under study.

Dimensional information can also be sourced from other forms of documentation, which may result from a measurement process (for example old maps, plans and elevations, which have already passed though at least one interpretation process) or from purely descriptive text (again, being the result of at least one interpretation process).

Figure 8: Statue of Zeus at Olympia. Derived from description by Pausanias, the object does not exist. Image © University of Melbourne and the Powerhouse Museum, Sydney

If a knowledge of the 'metric accuracy' of a reconstruction is deemed important, then the source or process of the measurements should somehow be included with the visual representation of the object. There may be occasions where the actual dimensions of a reconstruction are not important providing the visual result exhibits the correct 'shape', in this case it would seem to be important that that information was included as well.

2.2 The 3d Model

There are several approaches to the generation of a computer model of a monument or artefact, and the selection of method is often based on the available metric information.

2.2.1 Computer Aided Design (CAD)

The vast majority of CAD systems have been designed to work in a manufacturing or architecture environment. Packages like AutoCAD and MicroStation are graphical data bases containing coordinate and attribute information for geometric shapes like lines, polygons and 3d primitives. They rely on dimensioned information, either true or at least relative, and are often used to create plans and elevations of the objects. They also create very 'clean' elements that show very little of the small blemishes that the real world exhibits.

2.2.2 Other 3d Modelling Approaches

A very different approach to modelling is used in packages like 3d Studio Max and Maya. Whilst they are capable of accepting metric information, they are also capable of applying transformation to basic shapes (meshes) to create complex entities. These mesh figures can be transformed to fit the required geometry, and modified to more readily accept material maps and for ease of animation.

2.2.3 Point Clouds

Laser scanning systems, along with some photogrammetric processes, conventionally produce large data sets consisting of 3d points. These systems are also capable of acquiring images of the surfaces under study (effectively a material map of the actual object).

The geometry of the point clouds is known, they are to the correct scale in all dimensions. The data is generally in the form of a polygon mesh, although on occasion that data is reduced to the barest minimum needed to define conventional CAD surfaces like planes and cylinders. Apart from processes like filtering, point cloud data is often used in the form in which it was acquired.

Figure 9: Image of rendered laser scan data of a fossilised human footprint with solar illumination. Data acquired with a KonicaMinolta Vivid 910. Image © The University of Melbourne

2.3 Material and Texture Maps

Material maps are composed of images and transformations to these images, and are used to make the surfaces created in the modelling process resemble real objects.

For some complex surfaces, the impression of three dimensionality can be created just through the use of appropriate materials. When rendered, these surfaces exhibit the characteristics of the complex surface, but from the point of view of geometry are just a simple graphic element.

Figure 10: Elements in foreground in full 3d, objects in background simple shapes with derived material maps. Ancient Olympia. Image © The University of Melbourne and the Powerhouse Museum, Sydney

Figure 11: A complex surface perhaps better represented by a material map.

Material maps are critical to the appearance of the rendered image. They can be complex, and composed of a variety of images and transformation functions. For example, in 3d Studio Max materials can have any or all of the following attributes:

- Ambient colour
- Diffuse colour
- Specular colour
- Specular level
- Glossiness
- Transparency
- Self illumination
- Opacity
- Reflection
- Bump
- Refraction
- and displacement

Often the material map is based on the real appearance of the object, as seen in Figure 9 which is the image captured by the laser scanning device. In Figure 10 all of the material maps were created from images acquired on site of many of the surfaces, as well as images acquired in Melbourne that were then modified to represent an interpretation of the possible surface in the reconstruction.

2.4 Environment

In the context of computer graphics, the word environment has a specific meaning. In this paper it means the locality surrounding the object under study. To use the Olympia picture example, the environment is the topography, vegetation, ground cover and the associated statuary and other monuments. If an audiovisual production was the intended output from the visualisation process, it would also include music and sound effects.

Figure 12: Model of the Statue of Zeus/Poseidon in the Athens Museum. Model from 3d laser scanning, materials derived from photographs of real statue. No environment, black background.

In the image above, a viewer would most likely assume it was either a modified image (having had the background removed), or as the result of a computer rendering process. The lack of any realistic environment concentrates the attention on the object.

In the image below of a Chapel in Georgia, the 3d model of the building was inserted into another model depicting the 'real' environment in which the Chapel was located. The distant terrain is as it is seen from the Chapel, however very little of the vegetation around the Chapel has been included as it would obscure the building, which is the object of interest.

Figure 13: Chapel near Mtskheta, Georgia. The 3d model of the Chapel was derived from *Photomodeler*, the trees in the foreground are 3d, real image of background environment.

From the point of view of CG, an environment can include global lighting parameters, background images, sky images, and even images to be used as part of the scene illumination.

2.5 Lighting

The placement of light sources, the generation of shadows and the incorporation of solar illumination contribute greatly to the overall interpretation of an image, whether it be a photograph or CG imagery. The interplay of light with surfaces, reflections, the contrast between foreground and background, the way light refracts though transparent and translucent objects, all of these create 'atmosphere' and contribute to the realism of an image.

Most of the higher end visualisation and modelling packages have an array of light types that can be added to a model as part of the rendering process. The various rendering algorithms that are used to create images of the model use these light sources to create illumination, shadows and other lighting effects. Full radiosity solutions, where the contribution of all the graphic elements is used in the calculation of the lighting, create very 'realistic' looking images

One critical lighting element is that of solar illumination based on the true solar ephemeris. If the reconstructed monument is in its true orientation, and the geographic location is known, then daylight shadows will appear correct. Of course, this may not show the object off particularly well, in the case of the Olympia visualisation the sunlight was set at 2.00pm, which meant that the side of the Temple of Zeus with the door was in shadow. The interior of the Temple of Zeus would only have been illuminated by oil lamps, not a major problem if one actually was inside the temple as the human eye can compensate for the darkness. This does not happen with GCI, so the model needed to be lit so it would be visible on screen.

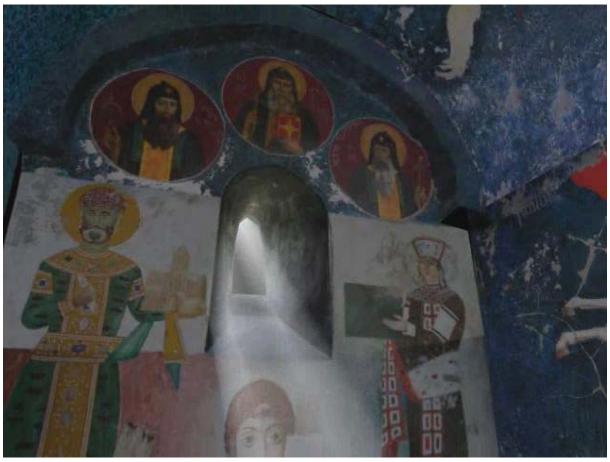


Figure 14: Interior of Chapel near Mtskheta, Georgia. Model from *Photomodeler*. Volumetric light added to create 'atmosphere'. Photographs of actual interior used as material maps.

2.6 Post Production

The idea of post-production may not at first appear to have much to do with the generation of output from virtual heritage, but many other processes are available to enrich the experience offered by the images. These include, but are not limited to:

- enhancement of images
    - contract, brightness, colour balance…
    - removal of image artefacts
- compilation of images into animations
    - a better process than just rendering animations
    - allows layers of images to be compiled into a single scene
    - facilitates transition between scenes
- the incorporation of backgrounds and environments
- the incorporation of human figures
- the addition of audio
    - soundtracks, background 'noise'
- addition of titles and credits

Each of these influence the interpretation of the reconstruction.

Figure15: The incorporation of live actors and reflections into the reconstructed audience chamber of King Narai, Aytthaya, around 1600AD.

2.7 Quantification

Is it possible to quantify the process of creating a visual reconstruction of a cultural heritage monument? If it is possible, can this then form the basis of a 'truthlikeness' assessment?

This paper proposes that knowledge of the process behind an image (or animation) of a cultural heritage reconstruction aids the viewer in understanding the truthfulness of the representation. The diagram below breaks down one aspect of the reconstruction process (the analysis of *a priori* or source data) into each of the relevant distinct activities. Similar diagrams can be prepared for the other activities, and is a useful exercise.

There are two processes in operation here, the generation of a descriptor and the dissemination of this descriptor with the product.

3. METADATA

Metadata is understood to mean information about data (like 'what' 'when' 'who' and more importantly 'how'), and is a popular term associated with a variety of data sources both digital and analogue. There are many metadata standards for the interchange of data across the web, as well as for storage of information in databases. Some of the more relevant include the Dublin Core (http://dublincore.org, originally for libraries but now more universal), CIDOC (established by the International Council on Museums [ICOM], http://cidoc.mediahost.org/), and ones similar to the Australia and New Zealand Land Information Council (ANZLIC) standards for infrastructure data (http://www.anzlic.org.au/infrastructure_metadata.html).

Other types of metadata include the information contained in image files, like the general EXIF information available in JPEG format images that deals primarily with camera information (but does include provision for GPS coordinates, http://www.exif.org/). The GeoTIFF header includes information to facilitate the transfer of raster based geo-coded imagery (http://www.remotesensing.org/geotiff/geotiff.html)

Whilst many of these contain elements relevant to this study, none are entirely suitable. Perhaps a new and specific metadata set is required?

3.1 Encapsulation of Metadata

The existence of metadata is somewhat pointless unless that information is made available to the user, either as an embedded part of the digital file or as a convenient look-up. There are presently several methods of supplying this information, some mentioned above and others introduced below.

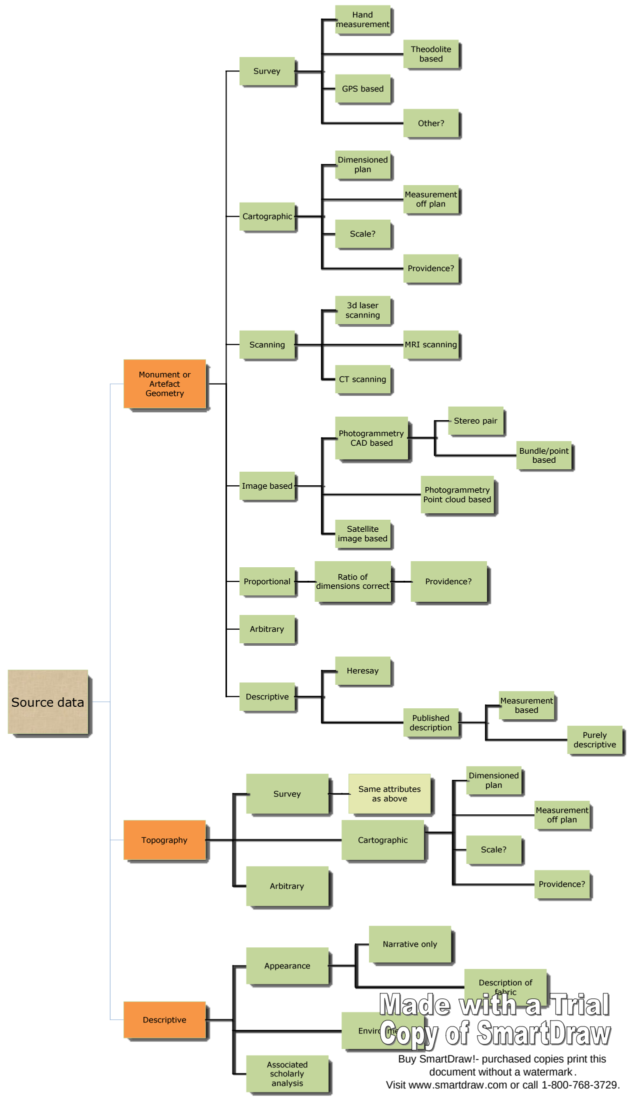
3.1.1 The Semantic Web, XML and Enhancements

The Extensible Markup Language is around 10 years old now, and has been enhanced many times over that period. XML is basically a way of supplying additional 'tags' within a web document to give meaning to the content of a web page. The concept has worked well, and XML has now been incorporated into the *Semantic Web* (http://www.w3.org/2001/sw/).

The Semantic Web uses XML, a Resource Description Framework (RDF) and a Web Ontology Language (OWL) to give both a common format for the interchange of data, and for recording how the data relates to real world objects. This offers excellent potential for the supply of additional information about virtual reconstructions when these are distributed over the Internet.

3.2 The Start of the Development of a Metadata Standard

The diagram below represents an attempt to 'deconstruct' the reconstruction process, and refers to only one part as mentioned previously, that of the analysis of *a priori* data about a monument.



This process can be applied to all the components of a visualisation project, space limitations prevent them being included here. The diagram illustrated the relationship between the entities, and the information that is represents could form the basis of a metadata standard specifically for the description of the process undertaken. Could this process even quantify the 'truthfulness' of the reconstruction?

What is necessary is an easy process to generate the metadata, and a central repository for the information (like the URL for a Resource Description Framework) specific to the visulisation of cultural heritage. Unless the process for the creation of the information is easy, accessible and unambiguous, then the existence or otherwise of a metadata standard is meaningless.

4. CONCLUSIONS

This paper raises many questions, and at this stage only answers a few. The research is on-going, and a new metadata standard for the visualisation of cultural heritage is in the process of being developed. Along with the 'standard' will be a simple method of transmitting this information to the viewer.

It is hoped that the in supply of supporting information along with CG images of reconstructed heritage a more informed, critical and qualified interpretation will be possible.

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