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3D Virtual Reality reconstruction on the Internet using VRML

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Abstract

This project details the investigation into the use of Virtual Reality Modelling Language (VRML) to reconstruct historical monuments so that they can then be easily accessed over the Internet. Detailed reconstructions that are intuitive to navigate can be produced and these potentially have many uses, in education, for virtual heritage and for archaeological visualisation.

Tourism is increasing, yet many aspects of tourism threaten and damage many historical sites. Local economies are often heavily dependant on tourism and so, despite the harmful aspects, it is still heavily encouraged. Tourism at the Theban Tombs, near Luxor in Egypt is a prime example of this.

To demonstrate the principles involved and to further investigate the practical issues, a prototype has been developed. The prototype is based around the Tomb of Menna in Egypt and uses historical photographic data from 1916, provided by the Griffith Institute.
Acknowledgements

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Also, the assistance of the Griffith Institute who provided the Mond photographs as well as the Egyptological advice and information is appreciated greatly. Especially the time given by Dr. Jaromir Malek and Dr. Diana Magee.
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1. **INTRODUCTION AND OVERVIEW**

1.1. Introduction

Advances in the field of desktop computer design have led to the creation of more powerful computers and at the same time, improvements in production techniques and economies of scale have forced prices down. This increase in power has been delivered into the hands of the users with a typical entry-level PC now being capable of far more than word processing. In performance terms, an important threshold is now starting to be crossed, that of the ability to deliver real time 3d computer graphics on a typical PC. Computer graphics used to be the exclusive domain of expensive workstations with dedicated hardware, but now, inexpensive PCs can start to deliver 3d graphics dependent technologies such as Virtual Reality (VR) to the masses.

Whilst this empowering of users has occurred, another technology has recently matured. The Internet, a very large network of networks, encompassing perhaps 100 million users has had a nearly explosive expansion with the introduction of the World Wide Web (WWW). The WWW runs over the existing structure of the underlying network with servers providing clients with information presented through multimedia. The client software hides the complexities of the underlying technologies and the structure of the Internet from the user, making the WWW suitable for ordinary users rather than computing specialists.

These two concepts above have come together in a technology that is called Virtual Reality Modelling Language (VRML). VRML extends the
existing hypermedia nature of the WWW, providing ordinary users with
the ability to use interactive 3 dimensional VR models as just another
form of media.

1.2. Background

1.2.1. Egyptian Tombs

Time and tourism are taking a heavy toll on many of the historical
monuments in Egypt [1-2]. In particular the tombs in the Valleys of the
Kings, Queens and Nobles, on the west bank of the River Nile near
Luxor, including the well known tomb of Tutankhamun. The tombs
were constructed for the burial of the dead and were intended to be
sealed forever, not to be opened to encourage tourism. Many aspects of
tourism are directly harmful to the delicate ecology of the area. For
instance, vibration from traffic, which consists of mostly tourist coaches
and taxis, is causing great concern because the geology of the area is
sedimentary and is essentially unstable. Another issue is the moisture
introduced to the tombs by the breath of tourists. The rock that many
of the tombs have been created in is of very poor quality, it absorbs
water readily at first expanding and then collapsing. The extremely low
humidity has helped to preserve the tombs for thousands of years and
now this moisture is causing the plasterwork of some tomb paintings to
crack and it also encourages mould to grow. This deterioration has
reached such a point in some tombs, that they are no longer open to the
public. Another very real worry is that the whole area is subject to very
occasional flash flooding. The opening up of the tomb entrances and
the creation of pathways and roads channels the floodwaters straight into the tombs, often causing irreparable damage. Many of the less important tombs have not been documented and consequently there are problems repairing the damage.

There is an argument put forward principally by John Romer, an eminent if somewhat controversial Egyptologist, that advocates the closure of the whole area to prevent further damage and conserve what is left [3]. However the Egyptian Government is reluctant to take such a drastic measure due to the damage it would do to the local economy, which is heavily dependent on tourism.

1.2.2. Damage to historical monuments

Similar problems to those illustrated with the Theban tombs above have been identified at different historical monuments[4]. UNESCO has identified 440 historical sites world-wide as being threatened and labelled them as World Heritage Sites. The need for conservation would seem to be paramount to prevent either serious damage or the contents of the various sites ending up in museums. The goals of tourism however are often contrary to those of conservation.

1.2.3. VRML as a potential solution

VR has the potential to at least partially solve the above problem of conservation. By recreating the monument using VR, virtual tourists can explore without interfering with the real monument. Indeed VR can in some cases provide a better experience than a visit to the real site. For instance, users can explore the model alone, without crowds or queues
and at their own pace, 24 hours a day. The VR experience doesn’t have to mimic the real site exactly, potentially removing undesirable features, such as modern day objects. This idea can be extended further to create a VR model of a monument that no longer exists, these ideas will be explored further later in the report.

Other aspects can be added to the model such as a guided tour that responds to the actions of the user, thus placing an emphasis on exploring the model, a idea often used in educational software. There is no reason why models such as these should not be useful in education, children can be let loose to explore a virtual model with little supervision. One of the major advantages of VR though is of particular benefit in education, the lack of necessity to travel. VR models are represented as computer data and can be transported as such, over networks, down phone lines or by floppy disc. In this way, many geographically distant places can be visited in a short space of time.

This vision has not yet been fully realised, but a potential enabling technology can be seen in VRML. What VRML can add to this scenario is easy accessibility to VR models and the integration with a hypertext multimedia delivery system, namely the WWW. Because VRML is an open standard, and is beneficial to many users of the Internet, the client software i.e. the VRML browsers are either free or inexpensive when compared to commercial proprietary offerings. For these reasons, it would seem that VRML is set to become a very important standard. The term Virtual Heritage[5] is starting to be used to refer to the various VR historical reconstruction projects.
1.3. This Report

1.3.1. Aims and objectives

The aim of this project is to investigate whether or not the scenario for a virtual heritage outlined in the previous sections is practical and is likely to become a reality using VRML as a solution.

To further the investigation, a VRML prototype will be constructed to investigate the practical aspects of virtual reconstruction and also to demonstrate the concepts and principles involved. This demonstrator system will be published on the WWW where it is hoped that it will help to stimulate interest amongst professional historians in the use of VRML for other reconstruction projects as well as provide some benefit to the casual Internet tourist.

1.3.2. Overview of the Report

HTML and the WWW are discussed in the next chapter to provide a background understanding and to put the use of VRML in context.

The report will then briefly explore, some of the issues surrounding the use of VR and VRML in particular for use in virtual heritage and will also expand on some of the more technical points.

In the next chapter, the relevant issues related to Heritage and Virtual Heritage are explored. The uses of computers in reconstruction is then discussed with reference to some of the more influential projects in the field that relate directly to this project.
This leads on to the production of the demonstrator. The creation and
evolution of the demonstrator are documented, leading on to an
evaluation and review of the demonstrator itself.

The report finishes with a conclusion which identifies the benefits of the
project, the experience gained by the author along with a critical review
of the mistakes made. This section concludes with areas for future work
on both on the demonstrator system and on similar projects.
2. HTML AND THE WORLD WIDE WEB

2.1. Introduction

This chapter describes the nature, structure and history of the World Wide Web and the use of HTML as background to the aims of the demonstrator.

2.2. The World Wide Web

The WWW as mentioned in section 1.1 is a phenomenon that was started in 1991 by Tim Berners-Lee at CERN [6]. He was responsible for a set of products and standards that revolutionised and popularised the Internet, the WWW browser and server. These products used the existing infrastructure of the Internet to deliver information, yet they presented it in a much richer form than any product before them.

The WWW has merged the techniques of networked information and hypertext to make an easy but powerful global information system. The project represents any information accessible over the Internet as part of a seamless hypertext information space. The WWW was originally developed to allow information sharing within internationally dispersed teams, and the dissemination of information by support groups. Originally aimed at the High Energy Physics community, it has spread to other areas and allowed a new, less computer literate generation to embrace the facilities that the Internet has offered. This in turn has opened up opportunities for commerce, especially amongst the computer industry.
The WWW is an architecture that is designed to embrace any future advances in technology, including new networks, protocols, object types and data formats. Clients and server for many platforms exist and are under continual development.

The WWW world consists of documents, and links. To help navigate this world a various indexes and search engines have been developed. The WWW contains documents in many formats. Those documents which are hypertext, contain links to other documents, or places within documents. All documents, look similar to the reader and are contained within the same addressing scheme. To follow a link, a reader clicks with a mouse. To search an index, a reader gives keywords (or other search criteria). These are the only operations necessary to access the entire world of data.

The addressing scheme used is known as the URL (Universal Resource Locator) that uniquely identifies the location of a document in a similar way to a directory path.

The information presented is of a multimedia nature and although it typically comprises of just text and images, other types of media can also be displayed. These can include sound and video and, more recently 3d models.

Despite having arrived so quickly, it is not likely to fade away. The AltaVista search engine [7] currently claims to index over 22 million documents.
2.3. HTML

2.3.1. About the language

Hypertext Mark-up Language is the means by which these previously mentioned documents are created. It has been derived from a more widely known standard known as Standardised Generalised Mark-up Language (SGML) and is based on tags. A HTML document is just an ASCII text file with tags delimiting features within it such as text attributes or a reference to another URL indicating an image to be inserted. A full description of the language would seem inappropriate here, when it is so well documented, especially on the WWW [8].

2.3.2. Standards and features

The Internet community has responded to the WWW by embracing it and constantly enhancing it. At time of writing, the latest version to be formally ratified was HTML 2.0, but the extensions to the language that comprise HTML 3.0 have been implemented by the dominant supplier of browser software, Netscape and have become an effective standard. As HTML has evolved, it has gained features in the form of new tags that allow more sophisticated formatting. Older versions of browser software ignore tags that they don’t understand allowing users to see information although possibly without the correct formatting.

2.3.3. Other WWW developments

CGI stands for Common Gateway Interface and is a development that allows a program to be run on the server at the request of a client user via a web browser. Typical applications for this are processing forms and
image maps. A form is a type of HTML 2.0 document but with text fields to fill in and options to select. When processing forms, the CGI interface provides a mechanism for the client to send back information collected in the form to the server. A program runs on the server and deals with this information, for instance converting it into an email message or by evaluating the contents and sending back an appropriate HTML page. The image map use referred to, is when the user is presented with an image as part of a HTML page that contains various different regions to select. For instance, if the user was presented with a map of the world and they performed a mouse click on a particular country, the client would send back the details of where the selection was on the image and the server would decide which predefined region (in this case country) had been selected and send back a HTML page for that country.

A new development has been from Sun Microsystems who have developed a platform independent Object Orientated programming language called Java [9] that has been adapted to integrate with the WWW. Java code can be embedded or referenced in web pages to give increased functionality. The difference between CGI and Java is that Java runs on the client. This means that Java can be used to provide complete applications to the WWW user. In practice though, it is more commonly used to provide visual enhancements such as animation to WWW pages.
3. APPLYING VR

3.1. Introduction

This section attempts to outline the field of VR. The major issues are discussed and some techniques used in the production of the prototype are explained. Issues related to the practical implementation of both VR and in particular VRML are investigated.

3.2. The fundamentals of Virtual Reality

VRML is a very new way of describing a Virtual World, but what is VR?

A VR model is always less detailed than what it represents, however, VR can allow greater freedom in viewing a model than physical constraints would allow. A typical example of this is the ability to zoom in and examine details that could not be distinguished with the naked eye.

3.2.1. What is VR?

Virtual Reality (VR) is the computer modelling of interactive 3d environments. It differs from many other types of 3d modelling by being interactive and performing in real time. VR has traditionally been expensive, with the computing equipment required usually pushing the bounds of performance. This has limited the application of VR to a few specialist fields, where cost has been less of an obstacle such as training astronauts for space exploration or visualising the structure of chemicals. However, the cost of VR is coming down as the performance of computers increases. Traditionally VR has aimed to be fully immersive, yielding the stereotypical picture of a user with head mounted display and
datagloves in a futile (with today's technology) attempt to convince the user that they are really there. VR techniques have broken through to the business mainstream by losing the specialist equipment for full immersion, the headset, gloves etc. Instead of immersive VR, the user is presented with what is being termed Desktop VR, essentially the same visual information presented via a monitor on a less specialised computer. Whilst the performance of a business PC running a VR world is going to be poorer and the sense of immersion is much less apparent, the acceptance among business professionals has been much higher due to a reluctance to don headsets etc. just in order to use a computer.

3.3. Using VRML

3.3.1. Where does VRML fit in with VR?

VRML stands for Virtual Reality Modelling Language. It is a language for the description of 3d VR worlds, or to simplify it further, it is a file format. To view a VRML world, you need a VRML browser or viewer which will display the file. The VRML browser is analogous to the HTML browser discussed earlier and the two work together to provide seamless hyperspace of information with the VRML browser adding the ability to manipulate 3d models.

As a 3d modelling language, it is based on Silicon Graphics' non-proprietary Open Inventor 2.0 standard [10]. Features specific to the WWW have been added such as the facility to implement hyperlinks to any URL. VRML and Inventor both share a core set of functionality yet each have features specific to themselves. Whilst not necessarily
providing compatibility between Inventor and VRML tools, existing Inventor tools can be easily modified to embrace VRML which has accelerated the uptake of VRML.

In practice, VRML appears as an ASCII text file full of co-ordinates and references to external files. Whilst it is possible to write VRML using a text editor, it is neither sensible or practical.

3.3.2. Texture Mapping

Probably the most important technique used in adding realism to VRML worlds is that of texture mapping. Texture mapping is the addition of images (textures) to surfaces in the 3d model, so the surface takes on the appearance of the image. The technique can be used to fool the eye and allow a geometrically simple model to appear much richer. Although not always the case, much more complex modelling techniques can often be used to simulate the effects of texture mapping. One of the classic examples used to prove the case for texture mapping is a model of a brick wall. To model this geometrically could involve creating a model for a brick, and sections of mortar and colouring them appropriately. The bricks then have to be individually placed in the modelling package, which without assistance from an intelligent algorithm would probably take as long as physically laying all of the bricks. The vast number of bricks and hence objects would require a very large amount of processing. A much quicker approach to the modelling would be to use texture maps. A simple plane would be used for the wall and an image known as a texture, showing a brick pattern can be placed on the wall. The image can be repeated, so that a image of a small number of bricks
could be tessellated many times to create a larger effect. It is somewhat akin to sticking a sheet of stamps on to a sheet of cardboard. Complex techniques exist for scaling and tiling textures and for mapping textures onto non-flat surfaces. The advantages of the texture mapping approach are that the modelling will take much less time and be computationally less expensive, although sweeping statements such as this are a relative term in computer graphics.

3.4. Design considerations in VR

When designing for (Desktop) VR these are a number of points to consider and to aim for in order to achieve widespread acceptance. These points also apply to VRML which will be considered later.

3.4.1. Performance

Ideally, there should be no perceived lag or jerkiness when manipulating or navigating the model. A screen refresh rate of greater than 30 frames a second is aimed for, however, this is a function dependent mainly on the computational power available.

3.4.2. Quality of the Model

The detail within the model must be sufficient to suit the purpose of the model. If the aim is to allow people to visit a virtual historic monument, then adequate detail must be present to represent the details that would be observed by a real visitor. If a model is oversimplified, possibly for performance reasons, then the model will be rejected and physical tourism is still going to yield a better experience.
3.4.3. Perceived resolution

In an ideal world, the model should be displayed at a resolution at least equal to that perceived by the human eye. In the real world however, the omnipresence of Cathode Ray Tube (CRT) displays is a very practical limitation. To increase the resolution of the display however, detracts from the performance. Another less obvious limitation of the CRT is its poor colour gamut. The inability to display pure colours, especially at the blue end of the spectrum subtly remind the user that the image which they are experiencing is computer generated, losing another degree of immersion.

3.4.4. Behaviour

Depending on the context of the model, it and objects within it, should behave as one would expect. For instance a flag might flap in the wind or a vase might break when dropped. This is can be considered less important in the context of a historical monument, where the object of the model is for example to show a tomb, where there is no expected motion.

3.4.5. Interface

An interface should aim to be both intuitive and unobtrusive. These are both key goals in determining the acceptance of VR especially in a heritage context, where the typical users are likely to be inexperienced in navigating through 3 dimensional structures. Any requirement for special hardware, such as head mounted displays or special controllers should be optional in order for wide spread acceptance.
3.5. Practical considerations in VRML

VRML models are subject to the same constraints as traditional VR models, but also a few more specific ones, especially when attempting to grant the model the widest possible audience.

3.5.1. Performance

Further to the previously mentioned performance issues, this becomes even more crucial when VRML is in use because the target machine is likely to be some kind of PC. The better performing the model, then the wider the audience it potentially has.

3.5.2. Internet bandwidth

The size of the model is also very important. Literally millions of users are connected to the Internet by (slow) modem and this means that the amount of data that they have to download is all important.

3.5.3. Edge detection

This is a notable feature missing from VRML 1.0. Without any form of edge detection, users are free to wander through walls with no regard for ‘virtual’ physical laws.
4. A VIRTUAL HERITAGE

4.1. Introduction

In this section an attempt is made to expand upon the idea of a Virtual Heritage and examine other work that has had a bearing on this project. The ideas behind using HTML and VRML are examined and the alternatives are explored.

4.2. The history of a virtual heritage

The concept of a virtual heritage is a progression of the use of computers by professional historians assisted by the infiltration of computers into museums.

4.2.1. Academic use of computers

Computers have been used by historians and archaeologists for research purposes since the 1960s[11]. These first applications tended to be the manipulation and analysis of the large quantities of data that were generated in the field. The use of computers remained small scale due to the need to use large mainframes and the scientific nature of the software. It was in the 1980's with the advent of the microcomputer, that computers became more accessible to scholars. Archaeologists benefited from this migration with the advent of computer aided design and visualisation techniques and the maturing of the available database technology. From collection of data in the field, to analysis in a laboratory, to visualisation, illustration and publication, computers could then start to support all the stages of an archaeologist's work.
As software and hardware have advanced, historians have taken advantage of the new opportunities offered. A recent example of this has been the use of computers with X-ray techniques to visualise and reconstruct the features of various Egyptian Mummies. [12] By this it can be see that 3d techniques are starting to be used in this context.

4.2.2. Museums

In some museums and historical sites, computers are being used as a means to present information to the public. Many have embraced the WWW such as the Natural History Museum [13] and others have provided public access multimedia information points, such as at Battersea Park.

4.3. The use of Virtual Reality

VR is now just starting to be used as a valuable tool in the field of heritage, although it is still not firmly established. Some of the most significant projects of recent years are outlined here to set the scene and their relevance to this project is discussed below.

4.3.1. Lascaux

The French prehistoric caves at Lascaux have been reconstructed using virtual reality techniques [14]. Users can now experience the caves, which have been closed to the public since 1963, by means of VR head sets. The paintings, sculptures and carvings within the caves can be viewed in a real time virtual world simulation. Live action video has been embedded into the reconstruction to add to the experience. Benjamin
Britton, the creator of the exhibit, has spent the past 5 years working with France's Ministry of Culture and a team of VR consultants, programmers, graphic artists and computer modellers.

Britton initially intended to re-create the cave by use of video wall technology and monitors hung around a gallery space. Upon consideration, it was decided that the problems of achieving consistent, effective lighting effects would make this impractical. A VR solution was investigated and found to be mature enough to help achieve his vision.

The target platform is a high end PC workstation, with the authoring done using WorldToolKit and C++ running on NT35.

An interesting aspect of this project is that Britton stresses that his Lascaux re-creation is not intended to be a literal representation of the cave, but rather as an artistic "interpretation" of the space.

4.3.2. Cluny Abbey

The Benedictine Abbey of Cluny in Burgundy, France was founded in 909 and occupies a unique place in history, having been regarded as the spiritual, artistic and cultural centre of Europe. Its 187 metre church was the largest in the world until the construction in 1615 of St. Peter's Basilica in Rome. In 1790, during the period of the French revolution, the abbey was declared property of the revolutionary government, the monks fled and it was subsequently destroyed in 1793.

In 1990 two students at the Ecole Nationale des Arts and Métiers, the national engineering school that has a branch in Cluny's former cloister, set about the virtual reconstruction of the abbey with the help of a local
art historian[15]. They approached IBM-France who agreed to support the project and using data collected by a Harvard professor, John Kenneth Conant, earlier this century, they have produced a virtual model using an IBM RS6000 workstation. This model has provided material that has been used in a film now being shown at the Ochier Museum.

This simulation was then refined by a group of VR researchers and used at the 1993 Imagina Computer Simulation Conference in Monte Carlo, where delegates could, by use of a head mounted display, experience the abbey in a fully immersive environment.

The reconstruction reflects what the abbey is thought to have looked like after its last enlargement around 1130. However, few details of its interior decoration survive and the interior of the electronic abbey is mostly unadorned. A fresco of Christ has been copied from a local chapel because it is thought to have been similar in style to Cluny. Also a depiction of the great rose window over the western main entrance has been copied, but these details have been deliberately blurred to reflect the lack of knowledge about their original appearance.

4.3.3. Horemheb

The Archaeological Museum of Bologna in Italy has produced a fly through of a reconstruction of the Saqqara tomb of General Horemheb and its reliefs[16]. At the beginning of the nineteenth century the tomb was emptied and some of the reliefs that decorated the walls were removed and sold to various museums. Five of these are now in the Archaeological museum of Bologna. The tomb was rediscovered in 1975 by G.Martin after having been freshly covered with desert sand. The
publication of these excavations has facilitated the reconstruction of the
tomb and a fly through has been produced onto video.

4.3.4. Nefertari

The tomb of Nefertari is, like that of Menna, in Thebes, Egypt and is
reckoned to be one of the most beautiful. However, whilst not publicly
available now, it has suffered very badly in the past from the effects of
tourism and has been the focus of much restoration work by the Getty
Conservation Institute. In order to facilitate access to the tomb without
physical access, an Italian company, Infobyte were commissioned. Virtual
reality reconstruction has been used to allow people to visit this place as
if they were really there [17]. One can wander about freely, and stop to
admire the magnificent wall paintings. It uses a powerful graphics system
to instantly recreate the view that would be had from any perspective,
and continuously updates this view as the observer moves about. To
display the model, special stereoscopic terminals provide three-
dimensional vision, thereby contributing to the visitor's sense of full
immersion in the environment. VR is used to provide within the model
the ability to visit the tomb, both as it appears today and as it appeared in
its original condition. Additional information is provided to the user
through an audio experience whereby they can hear voices describing the
ritual texts on the walls.

In hardware and software terms, the reconstruction runs on a Silicon
Graphics Onyx Reality Engine 2, two Raster Manager 5, 256 Mb of
RAM, Audio Serial Option, BG Systems FlyBox or Fakespace BOOM
3c.
4.3.5. Abu Simbel

A simple tour of the temple of Abu Simbel, Egypt has been constructed in a simple fashion using the powers of the WWW [18]. The exhibit is available to anyone with a HTML browser that will support image maps. It consists of a series of pictures that can be clicked upon as hyperlinks. The action of clicking on a doorway would take the user to another web page with a picture of the room beyond the doorway and clicking on a feature would provide a close up of that detail. The process is controlled by CGI and benefits from providing a very intuitive interface. It lacks flexibility in that the views available are fixed by the creator and so it can’t provide a true VR approach.

4.3.6. Summary

These various projects serve to illustrate the tremendous potential of applying computer techniques to heritage. Accessibility of these types of projects is an important issue, the hardware needed to display most of these models is outside the reach of the average user and would entail a visit to a museum or other viewing place. In particular, the Nefertari project uses what was until very recently, Silicon Graphics’ top performing platform, which commanded a price of some £1/4 million excluding the cost of the additional stereoscopic display hardware. The Horemheb project has elected to use a more established distribution mechanism, that of the video cassette, instead of allowing for an interactive user interface, sensible, if limited. The Abu Simbel product uses a well established interface and distribution mechanism and is
potentially much more valuable to the world despite its apparent simplicity.

4.4. Delivering a virtual heritage to the world

As shown previously, despite the quality and impressive nature of some of the other projects in this field, they suffer from inaccessibility. As suggested earlier, the Internet is potentially the vehicle by which to solve this.

4.4.1. VRML and HTML as a solution

A virtual heritage model produced using both HTML and VRML [19] can provide the combination of a multimedia presentation and a VR model that are integrated through hyperlinks. This potentially opens the use of this technology to the whole Internet community. The apparent problem that this creates though is that of performance. The expected user for this type of exhibit will not have access to powerful graphical workstations, so a compromise would have to be imposed with regards to the quality and hence complexity of the model.

4.4.2. Alternatives to VRML and HTML

Three alternative approaches exist to provide a virtual heritage over the Internet.

The first would be to use image maps in a similar manner to that of the Abu Simbel exhibit discussed above. The disadvantages that this has are to restrict the views that are available and restrict the interactive nature of
the exhibit, an advantage would be that it would be quick and easy to implement.

The second approach would be to use a technology from Apple Computer called QuicktimeVR [20]. This uses ex-military image processing technology to stitch together a series of perhaps 10-15 photographs taken from the same spot about a 360 degree angle. The photographs can be taken quickly and easily without special considerations for the processing techniques even by an inexperienced photographer. Provided the photographs overlap, they can be stitched together to produce a single image that circles the viewpoint. The user would make use of a viewing program that will take this single image and correct the perspectives to produce a view in a single direction. The user can rotate the viewpoint about, but not move it. Hyperlinks can be added to move between a number of these viewpoints. The main advantage of this technique is that it is very fast to author and although initially disorientating, proves easy to navigate. The viewer software is available free for the Mac and Windows platforms. The main disadvantage is that navigation is tightly constrained.

The third alternative is to use a technique called client side rendering. This involves using a powerful graphics server with a HTML front end. The user would make use of a HTML browser to navigate the model. The image that the user would see would be calculated by the server and sent to a graphics file. A HTML page would be dynamically generated and sent back to the user. The user would use hyper text controls to control the view. The advantages of this approach are that free
navigation is possible within the model and that high quality images can be produced. However the down side is that a powerful server needs to be dedicated to producing sufficient frames to support all of the simultaneous users. Another problem is that the lag associated with data propagation over the Internet is going to be the most significant impact on screen update times. To achieve real time updates, a very fast network infrastructure would need to be in place.
5. BUILDING A PROTOTYPE

5.1. Introduction

A prototype has been produced to demonstrate possibilities of a practical virtual heritage using a combination of VRML and HTML.

Silicon Graphics (SGI), a manufacturer of graphics workstations kindly agreed to provide the author access to suitable computers to facilitate the authoring process. They also agreed to provide space on a server, to publish the information. The finished product is available at http://realitysgi.com/employees/nigelj_manchester/Mattz/

The prototype produced followed an evolutionary design, being as it was, an investigation into the possibilities of modelling for Virtual Heritage purposes. Due to this, Aims and Objectives for the finished product were identified rather than a tight specification as would have been the case for a more traditional programming project. Choices faced at various stages have been elaborated upon and the reasons for the choice that was made are discussed.

At the beginning of the project, it was found to be very difficult to obtain data, so the choice of subject matter was at that time quite open. The aims and objectives were drawn up with this in mind and this is why they have been left quite vague.

5.2. Aims and Objectives

These are the design goals for the prototype.
5.2.1. Product

A prototype to illustrate the concept of a virtual heritage exhibit available via WWW is to be produced using a combination of VRML and HTML as inspired by the suggested application scenarios [19] and discussed in section 4.6. Hyperlinks are to be used to link between the VRML and HTML to integrate the exhibit. Other tools are to be used as appropriate.

5.2.2. Target audience

The target audience for the prototype will be the general public. However, the possibility of potential uses in the fields of education and archaeology are to be investigated.

5.2.3. Computing requirements

To use the demonstrator, access is expected to what can be considered a typical business entry level computer, an i486 at 66MHz with 16Mb RAM or better. Also expected, is access to the Internet, a HTML browser and the ability to run a VRML browser.

5.2.4. Use real data

The finished exhibit, should use genuine data and not be a mock up. This will allow the finished product to be of some value to the world.

5.2.5. Exponent of Virtual Heritage

The prototype should be an exponent of the concept Virtual Heritage as well as just displaying historical data. It should include information about
how it was produced and how the problems encountered were overcome.

5.2.6. Exponent of VRML

The prototype should demonstrate what it is possible to achieve with VRML in a historical/archaeological context. Its use for displaying data in a more natural context.

5.2.7. Identify problems and limitations of VRML in this context

Through practical experience, explore the problems and limitations faced with the creation of VRML models. This is intended to provide useful guidance to non-specialists attempting to create similar models.

5.3. Choosing the data

5.3.1. Subject Matter

The initial intention for the project was to recreate an Egyptian tomb, but it proved very hard to obtain a complete set of data. The Egyptologists that had taken the trouble to investigate and formally publish details of many tombs didn’t take into account the needs of 3D modelling. In practice this tended to mean that there was incomplete coverage of the walls and what photographic data there was, was taken from varying perspectives under different lighting conditions. The other surprising and yet major omission was often that of an accurate plan on which to base the geometric model upon. As time was pressing, a decision was taken to open up the search for data to non-Egyptian sites,
however, this proved to be unnecessary. In the end, data was provided by the Griffith Institute, an Egyptological organisation.

5.3.2. Mond Photographs

The Griffith Institute offered the use of a set of photographs [21] taken by Sir Robert Mond between 1914-1916 of the tomb of Menna, an Egyptian noble. These photographs were a fortunate find, Mond was concerned with conducting a detailed photographic survey of the Theban tombs for archaeological reasons. However, the methods that he used are very compatible with the modern day techniques that would be employed for capturing images for 3d modelling purposes. He used a simple camera attached along with lighting equipment to a framework mounted on rails. This allowed him to take many overlapping photographs from a distance of 18-20 inches to cover an entire wall of the tomb. These photographs were then developed and the positive prints produced were cut and arranged in a mosaic fashion on cardboard. The resulting composite image represents an entire wall scene, evenly scaled and seen from an frontal orthogonol perspective. This composite print was then retouched by hand to hide the joins between the prints and the result photographed again. Mond mounted small samples of his work on cardboard to facilitate access, along with a small scale plan of each tomb. For further details of Mond’s photographic methods, the reader is referred to an article in The Photographic Journal, Jan 1933 where a lecture he gave to the Royal Photographic Society about his work is transcribed[22].
A set of prints was taken from the original photographic plates used and these formed the basis of the data used for the prototype. One factor that becomes immediately apparent when observing the photographs is that they are in black and white. At the time that the photographs were taken however, colour photography was in its infancy and Mond did not have access to a suitable light source.

5.4. Geometry construction

5.4.1. Choice of tool

Various tools were available to perform the geometrical authoring process. Each with their own strengths and weaknesses. Before the choice of modellers was made, it became apparent that the underlying model was going to be very simple geometrically, based on the plans of the tomb, and the choice of modellers for the 3d structure would be less important.

5.4.2. 3d Studio

3d Studio is a PC based modelling package, it is probably the leader of its class on the PC platform. It has advantages in extensive functionality, although it has a difficult interface to easily master. Doubts were also expressed at converting the finished model file into either VRML 1.0 or Open Inventor 2.0 for applying the textures, which would undoubtedly have been processed on Silicon Graphics workstations, due to their speed and the wider range of image processing utilities available.
5.4.3. Autocad

Autocad is a Computer Aided Design (CAD) package produced for the PC. It is very capable at producing accurate 3d models although the interface is aimed at the professional draftsman making it difficult to use by the lay person. The same doubts as with 3d Studio existed in that it would be potentially problematic in converting files out of the Autocad format.

5.4.4. Medit

Medit is a 3d modelling tool for Silicon Graphics workstations, it differs significantly from the PC offerings, by allowing the model to be moved and rotated in real time. This adds greatly to the user’s comprehension of the model, by making it easy to see the model from many angles. Medit also had features for the addition and manipulation of textures as well as the ability to easily export data to Inventor format.

5.4.5. Webspace Author

Webspace Author is produced by Silicon Graphics and is intended for the production of complete VRML worlds. When first investigated, it was made available as a pre-release although it has subsequently been released. It possesses many tools for the production of VRML worlds, such as ways lowering the number of polygons in a model, in order to decrease the complexity of the model and speed up the performance. Also the ability to specify viewpoints, default views, the nature of the lighting.
The geometric modelling side of Webspace Author however proved to be awkward and difficult to use.

5.4.6. Choice

The decision was taken to use Medit for the modelling and then Webspace Author for the application of the texture maps and creation of viewpoints within the model and other details.

5.4.7. Modelling

By measuring the scale plan of the model, it was possible to infer the approximate dimensions of the tomb. The exact dimensions are not known as only a copy of the original document to which the scale of 1:250 refers was available (in appendix). In a virtual world however, cues for discerning scale are lacking and this can be used to advantage in this situation. The scales were worked out to be relative and to decide upon a final scale for the model, the height of the tomb was set at a virtual 2 metres, which from the author's experience is likely to be within 10% of the actual size.

Any small problems with scaling can be disguised by stretching the texture maps over the entire wall surface later in the process. Providing the scaling is not vastly inaccurate, then the effect will be disguised.

5.5. Processing the textures

In this model, the quality of the model is directly related to the quality of the textures, since the interest is in the wall decorations. Processing
images for the purpose of using them as texture maps is a notoriously
difficult problem.

5.5.1. Scanning the photographs

The photographs were scanned in grayscale at 150dpi on a PC. This
caused problems in that most of the images were taken as a 1:1 print
from the original glass photographic plates and this resulted in images
larger than the scanner was capable of handling. As a larger scanner was
not available, the scans had to be taken in two halves and the resulting 2
images recombined as a digital image. This was attempted on a PC
platform using the only available image manipulation utility, Paintshop
Pro 3.0, but the amount of time that the PC required to move and
manipulate the image was not conducive to the process. Instead the
images were saved to floppy disc and transferred to the Silicon Graphics
workstations, these being more capable for any form of image
manipulation, due to faster processing and larger amounts of memory.
The resolution at which to scan the images was initially decided upon at
150 dots per inch (dpi) in the very early experimental stages because this
produced files of around 1Mb that fitted conveniently on a floppy disc.

5.5.2. Stitching the images

As previously mentioned, the photographs had had to be scanned in two
halves due to their physical size, in fact two of the longer walls (6-7 and
8-9-10) are each spread over two photographs due to their length. They
had to be stitched together digitally to provide the full image. This in
itself was not a straightforward task, especially for the longer walls. An
image manipulation utility, Adobe Photoshop was made available by SGI for this purpose. In all cases, the scans were not perfectly aligned, mostly due to the physical constraints of placing a large photograph into a smaller scanner. Often the image was not accurately aligned on the photographic paper as well, so physical alignment with the edges was not practical. Instead careful adjustment was required once the photographs had been digitised, sometimes by quantities in the order of just 1 pixel. This entailed rotating one half of the image by fractions of a degree in order to align prominent features of the two halves. This task was often made somewhat easier by the common feature of long horizontal lines representing the floor in the images. Particular problems were experienced with the two long walls at the rear of the tomb, these had both been reduced to 4 separate scans and in matching the features around the join, this tended to induce a curvature throughout the image. Various solutions to this were contemplated, including, breaking the texture and down into two halves as well as subdividing the wall on to which it would be placed and resizing one half of the wall to fit the new texture. The tomb ceiling would have had to have been raised to compensate for the distortion, but it was thought that the repetitive pattern on the roof would disguise this modification. In the end, it proved possible to use a sheer function within Photoshop to bring the distortion back within the bounds. The results of these sheers, are to bring the image back to an approximately rectangular form. Any further distortion introduced by this technique is not immediately discernible and the overall effect is not compromised.
5.5.3. Retouching the images

After the process of stitching the images back together, it was necessary at times to smooth over the join to make it less apparent, using blurring filters and cutting and pasting small areas of lesser importance to cover introduced features. On the original photographs, the cuts that Mond made are just apparent, but are less visible on the scanned representations.

As each of the photographs had to represent an entire wall, including the surrounding bare rock, some cutting and pasting was performed to provide a uniform amount of unpainted wall around the edges of the image. Whilst this can be considered artistic interpretation or even tampering with the original data, it raises the question of what to do with missing or incomplete information, something that is a hot issue in the progress of virtual heritage. In this tomb, there are some smaller walls which do not have any data relating to them they have been left unadorned.

In the process of retouching, some of the artefacts introduced by Mond were corrected, notably misalignments in repeated decorative patterns around the edges of the walls.

5.5.4. Size considerations

The scanner was capable of discerning 2400dpi, but the file sizes for this resolution were typically of the order of $\frac{1}{2}$ GByte, clearly ridiculous. Even with 150dpi scans, the images were still proving too large for sensible texture mapping. The total collection of images as would have had to have been loaded into the viewing machine would have been well
in excess of 10Mb. Further to this, it was realised that most of these images were being represented in memory in a VRML viewer in true colour and not as grayscale. This meant in essence that 3 times the amount of memory was required, for 8 bits for each of red, green and blue per pixel, instead of just 8 bits for grey. The size of the texture maps is also directly proportional to the download time. After investigating the VRML standard it was found that one specified format for the texture maps was jpeg, a lossy compression algorithm. And a brief experimentation with a representative sample of viewers available for the PC market, found that the majority of the browsers understood the jpeg format. Jpeg would allow the images to be heavily compressed when stored as a file, potentially making the model (with regards to the download only) many times smaller although this size reduction is traded off against a reduction in the quality of the images.

The drawing performance of texture mapping is not affected by the size of the texture maps, instead it is dependent on viewing screen size, because for each pixel in the viewing window, an appropriate pixel from the texture map (texel) has to be found. However, having large texture maps in memory, requires the viewing machine to have a large amount of memory, something that is not necessarily the case for the target audience. It was clear that although quality might be compromised, the images would have to be reduced in size to achieve practicality.

The solution to this quandary was reasonably simple. The maximum required resolution would depend on the size of the displayed viewing window. A brief experimentation found that a virtual tomb wall was
approximately 400 pixels high, when used at a typical PC screen resolution (800 x 600) in conjunction with a HTML browser, i.e. with both on the same screen. The vertical dimension was compared, because all of the wall textures share a common height.

5.5.5. Image reduction

In the course of the modelling process, there was a need to reduce the size of the texture maps and it became very important to retain as much information as possible, for this reason, a judicious choice of scaling technique was required. Simple techniques such as point sampling simply discard information, taking one pixel from the original to represent each pixel in the final image, this usually is represented by very pixellated images.

More considered techniques average the intensities of several pixels in the neighbourhood of the sample pixel in the original image, but this method whilst simple is also less than perfect. It can be shown by examining the Nyquist limit that high frequency data still causes unwanted artefacts (aliases)[23, 24]. To further improve on this technique, a low pass filter can be applied to remove the high frequency components and prevent these aliasing effects. Various types of filters are available that have varying effects on different types of images.

A command line tool called izoom was found to rescale images. This tool is capable of using a variety of filters to process the information during the rescaling process. To quickly evaluate the variety of filters available a wall texture was scaled by 0.3 in both directions using each of the filters available. The results are shown in the appendix. The box
filter, whilst not the best filter available was felt to produce a result with the tomb walls that retained more information with less obvious blurring. This was subsequently used to reduce the image sizes, although a small amount of sharpening was performed before the reduction.

5.5.6. Applying textures

The textures were applied with Medit, not with Webspace Author as originally intended for reasons of efficiency. When attempting to import the wall textures to Webspace Author, a portent of future problems was displayed in the form of a dialogue box suggesting that texture maps should be limited to 128 x 128 pixels in size. Attempting to disregard this warning and import a larger texture caused Webspace Author to perform extensive CPU activity from which it didn’t recover. However, applying the wall textures in Medit and importing the model into Webspace Author for the definition of various parameters was much more practical. The wall textures have just been stretched to fill the appropriate wall, where as the ceiling was applied more carefully in an attempt to march up the patterns between the separate sections of roof. No scaling information was available for the ceiling texture, so a sense of judgement was used. This has not been entirely successful, because the work on this was performed towards the end of the project and time scales didn’t permit its perfection. It is hoped to remedy this and other minor points sometime later, outside the scope of the project.
5.6. Further modification to the geometric model

After the textures had been applied, viewing the model was particularly disorientating since the textured walls were visible from behind and hence the view from outside the tomb showed mirror images of some of the paintings on the internal walls. There was no way of specifying a way to turn off this feature. There were various options available to correct this problem.

5.6.1. Cladding the walls

It was possible to create a mirror image of the wall that wasn’t textured and place it slightly behind the offending walls on the outside, facing outwards (planes only have one face). This would result in a tomb that appeared like the untextured model (shown in appendix) from the outside, yet textured from the inside. The effects of doing this would have been to double the triangle count by doubling the number of surfaces. This would lead to an decrease in the all important performance, although the triangle count was still reasonably low.

5.6.2. Enclosing the tomb

A simpler and less time consuming approach was to encase the tomb in a larger box like structure, effectively hiding the exterior of the tomb. When visiting the real tomb, the space surrounding the tomb is solid rock and not accessible, this approach would reflect this. The structure would be broadly likened to that of the temple of Rameses II at Abu Simbel, Egypt. This temple was moved out of a rock face when the Aswan dam was constructed and it now exists inside a domed enclosure
with a false outer covering which mimics the effect of the solid rock from which it was moved. A potential disadvantage would be the null space that exists between the outer covering and the tomb. It would be possible to enter this space since there is no edge detection in the current VRML Specification, navigation in this space would be particularly disorientating.

This approach wouldn’t affect performance quite as much as the first due to the simpler nature of the covering and the increase in the number of composing triangles would be lower.

5.6.3. Enclosing and cladding

Essentially cladding the outer surfaces and also encasing the complete structure. This would facilitate navigation in the previously mentioned null space.

5.6.4. Choice

The second of these approaches was chosen, mainly because of time constraints but also because it would provide a much simpler outward appearance to the model with just the entrance as a feature. The third choice was rejected because navigation in this null space is not part of the intended use for the model. No benefit is gained from it.

5.7. Performance testing

The model was continually performance tested during the development on the SGI workstation, however a more acid test occurred when the nearly completed model was run on a selection of PC platforms. The
first, a 486dx2/66 with 16Mb yielded very poor performance with screen updates of the order of a minute, accompanied by high levels of disk activity. Broadly similar results were obtained with various different browsers. Moving to a similar specified PC, however this time with 32Mb of memory, yielded much better performance, although not screen update times of around 6 seconds were not conducive to real time navigation. Neither PC had any form of hardware support for 3d graphics or texture mapping. The performance of the model was improved drastically by shrinking the viewing window and hence lowering the amount of computational calculations required.

By the high level of disk activity and the extremely poor performance of the model on the first machine, it was hypothesised that the model was too large to fit into main memory with the VRML viewer and the operating system. The inference being that the operating system using virtual memory was swapping in and out various segments of memory to disk to simulate having more available RAM, with an access from disk being 5 orders of magnitude slower than a similar access from RAM, this has a well understood impact on performance. To quickly test this hypothesis, the actual texture maps were substituted for very small files (10 pixels square). This change effectively negated the size requirement of the texture maps, allowing the first PC to handle the entire model in main memory. It was observed that the performance of both PCs now came within 10% of each other. The conclusion being that the above hypothesis was correct. The original target specification for the computer the model is to be displayed on was for 16Mb, an amount of memory
that many PC users still consider extravagant. To briefly contrast this with the workstation market, the base option for an entry level Silicon Graphics workstation is 64Mb.

Due to the poor performance with a large viewing window it would seem likely that many users on lower powered machines will trade off window size for performance, in this case, it would seem practical to reduce the texture sizes still further. Thus improving download times and lowering memory requirements to within acceptable limits, however with the trade off being again quality. A compromise would have to be made, but reducing the image size still further would have produced a much poorer image on workstation class machines with greater than 16Mb available memory. To solve this problem, it was decided to split the model into 2 separate models, one intended for PC platform and another intended for workstation class machines. The additional maintenance incurred by having two separate models was a consideration, but since the texture image files are separate from the main model, they can be processed separately and the settings that existed to govern the behaviour of the texture maps were independent of the size of the file in all cases except the ceiling. This meant that the two models could each have a copy of the same VRML file but would exist in different directories.

The PC flavour of the model which was to cater for the less capable machines was to involve a further image size reduction, would render the necessity of retaining maximum detail of even more importance than before.
5.7.1. Hyperlinking

Using VRML, the smallest unit that can be used as a hyperlink is a single object. This meant that the smallest practical object was going to be a whole wall surface, dividing a wall surface (and corresponding texture maps) into smaller non regular objects would entail a lot of work. An early intention to outline various figures and other features on the tomb walls and have hyperlinks relating to them was clearly going to be difficult to achieve. It was also considered that resolving the model to this level of detail would be unnecessary within the scope of this project and it would be more important to prove the concept of using hyperlinks between VRML and HTML. For simplicity, one hyperlink per wall was added using Webspace Author. This proved to be as straightforward as adding a hypertext link in HTML. One of the main features of the corresponding HTML pages was going to be a larger image of the wall to compensate for the compromised quality of the texture maps.

5.7.2. Problems with non SGI viewers

A recent discovery was that whilst the model worked with the SGI VRML viewer, Webspace and the Webspace Author, the model wasn’t actually VRML compliant. What were thought to be VRML files were actually a combination of Open Inventor and VRML (adhering to neither format), a situation further complicated by having using a browser on the PC that didn’t validate the input file. After the model had been authored in Medit, it had been exported in Inventor 2.0 format and imported into Webspace Author, which had been used to add the viewpoints, hyperlinks etc. It had been presumed that Webspace Author
would save the files in VRML format, but it did not. The solution, once the problem had been identified was to run a command line conversion utility ‘IvToVRML’ (whose purpose should be obvious) on the offending files before importing them into the Webspace Author.

5.8. HTML Authoring

The HTML pages were created after the VRML model to take account of the unknown nature of the finished product.

5.8.1. Design

Various aspects of the design were created during the VRML authoring process, such as the need for a page per wall to compensate for the compromised texture maps. The outline design for the HTML pages was constructed by outlining the project to people with no prior knowledge of the tomb and asking them what they would like to know about the project. Certain answers were repeatedly encountered, suggesting an organisation which seeks to directly address these questions. Most of the target group used to establish this information were students with experience of the WWW and it is possible that the answers are in some respect skewed towards the information that they would require or expect. However as an aid to the design process it was remarkably effective.

The structure of the web site was deliberately kept simple to aid maintenance and to facilitate navigation.
5.8.2. Implementation

During the implementation, 4 different HTML authoring tools were used as well as the trusty text editor. None of them proved wholly satisfactory which is the reason for the variety used.

5.8.3. Internet Assistant (add in for Microsoft Word 7.0)

This product seeks to expand the functionality of the already feature heavy word processor to WWW browsing and authoring. The authoring facilities of the product would seem to be aimed at converting existing Word documents to HTML as opposed to editing existing HTML. In practice it was found to be very biased towards adding HTML tags specific to Microsoft’s Explorer product, a WWW browser with less than 15% market share.

In practice it exhibited the dangerous trait of reading in a file (feedback.htm) authored in a different tool, losing any information contained between tags that it didn’t understand and promptly saving the new abridged edition over the original. For this reason in particular, it wasn’t used for much of the authoring process.

5.8.4. Netscape Navigator Gold 2.0 beta 2

This is an advanced flavour of Netscape’s browser very popular product that adds WYSIWYG authoring capabilities to it. In practice the pre-release nature of the product showed itself with many unimplemented features and inherent instability. Whilst appearing initially promising, these problems prevented any significant amount of authoring to be
done using this product. At time of writing the finished product has just
been released.

5.8.5. Nesbitt Software’s WebEdit 1.4

This proved to be one of the most stable tools available. In practice it
resembles a standard text editor with additional options available to add
the various tags. It also adds an built in preview facility that speeds up
the authoring process. Most of the authoring was done using this tool.

5.8.6. SGI Webmagic Pro

This is a Silicon Graphics tool that was used to amend the HTML at a
late stage. It allows WYSIWYG editing and is quite easy to use, especially
for the creation of forms although doubts exist over its interpretation of
non-understood HTML tags.

5.8.7. Summary of HTML authoring tools

The author was fortunate in having had previous experience of HTML
authoring when on placement with CCTA, so the choice of tools was
less important than it might have been. An understanding of the
underlying tag based structure of a HTML document is seen as essential
in order to achieve the formatting required with the limited controls
available within HTML. This understanding is also sometimes necessary
to defeat the default behaviour of the higher level editing tools which
tend to stifle creative formatting in order to provide easy to use facilities.
5.8.8. Form submission

To obtain feedback from the users of the demonstrator, a HTML feedback form was designed with the appearance of a small questionnaire. The form was designed to be quick to fill in, in order to encourage participation. The technicalities of the form submission process involve sending the information to a public use form handling program running at the Johns Hopkins University, School of Medicine, where it is converted into email and mailed back to the author. The form, the HTML used to create it and a sample of the feedback received by this method have been included in the appendix.
6. EVALUATING THE DEMONSTRATOR

6.1. Introduction

To evaluate the demonstrator system, it can first be compared against its aims and objectives to see how well the finished product compares with the intended. Secondly feedback has been received via the web from a diverse audience, this will be examined. Thirdly, a limited number of interviews and demonstrations were performed with feedback forms filled in where appropriate. Issues that have been raised are discussed later.

6.2. Comparison with Aims and Objectives

6.2.1. Product

The product fulfils this objective well. It is also believed that it is the first and only Virtual Heritage site on the Internet of its type, that is, to the extent of including a VRML model.

6.2.2. Target Audience

An inspection of the feedback received via the WWW indicates that a reasonable proportion of the feedback so far has been from professional historians. This has probably been due to the announcement of this project on the Ancient Near East email list and the hyperlink available on the Griffith Institute’s web page. When the project is finally indexed with the major search engines, the demographics of the audience are likely to change.
6.2.3. Computing Requirements

Of the Aims and Objectives, this has probably been the most poorly achieved. The performance on a 486 platform is very poor and does not approach the VRML ideal of real time. The memory requirements can not be optimised much further and to do so would not yield any performance benefit.

It should be noted that since the Aims and Objectives were drawn up, the specification of what could be considered the entry level business PC has risen to a Pentium 75MHz. This performance on this platform is significantly faster mostly due to a much more efficient Floating Point Processor in the CPU. The model has regrettably not been tested on a computer with hardware support for texture mapping such as the new SGI Indigo² Max Impact. It is expected that performance will be of the order of 100 times faster than the Indigo² Extreme used to author the VRML. To improve the performance of the model for a particular hardware platform would require optimisations in the VRML browser, something beyond the control of the author and outside the scope of the project. However, VRML browsers are expected to evolve rapidly, especially with the forthcoming ratification of VRML 1.1 and VRML 2.0 on the horizon.

It is also expected that the introduction of low cost 3d graphics accelerators such as GLINT into the mainstream PC market in the near future will enhance the performance of VRML significantly.
6.2.4. Exponent of Virtual Heritage

The project illustrates some of the possibilities of Virtual Heritage over the Internet but fails to take advantage of others such as sound. A professionally produced equivalent site to this, to provide a real alternative to tourism although still based on the limitations of today’s PC platform should really have colour wall mappings, sound and more information.

6.2.5. Exponent of VRML

Although subjective, in with regards to the quality of other VRML models available, the project compares favourably. It uses texture mapping much more heavily than most others encountered by the author. Much of the VRML available over the Internet has little purpose, consisting of models converted from other 3d formats and bizarre ‘home worlds’. However, VRML is beginning to find more practical uses and it is hoped that this project will help show that.

6.2.6. Identify problems and limitations of VRML in this context

Various problems with VRML have been identified earlier and worked around. It is thought that with foreknowledge of these the production of the model could have proceeded much more quickly. It is hoped that this documentation of these limitations will be of benefit to individuals pursuing similar projects.
6.3. Web feedback

The collection of feedback as received via email from Internet is included in the appendices for reference, as is the feedback form used to collect this data.

6.3.1. Anonymous feedback

Anonymous feedback from the Internet has shown that many users have not been able to view the model satisfactorily and have been confused by the concepts involved in VRML. As remedial work, the section of the HTML pages where VRML is explained has been expanded to try and compensate for this. The feedback on the content has been mixed, some finding it of no use and others finding it very useful. Most of the respondents have been generally positive about the possibilities offered by the service, with an encouraging unanimous positive response to the final question, regarding whether they would visit other similar virtual heritage sites.

Most users appear to be attempting to view the model on a 486 PC or equivalent Macintosh. Approximately 50% of the respondents appear to be unable to view the model, however those that can generally rate the performance as being good.

The relation between the number of hits and feedback forms received has been about 3%.
6.4. Other issues raised

6.4.1. Usability

Many of the participants in the feedback process remarked on troubles either viewing the model or installing VRML viewers. The installation of viewers would appear to be too technical an issue for many of the potential users. As an issue this is quite understandable, but had not been considered as being one of the major factors inhibiting the take up of VRML. It is expected that as VRML evolves, the ease of installation will improve to mirror the evolution of the HTML browser. The next major release of Netscape Navigator will have built in 3d support and an intermediate release with a bundled suite of add-ins features VRML, so perhaps this is one issue that will be resolved in the next few months.

Users new to the concept of navigation in a 3d world were observed to have difficulties understanding the principles involved, although the poor performance of the model and the consequent lag between command and response did not help. The lack of collision detection in VRML further frustrated the efforts of some users. The model can be navigated in a simple fashion by using the predefined viewpoints that exist to show all three of the rooms and the entrance. Naïve users appeared to be much more comfortable with this method of navigation. Again, it is hoped that with the proliferation of 3d models on the Internet, the typical user will develop and understanding of the navigation metaphors and that the situation will improve in the future.
6.4.2. Educational potential

Several teachers were involved in the evaluation of the project and their consensus was that it had excellent potential as an educational aid. However, it was thought to be of little use in primary education. Doubts were expressed over whether it would fit into the all important national curriculum, but thought that the concept of using VR models for educational purposes was sound. Many subjects were suggested that would benefit in some form from this approach, as diverse as foreign languages, art, english and geography. A maths teacher was unsure of a use in his field but could immediately apply it to others.

6.4.3. Other issues

It was observed that non-technical users were prepared to accept very poor performance from the model and yet still derived benefit from it.

6.5. Quantifiable results

6.5.1. Typical Number of hits

With the addition of a page counter to the front page it became easy to count the number of accesses to the information. The site received approximately 200 hits in a 10 day period. The process of indexing the site with the web catalogues and search engines is a slow process, of the order of 2-6 weeks. As far as can be ascertained, none of the major search engines have yet referenced this model, Lycos, AltaVista, Webcrawler, Infoseek etc. When the indexing process is finished, the number of hits is expected to rise significantly. It would have been more appropriate to register the site for indexing much earlier, but it was
assumed that the process of indexing was governed by an automated process and not, as is the case, by a manual review. The lateness of the request for indexing was also due to the author making sure of the completeness of the model. If the model was incomplete when indexed, then potentially valuable information for the index would not be included.
7. CONCLUSIONS

7.1. Introduction

This conclusion attempts to summarise the work that has been carried out and justify the results. A discussion of the skills that were required and those that have been developed are presented as useful reference to those engaged in future projects of a similar nature. A look at costs, benefits and resources used, attempts to show the work in a more business like context, which could be essential should similar projects be attempted by other organisations. A review of the mistakes made and experience drawn from these will provide guidance and finally there is a brief look at the future of, and issues arising from this project, VRML, Virtual Heritage and future work.

7.2. Summary of the work

This project was started with the idea of using a new technology, VRML to model a very ancient object, a Theban Tomb, with the intention of trying avert the damage being done and to provide an alternative to tourism. The project was chosen more to reflect the author's interests than with any concept of Virtual Heritage. As the initial investigation was underway, the apparent benefits that the project could yield increased until the notion of Virtual Heritage was encountered. Virtual Heritage fitted in well with the aims of the project and added a justification to the work already in progress. The practical aims of this project were to show the viability of using the Internet as a vehicle for
the reconstruction and this has been achieved. The demonstrator system as developed, has highlighted some of the pitfalls of using VRML for this type of modelling, although these have been worked around in what are felt to have been justifiable ways. The creation of this demonstrator, whilst not on the cutting edge of computer graphics, attempts to bring a new concept to the masses and their PC class computers, a task for which they weren’t intended. It is almost to be expected that despite the optimisations performed, there are still many users who lack sufficiently powerful computers to view the model.

As far as can be ascertained, it is thought that this has been the first use of VRML in this context and due its success, it is hoped that it won’t be the last.

7.3. Skills

This project has enabled the author to develop valuable practical experience of implementing 3d models using professional equipment, courtesy of Silicon Graphics. Some limited experience of modelling on the PC platform and an observation of the performance of this model on similar machines has highlighted the benefits of using high quality authoring tools.

Both an understanding of some of the concepts behind and the skills related to image processing have also been refined. The intense work in correcting the deficits of the images heightened the author’s knowledge of some of the more advanced features of Adobe Photoshop.
HTML authoring skills have been employed allowing the author to update his knowledge of HTML with the reasonably recent introduction of HTML 3.0. Also the ability to create forms was developed.

7.4. Costs, resources and benefits

7.4.1. Costs
The only costs incurred in the project have been approximately £40 for the printing of the original photographs, various travel costs and the author’s time.

7.4.2. Resources
The project made use of the computational facilities of SGI and the Egyptological knowledge of the Griffith Institute. Details of the computers used are included in the appendices.

7.4.3. Benefits
The project and this report are expected to benefit other individuals or organisations following on from this work, or pursuing similar VRML based projects. The model is potentially of a small educational benefit although the concept is seen to have enormous potential. The author has benefited by gaining experience of professional modelling techniques. The Internet community have benefited by having gained access to information about Menna and the Mond photographs, which would otherwise be languishing in the Griffith Institute’s archives.
7.5. Mistakes made

7.5.1. Proprietary images
Insufficient research earlier on in the project lead to the decision to use proprietary SGI format images in the workstation VRML model. These images are not defined as compatible in the VRML Specification. The use of these limits the cross platform compatibility of this model. The author expects to remedy this at a later date outside the scope of the project.

7.5.2. Planning
The project was not time managed effectively. It suffered from a late start due to the need to collect data, and difficulty was found anticipating the length of stages due to the author’s inexperience of both time management and 3d modelling.

7.6. Futures

7.6.1. VRML
VRML has a potentially bright future, it has no real competitors and has gained a large amount of support from individuals and corporations in less than 2 years since it was first proposed. Shortfalls have been realised in the first version of the language and version 1.1 is well on the way to ratification. Such is the interest in the future of VRML, a fierce debate has sprung up over the what will become VRML version 2.0. The main aims are to add multi-user capabilities, behaviour models for objects and collision detection but this just scratches the surface. Two major
proposals have been put forward, ‘ActiveVRML’ by Microsoft and an alternative by SGI, Sony and WorldMaker. [25] They essentially attempt to provide similar functionality although in radically different manners. Other companies are not waiting for a standardised way to proceed and are implementing their own flavours.

The industry certainly believes that VRML has a future, Konstantin Guericke, executive vice president at Caligari Corp. suggests that every web site that is set up to receive visitors will eventually be three-dimensional. [26]

As the amount of processor power available to a typical user increases, so do their abilities to navigate more complex virtual worlds. This is only good news as is the introduction of low cost 3d accelerated graphics cards to the PC market. 3d chipsets such as GLINT promise to assist the uptake of 3d models in the near future.

7.6.2. Virtual Heritage

This has been, as far as can be ascertained, the first VRML based Virtual Heritage project to be published on the Internet. Feedback has been very positive for the concept of Virtual Heritage although the technical aspects have not yet caught up. Computing power is increasing all the time and decreasing in price and this can only facilitate more complex and ambitious projects. Other projects such as the tomb of Nefertari, could possibly be migrated to VRML when it becomes reasonable to expect the level of computing power to catch up.
When convenient finance mechanisms become established over the Internet it will be possible to have professionally produced models that can pay for themselves. A VRML model of a site could be produced that will help to generate funds to preserve the original, the concept of online donations is always a possibility.

From the investigation of similar projects it would seem that the recreation of historical sites is here to stay. Silicon Graphics have been known to use several historical reconstructions as demonstrations in their ‘Reality Centre’, to illustrate the power of their machines.

7.7. Following on from this project

7.7.1. Minor changes

A move to a feedback handling mechanism that is controlled either by MMU or Silicon Graphics would guarantee the availability of the service which at the moment is in the hands of Johns Hopkins University.

The texture maps in the workstation flavour of the model should be changed from the SGI proprietary format to JPEG to increase the compatibility of the model. It has only been recently discovered that SGI proprietary images are not widely supported.

A short video fly through, available via the WWW should be produced to widen the potential audience for the model, in light of the poor feedback regarding the availability of VRML browsers.
7.7.2. Issues

With regards to the maintenance of the pages, the author will retain responsibility for responding to feedback and dealing with other issues arising at least for the near future.

7.7.3. Possible directions for further work

The whole model could be upgraded by obtaining more information in order to model the tomb more closely. Information such as modern colour texture maps, more accurate geometric data with notes of distinct irregularities in the walls and measurements of the niche at the back of the tomb where the idol resides could be used. It should also be possible to furnish the tomb with a sarcophagus and some of the artefacts likely to have been there at the time of burial. This could enhance the educational and tourist potential of the model.

More details could be offered on the HTML side to provide a better visit. The addition of a virtual guided tour, possibly with a spoken voice might prove of benefit.

As a major project in itself, the wall paintings could be virtually reconstructed using computer techniques \[27\]

A related basis for an undergraduate project might be to further investigate the possibilities for using similar techniques to produce 3d models to put archaeological data in context.

This model is relatively simple geometrically and complex with regard to the texture mapping, it might be instructive to attempt to model a site that is the opposite of this and has complex geometry with little or no
textures. An Egyptian temple would seem to be a suitable vehicle for this although doubts would be expressed as to whether the volume of work involved in this is potentially beyond the scope of an undergraduate project.
8. APPENDICES

8.1. References

2. City of the Dead, Thebes in Egypt, Lise Manniche 1987
5. Virtual heritage conference http://www.dixon.co.uk/heritage/virtual/
8. HTML guide http://www.hempenac.ac.uk/ dos/HTMLPrimer/HTMLPrimer.html
16. Infobyte VR reconstruction of Nefertari’s tomb

20. The private tombs of Thebes, the photographic survey by Sir Robert Mond 1914-1916, Dr. J. Malek, Pamphlet available from the Griffith Institute, Ashmolean Museum Oxford.


24. What is VRML appropriate for?, http://livedv.com/Whitepapers/VRML.html

25. CCER, computer based reconstruction of Egyptian tomb paintings, http://www.ccer.ruw.nl/
8.2. Simple Tomb Plan
### 8.3. Machine specs

#### 8.3.1. Authoring Machine
- SGI Indigo2 Extreme
- 192Mb Memory
- 200MHz R4400
- 2GB local storage
- 3d graphics acceleration, but no support for texture mapping

#### 8.3.2. First PC
- 66MHz i486dx2
- 16Mb Memory
- 340Mb local storage
- No 3d graphics support

#### 8.3.3. Second PC
- Dell ME4/66
- 66MHz i486dx2
- 32Mb Memory
- 1Gb local storage
- No 3d graphics support
8.4. Effects of scaling

Effects of box kernel (-b option)
Effects of no filtering, -I, impulse option

Effects of mitchell filter, -m option
Effects of quadratic filter kernel, \textit{-q} option.

Effects of triangle filter kernel, default option.
8.5. Untextured model in M edit
8.6. Feedback form (in 3 parts)

You can use this page to send comments and general feedback. Please enter your feedback in the form below and press the Submit Feedback button at the bottom of the page when you're finished. If you make a mistake, then you can press the Clear Form button to reset everything to the defaults.

This form should only take a minute or two to fill in. If you have any particular comments about this form or the site in general, please enter them in the text box below or email the author, Matthew Pendlebury at ae74@cityscape.co.uk.

My occupation is:

My reason for viewing is: sheer curiosity

I have found this service very useful

I have found the quality of the information to be very good

It is appreciated that the VRML model will perform badly on non-workstation class computers, due to the sheer number of calculations that have to be performed. However if a picture of the computing equipment available to the users to this site can be ascertained, then possibly progress can be made.
3d Virtual Reality reconstruction on the Internet using VRML - Matthew Pendlebury, Manchester Metropolitan University 1996

available to the users to this site can be ascertained, then possibly progress can be made.

My computer is a 386. 486. 680x0 or equivalent

Some computers have special hardware that allows them to display 3d models such as the tomb very quickly, these are not very common on cheaper PCs, although this is expected to change.

My computer might have 3d acceleration

I have found the performance of the 3d model of the tomb to be very good

Please feel free to make any comments you wish. Any feedback will be appreciated, however negative. If you have problems with the model or otherwise wish to communicate, please include your email address:

Having seen this prototype of what a virtual heritage site could be. What do you think about the concept (restoring monuments using Virtual Reality)?

Yes, I would visit other WWW Virtual Heritage sites (like this one).
3d Virtual Reality reconstruction on the Internet using VRML - Matthew Pendlebury, Manchester Metropolitan University 1996

Location: file:///D/TREMERE/DESKTOP/Menna2 the rematch/FEEDBACK.HTM

Please feel free to make any comments you wish. Any feedback will be appreciated, however negative. If you have problems with the model or otherwise wish to communicate, please include your email address.

Having seen this prototype of what a virtual heritage site could be, what do you think about the concept (restoring monuments using Virtual Reality)?

Yes, I would visit other WWW Virtual Heritage sites (like this one).

If you have difficulty sending feedback through this form, you can send email to ae74@cityscape.co.uk.
8.7. Sample feedback

Received: fromwelchgate.welch.jhu.edu (gateway.welch.jhu.EDU [128.220.59.13]) by ns.cityscape.co.uk (8.6.4/8.6.4) withSMTP id
JAA14946 for <ae74@cityscape.co.uk>; Wed, 27 Mar 1996 09:39:44 GMT
Received: fromcwis.welch.jhu.edu (infonet.welch.jhu.EDU) by
welchgate.welch.jhu.edu (4.1/1.34)
  id AA20482; Wed, 27 Mar 96 04:37:09 EST
Received: bycwis.welch.jhu.edu; (5.65/1.1.8.2/22Aug95-0424PM)
  id AA16392; Wed, 27 Mar 1996 04:43:36 -0500
Date: Wed, 27 Mar 1996 04:43:36 -0500
Message-Id: <9603270943.AA16392@cwis.welch.jhu.edu>
From: "FormHandler on infonet.welch.jhu.edu" <www@infonet.welch.jhu.edu>
Reply-To: ae74@cityscape.co.uk
Apparently-To: ae74@cityscape.co.uk

^^
Occupation:
  History professor
^^
Reason for viewing:
  an interest in VRML
^^
I have found this service:
  very useful
^^
I have found the quality of the information to be:
  very good
^^
My computer is a:
  386, 486, 680x0 or equivalent
^^
My computer:
  does not have 3d graphics acceleration
^^
I have found the performance of the 3d model of the tomb to be:
  very good
^^
comments:
  The only problem I've encountered was that the quality of the black &
  white pictures
  was not very good BUT this might have been because of my poor
  hardware (486/DX2-50, 1024x728 NI/60Mhz color monitor, plain Tseng-4000
  card chip)
  I've viewed with live3D beta attachment of Netscape 2.0)

The whole project though is excellent and can be
used for educational purposes.
Congratulations.

^^
visit other WWW Virtual Heritage sites (like this one):
  Yes, I would
^^
feedback:
  Submit feedback
8.8. Sample screenshot

The complete model can be found at http://reality.sgi.com/employees/nigelj_manchester/Mattz/