High-Fidelity Rendering of Ancient Egyptian Gold

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Abstract

Testing virtual lighting simulations is now common practice in a number of different fields, not just computer graphics. This practice can help save time and money and help pick up on design flaws. It can also be used as a means to compare real images of the synthetic scene we derive to help us deduce whether algorithms currently in place are efficient and effective and possibly contrive new algorithmic theories. Simulations will never become accurate predictions of reality unless the reality of the physics is preserved within the modelling. Creating synthetic images is becoming more and more commonplace in the field of archaeology. With advanced graphics algorithms it is possible to take a glimpse back into our ancestors' surroundings. With accurate reconstructions, from lighting to modelling, it is possible to derive images as to how scenes may have been perceived in that period of history. This paper includes an analysis of and describes several ways to model light transport and propagation for a gold material, their validity and how gold may have been perceived in situ in Tut-Ankh-Amun's tomb. This paper also considers the effects of different renderers, both raster and physically based on synthetic images. Using accurate lighting it is possible to derive implications on perception changes in this environment from modern perception to perception dated 1323BC.

Keywords: High-Fidelity Graphics, 3-D Graphics, Realism, Archaeological Reconstructions.

1 Introduction

Archaeologists have adopted a trend of using Computer Graphics progressively more in their attempts at visualizing the past. Recording and the storage of data was the primary function. Lately however, images can be generated by computers that are based on physical reality. A lot of film and publishing industries have welcomed this technological advance as they can add extra dimensions to their shows. Three-dimensional computer models can help archeologists to examine and reconstruct.

Many archeological reconstructions are modeled and rendered in software that does not compute physically correct lighting [RUD*04]. These pictures are generally thought of as useful to the approximation of functional and sometimes photo-realism, however when the study of the visual perception of a certain site is desired we want to incorporate the effect of realistic, physically based, lighting. Part of this paper will investigate the effect on accuracy and perception of using non-physically based renderers versus physically based renderers on site reconstructions and presents a prognosis as to how this will affect quantitative and perceptual accuracy.

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1.1 Reconstructing Ancient Egypt

The Theban mapping project is currently attempting collect and collate data on all of the tombs both of Pharaohs and nobles in the Valley of Kings, Luxor. Until such a time as information is deemed to be preserved there are strict limitations on visiting, photographing or even researching any artefact associated with the Valley of Kings. Perhaps the most famous of finds, the Boy-King's tomb, is most fiercely guarded. Collaboration with Egyptologists would make it possible to create a model of the tomb which could be used for the production of high-fidelity renderings.

This paper investigates how light would have propagated in the tomb and more specifically into how light interacts with the gold that would have been found in the tomb. This is done by writing a number of shaders to simulate accurately the interaction of light with the gold materials for non-physically based renders and using approximated BRDF's for the physically based renders. We then compare the advantages and features of each to best represent the perception of the objects via shader viability through a real scene comparison. Finally, we investigate the pros and cons of different renderers - both physically and raster based in accurately representing such a virtual environment.

This project provides an insight into the perceptual attributes of high-fidelity gold in the tombs surroundings without being able to collect any data with which to accurately model the physical properties of the tomb. Ideally this would involve gonioreflectometers, laser mapping the site and measuring light levels with spectroradiometers

Figure 1– *Left:Real Image,Right:Maxwell Image lit by a candle*

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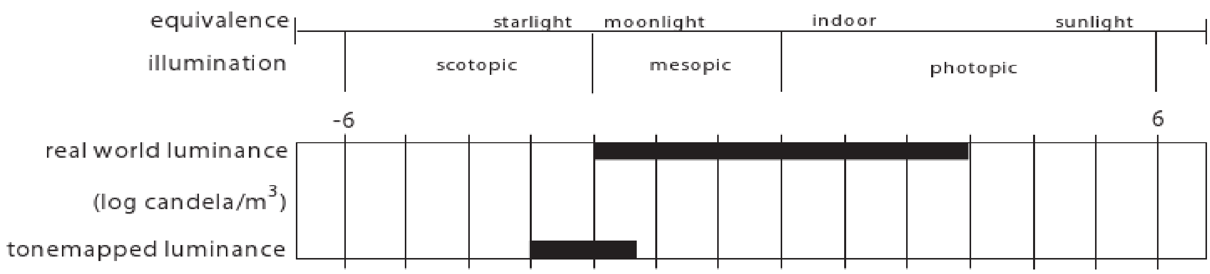

Figure 2 – *Luminance Range*

As seen from figure 1; one of the main applications of this type of work is to investigate the perceptual impact that different lighting has on effecting reconstruction [DEV*01]. Given the chance to have a glimpse at how our ancestors lived; the question that eludes us still is how realistic do we need to be? Complete physical accuracy is preferred however current trends suggest that trying to find ways to elicit the same perceptual response via means of selective rendering seems to be adequate [CAT*02].

The rest of the paper is organised as follows. In section 2 we go on to talk about relevant work and important background material and software. Section 3 considers the implementation and process of this work. In section 4 we discuss results and proceed to conclusions and future work in section 5. Acknowledgements and references follow.

2 Background

The three degrees of realism are scaled with physical realism being the hardest to achieve, almost impossible currently [FER03]. An example of functional realism is the information derived from a model of some real scene; some obviously better than others and verging on being photo realistic. Photo realism is often thought of as the same visual response being derived from the light energies in the scene [CHA06]. Models generally aspire to be photo-realistic in terms of photometry. Physical realism is where the model is exact and the light energies emitted from the image are the same as real life. Most display media is inadequate to reproduce the full range of light intensities present in natural scenes [SEE*04]. It is possible to tonemap an image (map and scale its luminance within a viewable range as shown in figure 2) so it can be viewed, but this doesn't represent physical reality.

A large number of projects have been undertaken in order to achieve different levels of realism for cultural and heritage sites, with varying degrees of success. A large area of Computer Graphics (CG) research is employed in the field of virtual reconstruction and attempting real-time photo realistic visualisations of cultural and heritage locations of differing degrees of global importance. [KSS*07, TRH*07] are good examples of the direction of this type of research; investigating scenarios for real-time photo-realism including High Dynamic Range content for day lighting simulation of a heritage site. This visualisation work is truly appreciated for use in historical contexts. This perceptual study work is not strictly employed for one channel of purpose. It can also be used for pre-visualisation of proposed designs, plans and advanced lighting scenarios within architectural plans.

[DEV*01] presents a perceptually orientated study of realistic visualisation of Pompeii Frescoes for high-fidelity graphics application. [SUN*04] provides the high-fidelity reconstruction of the ancient Egyptian temple of Kalabsha - a strong parallel to this work. Such diverse work as boring into structural validity of Maltese temples has been performed in this vein and stemmed from the original impetus [CHD*05]. These studies into perception of cultural and heritage sites provide wonderful insight into ancestral architecture and even behaviour.

Virtual reconstruction is a large field with a wide degree of application not the least of which is virtual tourism. Some sites are so protected and in such remote locations across the globe it is infeasible for many to see them; in many peoples opinion a huge shame, that can now be avoided. This focus of CG research helps with globalisation in at least a small, yet localised fashion.

2.1 Material and Light Properties

Both materials and light have their own properties in the real world. In order to provide accuracy in a simulation we need to be implementing as much information regarding the physical properties of the scene as we can. Materials have properties, as do photons and these are taken into account when producing synthetic images. Whether this is in a physically accurate sense or faked.

2.2 Image Comparison Metrics

Image comparison forms a lot of the basis upon which computer graphics tests are based. Comparing two images should be the task of finding differences or similarities between two or more images. Those differences could be analysed using comparison either quantitative (numerical) or qualitative (visual) or both. As reconstructions can easily be misleading and we are trying to provide an insight into how these reconstructions may have appeared and been perceived it is essential to ensure realism by whatever metric provides us with the best possible analysis.

2.2.1 Visual Psychophysics

This is defined as the study of the response to an image of known composition. This study can be used to measure perception and provide a basis for validating reconstructions. Comparing human reactions and stimuli both on an original scene and a synthetic composition of the original scene provides the basis for the test. If the response is similar in both cases we have achieved an accurate portrayal of the scene [ARA*06]. The obvious drawback of this type of metric for use in archaeological reconstructions is the lack of an original scene to which it can be directly applied. What we can do however is break down the original scene into components for which stimuli can be measured. If these provide results indicating an accurate scene the logical step for our experimental procedure is to composite the components together, this should give an accurate scene. A basic, hypothetical example is in the case of an ancient temple with several jade artefacts. Original images of a piece of jade are available, as well as pieces of stone. If the synthetic renderings of said artefacts are implied to be accurate through perceptual validation, it should be possible to reconstruct the temple with a high level of accuracy.

2.2.2 Visual Difference Predictor (VDP)

VDP can be used to forecast differences between pairs of images that are perceivable by the human visual system [DAL93]. VDP is designed to highlight effects at or above the Just-Noticeable-Difference level of the human visual system. However, VDP does not take into account visual attention. Output from the VDP system is a detection map, which establishes the probability of difference detection between the images as well as measurements for the degree of differentiation [ARA*06]. Identical images will produce a probability of 0 for a difference being detected, and 1 for disparate pairs. There is a high dynamic range (HDR) version of VDP which operates on images containing a large luminance range of pixel data. HDR VDP is necessary to achieve more accurate results when comparing with physically based synthetic images that output images with information about physically correct light transport.

2.2.3 Mean Squared Error (MSE)

This is a statistical measure which is a way of quantifying the amount by which an estimator differs from what it is attempting to estimate. An MSE of zero means the estimator is perfectly accurate. MSE must be used as more of a comparative measure in a concatenated sense as results by themselves mean very little. In conjunction with other results however they mean a lot more.

2.3 Rendering Packages

In order for more accurate results we consider four different rendering packages. Two non-physically based and two physically based. The only one used which cannot be plugged into or is not plugged into Maya (our modelling package) by default is Radiance. We will need to export geometry and view file descriptions to be able to render within this system as it is a Linux based rendering package that can only be accessed externally to Maya.

2.3.1 Maya Software

This is generally considered to be one of the more basic renderers currently. It is only used for simple pre-visualisation purposes. Material reflections do not use any advanced properties. It is not based on real light propagation and as such lights defined by physical plausibility are not supported. This is only included in our experiments as a worst case standard.

2.3.2 Mental ray

This is a production quality rendering system which can produce very perceptually realistic results albeit at the expense of some physical accuracy for increased render speed. It supports the ray tracing algorithm and uses an implementation of global illumination. This software can take advantage of parallel processing across render farms to speed up render time. It can handle advanced material properties but in a restrictive sense does not allow physically defined light sources.

2.3.3 Radiance

Radiance is a lighting simulation and rendering system [WAR*98]. It is a really physically based spectral renderer. Defualt materials used within this renderer need a little extra control for physical properties, light systems however account for physically defined light sources. To create scenes in Radiance we need a description of a scene, material and light source description and mapping file (optional). From these files it is possible to create an octree file, which is used by the rendering process in Radiance. The following commands take a scene and create a numerically correct image which, if done accurately, can be indistinguishable from a photograph [WAR*98]. Below is the common rendering pipeline when attempting to derive an image from Radiance:

obj2rad -m mapfile.map scene.obj > scene.rad
oconv material.rad scene.rad >scene.oct.
rpict -vf viewfile -rendersettings scene.oct >scene.pic
pfilt -x /2 -y /2 scene.pic > scenefiltered.pic
ximage scenefiltered.pic

Some common render settings to highlight the control that this render system gives over image production are shown below in table 1 [RAD]:

Param	Description	Min	Accur	Max
-ps	pixel sampling	16	4	1
-pt	sampling thresh	1	.05	0
-pj	anti-aliasing	0	.9	1
-ab	amb bounces	0	2	8
-aa	amb accuracy	.5	.15	0
-ar	amb resolution	8	128	0
-ad	amb divisions	0	512	4096
-as	amb sup-samples	0	256	1024

Table 1 – *Common Render Settings For Radiance renders [RAD]*

2.3.4 Maxwell

This rendering engine is an unbiased, completely physically based renderer. The global illumination algorithm it implements utilises a variation of metropolis light transport. It allows for environmental image-based lighting, physical sky and sun creation. When instantiating a render we can define which channels will be rendered (Rendering Channel (Default; Contains the actual image), Alpha Channel, Material ID Channel, Z-Buffer Channel, Shadow Channel, Opaque Channel, Object ID Channel) and which illumination channels will be rendered (Direct Illumination, Indirect Illumination, Direct Reflection Caustics, Direct Refraction Caustics, Indirect Reflection Caustics, Indirect Refraction Caustics). The fact that this renderer is completely unbiased means it will always converge to the correct solution, given enough time to render; even taken into account the fact it allows for advanced and physically correct material files and physically defined light sources; from wattage through correlated colour contribution and on into efficacy.

3 Implementation

3.1 Modelling

A detailed geometric model is the first step, before the rendering process, in the reconstruction process. Without authorisation it is not possible to laser map the tomb.

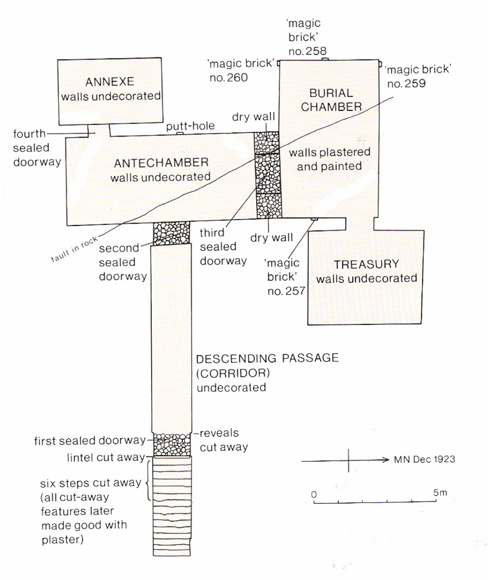

Figure 3 – *Bird's Eye Elevation of the Site[MET]*

This authorisation would never come for such a protected site. Unfortunately documentation also proved to be fairly sparse but finally the Theban mapping project provided us with the data required to map out the tomb with a high degree of accuracy [THE]. Figure 3 shows the tomb and also highlights what kind of information the tomb had to be modelled with. Autodesk Maya is used for all modelling.

Inexhaustive lists of different techniques were used in construction of the model. Dalton describes them thoroughly in his lecture series [Dal06].

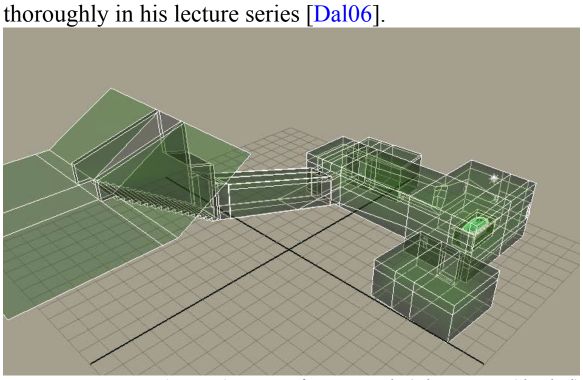

Figure 4 – *Wire frame Mesh (Flat X-Ray Shaded)*

3.2 Shaders

The success or failure of the project relies on the accurate description of the material shaders to simulate accurate light propagation from their surfaces. The mental ray API and shader library has built in definitions for calculating the specular lobe component of the BRDF approximation for all the standard models. For better analysis and variety of implementation we implement both mirror specular lobes and half-vector lobes for comparison purposes. The general consensus is that BRDFs that use the half-vector lobe in its approximation are better than mirror lobe BRDFs [SCH,SCH93,NGA*05]. These definitions are solely used within the shaders for their particular lobe component.

For a BRDF and the set of all BRDFs to be considered physically plausible it must follow the law of energy conservation and must obey the Helmholtz reciprocity principle [HEL25]. Following the law of energy conservation the BRDF should evaluate to a real number in the range [0, 1]. As presented in [LAF*94] we see that if $Kd + Ks \leq 1$ we preserve this law, where Kd and Ks are diffuse and specular reflectivity respectively. This means we can not reflect more light then we have received at an incident point. This modification is taken into account when publishing our shaders and this is the reason writing shaders was considered a viable option as the rendering package we use does offer these shaders by default, however not the advanced control we required from them.

We programmed, using the CPU, three BRDF approximations which tap into the mental ray rendering pipeline with user modifiable values. The shaders are accessed from within Maya under the mental ray node section of the Rendering Hypergraph (a section whereby advanced rendering attributes may be assigned and/or modified) or by right clicking on a material and choosing the option to assign new material and selecting from a choice of blinn_brdf, cooktor_brdf and phong_brdf from the list. They are also programmed to implement environmental reflection (tracing rays for the materials surrounding environment). This is done via a scalar called "refl_coeff" to control the reflection coefficient of the material; real number in the range [0, 1]. The shaders default setting are set so they are renderable automatically for the material gold [MCB*97].

However this is not the only material these shaders can describe. The ability to define completely different properties of artefacts was implemented for future use; simply by altering settings. This is indicated by the implementation of a refraction routine should it ever become necessary for future work and analysis as shown in figure 5. Figure 5 also and more importantly shows the shader interface for the Blinn BRDF when plugged into Maya:

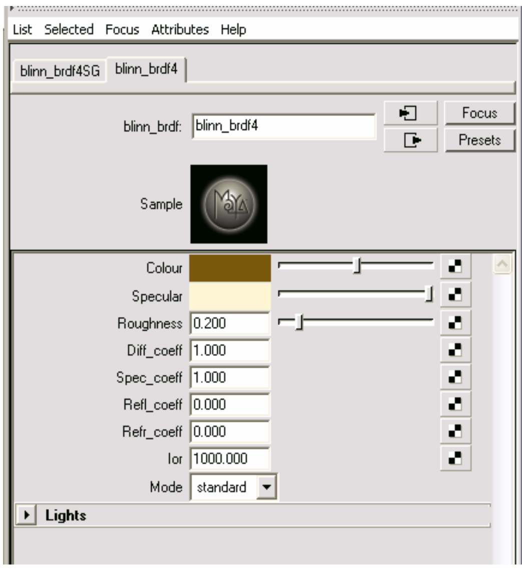

Figure 5 – *Blinn Shader Interface for Autodesk Maya*

The BRDF shaders fit data suggested by McReynolds and Blythe [MCB*97]. The reflection data is included in table 2:

Material	Ambient $\rho_{ar},\rho_{ag},\rho_{ab}$	Diffuse $\rho_{dr},\rho_{dg},\rho_{db}$	Specular $\rho_{sr},\rho_{sg},\rho_{sb}$	Exponent f
Gold	0.24725 0.1995 0.0745	0.75164 0.60648 0.22648	0.628281 0.555802 0.366065	51.2

Table 2 – *Suggested Reflection Coefficients [MCB*97]*

We omit the use of the ambient reflection in our shaders due to the nature of our testing. We do not want to account for ambient light in the scene as experimental control ensured there was none by using a dark room for the real image of the Cornell box. Luckily this is a constant that can be easily removed from summation of light that reaches the eye from a point P; another reason coding shaders proved viable:

I = ambient + diffuse + specular

$$I = I_a\rho_a + I_d\rho_d \times \text{lambert} + I_{sp}\rho_s \times \{\text{Phong}^f, \text{Cook-tor}, \text{Blinn}\} \quad [1.1]$$

3.3 Shader Viability

The shader viability resides on the comparison tests performed on the fabricated Cornell Box. If the metric indicates the match of the synthetic image with the real scene is accurate then we can safely assume that the shader is a perceptually accurate representation of the material properties. For rendering images it is necessary to define different properties for the renderer to understand what type of render is required, whether it be draft quality or production quality. Quick summation of rendering settings modified from their default settings:

Mental ray: Area Light 1unit^2– Photon emitter, Global illumination photons – 100000
Global Illumination Accuracy – 500, photon accuracy – 5, Final Gather Rays – 500.

Radiance: -ab 8 –ad 4096 –as2048.

Maxwell: Time Constraint – 20mins, Global Attenuation – 30, Film Iso – 100, Shutter Speed (1/n) – 250.

Maya Software: None

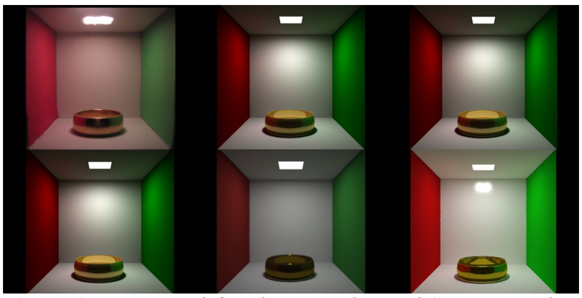

Figure 6 – *From top-left to bottom-right: Real Scene, Mentalray Blinn approximation, Mentalray Cook-Torrance approximation, Mentalray Phong approximation, Maxwell and Radiance Render*

3.3.1 Mean Squared Error Comparison

Performing MSE testing was done to derive a quantitative evaluation of our images. Qualitative metrics are only good to a certain extent as the judgement is often dynamic relying on perception. This is problematic as everyone's eyes are different and therefore we all perceive things slightly differently. The MSE comparison was performed in MatLab. MatLab is a high-level environment for performing data analysis, numeric computations, algorithm development and data visualisation. The images were first loaded into MatLab for comparison. The image size chosen for comparison was 800x600 versions of each of the six scenes, 1 real and 5 synthetic. The output of this form of comparison is an overall accuracy value.; a scale of 0 to 100 for how different the images were (0 for identical images, 100 for disparate pairs). The data structure in MatLab can also be manipulated to give a difference detection map. The scale of which can be seen in figure 7.

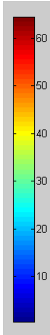

Figure 7 – *MSE Result Scale*

3.4 Light

Light in Egyptian times was completely different to modern lighting. We now attempt to create lighting which is flicker free. In the past different methods of illumination were used. In Egypt more notably lamps made with wicks and oils as fuel like sesame oil and organic olive oil. From [SUN*04] we are able to derive an RGB value for the spectral emission of this fuel type. By implementing this within our model, we can derive a high-fidelity model of perception dated 1323BC.

Due to the underground nature of the model, the sun will most probably play a reduced role in the perception of the environment. For the physically based renderers it is possible to create sun descriptions based on latitude and longitude of the site. This should be included to add to perception based on propagation of sunlight within the tomb, however negligible this may be.

4 Results

4.1 MSE – Results

Material/Renderer	Error
Blinn (Mentalray)	5.372
Cook-Torrance (Mentalray)	5.409
Phong (Mentalray)	5.251
Maya Software	8.736
Radiance	14.486
Maxwell	3.5898

Table 3 – *MSE vs Real Scene Error Prediction*

The large difference we can observe from table 3 is that the Radiance, a physically based render, performed worst in this case. The reason for this is that the process of edge alignment from camera views was not a perfectly accurate fit.

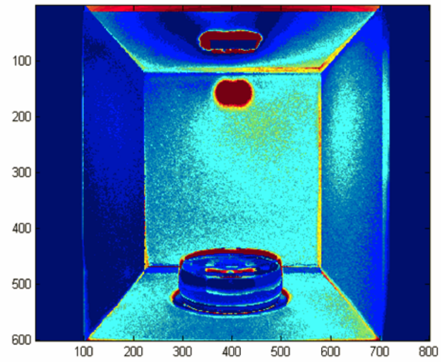

Figure 8 – *MSE Real Scene vs. Radiance Scene*

Also one can notice from figure 8 that the overall luminance emittance of the image is greater than we would expect if material properties and light sources had been assigned accurately and correctly for physical plausibility, a render time oversight when assigning materials within Radiance; compared with the real image it is clear to see the wall material was assigned as far too specular and hence supports the theory of excess luminance in the scene. This oversight unfortunately does not give entirely accurate results on which to base conclusions for Radiance.

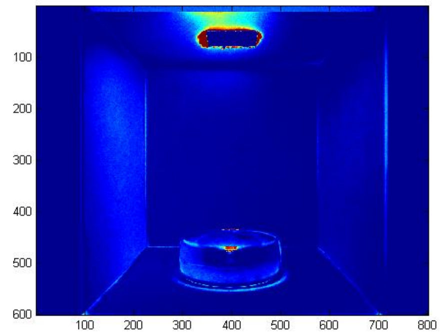

Figure 9 – *MSE Real Scene vs. Maxwell Scene*

The power of physically based lighting is evident in figure 9. These results are nearly perfect and just what you would expect from a render that is based entirely upon the representation of accurate light transport.

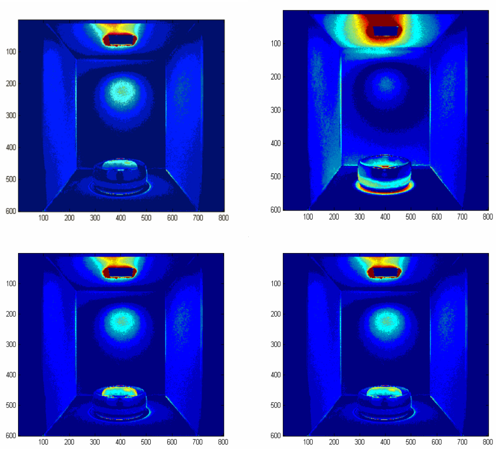

Figure 10 – *Other MSE Comparisons (Renderer Mentalray unless otherwise stated). From top left to bottom right: Real Scene vs. Phong, Real Scene vs Maya Software, Real Scene vs Cook-Torrance, Real Scene vs Blinn.*

4.2 MSE – Analysis of Results

It is interesting to see that the worst fit of all is the Radiance render. The clear explanation for that however is the edge-alignment problems encountered whenever 3D descriptions and view files change to a different package. A lot of the error on all the predictions is due to edge mis-alignment but this is specifically attributable to the Radiance file. It would be interesting to see however what psychophysical tests would prove in terms of qualitative accuracy of the scene.

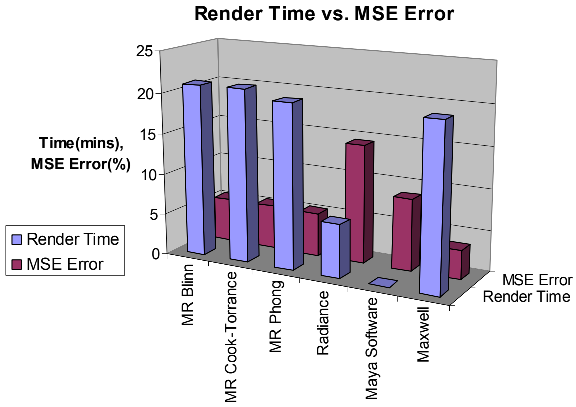

Figure 11 -*Comparison of Render Times vs. Visual Accuracy via MSE*

A lot of the error stems also from the light source as the lights entry point developed a halo when the light shined in. This could be due to edge fraying on the material or quality issues with the camera used to take the image.

4.3 Detection Maps

In order to satisfy the requirements of this project image comparison routines to create detection maps had to be created. These work along a similar vein to VDP which unfortunately we did not manage to implement within the project. These detection maps can be seen in figure 12:

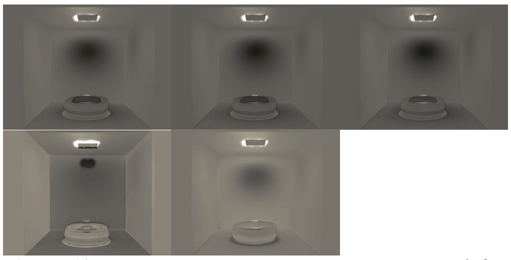

Figure 12 – *Detection map comparisons: From top left to bottom right, Real vs Blinn, Real vs Cook-Torrance, Real vs Phong, Real vs Radiance, Real vs Maya Software*

4.4 Concatenation

It is the coded shaders that are one of the closest matches to the real scene. These can now be used to visualise the tomb along with the Maxwell version.

Figure 13 – *Mentalray (Blinn), Burial Chamber with Approximate Lighting for 1323BC*

Figure 14 – *Mentalray (Blinn), Burial Chamber with Modern Lighting Applied*

Figure 15 – ***Maxwell,*** *Burial Chamber with Appropriate Lighting for 1323BC*

Figure 16 – *Maxwell, Burial Chamber with Modern Lighting Applied*

5 Conclusions & Future Work

The final image only displays certain artefacts. The reason for this is that the scope for the project was not big enough to encompass modelling in excess of 5000 artefacts. Some of which are possibly the hardest to model without access to an image library for bump / displacement mapping issues. The chosen scene would, however, have been significant prior to mummification as the three bottom coffin halves must have been laid to bear in the sarcophagus first and then all the paraphernalia have been brought to fruition around this. Hence it must have been out of the way for laying the coffins in situ. The simple scene is the product of an interesting project. The project can be rated as a success on the basis that the shaders were accurate and show that is possible to get, quantitavely at least, accurate synthetic images without using completely physically based techniques and renderers; however time saved is comparably none if any. However a fair amount of future work would be required to truly judge this endeavour a success.

In terms of future work there is always plenty of scope for improvements on projects such as this. The addition of even a single extra modelled artefact in the tomb would be an improvement for indirect lighting contribution. We see this project exploring the day lighting effects within the tomb. To validate whether or not the soot on the ceilings of the tomb is from painters in the tomb from 1323BC or whether it is possibly from Howard Carter's men. To visualise how far daylight would have propagated within the tomb would be an interesting project to undertake:

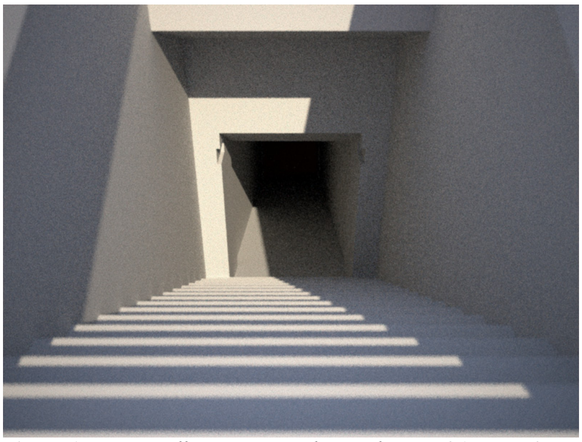

Figure 17 – *Maxwell, Entrance to the Tomb, June 8AM, Lat 25.44 N, Lon 32.36 E*

This could also be undertaken with mental ray and Maxwell as well as Radiance as a newer version of Autodesk Maya (8.5) has a mental ray plugin supporting day lighting capabilities similar to that of Radiance's gensky program and Maxwell's physically based sky creator. Maxwell also supports the possibility of HDR image based lighting (IBL). We could visit Thebes and take 24 hour time lapsed HDR images of the site and animate a day tour using this method.

Latitude	25.44 N
Longitude	32.36 E
Elevation	170.55 msl

Table 4 – *Site Location,Tut -Ankh-Amun's Tomb*

Another step the project could take is in the way of animation. Guided tours around the high-fidelity tomb. No one has seen it as it was when Howard Carter excavated it (apart from that group) and it should be able to be shared and visualised by everybody.

Extensive psychophysical tests will be required in order to deduce the perceptual difference between scenes which are quantitatively and scenes which are qualitatively accurate.

Comparatively speaking the project is lacking measurement with acquired BRDF data of gold using a gonioreflectometer, preferably but not necessarily, gold from an ancient Egyptian site. In addition to this, measuring scene irradiant stimuli with equipment such as a spectroradiometer should also be undertaken in the scope of future work for true accuracy.

Finally, the perception of the tomb under flame light is qualitatively different to the approximation of modern day lighting. Extensions could be implemented within the scope for the project to handle the accurate representation of flame and maybe in an animated context to fit in with other suggestions.

Acknowledgements

My step father used to be an avid archaeologist in his spare time. He is a distant relation to Howard Carter. From an impressionable age I heard tall tales. For him, I owe him my motivation towards this project.

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References

[ARA*06] ARANHA M., DEBATTISTA K., CHALMERS A., HILL S.: Perceived Rendering Thresholds for High-Fidelity Graphics on Small Screen Devices, In Eurographics UK, 2006.

[CAT*02] CATER K., CHALMERS A., LEDDA P.: Selective quality rendering by exploiting human inattentional blindness: looking but not seeing, Proceedings of the ACM symposium on Virtual reality software and technology, 2002, Hong Kong, China

[CHA06] CHALMERS A.: Advanced Computer Graphics Lecture Course (University of Bristol, 2006).

[CHD*05] CHALMERS A., DEBATTISTA K.: Investigating the Structural Validity of Virtual Reconstructions of Prehistoric Maltese Temples, In VAST, Eurographics, 2007.

[Dal06] DALTON C.: Character and Set Design Lecture Course (University of Bristol, 2006), dalton@cs.bris.ac.uk.

[DAL93] DALY S.: The visible differences predictor: an algorithm for the assessment of image fidelity. MIT Press, Cambridge,MA, USA, 1993, pp. 179–206.

[DEV*01] DEVLIN K., CHALMERS A.: Realistic Visualisation of the Pompeii Frescoes. In ACM AFRIGRAPH 2001 (Nov 2001), ACM SIGGRAPH.

[DZI] DZIKOWSKI F.: Theban Mapping Project, Image Gallery for KV62, Texture Files.

[FER03] FERWERDA J.: Three varieties of realism in computer graphics. Proceedings SPIE Human Vision and Electronic Imaging '03, 290-297.

[HEL25] HELMHOLTZ H.: Treatise on Physiological Optics, p231. Dover (New York), 1925.

[KSS*07] KUCHAR R., SCHAIRER T., Straber W.: Photorealistic Real-Time Visualization of Cultural Heritage: A Case Study of Friedrichsburg Castle in Germany, In Eurographics, 2007.

[LAF*94] LAFORTUNE E., WILLEMS Y.: Using the Modified Phong BRDF For Physically Based Rendering, Report CW197, 1994.

[MCB*97] MCREYNOLDS T., BLYTHE B.: Advanced Programming Techniques Using OpenGL, In SIGGRAPH Course Notes, 1997.

[MET]http://www.metmuseum.org/special/discovering_tutankhamun/images/tomb_plan_300.jpg

[NGA*05] NGAM F., DURAND F., MATUSIK W.: Experimental Analysis of BRDF Models, Massachusetts Institute of Technology, In EGSR 2005.

[RAD] http://radsite.lbl.gov/radiance/refer/Notes/rpict_options.html

[RUD*04]RUDOLFOVA I., SUNDSTEDT V.: High Fidelity Rendering of the Interior of an Egyptian Temple, In CESCG Proceedings 2004.

[SCH] SCHLICK C.: An Inexpensive BRDF model for Physically-Based Rendering. Computer Graphics Forum 13 (3), p233–246.

[SCH93] SCHLICK C.: A Survey of Shading and Reflectance Models for Computer Graphics. Technical Report 93/116. La BRI, University of Bordeaux (1993).

[SEE*04] SEETZEN H., HEIDRICH W., STUERZLINGER W., WARD LARSON G., WHITEHEAD L., TRENTACOSTE M., GHOSH A., VOROZCOVS A.: High Dynamic Range Display Systems, In ACM SIGGRAPH 2004.

[SUN*04] SUNDSTEDT V., CHALMERS A., MARTINEZ P.: High Fidelity Reconstruction of the Ancient Egyptian Temple of Kalabsha. In ACM AFRIGRAPH 2004 (Nov 2004), ACM SIGGRAPH.

[THE] http://www.thebanmappingproject.com.

[TRH*07] TODT S., REZK-SALAMA C., HORZ T., PRITZKAU A., KOLB A.: An Interactive Exploration of the Virtual Stronghold Dillenburg, In EUROGRAPHICS, 2007.

[WAR*98] WARD LARSON G. and SHAKESPEARE R.: Rendering with Radiance: The Art and Science of Lighting Visualisation (Morgan Kauffman, 1998).