Final Report

The Benefits of Using Physically Based Shading Models in Real-time Rendering

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Submitted in accordance with the requirements for the degree of
Computer Science (Digital & Technology Solutions) BSc

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COMP3932 Synoptic Project

The candidate confirms that the following have been submitted.

Items	Format	Recipient(s) and Date
Final Report	PDF file	Uploaded to Minerva (DD/MM/YY)
<Example> Scanned participant consent forms	PDF file / file archive	Uploaded to Minerva (DD/MM/YY)
<Example> Link to online code repository	URL	Sent to supervisor and assessor (DD/MM/YY)
<Example> User manuals	PDF file	Sent to client and supervisor (DD/MM/YY)

The candidate confirms that the work submitted is their own and the appropriate credit has been given where reference has been made to the work of others.

I understand that failure to attribute material which is obtained from another source may be considered as plagiarism.

(Signature of Student) _____

Summary

$<$Concise statement of the problem you intended to solve and main achievements (no more than one A4 page)$>$

Acknowledgements

<The page should contain any acknowledgements to those who have assisted with your work. Where you have worked as part of a team, you should, where appropriate, reference to any contribution made by other to the project.>

Note that it is not acceptable to solicit assistance on 'proof reading' which is defined as the "the systematic checking and identification of errors in spelling, punctuation, grammar and sentence construction, formatting and layout in the test"; see
https://www.leeds.ac.uk/secretariat/documents/proof_reading_policy.pdf

Contents

Chapter 1

Introduction and Background Research

1.1 Introduction

Rendering is the process of generating images, or *frames*, of a virtual world. Real-time rendering requires that the generation of these frames is done at a fast enough rate, so that the viewer feels they are taking part in an immersive, dynamic experience. Typically, this rate needs to be at least 30 FPS (Frames Per Second), with 60 FPS and beyond being desirable [*potentially http://web.cs.wpi.edu/ claypool/papers/fr-rez/paper.pdf*]. This imposes a maximum time budget of 33 to 16 milliseconds in which each frame must be generated, the *frame time*. Real-time rendering presents a compelling problem: how can the visual fidelity of a rendered scene be maximised, whilst adhering to this strict computational budget.

Rendering can be performed using one of two techniques, ray tracing or rasterization. Ray tracing is based on a model that is analogous to how humans perceive light and colour in the real-world. In the real-world, rays of light are produced from many sources, bounce from one object to the next, and eventually reach the viewers eyes. Ray tracing models this same process, but in reverse, with the rays emanating from the views eyes, and being traced back to their sources. Although ray tracing is the standard in the realm of movie production, its expensive computational requirements lead to frame times in the region of hours [citation] instead of milliseconds. Aside from so notable exceptions[1], this prohibits its use in real-time applications. As a result, real-time rendering employs another technique, rasterization.

With rasterization, each object in the world is composed of an arrangement of primitive shapes, most commonly, triangles, and their material is described through a number of parameters. When rendering, the objects are transformed and projected onto the 2D screen. Each triangle that lies on the screen is then split into granular pieces, called *fragments*. A colour is calculated for each fragment by evaluating the amount of light that shines on that fragment in the world, and then how that light interacts with the material of the object. Performing this calculation is called *shading*, and how it is done is defined by a *shading model*. After resolving which fragments lie on top of which others, the final image is presented to the user.

The appearance of the final rendered frames is largely determined by the choice of shading model. In the pursuit of photorealism, one such approach that has seen widespread adoption is the use of physically based shading models. Such models work by evaluating equations that simulate the real world physical interaction of light and objects. Using these models for shading is known as *Physically Based Shading* (PBS), and their use in the wider rendering pipeline is called *Physically Based Rendering* (PBR). PBR represented a seismic shift in the real-time rendering industry, with major game engines migrating to a PBR pipeline [2] [1].

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[1]With the introduction of hardware accelerated ray tracing on consumer GPUs [citation], the use of ray tracing to render specific visual phenomena, such as shadows and reflections, has seen use in modern games [citation].

Prior to PBR, the standard shading model used for photo-realistic real-time rendering was Blinn-Phong [citation]. Blinn-Phong bears little relation to how light interacts with objects in the real-world, rather it's based on empirical observations [citation].

The aim of this project is to investigate the benefits of using physically based shading models in real time rendering. Specifically, I will seek to highlight these benefits by comparing PBS to the technology is superseded, Blinn-Phong shading.

The advantages of using PBS over Blinn-Phong shading can be broadly categorised into two groups: the improvements to artist workflow; and the improved photorealism. Examples of the former are numerous. [someone] talks about the portability of lighting rigs, [someone] talks about the reuse of assets... etc [references]. However, due to practical issues that arise from investigating such advantages (I don't have access to a team of artists), the focus of this project will solely be on exploring those advantages in the latter category – how does PBS render frames that are more photorealistic than Blinn-Phong?

Answering this question by simply commenting on the general perceived realism of a frame when compared to another, is a largely subjective exercise. Instead, in a concerted effort to be as objective as possible, I will examine the benefits of PBS by identifying physical phenomena that it models in its rendered frames, but that are [conspicuously] absent when using Blinn-Phong shading.

1.2   Literature review

<This section heading is purely a suggestion – you should subdivide this chapter in whatever manner you think makes most sense for your project. It may also make sense to spread the 'Background Research' over more than one chapter, in which case they should be named sensibly.>

Chapter 2

Methods

<Everything that comes under the 'Methods' criterion in the mark scheme should be described in one, or possibly more than one, chapter(s).>

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Chapter 3

Results

<Results, evaluation (including user evaluation) *etc.* should be described in one or more chapters. See the 'Results and Discussion' criterion in the mark scheme for the sorts of material that may be included here.>

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Chapter 4

Discussion

<Everything that comes under the 'Results and Discussion' criterion in the mark scheme that has not been addressed in an earlier chapter should be included in this final chapter. The following section headings are suggestions only.>

4.1   Conclusions

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4.2   Ideas for future work

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References

[1] B. Karis. Real shading in unreal engine 4. In *SIGGRAPH 2013 Course: Physically Based Shading in Theory and Practice*, Anaheim, California.

[2] S. Lagarde and C. Rousiers. Moving frostbite to physically based rendering 3.0. In *SIGGRAPH 2014 Course: Physically Based Shading in Theory and Practice*, Vancouver.

Appendix A

Self-appraisal

<This appendix should contain everything covered by the 'self-appraisal' criterion in the mark scheme. Although there is no length limit for this section, 2—4 pages will normally be sufficient. The format of this section is not prescribed, but you may like to organise your discussion into the following sections and subsections.>

A.1 Critical self-evaluation

A.2 Personal reflection and lessons learned

A.3 Legal, social, ethical and professional issues

<Refer to each of these issues in turn. If one or more is not relevant to your project, you should still explain *why* you think it was not relevant.>

A.3.1 Legal issues

A.3.2 Social issues

A.3.3 Ethical issues

A.3.4 Professional issues

Appendix B

External Material

<This appendix should provide a brief record of materials used in the solution that are not the student's own work. Such materials might be pieces of codes made available from a research group/company or from the internet, datasets prepared by external users or any preliminary materials/drafts/notes provided by a supervisor. It should be clear what was used as ready-made components and what was developed as part of the project. This appendix should be included even if no external materials were used, in which case a statement to that effect is all that is required.>