Feasibility Study of Real Time Path Tracing

Or: How Much Noise Is Too Much?

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Abstract

This study aims to investigate the viability of a physically-based technique called **path tracing** in lieu of or in corporation with classical techniques in interactive media such as video games and visual effects tools.

Real time path tracing has been prohibitively expensive in regards to computational complexity. However, modern GPUs and even CPUs have finally gotten fast enough for real time path tracing to become a viable alternative to traditional real time approaches to rendering. Based on that assumption, this thesis presents the idea, algorithm and complexity behind path tracing in the first part and extrapolates feasibility and suitability of real time path tracing on consumer hardware according to the current state of technology and trends in the second part.

As part of the research, the author has implemented a path tracing 3D engine in modern C++ in order to empirically test the assumptions made in this thesis. The study found path tracing to be a viable rendering technique for average commodity hardware in approximately 4 years.

Acknowledgments

I would like to express my sincere gratitude to the teachers throughout school and university for the knowledge they've passed on.

I thank my friends for the laughs, horrible mistakes and awesome successes we shared with one another.

Furthermore, none of this would have been possible without the incredible efforts and love of my parents who have supported me throughout the years and enabled me to live a carefree life until I was ready to fend for myself.

Lastly, but certainly not least, I would like to declare my gratefulness to Alisa, whose endless love has given my life a new meaning.

We all make choices in life, but in the end, our choices make us.

<div align="right">

Andrew Ryan

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1 Introduction

As part of the quest for ever-improving game graphics, researchers, graphics hardware developers and video game developers alike have been coming up with more and more convoluted and technically challenging ways of improving the graphics in interactive media such as games and visualizations in order to give users a deeper sense of immersion or to provide special effects artists with faster feedback.

While rendering techniques are currently shifting from the traditional fixed pipeline approach towards the new, fully programmable approach that lets developers implement deferred renderers that can more closely mimic reality by using multiple combined shading and lighting algorithms and rendering the scene multiple times for different buffers, the fundamental concept of rasterization-based rendering has largely remained the same.

The real world photon-collecting approach that actual cameras use has so far not been adopted for interactive media by the industry in any capacity because the computational cost has historically been prohibitively expensive. It is, however, used extensively (and has been in use since decades) for offline, non-interactive rendering of computer-generated movies and visualizations of scientific simulations.

This study assumes that the next logical step for the industry will be to adopt this method for real time media as well. For the purpose of this thesis, a renderer is considered *real time* when it manages to render a frame within $16.67ms$ since that equals 60 frames per second which is the current de-facto standard refresh rate for most available computer screens. Conversely, a renderer is called *offline* when it is not designed for interactive rendering which usually means that it will renderer an image or a batch of images over the course of a few days. The differences of real time and offline path tracing renderers will be explained in the next chapter.

1.1 Motivation

Real time path tracing (and physically based rendering in general) offers many benefits over traditional real time rendering methods such as better visuals and simpler implementation but also allows for completely new types of graphics such as realistic caustics [1] and even light dispersion [2] (using a prism, for instance) since path tracers might simulate wavelenghts instead of plain RGB colors. Modern video games tend to rely on

a growing number of tricks to keep them visually appealing as the consumer grows more demanding. They're called *tricks* in this study because they merely trick the beholder into seeing something that appears to be physically accurate when it is, in fact, not the result of a physically-based calculation and as such this study aims to keep tricks and emergent phenomena separated by language. Some notable tricks include screen-space ambient occlusion (SSAO) [3], motion blur [4], lens flare [5], chromatic aberration [6], depth of field [7] and light mapping [8].

2 Real Time Path Tracing Explained

This chapter will explain the concepts, mathematics and algorithms behind path tracing, how real time path tracing differs from offline path tracing and what the difference in speed means for quality. It will also explain how path tracing differs from rasterization and other global illumination techniques.

2.1 Theoretical Basis

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2.2 Path Tracing in Comparison to Other Techniques

2.2.1 Comparison to Rasterization

2.2.2 Comparison to Other Algorithms

2.3 History of Path Tracing

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2.4 Current State of Technology

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3 Research

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3.1 Results

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3.2 Evaluation

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4 Conclusion

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4.1 Outlook

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Bibliography

[1] Wikipedia. Caustic (optics) — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[2] Wikipedia. Dispersion (optics) — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[3] Wikipedia. Screen space ambient occlusion — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[4] Wikipedia. Motion blur — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[5] Wikipedia. Lens flare — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[6] Wikipedia. Chromatic aberration — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[7] Wikipedia. Depth of field — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].

[8] Wikipedia. Lightmap — wikipedia, the free encyclopedia, 2015. [Online; accessed 16-September-2015].