Physically Based Rendering

The art of the science of Light

$$L_o(p, \omega_0) = L_e(p, \omega_0) + \int_{S^2} f(p, \omega_0, \omega_i) L_i(p, \omega_i) |cos\theta_i| d\omega_i$$

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A thesis presented for an Extented Project Qualification

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2024-03-10

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1 Introduction

Since the inception of computing technology, there has been an concerted effort to replicate observable phenomena from the natural world as a means of solving problems that once couldn't be solved without computers.
For example, Craig Reynolds in his seminal paper [2] is an excellent case study, of such an example. Reynolds defined three very simple rules pertaining to the behaviours of birds in a flock. These rules are:

- Alignment: the birds will steer towards the average heading of their peers.
- Cohesion: the birds will steer towards the center of the mass of its peers.
- Separation the birds will steer away from colliding with their peers.

These simple laws, though primitive, produce a "realistic" approximation of how birds behave in actuality, so much so, that the US Army uses this algorithm, for their UAV-UGV programs [3].

In essence, computer simulation provides a "good enough" approximation for the theories encompassing the real world, crafted by mathematicians and physicists alike.

1.1 Motivation

Rendering is the process of producing an image from a description of a 3D scene. This daunting task can be easily understood by asking: Given a set configuration of a room, what would a camera see, in a set location within the room. If left pondering, one can easily come to a reasonable algorithm, befit the style of rendering they want. For example, a very simple approach could be to check if a light ray enters the camera from light sources (if any) within the room. If so, then the camera could record a colour based on some product of the colours the light ray hit before it entered the camera.
However, I intend to implement the "Physically Based" rendering algorithm. As the name suggests, this algorithm tries to stay true to the physics of the world, imitating its behaviour as matter and light mesh together. It differentiates different materials dependent on their reaction with light incident upon them, as well as how light itself reacts through mediums not necessarily vacuums, like fog.

I intend to implement this algorithm not only because it is a excellent opportunity to mix the three subjects I do for A-Level together (Physics, Maths, Computing), but also as an challenging extension in the field, in which I will be considering a future in.

1.2 The Ray-tracing Algorithm

TODO

1.3 History and Current State of the Field

Unsurprisingly, Physically Based Rendering (PBR), is a relativly nascent field (only being studied since the 70s), and as the field has advanced to cleverer solution to increasingly difficult problems. For example, in the 70s, the biggest problem to solve was the lack of memory available to computers (1 MB at its rare), where physical accuracy was not biggest focus, but to speed up how long an image took to render [1]. As computers became less expensive and more powerful, more demanding scenes could be rendered.

The best example of this is the rise of Computer Generated Imagery (CGI) within the film industry, where some of the biggest blockbuster releases, leveraged the power of computers to render backgrounds and add complex elements to a scene, or augment a character's physical appearance (e.g. Terminator 2).

However, as Jim Blinn states: "as technology advances, rendering time remains constant". This observes that as technology advances, people's demand for "better" and "more realistic" images increases, rather than being content with current standards, and rendering those scenes faster [1].

1.3.1 Research

References

[1] Matt Pharr, Wenzel Jakob, and Greg Humphreys. *Physically Based Rendering: From Theory to Implementation (3rd Ed.)* 3rd. San Francisco, CA, USA: Morgan Kaufmann Publishers Inc., Nov. 2016. 1266 pp. ISBN: 978-0-12-800645-0.

[2] Craig W. Reynolds. "Flocks, Herds and Schools: A Distributed Behavioral Model". In: *Proceedings of the 14th Annual Conference on Computer Graphics and Interactive Techniques*. SIGGRAPH '87. New York, NY, USA: Association for Computing Machinery, Aug. 1, 1987, pp. 25–34. ISBN: 978-0-89791-227-3. DOI: 10.1145/37401.37406. URL: https://dl.acm.org/doi/10.1145/37401.37406 (visited on 03/11/2024).

[3] Martin Saska et al. "Coordination and Navigation of Heterogeneous MAV–UGV Formations Localized by a 'Hawk-Eye'-like Approach under a Model Predictive Control Scheme". In: *The International Journal of Robotics Research* 33.10 (Sept. 1, 2014), pp. 1393–1412. ISSN: 0278-3649. DOI: 10.1177/0278364914530482. URL: https://doi.org/10.1177/0278364914530482 (visited on 03/13/2024).