A Novel Query Reordering Algorithm to Reduce Photon Mapping Bandwidth

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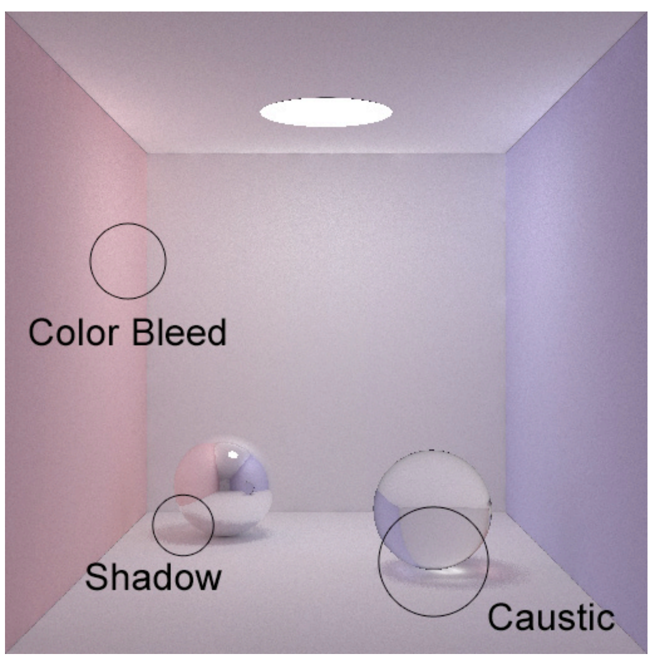

Figure 1: Three light effects that can be produced by global illumination. These effects are currently too expensive to render in interactive applications, a problem this research addresses [3].

INTRODUCTION

The purpose of this project is to improve the efficiency of an existing algorithm for light simulation. Algorithms like the one I will be exploring are currently used in 3D computer graphics in the fields of education, film, and computer games. High realism algorithms for light simulation require significant computer memory and processing. Because of this, there is a large discrepancy between the visual quality of movies versus video games. For example, each frame in Pixar's "Cars" took approximately 20 hours to generate [5]. This is because they use global illumination algorithms. Global illumination can accurately simulate complex scenes with many objects as well as physical properties of light such as shadows, color bleeding, and caustics (as seen on the cover page image). Caustics occur when light travels through a semi-transparent object and is bent to create concentrated areas. Global illumination accounts for light which bounces off or travels through several objects before striking the camera. This is in contrast to local illumination, used in current-generation interactive applications. Local illumination assumes that light is emitted from a source (light bulb, the sun, etc.), bounces off one object, and strikes the camera. While this has been a cheap and successful approach, it is unable to simulate caustics, shadows, refraction, or other important qualities of light which then must be custom-drawn into a scene by artists. While global illumination can simulate all of the above phenomena, current algorithms are too slow for use in interactive applications and are used primarily in film.

An algorithm that precisely simulates light would require the recursive application of eight–dimensional integrals [1]. Consequently, practical approaches to global illumination have been developed. A popular approach, called ray tracing, quantifies light into a discrete set of rays, emanating from a light source along various vectors. This is still extremely computationally intensive, however, because many rays must be used to get an accurate picture. When rays hit certain surfaces, the light may bounce off in a number of directions. Thus, many more rays must be simulated, and each of these rays may spawn many more.

Photon mapping is one way of making ray tracing more efficient. This method sends discrete packets of light energy (named photons) from the light sources out into the scene. Every intersection they make with a surface is recorded along with other information in a data structure, called the photon map. This data structure is then consulted during the rendering process and is used to approximate the light striking any given point being rendered. This is extremely beneficial because it allows the recursive spawning of new rays after each surface intersection to be stopped after the second ray. It is the photon mapping algorithm which I will be working to make even more efficient.

PROJECT DETAILS

In his research, Professor Steinhurst has devised the concept of query reordering. This method improves upon standard photon mapping by reordering memory accesses, a slow operation which is a limiting factor in the speed of photon mapping. Professor Steinhurst is in an excellent position to assist with my research since he has already explored three reordering algorithms [3, 4]. I will be testing the novel hypothesis, originally suggested by Dr Prins of UNC-Chapel Hill, that the using information computed but currently discarded during ray tracing to reorder memory queries will increase the efficiency of query reordering even further.

I will be in a position to be extremely productive this summer. I am currently taking CSCI367 for a balanced introduction to computer graphics as well as an independent study on this research topic. Therefore, I will have already learned the background material, familiarized myself with the existing source code, and written the first half of a conference paper explaining the algorithm and its difficulties to implement in detail. I will be able to begin my summer with the implementation of the algorithm, proceeding directly to experimentation.

This research is an exciting opportunity to explore a topic of great interest of mine in detail. Spending the summer learning will give me a valuable first hand look at the research experience. I will be able to live around other student researchers and professors while enjoy a community more focused on acquiring knowledge than the average student body. This research will prepare me for the environment of graduate school, which is something I ardently plan on pursuing, as well as give me a great advantage when applying.

It will be our goal to conclude the summer with a conference style paper detailing my research methods and results, as well as a poster made during fall semester. This is feasible because the first half of the paper would already have been written in the spring. In addition to teaching me research procedures and preparing me for graduate school, this research could result in the discovery of a more efficient way to render 3D computer graphics scenes.

RESEARCH ENVIRONMENT

This research will take place at Bucknell University during the summer of 2008. Although I will be in Europe for the first three weeks of the summer for ENGR 290, I will be returning to school after a week with my parents and will be present for the next eight weeks. At the beginning, myself and Professor Steinhurst will meet on a daily basis, and this schedule would taper to no less than two formal meetings a week. Professor Steinhurst will be available on campus during much of the summer, as he will be conducting research of his own at Bucknell and only leaving town for short trips. In addition to being available in his office, he will be available via email and instant messaging. I will be utilizing the Linux cluster purchased by Professor Perrone, as well as other computing facilities belonging to the College of Engineering. Since most of the investigative work will have been completed in the spring, my time will primarily be spent programming the algorithm and running experiments on the code. I will be programming on top of the existing "pbrt" code base [2], as modified by Professor Steinhurst.

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