# Introduction

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## 1 Introduction

The goal of Image Synthesis is, broadly, to generate realistic images. Recently, we have seen this subject reaching a higher profile, being used in movies, as well as video games, and other interactive entertainment. It has many other applications in society today as well, including industrial design, virtual reality and scientific simulation. To do all of these things, a lot of different elements need to be incorporated. In general, Image Synthesis is very inter-disciplinary. We will talk a lot about art and human perception, human biology, physics and light transport, and of course math and computer science.

## 2 Why is Realistic Image Synthesis Hard?

Simulating everything a human can perceive is an incredibly complex task. As has been said before, the world itself is incredibly complex. Light bounces off surfaces, penetrates others, and ends up with entirely different properties than from when the photon was first generated. There are all sorts of things in the real world you need to be able to model and simulate to get this right, such as shape, material, motion, light, and appearance. Appearance is in fact what we will care about most in this class, we want to create images that would look just like they would in real life.

## 3 A Brief History

In the 1960's and 1970's these problems were mostly seen as geometric problems with a very simplified lighting model. After this, hidden line and surface algorithms became very prolific, but were generally all hacks. Shading was really simple using typical Gouraud shading. These algorithms weren't physically based, but were designed to give you an image that looked plausible.

Beginning in the 1980's, people decided that the geomteric problem was solved for the most part and began looking at optical problems. Reflection was one thing that people started formalizing. Turner Whitted is noted for producing one of the first papers decsribing a physically based illumination model. After this, radiosity was discovered

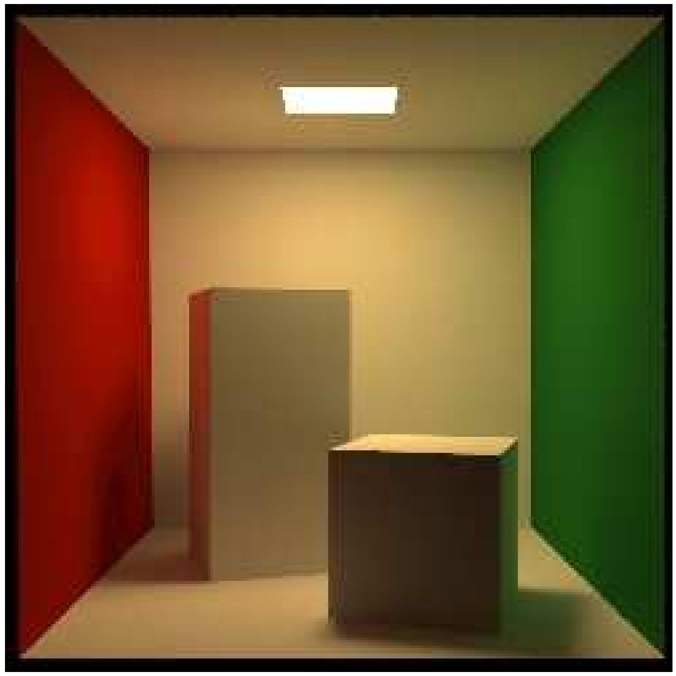

Figure 1: The Cornell Box.

as an approximation to complex intgrals in an attempt to solve the problem of global illumination. This course of study culminated with Jim Kajiya when he published a paper on the rendering equation, which completely captures the nature of light transport in computer graphics. In essence, the whole course is about solving this equation.

# 4 Lighting

The problem that the rendering equation encapsulates is finding the illumination at the surface of each object in a three-dimensional world. However, lighting in general can be very complicated, as can materials and shapes. In the real world, we have incredibly complex lighting that is difficult to model on a computer.

The cornell box (see figure 1) is a classic experiment that was set up to find the best way to simulate lighting in computer graphics. By carefully calibrating the box setup and the camera, they were able to model the same scene on a computer. What this leads to is essentially a turing test for graphics, or an attempt to distinguish two images from each other.

Radiosity was being addressed as early as the 1940's by Parry Moon and Domina Spencer using a calculator. To date, it has been used to create realistic looking images, although only capable of modelling diffuse, polygonal surfaces. Early attempts tried to extend the radiosity model to include glossy surfaces as well. Eventually, people realized that the model couldn't be generalized, and as a result radiosity has all but been abandoned.

One of the main problems with radiosity is that it can't model caustics. It can do indirect illumination, but curved reflectors aren't possible. Henrik Wann Jensen has come up with one method to attempt to solve the problem of global illumination, which also takes caustics into account. Methods like these will be looked at later in the semester.

# 5 Materials

While the lighting problem hasn't been solved, the focus of computer graphics is moving towards creating really complex materials. Older material models were parameterized, letting the user define the way a surface reacts to different kinds of light (diffuse, specular, ambient), and the surface's shininess. Taxonomies of materials take into account these things, but still aren't physically based. There are many attributes of elements that aren't addressed in these taxonomies, such as sub-surface scattering and the accumulation of texture such as rust or dirt. These are the types of characteristics that we are currently trying to model in image synthesis. We want to create materials that behave exactly as they would in nature.

Today, there is also a big push to model virtual actors, such as in the movie Final Fintasy. Final Fantasy was the first movie to attempt to create a realistic looking sythetic movie. As an indication of the difficulty, it can be noted that SquareUSA lost $100 million on the movie. Hair is another aspect of nature that people are currently attempting to model realistically. Other elements of nature pose their own unique problems to computer graphics. Outdoor scenes are particularly difficult to render. This is mainly because the sky is essentially a giant light source. Every point on the ground can simultaneously be lit by a large part of the sky. Furthermore, nature presents an amount of randomness that is particularly hard to model geometrically. Accurately simulating every single leaf and flower can be incredibly daunting.