

CS348B: Image Synthesis

Goal: How to generate realistic images?

Applications

- **Movies**
- **Interactive entertainment**
- **Industrial design**
- **Architecture**
- **Showcase products**
- **Cultural heritage**
- **Holy Grail: Virtual reality**



Final Fantasy

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Modeling & Simulating Appearance

Models

- **Light and color**
- **Light sources**
- **Shapes**
- **Materials**
 - **Interfaces: Reflection and texture models**
 - **Medium: Atmospheric scattering models**
- **Cameras**
 - **Lens and film**

Simulation

- **Illumination**

CS348B Lecture 1

Pat Hanrahan, Spring 2006

History: Geometric Aspects First

Transformation/clipping and the graphics pipeline

- Evans and Sutherland

Hidden line and surface algorithms

- Sutherland, Sproull, Shumacker

CS348B Lecture 1

Pat Hanrahan, Spring 2006

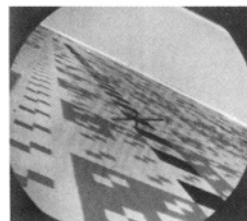
History: Simple Shading

Simple shading and texturing

- Gouraud \Rightarrow interpolating colors
- Phong \Rightarrow interpolating normals
- Blinn, Catmull, Williams \Rightarrow texturing



SGI flight 1987



GE Apollo Simulator 1963

CS348B Lecture 1

Pat Hanrahan, Spring 2006

History: Optical Aspects Second

Reflection and texture models

- **Cook and Torrance** ⇒ **BRDF**
- **Perlin** ⇒ **Procedural textures**
- **Cook, Perlin** ⇒ **Shading languages**

Illumination algorithms

- **Whitted** ⇒ **Ray tracing**
- **Cohen, Goral, Wallace, Greenberg, Torrance**
Nishita, Nakamae ⇒ **Radiosity**
- **Kajiya** ⇒ **Rendering equation**

Lighting

Lighting Simulation

The Rendering Equation

Given a scene consisting of geometric primitives with material properties and a set of light sources, compute the illumination at each point on each surface

Challenges

- Primitives complex: lights, materials, shapes
- Infinite number of light paths

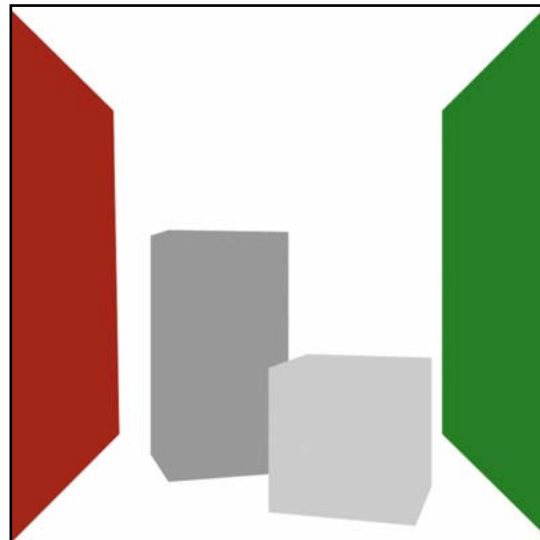
How to solve it?

- Radiosity \Rightarrow Finite element
- Ray tracing \Rightarrow Monte Carlo

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Lighting Example: Cornell Box

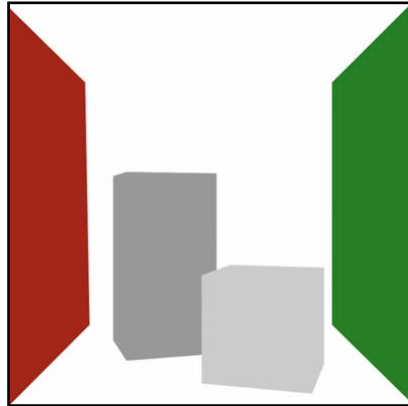


Surface Color

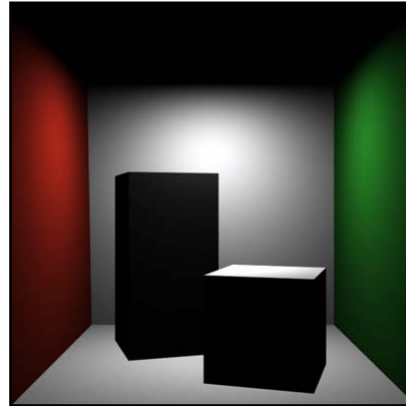
CS348B Lecture 1

Pat Hanrahan, Spring 2006

Lighting: Diffuse Reflection



Surface Color

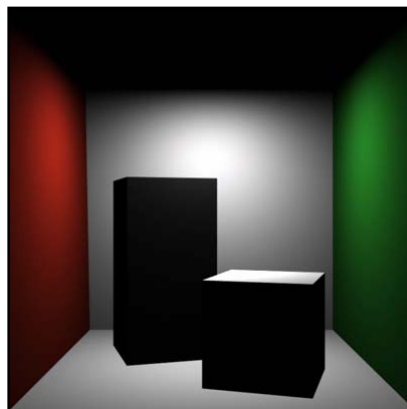


**Diffuse Shading
Point Light Source**

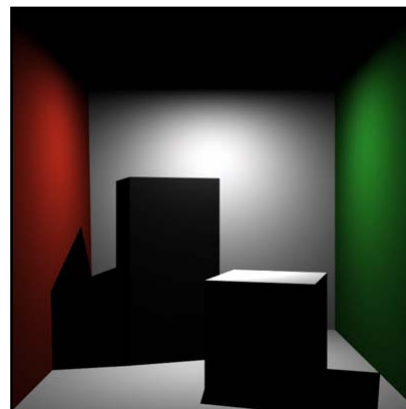
CS348B Lecture 1

Pat Hanrahan, Spring 2006

Lighting: Shadows



**No Shadows
Point Light Source**

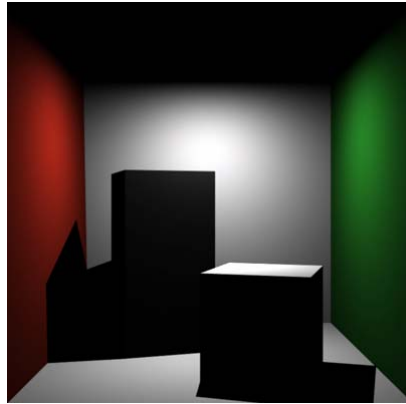


**Shadows
Point Light Source**

CS348B Lecture 1

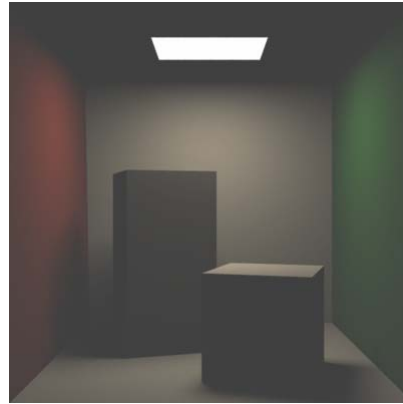
Pat Hanrahan, Spring 2006

Lighting: Soft Shadows



Hard Shadows
Point Light Source

CS348B Lecture 1



Soft Shadows
Area Light Source

Pat Hanrahan, Spring 2006

Lighting: Indirect Illumination

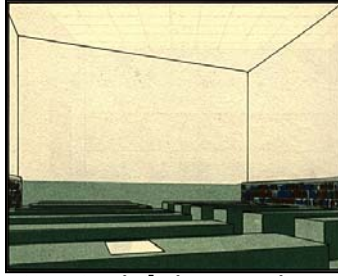
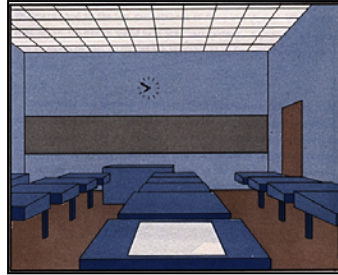
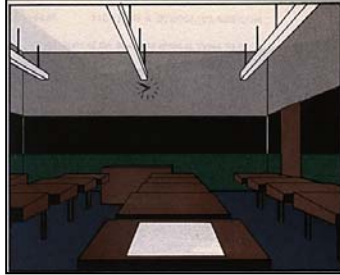


Program of Computer Graphics
Cornell University

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Early, Early Radiosity



Parry Moon and Domina Spencer (MIT), *Lighting Design*, 1948
CS348B Lecture 1 Pat Hanrahan, Spring 2006

Early Radiosity



CS348B Lecture 1

Pat Hanrahan, Spring 2006

Early Diffuse+Glossy

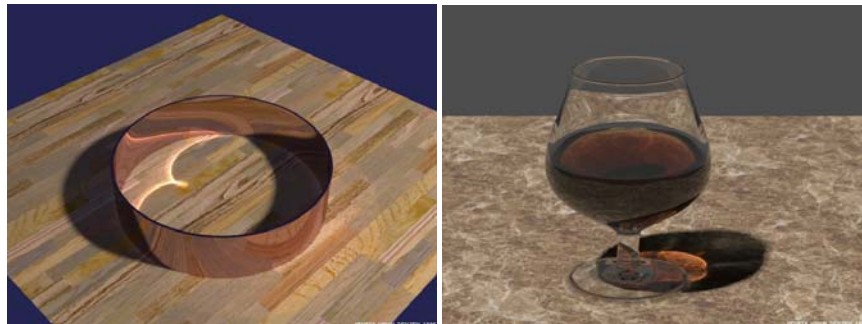


Tribute to Vermeer
Program of Computer Graphics, Cornell

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Caustics



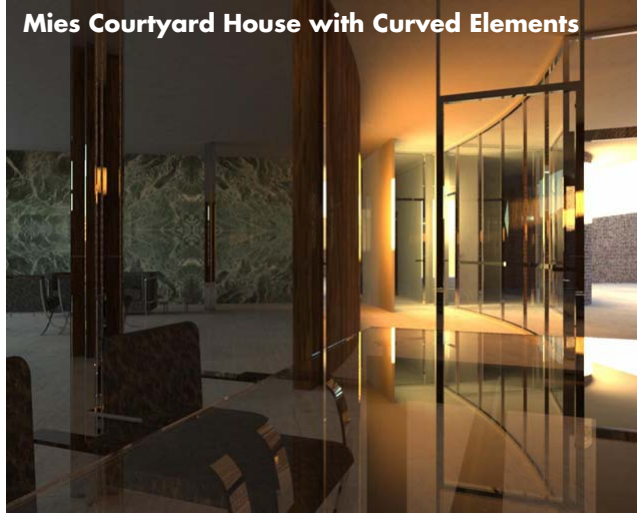
Jensen 1995

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Complex Indirect Illumination

Mies Courtyard House with Curved Elements



Modeling: Stephen Duck; Rendering: Henrik Wann Jensen

CS348B Lecture 1

Pat Hanrahan, Spring 2006

"Turing Test"



Measured



Simulated

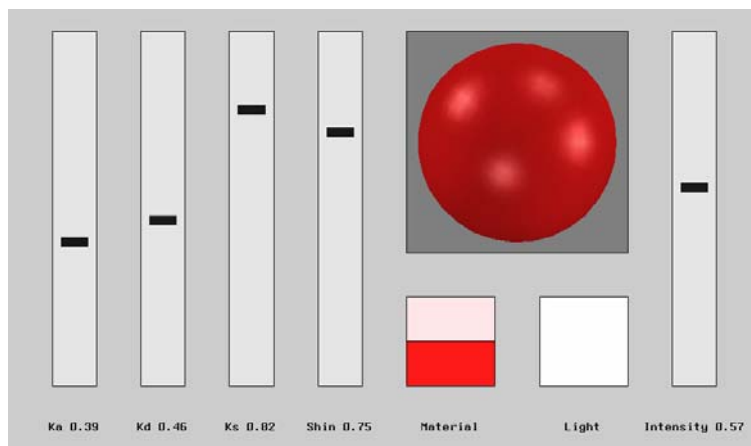
Program of Computer Graphics
Cornell University

CS348B Lecture 1

Pat Hanrahan, Spring 2006

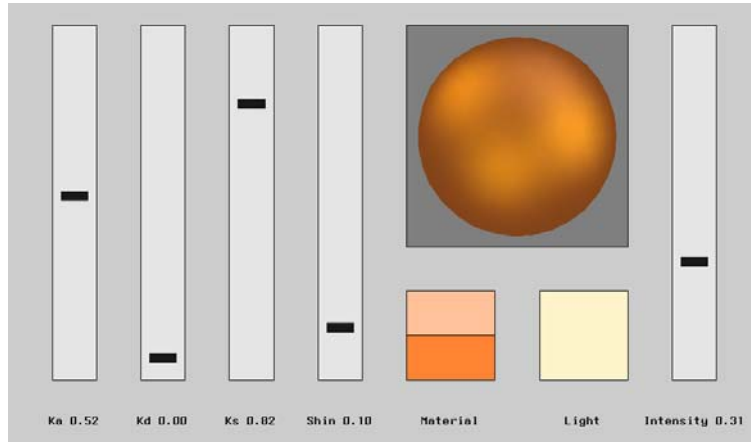
Materials

Classic Computer Graphics Model



Plastic

Classic Computer Graphics Model



Brushed Copper

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Material Taxonomy

RenderMan



Plastic
Shiny Plastic

Rough Metal
Shiny Metal

Matte

From Apodaca and Gritz, *Advanced RenderMan*

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Shadows on Rough Surfaces



CS348B Lecture 1

Pat Hanrahan, Spring 2006

Translucency



Surface Reflection

CS348B Lecture 1



Subsurface Reflection

Pat Hanrahan, Spring 2006

Water Flows on the Venus



CS348B Lecture 1



Pat Hanrahan, Spring 2006

Patinas



A Sense of Time

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Virtual Actors: Faces



**Final Fantasy
SquareUSA**

**Jensen,
Marschner,
Levoy,
Hanrahan**

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Virtual Actors: Hair



Black



Brown

CS348B Lecture 1

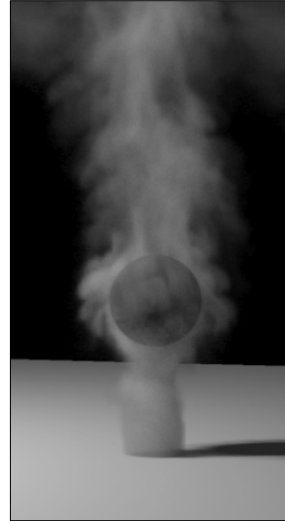
Pat Hanrahan, Spring 2006

Coupling Modeling & Rendering



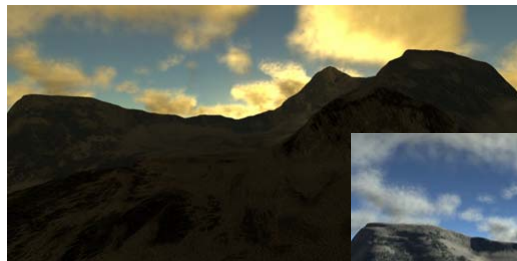
Fedkiw, Stam, Jensen 2001

CS348B Lecture 1



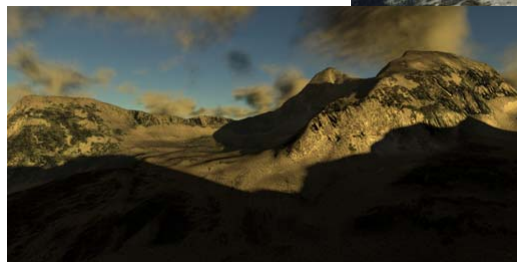
Pat Hanrahan, Spring 2006

Clouds and Atmospheric Phenomena



7am

**Hogum Mountain
Sunrise and sunset**



6:30pm

Modeling: 9am
Simon Premoze
William Thompson
Rendering:
Henrik Wann Jensen

CS348B Lecture 1

Pat Hanrahan, Spring 2006



CS348B Lecture 1

Pat Hanrahan, Spring 2006

The Everyday World ...



Troy Maxwell-Hanrahan

CS348B Lecture 1

Pat Hanrahan, Spring 2006

Interdisciplinary

Computer science

- **Computational geometry**
- **Software engineering**

Physics

- **Radiometry and light fields**
- **Bidirectional reflectance distribution function**
- **Radiative transport**

Mathematics

- **Integral equations**
- **Monte Carlo methods**

Perception

Art