CS348B: Image Synthesis

**Goal:** *How to generate realistic images?*

**Applications**
- Movies
- Interactive entertainment
- Industrial design
- Virtual reality

**Interdisciplinary**
- Art and perception
- Physics and mathematics
- Computer science

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Modeling and Simulating Appearance

**Models**
- Light and Color
  - Radiometry, Photometry, Colorimetry
- Light Sources
- Shapes
- Materials
  - Reflection and texture models
  - Atmospheric scattering models
- Camera
  - Lens and film effects

**Simulation**
- Illumination
Perception

Visual Cues
- Motion
- Shape
- Perspective and foreshortening; Stereopsis
- Occlusion
- Shading
- Shadows
- Aerial perspective: desaturation, blurring
- Transparency
- Textures
- Color

‘60-’70’s : Geometric Aspects

Transformation/clipping
- Evans and Sutherland display pipeline

Hidden line and surface algorithms
- Sutherland, Sproull, Shumacker sort taxonomy
- Object vs. Image space

Simple shading and texturing
- Gouraud: interpolating colors
- Phong: interpolating normals
- Blinn, Catmull, Williams ⇒ texturing
‘80–‘90’s: Optical Aspects

Reflection and texture models
- Cook and Torrance ⇒ \textit{BRDF}
- Cook, Perlin ⇒ \textit{Procedural textures}

Illumination algorithms
- Whitted ⇒ \textit{Ray tracing}
- Cohen, Goral, Wallace, Greenberg, Torrance
  Nishita, Nakamae ⇒ \textit{Radiosity}
- Kajiya ⇒ \textit{Rendering equation}

Ray Tracing

From Appel ‘68
Ray Tracing

Ray-Surface intersection algorithms
- Polygons and parametric surfaces
- Algebraic and implicit surfaces; quadrics
- Procedural models; CSG

Acceleration techniques: Efficient ray queries
- Find the closest intersection?
- Is there any intersection?

Mathematical Technique
- Reduce rendering to integration and sampling
- Monte Carlo ray tracing

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
- Exponential number of paths, dense coupling

How to solve it?
- Radiosity \(\rightarrow\) Finite element
- Ray tracing \(\rightarrow\) Monte Carlo
Lighting Example: Cornell Box

Surface Color

Lighting Example: Diffuse Reflection

Surface Color

Diffuse Shading
Lighting Example: Shadows

No Shadows

Shadows

Lighting Example: Soft Shadows

Hard Shadows: Point Light Source

Soft Shadows: Area Light Source
Radiosity

Joint work w/ S. Teller, T. Funkhouser, P. Schroeder, C. Fowler

Lighting Effects

Hard Shadows

Soft Shadows

Caustics

Indirect Illumination
Early Diffuse+Glossy

Tribute to Vermeer
Program of Computer Graphics, Cornell

Complex Indirect Illumination

Mies Courtyard House with Curved Elements

Modeling: Stephen Duck; Rendering: Henrik Wann Jensen
Caustics

Jensen 1995

Clouds and Atmospheric Phenomena

Hogum Mountain
Sunrise and sunset

7am

Modeling:
Simon Premoze
William Thompson

Rendering:
Henrik Wann Jensen

9am

6:30pm
Coupling Modeling & Rendering

Fedkiw, Stam, Jensen 2001

Outdoor Environment

CS348B Lecture 1
Pat Hanrahan, Spring 2001
Material Taxonomy

RenderMan

Plastic
Shiny Plastic
Rough Metal
Shiny Metal
Matte

From Apodaca and Gritz, Advanced RenderMan

Faces

Final Fantasy
SquareUSA

Jensen,
Marschner,
Levoy,
Hanrahan

CS348B Lecture 1
Pat Hanrahan, Spring 2001
Material Models

Appearance reflects the material **structure**
For example: skin

Physical processes
- Surface scattering
- Subsurface scattering

Joint work w/ W. Krueger

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Marble

Surface Reflection  Subsurface Reflection
Water Flows on the Venus

Shadows on Rough Surfaces
Creating Appearance

// bowling pin, based on RenderMan example
(CIRCLE over (BRUNS over BASE)) * MARKS * Cd + Cs