

## CS348B: Image Synthesis

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*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

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### 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

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## Perception

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### Visual Cues

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

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## '60-'70's : Geometric Aspects

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### 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  $\Rightarrow$  texturing

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## '80-'90's : Optical Aspects

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### Reflection and texture models

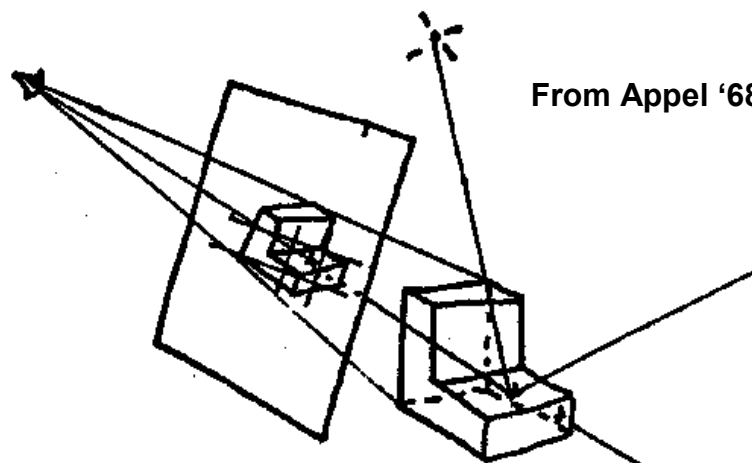
- Cook and Torrance  $\Rightarrow$  *BRDF*
- Cook, Perlin  $\Rightarrow$  *Procedural textures*

### Illumination algorithms

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

## Ray Tracing

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## Ray Tracing

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### 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

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## Lighting Simulation

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### 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?

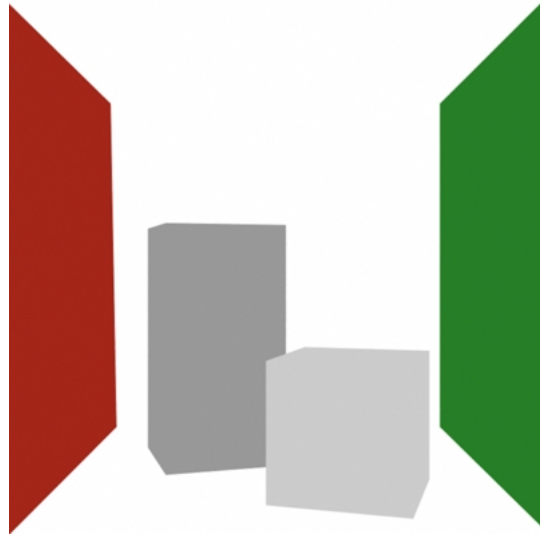
- Radiosity  $\Rightarrow$  Finite element
- Ray tracing  $\Rightarrow$  Monte Carlo

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## Lighting Example: Cornell Box

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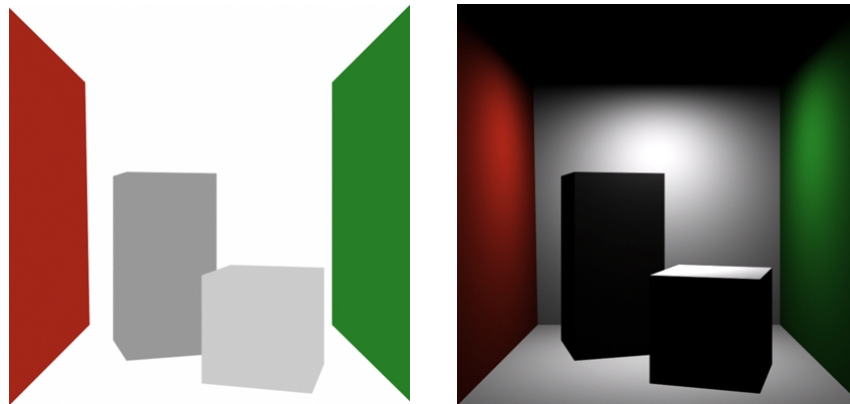
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Surface Color

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## Lighting Example: Diffuse Reflection

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Surface Color

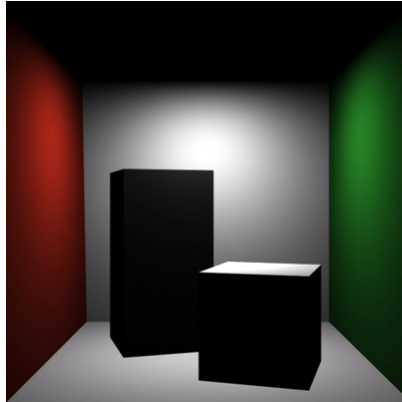
Diffuse Shading

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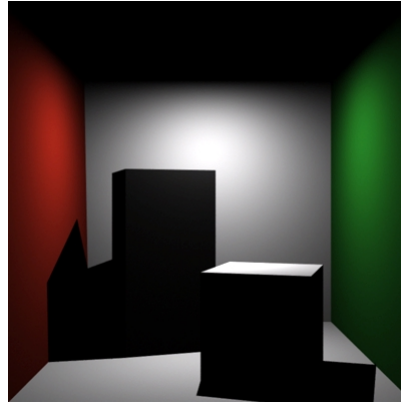
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## Lighting Example: Shadows

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No Shadows



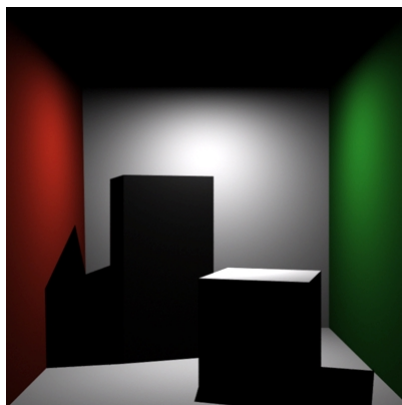
Shadows

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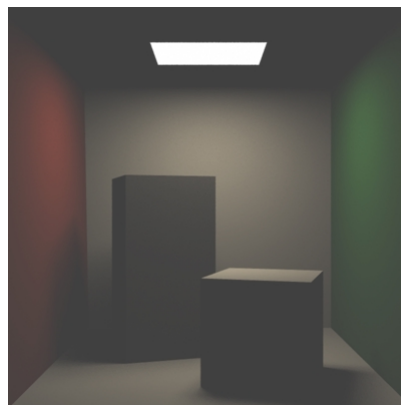
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## Lighting Example: Soft Shadows

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Hard Shadows: Point Light Source



Soft Shadows: Area Light Source

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## Radiosity: Cornell Experiment

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Measured



Simulated

Program of Computer Graphics, Cornell

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## Early Radiosity

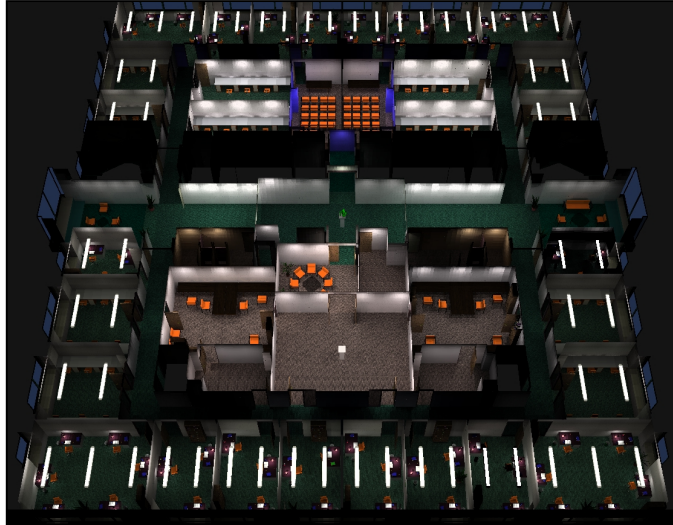
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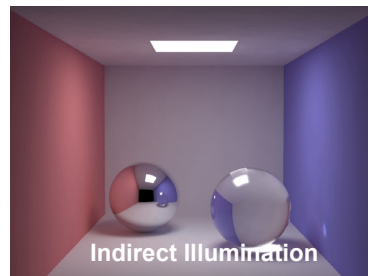
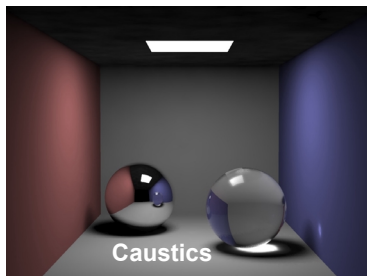
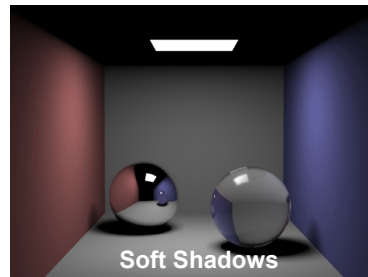
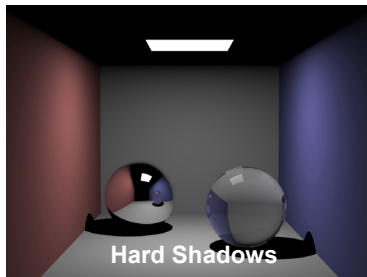
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# Radiosity



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



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## Early Diffuse+Glossy

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Tribute to Vermeer  
Program of Computer Graphics, Cornell

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## Complex Indirect Illumination

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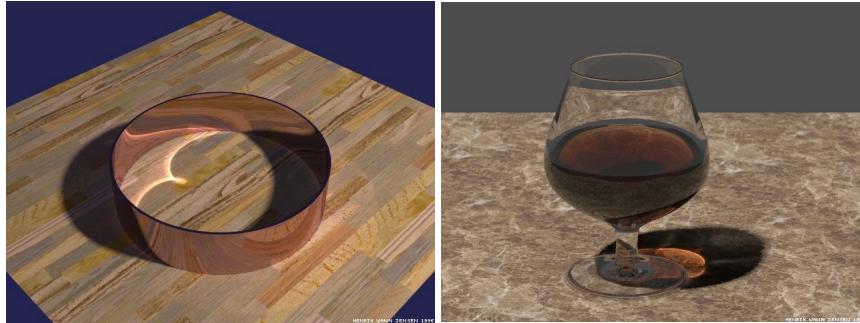
Modeling: Stephen Duck; Rendering: Henrik Wann Jensen

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## Caustics

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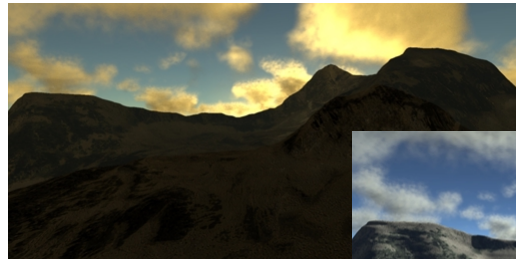
**Jensen 1995**

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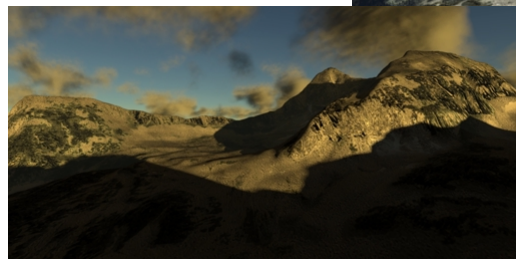
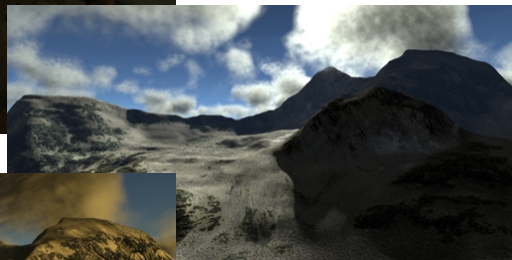
## Clouds and Atmospheric Phenomena

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**Hogum Mountain  
Sunrise and sunset**

**7am**



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

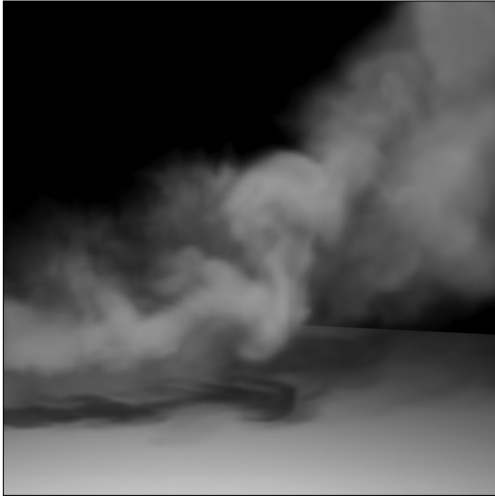
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**6:30pm**

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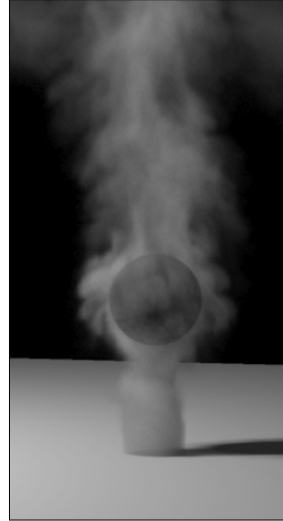
## Coupling Modeling & Rendering

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Fedkiw, Stam, Jensen 2001

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## Outdoor Environment

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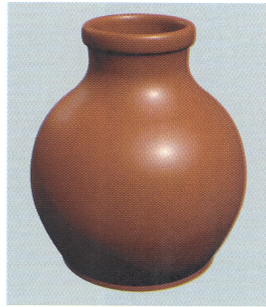
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## Material Taxonomy

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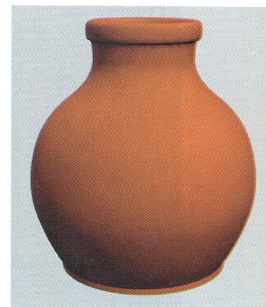
### RenderMan



Plastic  
Shiny Plastic



Rough Metal  
Shiny Metal



Matte

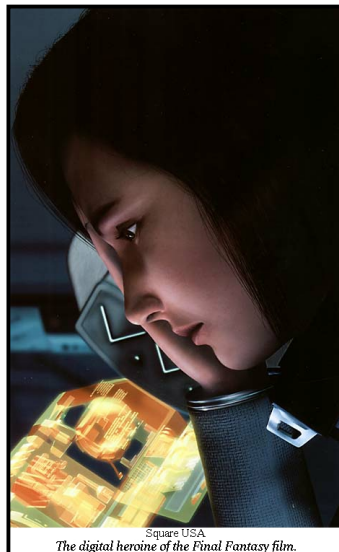
From Apodaca and Gritz, *Advanced RenderMan*

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## Faces

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Final Fantasy  
SquareUSA

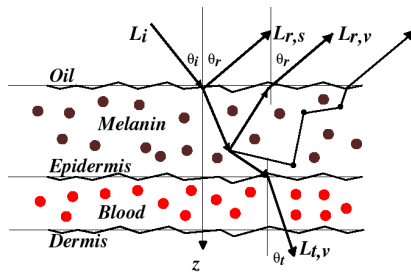
Jensen,  
Marschner,  
Levoy,  
Hanrahan

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## Material Models

Appearance reflects the material *structure*

For example: skin



Joint work w/ W. Krueger

Physical processes

- Surface scattering
- Subsurface scattering

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## Marble



Surface Reflection



Subsurface Reflection

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## Water Flows on the Venus

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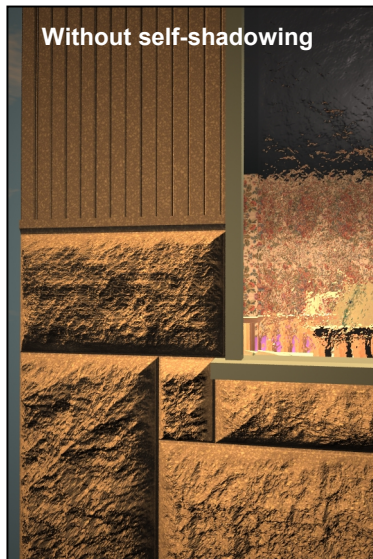
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## Shadows on Rough Surfaces

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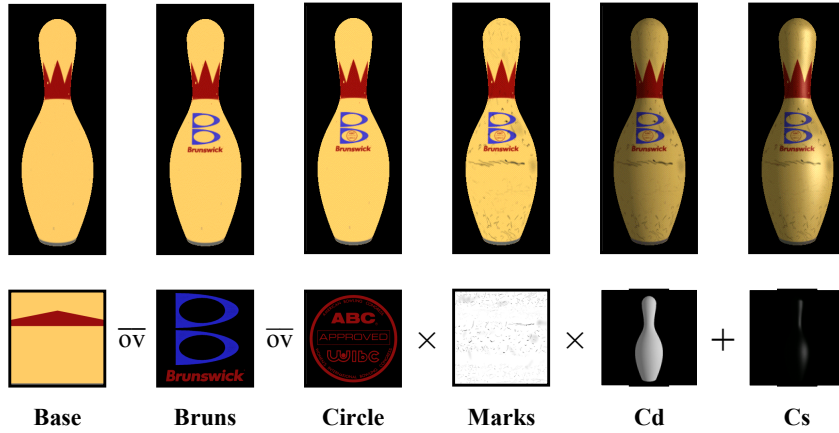
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# Creating Appearance

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



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