

## CS348B: Image Synthesis Techniques

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### Three aspects

- Lights and Lighting
  - Light sources
  - Illumination algorithms
- Materials
  - Reflection models
  - Texture models
- Camera
  - Lens and film effects

Fundamentally involves physical modeling and simulation

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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  $\mathbb{P}$  texturing

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

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### Reflection 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*

## Topics

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Ray tracing  
Light fields  
Lights and illumination  
Camera simulation and film models  
Reflection models (materials)  
Texture models  
Rendering equation  
Radiosity and finite elements  
Monte Carlo ray tracing  
Volume rendering  
Image-based rendering  
Artistic styles

# Ray Tracing

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Ray-Surface intersection algorithms

- Polygons and parametric surfaces
- Algebraic and implicit surfaces
- Procedural models; CSG

Acceleration techniques: Efficient ray queries

- Find the closest intersection?
- Is there any intersection?

Sampling

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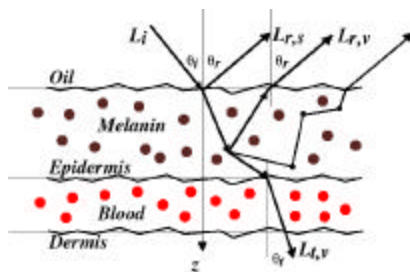
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# Material Models

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Appearance reflects the material *structure*

For example: skin



Physical processes

- Surface scattering
- Subsurface scattering

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Final Fantasy  
Square USA



Bingo  
Chris Landreth  
Alias/Wavefront

## Beauty of Subsurface Scattering



Courtesy Dorsey, Edelman, Wann Jensen, Legakis, Pederson  
Modeling and Rendering of Weathered Stone, SIGGRAPH '99

## A Sense of Time ...

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## Water Flows on the Venus

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## Lights and Lighting

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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

How to solve it?

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

### Challenges

- Primitives complex: lights, materials, shapes
- Exponential number of paths, dense coupling

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## Shadows on Rough Surfaces

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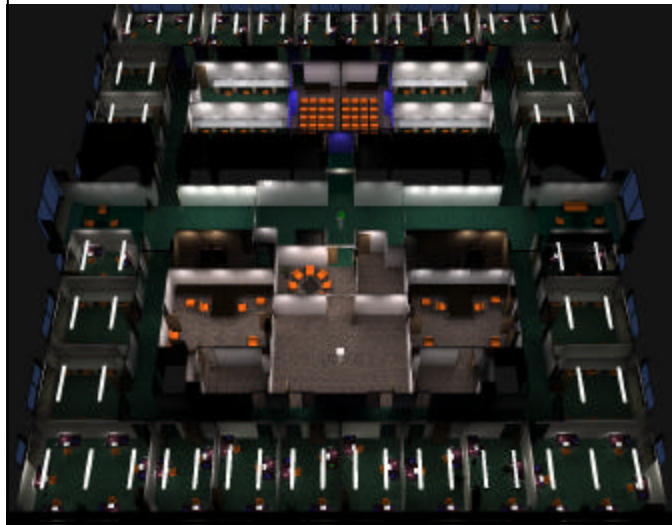


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## Radiosity

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Joint work w/ S. Teller, T. Funkhouser, P. Schroeder, C. Fowler  
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## Complex Indirect Illumination

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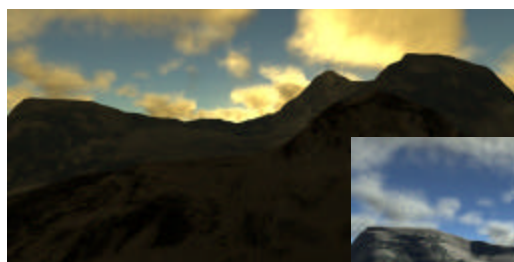


Modeling: Stephen Duck; Rendering: Henrik Wann Jensen  
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## Clouds and Atmospheric Phenomena



Hogum Mountain  
Sunrise and sunset

7am



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



6:30pm

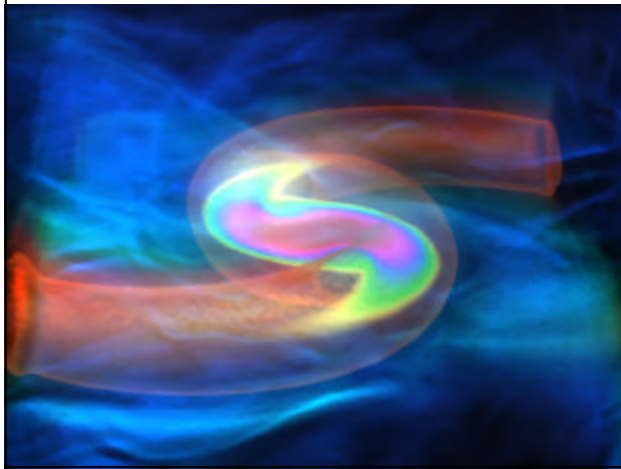
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## Volume Rendering

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Binary Neutron Star Collision  
Image Courtesy of David Bock, NCSA

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## Perception

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### Visual Cues

- Perspective and foreshortening
- Aerial perspective: desaturation, blurring
- Shadows
- Shading
- Transparency
- Occlusion
- Motion parallax
- Stereopsis

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## Perception and Artistry

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### Perception

- Surfaces
  - Diffuse -> basic 3d shape
  - Specular -> curvature
- Edge highlighting
- Textures

### Artistic convention

- Cross-hatching, axial lines, etc.
- Color coding
- Cutaways, cross-sections, exploded views

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## Non-Photorealistic Rendering

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"Mock Media," Scott Johnson  
In *Advanced RenderMan: Beyond the Companion*

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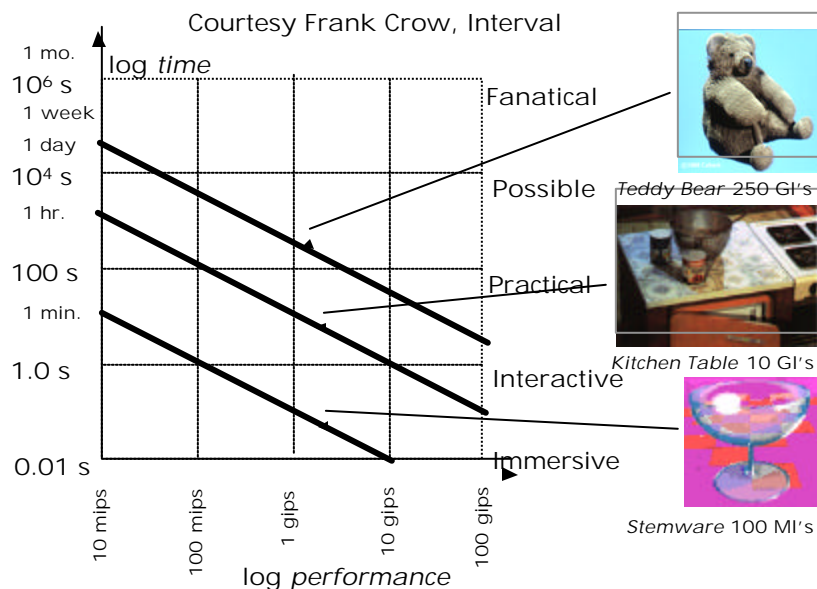
# Rendering Engines

1st generation (1985), e.g. SGI 3000, DN 570	10,000
■ Transformation and rasterization of lines	
2nd generation (1988), e.g. SGI GT, HP VRX	100,000
■ Lighting, smooth-shading	
■ Efficient polygon rasterization	
■ Z-buffered hidden surface engine	
3rd generation (1992), e.g. SGI RE	1,000,000
■ Antialiasing	
■ Texture mapping	
4th generation (1995?)	10,000,000
■ Flexible lighting, shading, texturing	
■ Higher-level (e.g. curved) geometric primitives	
5th generation (2000?)	100,000,000?
■ Global illumination: shadows, ray tracing, radiosity	

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## From Batch to Interactive



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## Movie Quality Rendering in Realtime?

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*Toy Story*  
Image Courtesy of Disney

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