Rendering

- Engineering
  - Computer generation of visual media
  Printing, video, workstations; compression
  - Provide visual cues for applications
  Perspective, shading, shadows, ...
  Why? - Discriminate and comprehend
- Science
  - Models of appearance
  Perceptual, physical, mathematical, computational
  Why? - Realism
  - Visualization and Illustration
  Transformation of abstract data to images
- Artistic

Visual Cues

Perspective and foreshortening

Aerial perspective: desaturation, blurring

Shadows

Shading

Transparency

Occlusion

Motion parallax

Stereopsis

‘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 models = <u>Shading</u>

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

Illumination algorithms = <u>Lighting</u>

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

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, radiosity

Physically-based Rendering

Basic optics
- Physics of light and color
- Geometrical optics
  - Ray "metaphor"
  - Reflection and transmission
- Radiative transfer
  - Radiometry and photometry; measurement
  - Transport theory and integral equations

Questions

1. How is light measured?
2. How is the spatial distribution of light energy described?
3. How is reflection from a surface characterized?
4. What are the conditions for equilibrium flow of light in an environment?

What do the numbers 0-255's mean?

Why Physically-based Rendering?

- Interesting scientific challenge
- Necessary to simulate/augment reality
  - Applications: design, entertainment
- Use real-world data
  - Acquire geometric models
  - Acquire reflection models
- Example of high complexity simulation
  - "Grand Challenge" type problem
  - Procedural modeling and data amplification

Non-photorealistic Rendering

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

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

Topics

Classic HSR algorithms
Ray tracing
Radiometry
Spectral representations
Camera simulation
Reflection models (materials)
Texture mapping
Rendering equation
Illumination algorithms (radiosity and MC RT)

Ray Tracing Topics

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 strategies

Writing a ray tracer