Global Illumination
(BRDFs, Ray Tracing)
Reflection Geometry (BRDF)

Bidirectional Reflection Distribution Function
Light Measurement Laboratory
Reflection Processes

First surface reflections

Multiple surface reflections

Subsurface reflections
Comparison of experiment and theory

Aluminum $\sigma_0 = 0.28\mu, \quad \tau = 1.77\mu$
Bidirectional Reflectance (BRDF)
Retroreflection
Reflectance of Copper Mirror
Light Reflected from Copper

![Graph showing energy distribution of light reflected from copper mirror.](image)
Cook-Torrance Renderings

- Carbon
- Red
- Rubber
- Obsidian
- Lunar
- Dust
- Olive
- Drab
- Rust
- Bronze
- Tungsten
- Copper
- Tin
- Nickel
- Stainless
- Steel
Copper Vase

Copper-colored plastic

Copper
The geometry of scattering from a layered surface
Schematic model of the image process
Direct Illumination

- User Input
- Camera
- Perspective
- Raster Operations
- Image Storage
- Display
Phong Goblet

1973
Direct Lighting and Indirect Lighting
Direct and Global Illumination

Light source

Direct lighting

Indirect lighting

Surface A

Surface B
Light Rays Propagating from Source
Global Illumination Methods

• Ray Tracing
• Radiosity
• Path Tracing
Escher
Ray Tracing

Note: Point Sampling at center of each pixel
Ray Tracing (Whitted 1979)

• Assumptions:
  – Light Source
    > point light source
  – Material
    > diffuse with specular spike (e.g., Phong Model)
  – Light Propagation
    > occluding objects (shadows, but no penumbra)
    > no attenuation
    > Specular inter-reflections only (trace rays in mirror reflection direction only)
Whitted Ray Tracing Model

\[ I = k_d \sum_{i=1}^{l} (\overrightarrow{N} \cdot \overrightarrow{L}) \]  
(object color)

\[ + k_s \sum_{i=1}^{l} (\overrightarrow{N} \cdot \overrightarrow{H})^n \]

direct diffuse

\[ + I_a + k_s I_r + k_t I_t \]

direct specular   global diffuse   global specular reflected   global specular transmitted
Whitted Ray Tracing Model

\[
\text{DIFFUSE} = k_d (\hat{N} \cdot \hat{L}) R_d I_j \\
\text{SPECULAR} = k_s (\hat{N} \cdot \hat{H})^n R_f I_f \\
\text{TRANSMITTED} = k_s (\hat{N} \cdot \hat{R'})^n T_f I_j
\]

\[
\text{DIFFUSE} = I_d R_d \\
\text{SPECULAR} = k_s R_f I_f F_f^{dr} \\
\text{TRANSMITTED} = k_s T_f I_f F_f^{dt}
\]
First Reflection
Two Reflections
Four Reflections
Six Reflections
sample point:
X = 0020
Y = 0220

eye

intersection block address: 736112
object intersected at this node: 13
reflected ray through air
transmitted ray through material: 9
intersection location:
-3.565
2.302
9.426
normal vector cosines:
0.00000
-0.99994
reflected vector cosines:
0.16672
-0.00338
-0.98543
transmitted vector cosines:
0.11002
-0.00410
0.99392
fresnel reflectance: 0.04198
node contribution: 0.79675
scaled XYZ at this node:
1760.99
1616.22
1406.40
Ray Tracing

- Model
  - Camera
    - Perspective
      - Raster Operations
        - Image Storage
  - Ray Tracing
  - Display
End