Reflection Models

Previous lectures
- Ideal materials: mirrors, glass, matte
- Glossy materials

Today
- Anisotropic reflection
- Subsurface reflection; translucent materials

Anisotropic Reflection Model
Anisotropic Reflection

Quarterhorse
Reflection from a Cylinder

\[ \hat{T} \]

\[ \hat{L} \]

\[ R_N(\hat{L}) \]

Anisotropic Reflection

\[ L \]

\[ P \]
Shape of Anisotropic Highlights

Fibers tangent to the plane defined by the halfway vector reflect light

From Lu, Koenderink, Kappers
**Kajiya-Kay Model**

**Diffuse**

\[
\sin \theta_L = \sqrt{1 - (\hat{T} \cdot \hat{L})^2}
\]

**Specular**

\[
\cos^s (\theta_E - \theta_L) = (\cos \theta_E \cos \theta_L + \sin \theta_E \sin \theta_L)^s
\]
Previous Work

Measurements for cosmetics industry
  - [Stamm 1977; Bustard & Smith 1994]

Structure of fiber surface

[Robbins ’94]

Fiber Model

interior: colored transparent medium

R  TRT  TT

root  tip
Fiber Model

interior: colored transparent medium

elliptical cross-section

tilted cuticle scales

root tip
Caustics

[Diagram of caustics showing absorption, reflection factor, and ray density]

Hair Appearance

[Image of hair with texture sample]

Pat Hanrahan, Spring 2006
Hair Appearance
Subsurface Reflection
Traditional Reflection Models: BRDF

\[ f_r(x, \omega_i, \omega_o) \equiv \frac{dL_r(x, \omega_o)}{dE_i(x, \omega_i)} \]

Subsurface Scattering: BSSRDF

\[ S(x_i, \omega_i; x_o, \omega_o) \equiv \frac{dL_r(x_o, \omega_o)}{d\Phi_i(x_i, \omega_i)} \]
Translucent Materials: Jade

Translucent Materials: Marble
Translucent Materials: Skin

Translucent Materials: Leaves
How?

Highly Scattering Media
Highly Scattering Media

\[ \phi(r) = \Phi \frac{e^{-kr}}{r} \]

Diffusion Approximation

\[ \phi(r) = \Phi \frac{e^{-kr}}{r} \]
Dipole Diffusion Approximation

\[ R_d(r) = -\frac{\mathbf{N} \cdot (\nabla \phi_1(r) - \nabla \phi_2(r))}{\Phi_i} \]

Single Scattering
Evaluating the BSSRDF

\[ L_r(x_o, \omega_o) = \int \int_A \int_{\Omega} S(x_i, \omega_i; x_o, \omega_o) L_i(x_i, \omega_i) \cos \theta_i d\omega_i dA \]

Marble: BDRF versus BSSDRF

BRDF  BSSRDF
Marble: MCRT vs BSSRDF

MCRT | BSSRDF

Skim Milk
Whole Milk

Diffuse Milk
A Face (BSSRDF Model)

A Face (BRDF Approximation)