Reflection Models

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Outline

- Reflection Models
- Geometric Setting
- Fresnel Reflectance
- Specular Refletance & Transmission
- Microfacet Models
- Lafortune Model
- Fresnel Incidence Effects

Diffuse

- Scatter light equally in all directions
  - Dull chalkboards, matte paint

Glossy Specular

- Scatter light preferentially in a set of reflected directions
  - Show blurry reflections
  - Plastic or High-gloss paint

Perfect Specular

- Scatter light in a single direction
  - Mirrors and glass

Retro-reflected

- Scatter light primarily back along the incident direction
  - Velvet and the Moon

Geometric Setting

- Reflectance coordinate system defined by two tangent vectors and a normal vector
- Point (x, y) is defined as (r*cos F , r*sin F)

Snell’s Law

- Snell’s law relates an incident ray and a transmission ray
  - Based on 2 indices of refraction, $?_i$ and $?_t$
- Index of refraction, ?, defines how much slower light travels in a medium than in a vacuum

Fresnel Reflectance

- Describes the amount of light reflected or transmitted from a surface
  - Two equations that each have two forms

PBRT assumes that light is unpolarized

Fresnel Basics

- $?_i$ and $?_t$ are the indices of refraction for the incident medium and the transmission medium respectively
- $?_o$ and $?_t$ are outgoing incident and transmission directions
- $r_{||}$ and r_- are the Fresnel equations for parallel and perpendicular polarized light

Fresnel Dielectrics

Computing Fresnel reflectance for dielectrics requires the indices of refraction for both mediums

$F_r = \frac{1}{2} * (r_{||}^2 + r_{\perp}^2)$

Conservation of energy requires that the energy transmitted is $1 - F_r$

Fresnel Conductors

- Conductors don’t transmit light, but do absorb it
- Depends on the conductors index of refraction and its absorption coefficient
- Can calculate the index from the coefficient or vice versa

Specular Reflectance

- Need a BRDF of the form:

$$L_o(?_o) = f_r(?_o, ?_i)\ L_i(?_i) = F_r(?_i)\ L_i(?_i)$$

Using the Dirac Delta function to restrict the incident direction to the reflectance angle $?_r$ yields:

$$f_r(p, ?_o, ?_i) = d(?_i – ?_r) = d(\cos ?_i – \cos ?_r)\ d(F_o +/– F_r)$$

Specular Transmission

- The amount of transmitted incident light is $t = 1 - F_r$
- This means the differential flux is $dF_o = t\, dF_i$
- Using the definition of reflectance gives the equation $(L_o \cos ?_o dA d?_o) = t (L_i \cos ?_i dA d?_i)$

- Simplifying this gives the BTDF $f_t(p, ?_o, ?_i) = (?_i 2/?_t 2)(1 - F_r(?_i))(d(?_i - T(?_i, \mathbf{n}))/|\cos ?_i|)$

Microfacet Models

Rough surfaces can be modeled as collection of small microfacets.

If the surface area, dA, is relatively large compared to the size of a single facet then the light scattering is the aggregate behavior.

Oren-Nayar Diffuse

Real world object don’t exhibit the perfect diffuse reflectance of the Lambertian Model

Used a Gaussian distribution of symmetric V-shaped grooves that exhibit Lambertian diffuse to derive a BRDF

Oren-Nayar accounts for masking, shadowing and interreflection

Torrance-Sparrow Model

This models surfaces as collections of perfectly smooth mirrored microfacets.

Only microfacets with normals equal to the half-angle vector, $?_h$, cause reflectance

$$?_h = ?_i + ?_h$$

Blinn Distribution

- Approximates distribution with an exponential falloff
- Most likely orientation is the surface normal direction
- Accomplishes this by raising cos $?_h$ by e

Anisotropic Model

- Produces varying reflectance based on the rotation of the surface
- Uses two parameters, e_x and e_y
- Normalized distribution function is $D(?_h) = \text{sqrt}((e_x + 1)(e_y + 1)) * \text{Dot}(?_h, \mathbf{n})\ \hat{}\ (e_x \cos^2 F + e_y \sin^2 F)$

Lafortune Model

Models measured BRDF data with a small number of parameters

Uses a modified the Phong model that handles reciprocal and energy conservation

Lafortune BRDF sums Phong lobes to form reflectance value

Fresnel Incidnce Effects

- Most BRDF's don't account for the reduction of light reaching the bottom of a glossy surface
- Uses two spectra and a Microfacet distribution to produce a BRDF

References

- Slides from cs534b-06; Matt Phar
- Physically-Based Rendering; Phar and Humphreys