Illumination Models

Things to Model

Light sources
- What color, intensity, lines through space
Reflection of light off surfaces
- How much light reflected in each direction
  — How are color and intensity changed

Real Lights

Real lights are complicated
- Sun light, iridescent bulbs, fluorescent bulbs
- Different spectra in different directions
  — probably time-varying as well, but we don’t perceive much of that

Simpler Light Models

- Point lights
- Directional lights
- Spot (Warn) lights
- Area lights (not really so simple)

Real Reflection

Again, pretty complicated
- May be described by bidirection reflectance distribution function (BRDF)
- BRDF is 5D function
  — 2D for incoming light direction
  — 2D for outgoing light direction
  — 1D for wavelength of light

Simpler Reflection Models

- Phong illumination
- Cook and Torrance illumination
**Life on a Surface**

- **L**: direction to light
- **N**: normal vector
- **R**: reflection of light about normal
- **V**: direction to viewer (i.e. reflection direction of interest)

**Point Light**

- Specified by:
  - position $(x,y,z)$
  - intensity $(r,g,b)$
- Radiates equal intensity in all directions
- $L = P_{\text{light}} - P_{\text{surface}}$

**Directional Light**

- Point light at infinity
- Specified by:
  - direction $(x,y,z)$
  - intensity $(r,g,b)$
- All light rays are parallel
- $L = -\text{direction}$

**Spot (Warn) Light**

- Specular reflection of point light source
- Specified by:
  - position of reflector
  - position of point light (or direction to point light)
  - intensity of point light
  - falloff exponent

$$I_{\text{warn}} = I_{\text{point}} \cos \gamma = I_{\text{point}} (V \cdot R)^p = I_{\text{point}} (L \cdot L')^p$$

**Warn Light (cont.)**

- Also possible to truncate region of effect
  - flaps
  - cone (used in OpenGL spotlight)

**Warn Light Profile and Examples**

*From Skray, vantaa, twiner, and stugney, c-omputer araphics: Principles and Practice, 2nd edition, page 732, 733*
Phong Illumination

Empirically divides reflection into 3 components

- Ambient
- Diffuse (Lambertian)
- Specular

Ambient Light

Independent of location of viewer, location of light, and curvature of surface

\[ I = I_a k_s \]

- \( I_a \) is intensity of ambient light
- \( k_s \) is ambient coefficient of surface

Note: this is a total hack, of course

Diffuse Reflection

Component of reflection due to even scattering of light by uniform, rough surfaces

Depends on direction of light and surface normal

\[ I_d = I_p (L \cdot N) \]

- \( I_p \) is intensity of point light

Important Note

When we write:

\( ( N.L ) \)

we often really mean:

\[ \text{max}( N.L , 0 ) \]

- The latter computes 1-sided lighting
- For 2-sided lighting, use:

\[ \text{abs}( N.L ) \]

Diffuse Reflection Examples

Specular Reflection

Component of reflection due to mirror-like reflection off shiny surface

Depends on perfect reflection direction, viewer direction, and surface normal

\[ I_s = I_p (R.V)^n \]

- \( n \) is specular exponent, determining falloff rate
Phong Illumination Example

Illumination with Color

Surface reflection coefficients and light intensity may vary by wavelength

For RGB color

- Light intensity specified for R, G, and B
- Surface reflection coefficients also for R, G, B
- Compute reflected color for R, G, and B

Cook and Torrance Illumination

Replace specular component with more physically accurate model

\[ P_s = F_s D G / \pi (N \cdot V) (N \cdot L) \]

- \( F_s \) is Fresnel term, which accounts for change of highlight color with respect to angle of incidence
- \( D \) is microfacet distribution term, for more accurate measurement specular reflection off tiny microfacets
- \( G \) is geometry term, which models self-shading effects

Phong vs. Cook/Torrance Example