CS174A Lecture 11

Announcements & Reminders

- *Team project proposals due (final version): Nov 8*
- *Projects due: Dec 1*
- *Project presentations: Dec 3 and 5, in class*
- *Final exam: Dec 12*

TA Session This Friday

- *Team project proposals*

Last Lecture Recap

- ***Hidden Surface Removal***
  - Painter’s algorithm
  - Z-buffer algorithm
  - Scanline z-buffer algorithm
  - Properties, advantages, disadvantages of each
  - Efficiency considerations

Next Up

- ***Lighting/Illumination Models***
  - Ambient
  - Diffuse
  - Specular
- ***Barycentric Coordinates, Trilinear Interpolations***
- ***Flat and Smooth Shading***
- ***Hidden Surface Removal***
  - 2-pass z-buffer algorithm (shadows)
  - Ray casting

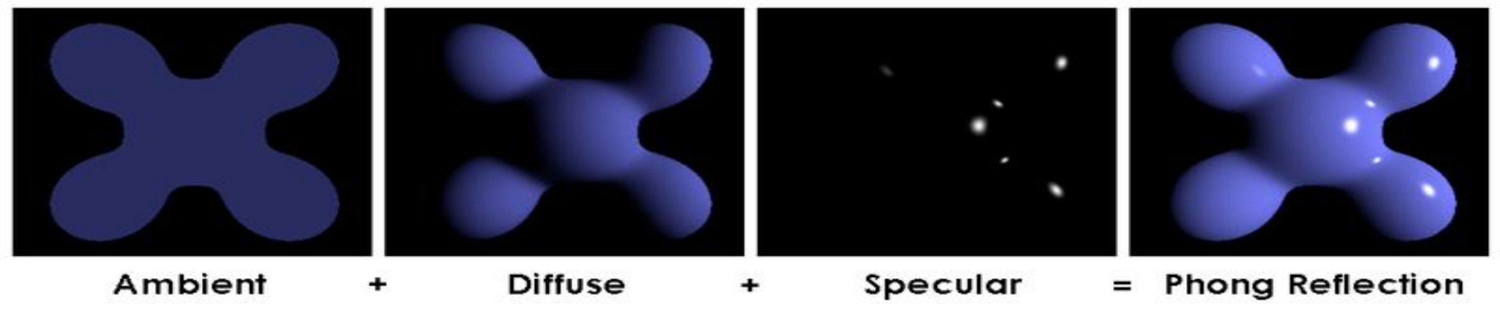
Lighting/Illumination

- ***Geometric Properties***
  - **Object**: position, orientation (normal)
  - **Light**: position, direction, point vs. spot vs. area
  - **Eye**: position, orientation

- ***Material Properties***
  - **Object**: color, reflectivity, shininess, bumpiness, translucency
  - **Light**: color
  - **Eye**: filter, color blindness

Lighting/Illumination

- ***Types of Lighting***
  - Ambient
  - Diffuse
  - Specular

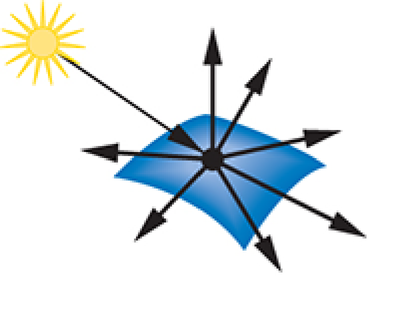


Ambient Lighting

- ***Properties***
  - Background light
  - Unrealistic
  - Works as a good approximation of scattered light
  - Does NOT depend on position/orientation of light, object or eye
  - Only depends on object's material property
  - k_a = ambient reflection coefficient, values [0..1], may be different for R, G, B
  - I_a = intensity of ambient light source, values [0..1], different for R, G, B
  - **Ambient light reflected off object = $k_a * I_a$**

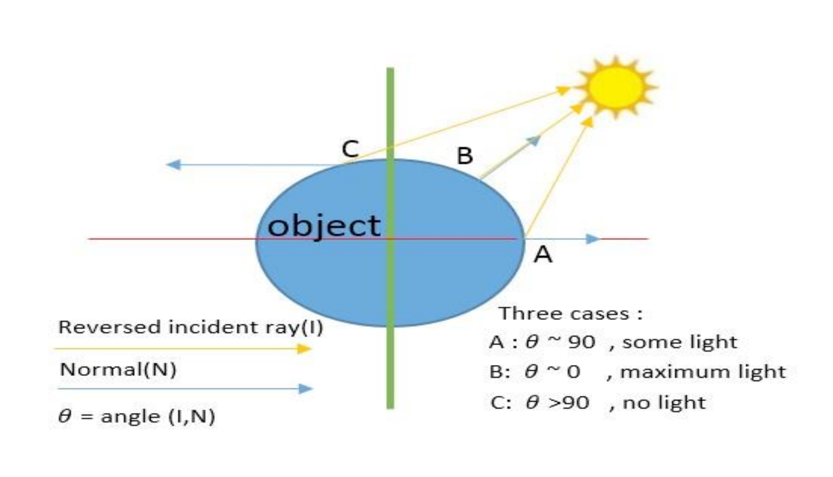
Diffuse Lighting

- ***Properties***
  - Point light source
  - Lambertian (of diffuse) reflection for dull, matte surfaces
  - Surfaces look equally bright from all directions
  - Reflect light **equally** in all directions
  - Lambert's Law: *amount of light reflected from a differential unit area dA toward a viewer is $\propto$ the cosine of the angle between the incident light and the normal (θ)*
  - k_d = diffuse reflection coefficient, values [0..1]
  - I_p = intensity of point light source, values [0..1]
  - **Diffuse light reflected off object = $k_d * I_p * \cos\theta = k_d * I_p * (N \cdot L)$**



Diffuse Lighting (Contd.)

- ***Incident angle θ***
  - $\theta < 90^o \Rightarrow$ some light based on angle θ
  - $\theta = 0^o \Rightarrow$ max light
  - $\theta > 90^o \Rightarrow$ self occlusion
- ***Directional light source***
  - A light at sufficient distance from object (e.g., sun)
  - L remains the same for entire scene
  - N remains the same for entire polygon
  - Therefore, N·L = constant on poly; L = constant everywhere
- ***Attenuated light source***
  - Diffuse light reflected off object = $f_{att} * k_d * I_p * \cos\theta = f_{att} * k_d * I_p * (N \cdot L)$
  - $f_{att} = \frac{1}{d^2}$ or $\frac{1}{c_1 + c_2 * d + c_3 * d^2}$; $f_{att} = \min(f_{att}, 1)$



Diffuse Lighting (Contd.)

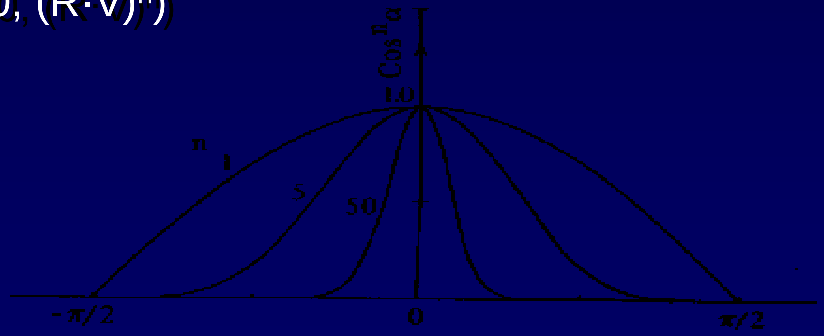
- ***Colored Light and Objects***
  - Object's Diffuse Color ($O_{d\lambda}$): O_{dR}, O_{dG}, O_{dB}
  - $I_\lambda = [k_a * I_{a\,\lambda} + f_{att} * k_d * I_{p\,\lambda} * (N \cdot L)] * O_{d\,\lambda}$
- ***Atmospheric Attenuation or Blending***
  - Depth cueing or fog (fog color = $I_{dc\lambda}$)
  - $I'_\lambda = s_o * I_\lambda + (1 - s_o) * I_{dc\lambda}$
  - $s_o = s_b$ when $z > z_b$
  - $s_o = s_f$ when $z < z_f$
  - $s_o = s_f + \frac{(sb - sf)}{(zb - zf)}(z - zf)$

Specular Lighting

- ***Properties***
  - Shiny surfaces
  - Color of light, not object
  - Does depend on position of light, object and eye
  - Light reflects **unequally** in different directions (e.g., perfect reflector: mirror)
  - For non-perfect reflectors
  - k_s = specular reflection coefficient, values [0..1], may be different for R, G, B
  - n = material’s specular reflection exponent, values [1..100s], perfect reflector n = ∞
  - **Specular light reflected off object = $f_{att} * k_s * I_p * \cos^n\alpha = f_{att} * k_s * I_p * (R \cdot V)^n$**
  - $I_\lambda = k_a * I_{a\lambda} * O_{d\lambda} + f_{att} * k_d * I_{p\lambda} * (N \cdot L) * O_{d\lambda} + f_{att} * k_s * I_{p\lambda} * (R \cdot V)^n$

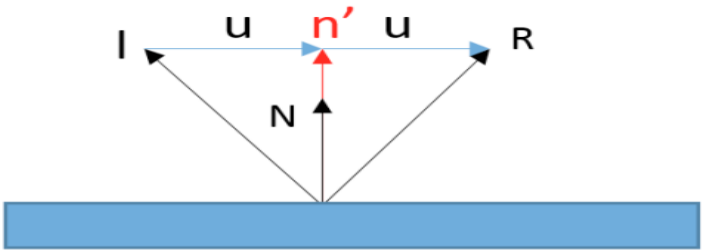
Specular Lighting (Contd.)

- ***Specular Term: Smoothness Exponent Effect***
  - Exponentiating a term that has values < 1 draws it closer to 0
  - Higher exponent ⇒ smaller region where point light's reflection is considered aligned with the viewer ⇒ smaller shiny spot
  - -ve values of cosα is clamped to 0 = max(0, (R·V)^n)
  - Max specular reflection when α = 0



Specular Lighting (Contd.)

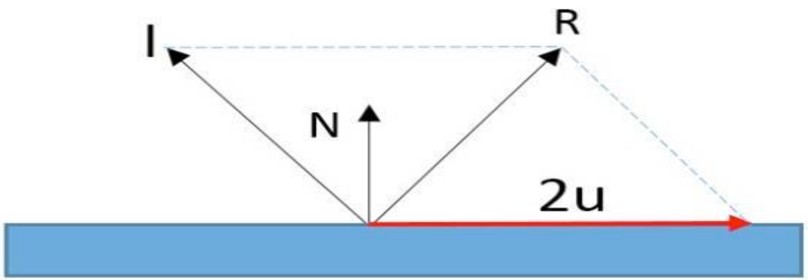
- ***Calculating R Vector: reflection of point light source***



The $\overrightarrow{n'}$ is the projection of $\vec{I}$ on $\vec{N}$

$\overrightarrow{n'} = (\vec{N} \cdot \vec{I})\, \vec{N}$, with $\|\vec{N}\|^2 = 1$

$\vec{u} = \overrightarrow{n'} - \vec{I}$



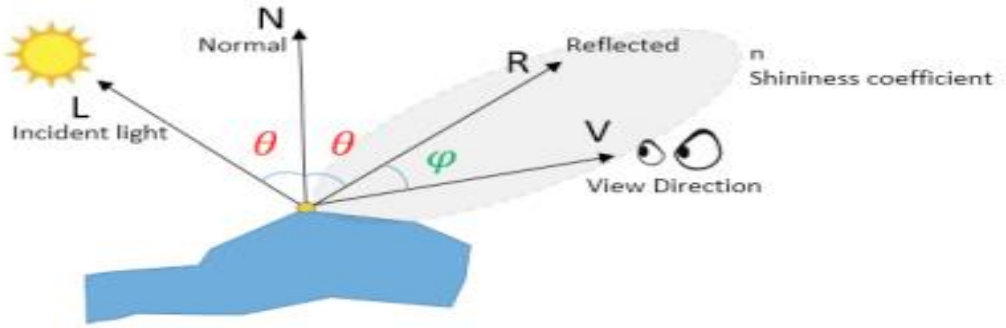
$$\vec{R} = \vec{I} + 2\vec{u} = \vec{I} + 2(\overrightarrow{n'} - \vec{I})$$

$$\vec{R} = 2(\vec{N} \cdot \vec{I})\, \vec{N} - \vec{I}$$

Specular Lighting (Contd.)

- ***Halfway Vector: Alternate Formulation of R·V***
  - Halfway vector (H) between L and V = normalize(L + V)
  - Replace $(R \cdot V)^n$ with $(H \cdot N)^n$

Final Light Equation



I = emissive + ambient + diffuse + specular

$$\text{emissive} = k_e$$

$$\text{ambient} = k_a * ambientColor$$

$$\text{diffuse} = k_d * lightColor * \cos(\theta)$$
$$= k_d * lightColor * \max(0, N \cdot L)$$

$$\text{specular} = k_s * lightColor * \cos(\varphi)^n$$
$$= k_s * lightColor * \max(0, R \cdot V)^n$$

Lighting: Misc Improvements

- ***Spot Lights***
  - Smooth spot silhouette
- ***Multiple Light Sources***
  - Sum the light terms over all light sources
- ***Clamping***
  - x = max(0,x) and min(x,1)
  - x = normalize(x) wrt to max value of color in entire image
- ***Fast Alternative to Phong Illumination***
  - t = R·V or H·N
  - Instead of t^n, do $\frac{t}{n - nt + t}$