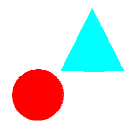
Illumination: Lights and Materials. Overview of Shading Computations in OpenGL

Textbook: "Shading" , OpenGL Guide :Lighting

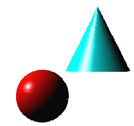
Shading Review 2

- a circle and a triangle or a sphere and a cone?



Shading Review 3

- More realistic shading:



Lighting and Shading

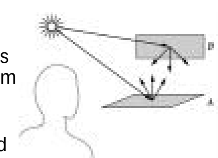
- Lighting interaction between objects' materials and geometry, and the light sources
- Shading the process of performing the lighting computations and determining pixels' color from them. Three basic algorithms
  - **Flat/Polygonal**
  - **Gouraud/Smooth**
  - **Phong**

Light, Position, Materials

- Nate Robins' Tutorial
- www.xmission.com/~nate/tutors.html

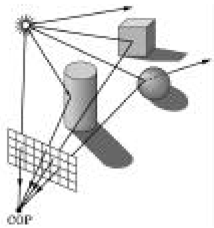
Light and Matter

- Physics:
  - Light sources
  - Material characteristics
- Object is seen if photons emitted or bounced from it reach the eye.
- Multiple interactions among light sources and reflective surfaces determine the color observed



Light and Matter

- Viewer sees the color of the light reflected from the surface
- Replace the viewer by a projection plane
- Color of light source and surfaces determine the color of pixels in the frame buffer



Light Sources

- **Point Sources**
- **Spotlights**
- **Distant Lights**
- **Ambient Light –** simulates uniform indirect lighting (cloudy day).

Light Sources

- Light sources emit different amounts of light at different frequencies
- We describe a source through a three component vector (R,G,B) ,intensity or luminance vector (often denoted L):

$$\mathbf{I} = \begin{bmatrix} I_r \\ I_g \\ I_b \end{bmatrix}$$

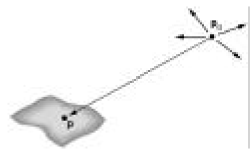
Point Sources

- An ideal point source emits light equally in all directions
- Intensity of of a point light source at $\mathbf{p}_0$:

$$\mathbf{I}(\mathbf{p}_0) = \begin{bmatrix} I_r(\mathbf{p}_0) \\ I_g(\mathbf{p}_0) \\ I_b(\mathbf{p}_0) \end{bmatrix}$$

Point Sources

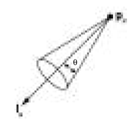
- Intensity of light that reaches a point p on an object is inversely proportional to the square distance to the light source.

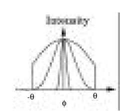


$$\mathbf{I}(\mathbf{p}, \mathbf{p}_0) = \frac{1}{|\mathbf{p} - \mathbf{p}_0|^2} \mathbf{I}(\mathbf{p}_0)$$

Distance between p and p_0 can be replaced with: $(a + bd + cd^2)^{-1}$

Spotlights





- Spotlights are characterized by a narrow range of angles through which light is emitted
- Given a point source, limit the angles at which light from the source can be seen
- Use a cone whose apex is at $\mathbf{p}_s$, which points in the direction $\mathbf{l}_s$, and width is determined by an angle q

Distant/Directional Light

- Source is at infinity
- Replace a point source with a parallel source that illuminates objects with parallel rays of light
- Replace location of the light source with direction of the light source

Distant Light

$$\mathbf{p}_0 = \begin{bmatrix} x \\ y \\ z \\ 1 \end{bmatrix} \qquad \mathbf{p}_0 = \begin{bmatrix} x \\ y \\ z \\ 0 \end{bmatrix}$$

point source — direction vector source

Ambient Light

- Ambient Light is the uniform lighting in an environment – “background glow”
- Ambient illumination is characterized by an intensity, I_a, that is identical at every point in the scene
- It has three color components:

$$\mathbf{I}_a = \begin{bmatrix} I_{ar} \\ I_{ag} \\ I_{ab} \end{bmatrix}$$

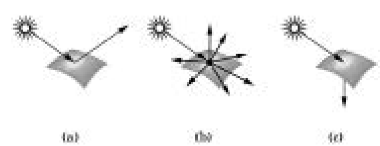
- We use the scalar I_a to denote any on of the red, green or blue components

Light-Material Interaction

The color of a surface is determined by its material, the parameters of the light sources and the lighting model.

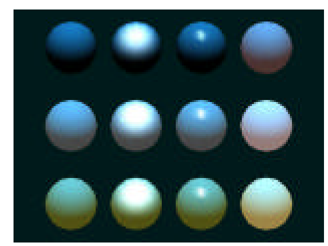
Material: specified as a combination of material parameters: specularity, shininess, diffusivenes, emmisiveness, ambient color

Material Properties



(a) specular surface — (b) diffuse surface — (c) translucent surface

Material Properties



no ambient reflection

gray ambient reflection

blue ambient reflection

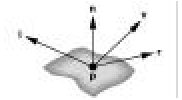
blue diffuse no specular — white specular low shininess — white specular high shininess — blue diffuser emissive

Phong Reflection Model

- introduced in 1975
- approximation to physical reality
- supports three types of material-light interactions: ambient, diffuse and specular

Phong Reflection Model

- Model uses four vectors to calculate a color for each point **p** on a surface when viewed
- **Normal n,** is the normal at **p**
- **View vector v,** is in the vector from **p** to the viewer or COP
- **Illumination vector l** is in the vector from **p** to the light source
- **Reflection vector r,** is in a vector along which light is refelected



OpenGL: Illumination matrix, models the incident light at a surface point

- Given a set of point sources, assume each has separate ambient, diffuse and specular components for each of the primary colors
- The incident light at a surface point from a light source, i, is modeled by a 3x3 illumination matrix: in each primary color, and in each of ambient, diffuse and specular components for that light source

$$\mathbf{L}_i = \begin{bmatrix} L_{ira} & L_{iga} & L_{iba} \\ L_{ird} & L_{igd} & L_{ibd} \\ L_{irs} & L_{igs} & L_{ibs} \end{bmatrix}$$

OpenGL: for each surface point and a light source a reflection matrix models the incident light from the light source, i, that is reflected at the point

- How much of the incident light is reflected at a point depends on the material properties, surface orientation, light source direction and distance
- 3x3 reflection matrix for the *i* th light source at point **p** on the surface is:

$$\mathbf{R}_i = \begin{bmatrix} R_{ira} & R_{iga} & R_{iba} \\ R_{ird} & R_{igd} & R_{ibd} \\ R_{irs} & R_{igs} & R_{ibs} \end{bmatrix}$$

OpneGL: Phong Reflection Model

- For each source, each primary color, illumination and reflection contributions in each of the ambient, diffuse and specular components are used to compute the intensity we see at **p** from source.

$$I_{ir} = R_{ira} L_{ira} + R_{ird} L_{ird} + R_{irs} L_{irs} = I_{ira} + I_{ird} + I_{irs}$$

- Obtain the total intensity by adding the contributions of all sources and a global ambient term. Thus, the red term is

$$I_r = \sum_i (I_{ira} + I_{ird} + I_{irs}) + I_{ar}$$

OpenGL:Phong Reflection Model

- Similar computations are done for each source and for each primary color
- omit the subscript and write

$$I = I_a + I_d + I_s = R_a L_a + R_d L_d + R_s L_s$$

understanding that the computation will be done for each of the primaries and each source

Local lighting models

- Add also emission term
- This is all empirical! Looks good often but physics is bogus
  - Enhancements
    - Physically based specular reflection (Blinn'77, Cook & Torrance'82). Accounts for micro-geometry, shadowing and masking effects, Fresnel's term, glare
    - Physically based diffuse reflection (Hanrahan & Kreuger'93). Layered materials, anisotropy

Teapots, Teapots, …