CZ2003 Tutorial 11 (2020/2021, Semester 1)

Illumination

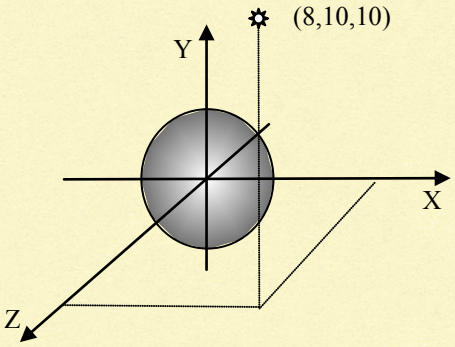
1. Which three components does the Phong illumination model contain? Which of them will change if one of the followings happens in a scene?

   a. A light source is moved to a new location.
   b. The object is moved to a new location.
   c. The observer is moved to a new location.

2. What is the value of the specular exponent for a perfect mirror? Why?

3. A plane is defined by equation $x + z - 2 = 0$, with the diffuse reflection coefficient 0.6. A point light source with intensity 1 is located at (10, 10, 10). Calculate a diffuse reflection on the plane at point (1, 10, 1).

4. A point light source with intensity 1 is located at coordinates (8, 10, 10). It illuminates an origin-centered sphere with radius 2, diffuse coefficient 0.7, specular coefficient 0.2, and specular exponent 2. The ambient reflection coefficient is 0.1. The intensity of the ambient light source is 1. An observer located at the position with coordinates (10, 0, 0) is looking at a point on the sphere, along the direction [-1 0 0]. Find the point and calculate the illumination on the surface of the sphere at the point seen by the observer.



K: depends on material.

1. Which three components does the Phong illumination model contain? Which of them will change if one of the followings happens in a scene?

   a. A light source is moved to a new location.
   b. The object is moved to a new location.
   c. The observer is moved to a new location.

Reflection vector.

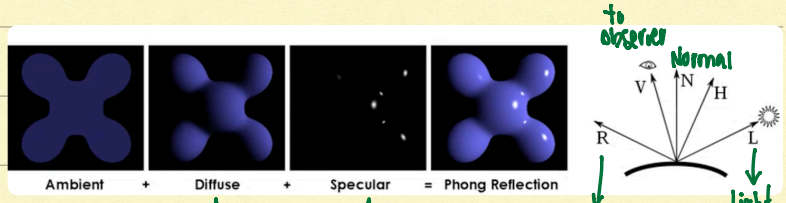
Phong illumination model: $I = K_a I_a + K_d I_s \cos\theta + K_s I_s \cos^n\phi$

- K_a: constant
- I_a: Intensity of Ambient light source
- $\cos\theta$: light source vector · Normal vector. ($\vec{L} \cdot \vec{N}$)
- $\cos^n\phi$: ($\vec{R} \cdot \vec{V}$)^n — vector of observer; how shiny the surface will be (shiner if n↑)

$K_a I_a$: Ambient Reflection

$K_d I_s \cos\theta$: diffuse Reflection

$K_s I_s \cos^n\phi$: specular reflection.



Ambient: does not Δ w.r.t location

Diffuse: Δ w.r.t location

Specular: highlights

R: Perfect reflection from point of interest from light source L.

L: Light source

(a) light source moved to a new location.

ambient reflection: No change

diffuse reflection: changes, $\vec{L}\,\Delta$

specular reflection: changes, $\vec{L}\,\Delta$

(b) object moved to new location.

ambient reflection: No change

diffuse reflection: changes, $\vec{N}, \vec{L}\,\Delta$

specular reflection: changes, $\vec{N}, \vec{L}\,\Delta$

(c) observer moved to a new location.

ambient reflection: No change.

diffuse reflection: changes ~~X~~ No change

specular reflection: changes. $\Delta\vec{V}$

→ 100% reflection in one direction, no diffuse reflection

2. What is the value of the specular exponent for a perfect mirror? Why?

for specular reflection, any other direction ≠ 0

$K_s I_s \cos^n\phi = K_s I_s (R \cdot V)^n$, $n \to \infty$, $\cos\phi \to 1$, $1^\infty = 1$

Exponent value = $\pm\infty$

This is because when the value is at infinity, the lightning vector, L, the surface normal N and the reflected vector lie in a common plane, and L and R are symmetric wrt N. This is because the value of ∞ makes no reflection along any other directions other than the ideal reflection direction for an incoming ray.

v. smooth?

3. A plane is defined by equation $x + z - 2 = 0$, with the diffuse reflection coefficient 0.6. A point light source with intensity 1 is located at (10, 10, 10). Calculate a diffuse reflection on the plane at point (1, 10, 1).

formula for diffuse reflection:

$$I_{diffuse} = K_d I_{source} \cos\theta = K_d I_s [N \cdot L]$$

$I_s = 1$ $K_d = 0.6$

plane eqn: $x + z - 2 = 0$

$\therefore$ unit normal vector $= \begin{pmatrix}1\\0\\1\end{pmatrix}/\sqrt{2} = \begin{pmatrix}1/\sqrt{2}\\0\\1/\sqrt{2}\end{pmatrix}$

directional lighting vector

$= \begin{pmatrix}10\\10\\10\end{pmatrix} - \begin{pmatrix}1\\10\\1\end{pmatrix} = \begin{pmatrix}9\\0\\9\end{pmatrix}$

unit lighting vector $= \dfrac{\begin{pmatrix}9\\0\\9\end{pmatrix}}{9\sqrt{2}} = \begin{pmatrix}1/\sqrt{2}\\0\\1/\sqrt{2}\end{pmatrix}$

Therefore, the diffuse reflection is

$= K_d I_s (N \cdot L)$

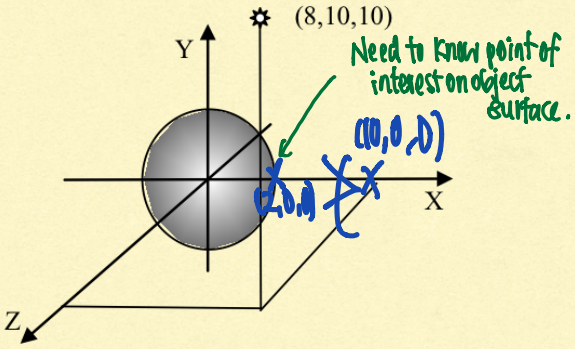
$= (0.6)(1)\begin{pmatrix}1/\sqrt{2}\\0\\1/\sqrt{2}\end{pmatrix} \cdot \begin{pmatrix}1/\sqrt{2}\\0\\1/\sqrt{2}\end{pmatrix}$

$= 0.6\left(\frac{1}{\sqrt{2}}\cdot\frac{1}{\sqrt{2}} + 0.0 + \frac{1}{\sqrt{2}}\cdot\frac{1}{\sqrt{2}}\right)$

$= 0.6(1)$

$= \underline{\underline{0.6}}$

4. A point light source with intensity 1 is located at coordinates (8, 10, 10). It illuminates an origin-centered sphere with radius 2, diffuse coefficient 0.7, specular coefficient 0.2, and specular exponent 2. The ambient reflection coefficient is 0.1. The intensity of the ambient light source is 1. An observer located at the position with coordinates (10, 0, 0) is looking at a point on the sphere, along the direction [-1 0 0]. Find the point and calculate the illumination on the surface of the sphere at the point seen by the observer.



Since the observer is on axis x and the sphere is origin centered, the point on the sphere observer looking at $\begin{pmatrix}2\\0\\0\end{pmatrix}$

Lightning vector = $\begin{pmatrix}8\\10\\10\end{pmatrix} - \begin{pmatrix}2\\0\\0\end{pmatrix} = \begin{pmatrix}6\\10\\10\end{pmatrix}$

unit L = $\frac{\begin{pmatrix}6\\10\\10\end{pmatrix}}{\sqrt{236}}$

$= \begin{pmatrix}3/\sqrt{59}\\5/59\\5/59\end{pmatrix} = \begin{pmatrix}0.39\\0.65\\0.65\end{pmatrix}$

V = (1,0,0)
N = (1,0,0)
} Why?

R = 2(LN)N - L

$= 2\begin{pmatrix}0.39\\0.65\\0.65\end{pmatrix}\begin{pmatrix}1\\0\\0\end{pmatrix}\begin{pmatrix}1\\0\\0\end{pmatrix} - \begin{pmatrix}0.39\\0.65\\0.65\end{pmatrix}$

$$= \begin{pmatrix} 0.39 \\ -0.65 \\ -0.65 \end{pmatrix}$$

$$I = k_a i_a + \sum k_d i_s (N \cdot L) + \sum k_s i_s (V \cdot R)^n$$

$$= (0.1)(1) + (0.7)(0.39) + (0.2)(0.39)^2$$

$$= 0.4$$