Introduction to Computer Graphics

2023/2024

Application Examples: The Phong Illumination Model

1- Consider a sphere with center (0, 0, 0) and radius 2. The viewer is located at (0, 20, 0) and looks at point P = (0, 2, 0) on the sphere's surface.

The sphere is illuminated by two point light sources:

- a red point light source, F_1, located at (-10, 12, 0),
- a blue point light source, F_2, located at (10, 12, 0).

In addition to the light sources, there is an ambient illumination component: I_a = (0.1, 0.1, 0.1).

The sphere has the following properties:

- The ambient and diffuse reflection coefficients have the same value:

$$k_a = k_d = (0.5, 0.5, 0.5).$$

- The specular reflection coefficient is k_s = (0.6, 0.6, 0.6).
- The *Phong* coefficient is n = 10.

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point P on the sphere's surface.

a) Compute the intensity of the reflected light due to the ambient illumination component.

b) Compute the intensity of the reflected light due to diffuse reflection. Explain the steps carried out.

c) Compute the intensity of the reflected light due to specular reflection. Explain the steps carried out.

d) What is the light intensity perceived by the viewer? Briefly comment on the results obtained.

2- Consider a given 3D scene, made up of a single sphere of unit radius, centred at (0, 0, 0). The viewer is located at point (10, $\sqrt{2}/2$, 0).

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point P = ($\sqrt{2}/2$, $\sqrt{2}/2$, 0) on the sphere's surface.

There is just one point light source,

- F, located at point ($\sqrt{2}/2$, 5, 0) e and emitting white light.

In addition to the point light source, there is the following ambient light: I_a = (0.1, 0.1, 0.1).

The sphere has the following features:

- The ambient and diffuse reflection coefficients are the same: $k_a = k_d = (0.5, 0, 0)$.
- The specular reflection coefficient is $k_s = (0.6, 0.6, 0.6)$.
- The *Phong* coefficient is $n = 2$.

a) Compute the intensity of the reflected light that is due to diffuse reflection. Explain all the steps carried out.

b) Now, compute the intensity of the reflected light that is due to specular reflection. Explain all the steps carried out.

3- Consider a given 3D scene, made up of a single cube of edge length 2, centred at (0, 0, 0). The viewer is located at point (5, 3, 0).

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point $P = (1, 0, 0)$ on the cube surface, which is the centre of one of the side faces.

There is just one point light source,

- *F*, placed at point (6, -5, 0) and emitting blue light.

In addition to the point light source, there is the following ambient light: $I_a = (0.1, 0.1, 0.1)$.

The cube has the following features:

- The ambient and diffuse reflection coefficients are the same: $k_a = k_d = (0.5, 0.5, 0.5)$.
- The specular reflection coefficient is $k_s = (0.6, 0.6, 0.6)$.
- The *Phong* coefficient is $n = 2$.

a) Compute the intensity of the reflected light that is due to ambient illumination.

b) Compute the intensity of the reflected light that is due to diffuse reflection. Explain all the steps carried out.

c) Now, compute the intensity of the reflected light that is due to specular reflection. Explain all the steps carried out.

d) What is the intensity of the light perceived by the viewer as reflected form point *P*? Briefly comment on the results obtained in the previous steps.

4- Consider a given 3D scene, made up of a sphere with unit radius, centred at (0, 0, 0). The viewer is located at point (5, 1/2, 0).

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point $P = (\sqrt{3}/2, 1/2, 0)$ on the sphere's surface.

There is just one point light source,

- *F*, placed at point (√3/2, 10, 0) and emitting white light.

In addition to the point light source, there is the following ambient light: I_a = (0.1, 0.1, 0.1).

The sphere has the following features:

- The ambient and diffuse reflection coefficients are the same: $k_a = k_d$ = (0.5, 0, 0).
- The specular reflection coefficient is k_s = (0.6, 0.6, 0.6).
- The *Phong* coefficient is n = 2.

a) Compute the intensity of the reflected light that is due to diffuse reflection. Explain all the steps carried out.

b) Now, compute the intensity of the reflected light that is due to specular reflection. Explain all the steps carried out.

NOTE: use the following expression, where all vectors are unit vectors, to obtain the unit vector **R**:

$$\mathbf{R} = 2\,\mathbf{N}\,(\,\mathbf{N}\cdot\mathbf{L}\,) - \mathbf{L}$$

5- Consider a given 3D scene, made up of a single sphere of **radius 1**, centred at **(2, 0, 0)**. The viewer is located at point **(−10, √2/2, 0**).

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point $\boldsymbol{P} = (2 - \sqrt{2}/2, \sqrt{2}/2, 0)$ on the sphere's surface.

There is just one light source,

- *F*, placed at an indefinite distance (**directional light source**) along the positive *YY'* semi-axis and emitting white light.

In addition to the point light source, there is the following ambient light: I_a = (0.1, 0.1, 0.1).

The sphere has the following features:

- The ambient and diffuse reflection coefficients are the same: $k_a = k_d$ = (0.5, 0, 0).
- The specular reflection coefficient is k_s = (0.6, 0.6, 0.6).
- The *Phong* coefficient is n = 2.

a) Compute the intensity of the reflected light that is due to diffuse reflection. Explain all the steps carried out.

b) Now, compute the intensity of the reflected light that is due to specular reflection. Explain all the steps carried out.

Attention: use the following expression, where all vectors are unit vectors, to compute the unit vector **R**:

$$\mathbf{R} = 2\,\mathbf{N}\,(\,\mathbf{N}\cdot\mathbf{L}\,) - \mathbf{L}$$

6- Consider a given 3D scene, made up of a single cylinder of radius 1 and height 10, centred at (0, 0, 0) and whose axis coincides with *ZZ'*. The viewer is located at point (5, √3/2, 2).

Compute, using the *Phong Illumination Model*, the light intensity perceived by the viewer as reflected by point P = (1/2, √3/2, 2) on the cylinder surface.

There is just one light source,

- *F*, placed at an indefinite distance (**directional light source**) along the positive *YY'* semi-axis and emitting white light.

In addition to the point light source, there is the following ambient light: I_a = (0.1, 0.1, 0.1).

The cylinder has the following features:

- The ambient and diffuse reflection coefficients are the same: $k_a = k_d$ = (0.6, 0.6, 0.0).
- The specular reflection coefficient is k_s = (0.5, 0.5, 0.5).
- The *Phong* coefficient is n = 2.

a) Compute the intensity of the reflected light that is due to diffuse reflection. Explain all the steps carried out.

b) Now, compute the intensity of the reflected light that is due to specular reflection. Explain all the steps carried out.

Attention: use the following expression, where all vectors are unit vectors, to compute the unit vector **R**:

$$\mathbf{R} = 2\,\mathbf{N}\,(\,\mathbf{N}\cdot\mathbf{L}\,) - \mathbf{L}$$

c) What is the intensity of the light perceived by the viewer as reflected form point *P*? Briefly comment on the results obtained in the previous steps.