Illumination Model

Wireframe rendering
simple, ambiguous

Color filling
flat without any
3D information

Requires modeling interaction of light with the object/surface to have a different color (shade) in 3D
Illumination Model

Light on a surface is
• Absorbed
• Reflected
• Transmitted

The amount reflected determines the color and brightness of the object
light material (surface) interaction
Illumination Model

The reflected light is scattered depending upon the surface properties and incident light.

Ambient light comes from all directions, is scattered in all directions.

Diffuse light comes from one direction and is scattered in all directions.

Specular light comes from one direction and is scattered in preferred direction.
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Diffuse Reflection

L: Light vector
N: Normal
θ: Angle between L and n

Lambert’s Law

\[ I_{\text{diffuse}} \propto \cos \theta \]
\[ I_d = k_d I_l \cos \theta \]
\[ I_d = k_d I_l (L \cdot N) \]

\( k_d \) diffuse reflection coefficient
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Diffuse Reflection
Illumination Model

Diffuse Reflection

Lambert's Cosine Law
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Diffuse Reflection

Amount of light reflected depends on the direction to the light source and not on the direction to the viewer

Viewer independent

Distance from light source $q$ can also be incorporated

\[ I_d = k_d I_l (L \cdot N) \]

\[ = \frac{k_d}{a + bq + cq^2} I_l (L \cdot N) \]
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Specular Reflection

• Highlights / Shininess
• Viewing Direction
Illumination Model

Specular Reflection

L: Light vector
N: Normal
\( \theta \): Angle between L and N
\( \alpha \): Angle between R and V

\[ I_s = k_s I_i \cos^n \alpha \]

\( I_s \): Specular reflection coefficient
\( k_s \): Specular reflection coefficient
\( n \): Specular reflection exponent
Illumination Model

Specular Reflection

large $n$: metals
small $n$: paper
Illumination Model

Specular Reflection

Example
Illumination Model

Ambient Reflection

Light from distributed light sources (and surroundings)

Also approximates effects of diffusely reflected light from outer bodies / objects.

\[ l_{ambient} = k_a l_a \]

- \( k_a \) ambient reflection coefficient
- \( l_a \) ambient incident light
Illumination Model

Phong Illumination Model

\[ I_{total} = \text{ambient reflection} + \text{diffuse reflection} + \text{specular reflection} \]
\[ = k_a I_a + k_d I_i \cos \theta + k_s I_i \cos^n \alpha \]
\[ = k_a I_a + k_d I_i (L \cdot N) + k_s I_i (R \cdot V)^n \]
\[ = k_a I_a + \sum_{i=1}^{m} k_d I_i (L_i \cdot N) + k_s I_i (R_i \cdot V)^n \]
Illumination Model

Phong Illumination Model

Local computation for obtaining color (intensity) at a point of the surface

Basic inputs are light(s), material properties
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Reflection Vector

\[ R = 2(L \cdot N)N - L \]
Instead of $R \cdot V$ can use $N \cdot H$

$$H = \frac{L + V}{|L + V|}$$
Illumination Model

Normal Vector

Plane

\[ ax + by + cz + d = 0 \]

\[ n \cdot (p - p_0) = 0 \]
\[ n = [a \ b \ c] \]

Normalize
Illumination Model

Normal Vector

Plane

\[ n = (v_3 - v_1) \times (v_2 - v_1) \]

Normalize
Illumination Model

Normal Vector

Sphere

Implicit Equation

\[
f(x, y, z) = x^2 + y^2 + z^2 - 1 = 0
\]

\[
n = \begin{bmatrix}
\frac{\partial f}{\partial x} & \frac{\partial f}{\partial y} & \frac{\partial f}{\partial z}
\end{bmatrix}
\]
Illumination Model

Normal Vector

Parametric Surface

\[ n(u, v) = \frac{\frac{\partial}{\partial u} b^{m,n}(u, v) \times \frac{\partial}{\partial v} b^{m,n}(u, v)}{\left| \frac{\partial}{\partial u} b^{m,n}(u, v) \times \frac{\partial}{\partial v} b^{m,n}(u, v) \right|} \]
Illumination Model

Light Sources

Point light source
  Given by a point
  Light emitted in all directions

Direction light source
  Given by a vector

Spotlight light
  Given by a cone
Rendering

Illumination Model