Illumination and Shading

Illumination
- Illumination models
  - Light and surfaces
  - Local illumination versus Global illumination
  - Phong reflection model
    - Ambient reflection
    - Diffuse reflection
    - Specular reflection
    - Light attenuation
- Polygonal shading
  - Flat Shading
  - Gourand Shading
  - Phone Shading

Illumination Model
- Also called reflection model or lighting model.
- Describe the interaction between the light sources and the surfaces.
- Local illumination models versus global illumination models.
- Local models are ad-hoc, but fast and easy.
- Global models are more accurate, but much more expensive.

Light Sources
- Point sources
- Spotlights
- Distant light

Point Source

Spotlights
Distant light

Surface types

Phong Reflection Model

• An efficient approximation of physical reality.
• Supports three types of material-light interactions.
  • Ambient
  • Diffuse
  • Specular

Ambient Reflection

• \( I_a = k_a L_a \)
• \( 0 \leq k_a \leq 1 \)

Diffuse Reflection

• \( I_d = k_d L_d \cos \theta \)
• \( \cos \theta = l \cdot n \)
• \( I_s = k_s L_s (l \cdot n) \)

Specular Reflection

• \( I_s = k_s L_s \cos^\alpha \phi \)
• \( \cos \phi = r \cdot v \)
• \( I_s = k_s L_s (r \cdot v)^\alpha \)
**Phong Model**

- \( I = I_a + I_d + I_s = k_s L_s (r \cdot v)^{\alpha} + k_d L_d (l \cdot n) + k_a L_a \)
- With light attenuation by distance
  
  \[ I = \frac{1}{(a + b d + c d^2)} \left( k_d L_d (l \cdot n) + k_s L_s (r \cdot v)^{\alpha} \right) + k_a L_a \]

**Polygonal Shading**

- Flat shading
- Gourand shading
- Phong shading

**Flat Shading**

- `glShadeModel(GL_FLAT)`
  - Constant intensity shading, i.e. the intensity is constant for each polygon.
  - Very simple to implement, however, it may introduce intensity discontinuities by Mach band effect.

**Mach Band Effect**

- The human visual system is very sensitive to small differences in light intensity.
- Because of a property known as lateral inhibition.

**Gourand Shading**

- `glShadeModel(GL_SMOOTH)`
  - Interpolative intensity shading.
  - Calculate intensity at each vertex of the polygon and interpolate the other intensity values.

**Normal vector calculation**

```
\[ n_1 \quad n_2 \quad n_3 \quad n_4 \]
```
Phong shading

- Evaluate the intensity at each pixel.
- The normals are interpolated.
- Often done off-line.
- \( n_c = (1-\alpha)n_a + \alpha n_b \)
- \( n_a = n_a / |n_a| \)

\[ \begin{align*}
&n_a \\
&n_b \\
&n_c
\end{align*} \]