CS 378: Computer Game Technology

Basic Rendering Pipeline and Shading
Spring 2012
Recall the standard graphics pipeline:
Normal Vectors

- The intensity of a surface depends on its orientation with respect to the light and the viewer
  - CDs are an extreme example
- The surface normal vector describes the orientation of the surface at a point
  - Mathematically: Vector that is perpendicular to the tangent plane of the surface
    - What’s the problem with this definition?
  - Just “the normal vector” or “the normal”
- Will use N to denote
Local Shading Models

- Local shading models provide a way to determine the intensity and color of a point on a surface
  - The models are local because they don’t consider other objects at all
  - We use them because they are fast and simple to compute
  - They do not require knowledge of the entire scene, only the current piece of surface
Local Shading Models (Watt 6.2)

- What they capture:
  - Direct illumination from light sources
  - Diffuse and Specular components
  - (Very) Approximate effects of global lighting

- What they don’t do:
  - Shadows
  - Mirrors
  - Refraction
  - Lots of other stuff …
“Standard” Lighting Model

- Consists of several simple terms linearly combined:
  - Diffuse component for the amount of incoming light reflected equally in all directions
  - Specular component for the amount of light reflected in a mirror-like fashion
  - Ambient term to approximate light arriving via other surfaces
Diffuse Illumination

- Incoming light, $I_i$, from direction $L$, is reflected equally in all directions $k_d I_i (L \cdot N)$
  - No dependence on viewing direction

- Amount of light reflected depends on:
  - Angle of surface with respect to light source
    - Actually, determines how much light is collected by the surface, to then be reflected
  - Diffuse reflectance coefficient of the surface, $k_d$

- Don’t want to illuminate back side. Use

\[ k_d I_i \max(L \cdot N,0) \]
Diffuse Example

Where is the light source?
Specular Reflection (Phong Model)

- Incoming light is reflected primarily in the mirror direction \( \mathbf{R} \)
  - Perceived intensity depends on the relationship between the viewing direction \( \mathbf{V} \) and the mirror direction \( \mathbf{R} \)
  - Bright spot is called a specular highlight

- Intensity controlled by:
  - The specular reflectance coefficient \( k_s \)
  - The parameter \( n \) controls the apparent size of the specular highlight
    - Higher \( n \), smaller highlight

\[
k_s I_i (\mathbf{R} \cdot \mathbf{V})^n
\]
Specular Example

Plus Specular Highlight
Putting It Together

- Global ambient intensity, $I_a$:
  - Gross approximation to light bouncing around of all other surfaces
  - Modulated by ambient reflectance $k_a$
- Emitted term $I_e$ – no reflected light, comes from object
- Just sum all the terms
- If there are multiple lights, sum contributions from each light
- Several variations, and approximations …

$$I = I_e + k_a I_a + \sum_{\text{lights } i} I_i \left( k_d (L_i \cdot N) + k_s (R_i \cdot N)^n \right)$$
**Flat shading**

- Compute shading at a representative point and apply to whole polygon
  - OpenGL uses one of the vertices

**Advantages:**
- Fast - one shading value per polygon

**Disadvantages:**
- Inaccurate
- Discontinuities at polygon boundaries
Gourand Shading

- Shade each vertex with its own location and normal
- Linearly interpolate across the face

**Advantages:**
- Fast - incremental calculations when rasterizing
- Much smoother - use one normal per shared vertex to get continuity between faces

**Disadvantages:**
- Specular highlights get lost
Phong Interpolation

- Interpolate normals across faces
- Shade each pixel

**Advantages:**
- High quality, narrow specular highlights

**Disadvantages:**
- Expensive
- Still an approximation for most surfaces

- Not to be confused with Phong’s shading model