Illumination, Phong, Gouraud

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Illumination and Shading

• Shading: model the appearance of the object under the influence of light
  – reflection
  – refraction
  – transparency

• Object material model
  – heuristic models (=hacks): Phong
  – physically based: Torrance-Sparrow
Map of the lecture

• Material models:
  – ambient light
  – diffuse light
  – specular light
  – Phong model

• Interpolation:
  – Gouraud shading, Phong shading
  – Problems with interpolation
Shading

- Objects under the influence of light
- Assume point light source
- Excludes any interaction between objects:
  - shadows, reflections, color-bleeding
- Compute color at every point
Ambient Light

• Color does not depend on the position, only on the object:
  \[ I = I_a k_a \]

• \( I_a \): ambient light
• \( k_a \): ambient reflection coefficient

• Very crude model
  – object shape is invisible
  – but used nevertheless to hide other models artefacts
Ambient Light

Increasing $k_a$
Diffuse Reflection

• aka mate reflection
• Light from the light source is sent in every direction
• Object aspect independant from viewer position
• Only depends on relative position of light source:
  \[ I = I_{pk}d \cos\theta \]
Diffuse Reflection

- \( I = I p k_d \cos \theta \)
- \( I_p \): point light source
- \( k_d \): diffuse reflection coefficient
- \( \theta \): angle between light source and normal

\[ P \]
Diffuse reflection alone

Increasing $kd$ ($ka=0$)
Diffuse + ambient

Increasing $ka$

Increasing $kd$
Specular reflection

- Snell’s law:
  - light reaching the object is reflected in the direction having the same angle:
Specular Reflection problem

- With point light source, effect is visible only at one point on the surface
- Useful for indirect illumination (reflection and shadows)
Phong Model

• Imperfect specular reflector:
Phong Model

- \( I = I_p \ k_s \ (\cos \alpha)^n \)
Phong Model

Increasing $n$

$ks$
Torrance-Sparrow Model

- Phong model has no physical meaning
- Happens to look good, but we don’t know why
- How to relate it to physical properties (roughness)?
- Cook-Torrance-Sparrow Model
  - related to physical properties
  - but complex
Torrance-Sparrow Model (2)

- The surface is modelled as micro-facets:

- Light incoming on the facets is scattered, reflected, obscured…

- Depends on the geometrical distribution of the facets
Torrance-Sparrow

• Geometrical factor expressing the facets effects

• Depends on light and viewpoint direction: \( \rho(\theta,\phi,\theta',\phi') \)

• No simple function like \((\cos \theta)^n\)

• Approximates very well physical effects (shininess, roughness...)
Shading a whole object

• We have seen only shading computations for a single point
• We could compute shading information for all visible points in the scene
  – What??
• Constant shading for each patch

• Interpolated shading across the patch
• Mach banding effect
Mach Banding

• The eye is a complex receptor
  – can adapt from a starry night to a bright halogen lamp

• The eye exagerates changes in intensity and changes in slope of intensity
  – called Mach banding effect

• Problem if we compute a constant value for each polygon
Mach banding

Perceived intensity

Actual intensity
Interpolated Shading

- **Gouraud**: compute color value for each vertex, then interpolate
- **Start with a polygonal mesh**
- **What is the normal at a vertex?**
Gouraud shading

• Normal at one vertex:
  – interpolate normals at neighbouring patches
Gouraud Shading

• Having the normal at one vertex:
  – compute color value at this vertex

• Then, interpolate on each scan line:
Phong Shading

• Instead of interpolating the colors, interpolate the normals
• Interpolation of the normals on each scan line too
• Much slower than Gouraud, but looks better
Problems with interpolation

- Polygonal silhouette
  - add more patches
- Orientation dependant:
Shadows and transparency

• So far, only one object
• Objects may interact with each other
• Local vs. global approach:
    • ray-tracing
    • radiosity
Local computation of shadows

• Visible surface determination from the light source

• Surfaces invisible from the light source are in the shadow
  – but still lit by ambient term, in order to appear on the picture.
Local transparency

• Each polygon is colored using not only its color, but that of the polygon immediately behind
  – implies knowledge of relative order
    • depth-sort algorithm
    • scan-line algorithm
    • specifically excludes Z-buffer
Texture mapping

- Change the surface local behaviour to model complex objects
- Map an image onto the surface of the object
- Correspondance between \((u,v)\) space of the image and \((s,t)\) space of the object
Shading: conclusion

• Realism has its price
• Trading between quality and time
• Most of the time, hacks that happen to look good
• Algorithm simplicity is crucial:
  – Gouraud shading and texture mapping can be done in hardware, or optimized in assembly language