Illumination and Shading

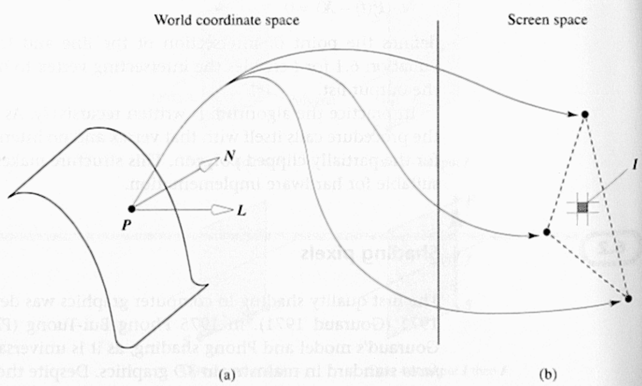
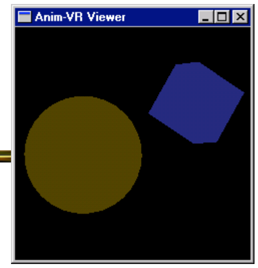


Figure 6.5 Illustrating the difference between local reflection models and shading algorithms. (a) Local reflection models calculate light intensity at any point ***P*** on the surface of an object. (b) Shading algorithms interpolate pixel values from calculated light intensities at the polygon vertices.

Illumination and Shading

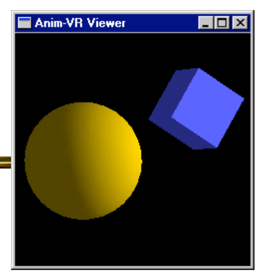
- Illumination Models
  - Ambient
  - Diffuse
  - Attenuation
  - Specular Reflection
- Interpolated Shading Models
  - Flat, Gouraud, Phong
  - Problems

Illumination Models: Ambient Light



- Simple illumination model
  $I = k_i$
- Use nondirectional lights
  $I = I_a k_a$
- I_a = ambient light intensity
- k_a = ambient-reflection coefficient
- Uniform across surface

Diffuse Light



- Account for light position
  - Ignore viewer position
- Proportional to cosθ between N and L

$$I = I_p k_d \cos\theta = I_p k_d (N \cdot L)$$

- Model:

$$I = I_a k_a + I_p k_d (N \cdot L)$$

Attenuation: Distance

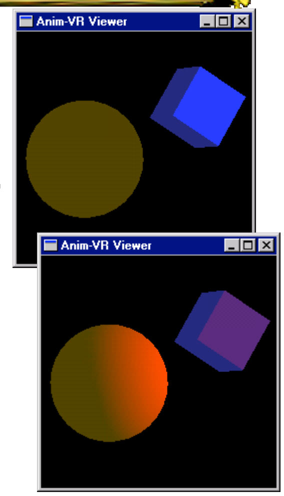
- f_{att} models distance from light
  $I = I_a k_a + f_{att} I_p k_d\ (N \cdot L)$
- Realistic
  $f_{att} = 1/(d_L^2)$
- Hard to control, so OpenGL uses
  $f_{att} = 1/(c_1 + c_2 d_L + c_3 d_L^2)$

Attenuation: Atmospheric (fog, haze)

- z_f and z_b: near/far depth-cue plane
- s_f and s_b: scale factors
- I_{dc}: depth cue color
- Given $z_f > z_0 > z_b$ interpolate $s_f > s_0 > s_b$
- Adjust intensity
  $I' = s_0 I + (1 - s_0) I_{dc}$

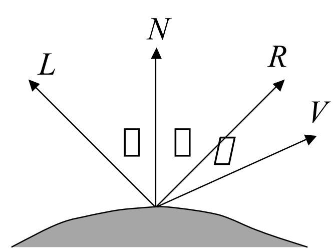
Colored Lights
(slightly different, but equivalent, to book)

- O_d: diffuse color
  - (O_{dR}, O_{dG}, O_{dB})
- Compute for each component
- i.e. red compenent is
  $I_R = I_{aR} k_a O_{dR} + f_{att} I_{pR} k_d O_{dR} (N \cdot L)$
- Note: use O_d for ambient and diffuse



Specular Reflection: Phong Model

- Account for viewer position
  - Create highlights
- Based on $\cos^n \phi = (R \cdot V)^n$
  - Larger n, smaller highlight
- k_s: specular reflection coef.



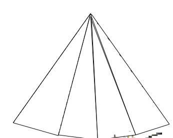
$$I = I_a k_a O_d + f_{att} I_p \left[k_d O_d (N \cdot L) + k_s (R \cdot V)^n \right]$$

Multiple Light Sources

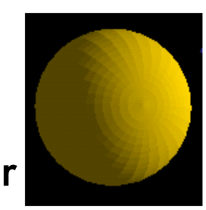
- Obvious summation over *m* lights:

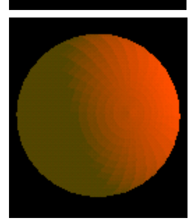
$$I = I_a k_a O_d + \sum_{1 \le i \le m} f_{att\,i} I_{pi} [\, k_d O_d (N \cdot L_i) + k_s (R_i \cdot V)^n]$$

Shading Models: Flat Shading



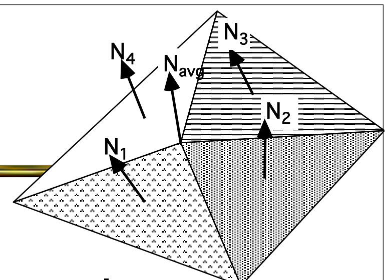
- Compute one color for polygon
  - Use polygon normal in lighting eqs.
- Every pixel is assigned same color



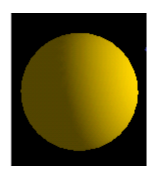


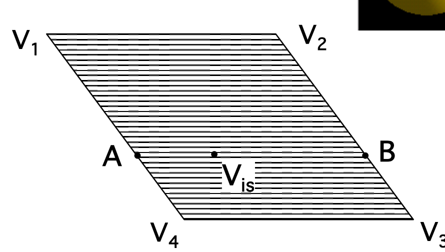
- Fast and simple
- Shade of polygons independent

Gouraud Shading



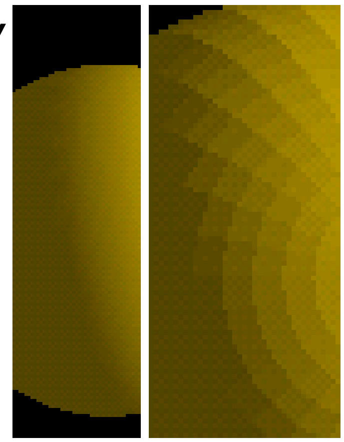
- Compute vertex normals
  - Average normals of abutting polygons
- Use vertex normal in lighting eqs.
- Linearly interpolate vertex intensities
  - Along edges
  - Along scan lines





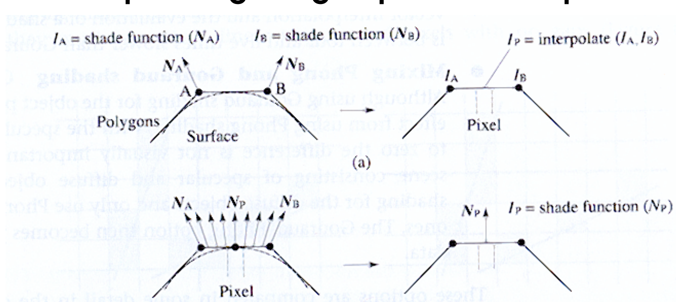
Gouraud Shading

- Often appears dull, chalky
  - Lacks accurate specular component
    - If included, will be averaged over entire polygon
- Mach banding
  - Artifact at discontinuities in intensity or intensity slope



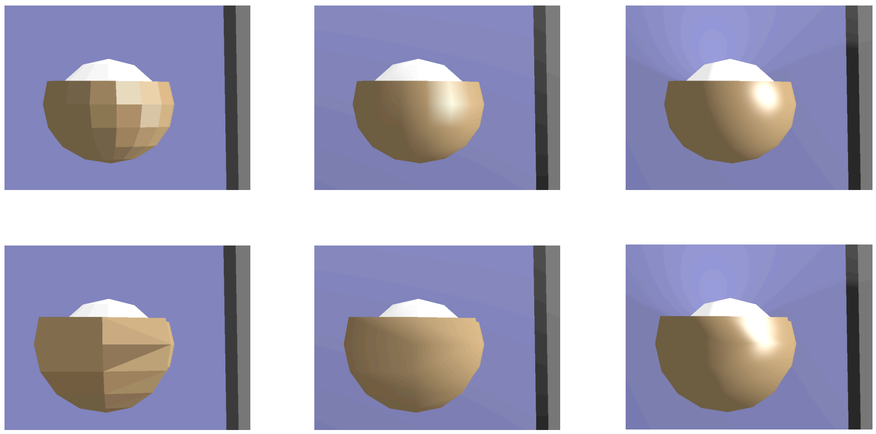
Phong Shading

- Linearly interpolate vertex normals
  - Compute lighting eqs. at each pixel



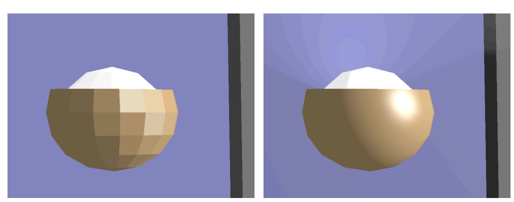
- Can use specular component

Closeup: Flat, Gouraud, Phong

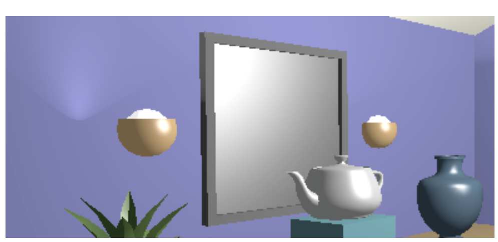


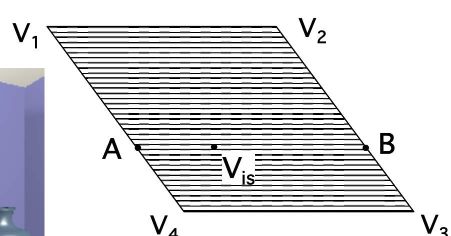
Problems with Interpolated Shading

- Polygonal silhouette



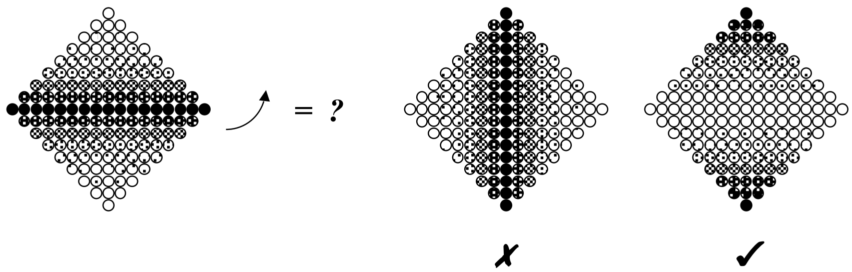
- Perspective distortion





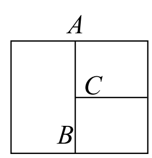
Problems with Interpolated Shading

- Scanline/orientation dependent
  - Creates temporal aliasing when used to render animation frames:

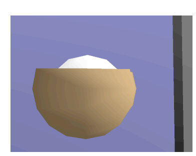


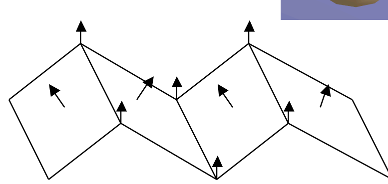
Problems with Interpolated Shading

- Shared vertices



- Unrepresentative vertex normals
  - Missed specular highlights
  - Missed geometry





Lighting, in practice

- Full lighting equation:

$$I = I_a k_a O_d + \sum_{1 \le i \le m} f_{att_i} I_{p_i} [\, k_d O_d (N \cdot L_i) + k_s (R_i \cdot V)^n]$$

- Ignore specular for now
- Each surface: O_d, k_a, k_d, $v_{i\ (i=0..n)}$, N
- Each light: $I_{a \text{ or } d}$, f_{att} (c_1, c_2, c_3), P_L (position)

At a given point

- Start with ambient: $I_a k_a O_d$
  - R/G/B using I_{aR}, I_{aG}, I_{aB}, O_{dR}, O_{dG}, O_{dB}
- For each Light, compute: $f_{att} I_p k_d O_d (N \cdot L_i)$
  - Position (P_P), normal (N_P)
  - L vector
  - d_L
  - $f_{att} = 1/(c_1 + c_2 d_L + c_3 d_L^2)$
  - R/G/B using I_{pR}, I_{pG}, I_{pB}, O_{dR}, O_{dG}, O_{dB}

Light Intensity Values

- I_a, I_d
  - Represent intensity
  - Have R,G,B components
  - Do not need to fall in the 0..1 range!
    - Often need I_d>1
    - Final computed $I \le 1$

Specular

- A light might have a diffuse and specular specification, say I_s
  - Allow slightly different colors, more control
    - Remember, it's a hack anyway!
- I_s would have RGB parts, as with I_a, I_d
- Illumination formula becomes

$$I = I_a k_a O_d + \sum_{1 \le i \le m} f_{att\,i} \left[I_{pd\,i} k_d O_d (N \cdot L_i) + I_{ps\,i} k_s (R_i \cdot V)^n \right]$$