IMGD 3000 - Technical Game Development I: Illumination

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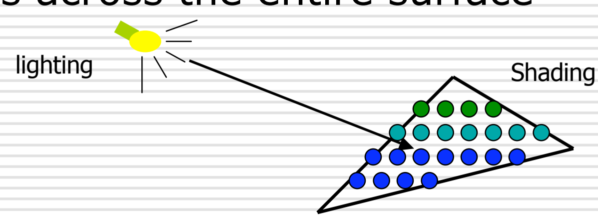
3D Illumination and Shading

- Problem: Model light/surface point interactions to determine final color and brightness
- Actual light computation is too costly!
- Apply the lighting model at a set of points across the entire surface

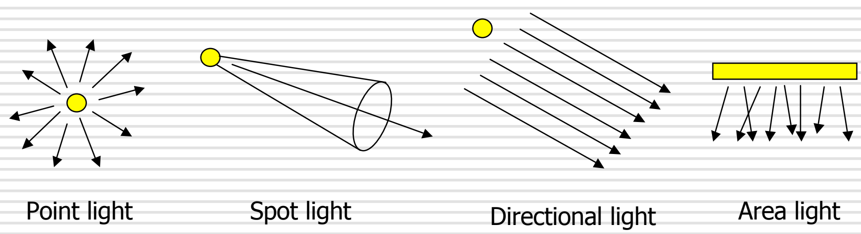


Illumination Model

- The governing principles for computing the illumination
- An illumination model usually considers
  - Light attributes (intensity, color, position, direction, shape)
  - Object surface attributes (color, reflectivity, transparency, *etc.*)
  - Interaction among lights and objects

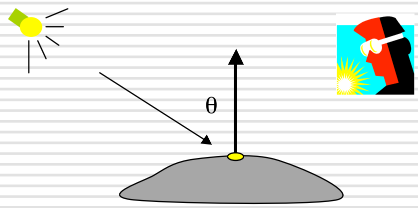
Basic Light Sources

- Light intensity can be independent or dependent of the distance between object and the light source



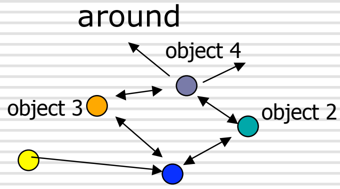
Local Illumination

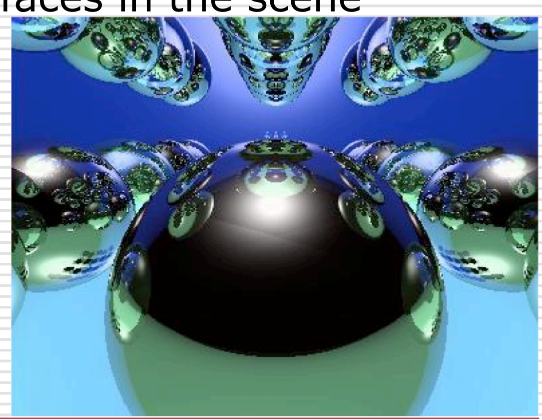
- Only consider the light, the observer position, and the object material properties



Global Illumination

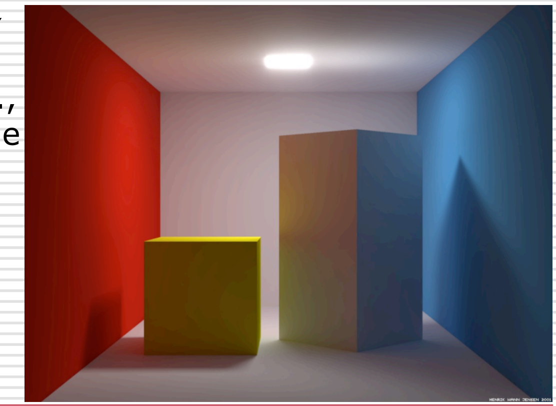
- Take into account the interaction of light from all the surfaces in the scene
- Example:
  - Ray Tracing
  - Model light rays bouncing around





Global Illumination (cont.)

- Example:
  - Radiosity
    - Model *energy* moving from emitters (e.g., lights) into the scene
    - View independent

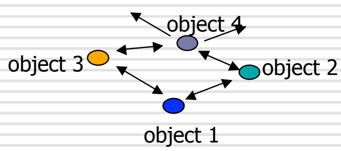


Simple Local Illumination

- Reduce the complex workings of light to three components
  - Ambient
  - Diffuse
  - Specular
- Final illumination at a point (vertex) = ambient + diffuse + specular
- Materials reflect each component differently
  - Use different material reflection coefficients
    - K_a, K_d, K_s

Ambient Light Contribution

- Ambient light = background light
- Light that is scattered by the environment
  - It's just there
- **Frequently assumed to be constant**
- Very simple approximation of global illumination
- No direction: independent of light position, object orientation, observer's position/orientation

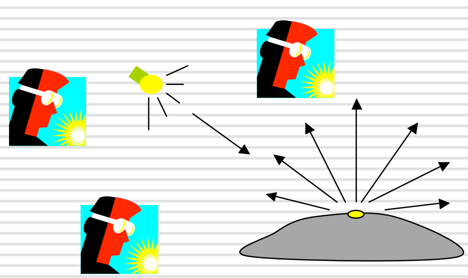


constant

$$\text{Ambient} = I \times K_a$$

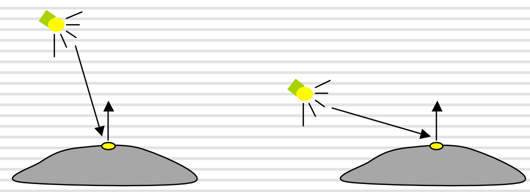
Diffuse Light Contribution

- Diffuse light: The illumination that a surface receives from a light source that reflects equally in all direction
  - Eye point does not matter



Diffuse Light Calculation

- Need to decide how much light the object point receives from the light source
  - Based on Lambert's Law



Diffuse Light Calculation (cont.)

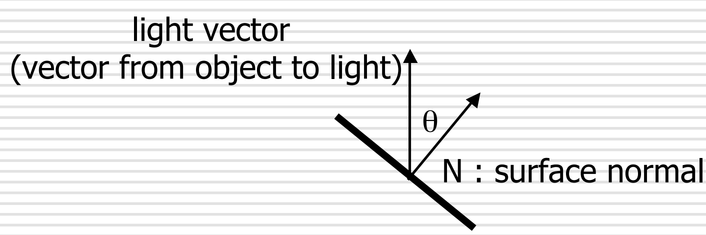
- Lambert's law: the radiant energy D that a small surface patch receives from a light source is:

$$\text{Diffuse} = K_d \times I \times \cos(\theta)$$

K_d: diffuse reflection coefficient

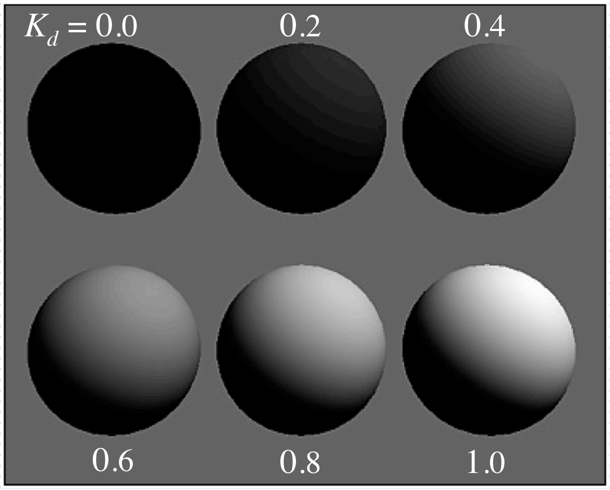
I: light intensity

θ: angle between the light vector and the surface normal



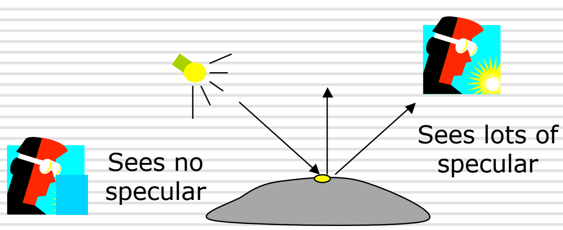
Diffuse Light Examples

I = 1.0



Specular Light Contribution

- The bright spot on the object
- The result of total reflection of the incident light in a concentrate region

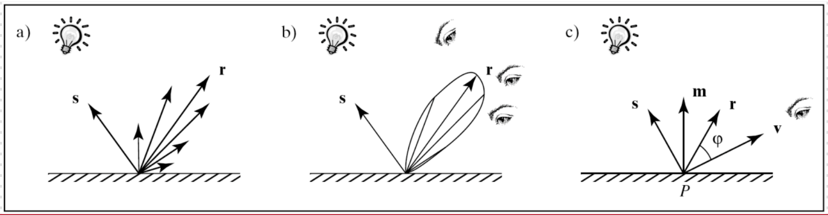


Specular Light Calculation

- How much reflection you can see depends on where you are
  - But for non-perfect surface you will still see specular highlight when you move a little bit away from the ideal reflection direction

  Φ is deviation of view angle from mirror direction

  - When ϕ is small, you see more specular highlight



Specular Light Calculation (cont.)

- Phong lighting model
  - Not Phong *shading* model

$\boxed{\text{Specular} = K_s \times I \times \cos^{f}(\phi)}$

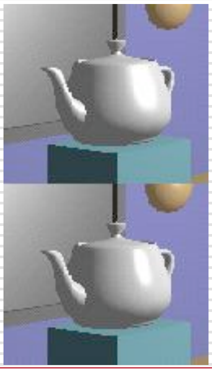
- The effect of 'f' in the Phong model

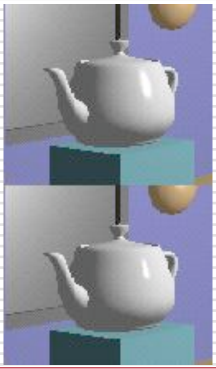
f = 10

f = 90

f = 30

f = 270



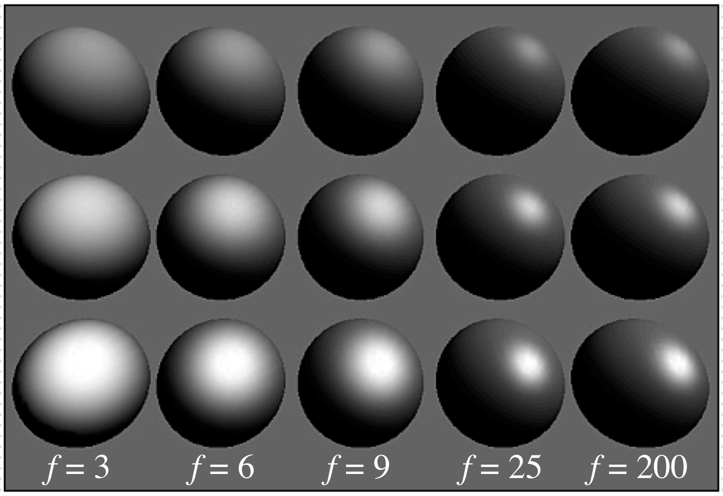


Specular Light Examples

$K_s = 0.25$

$K_s = 0.5$

$K_s = 0.75$



Putting It All Together

- Illumination from a light

  Illum = ambient + diffuse + specular

  $$= K_a \times I + K_d \times I \times \cos(\theta) + K_s \times I \times \cos^f(\phi)$$

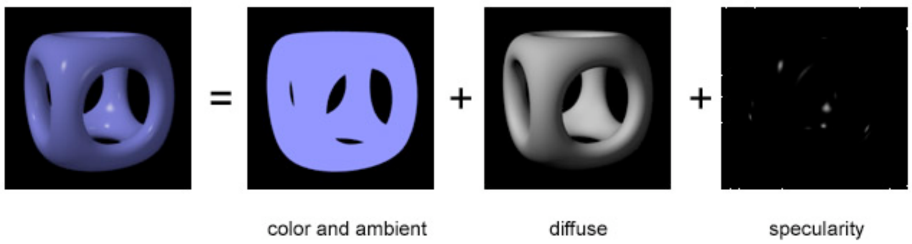
- If there are N lights

  Total illumination for a point P = Σ (Illum)

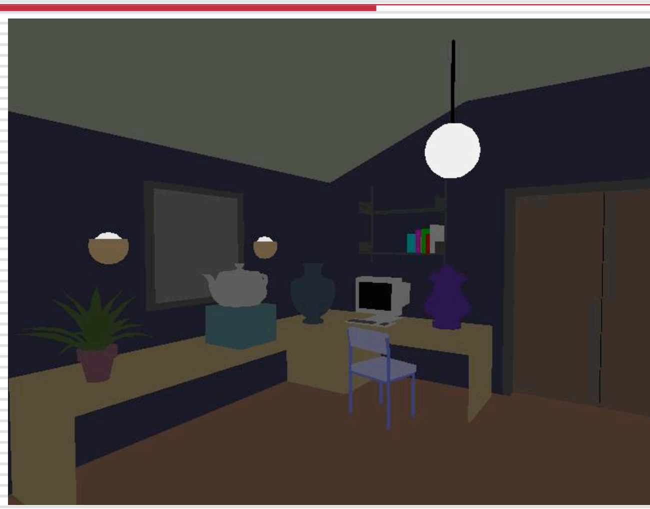
- Some more terms to be added
  - Self emission
  - Global ambient
  - Light distance attenuation and spot light effect

Putting It All Together (cont.)

- Illum = ambient + diffuse + specular



Ambient Lighting Example



Diffuse Lighting Example

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Specular Lighting Example

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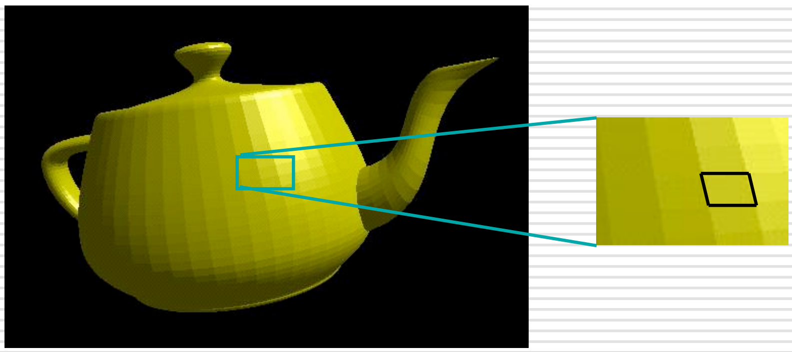
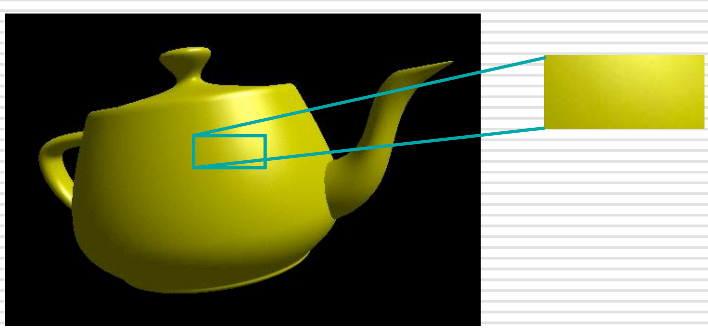
Polygon Shading Models

- Flat shading
  - Compute lighting once and assign the color to the whole polygon (or mesh)

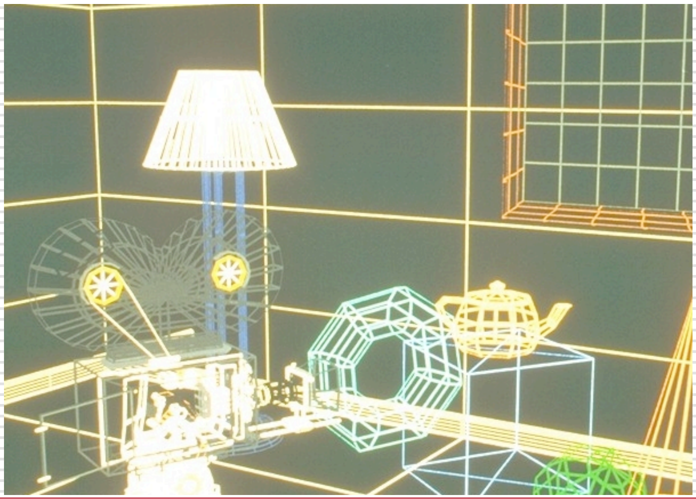


Gouraud Shading

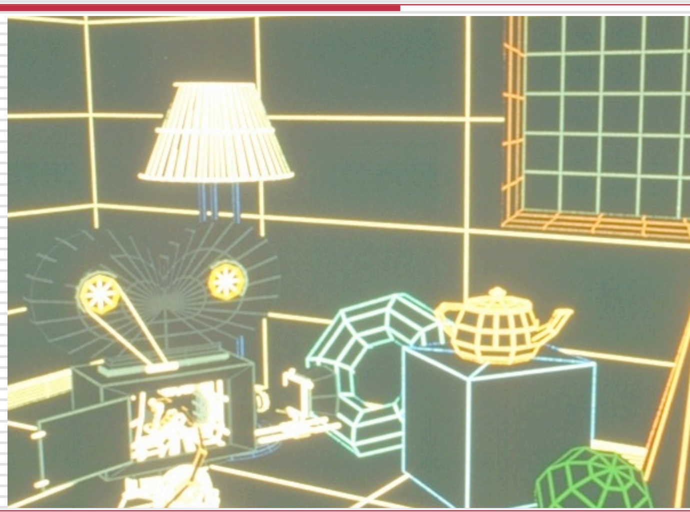
- Lighting is calculated for each of the polygon vertices
- Colors are interpolated for interior pixels



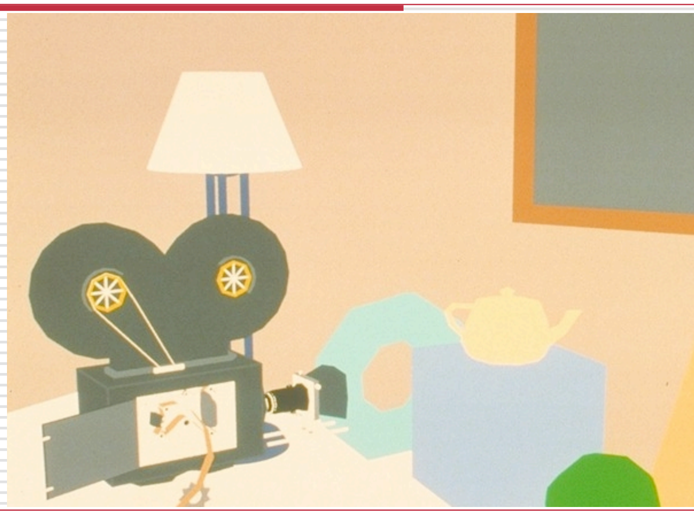
Colored Wireframe



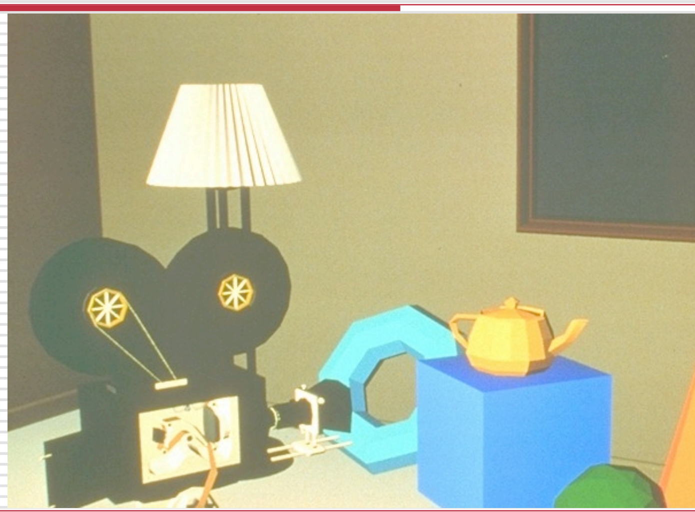
Colored Hidden-Line Removal



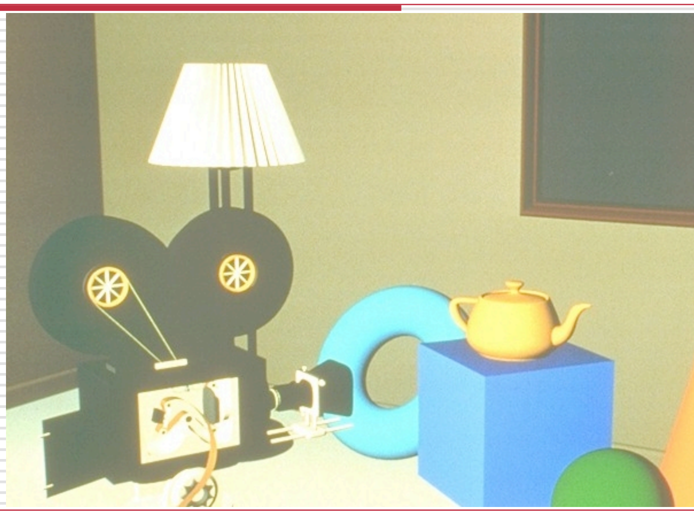
Ambient Term Only



Flat Shading

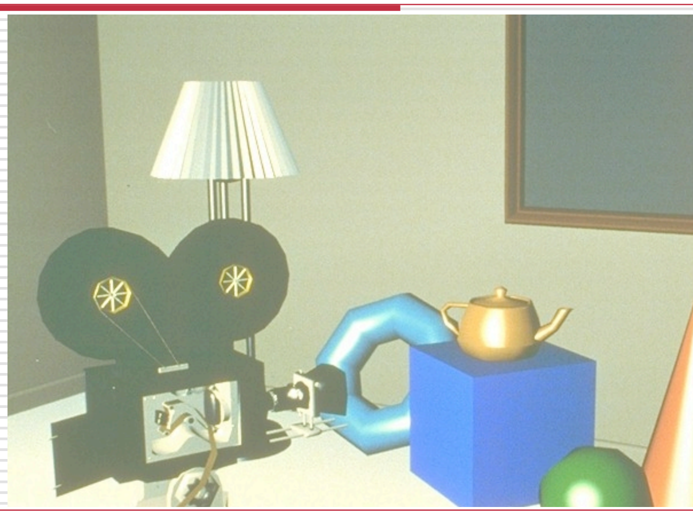


Diffuse Shading + Interp. Normals



Gouraud Shading

Ambient + Diffuse + Specular



Ambient + Diffuse + Specular + Interpolated Normals

Radiosity

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Radiosity + Texture Mapping

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Texture Mapping + Ray Tracing