Shading II

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Objectives

- Continue discussion of shading
- Introduce modified Phong model
- Consider computation of required vectors

Ambient Light

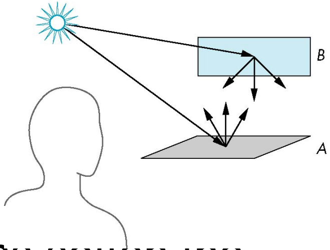
- Ambient light is the result of multiple interactions between (large) light sources and the objects in the environment
- Amount and color depend on both the color of the light(s) and the material properties of the object
- Add $k_a I_a$ to diffuse and specular terms

reflection coef

intensity of ambient light

Distance Terms

- The light from a point source that reaches a surface is inversely proportional to the square of the distance between them
- We can add a factor of the form $1/(ad + bd + cd2)$ to the diffuse and specular terms



- The constant and linear terms soften the effect of the point source

Light Sources

- In the Phong Model, we add the results from each light source
- Each light source has separate diffuse, specular, and ambient terms to allow for maximum flexibility even though this form does not have a physical justification
- Separate red, green and blue components
- Hence, 9 coefficients for each point source

  Idr, Idg, Idb, Isr, Isg, Isb, Iar, Iag, Iab

Material Properties

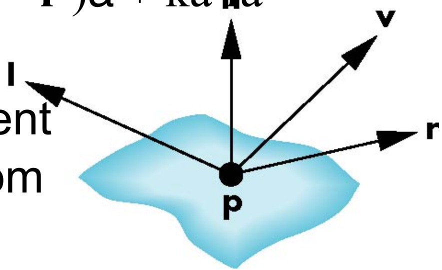
- Material properties match light source properties
  - Nine absorbtion coefficients
    - kdr, kdg, kdb, ksr, ksg, ksb, kar, kag, kab
  - Shininess coefficient a

Adding up the Components

For each light source and each color component, the Phong model can be written (without the distance terms) as

$$I = kd\ Id\ \mathbf{l} \cdot \mathbf{n} + ks\ Is\ (\mathbf{v} \cdot \mathbf{r})a + ka\ Ia$$

For each color component we add contributions from all sources



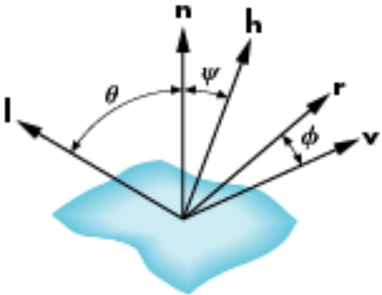
Modified Phong Model

- The specular term in the Phong model is problematic because it requires the calculation of a new reflection vector and view vector for each vertex
- Blinn suggested an approximation using the halfway vector that is more efficient

The Halfway Vector

- **h** is normalized vector halfway between **l** and **v**

$$\mathbf{h} = (\mathbf{l} + \mathbf{v}) / |\mathbf{l} + \mathbf{v}|$$

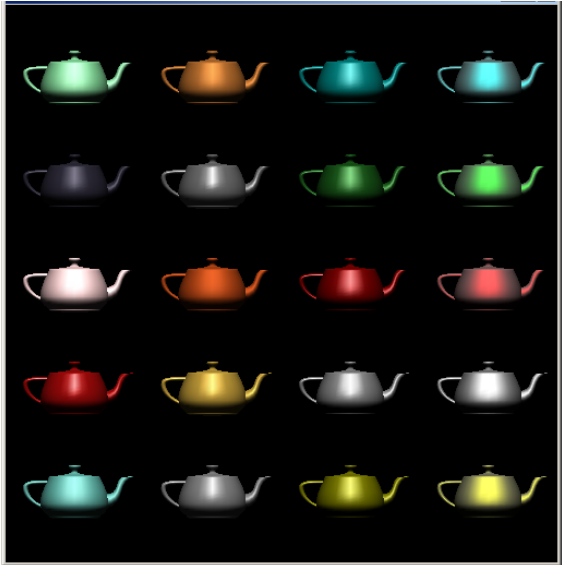


Using the halfway vector

- Replace $(\mathbf{v} \cdot \mathbf{r})^{\alpha}$ by $(\mathbf{n} \cdot \mathbf{h})^{\beta}$
- β is chosen to match shineness
- Note that halway angle is half of angle between $\mathbf{r}$ and $\mathbf{v}$ if vectors are coplanar
- Resulting model is known as the modified Phong or Blinn lighting model
  - Specified in OpenGL standard

Example

Only differences in these teapots are the parameters in the modified Phong model



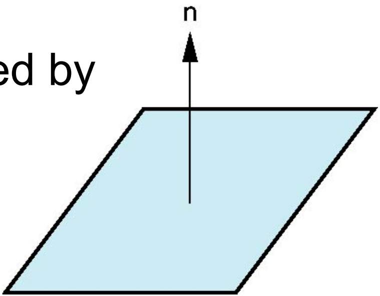
Computation of Vectors

- **l** and **v** are specified by the application
- Can computer **r** from **l** and **n**
- Problem is determining **n**
- For simple surfaces is can be determined but how we determine **n** differs depending on underlying representation of surface
- OpenGL leaves determination of normal to application
  - Exception for GLU quadrics and Bezier surfaces (Chapter 11)

Plane Normals

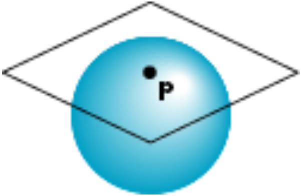
- Equation of plane: $ax+by+cz+d = 0$
- From Chapter 4 we know that plane is determined by three points $p0$, $p2$, $p3$ or normal $\mathbf{n}$ and $p0$
- Normal can be obtained by

n = (p2-p0) × (p1-p0)



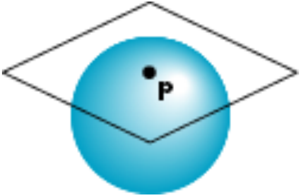
Normal to Sphere

- Implicit function $f(x,y.z)=0$
- Normal given by gradient
- Sphere $f(\mathbf{p})=\mathbf{p}\cdot\mathbf{p}-1$
- $n = [\partial f/\partial x, \partial f/\partial y, \partial f/\partial z]T=\mathbf{p}$



Parametric Form

- For sphere



$$x=x(u,v)=\cos u \sin v$$
$$y=y(u,v)=\cos u \cos v$$
$$z= z(u,v)=\sin u$$

- Tangent plane determined by vectors

$$\partial \mathbf{p}/\partial u = [\partial x/\partial u, \partial y/\partial u, \partial z/\partial u]T$$
$$\partial \mathbf{p}/\partial v = [\partial x/\partial v, \partial y/\partial v, \partial z/\partial v]T$$

- Normal given by cross product

$$\mathbf{n} = \partial \mathbf{p}/\partial u \times \partial \mathbf{p}/\partial v$$

General Case

- We can compute parametric normals for other simple cases
  - Quadrics
  - Parameteric polynomial surfaces
- Bezier surface patches (Chapter 11)