The University of New Mexico

Introduction to Computer Graphics with WebGL

Ed Angel

Professor Emeritus of Computer Science

Founding Director, Arts, Research, Technology and Science Laboratory

University of New Mexico

Lighting and Shading II

Ed Angel
Professor Emeritus of Computer Science
University of New Mexico

Objectives

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

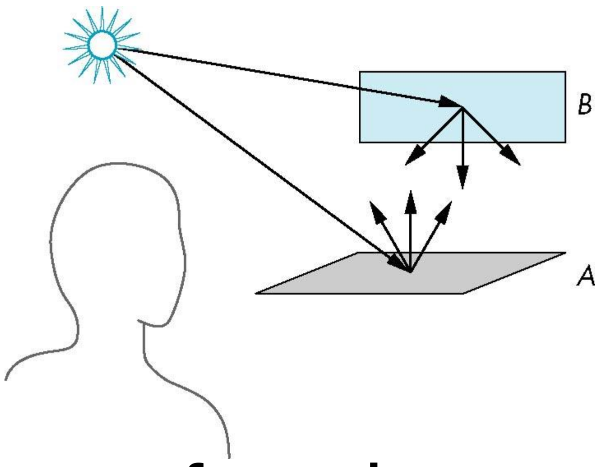
Ambient Light

- 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 $1/(a + bd + cd^2)$ 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
  - I_{dr}, I_{dg}, I_{db}, I_{sr}, I_{sg}, I_{sb}, I_{ar}, I_{ag}, I_{ab}

Material Properties

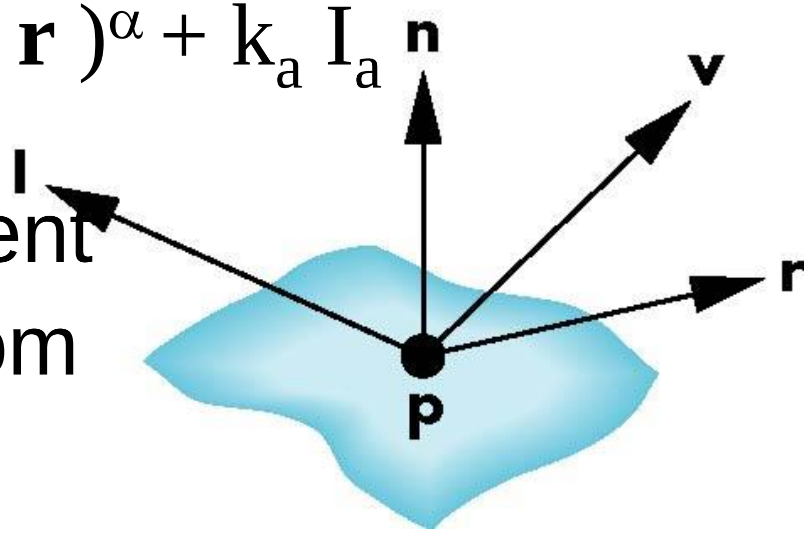
- Material properties match light source properties
  - Nine absorbtion coefficients
    - k_{dr}, k_{dg}, k_{db}, k_{sr}, k_{sg}, k_{sb}, k_{ar}, k_{ag}, k_{ab}
  - Shininess coefficient α

Adding up the Components

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

$$I = k_d I_d \, \mathbf{l} \cdot \mathbf{n} + k_s I_s (\mathbf{v} \cdot \mathbf{r})^{\alpha} + k_a I_a$$

For each color component we add contributions from all sources



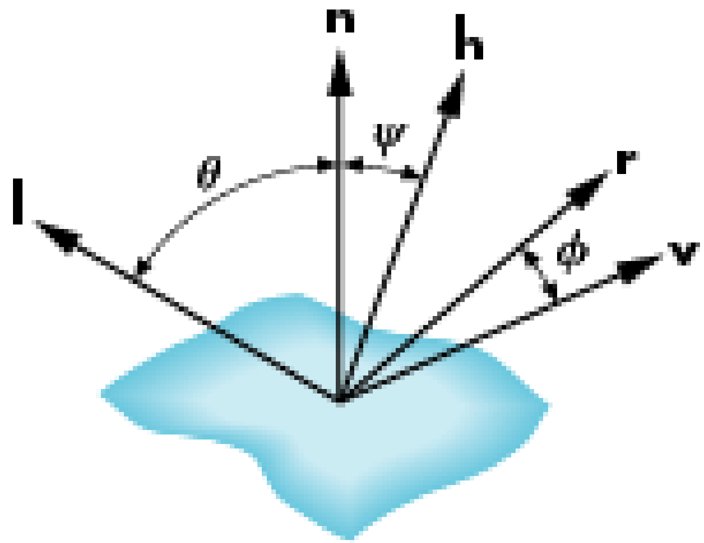
Modified Phong Model

- 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**

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

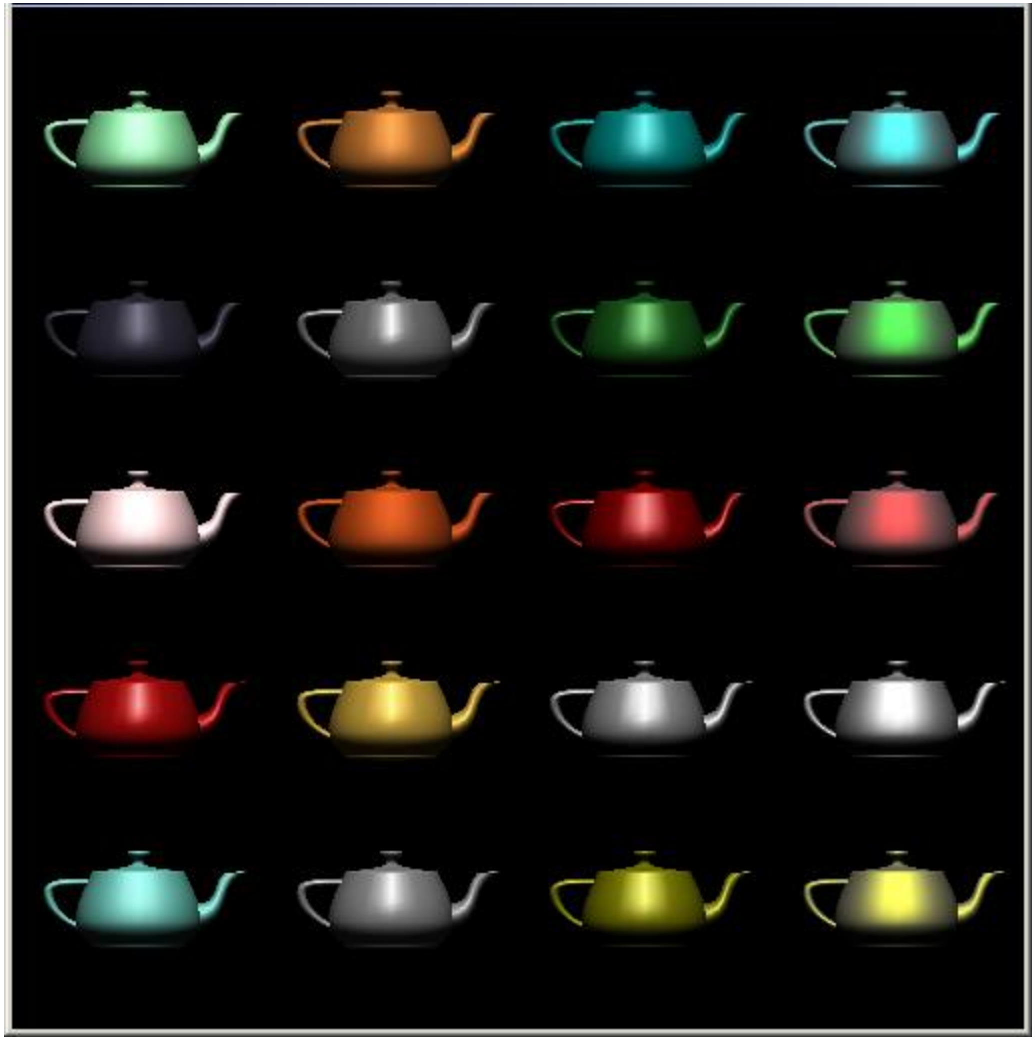


Using the halfway vector

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

Example

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



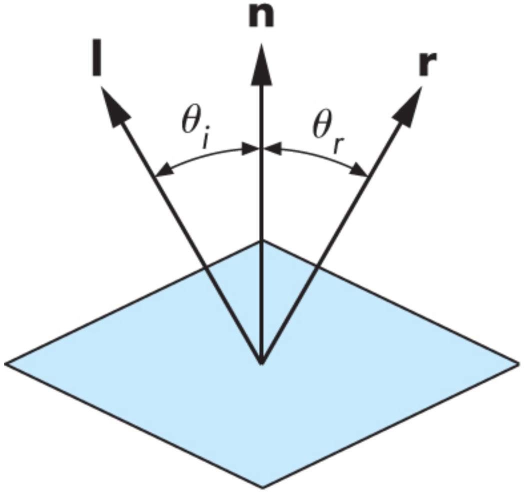
Computation of Vectors

- **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 was deprecated

Computing Reflection Direction

- Angle of incidence = angle of reflection
- Normal, light direction and reflection direction are coplaner
- Want all three to be unit length

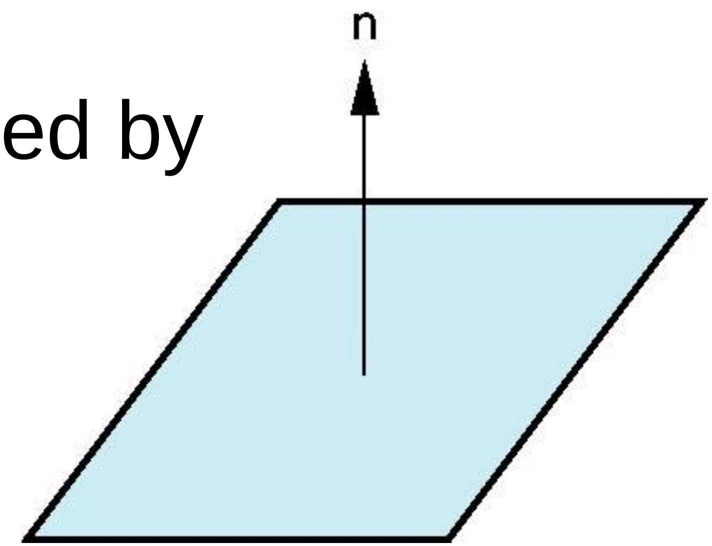
$$r = 2(l \bullet n)n - l$$



Plane Normals

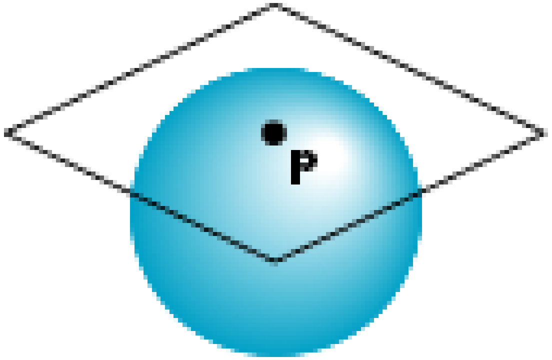
- Equation of plane: $ax+by+cz+d = 0$
- From Chapter 4 we know that plane is determined by three points p_0, p_2, p_3 or normal $\mathbf{n}$ and p_0
- Normal can be obtained by

$$\mathbf{n} = (p_2-p_0) \times (p_1-p_0)$$



Normal to Sphere

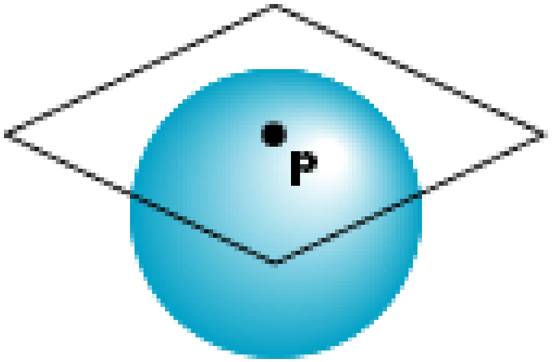
- Implicit function $f(x,y.z)=0$
- Normal given by gradient
- Sphere $f(\mathbf{p})=\mathbf{p}\cdot\mathbf{p}-1$
- $n = [\partial f/\partial x, \partial f/\partial y, \partial f/\partial z]^T=\mathbf{p}$



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
  - Parametric polynomial surfaces
    - Bezier surface patches (Chapter 11)

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Lighting and Shading in WebGL

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Objectives

- Introduce the WebGL shading methods
  - Light and material functions on MV.js
  - per vertex vs per fragment shading
  - Where to carry out

WebGL lighting

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- Need
  - Normals
  - Material properties
  - Lights
- State-based shading functions have been deprecated (glNormal, glMaterial, glLight)
- Compute in application or in shaders

Normalization

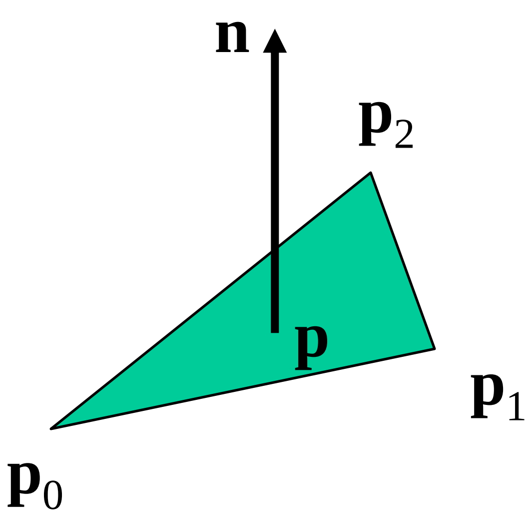
- Cosine terms in lighting calculations can be computed using dot product
- Unit length vectors simplify calculation
- Usually we want to set the magnitudes to have unit length but
  - Length can be affected by transformations
  - Note that scaling does not preserved length
- GLSL has a normalization function

Normal for Triangle

plane $\mathbf{n} \cdot (\mathbf{p} - \mathbf{p}_0) = 0$

$$\mathbf{n} = (\mathbf{p}_2 - \mathbf{p}_0) \times (\mathbf{p}_1 - \mathbf{p}_0)$$

normalize $\mathbf{n} \leftarrow \mathbf{n} / |\mathbf{n}|$



Note that right-hand rule determines outward face

Specifying a Point Light Source

- For each light source, we can set an RGBA for the diffuse, specular, and ambient components, and for the position

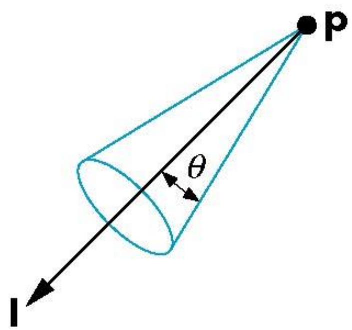
```
var diffuse0 = vec4(1.0, 0.0, 0.0, 1.0);
var ambient0 = vec4(1.0, 0.0, 0.0, 1.0);
var specular0 = vec4(1.0, 0.0, 0.0, 1.0);
var light0_pos = vec4(1.0, 2.0, 3,0, 1.0);
```

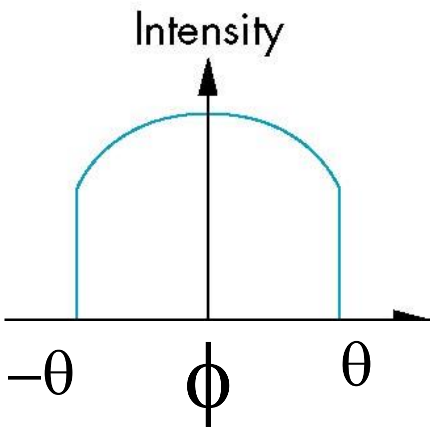
Distance and Direction

- The source colors are specified in RGBA
- The position is given in homogeneous coordinates
  - If w =1.0, we are specifying a finite location
  - If w =0.0, we are specifying a parallel source with the given direction vector
- The coefficients in distance terms are usually quadratic (1/(a+b*d+c*d*d)) where d is the distance from the point being rendered to the light source

Spotlights

- Derive from point source
  - Direction
  - Cutoff
  - Attenuation Proportional to $\cos^{\alpha}\phi$





Global Ambient Light

- Ambient light depends on color of light sources
  - A red light in a white room will cause a red ambient term that disappears when the light is turned off
- A global ambient term that is often helpful for testing

Moving Light Sources

- Light sources are geometric objects whose positions or directions are affected by the model-view matrix
- Depending on where we place the position (direction) setting function, we can
  - Move the light source(s) with the object(s)
  - Fix the object(s) and move the light source(s)
  - Fix the light source(s) and move the object(s)
  - Move the light source(s) and object(s) independently

Light Properties

```
var lightPosition = vec4(1.0, 1.0, 1.0, 0.0 );
var lightAmbient = vec4(0.2, 0.2, 0.2, 1.0 );
var lightDiffuse = vec4( 1.0, 1.0, 1.0, 1.0 );
var lightSpecular = vec4( 1.0, 1.0, 1.0, 1.0 );
```

Material Properties

- Material properties should match the terms in the light model
- Reflectivities
- w component gives opacity

```
var materialAmbient = vec4( 1.0, 0.0, 1.0, 1.0 );
var materialDiffuse = vec4( 1.0, 0.8, 0.0, 1.0);
var materialSpecular = vec4( 1.0, 0.8, 0.0, 1.0 );
var materialShininess = 100.0;
```

Using MV.js for Products

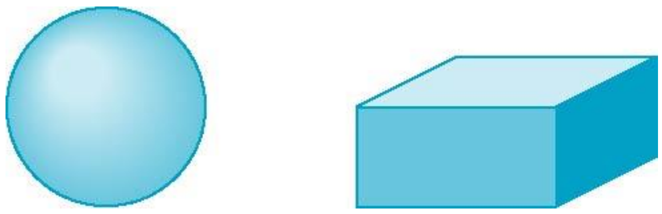
```
var ambientProduct = mult(lightAmbient, materialAmbient);
var diffuseProduct = mult(lightDiffuse, materialDiffuse);
var specularProduct = mult(lightSpecular, materialSpecular);
 gl.uniform4fv(gl.getUniformLocation(program,
                "ambientProduct"),      flatten(ambientProduct));
 gl.uniform4fv(gl.getUniformLocation(program,
                "diffuseProduct"),      flatten(diffuseProduct) );
 gl.uniform4fv(gl.getUniformLocation(program,
                 "specularProduct"),      flatten(specularProduct) );
 gl.uniform4fv(gl.getUniformLocation(program,
                 "lightPosition"),      flatten(lightPosition) );
gl.uniform1f(gl.getUniformLocation(program,
                "shininess"),materialShininess);
```

Adding Normals for Quads

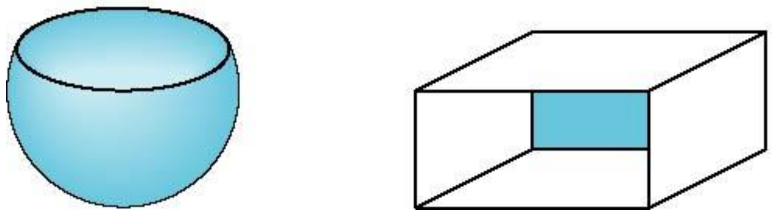

```
function quad(a, b, c, d) {
    var t1 = subtract(vertices[b], vertices[a]);
    var t2 = subtract(vertices[c], vertices[b]);
    var normal = cross(t1, t2);
    var normal = vec3(normal);
    normal = normalize(normal);

    pointsArray.push(vertices[a]);
    normalsArray.push(normal);
      .
      .
      .
```

Front and Back Faces

- Every face has a front and back
- For many objects, we never see the back face so we don't care how or if it's rendered
- If it matters, we can handle in shader



back faces not visible



back faces visible

Emissive Term

- We can simulate a light source in WebGL by giving a material an emissive component
- This component is unaffected by any sources or transformations

Transparency

- Material properties are specified as RGBA values
- The A value can be used to make the surface translucent
- The default is that all surfaces are opaque
- Later we will enable blending and use this feature
- However with the HTML5 canvas, A<1 will mute colors