Foundations of Computer Graphics (Spring 2010)

CS 184, Lecture 11: OpenGL 3

http://inst.eecs.berkeley.edu/~cs184

Methodology for Lecture

- Lecture deals with lighting (teapot shaded as in HW1)
- Some Nate Robbins tutor demos in lecture
- Briefly explain OpenGL color, lighting, shading
- Also talk a little about programmable shaders
- Demo
- Lecture corresponds chapter 5 (and some of 4)
  - But of course, better off doing rather than reading

Importance of Lighting

- Important to bring out 3D appearance (compare teapot now to in previous demo)
- Important for correct shading under lights
- The way shading is done also important

glShadeModel(GL_FLAT)

glShadeModel(GL_SMOOTH)

Outline

- *Basic ideas and preliminaries*
- Types of materials and shading
  - Ambient, Diffuse, Emissive, Specular
- Source code
- Moving light sources

Brief primer on Color

- Red, Green, Blue primary colors
  - Can be thought of as vertices of a color cube
  - R+G = Yellow, B+G = Cyan, B+R = Magenta, R+G+B = White
  - Each color channel (R,G,B) treated separately
- RGBA 32 bit mode (8 bits per channel) often used
  - A is for alpha for transparency if you need it
- Colors normalized to 0 to 1 range in OpenGL
  - Often represented as 0 to 255 in terms of pixel intensities
- Also, color index mode (not so important)

Shading Models

- So far, lighting disabled: color explicit at each vertex
- This lecture, enable lighting
  - Calculate color at each vertex (based on shading model, lights and material properties of objects)
  - Rasterize and interpolate vertex colors at pixels
- Flat shading: single color per polygon (one vertex)
- Smooth shading: interpolate colors at vertices
- Wireframe: glPolygonMode (GL_FRONT, GL_LINE)
  - Also, polygon offsets to superimpose wireframe
  - Hidden line elimination? (polygons in black…)

Demo and Color Plates

- See OpenGL color plates 1-8
- Demo
- Question: Why is blue highlight jerky even with smooth shading, while red highlight is smooth?

Lighting

- Rest of this lecture considers lighting on vertices
- In real world, complex lighting, materials interact
- We study this more formally in next unit
- OpenGL is a hack that efficiently captures some qualitative lighting effects. But not physical
- Modern programmable shaders allow arbitrary lighting and shading models (briefly covered)

Types of Light Sources

- Point
  - Position, Color [separate diffuse/specular]
  - Attenuation (quadratic model) $atten = \frac{1}{k_c + k_l d + k_q d^2}$
- Directional (w=0, infinitely far away, no attenuation)
- Spotlights
  - Spot exponent
  - Spot cutoff
- All parameters: page 215 (should have already read HW1; see there for page numbers in previous editions)

Material Properties

- Need normals (to calculate how much diffuse, specular, find reflected direction and so on)
- Four terms: Ambient, Diffuse, Specular, Emissive

Specifying Normals

- Normals are specified through glNormal
- Normals are associated with vertices
- Specifying a normal sets the *current* normal
  - Remains unchanged until user alters it
  - Usual sequence: glNormal, glVertex, glNormal, glVertex, glNormal, glVertex…
- Usually, we want unit normals for shading
  - glEnable(GL_NORMALIZE)
  - This is slow – either normalize them yourself or don't use glScale
- Evaluators will generate normals for curved surfaces
  - Such as splines. GLUT does it automatically for teapot, cylinder,…

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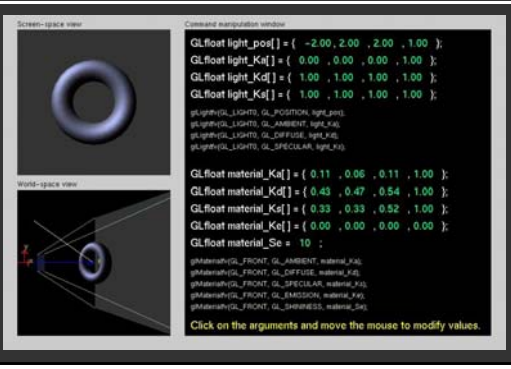
LightMaterial Demo



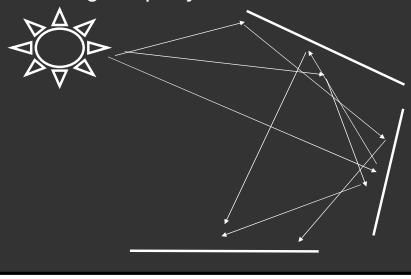
Emissive Term

$$I = Emission_{material}$$

Only relevant for light sources when looking directly at them
- Gotcha: must create geometry to actually see light
- Emission does not in itself affect other lighting calculations

Ambient Term

- Hack to simulate multiple bounces, scattering of light
- Assume light equally from all directions



Ambient Term

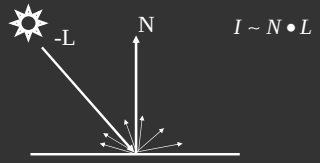
- Associated with each light and overall light
- E.g. skylight, with light from everywhere

$$I = ambient_{global} * ambient_{material} + \sum_{i=0}^{n} ambient_{light\ i} * ambient_{material} * atten_i$$

Most effects per light involve linearly combining effects of light sources

Diffuse Term

- Rough matte (technically Lambertian) surfaces
- Light reflects equally in all directions



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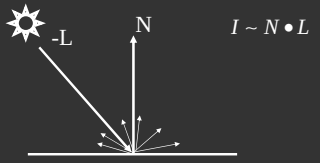
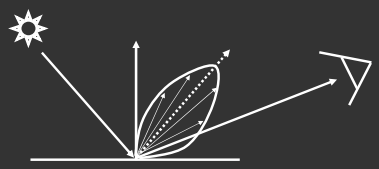


$$I = \sum_{i=0}^{n} diffuse_{light\ i} * diffuse_{material} * atten_i * [\max(L \bullet N, 0)]$$

- Why is diffuse of light diff from ambient, specular?

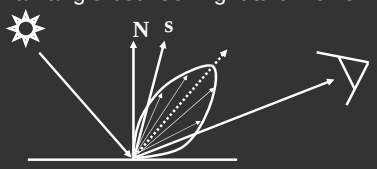
Specular Term

- Glossy objects, specular reflections
- Light reflects close to mirror direction



Specular Term

- Glossy objects, specular reflections
- Light reflects close to mirror direction
- Consider half-angle between light and viewer



$$I = \sum_{i=0}^{n} specular_{light\ i} * specular_{material} * atten_i * [\max(N \bullet s, 0)]^{shininess}$$

Demo

- What happens when we make surface less shiny?
- What happens to jerkiness of highlights?

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Source Code (in display)

```
/* New for Demo 3; add lighting effects */
  /* See hw1 and the red book (chapter 5) for details */
  {
   GLfloat one[] = {1, 1, 1, 1};
   //    GLfloat small[] = {0.2, 0.2, 0.2, 1};
   GLfloat medium[] = {0.5, 0.5, 0.5, 1};
   GLfloat small[] = {0.2, 0.2, 0.2, 1};
   GLfloat high[] = {100};
   GLfloat light_specular[] = {1, 0.5, 0, 1};
   GLfloat light_specular1[] = {0, 0.5, 1, 1};
   GLfloat light_position[] = {0.5, 0, 0, 1};
   GLfloat light_position1[] = {0, -0.5, 0, 1};

   /* Set Material properties for the teapot */
   glMaterialfv(GL_FRONT, GL_AMBIENT, one);
   glMaterialfv(GL_FRONT, GL_SPECULAR, one);
   glMaterialfv(GL_FRONT, GL_DIFFUSE, medium);
   glMaterialfv(GL_FRONT, GL_SHININESS, high);
```

Source Code (contd)

```
/* Set up point lights, Light 0 and Light 1 */
 /* Note that the other parameters are default values */

 glLightfv(GL_LIGHT0, GL_SPECULAR, light_specular);
 glLightfv(GL_LIGHT0, GL_DIFFUSE,  small);
 glLightfv(GL_LIGHT0, GL_POSITION, light_position);

 glLightfv(GL_LIGHT1, GL_SPECULAR, light_specular1);
 glLightfv(GL_LIGHT1, GL_DIFFUSE,  medium);
 glLightfv(GL_LIGHT1, GL_POSITION, light_position1);

 /* Enable and Disable everything around the teapot */
 /* Generally, we would also need to define normals etc. */
 /* But glut already does this for us */

 glEnable(GL_LIGHTING) ;
 glEnable(GL_LIGHT0) ;
 glEnable(GL_LIGHT1) ;
 if (smooth) glShadeModel(GL_SMOOTH) ; else glShadeModel(GL_FLAT);
}
```

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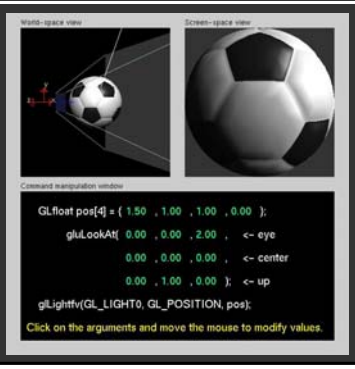
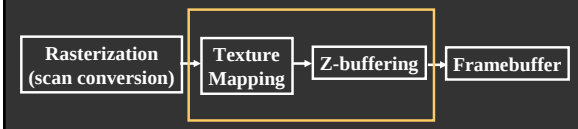
Moving a Light Source

- Lights transform like other geometry
- Only modelview matrix (not projection). The only real application where the distinction is important
- See types of light motion pages 222-
  - Stationary light: set the transforms to identity before specifying it
  - Moving light: Push Matrix, move light, Pop Matrix
  - Moving light source with viewpoint (attached to camera). Can simply set light to 0 0 0 so origin wrt eye coords (make modelview matrix identity before doing this)

Lightposition demo



Pixel or Fragment Pipeline



These fixed function stages can be replaced by a general per-fragment calculation using fragment shaders in modern programmable hardware

Shading Languages

- Vertex / Fragment shading described by small program
- Written in language similar to C but with restrictions
- Long history. Cook's paper on Shade Trees, Renderman for offline rendering
- Stanford Real-Time Shading Language, work at SGI
- Cg from NVIDIA, HLSL
- GLSL directly compatible with OpenGL 2.0 (So, you can just read the OpenGL Red Book to get started)

Shader Setup

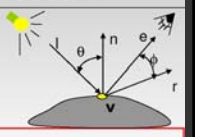
```
GLhandleARB phongVS, phongkFS, phongProg; // handles to objects

// Step 1: Create a vertex & fragment shader object
phongVS = glCreateShaderObjectARB(GL_VERTEX_SHADER_ARB);
phongFS = glCreateShaderObjectARB(GL_FRAGMENT_SHADER_ARB);

// Step 2: Load source code strings into shaders
glShaderSourceARB(phongVS, 1, &phongVS_String, NULL);
glShaderSourceARB(phongFS, 1, &phongFS_String, NULL);

// Step 3: Compile the vertex, fragment shaders.
glCompileShaderARB(phongVS);
glCompileShaderARB(phongFS);

// Step 4: Create a program object
phongProg = glCreateProgramObjectARB();

// Step 5: Attach the two compiled shaders
glAttachObjectARB(phongProg, phongVS);
glAttachObjectARB(phongProg, phongFS);

// Step 6: Link the program object
glLinkProgramARB(phongProg);

// Step 7: Finally, install program object as part of current state
glUseProgramObjectARB(phongProg);
```

Cliff Lindsay web.cs.wpi.edu/~rich/courses/imgd4000-d09/lectures/gpu.pdf

Phong Shader: Vertex

This Shader Does

- Gives eye space location for v
- Transform Surface Normal
- Transform Vertex Location




```
varying vec3 N;
varying vec3 v;

void main(void)
{
   v = vec3(gl_ModelViewMatrix * gl_Vertex);
   N = normalize(gl_NormalMatrix * gl_Normal);

   gl_Position = gl_ModelViewProjectionMatrix * gl_Vertex;
}
```

Created For Use Within Frag Shader

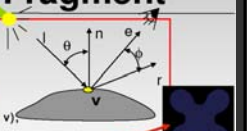
(Update OpenGL Built-in Variable for Vertex Position)

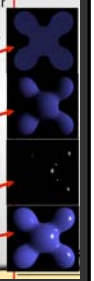
Cliff Lindsay web.cs.wpi.edu/~rich/courses/imgd4000-d09/lectures/gpu.pdf

Phong Shader: Fragment

```
varying vec3 N;
varying vec3 v;

void main (void)
{
   // we are in Eye Coordinates, so EyePos is (0,0,0)
   vec3 L = normalize(gl_LightSource[0].position.xyz - v);
   vec3 E = normalize(-v);
   vec3 R = normalize(-reflect(L,N));

   //calculate Ambient Term:
   vec4 Iamb = gl_FrontLightProduct[0].ambient;

   //calculate Diffuse Term:
   vec4 Idiff = gl_FrontLightProduct[0].diffuse * max(dot(N,L), 0.0);

   // calculate Specular Term:
   vec4 Ispec = gl_FrontLightProduct[0].specular
            * pow(max(dot(R,E),0.0), gl_FrontMaterial.shininess);

   // write Total Color:
   gl_FragColor = gl_FrontLightModelProduct.sceneColor + Iamb + Idiff + Ispec;
}
```

Passed in From VS





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