Computer Graphics (Fall 2006)

COMS 4160, Lecture 12: OpenGL 3

http://www.cs.columbia.edu/~cs4160

To Do

- HW 3 Milestones due on Thu
- If stuck, please get help from me or TAs
- Important you feel confident you can finish HW 3
- Programs in class, red book probably most help

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
- Demo 4160-opengl\opengl3\opengl3-orig.exe
- 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: 4160-opengl\opengl3\opengl3-orig.exe
- 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 (not covered in class)

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 195 (should have already read HW1)

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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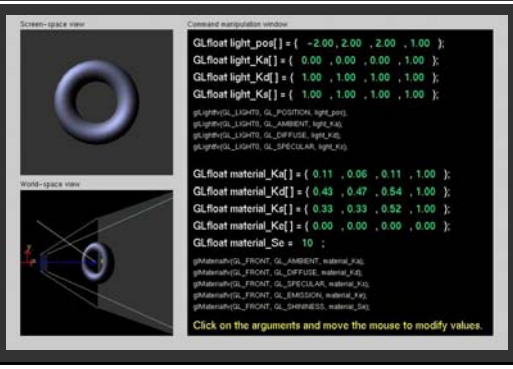
LightMaterial Demo



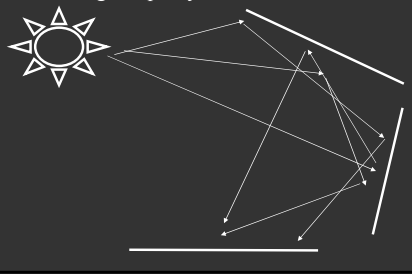
Emissive Term

$$I = Emission_{material}$$

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

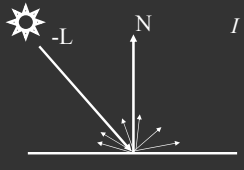
- Associated with each light and overall light
- E.g. skylight, with light from everywhere

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

Most effects per light involve linearly combining effects of light sources

Diffuse Term

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



$$I \sim N \bullet L$$

Diffuse Term

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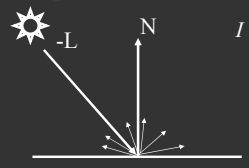


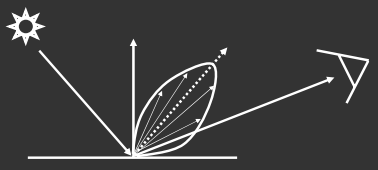
$I \sim N \bullet L$

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

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

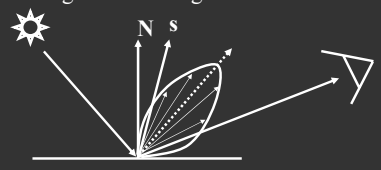
Specular Term

- 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 202-
  - 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