OpenGL_Programming-3

EE – 7000

Sep, 26/28,2011

Previous Class

OpenGL basics

Drawing geometric objects

Viewing

Color

- This Class:

Lighting

Texture Mapping

Lighting

Why Lighting?

- What light source is used and how the object response to the light makes difference

    Ocean looks bright bluish green in sunny day but dim gray green in cloudy day

- Lighting gives you a 3D view to an object

    A unit sphere looks no difference from a 2D disk

- To get realistic pictures, the color computation of pixels must include lighting calculations

Types of Light

- Ambient:

  Light that's been scattered so much by the environment that its direction is impossible to determine – it seems to come from all directions

- Diffuse

  Light that comes from one direction, but it gets scattered equally in all directions

- Specular

  Light comes from a particular direction, and its tends to bounce off the surface in a preferred direction

Materials Colors

- A material's color depends on the percentage of the incoming different lights it reflects

- Materials have different ambient, diffuse and specular reflectances

- Material can also have an emissive color which simulates light originating from an object

  Headlights on a automobile

OpenGL Lighting Model

- Lighting has four independent components that are computed independently

  Emission, Ambient, Diffuse, and Specular

- OpenGL approximates lighting as if light can be broken into red, green, and blue components

  The RGB values for lights mean different than for materials

  For light, the numbers correspond to a percentage of full intensity for each color

  For materials, the numbers correspond to the reflected proportions of those colors

- Total effect is a combination of corresponding components of incoming light and illuminated material surface

  (LR*MR, LG*MG, LB*MB)

Theory of Illumination

- Not only knowledge about light but also about what happens when light is reflected from an object into our eyes is important to obtain realistic images
- The general problem is to compute the apparent color at each pixel that corresponds to part of the object on the screen
- The color produced by lighting a vertex (or a object) has several contributions

    Emission

    Global ambient light

    Contributions from light sources

Material Emission

- Emissive brightness of the material = **Me**

- There is no attempt to model properties of the light or its effects on the objects

- The emissive color adds intensity to the object

$$\mathbf{Ie = \mathit{M}e}$$

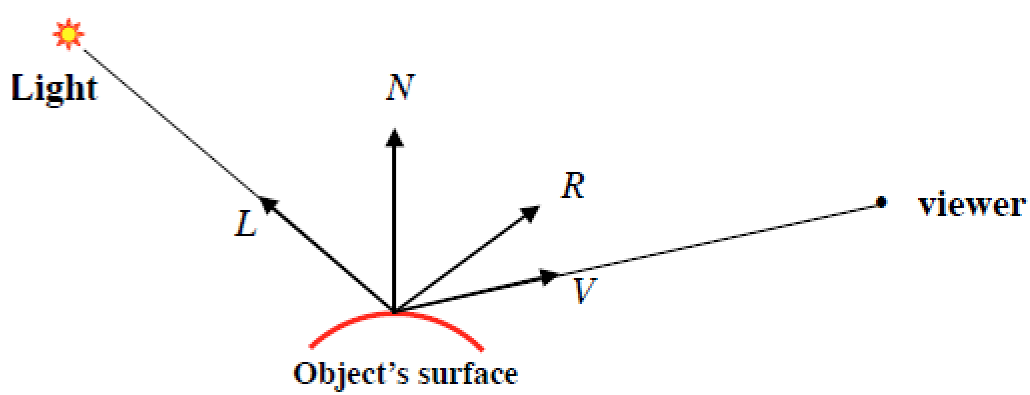
Global Ambient Light

- Light from all directions but not from any specific sources
- Ambient light intensity = Ga
- Ambient reflection coefficient of material = Ma

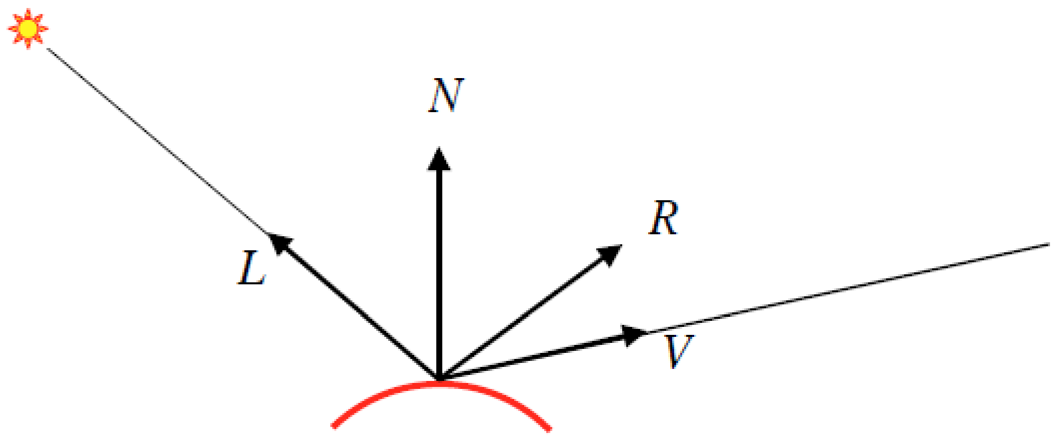
$$I_G = G_a M_a$$

A Point Source of Light

- Contribution from a point source of light include three terms
- Light has ambient (Ia), diffuse (Id) and specular (Is) components
- Material has ambient(Ma), diffuse (Md) and specular reflection (Ms) properties



Point Light's Contribution



$$I_L^1 = I_a M_a + I_d M_d (\max\{N \bullet L, 0\}) + I_s M_s (\max\{R \bullet V, 0\})^n$$

- First term = ambient
- Second term = diffuse
- Third term = specular

Point Light's Contribution

- Ambient term

  The ambient component of each incoming light source is combined with a material's ambient reflectance

- Diffuse term

  Brightness is inversely proportional to the area of the object illuminated (dot produce of light vector and surface normal)

  greatest when N and L are parallel

  smallest when N and L are orthogonal

  In calculations, max {N.L, 0} is used to avoid negative values

- Specular term

  Brightness depends on the angle between reflection vector (R) and viewer vector (V), i.e., on direction of viewer

  The specular reflection exponent n is 1 for a slightly glossy surface and infinity for a perfect mirror

Attenuation

- Attenuation factor

Light attenuates with distance from the source

$$f = \frac{1}{k_c + k_l d + k_q d^2}$$

where d = distance between the light and object

k_c = constant attenuation

A light source does not give an infinite amount of light

k_l = linear term

The light source is not a point

k_q = quadratic term

Models the theoretical attenuation from a point source

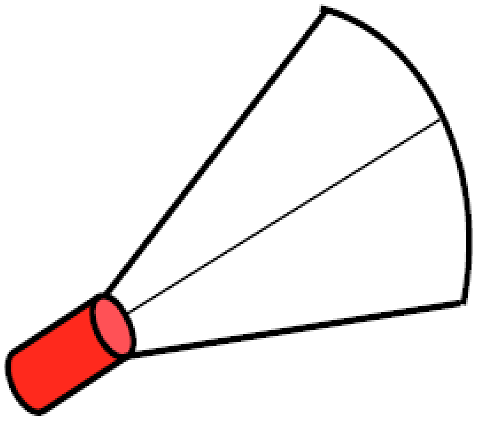
The intensity becomes

$$I_L^2 = f[I_a M_a + I_d M_d(\max\{N \bullet L, 0\}) + I_s M_s(\max\{R \bullet V, 0\})^n]$$

Spotlight Effect

- When the vertex lies inside the cone of illumination produced by spotlight, its contribution to the light intensity is

$$s = (\max\{D \bullet L, 0\})^m$$



Where D gives the spotlight's direction. The intensity is maximum in the center of cone and is attenuated toward the edge of the cone

s is 1 if the source is not spotlight

m is exponent determining the concentration of the light

The intensity of light source is

$$I_L = fs[I_a M_a + I_d M_d (\max\{N \bullet L, 0\}) + I_s M_s (\max\{R \bullet V, 0\})^n]$$

Putting All Together

- Entire lighting calculation in RGB mode gives

$$\text{Vertex color} = M_e + G_a M_a + \sum_{i=1}^{n-1} f_i s_i [I_a M_a + I_d M_d (\max\{N \bullet L, 0\}) + I_s M_s (\max\{R \bullet V, 0\})^n]_i$$

Adding Lighting to the Scene

- Define normal vectors for each vertex of each object
- Create, select, and position one or more light sources
- Create and select a lighting model
- Define material properties for the objects in the scene

Creating Light Sources

- Properties of Light sources are color, position, and direction

  void **glLight**{if}(Glenum *light*, Glenum *pname*, TYPE *param*);

  void **glLight**{if}v(Glenum *light*, Glenum *pname*, TYPE **param*);

  Creates the light specified by light that can be GL_LIGHT0, GL_LIGHT1,…or GL_LIGHT7

  pname specifies the characteristics of the light being set

  parama indicates the values to which the pname characteristic

- **glEnable** (GL_LIGHT0)

Color for a Light Source

```
GLfloat light_ambient[] = {0.0,0.0,0.0,1.0};
GLfloat light_diffuse[] = {1.0,1.0,1.0,1.0};
GLfloat light_specular[] = {1.0,1.0,1.0,1.0};

glLightfv(GL_LIGHT0, GL_AMBIENT, light_ambient);
glLightfv(GL_LIGHT0, GL_DIFFUSE, light_diffuse);
glLightfv(GL_LIGHT0, GL_SPECULAR, light_specular);
```

Position of Light Source

- Positional light source

  (x, y, z) values specify the location of the light

  GLfloat light_position[] = {x, y, z, w};

  glLightfv(GL_LIGHT0, GL_POSITION, light_position);

- Directional light source

  (x, y, z) values specify the direction of the light located at the infinity

  No attenuation

  GLfloat light_position[] = {$x, y, z, 0$};

  glLightfv(GL_LIGHT0, GL_POSITION, light_position);

Attenuation

- Attenuation factor for a positional light $$f = \frac{1}{k_c + k_l d + k_q d^2}$$

  Needs to specify three coefficients

  glLightf(GL_LIGHT0, GL_CONSTANT_ATTENUATION, 2.0);

  glLightf(GL_LIGHT0, GL_LINEAR_ATTENUATION, 1.0);

  glLightf(GL_LIGHT0, GL_QUADRATIC_ATTENUATION, 1.0);

- Ambient, diffuse, and specular contributions are all attenuated

Spotlights

- The shape of the light emitted is restricted to a cone

- **glLightf**(GL_LIGHT0, GL_SPOT_CUTOFF, 45.0);

  The cutoff parameter is set to 45 degrees

- GLfloat spot_direction[] = {-1.0, -1.0, 0.0];

  glLightfv(GL_LIGHT0, GL_SPOT_DIRECTION, spot_direction);

  specifies the spotlight's direction which determines the axis of the cone of light

- **glLightf**(GL_LIGHT0, GL_SPOT_EXPONENT, 2.0);

  Controls how concentrated the light is

Multiple Lights

- You can define up to eight light sources

  Need to specify all the parameters defining the position and characteristics of the light

- OpenGL performs calculations to determine how much light each vertex gets from each source

- Increasing number of lights affects performance

Controlling a Light's Position and Direction

- A light source is subject to the same matrix transformations as a geometric model
  - Position or direction is transformed by the current modelview matrix and stored in eye coordinates
- Keeping the light stationary
  - Specify the light position after modelview transformations
- Independently moving the light
  - Set the light position after the modeling transformation that you want to apply for light
- Moving the light together with the viewpoint
  - Set the light position before the viewing transformation

Setting a Lighting Model

- How to specify a lighting model

- **glLightModel**{if}(GLenum *pname*, *TYPE param*);

  glLightModel(if}**v**(GLenum *pname*, *TYPE *param*);

  Sets properties of the lighting model

  pname defines the characteristic of the model being set

  param indicates the values to which the *pname* characteristic is set

- Needs to be enabled or disabled

  glEnable(GL_LIGHTING);

  glDisable(GL_LIGHTING);

Components of Lighting Model

- Global ambient light

  Ambient light from not any particular source

  GLfloat lmodel_ambient[] = {0.2, 0.2, 0.2, 1.0}

  glLightModelfv(GL_LIGHT_MODEL_AMBIENT, lmodel_ambient);

- Local or Infinite viewpoint

  Whether the viewpoint position is local to the scene or whether it should be considered to be an infinite distance away

  glLightModeli(GL_LIGHT_MODEL_LOCAL_VIEWER, GL_TRUE);

  Default is an infinite viewpoint

- Two-sided lighting

  Whether lighting calculations should be performed differently for both the front and bacl faces of objects

  glLightModeli(GL_LIGHT_MODEL_TWO_SIDE, GL_TRUE);

Defining Material Properties

- Specifying the ambient, diffuse, and specular colors, the shininess, and the color of any emitted light

- void **glMaterial**{if}(GLenum *face*, GLenum *pname*, *TYPE param*);
  void **glMaterial**{if}**v**(GLenum *face*, GLenum *pname*, *TYPE* **param*);
  Specifies a current material property for use in lighting calculations
  Face can be GL_FRONT, GL_BACK, or GL_FRONT_AND_BACK
  Pname identifies the particular material property being set
  Param defines the desired values for that property

Reflectances

- Diffuse and ambient reflection

  Gives color

  GLfloat mat_amb_diff[] = {0.1, 0.5,0.8,1.0};
  glMaterialfv(GL_FRONT_AND_BACK,
  GL_AMBIENT_AND_DIFFUSE, mat_amb_diff);

- Specular reflection

  Produces highlights

  GLfloat mat_specular[] = {1.0,1.0,1.0,1.0);
  Glfloat low_shininess[] = {5.0};
  glMaterialfv(GL_FRONT, GL_SPECULAR, mat_specular);
  glMaterialfv(GL_FRONT, GL_SHININESS, low_shininess);

- Emission

  Make an object glow (to simulate lamps and other light sources

  GLfloat mat_emission[] = {0.3,0.2,0.2,0.0};
  glMaterialfv(GL_FRONT, GL_EMISSION, mat_emission);

Changing Material Properties

- Different material properties for different vertices on the same object or different objects

- **glMaterialfv**() needs to be called repeatedly to set the material property that needs to be re-specified for each case
- **glColorMaterial**(GLenum *face*, GLenum *mode*);

  Specifies the property (properties) defined by *mode* of the selected material *face* (or faces) to track the value of the current color at all times

  Needs enabling

Example: A lit sphere

- 2D disk in the absence of lighting
- 3D sphere
- Shinning sphere
- Emissive sphere
- Moving light source

Texture Mapping

Drawing Pixel Data

Geometric Versus Pixel Data

- Rendering of geometric data (arrays of vertices)
  - points, lines, polygons

- Rendering of pixel data (arrays of pixels)
  - Bitmaps
    - Characters in fonts
    - Array of 0s and 1s(1 = the pixel is affected)
    - Serves as drawing mask for overlying another image
  - Image data
    - A photograph that is scanned or an image calculated by some program in memory by pixels or an image first drawn and then read back pixel by pixel
    - Several pieces of data per pixel (R,G,B,A values)
    - Simply overwrites in the framebuffer

Current Raster Position

- void **glRasterPos**{234}{sifd}(*TYPE x*, *TYPE y*, *TYPE z*, *TYPE w*);

  Sets the current raster position where the next bitmap (or image) is to be drawn

  The raster position coordinates are subject to the modelview and projection transformations in the same way as the vertex Coordinates

- To specify the raster position directly in the screen coordinates, only 2D version of transformations need to be specified

Drawing Bitmaps

- void **glBitmap**(GLsizei *width*, GLsizei *height*, GLfloat *xbo*, GLfloat *ybo*, GLfloat *xbi*, GLfloat *ybi*, const Glubyte **bitmap*);

  Draws the bitmap specified by *bitmap*

  Width and height define size of the bitmap

  Subscript *bo* means the origin of the bitmap

  Subscript *bi* means increment to the current raster position after the bitmap is rasterized

Manipulating Images

- void **glReadPixels**(GLint *x*, GLint *y*, GLsizei *width*, Glsizei *height*, GLenum *format*, GLenum *type*, GLvoid **pixels*)

  Reads pixel data from the *specified* framebuffer rectangle and stores data in the array pointed by *pixels*

  format can be GL_RGBA, GL_RED, GL_ALPHA, GL_DEPTH_COMPONENT

  type can be s, u, i, f, etc.

- void **glDrawPixels**(GLsizei *width*, GLsizei *height*, Glenum *format*, GLenum *type*, GLvoid **pixels*)

  Draws a rectangle of pixel data with dimensions *width* and *height*

  Pixel rectangle has its lower-left corner at the current raster position

- void **glCopyPixels**(GLint *x*, GLint *y*, GLsizei *width*, Glsizei *height*, GLenum *buffer*)

  Copies pixel data from the specified framebuffer rectangle

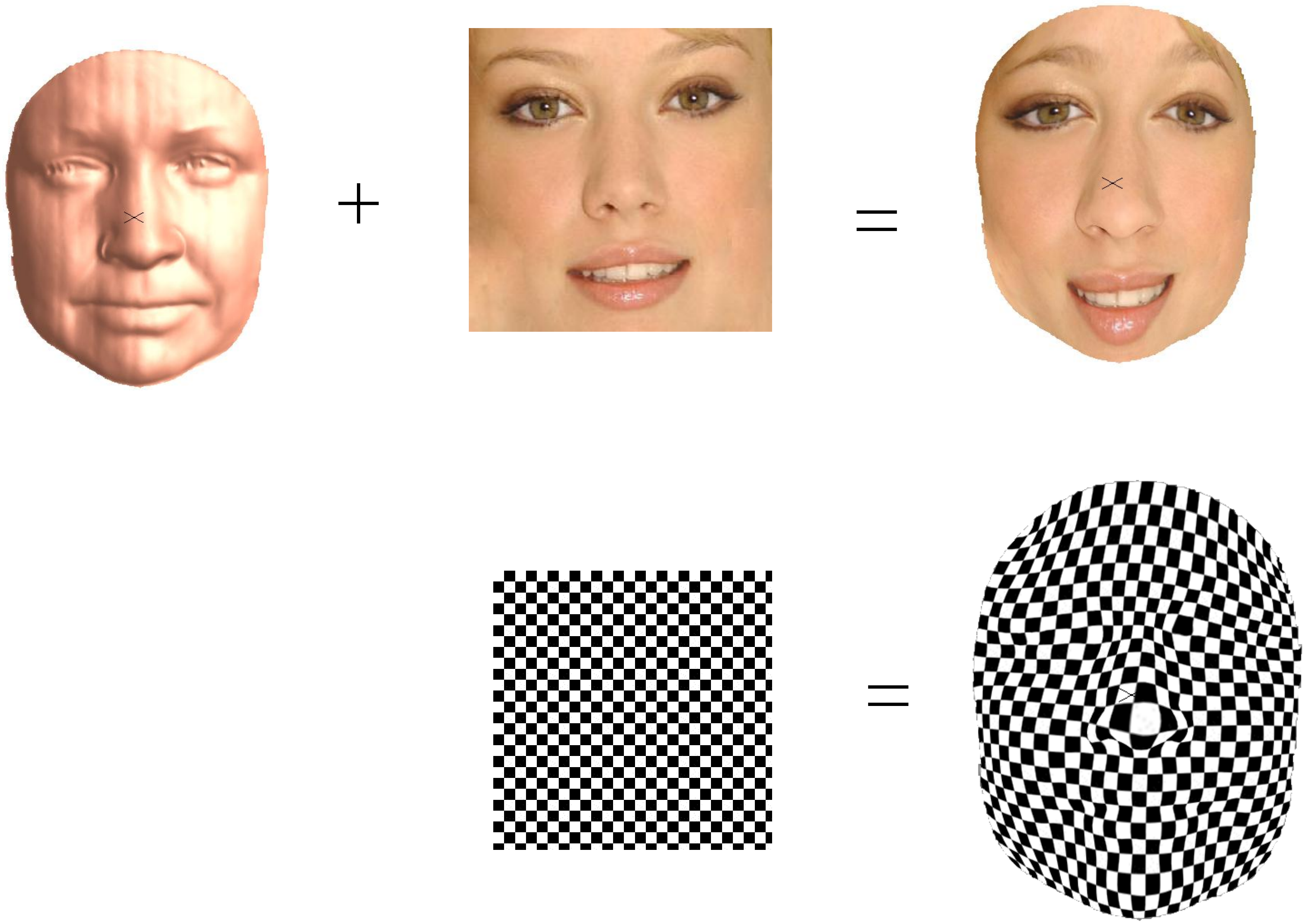
  Buffer can be GL_COLOR, GL_DEPTH, GL_STENCIL

Example: Drawing Image

- Make a checkerboard image
- Define raster position
- Draw an pixel rectangle of the image

What is Texture Mapping?

- Gluing an image (such as scanned photograph) to a polygon
  - Bricks on wall
  - Ground in flight simulation
  - Vegetation
- Textures are rectangular arrays of data (colors, luminace)
  - Individual values are called texels
- Textures can be manipulated with transformations
  - Repeat textures in different directions to cover the surface
  - Apply textures in different shapes and sizes



Steps in Texture Mapping

- Create a texture object and specify a texture for the object
- Indicate how the texture is to be applied to each pixel
- Enable texture mapping
- Draw the scene by supplying both texture and geometric coordinates

Sample Example

- Check board texture is generated
  makeCheckImage()

- All texture mapping initialization occurs in **init**()
  glGenTextures(1, &texName);
  glBindTexture(GL_TEXTURE_2D, texName);

- Single, full resolution texture map is specified
  glTexImage2D(GL_TEXTURE_2D, 0, GL_RGBA, checkImageWidth, checkImageHeight, 0, GL_RGBA, GL_UNSIGNED_BYTE, checkImage);

- Specify how the texture to be wrapped and how the colors are to be filtered if there is not an exact match between texels and pixels
  - **glTexParameteri**(GL_TEXTURE_2D,GL_TEXTURE_WRAP_S,GL_REPEAT);
  - **glTexParameteri**(GL_TEXTURE_2D,GL_TEXTURE_MAG_FILTER,GL_NEAREST);

More on Example

- In **display**(void), texture is turned on
  glEnable(GL_TEXTURE_2D);

- Drawing mode is set so as to draw the textured polygons using the colors from the texture map
  glTexEnvf(GL_TEXTURE_ENV, GL_TEXTURE_ENV_MODE, GL_REPLACE);

- Two polygons are drawn by specifying texture coordinates along with vertex coordinates
  glTexCoord2f(0.0,0.0); **glVertex3f**(-2.0,-1.0,0.0);
  .....

- Texture is finally turned off
  glDisable(GL_TEXTURE_2D);

3D Textures

- 3D textures are used in scientific visualization

  e.g. volume rendering
- Defining a 3D texture:

  glTexImage3D(GL_TEXTURE_3D, 0, GL_RGB, iWidth, iHeight, iDepth,

  0, GL_RGB, GL_UNSIGNED_BYTE, image);
- Replace all or some of the texels of a 3D texture
- Using compressed texture images
- Mipmaps: Multiple levels of detail
- Filtering
- Texture objects
- Texturing functions

Example:

- Putting all together: cube.cpp

Viewing

Color

Lighting

Texture Mapping