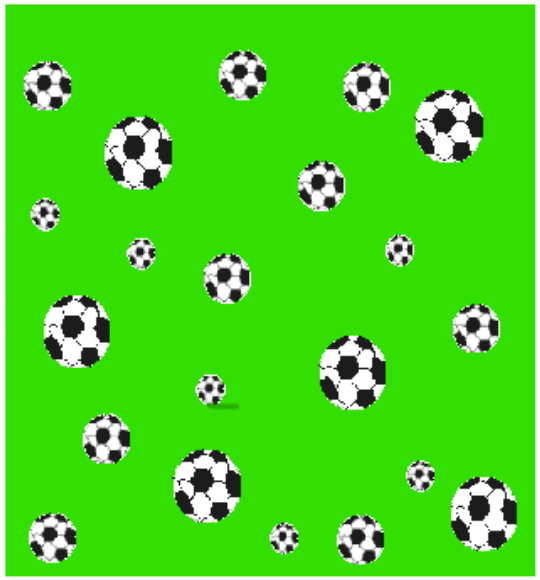
Texture Mapping

Woo, Neider et Al., Chapter 9

Texture Mapping in OpenGL

- Allows you to modify the color of a polygon surface
- Textures are simply rectangular arrays of data (color, luminance, color+alpha). Individual values in a texture are called **texels**



Texture Mapping Modalities

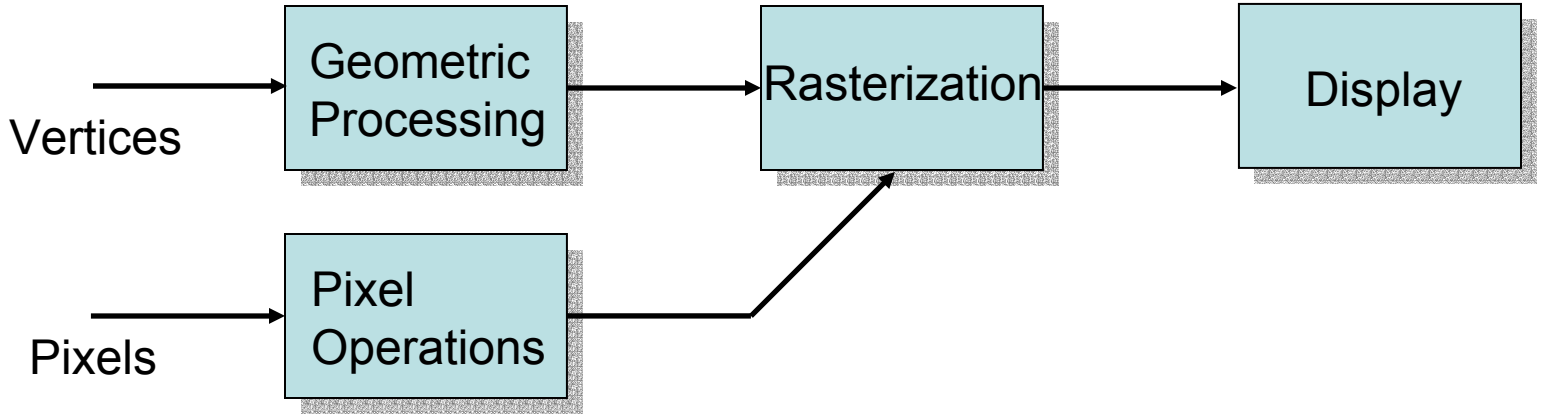
- You can repeat a texture (in one or both directions) to cover a surface

- A texture can be applied to a surface in different ways:
  1) Painted directly (like a decal)
  2) Used to modulate the original surface-color
  3) Use to blend with the original surface-color

Using Texture Mapping

Steps necessary to use texture mapping:

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



Texture Specification

- A texture is usually 2D
- It's data can consist of 1, 2, 3, 4 elements per texel
- A method called **mipmapping** can be used to generate textures at different resolutions and increase performance
- Mipmapping prevents unnecessary and expensive mappings to small polygons

2D Texture Specification

glTexImage2D(GLenum target, GLint level,
GLint internalFormat, GLsizei width, GLsizei height,
Glint border, GLenum format, Glenum type,
const Glvoid *pixels);

- **target**: GL_TEXTURE_2D, GL_PROXY_TEXTURE_2D
- **level**: specifies the level of detail when using multi resolution textures. “0” is the base image, “n” is the n-th mipmap reduction image
- **internalFormat**: an integer 1 to 4, or one of 38 symbolic constants
- **width, height**: the dimensions of the texture (MUST BE power of 2)
- **format**: the kind of pixel-data elements
- **type**: the data-type of each element
- **pixels**: array containing the texture image data

Values for Format and Type

- **Format Constants**:

GL_COLOR_INDEX	A single color index
GL_RGB	A red component, followed by green & blue components
GL_RGBA	Like GL_RGB, followed by an alpha component.
GL_RED	A single red-color component
GL_GREEN	A single green-color component
GL_BLUE	A single blue-color component
GL_ALPHA	A single alpha-color component

- **Type Constants:**

GL_UNSIGNED_BYTE	unsigned 8-bit integer
GL_BYTE	signed 8-bit integer
GL_UNSIGNED_SHORT	unsigned 16-bit integer
GL_SHORT	signed 16-bit integer
GL_INT	signed 32-bit integer
GL_FLOAT	single-precision floating point

Scaling and Copying Images

- Scales the image, using appropriate pixel storage modes to unpack the data from datain. Image is scaled using linear interpolation

```
int gluScaleImage(GLenum format, GLint widthin,
        GLint heightin, GLenum typein,
        const void *datain, GLint widthout,
        GLint heightout, GLenum typeout, void *dataout );
```

- Creates a 2D texture, using framebuffer data to define the texels. The pixels are read from the current GL_READ_BUFFER

```
void glCopyTexImage(GLenum target GLint level,
        GLint internalFormat, GLint x, GLint y, GLsizei width,
        GLsizei height, GLint border);
```

Enable Texture Mapping

To enable or disable texture mapping:

glEnable(mode)

glDisable(mode)

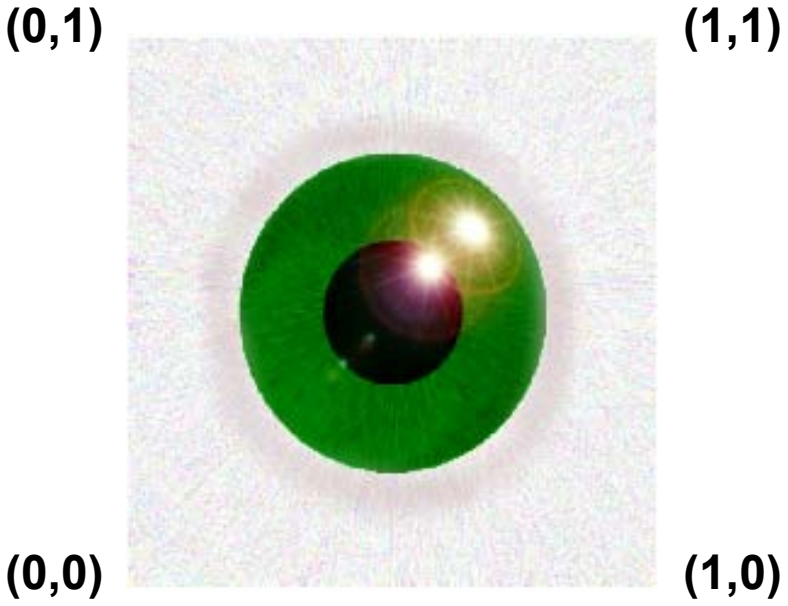
where **mode** is GL_TEXTURE_1D
GL_TEXTURE_2D or
GL_TEXTURE_3D

Texture Coordinates

- You need to specify BOTH texture & geometric coordinates as you specify the object in your scene

- **Example**:

```
glBegin(GL_QUADS);
   glTexCoord2f(0.0, 0.0);
   glVertex3f(-2.0, -1.0, 0.0);
   glTexCoord2f(0.0, 1.0);
   glVertex3f(-2.0, 1.0, 0.0);
   glTexCoord2f(1.0, 1.0);
   glVertex3f(0.0, 1.0, 0.0);
   glTexCoord2f(1.0, 0.0);
   glVertex3f(0.0, -1.0, 0.0);
glEnd();
```



Texture Coordinates

- **Example**: texture mapped polygons

Original texture

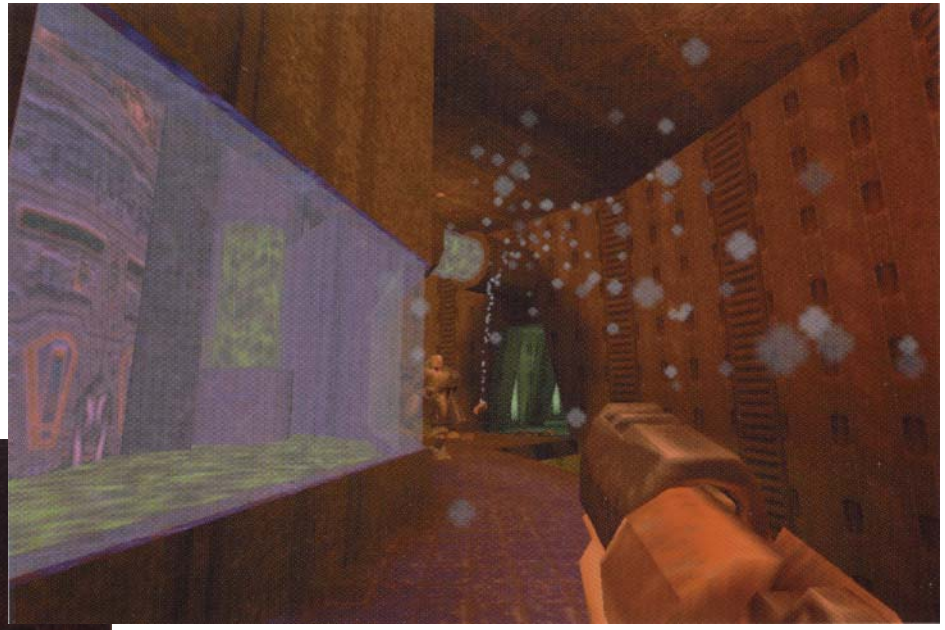
Texturing Functions

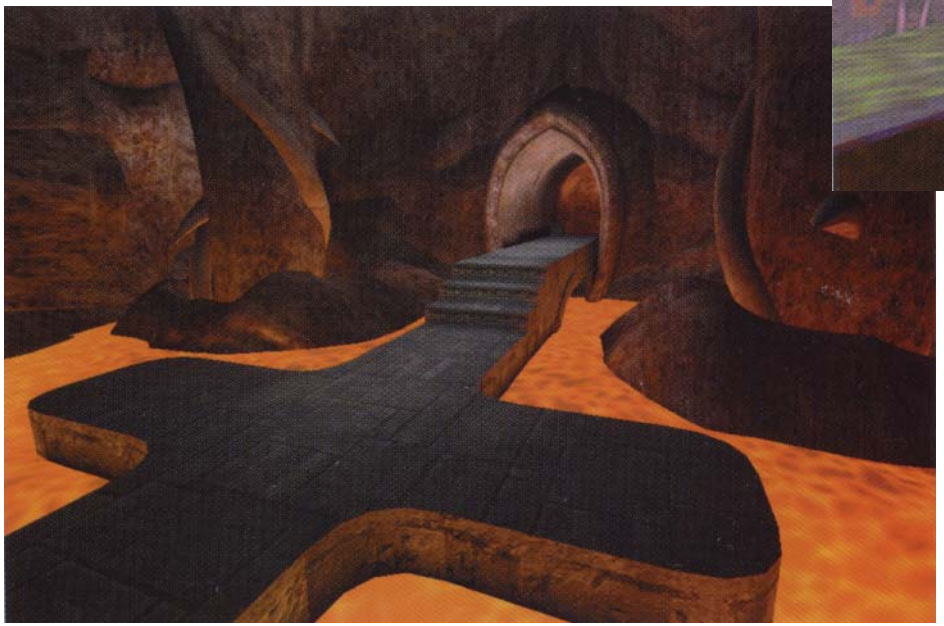
- Indicate how the texture is applied to each pixel:

  - **REPLACE** or **DECAL**: Texture is painted on top of the fragment
  - **MODULATE:** Combine texture with fragment color. This technique is useful to combine the effects of lighting with texturing
  - **BLEND:** A constant color is blended with that of the fragment, based on the texture value

Texturing Functions

Example: Quake





Texturing Functions

glTexEnvf{if}(GLenum target, GLenum pname, GLfloat param);

target: GL_TEXTURE_ENV
pname: GL_TEXTURE_ENV_MODE, GL_TEXTURE_ENV_COLOR
param: GL_DECAL, GL_REPLACE, GL_MODULATE, GL_BLEND

Internal Format	Decal	Replace	Modulate	Blend
GL_ALPHA	ND	$C = C_f$ $A = A_t$	$C = C_f$ $A = A_fA_t$	$C = C_f$ $A = A_fA_t$
GL_LUMINANCE	ND	$C = L_t$ $A = A_f$	$C = C_fL_t$ $A = A_f$	$C = C_f(1-L_t)+C_cL_t$ $A = A_f$
GL_LUMINANCE_ALPHA	ND	$C = L_t$ $A = A_t$	$C = C_fL_t$ $A = A_fA_t$	$C = C_f(1-L_t)+C_cL_t$ $A = A_fA_t$
GL_INTENSITY	ND	$C = I_t$ $A = I_t$	$C = C_fI_t$ $A = A_fI_t$	$C = C_f(1-I_t)+C_cI_t$ $A = A_f(1-I_t)+A_cI_t$
GL_RGB	$C = C_t$ $A = A_f$	$C = C_t$ $A = A_f$	$C = C_fC_t$ $A = A_f$	$C = C_f(1-C_t)+C_cC_t$ $A = A_f$
GL_RGBA	$C = C_f(1-A_t)+C_tA_t$ $A = A_fA_t$	$C = C_t$ $A = A_t$	$C = C_fC_t$ $A = A_fA_t$	$C = C_f(1-C_t)+C_cC_t$ $A = A_fA_t$

Repeating and Clamping

glTexParameter{if}(GLenum target, Glenum pname, GLfloat param);

target: GL_TEXTURE_2D
pname: Parameter symbolyc-constant
param: The value of “pname”

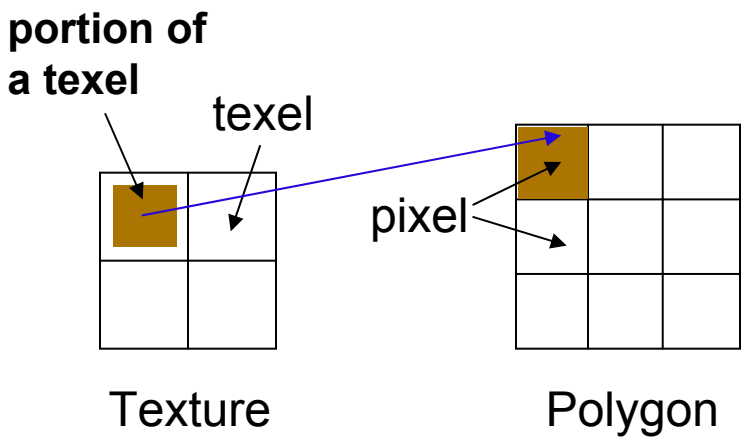
Parameter	Value
GL_TEXTURE_WRAP_S	GL_CLAMP, GL_REPEAT
GL_TEXTURE_WRAP_T	GL_CLAMP, GL_REPEAT
GL_TEXTURE_MAG_FILTER	GL_NEAREST, GL_LINEAR
GL_TEXTURE_MIN_FILTER	GL_NEAREST, GL_LINEAR, GL_NEAREST_MIPMAP_NEAREST, GL_NEAREST_MIPMAP_LINEAR, GL_LINEAR_MIPMAP_NEAREST, GL_LINEAR_MIPMAP_LINEAR
GL_TEXTURE_BORDER_COLOR	Any 4 values in [0.0, 1.0]
GL_TEXTURE_PRIORITY	[0.0, 1.0] for the current texture object

Filtering Methods

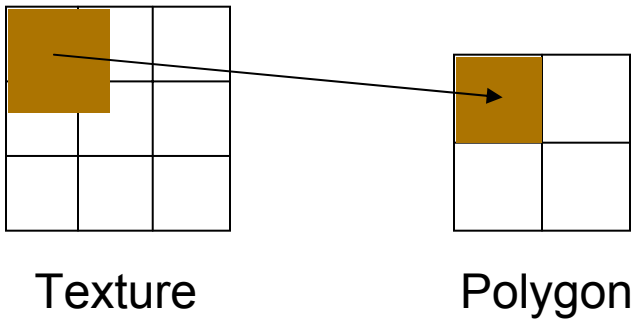
- Usually the size of a texel does not match the size of the corresponding pixel

- In order to map the texels to the pixels, we need to do some kind of **filtering**

Magnification



Minification



Filtering Methods

- **GL_NEAREST:** The texel with coordinates nearest to the center of the pixel is used. This might result in aliasing artifacts

- **GL_LINEAR:** A weighted linear average of the 2x2 array of texels that lie nearest to the center of the pixel is used

- **GL_NEAREST_MIPMAP_NEAREST:** In the nearest mipmap, choose the nearest texel value

- **GL_LINEAR_MIPMAP_NEAREST:** In the nearest mipmap, interpolate linearly between the 2 nearest texels

- **GL_LINEAR_MIPMAP_LINEAR:** Interpolate between the nearest values in the 2 best choices from the mipmaps.

Mipmaps

- To use mipmapping, all sizes (in powers of 2) of the texture must be provided, either by calls to glTexImage2D() once for each resolution, or by using:

int gluBuild2DMipMaps(
GLenum target, GLint comps,
GLint width, GLint height,
GLenum format,
GLenum type, void *data);

This function constructs a series of mipmaps and calls glTexImage to load the images