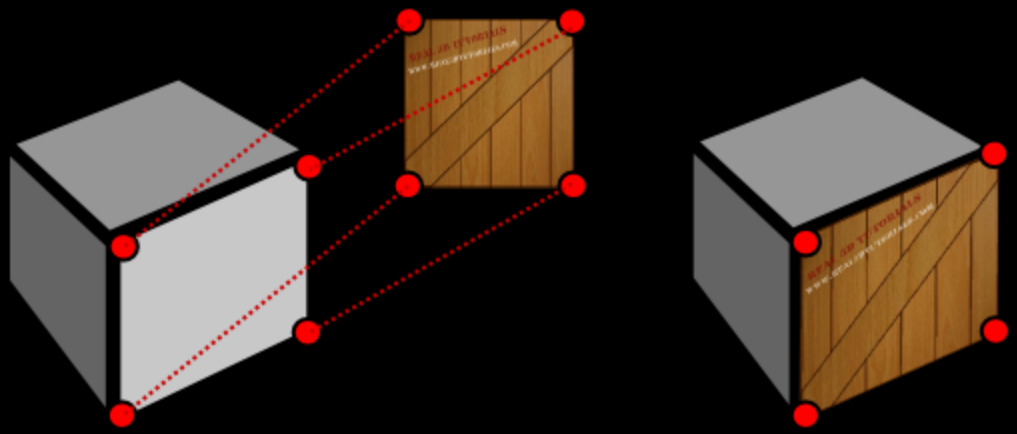
TEXTURE MAPPING



OUTLINE

- Implementing Texturing
- What Can Go Wrong and How to Fix It
  - Mipmapping
  - Filtering
  - Perspective Correction

BASIC STRAGEGY

Three steps to applying a texture

1. specify the texture
   - read or generate image
   - assign to texture
   - enable texturing
2. assign texture coordinates to vertices
   - Proper mapping function is left to application
3. specify texture parameters
   - wrapping, filtering

SPECIFY THE TEXTURE

- Data and mechanisms needed:
  - A Texture object – to hold the texture image
  - Uniform sampler variable in the vertex shader – so shader can access texture
  - Buffer to hold texture coordinates
  - Vertex attribute to pass texture coordinates through pipeline
  - Texture unit on the graphics card

TEXTURE OBJECT

- The loadTexture method from the Java/JOGL example code

```
public Texture loadTexture(String textureFileName)
{
    Texture tex = null;
    try
    {
        tex = TextureIO.newTexture(new File(textureFileName),
                                   false);
    }
    catch (Exception e)
    {
        e.printStackTrace();
    }
    return tex;
}
```

SETTING UP THE TEXTURE AS AN OPENGL TEXTURE

- Instance variables:

```
private int brickTexture;
private Texture joglBrickTexture;
```

- In init():

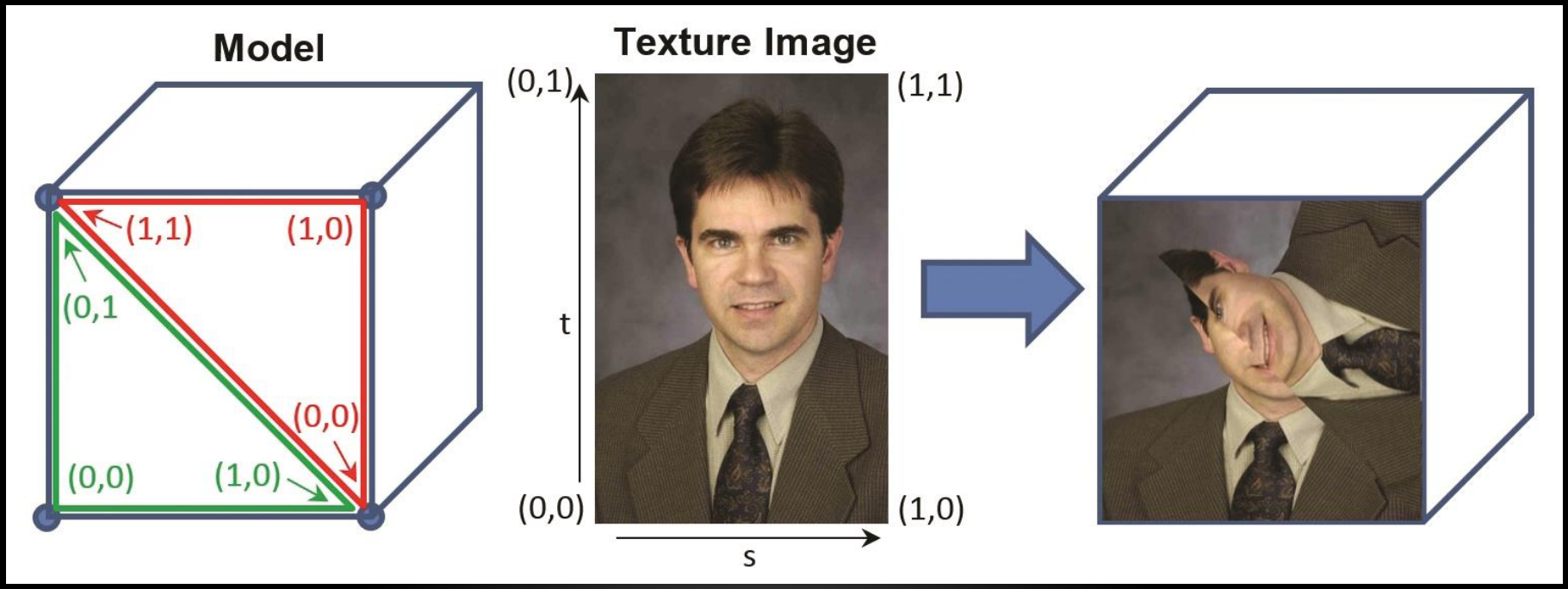
```
joglBrickTexture = loadTexture("brick1.jpg");
brickTexture = joglBrickTexture.getTextureObject();
```

TEXTURE COORDINATES

- Need to specify texture coordinates for each vertex in our object(s)
  - Two buffers for each set of vertex coordinates
    - Vertex coordinates in 3D space (x, y, z)
    - Texture coordinates in 2D space (s, t)
      - Assumption is that texture image is rectangular with 0, 0 in the lower left and 1,1 in the upper right.
      - Coordinates should all be between 0 and 1
- Texture coordinates are stored in a vertex attribute so they are also interpolated by the rasterizer
- Difficult to specify by hand for complex objects
  - If built in an object modeling tool, often they provide “UV-mapping” for this purpose

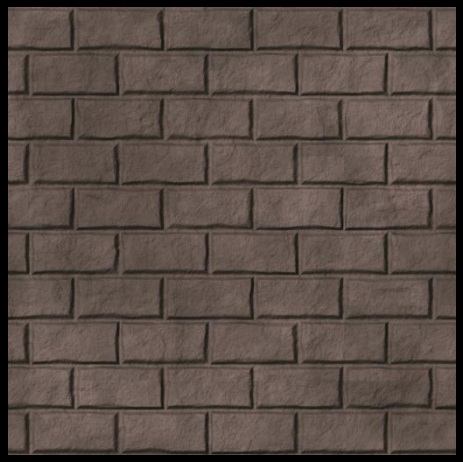
TEXTURE MAPPING GONE WRONG

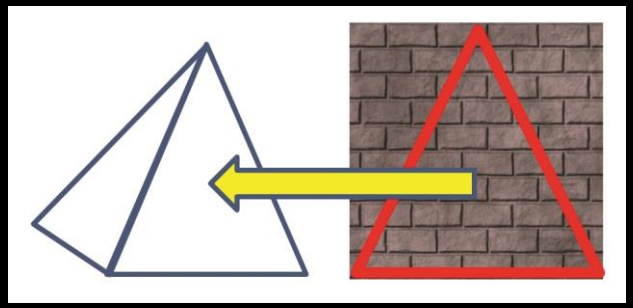
We saw this mapping last time – specifying coordinates incorrectly can have bad results

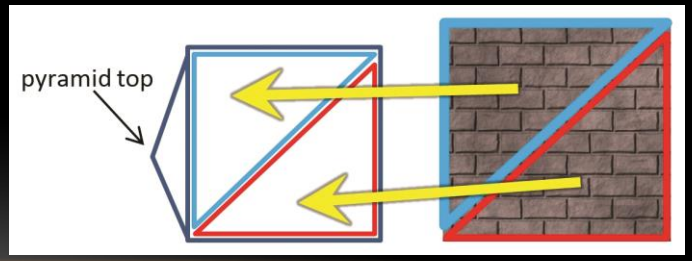


TEXTURE MAPPING

Specifying them correctly can look realistic







TEXTURE MAPPING – THE PYRAMID

Vertices			Texture Coordinates		
-1.0	-1.0	1.0	0	0	front face
1.0	-1.0	1.0	1	0	
0.0	1.0	0.0	.5	1	
1.0	-1.0	1.0	0	0	right face
1.0	-1.0	-1.0	1	0	
0.0	1.0	0.0	.5	1	
1.0	-1.0	-1.0	0	0	back face
-1.0	-1.0	-1.0	1	0	
0.0	1.0	0.0	.5	1	
…					

TEXTURE MAPPING – THE PYRAMID CODE, SETUPVERTICES() METHOD

```
float[] pyramid_positions =
{-1.0f, -1.0f, 1.0f, 1.0f, -1.0f, 1.0f, 0.0f, 1.0f, 0.0f,   //front
1.0f, -1.0f, 1.0f, 1.0f, -1.0f, -1.0f, 0.0f, 1.0f, 0.0f,   //right
1.0f, -1.0f, -1.0f, -1.0f, -1.0f, -1.0f, 0.0f, 1.0f, 0.0f, //back
-1.0f, -1.0f, -1.0f, -1.0f, -1.0f, 1.0f, 0.0f, 1.0f, 0.0f, //left
-1.0f, -1.0f, -1.0f, 1.0f, -1.0f, 1.0f, -1.0f, -1.0f, 1.0f, //LF
1.0f, -1.0f, 1.0f, -1.0f, -1.0f, -1.0f, 1.0f, -1.0f, -1.0f  //RR
};
float[] texture_coordinates =
{0.0f, 0.0f, 1.0f, 0.0f, 0.5f, 1.0f,
0.0f, 0.0f, 1.0f, 0.0f, 0.5f, 1.0f,
0.0f, 0.0f, 1.0f, 0.0f, 0.5f, 1.0f,
0.0f, 0.0f, 1.0f, 0.0f, 0.5f, 1.0f,
0.0f, 0.0f, 1.0f, 1.0f, 0.0f, 1.0f,
1.0f, 1.0f, 0.0f, 0.0f, 1.0f, 0.0f
};
```

LOADING TEXTURE COORDINATES INTO BUFFERS

- Instance variables:

```
private int vao[] = new int[1];
private int vbo[] = new int[2];
```

- In display():

```
gl.glBindBuffer(GL_ARRAY_BUFFER, vbo[0]);
gl.glVertexAttribPointer(0, 3, GL_FLOAT, false, 0, 0);
gl.glEnableVertexAttribArray(0);

gl.glBindBuffer(GL_ARRAY_BUFFER, vbo[1]);
gl.glVertexAttribPointer(1, 2, GL_FLOAT, false, 0, 0);
gl.glEnableVertexAttribArray(1);
```

GLSL CODE

- Vertex shader needs coordinates
- Fragment shader needs access to the texture object

VERTEX SHADER

```
#version 430

layout (location=0) in vec3 pos;
layout (location=1) in vec2 texCoord;
out vec2 tc;

uniform mat4 mv_matrix;
uniform mat4 proj_matrix;
layout (binding=0) uniform sampler2D samp;

void main(void)
{
    gl_Position = proj_matrix * mv_matrix * vec4(pos,1.0);
    tc = texCoord;
}
```

FRAGMENT SHADER

```
#version 430

in vec2 tc;
out vec4 color;

uniform mat4 mv_matrix;
uniform mat4 proj_matrix;
layout (binding=0) uniform sampler2D samp;

void main(void)
{
    color = texture(samp, tc);
}
```

BACK TO JAVA/JOGL CODE

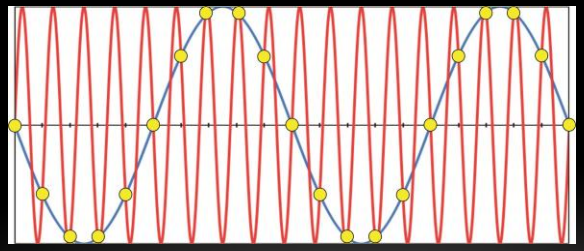
- After binding buffers with vertices and texture coordinates in display():

```
gl.glActiveTexture(GL_TEXTURE0);
gl.glBindTexture(GL_TEXTURE_2D, brickTexture);
```

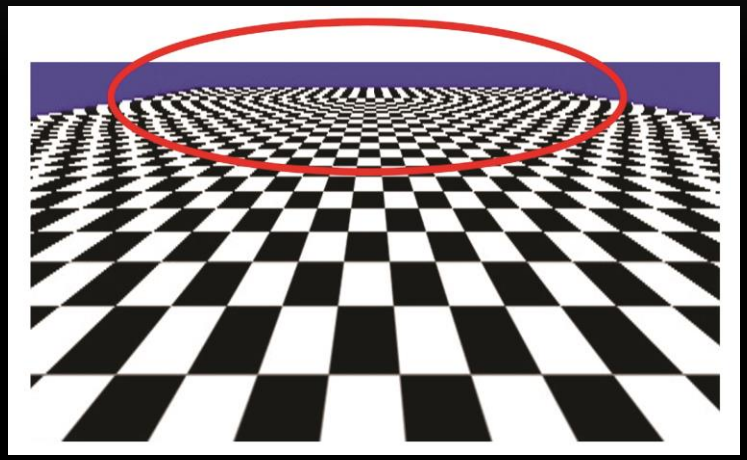
- Recall that brickTexture is an integer that holds the pointer to the OpenGL texture object we created in init()

WHAT CAN GO WRONG

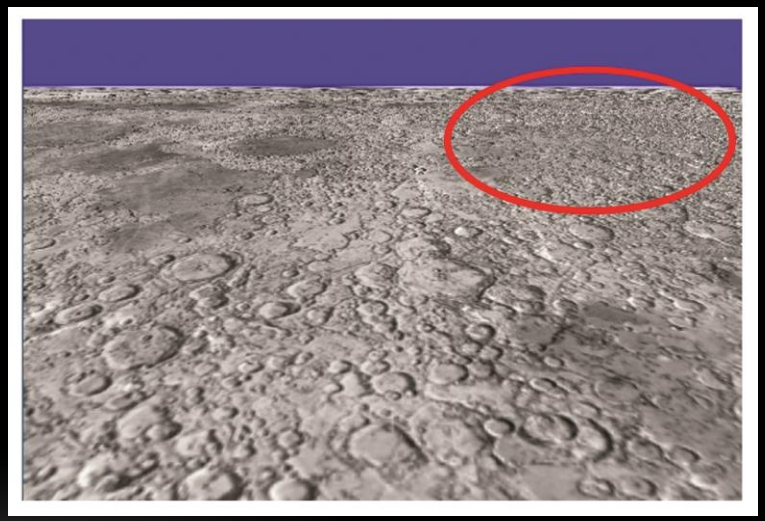
- Differences between texture image size and object image size
  - Texture image resolution less than that of object
    - Can stretch texture across image region
      - May become blurry and possibly distorted
  - Texture image resolution higher than that of object
    - Aliasing – caused by sampling errors
      - Can cause false patterns or shimmering in moving objects



WHAT CAN GO WRONG



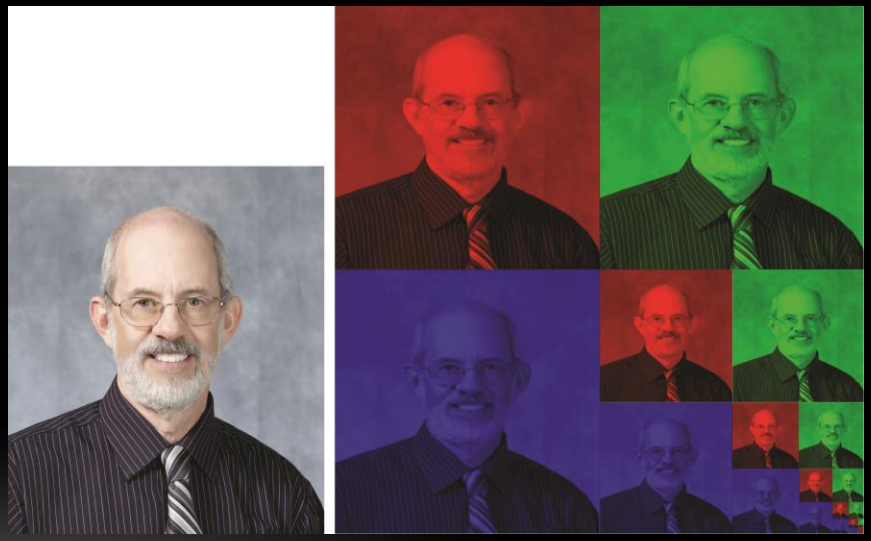
False patterns



Shimmering

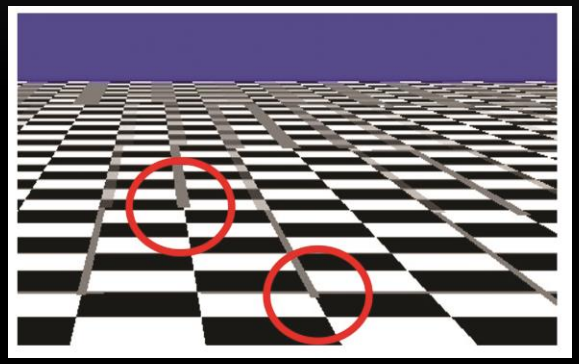
MIPMAPPING

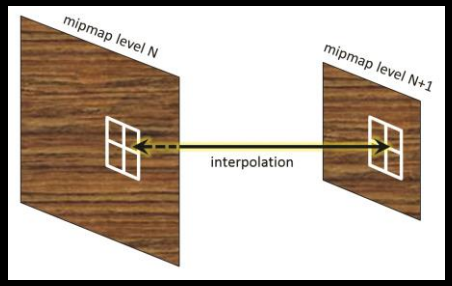
- Can often correct aliasing errors
- Different versions (sizes) of the image stored in the texture buffer
  - The one closest to the size of the region is used for texturing
  - Separate RGB versions of the image are stored at each resolution
- Several ways to sample a mipmap
  - GL_NEAREST_MIPMAP_NEAREST
  - GL_LINEAR_MIPMAP_NEAREST
  - GL_NEAREST_MIPMAP_LINEAR
  - GL_LINEAR_MIPMAP_LINEAR

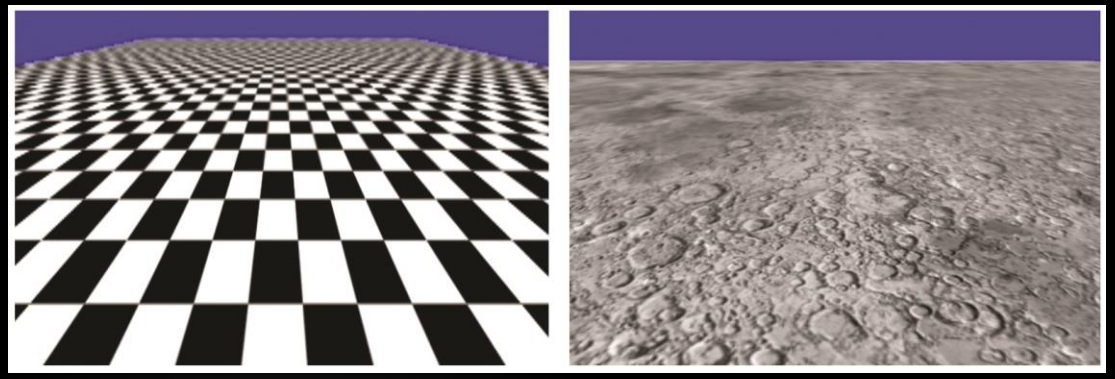


MIPMAPPING

Linear filtering
(GL_LINEAR_MIPMAP_NEAREST)







Trilinear filtering
(GL_LINEAR_MIPMAP_LINEAR)

MIPMAPPING

- In the Java/JOGL code, after loading the texture object:

```
gl.glBindTexture(GL_TEXTURE_2D, brickTexture);
gl.glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER,
                   GL_LINEAR_MIPMAP_LINEAR);
gl.glGenerateMipmap(GL.GL_TEXTURE_2D);
```

FILTERING

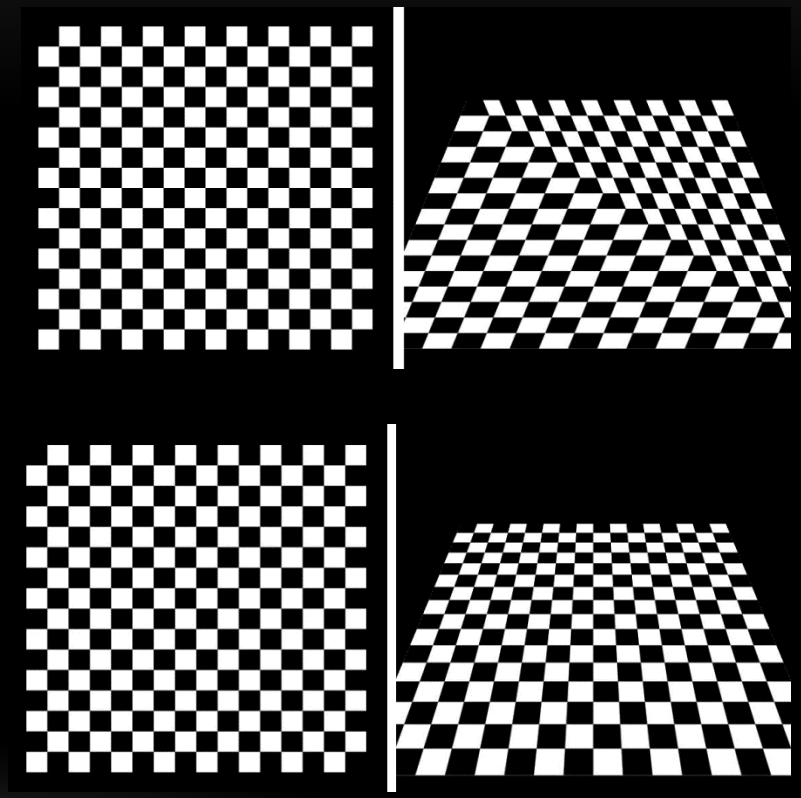
- Mipmapped images can appear more blurry
- Anisotropic filtering uses rectangular resolutions of the image as well as the square versions in mipmapping
  - More computationally expensive (of course)
- Java/JOGL code in init():

```
if (gl.isExtensionAvailable("GL_EXT_texture_filter_anisotropic"))
{
   float anisoset[] = new float[1];
   gl.glGetFloatv(GL_MAX_TEXTURE_MAX_ANISOTROPY_EXT, anisoset, 0);
   gl.glTexParameterf(GL_TEXTURE_2D, GL_TEXTURE_MAX_ANISOTROPY_EXT,
                      anisoset[0]);
}
```

PERSPECTIVE CORRECTION

- OpenGL applies perspective correction by default
  - Corrects for distortion caused by perspective projection
  - If you don't want this, can turn it off by including the following in both the vertex and fragment shaders:

```
noperspective out vec2 texCoord;
```



SUMMARY

- Implementing Texturing
- What Can Go Wrong and How to Fix It
  - Mipmapping
  - Filtering
  - Perspective Correction