

Texture Mapping

CSCI 4229/5229

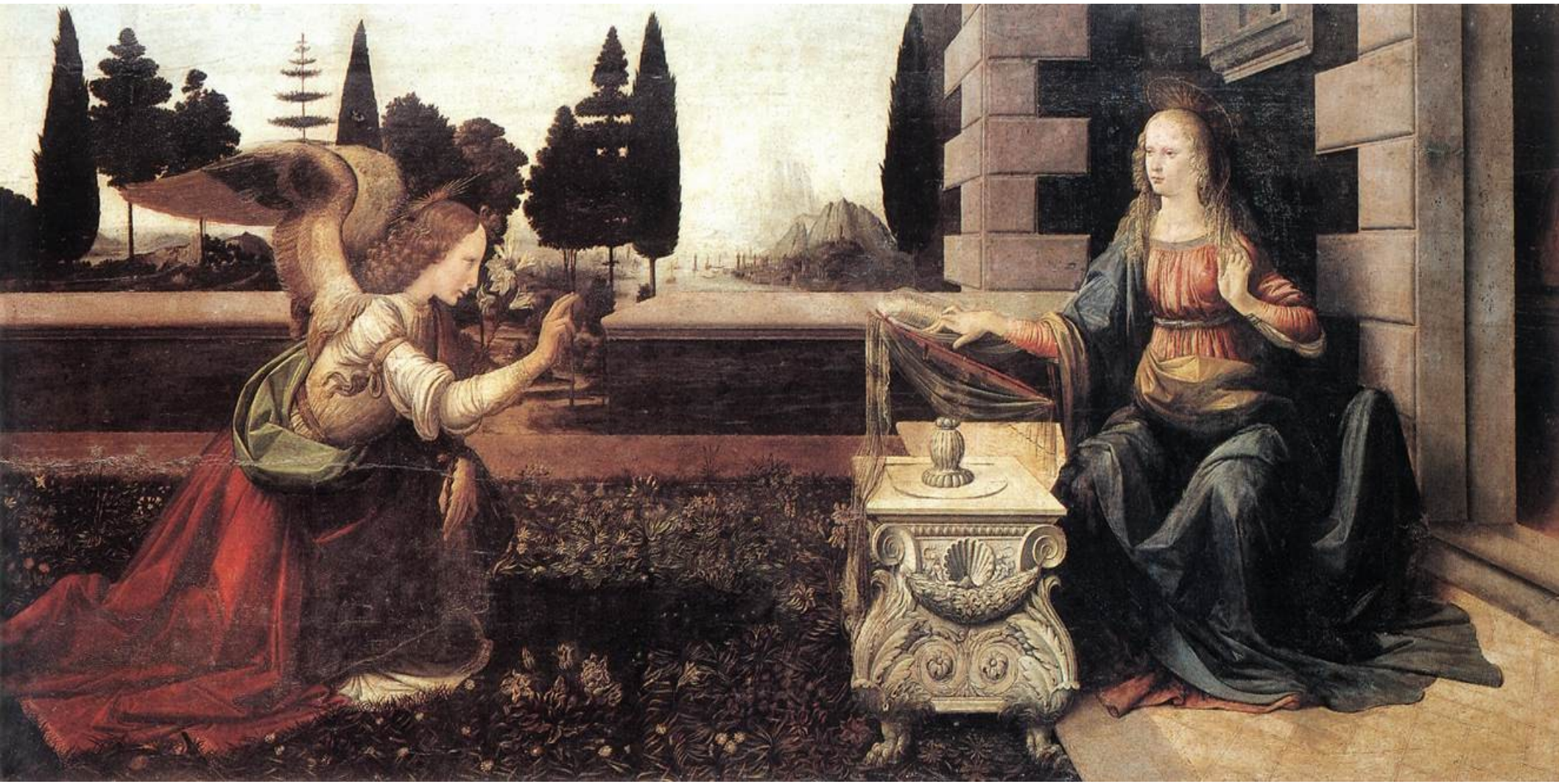
Computer Graphics

Summer 2024

What are texture maps?

- Bitmap images used to assign fine texture to displayed surfaces
- Used to make surfaces appear more realistic
- Must move with the surfaces
- Can be stretched or repeated
- Simple in concept, but hardware intensive

Annunciation Leonardo da Vinci (1472)



OpenGL Texture Types

- Images are draped over polygon surfaces
- 1D, 2D and 3D textures
 - (s,t,r,q) coordinates
 - 2D uses (s,t) , q is the homogeneous w
- 1D, 2D and 3D textures set separately
- 2D textures most commonly used

OpenGL Texture Calls

- glGenTextures
 - Returns unused texture name(s)
- glBindTexture
 - Sets the active (current) texture
- glTexImage*
 - Copies image to texture memory
- glTexCoord*
 - Sets texture coordinates for vertex
- glTexEnv*, glTexParameter*
 - Control application of textures

Creating a Texture

- `glGenTextures(1,&texname);`
 - Returns unique texture name
- `glBindTexture(GL_TEXTURE_2D,texname);`
 - First use - allocates memory and makes current
- `glTexImage2D(GL_TEXTURE_2D,0,3,dx,dy,0,GL_RGB,GL_UNSIGNED_BYTE,image);`
 - Copies RGB *image* to texture memory (size *dx,dy*)
 - Image size must be power of two before OpenGL 2

Setting the Texture Properties

```
glTexParameteri(GL_TEXTURE_2D,  
    GL_TEXTURE_MAG_FILTER, GL_LINEAR);
```

- How to magnify texture

```
glTexParameteri(GL_TEXTURE_2D,  
    GL_TEXTURE_MIN_FILTER, GL_LINEAR);
```

- How to minify texture

```
glTexEnvf(GL_TEXTURE_2D,  
    GL_TEXTURE_ENV_MODE, GL_MODULATE);
```

- How textures interact with underlying surface

Applying a Texture Map

```
glBindTexture(GL_TEXTURE_2D, texname);
glBegin(GL_POLYGON);
for (i=0; i<n; i++)
{
    glTexCoord2d(s[i], t[i]);
    glVertex3d(x[i], y[i], z[i]);
}
glEnd();
```


Automatic Texture Coordinates

- `glTexGen*`()
 - Can generate textures automatically for polygons
- `glutSolidTeapot()`
 - Textures coordinates generated
- `gluQuadric` objects
 - `gluQuadricTexture(obj, bool)` controls automatic texture coordinate generation

Creating a Texture

- `glGenTextures(n, texname[]);`
 - Returns n unique texture names
- `glBindTexture(GL_TEXTURE_2D, texname);`
 - First use - allocates memory and makes current
 - Subsequent uses just makes it current
 - All operations applies to current texture
 - Current texture is applied to surfaces
 - Current texture is modified by `glTexImage`, etc

```
glTexImage2D(GL_TEXTURE_2D,0,3,dx,dy,  
0,GL_RGB,GL_UNSIGNED_BYTE,image);
```

- `GL_TEXTURE_2D` or `GL_PROXY_TEXTURE_2D`
- Level 0 (or higher for MIPmaps)
- Internal representation 3 (or one of many others)
- Size $dx \times dy$ [must be 2^n before OpenGL 2.0]
- Border 0 (none) or 1 (pixel width)
- Source image is RGB (or one of many others)
- Source data is unsigned char (or short, etc)
- Image data pointer (can be freed after call)

```
glTexParameter*(GL_TEXTURE_2D,par,val);
```

- **GL_TEXTURE_MAG_FILTER** (magnification)
 - GL_LINEAR (interpolate)
 - GL_NEAREST
- **GL_TEXTURE_MIN_FILTER** (minification)
 - GL_LINEAR (interpolate)
 - GL_NEAREST
 - GL_NEAREST_MIPMAP_NEAREST
 - GL_NEAREST_MIPMAP_LINEAR
 - GL_LINEAR_MIPMAP_NEAREST
 - GL_LINEAR_MIPMAP_LINEAR

```
glTexParameter*(GL_TEXTURE_2D,par,val);
```

- GL_TEXTURE_WRAP_S (horizontal)
- GL_TEXTURE_WRAP_T (vertical)
- GL_TEXTURE_WRAP_R (depth)
 - GL_REPEAT (ignore integer part of s,t)
 - GL_MIRRORED_REPEAT (odds backward)
 - GL_CLAMP - limit to (0,1)
 - GL_CLAMP_TO_EDGE - limit to $\frac{1}{2}$ pixel in
 - GL_CLAMP_TO_BORDER - limit to $\frac{1}{2}$ pixel out

```
glTexParameter*(GL_TEXTURE_2D,par,val);
```

- `GL_TEXTURE_BORDER_COLOR`
 - Set border RGBA (4 component float vector)
- `GL_TEXTURE_PRIORITY (0-1)`
- *and many more ...*

glTexEnvi(GL_TEXTURE_2D, val, par)

- GL_TEXTURE_ENV_MODE
 - GL_MODULATE (multiply)
 - GL_REPLACE
 - GL_DECAL (transparent combine)
 - GL_BLEND
 - GL_COMBINE
 - GL_ADD (arithmetic)
- *and many more ...*

Multiple Textures

- `glActivateTexture(GL_TEXTUREn);`
 - Call BEFORE `glBindTexture()` etc
- Specify multiple texture coordinates per vertex
 - `glMultiTexCoord2f(GL_TEXTURE0,r0,s0);`
 - `glMultiTexCoord2f(GL_TEXTURE1,r1,s1);`
 - `glMultiTexCoord2f(GL_TEXTURE2,r2,s2);`
 - `glVertex3d(x,y,z);`

MIPmaps

- *multum in parvo* (much in little)
- Textures adapted to great distances
 - Level 0=64x64, Level 1=32x32, ... ,
Level 6=1x1
- Can be generated manually or automatically
 - gluBuild2DMipmaps()
 - gluBuild2DMipmapLevels()