CS380: Computer Graphics
Texture Mapping

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Course URL:
http://sgvr.kaist.ac.kr/~sungeui/CG

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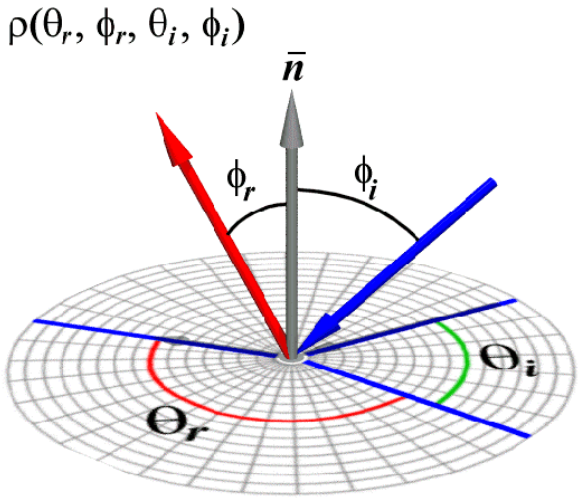
Class Objectives (Ch. 9)

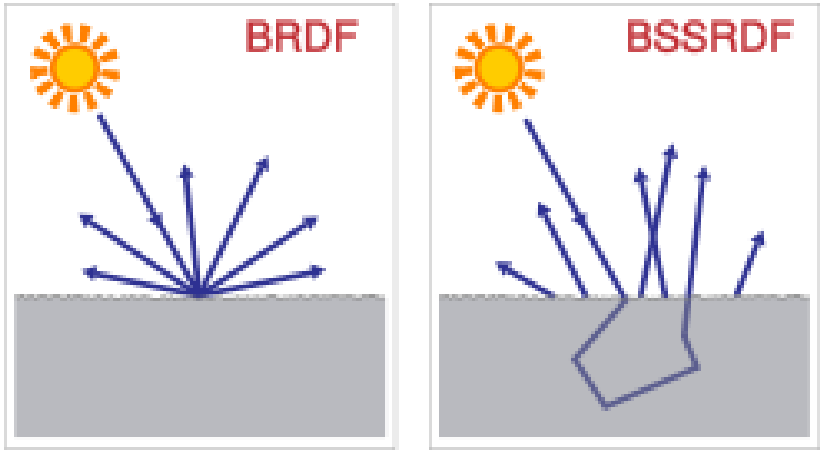
- Texture mapping overview
- Texture filtering

- At the last time
  - Phong illumination: ambient, diffuse, specular, and non-ideal reflectors
  - Shading methods

Questions

- **In BRDF, if the material is transparent, can phi_r value could be over 90 degrees?**





wiki

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Texture Mapping

- **Requires lots of geometry to fully represent complex shapes of models**
- **Add details with image representations**

Excerpted from MIT EECS 6.837,
Durand and Cutler

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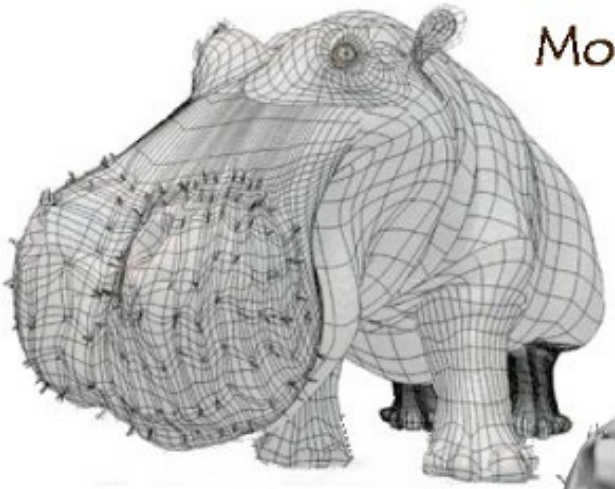
The Quest for Visual Realism



Model

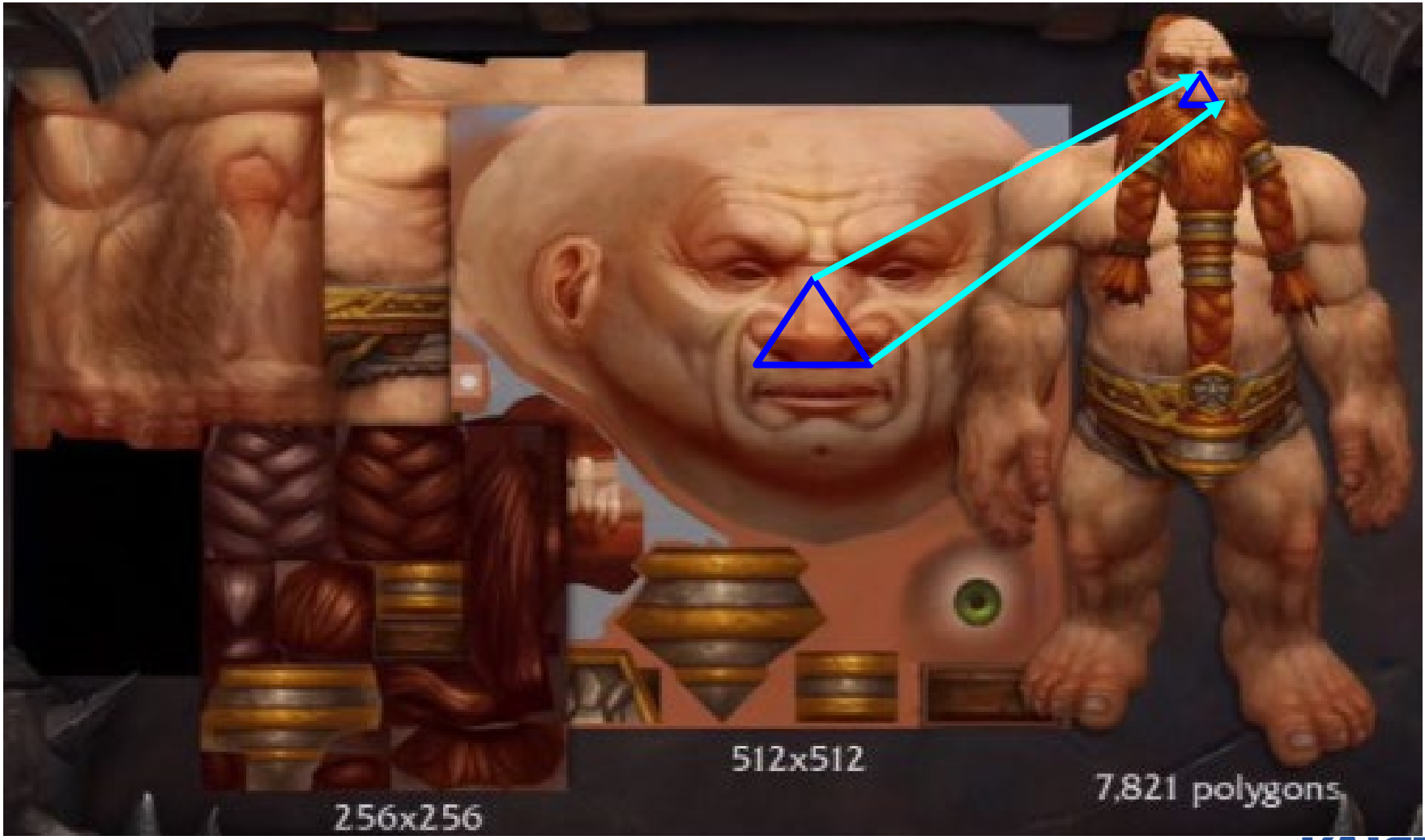
Model + Shading

Model + Shading + Textures

At what point do things start looking real?

For more info on the computer artwork of Jeremy Birn see http://www.3drender.com/jbirn/productions.html

Texture Mapping



From MMO-champion

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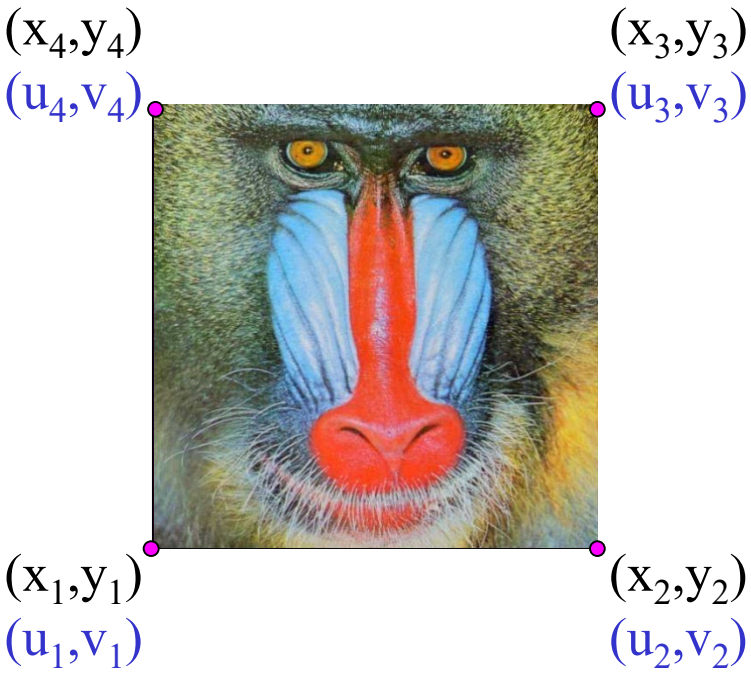
Texture Maps in OpenGL



- **Specify normalized texture coordinates at each of the vertices**
- **Texel indices**
  (s,t) = (u, v) · (width, height)

```
glBindTexture(GL_TEXTURE_2D, texID)
glBegin(GL_POLYGON)
  glTexCoord2d(0,1); glVertex2d(-1,-1);
  glTexCoord2d(1,1); glVertex2d( 1,-1);
  glTexCoord2d(1,0); glVertex2d( 1, 1);
  glTexCoord2d(0,0); glVertex2d(-1, 1);
glEnd()
```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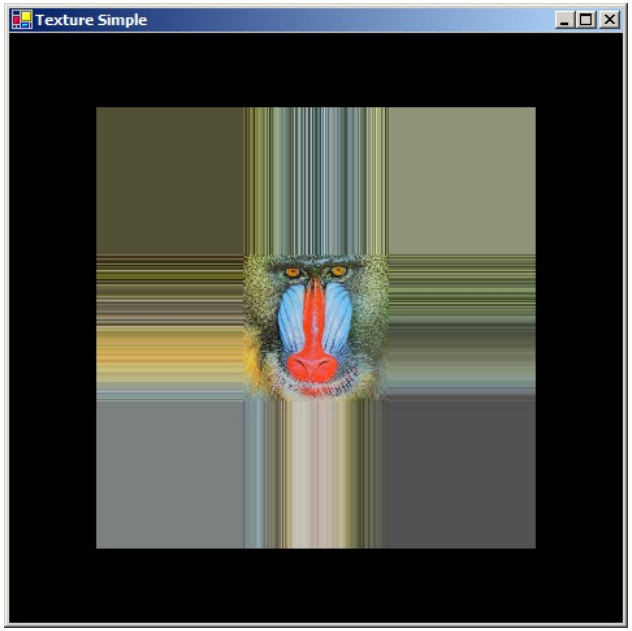
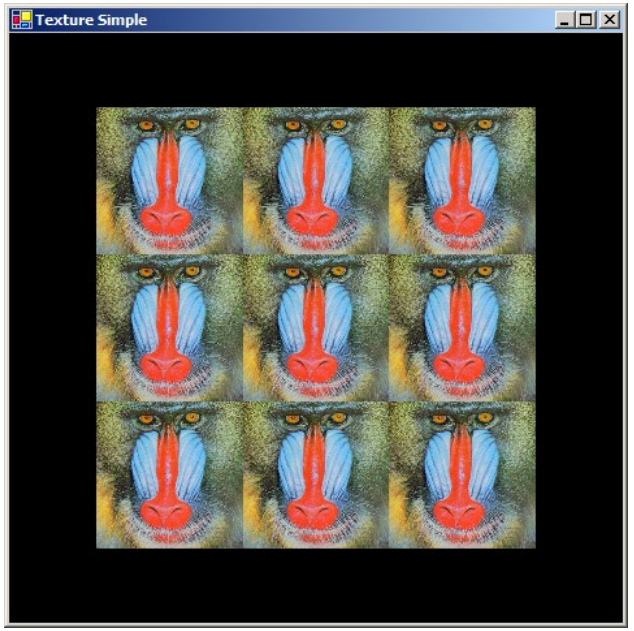
Wrapping

- **The behavior of texture coordinates outside of the range [0,1) is determined by the texture wrap options.**

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_S, wrap_mode )
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_WRAP_T, wrap_mode )
```



GL_CLAMP



GL_REPEAT

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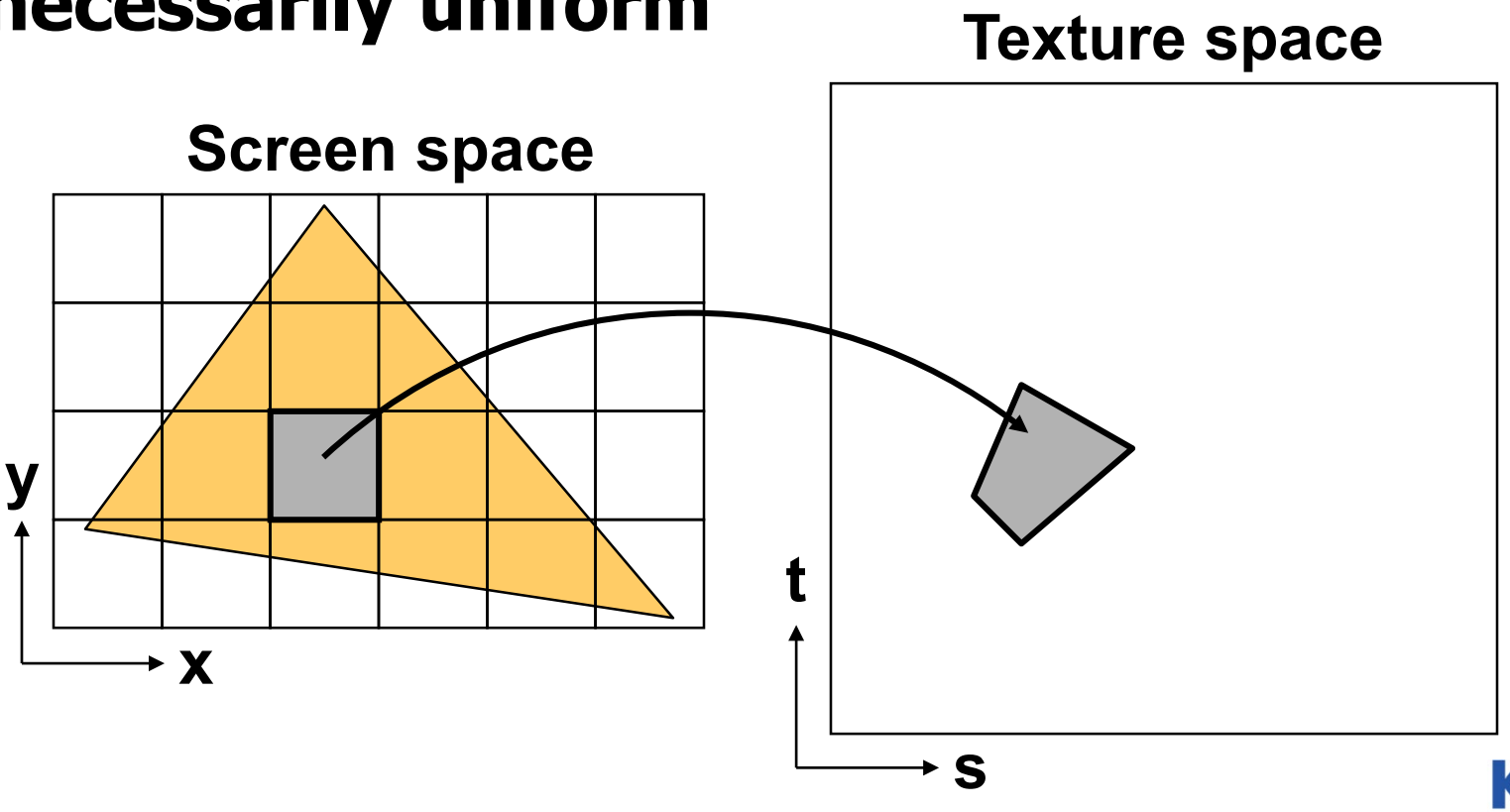
Sampling Texture Maps

- **The uniform sampling pattern in screen space cooresponds to some sampling pattern in texture space that is not necessarily uniform**



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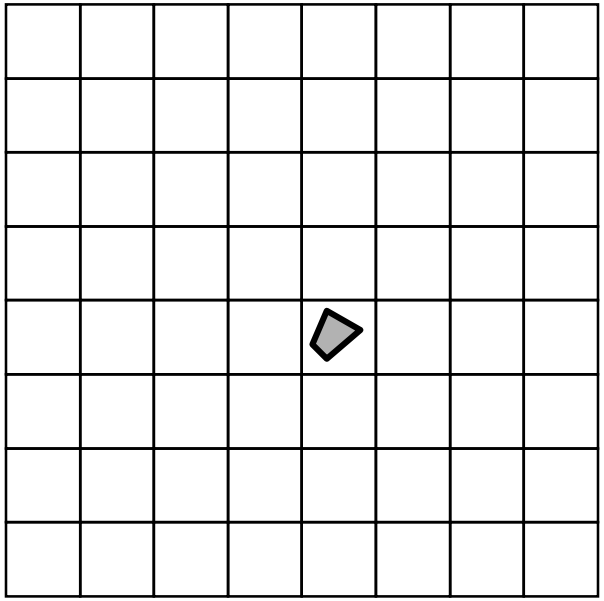
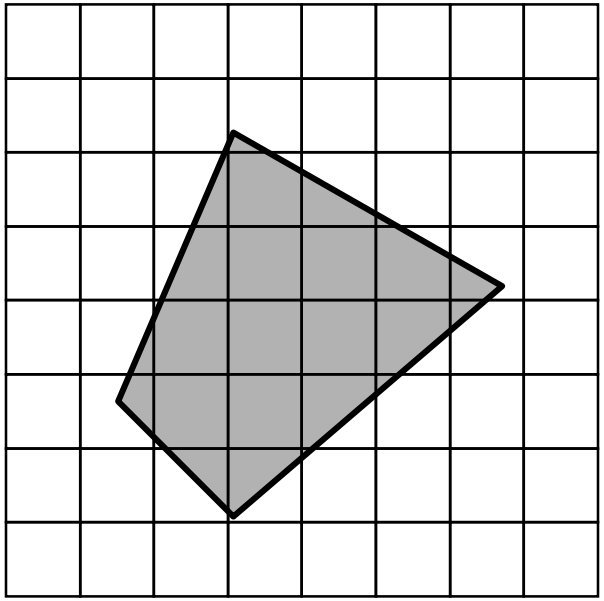
Sampling Density Mismatch

- **Sampling density in texture space rarely matches the sample density of the texture itself**

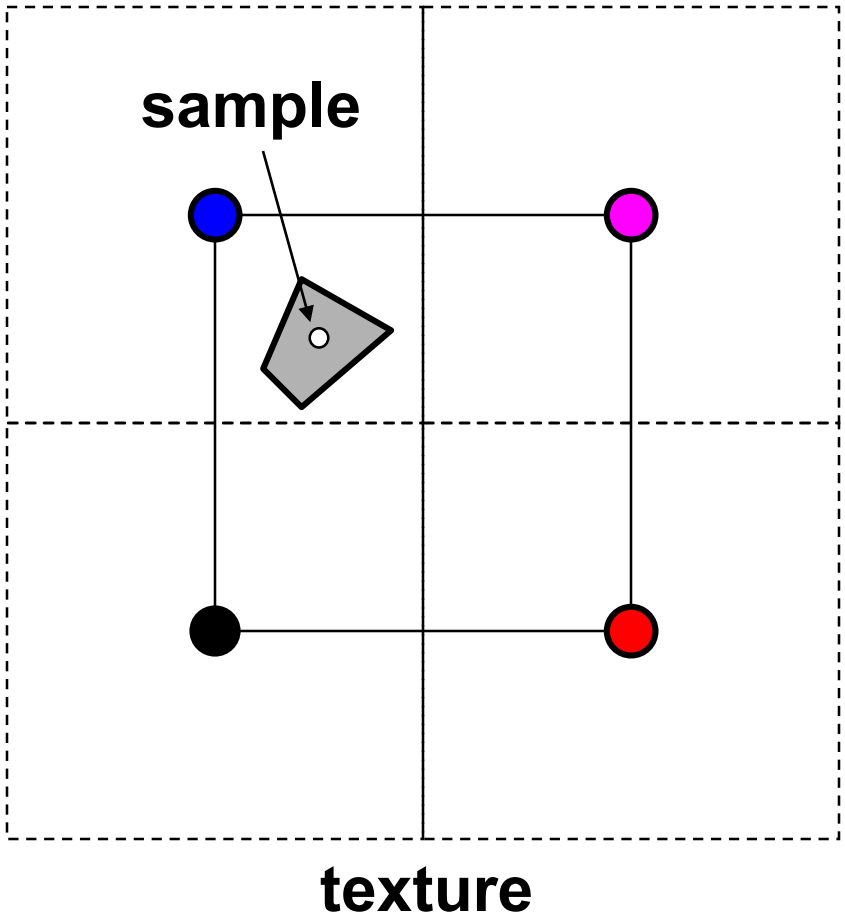


Oversampling (Magnification)



Undersampling (Minification)

Handling Oversampling



- How do we compute the color to assign to this sample?

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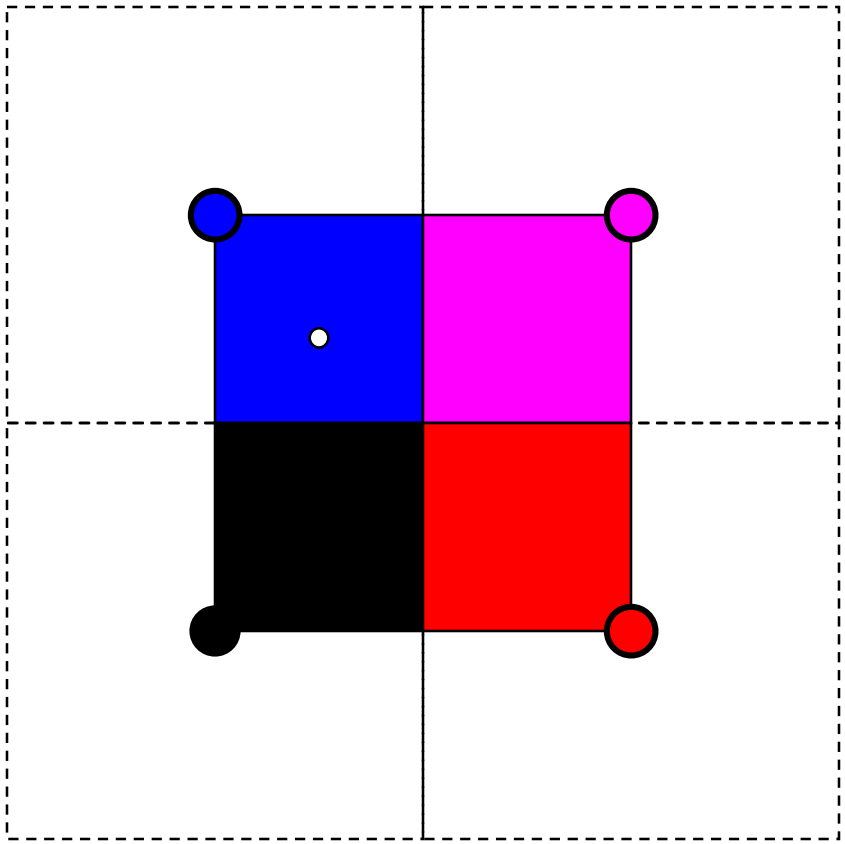
Handling Oversampling



- How do we compute the color to assign to this sample?
- Nearest neighbor – take the color of the closest texel

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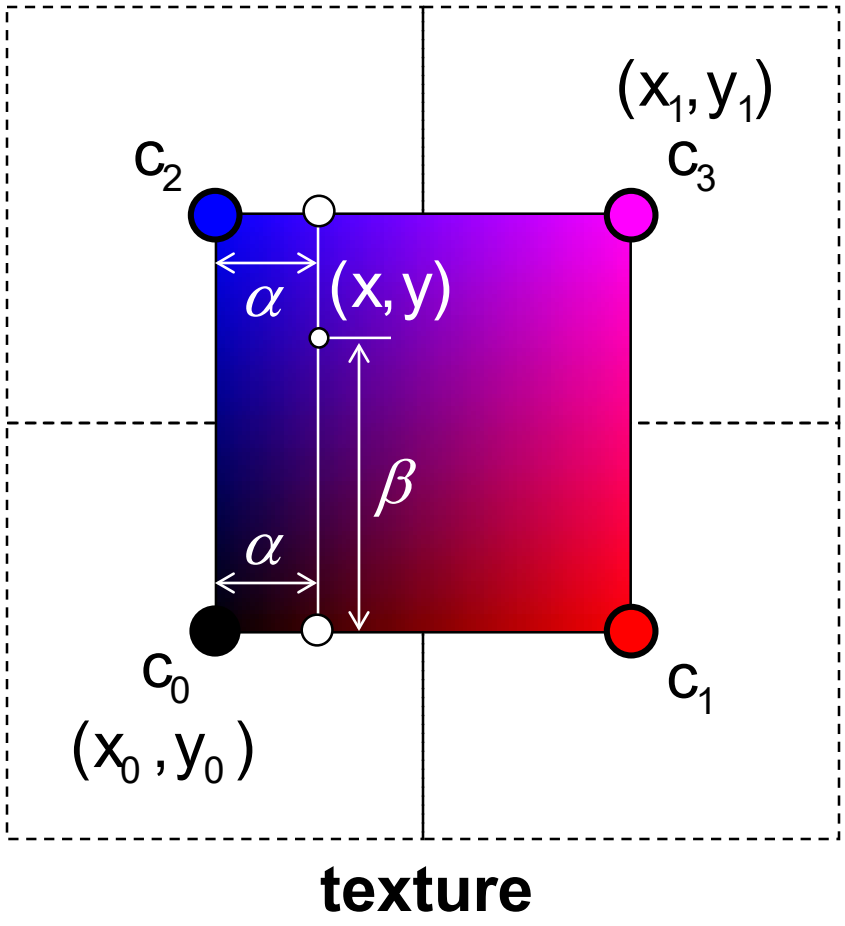
Handling Oversampling



- **How do we compute the color to assign to this sample?**
- **Nearest neighbor – take the color of the closest texel**
- **Bilinear interpolation**

$$\alpha = \frac{x - x_0}{x_1 - x_0} \qquad \beta = \frac{y - y_0}{y_1 - y_0}$$

$$c = ((1-\alpha)c_0 + \alpha c_1)(1-\beta) + ((1-\alpha)c_2 + \alpha c_3)\beta$$

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Visual Comparison

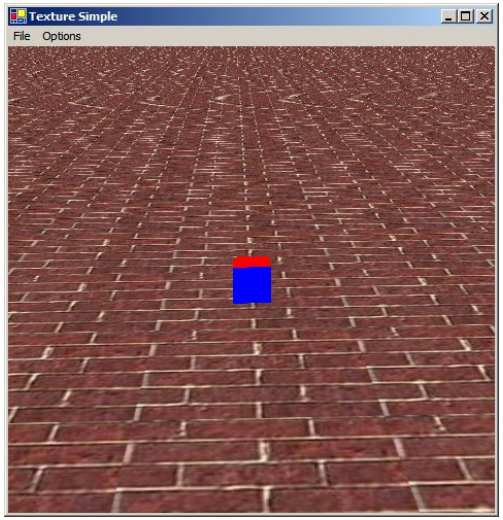
Mag. filter: nearest
Min. filter: linear

Mag. filter: linear
Min. filter: linear

Original texture

Mag. filter: linear
Min. filter: mipmap

Undersampling



- Details in the texture tend to pop (disappear and reappear)
  - Mortar (white substances) in the brick
- High-frequency details lead to strange patterns
  - Aliasing

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Spatial Filtering

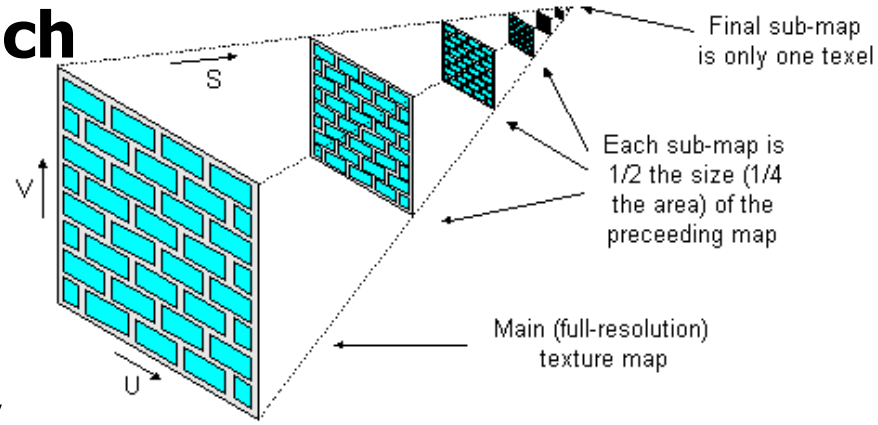
- To avoid aliasing we need to prefilter the texture to remove high frequencies
  - Prefiltering is essentially a spatial integration over the texture
  - Integrating on the fly is expensive: perform integration in a pre-process

Samples and their extents

Proper filtering removes aliasing

MIP Mapping

- **MIP is an acronym for the Latin phrase *multium in parvo*, which means "many in one place"**
  - **Constructs an *image pyramid***
  - **Each level is a prefiltered version of the level below resampled at half the frequency**



- **While rasterizing use the level with the sampling rate closest to the desired sampling rate**
  - **Can also interpolate between pyramid levels**
- **How much storage overhead is required?**

$$\text{mip map size} = \sum_{i=0}^{\infty} \left(\frac{1}{4}\right)^i = \frac{1}{1-\frac{1}{4}} = \frac{4}{3}$$

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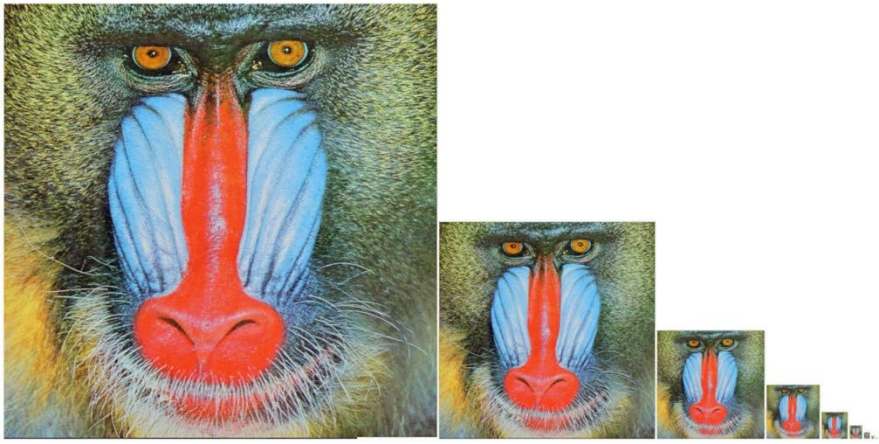
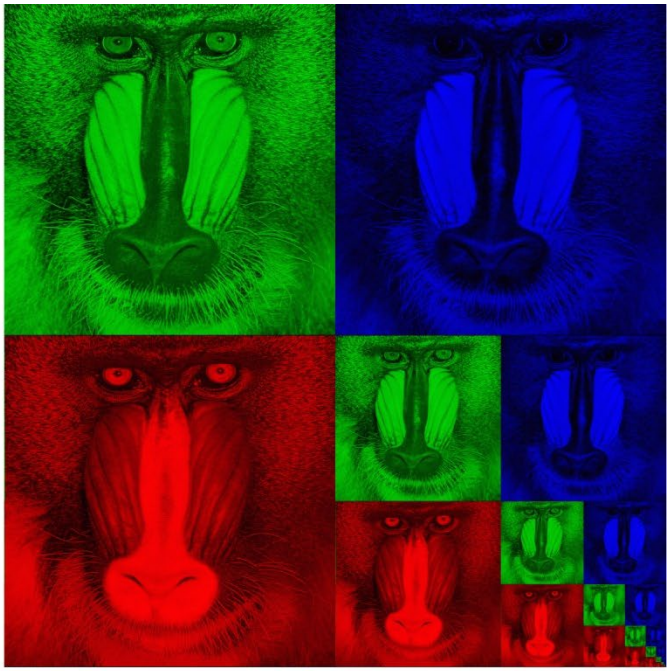
Storing MIP Maps

- One convenient method of storing a MIP map is shown below
  - It also nicely illustrates the 1/3 overhead of maintaining the MIP map



10-level mip map



Memory format of a mip map

Finding the MIP Level

- **Use the projection of a pixel in screen into texture space to figure out which level to use**

Texture Filtering in OpenGL

- **Automatic creation**

```
gluBuild2DMipmaps(GL_TEXTURE_2D, GL_RGBA, width, height,
                  GL_RGBA, GL_UNSIGNED_BYTE, data)
```

- **Filtering**

```
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MAG_FILTER, filter )
glTexParameteri(GL_TEXTURE_2D, GL_TEXTURE_MIN_FILTER, filter )
```

where filter is:

```
GL_NEAREST
GL_LINEAR

GL_LINEAR_MIPMAP_LINEAR
GL_NEAREST_MIPMAP_NEAREST
GL_NEAREST_MIPMAP_LINEAR
GL_LINEAR_MIPMAP_NEAREST
```

inter-level **intra-level**

Class Objectives were:

- Texture mapping overview
- Texture filtering

Next Time

- Various applications of texture mapping
- Visibility and ray tracing

Homework

- **Go over the next lecture slides before the class**
- **Watch 2 SIGGRAPH videos and submit your summaries before every Mon. class**
- **Submit questions two times during the whole semester**