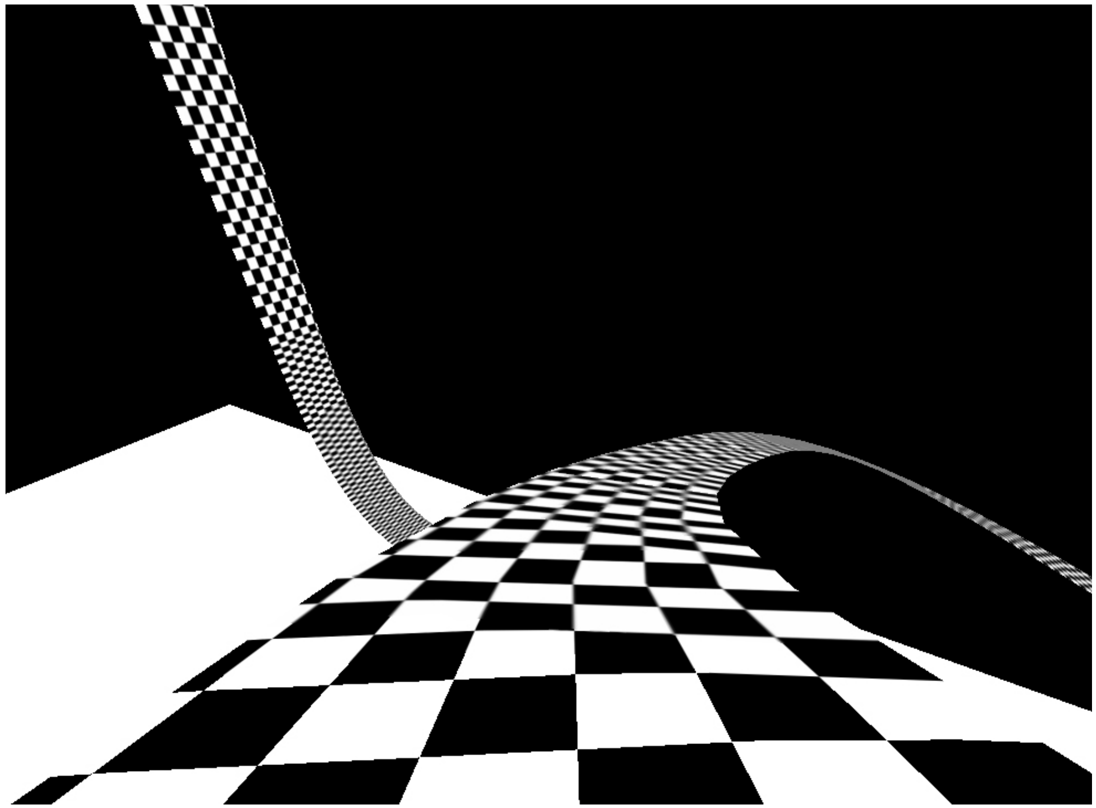
MipMap Texturing



Outline

- MipMapping
- Creating MipMaps
- Using MipMaps
- Trilinear MipMapping
- Anisotropic MipMapping
- Exercise Demo

Goals

- You can explain why it is a good idea to use mipmaps
- You know how to generate mipmaps in OpenGL
- You know the different filters for mipmap generation
- You can implement more sophisticated filters by yourself

MipMapping I

Without mipmapping:
artifacts/aliasing at details

Solution:
filter details before rendering

This happens without mipmapping

MipMapping II

- Textured objects can be viewed at different distances from the viewpoint

Problem: Which level of detail (Resolution) should one use for the texture image?

Too high resolution:	Aliasing effects
Too small resolution:	Too few details visible

Solution: Use different levels of detail according to the distance between object and viewpoint
→ mipmaps

MipMapping III

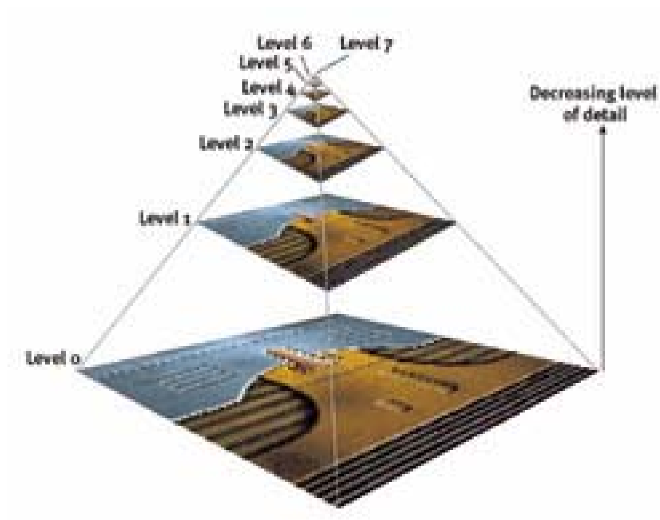
- History: 1983 Lance Williams introduced the word “mipmap” in his paper “Pyramidal Parametrics”
- mip = “multum in parvo”
(lat.: many things in small place)

- Solves LOD problem by generating a pyramid of textures
  - Highest texture resolution at pyramid level 0
  - Halfed Resolution at each subsequent level

MipMapping IV

- MipMap pyramid:
  - needs 1 1/3 times the space

$$\sum_{i=0}^{\infty} \frac{A}{4^i} = A \cdot \frac{4}{3}$$



- OpenGL automatically determines the mipmap level to use based on the projected size of the object

Creating MipMaps I

- When creating the mipmap pyramid we have to compute the smaller levels

  - this is done by downsampling the original texture

- Definition:

  $\mathbf{c_i}(x,y)$ = color of the texture of level i at (x,y)

Creating MipMaps II

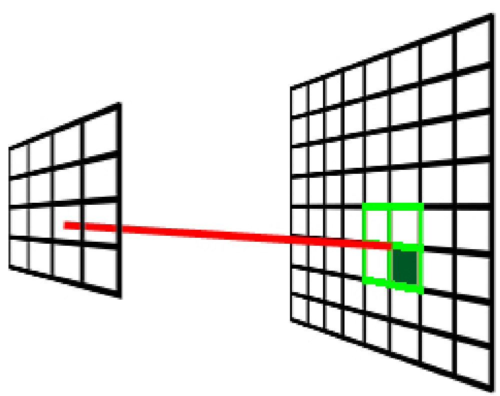
1. Nearest Neighbour

$$\mathbf{c}_\mathbf{i}(x,y) = \mathbf{c}_\mathbf{i-1}(x\cdot 2, y\cdot 2)$$

sampling from the level below

$$\mathbf{c}_\mathbf{i}(x,y) = \mathbf{c}_\mathbf{0}(x\cdot 2^i, y\cdot 2^i)$$

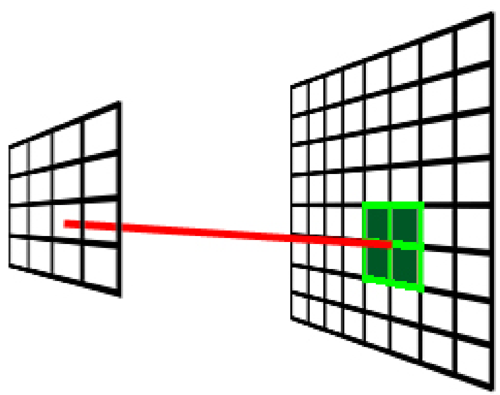
sampling from the original texture



Creating MipMaps III

2. Boxfilter

$$\mathbf{c_i}(x,y) = \frac{1}{4}\left(\mathbf{c_{i-1}}(x\cdot 2, y\cdot 2) + \mathbf{c_{i-1}}(x\cdot 2+1, y\cdot 2) + \mathbf{c_{i-1}}(x\cdot 2, y\cdot 2+1) + \mathbf{c_{i-1}}(x\cdot 2+1, y\cdot 2+1) \right)$$



Creating MipMaps IV

3. Gaussian filter

To avoid aliasing effects a low pass filter (like a gaussian or sinc filter) is optimal

Unfortunately this is computational expensive

Therefore we discretize the filter into a matrix and perform a discrete convolution

Filter Matrix:
(Gaussian)

$$(1/256) * \begin{bmatrix} 1 & 4 & 6 & 4 & 1 \\ 4 & 16 & 24 & 16 & 4 \\ 6 & 24 & 36 & 24 & 6 \\ 4 & 16 & 24 & 16 & 4 \\ 1 & 4 & 6 & 4 & 1 \end{bmatrix}$$

Creating MipMaps V

- MipMapping in OpenGL:

```
void glTexImage2D( GL_TEXTURE_2D, GLint level,
   GLint components, GLsizei width, GLsizei height,
   GLint border, GLenum format, GLenum type, const
   GLvoid *pixels);
```

→ loads texture for the MipMap level
(level 0 = original texture)

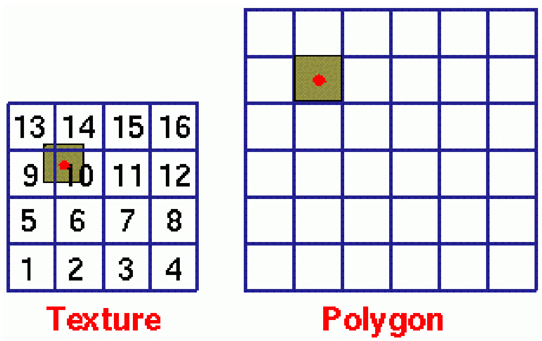
```
void gluBuild2DMipMaps();
```

→ calls `glTexImage2D(...)` for each level

Texture-Lookup I

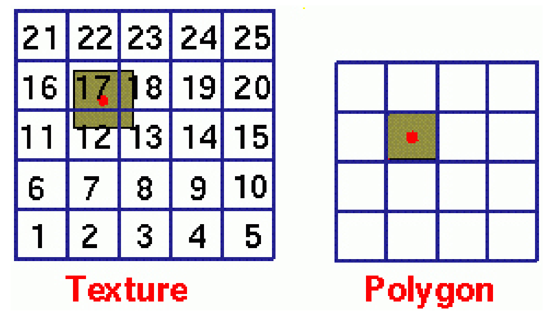
- Problems when looking up color in the texture

Minification:



- Pixels map to less than one texel

Magnification:



- Pixels map to more than one texel

Filtering:

Nearest: centre of texel on texture determines color
Bilinear: weighted average of overlapping pixel

Texture-Lookup II

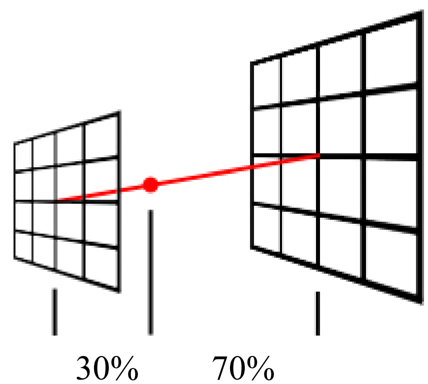
- Problem with bilinear:

  - it is visible where the mipmap level changes

←

Trilinear Filtering I

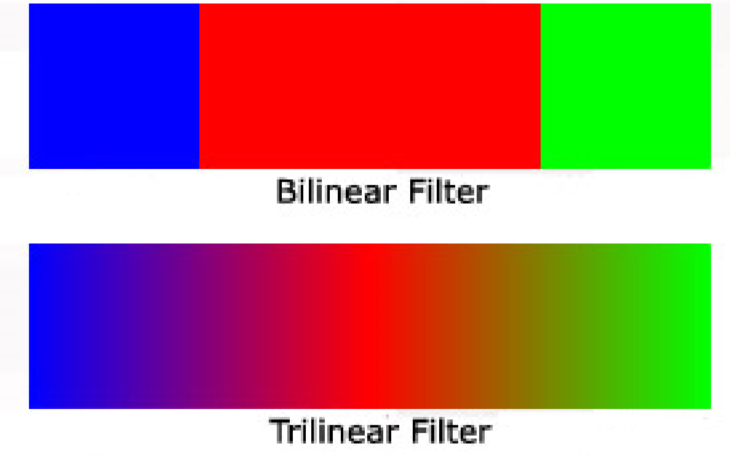
- linear filtering between two mipmap levels



In this example, the color of the pixel would be :
0.3 * (color of level i) + 0.7 * (color of level i-1)

Trilinear Filtering II

- Colored mipmaps:



- with bilinear the change of levels is acute
- with trilinear the levels fade in smoothly

Trilinear Filtering III

- MipMap filtering in OpenGL:

```
void glTexParameteri( GL_TEXTURE_2D,
                      GL_TEXTURE_MIN_FILTER,
GLenum filter         );
```

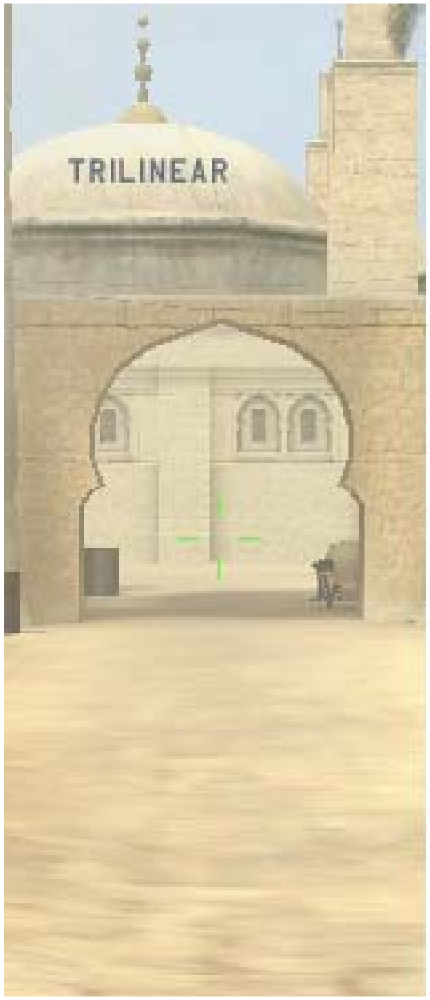
→ filter:

```
GL_NEAREST
GL_LINEAR
GL_NEAREST_MIPMAP_NEAREST
GL_NEAREST_MIPMAP_LINEAR
GL_LINEAR_MIPMAP_NEAREST
GL_LINEAR_MIPMAP_LINEAR
```
(trilinear)

↑ filter used to sample texture

↑ filter used when combining mipmap levels

Anisotropic Filtering I

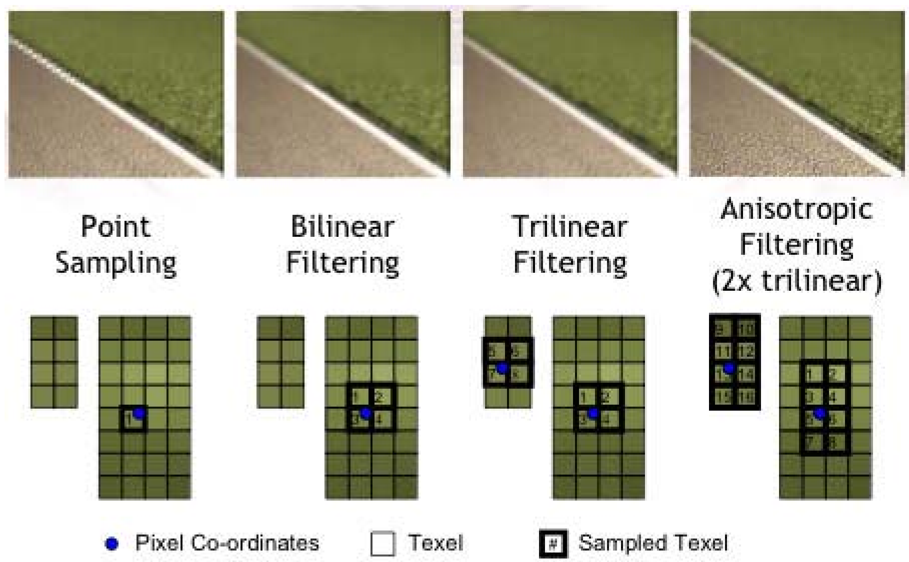


- Trilinear mipmapping blurs for acute angles

trilinear (also bilinear) filtering does not take the perspective into account

Anisotropic Filtering II

- Anisotropic filtering looks at the projection of the pixel onto the texture



k anisotropic means that k samples of the texture are used to approximate the projection of the pixel (here k=8)

Anisotropic Filtering III