Mipmaps

Lecture 31

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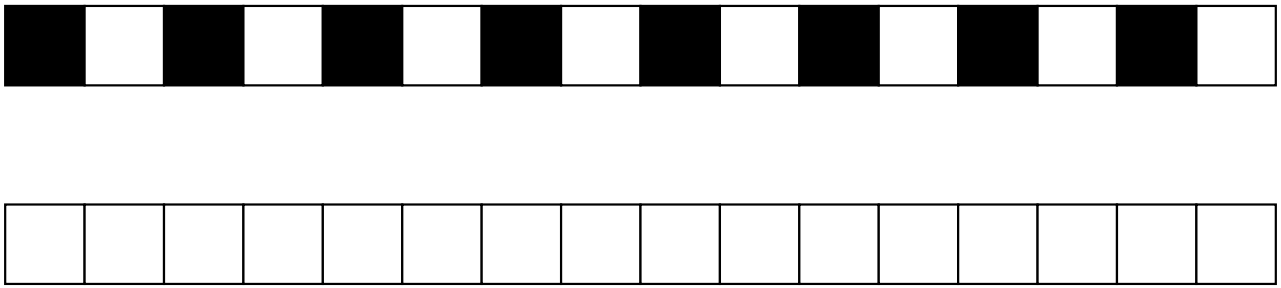
Outline

Discrete Sampling

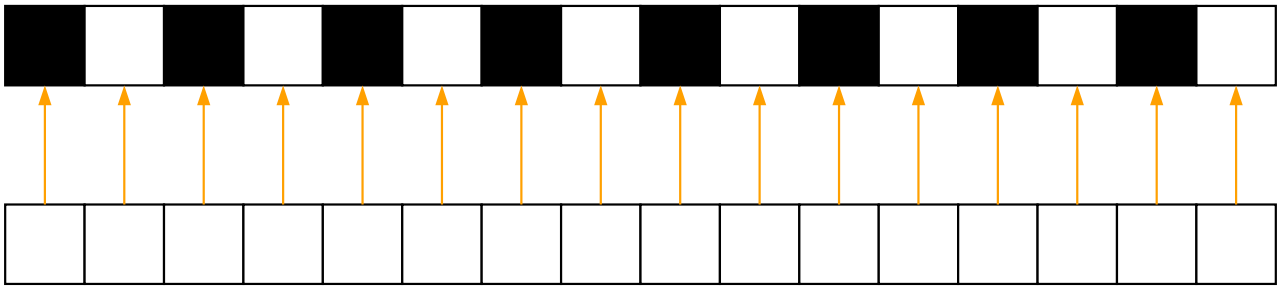
- Suppose we are drawing a 2-dimensional black-and-white checkerboard pattern.
- Suppose that the surface is close enough to the camera and oriented just right that each texel matches exactly one pixel.

Discrete Sampling



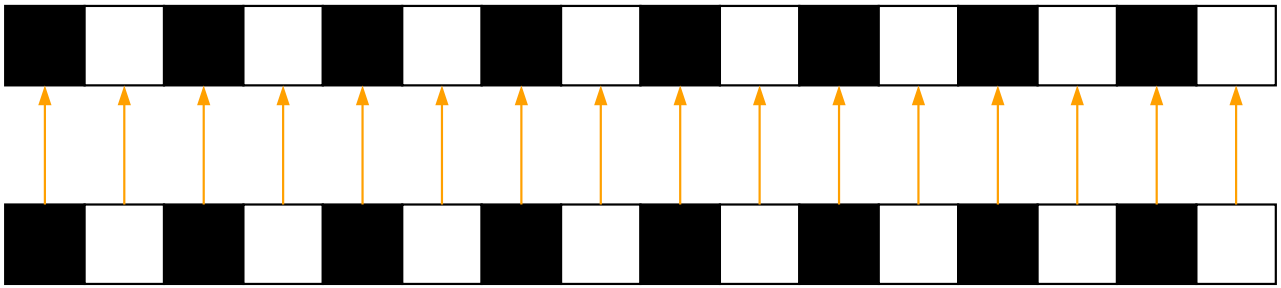
Consider one row of pixels and texels, where the pixels and texels are the same size.

Discrete Sampling



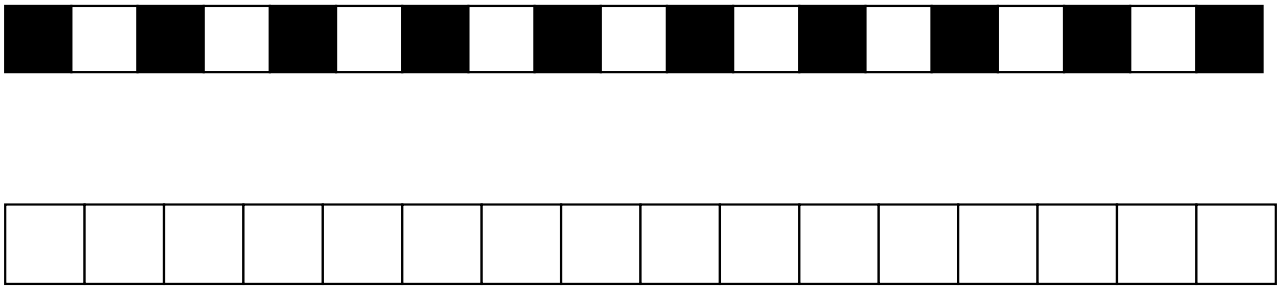
Using the nearest texel, the pixels will be colored alternately black and white.

Discrete Sampling



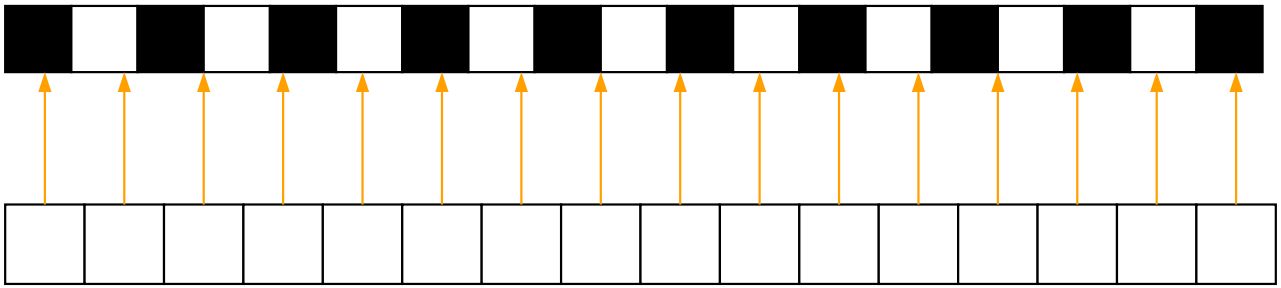
Using the nearest texel, the pixels will be colored alternately black and white.

Discrete Sampling



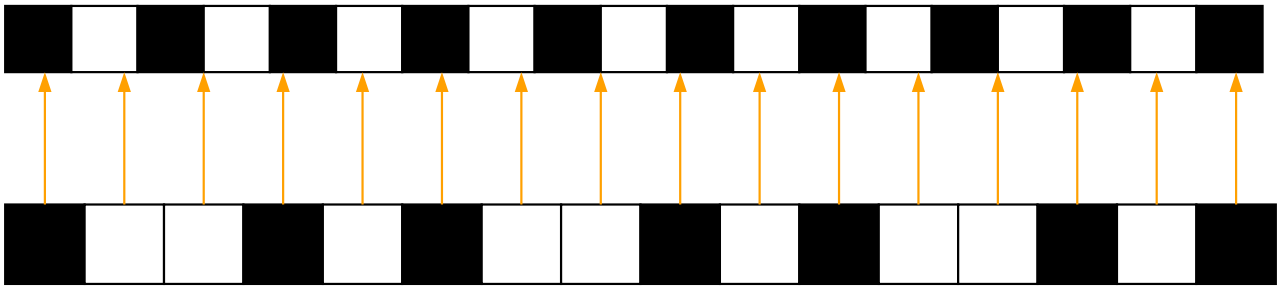
What if the texels were somewhat smaller than the pixels?

Discrete Sampling



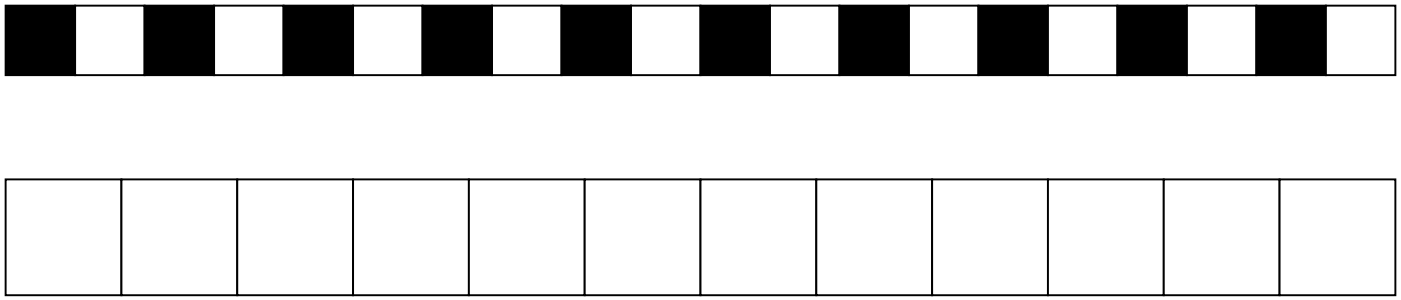
What if the texels were somewhat smaller than the pixels?

Discrete Sampling



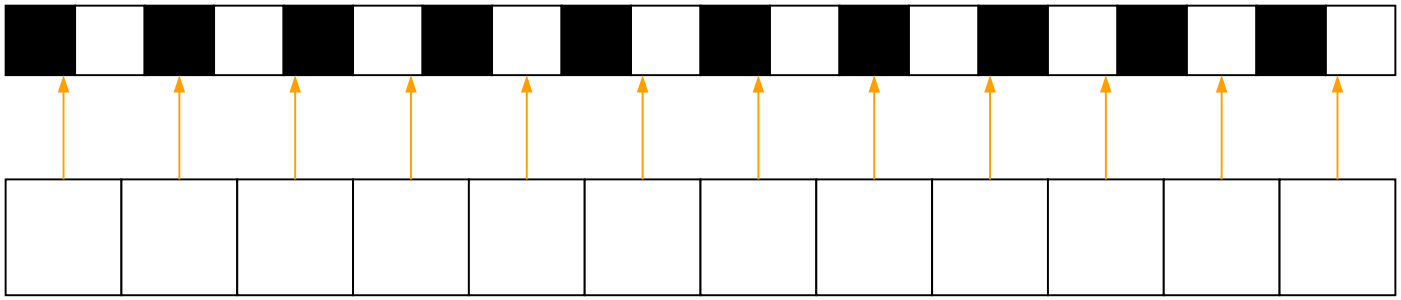
What if the texels were somewhat smaller than the pixels?

Discrete Sampling



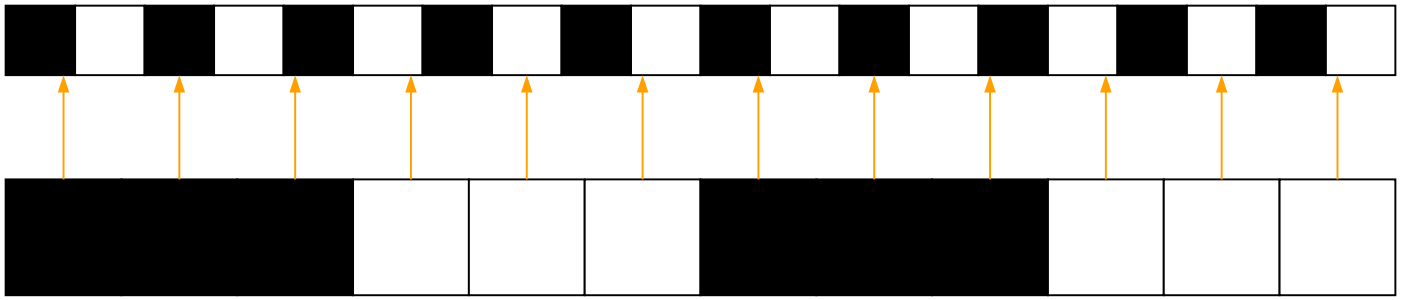
What if the texels are *almost* half the size of the pixels?

Discrete Sampling



What if the texels are *almost* half the size of the pixels?

Discrete Sampling



Uh oh.

Discrete Sampling

- What will happen when the texels are exactly half the width of a pixel?
- Exactly one fourth?
- Exactly one third?

Outline

Mipmaps

Definition (Mipmap)

A mipmap is a reduced copy of a texture, with the colors averaged.

$$\begin{aligned} \text{mip} &= \textit{multum in parvo} \\ &= \text{“many things in a small place.”} \end{aligned}$$

- Rather than use the nearest texels or the average of the four texels that happen to be nearest to the pixel, we can create smaller and smaller copies of the entire texture and use their texels.

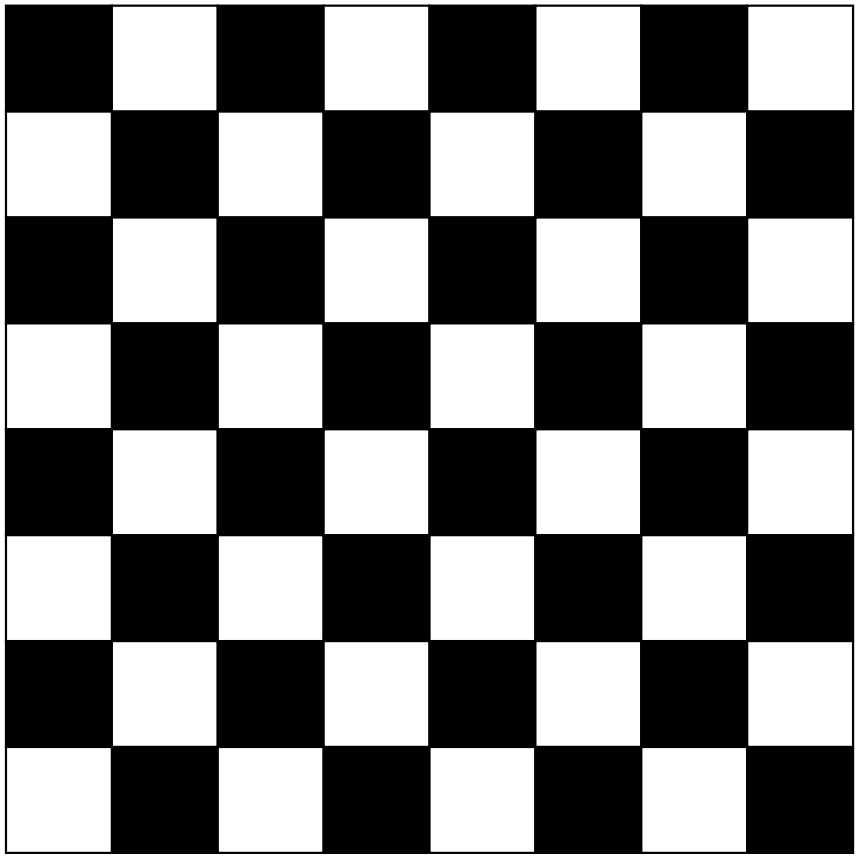
Mipmaps

- If the original texture is 64×64, then we should create copies at the scales of 32×32, 16×16, 8×8, 4×4, 2×2, and 1×1.
- If the original texture is 64×16, then we should create copies at the scales of 32×8, 16×4, 8×2, 4×1, 2×1, and 1×1.

Mipmap Levels

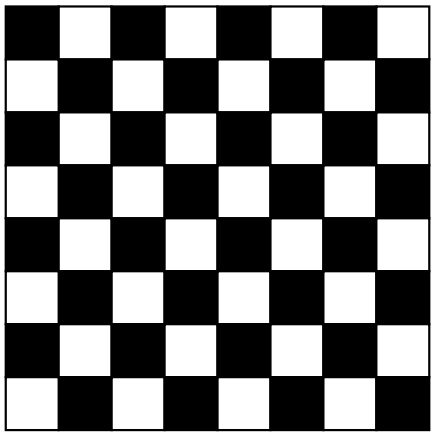
- The original texture is level 0.
- The next level is level 1.
- And so on.

Mipmaps



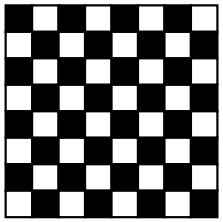
Level 0 Mipmap - 64×64

Mipmaps



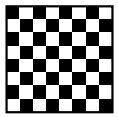
Level 1 Mipmap - 32×32

Mipmaps



Level 2 Mipmap - 16×16

Mipmaps



Level 3 Mipmap - 8×8

Mipmaps

Level 4 Mipmap - 4×4

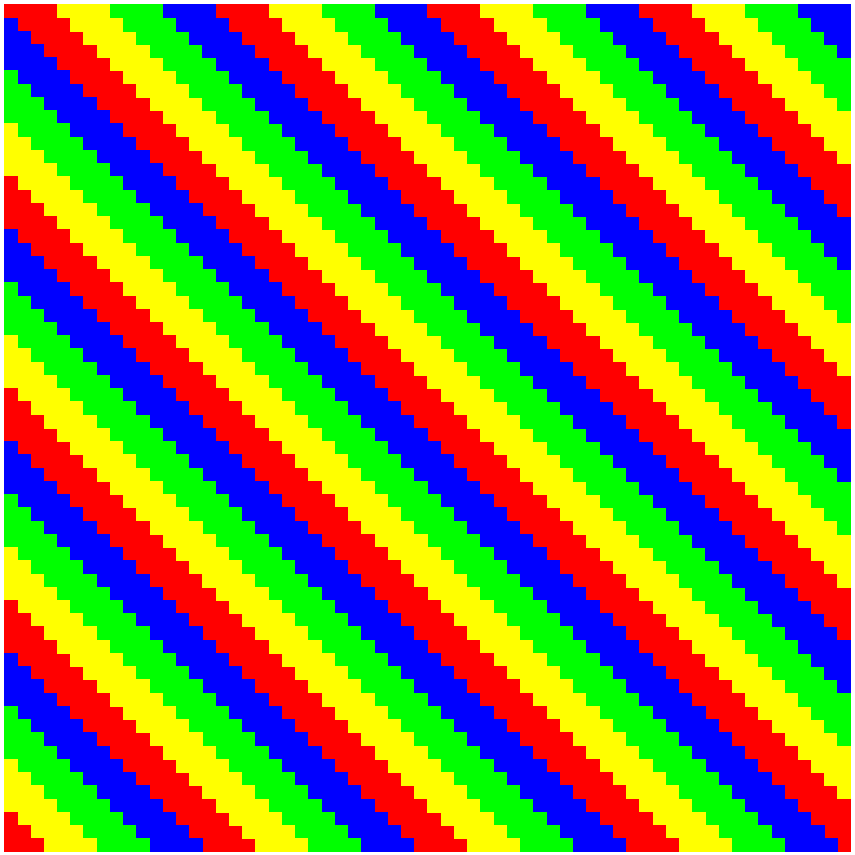
Mipmaps

Level 5 Mipmap - 2×2

Mipmaps

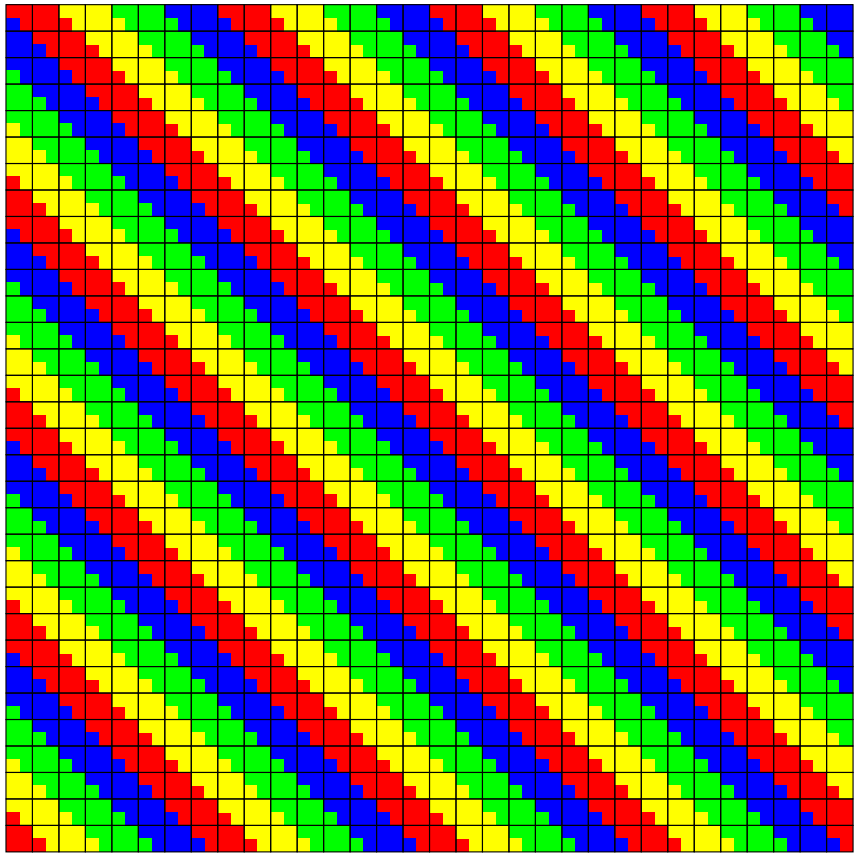
Level 6 Mipmap - 1×1

Mipmaps



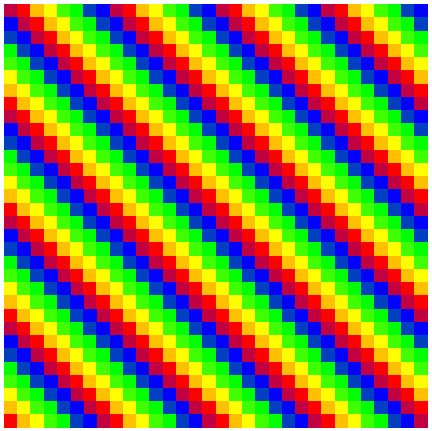
Level 0 Mipmap - 64×64

Mipmaps



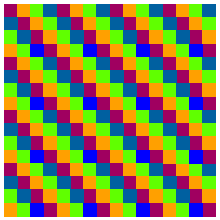
Level 0 Mipmap - 64×64

Mipmaps



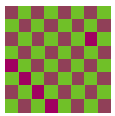
Level 1 Mipmap - 32×32

Mipmaps



Level 2 Mipmap - 16×16

Mipmaps



Level 3 Mipmap - 8×8

Mipmaps

Level 4 Mipmap - 4×4

Mipmaps

Level 5 Mipmap - 2×2

Mipmaps

Level 6 Mipmap - 1×1

Outline

Generating Mipmaps

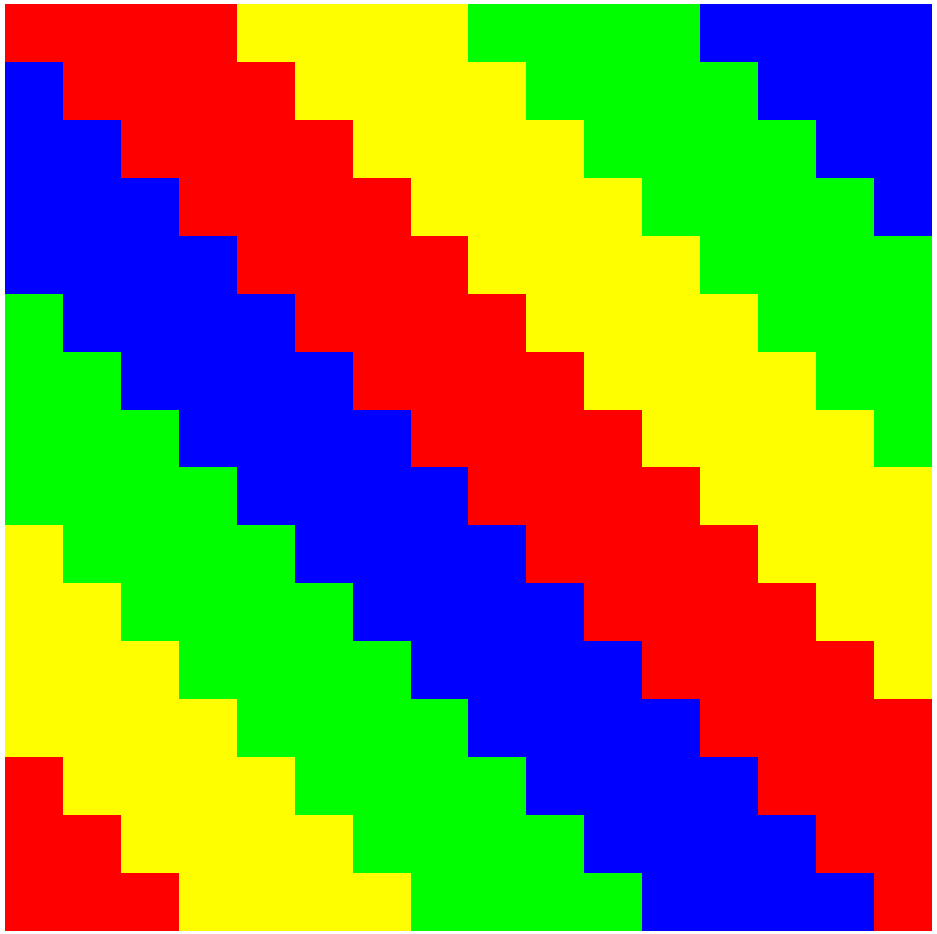
- If we hand-code a texture, then we also hand-code the mipmaps. (See demo.)
- The website `http://online-converting.com/image/convert2dds/` includes an option to create mipmaps in the `.dds` file.

Outline

Programming Mipmaps

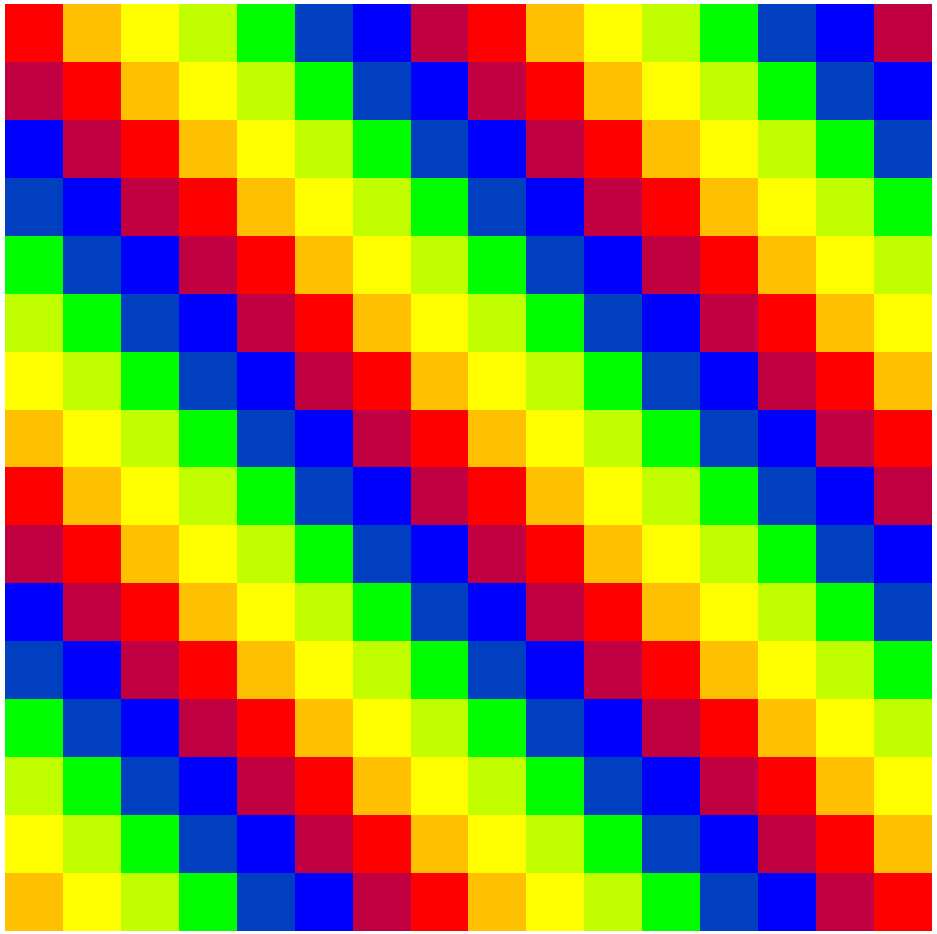
- Mipmaps are implemented using the same function `glTexImage2D()` that we used to set the original texture.
- The second parameter is the level.

Screen Shots



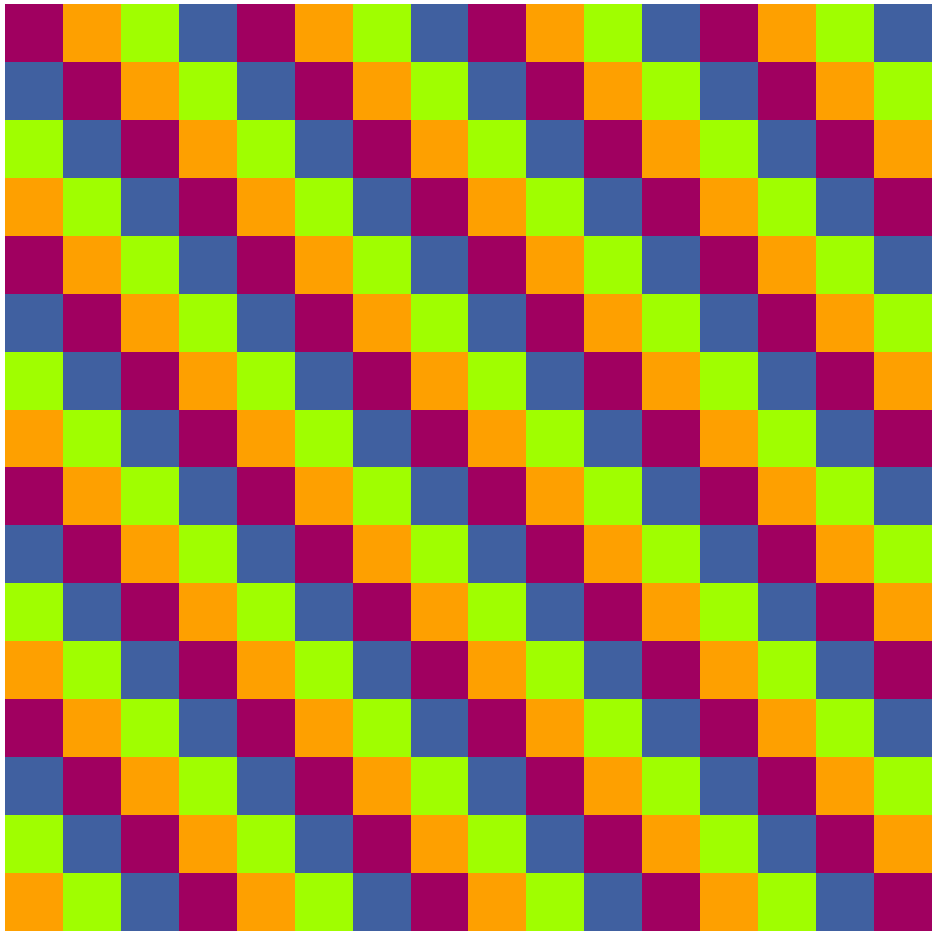
Close-up of Level 0

Screen Shots



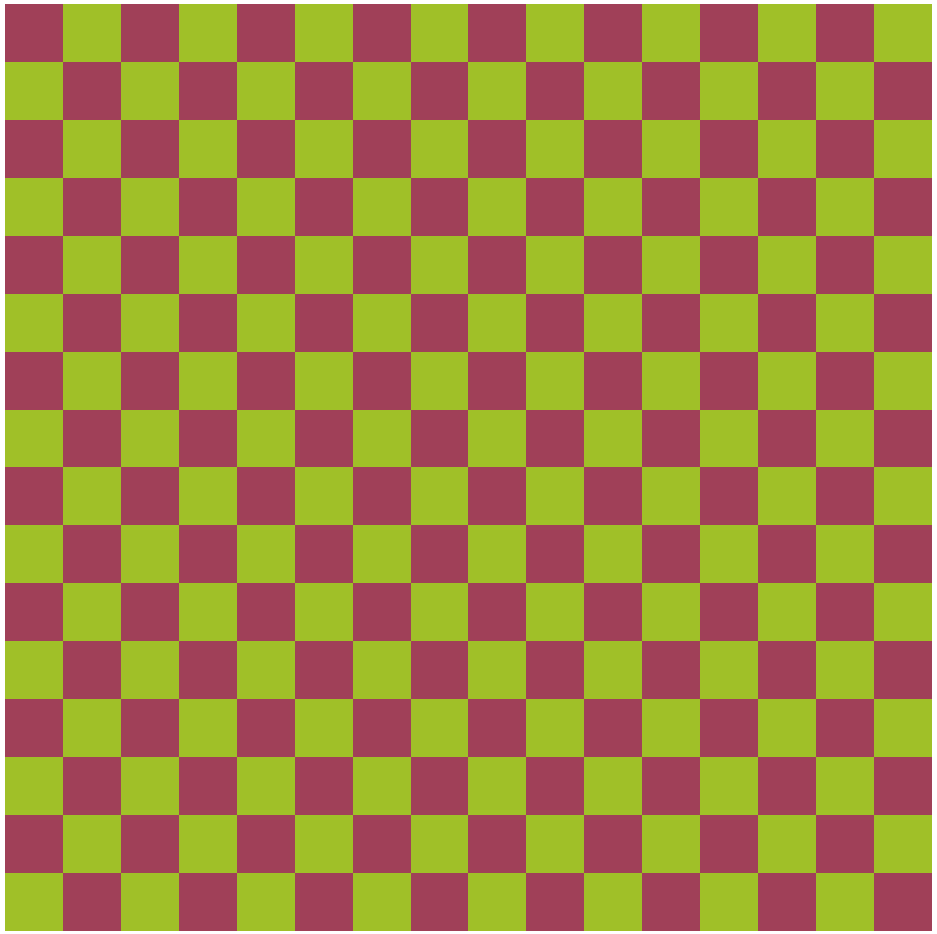
Close-up of Level 1

Screen Shots



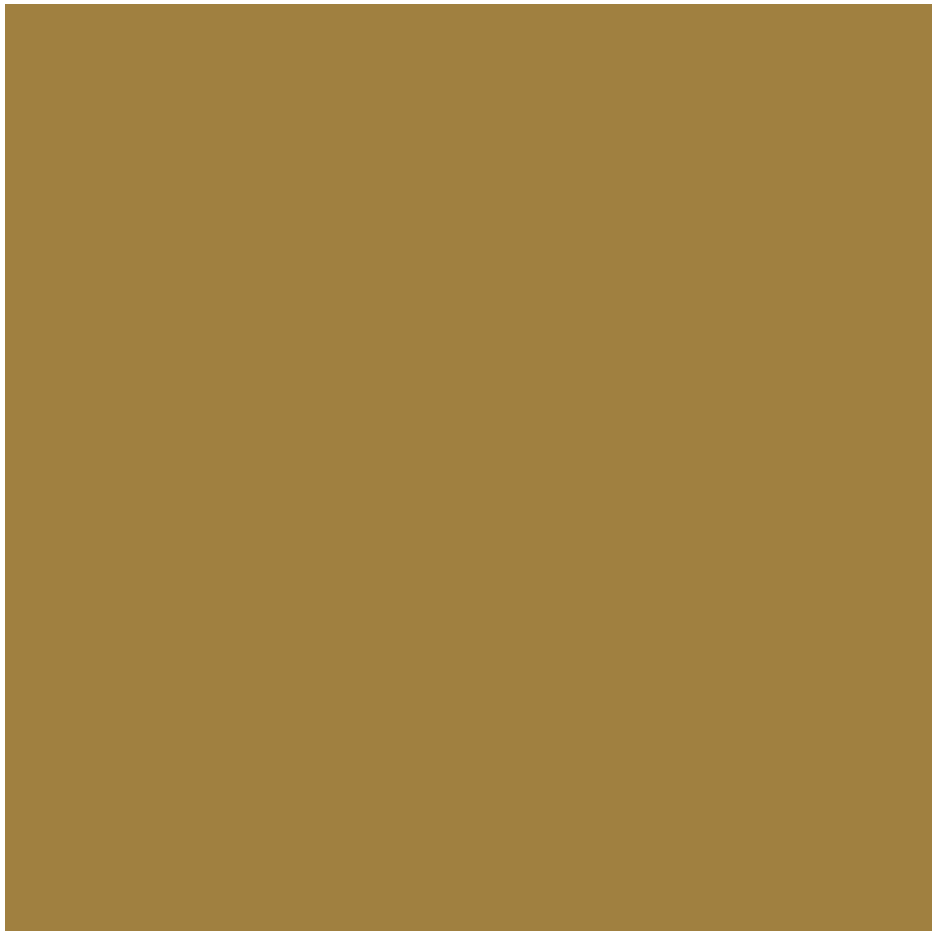
Close-up of Level 2

Screen Shots



Close-up of Level 3

Screen Shots



Close-up of Levels 4, 5, and 6

Using Mipmaps

- When using mipmaps, we have two separate choices.
- Whether to use the nearest texel in a mipmap or to interpolate among the 4 nearest texels.
- Whether to use the nearest mipmap or to interpolate between the two nearest mipmaps.

Using Mipmaps

- Thus, the combinations of choices are
  - Nearest texel and nearest mipmap
  - Nearest texel and interpolate mipmaps
  - Interpolate texels and nearest mipmap
  - Interpolate texels and interpolate mipmaps
- Which is the most “expensive?”
- Which gives the best results?

Outline

Interpolating Between Mipmaps

- Assume that a single color has been selected from each of the two nearest mipmaps (from either the nearest texel or an average of texels).
- Compute the scale factor r between the level 0 (original) mipmap and the polygon.
- Then compute $\lambda = \log_2 r$.

Interpolating Between Mipmaps

- The value of λ tells us which mipmap to use.
- If $\lambda = 0$, use level 0.
- If $\lambda = 1$, use level 1.
- If $\lambda = 2$, use level 2, etc.
- What if $\lambda = 1.5$?
- Then we interpolate between level 1 and level 2.
- Different scale factors may be used for different regions of a single polygon.

Example

- Suppose $\lambda = 1.3$ and the level 1 mipmap color is yellow $(1, 1, 0)$ and the level 2 mipmap color is cyan $(0, 1, 1)$.
- Then the interpolated color is

$$0.7(1, 1, 0) + 0.3(0, 1, 1) = (0.7, 1.0, 0.3).$$

Interpolating Mipmaps

Interpolating Mipmaps

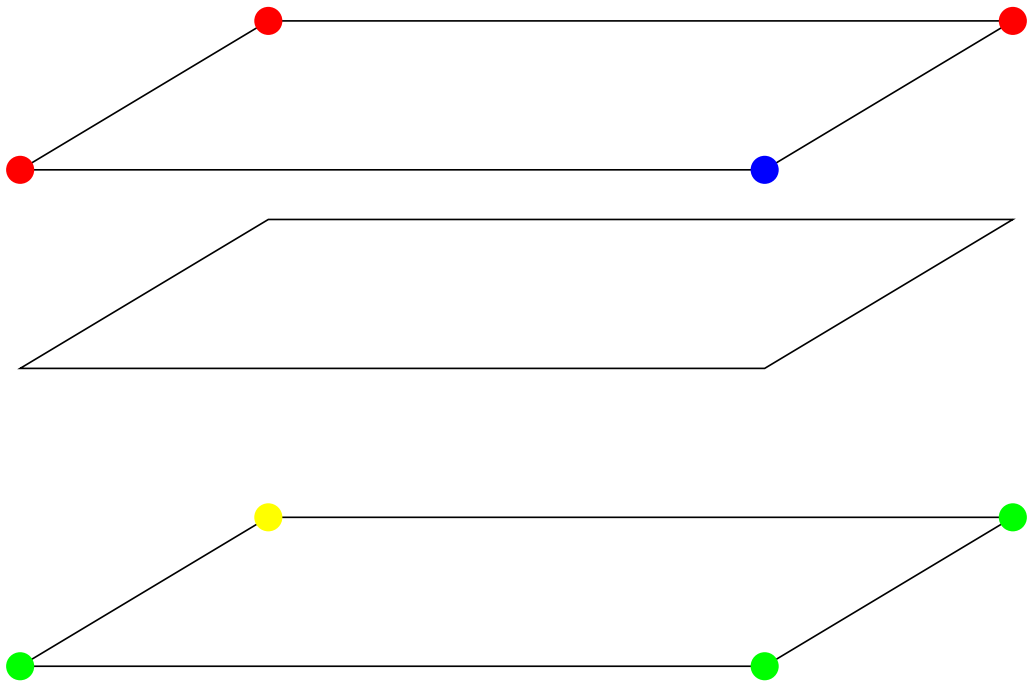
```
glTexParameteri(GL_TEXTURE_2D,
    GL_TEXTURE_MIN_FILTER, method);
```

- Use the `glTexParameter*()` function to set the method of applying mipmap filters.
- The third parameter is one of
  - `GL_NEAREST_MIPMAP_NEAREST`
  - `GL_NEAREST_MIPMAP_LINEAR`
  - `GL_LINEAR_MIPMAP_NEAREST`
  - `GL_LINEAR_MIPMAP_LINEAR`

Trilinear Interpolation

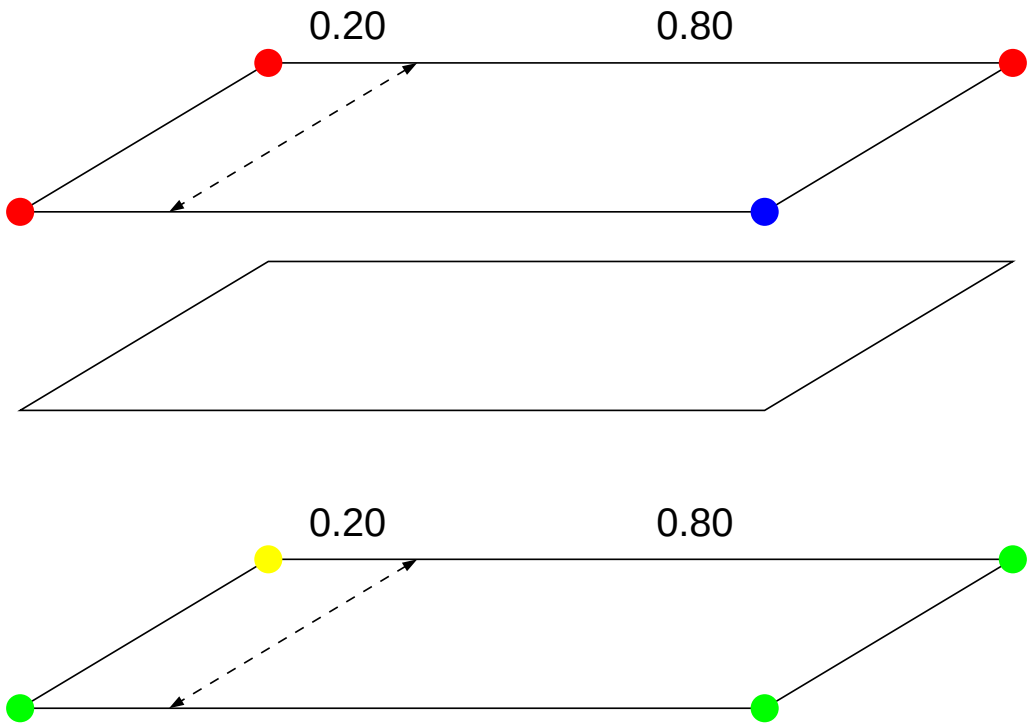
- If we interpolate bilinearly within mipmaps and then interpolate those values between mipmaps, we get trilinear interpolation.

Trilinear Interpolation



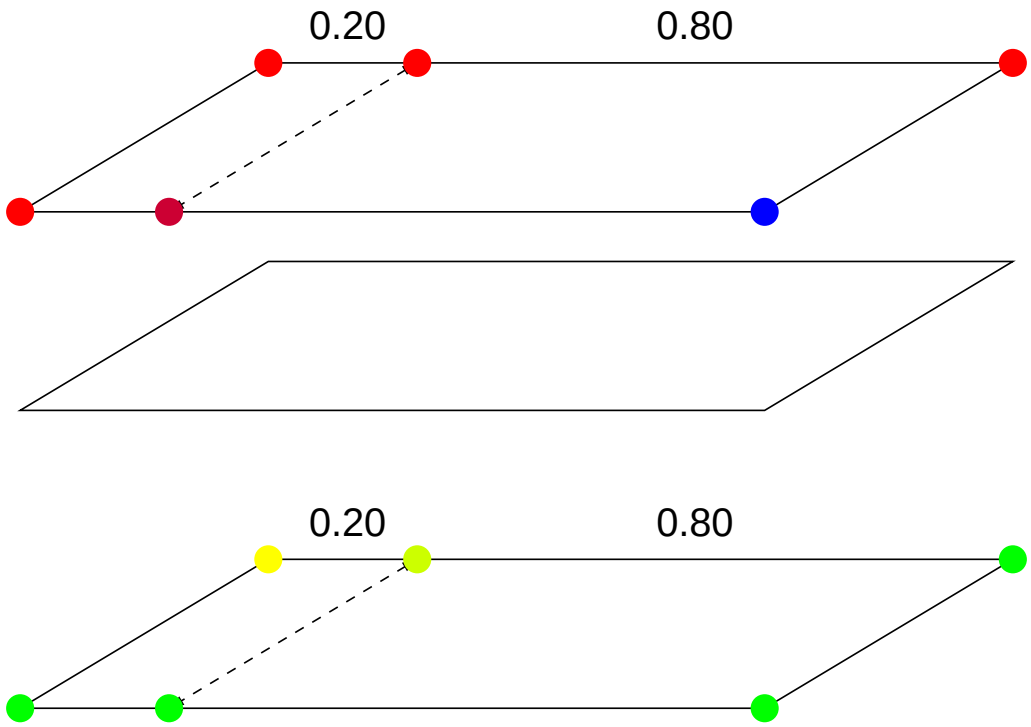
How many individual interpolations are required?

Trilinear Interpolation



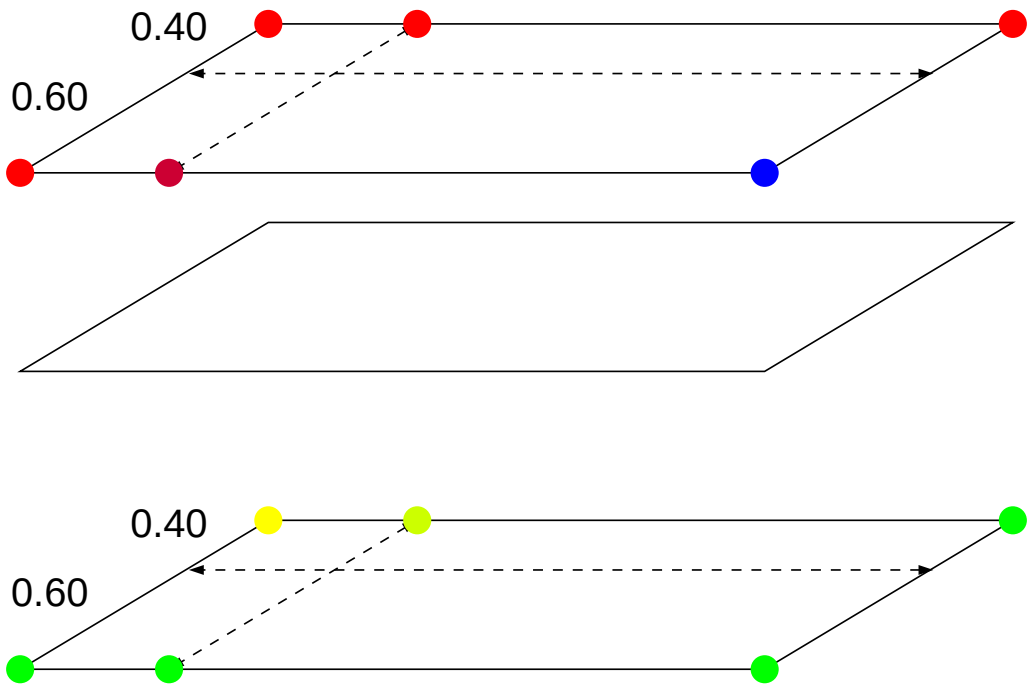
Four in the *s* direction.

Trilinear Interpolation



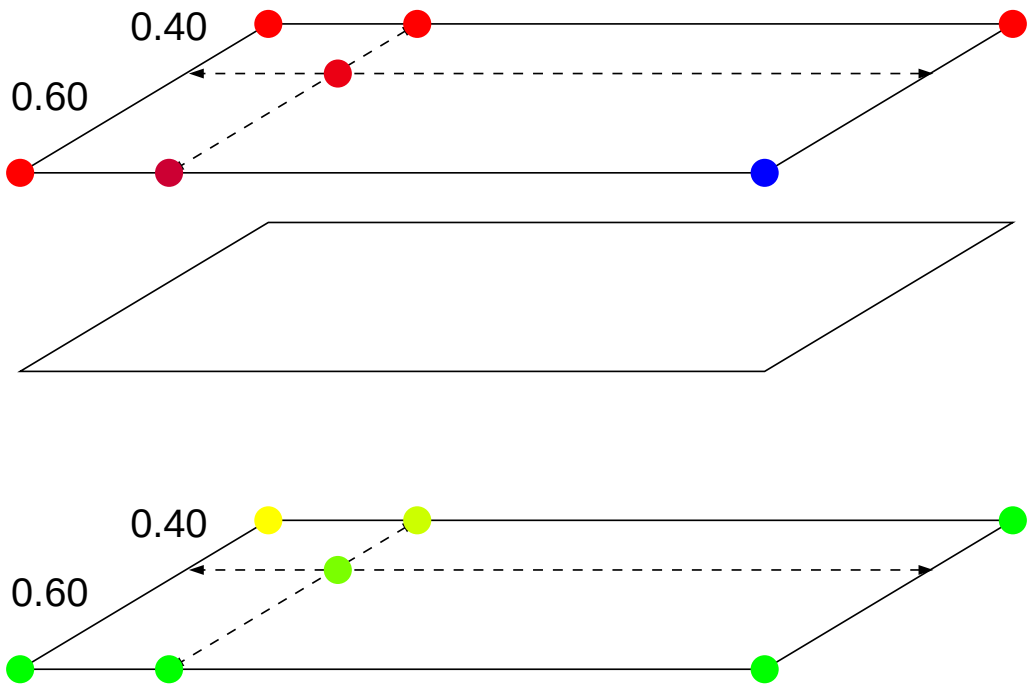
Four in the *s* direction.

Trilinear Interpolation



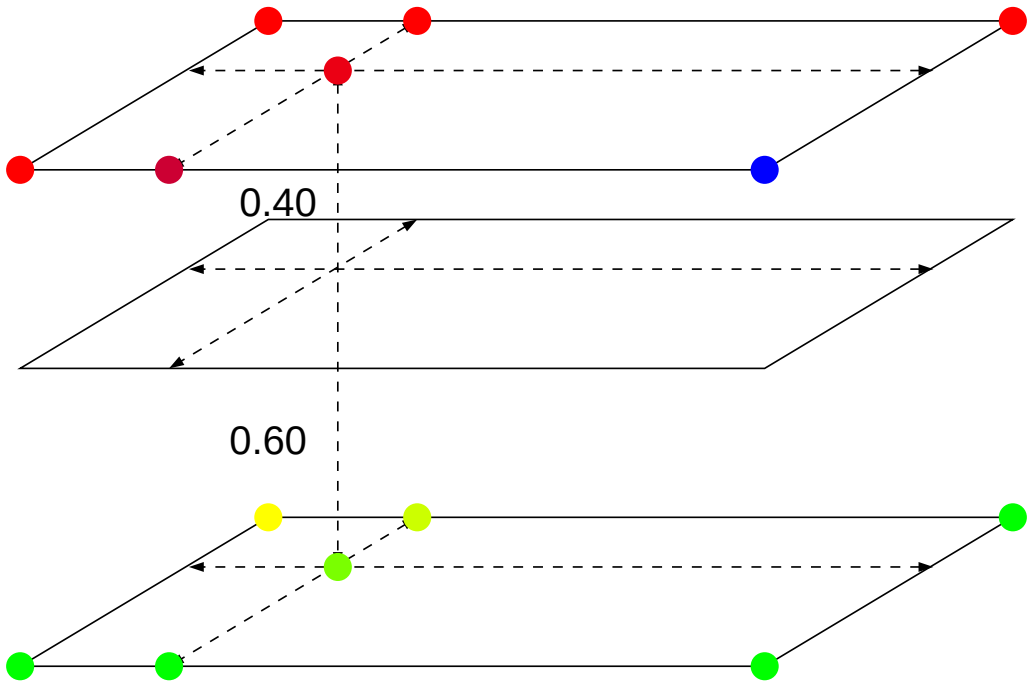
Two more in the t direction.

Trilinear Interpolation



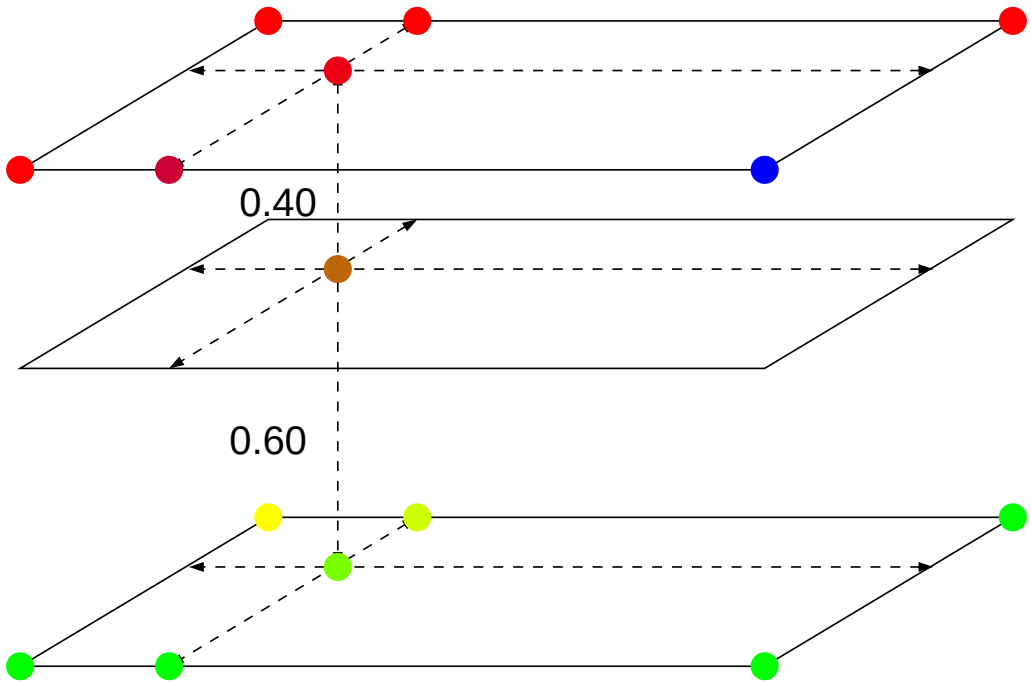
Two more in the t direction.

Trilinear Interpolation



One more between the mipmap levels.

Trilinear Interpolation



One more between the mipmap levels.

Trilinear Interpolation

- A total of 7 interpolations are required.

Outline

Assignment 20

Assignment 20

- Add a water texture to the water.
- Add textures to the boat and its cabin.
- Turn in by Monday, November 30.

Outline

Assignment 21

Assignment 21

- Add grass. (See handout.)