Surface Mapping Two

CS7GV3 – Real-time Rendering

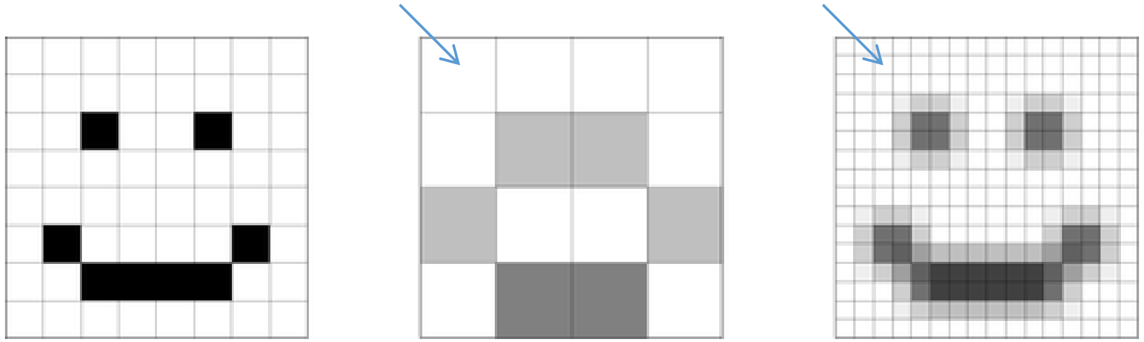
Overview

- Texture Mapping
  - Aliasing
  - Filtering
  - Mip-Maps
  - Summed Area Table
  - Anisotropic Filtering

2D Texturing Issues

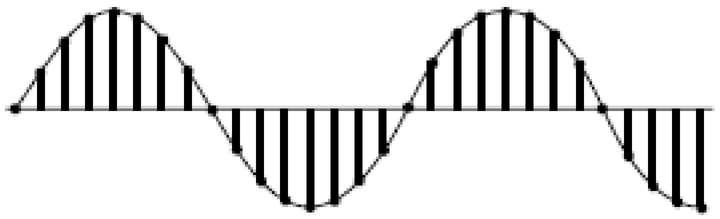
- 2D Texture made up of texels mapped on to 3D object
  - Texture object mapped on to 2d screen pixels
  - 2d – 2d warping: Sampling is not always uniform

- Texture **Minification**
  - Many pixels to few texels
- Texture **Magnification**
  - Few texels to many pixels

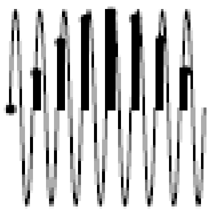


- Can lead to Aliasing
- Sampling/filtering techniques to account for this

Aliasing

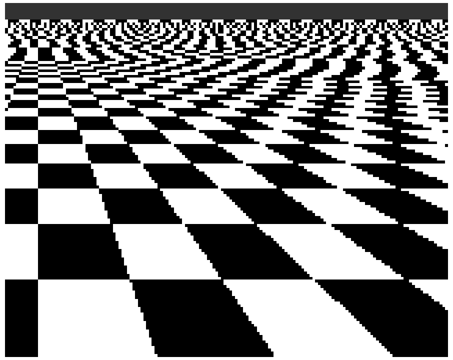


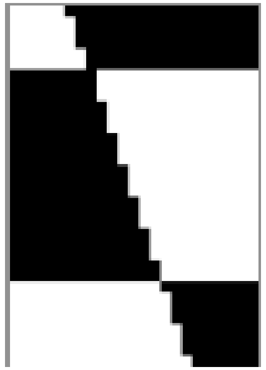
low frequency sinusoid:
no aliasing

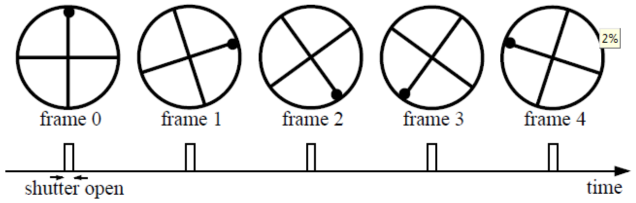


high frequency sinusoid:
aliasing occurs
(high freq. looks like low freq.)

- Leads to:
  - Jaggies
  - Moire-patterns
  - Temporal aliasing



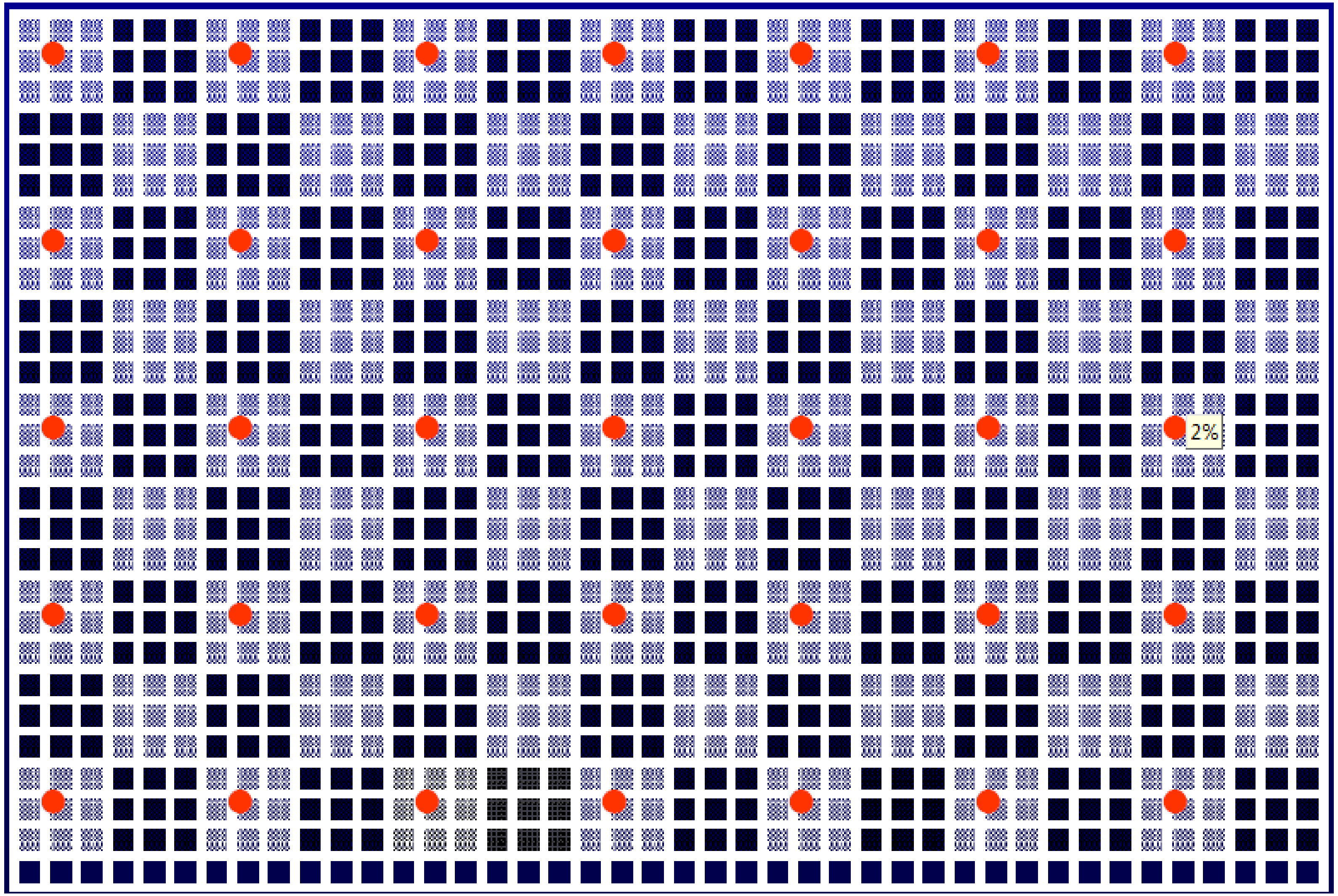




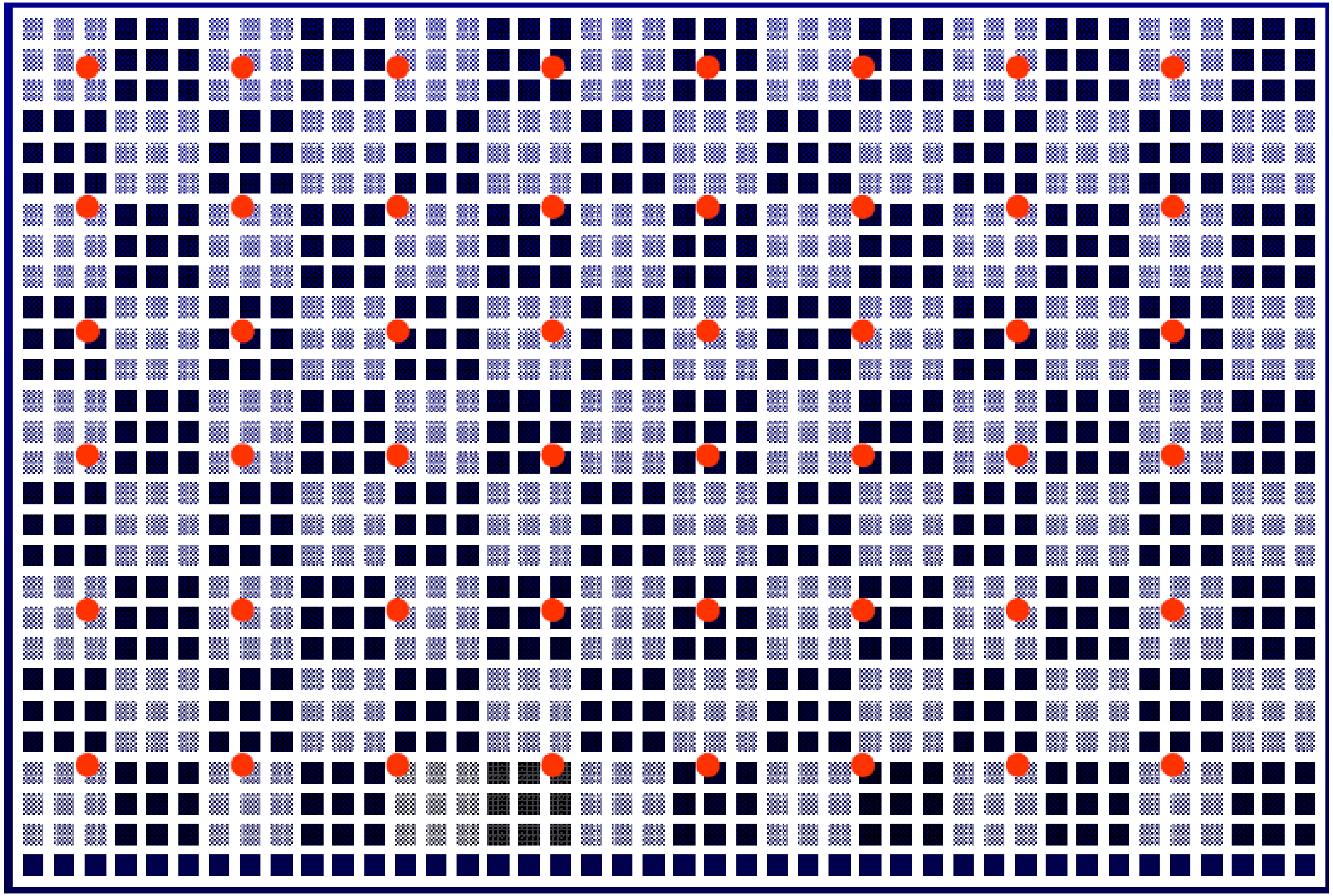
Without dot wheel appears to rotate backwards

- Nyquist law: maz frequency displayable is half the sampling frequency

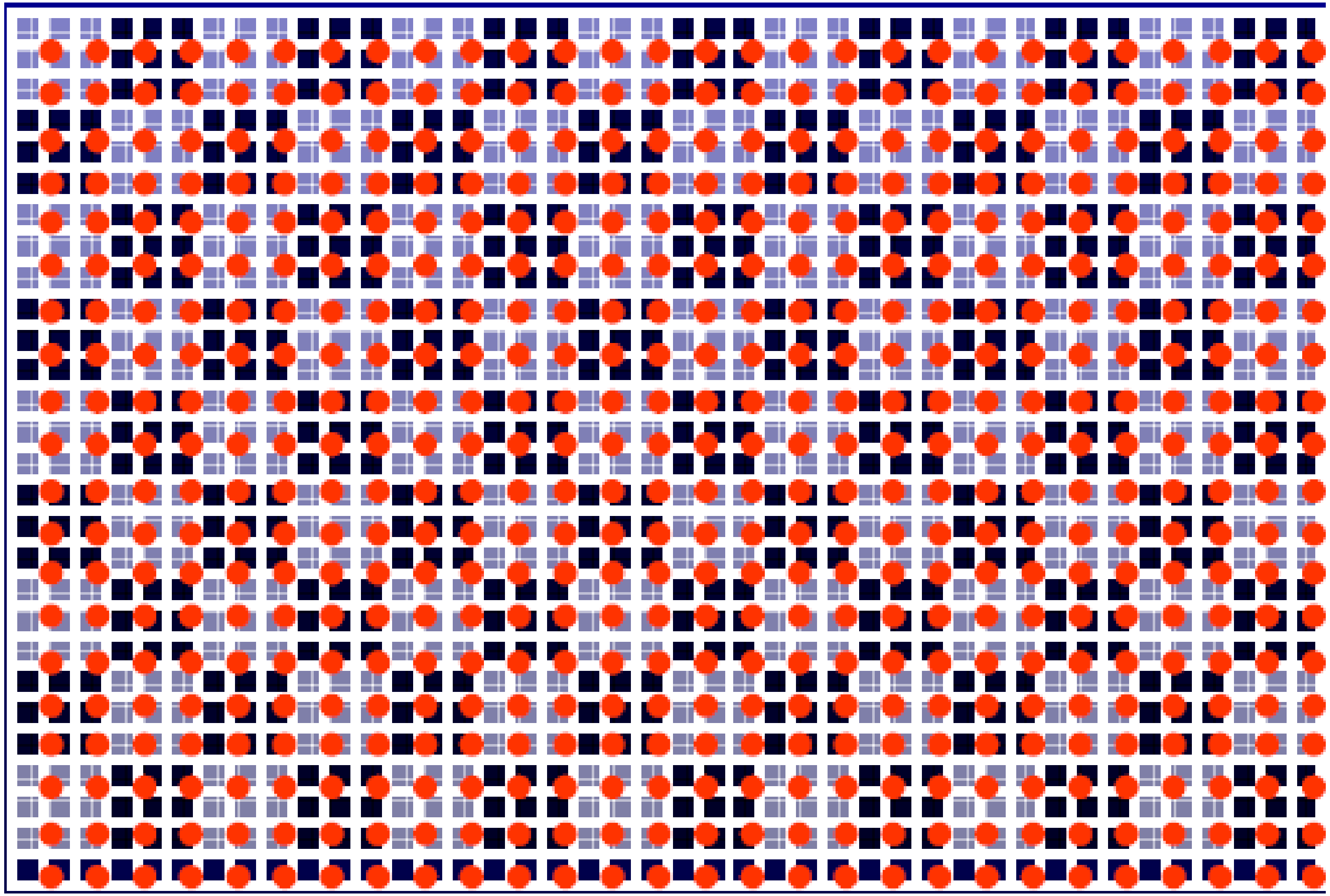
Texture Minification



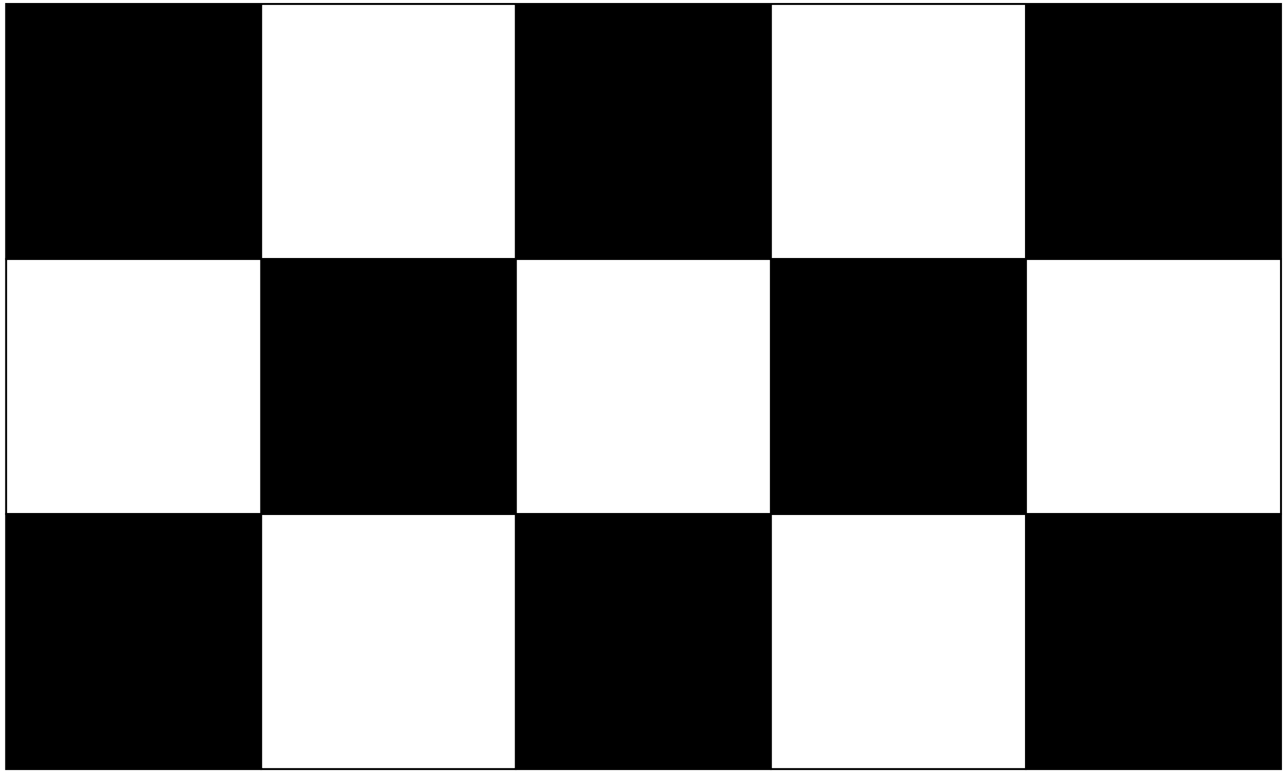
Texture Minification



Nyquist Frequency for Textures

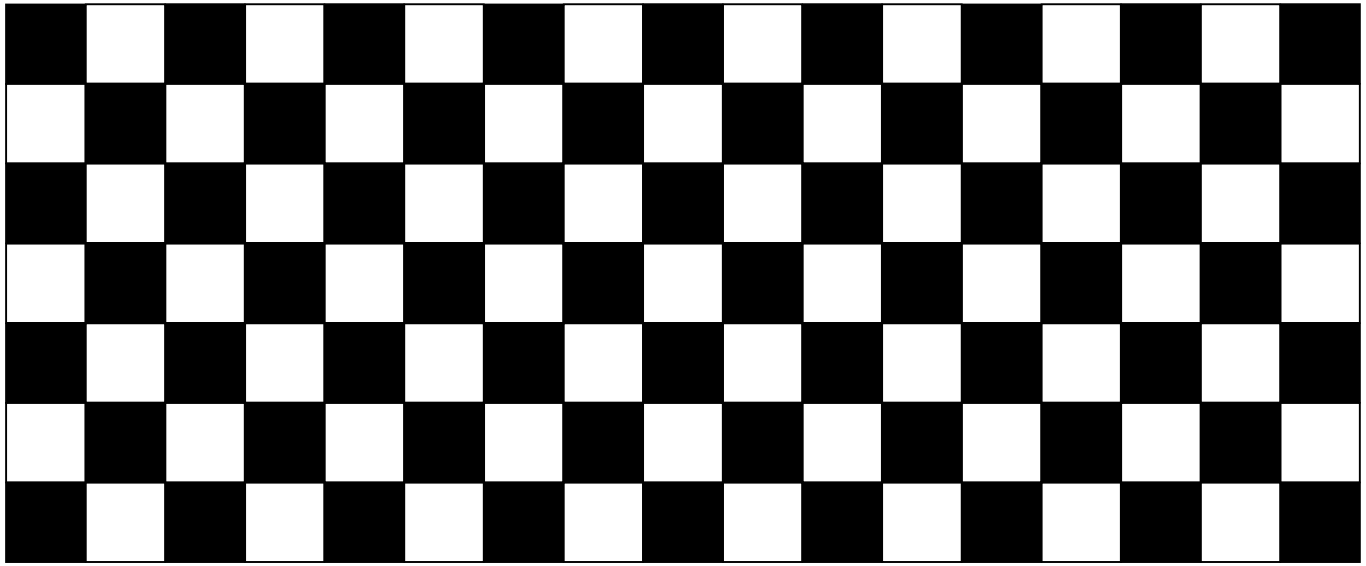


Discrete Sampling



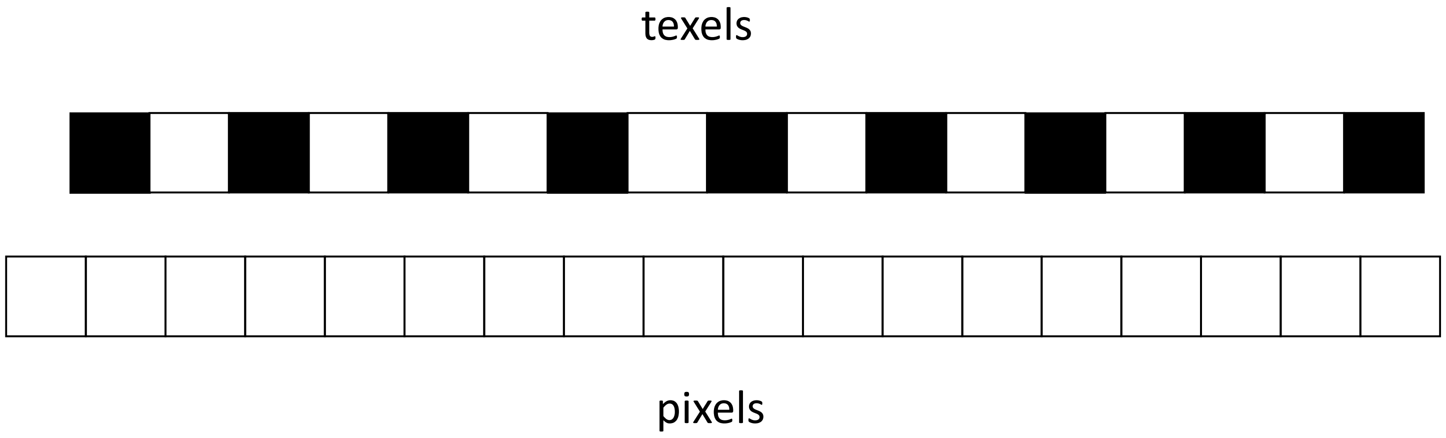
Discrete Sampling

- Now suppose that the object moves away from us so that each square occupies 1 pixel.



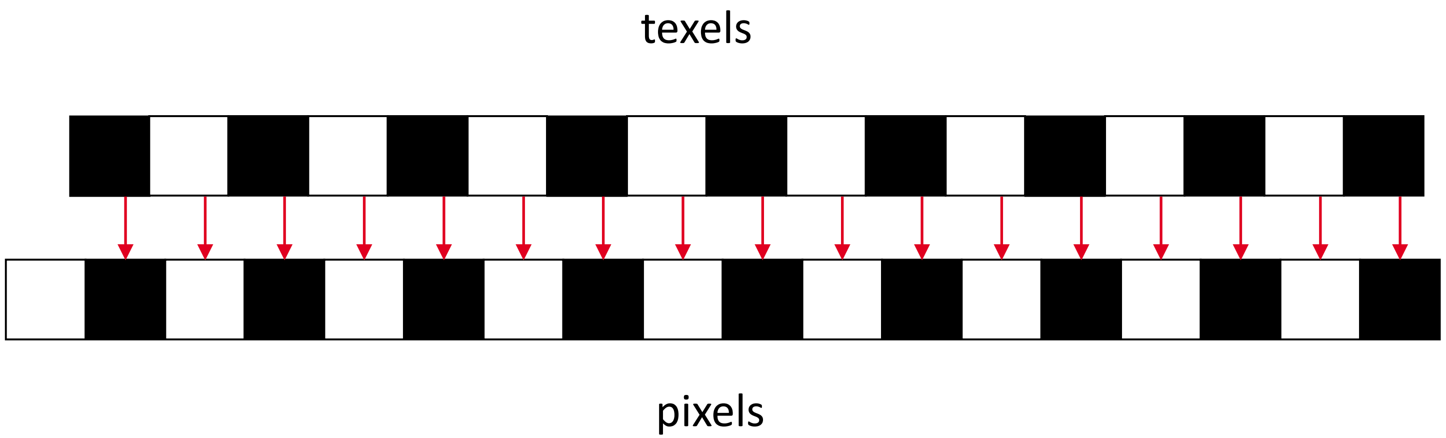
Discrete Sampling

- Consider one row of pixels and texels



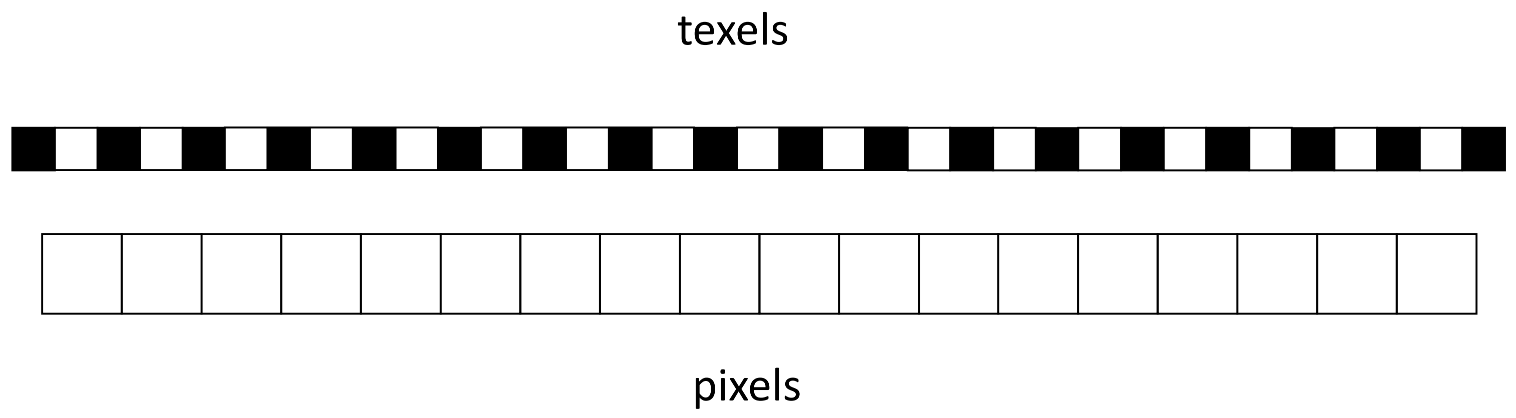
Discrete Sampling

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



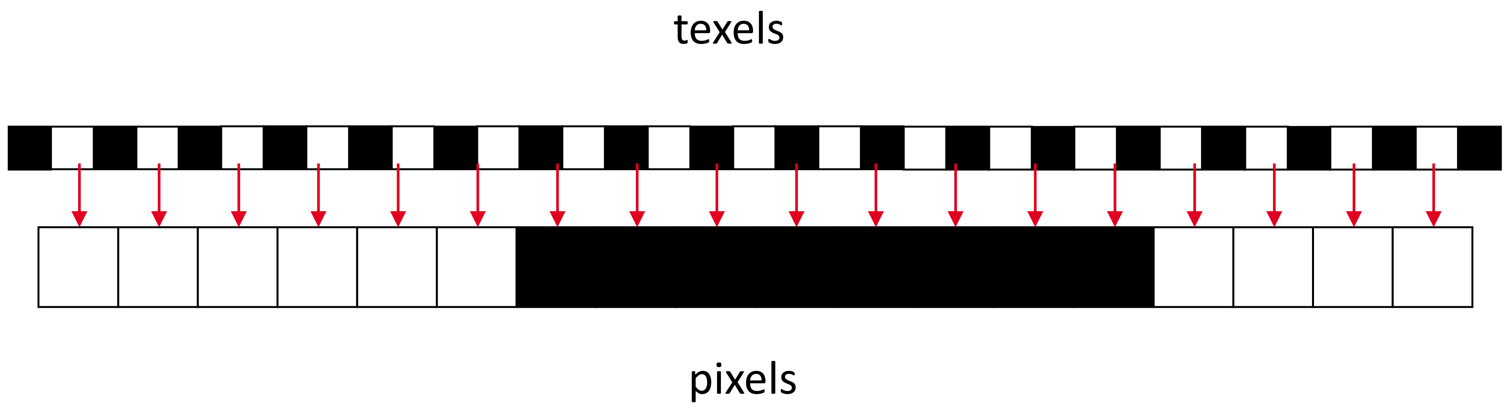
Discrete Sampling

- Now suppose the surface moves a little further away so that nearly 2 texels cover one pixel.



Discrete Sampling

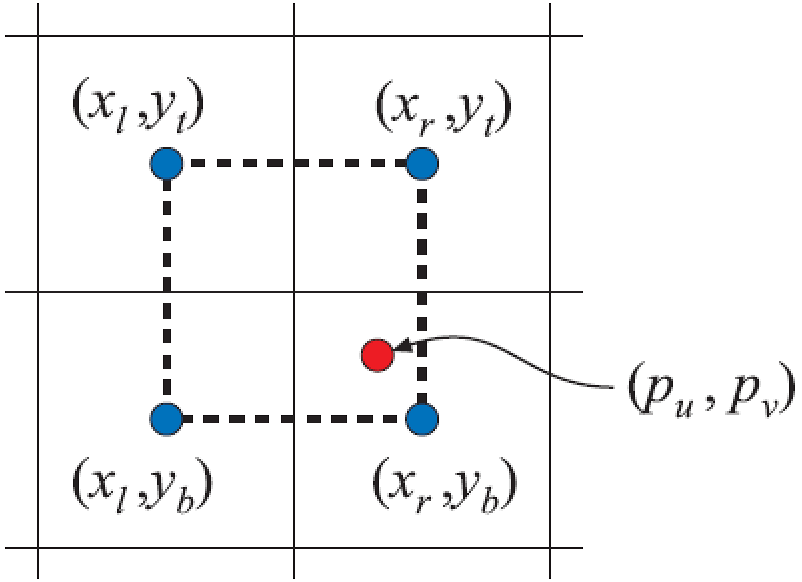
- Using the nearest texel, there will be long stretches of black and white pixels



Discrete Sampling

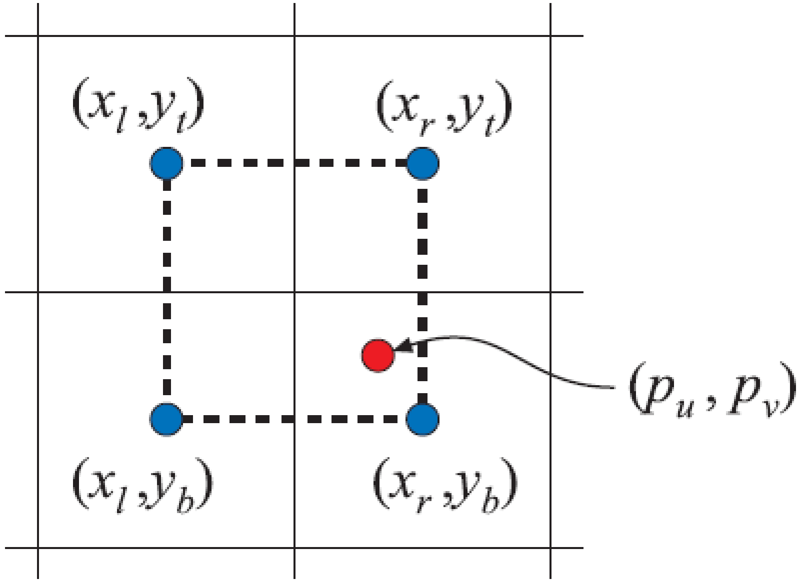
- What will happen when the texels are exactly half the width of a pixel?
- What will happen when the texels are exactly one third the width of a pixel?
- Exactly one fourth?

Nearest-Neighbour Filtering



- Use colour of texel closest to the pixel center
- Fast
- Results in a large number of artifacts
  - Texture 'blockiness' during magnification
  - and aliasing and shimmering during minification

Bi-linear filtering



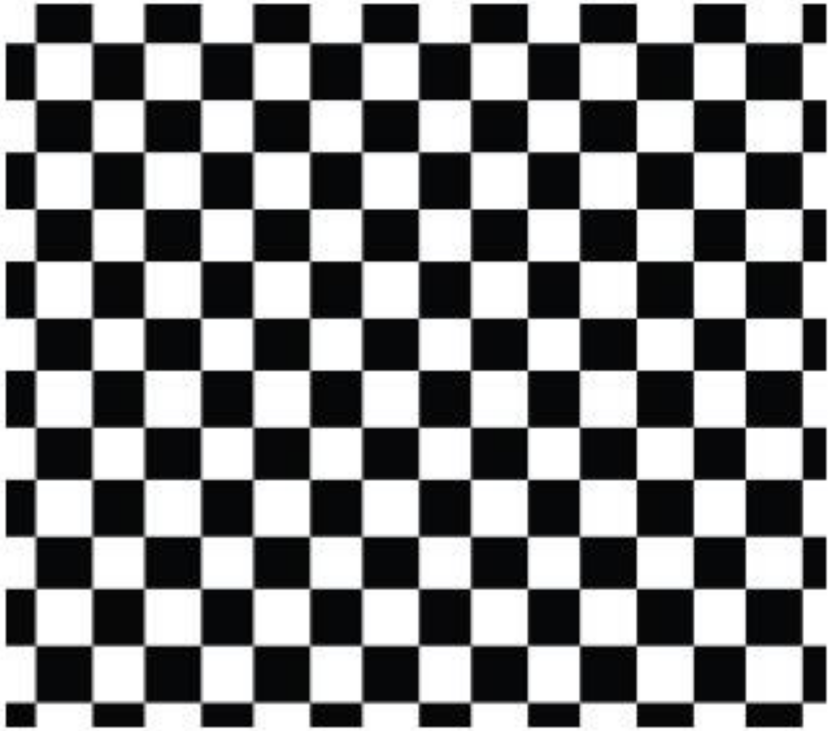
- Get values of four neighbouring texels and linearly interpolate to find a blended value
- removes the blockiness seen during magnification

Texture Magnification

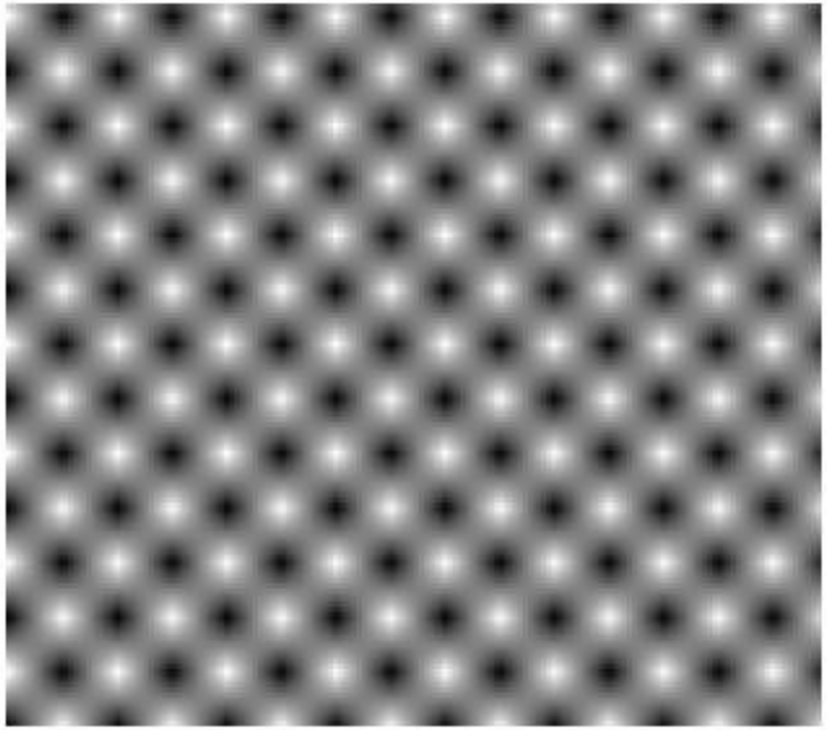
Nearest neighbour

Bi-linear filtering

Texture Magnification

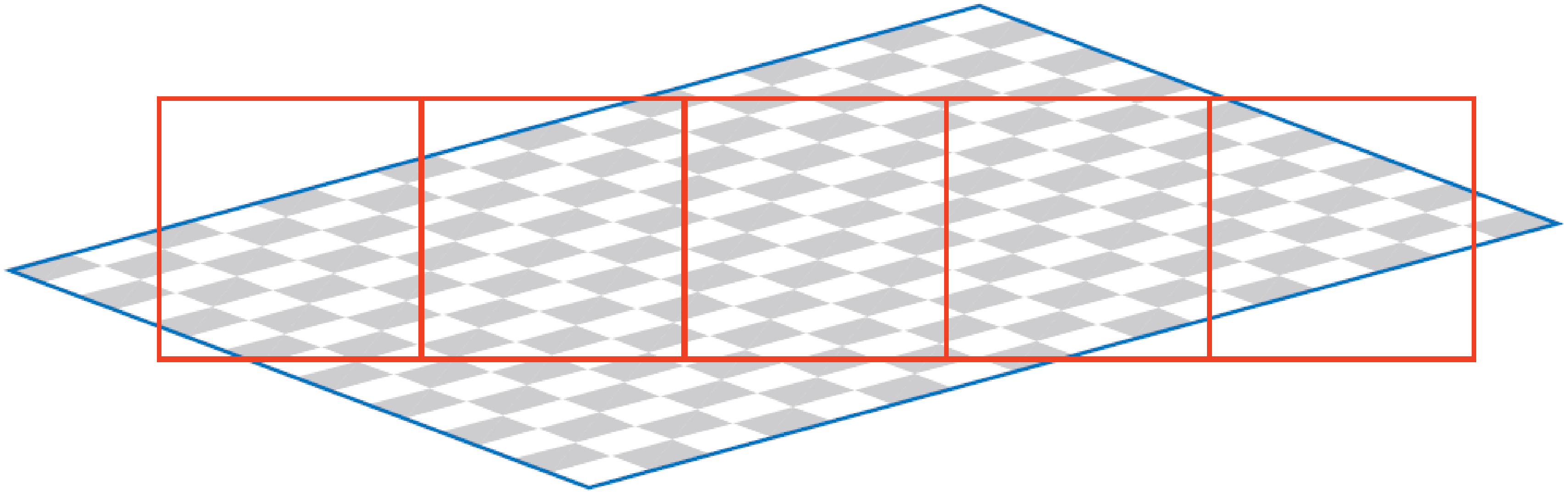


Nearest neighbour



Bi-linear filtering

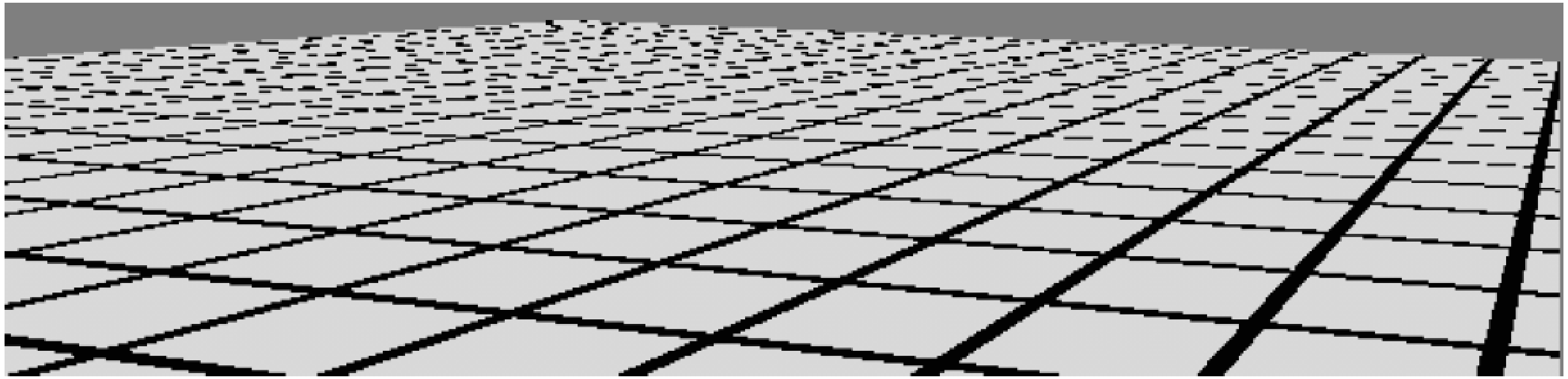
Minification

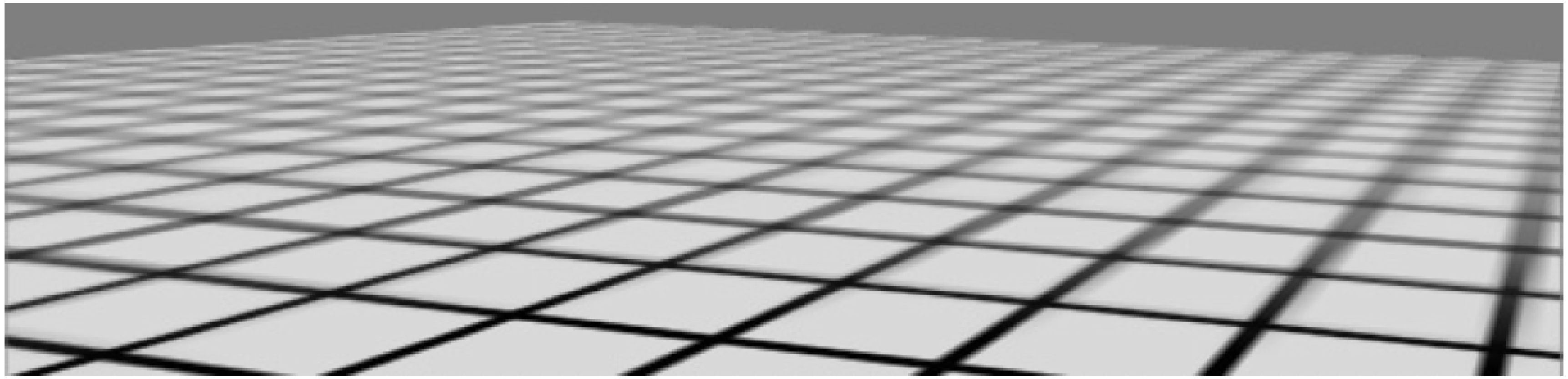


- Several texels mapped to single pixels

Texture Minification

Nearest neighbour

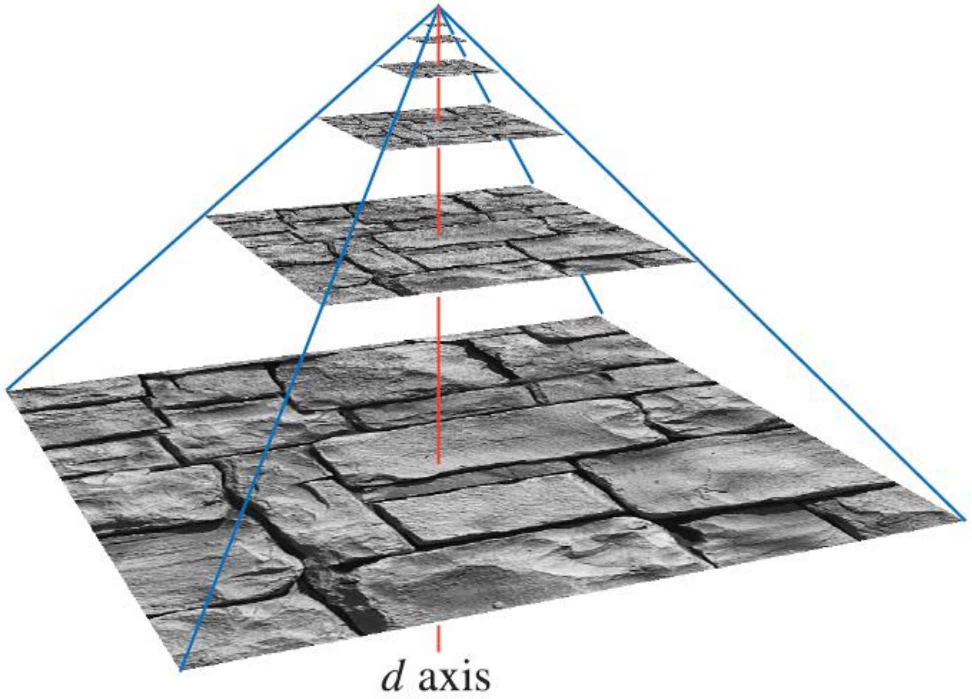




Mip-mapping

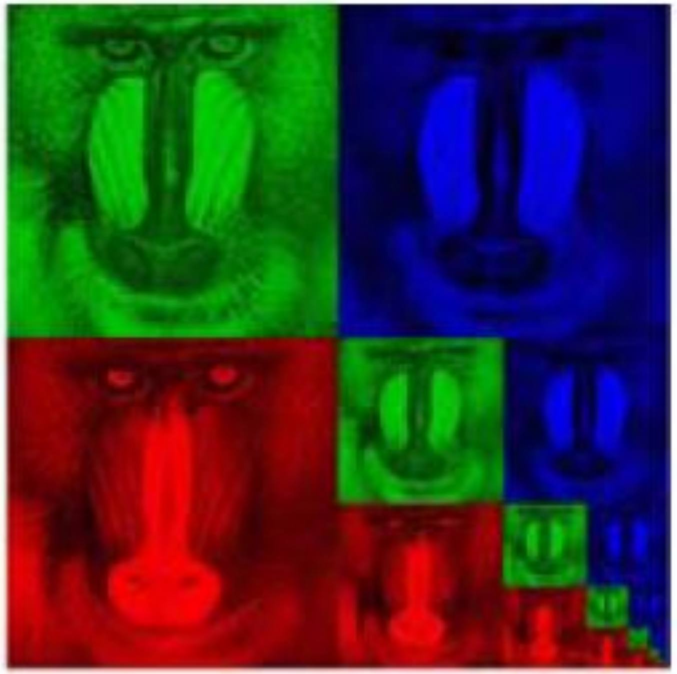
Mip-Mapping

- mip = *multum in parvo* = “many things in a small place.”
- Create level of detail simplifications of the entire texture
- Basic technique
  - take 2x2 squares and average
  - Box filter (not great)
- Some are better:
  - gaussian, Lanczos, Kaiser



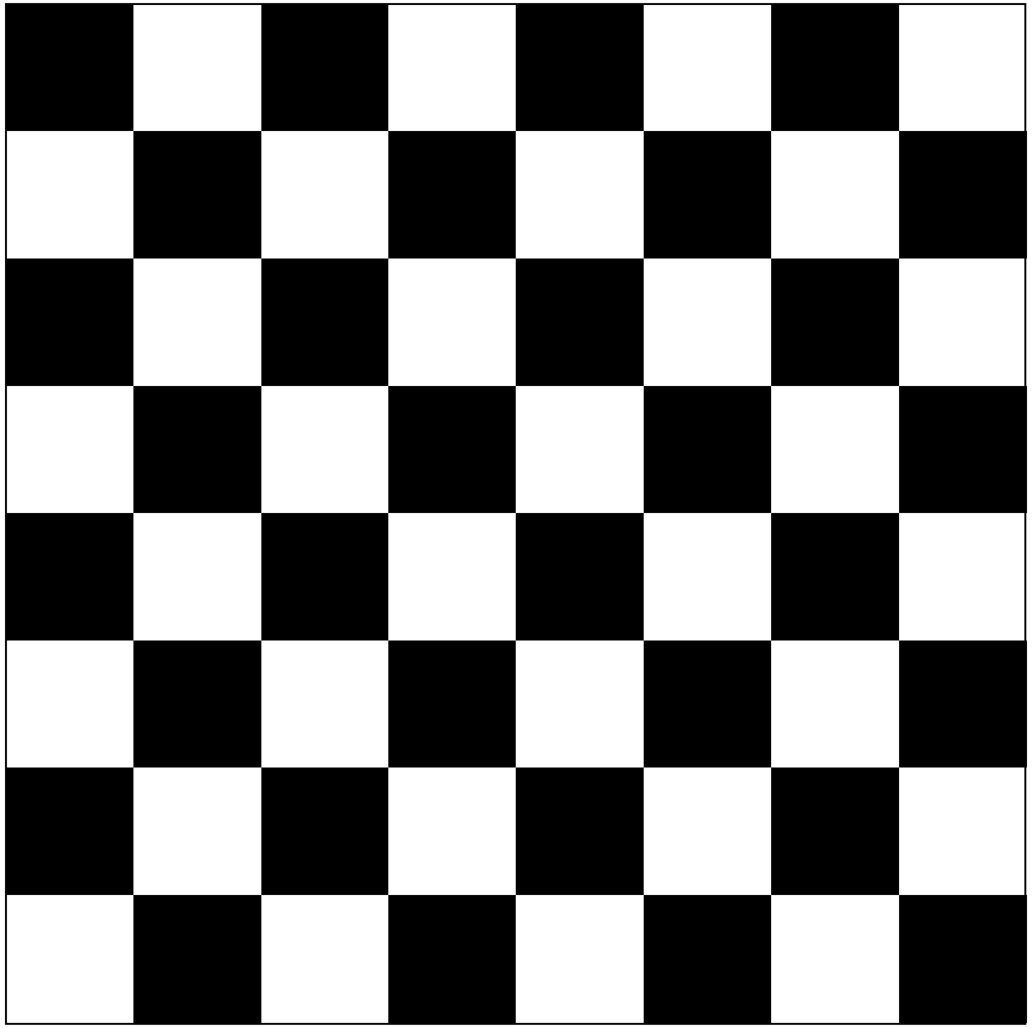
If the original texture is 64 × 64, then we should create copies at the scales of 32 × 32, 16 × 16, 8 × 8, 4 × 4, 2 × 2, and 1 × 1:
This is why graphics API’s prefer power of 2 textures

Mip-map storage

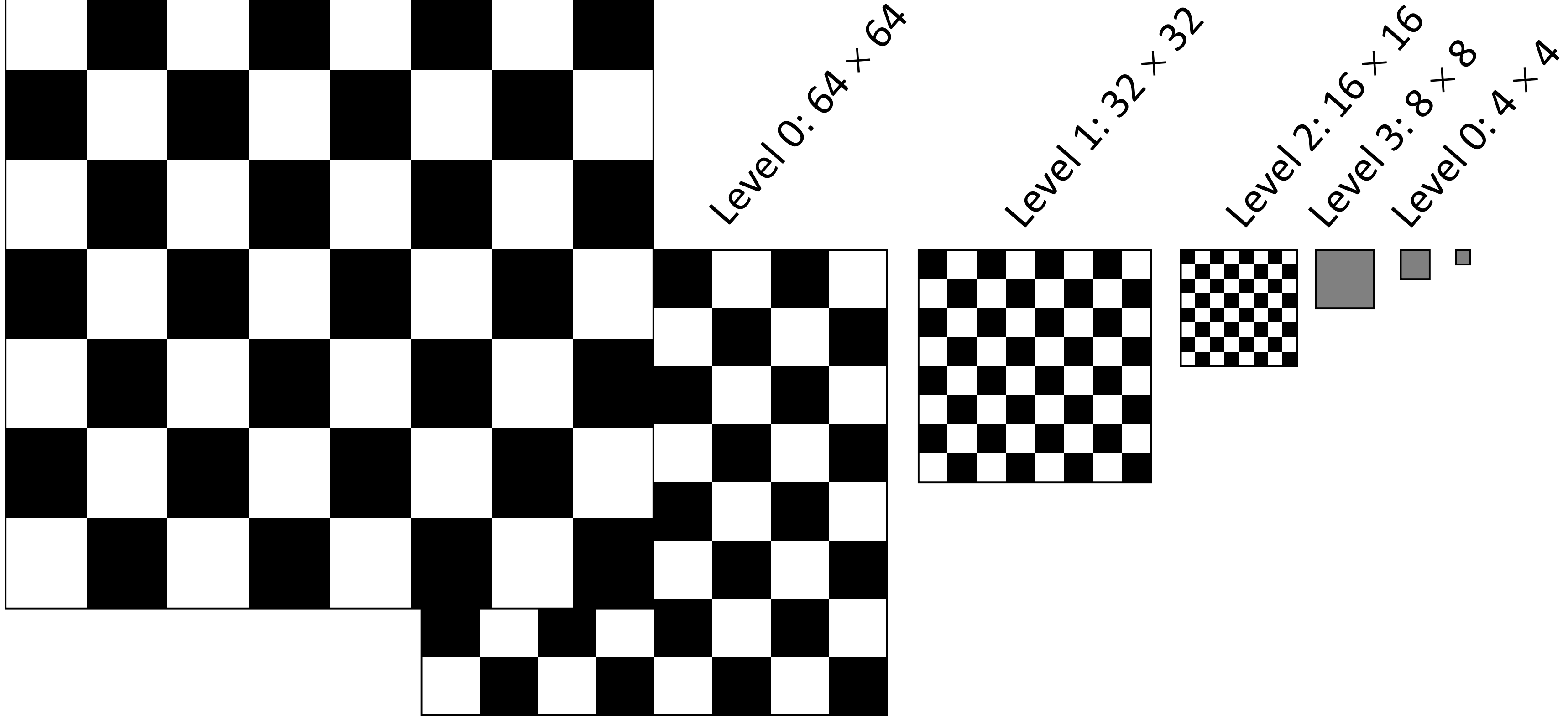


10-level Mip Map

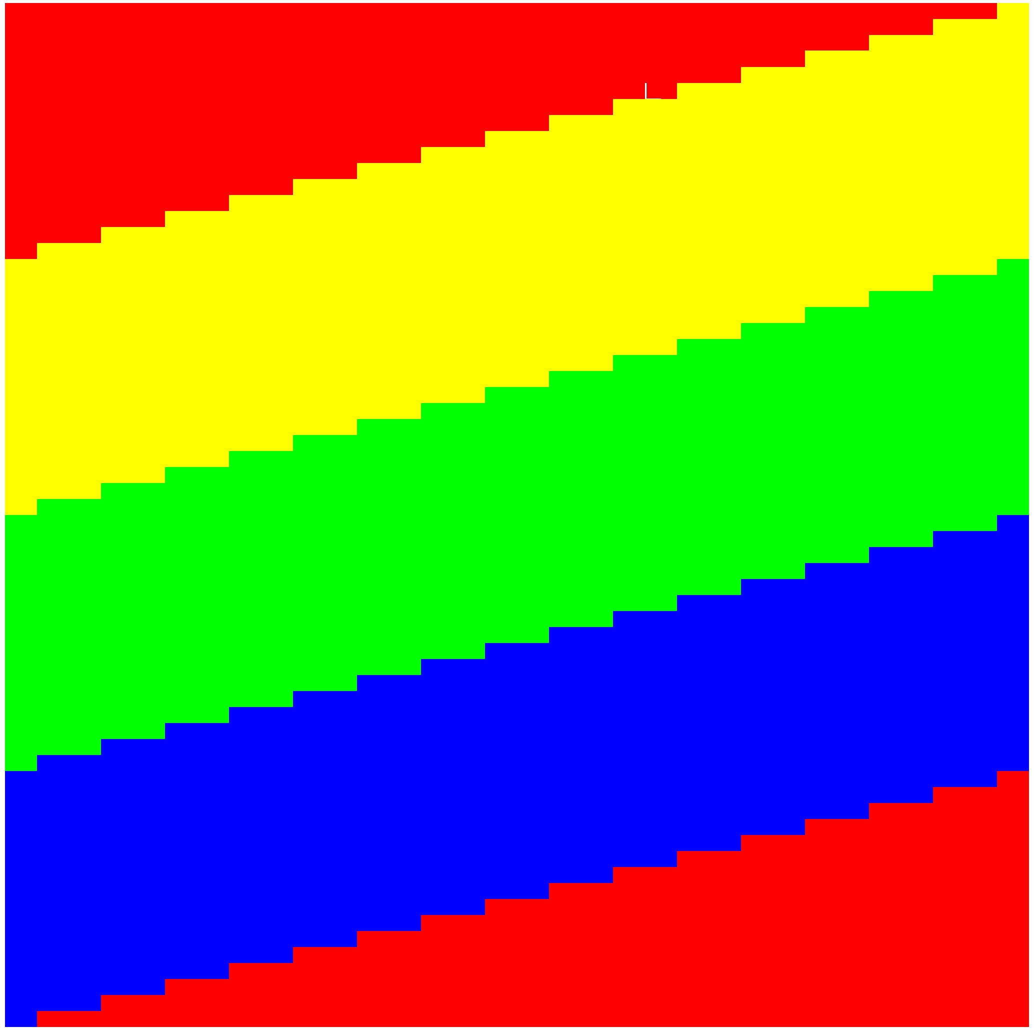
Level 0 Mipmap – 64 × 64



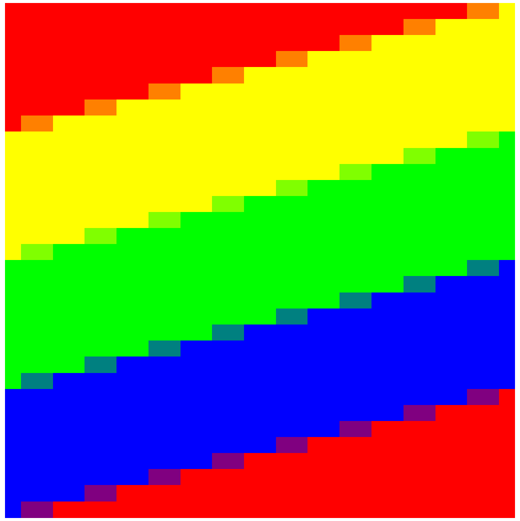
Level 1 Mipmap – 32 × 32



Level 0 Mipmap – 64 × 64

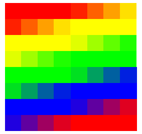


Level 1 Mipmap – 32 × 32

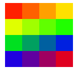


Level 2 Mipmap – 16 × 16

Level 3 Mipmap – 8 × 8



Level 4 Mipmap – 4 × 4



Level 5 Mipmap – 2×2

Level 6 Mipmap – 1×1

Using Mipmaps

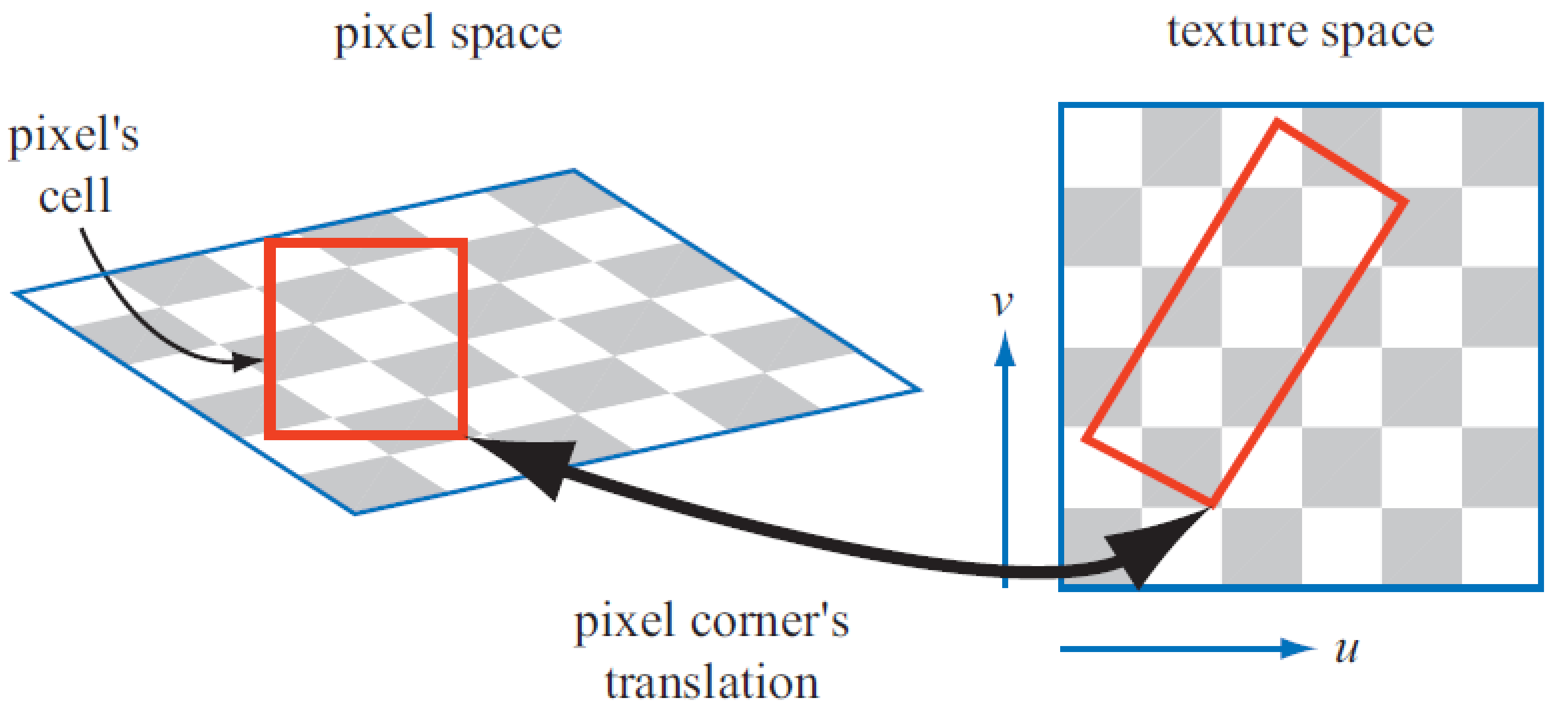
- When using mipmaps, we have two separate choices:
  - Whether to use the nearest texel in a mipmap or to interpolate among the 4 nearest texels
  - Whether to use the nearest mipmap or to interpolate between the nearest two mipmaps
- Thus, the choices are:
  - Nearest texel, nearest mipmap
  - Nearest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

Interpolating Between Mipmaps

- Assume that a single color has been selected from each of the nearest two 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 $\lambda = \log_2 r$
- $\lambda = \log(\text{texture\_size}/\text{polygon\_size}))$

Which Mip Map Level To Use

- Count number of changes in texels along length of pixcel cell



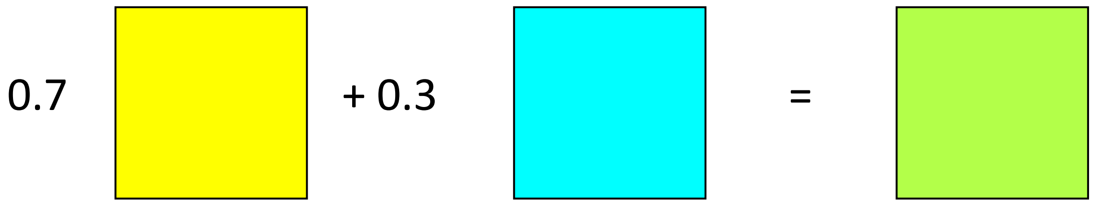
Interpolating Between Mipmaps

- 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

Example

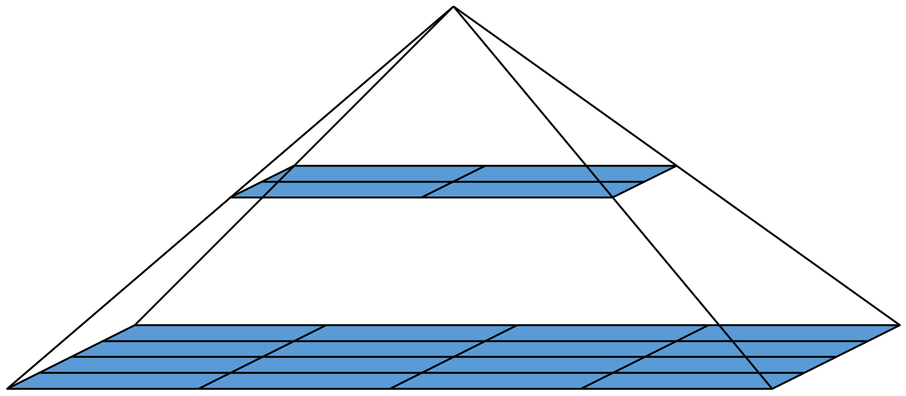
- Suppose λ = 1.3 and the level 1 mipmap color is yellow (1, 1, 0) and the level 2 mipmap color is cyan (0, 1, 1)
- Then the interpolated color is

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



Trilinear Interpolation

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

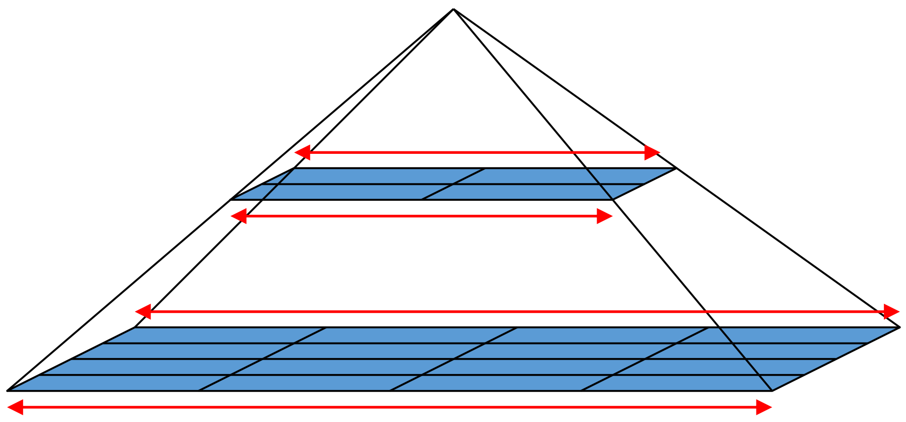


Trilinear Interpolation

- How many individual interpolations are required to perform trilinear interpolation?

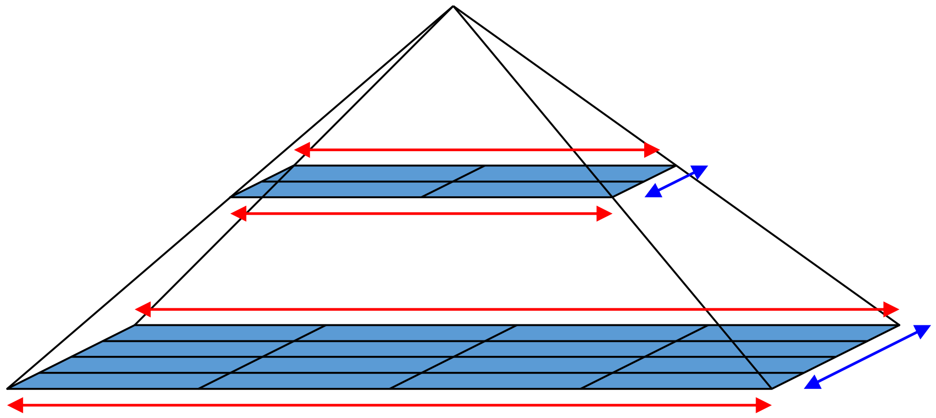
Trilinear Interpolation

- 4 from “left to right” (s direction)



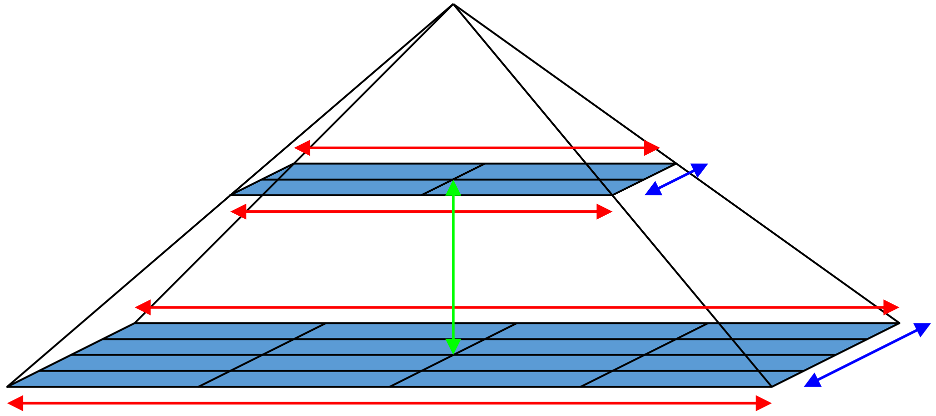
Trilinear Interpolation

- Plus 2 more from “front to back” (t direction)

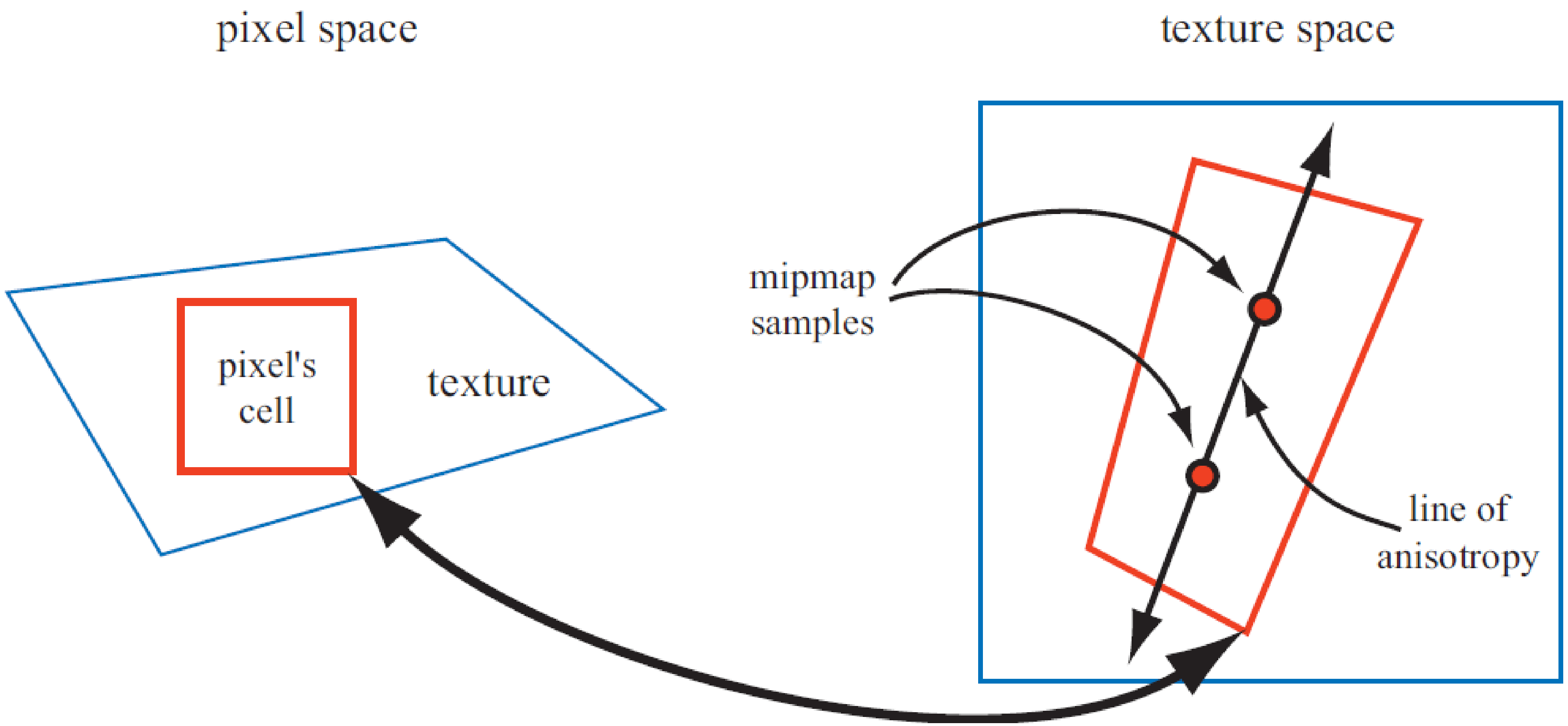


Trilinear Interpolation

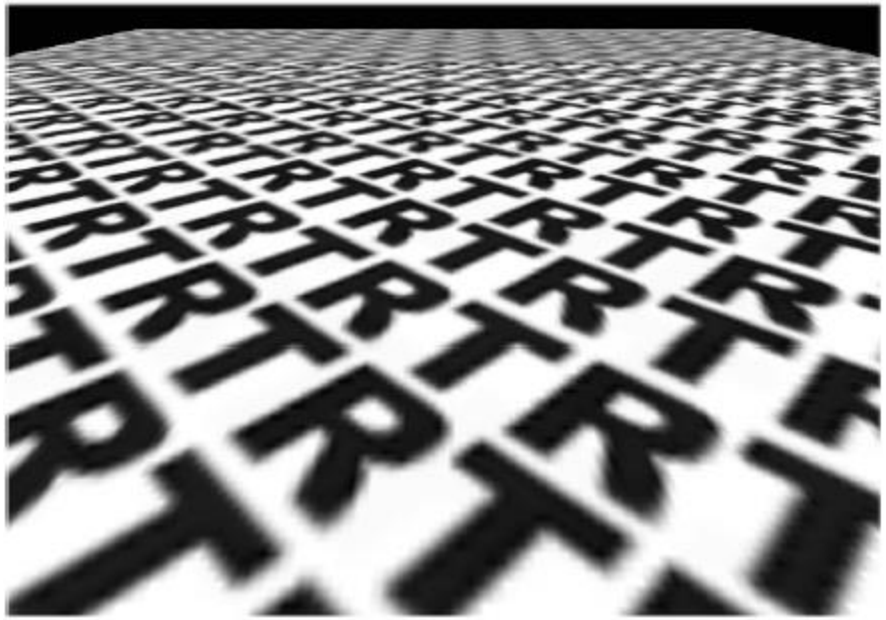
- Plus 1 between levels = 7



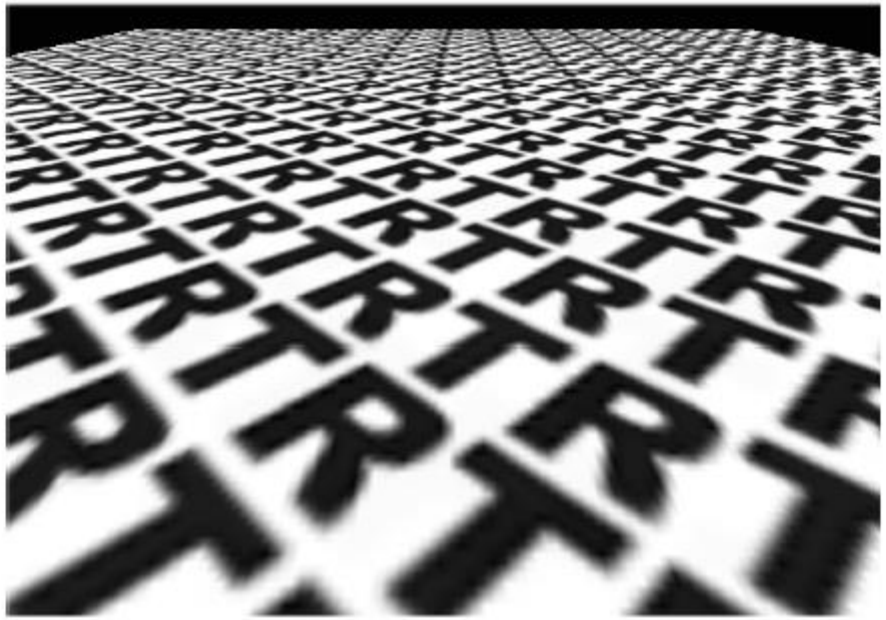
Anisotropic Filtering



Anisotropic Filtering



Mip Map



Anisotropic