Computer Graphics

MTAT.03.015

Raimond Tunnel

Study IT in .ee

The Road So Far...

Construct geometry
Define transformations
Assign material properties
...

This week

Last week

Vertex Transformations

Vertex Shader
Object's local space → viewport space

Culling & Clipping

Determine front-facing triangles
Determine which vertices are visible

Rasterization

Fill the triangle with fragments

Fragment Shading

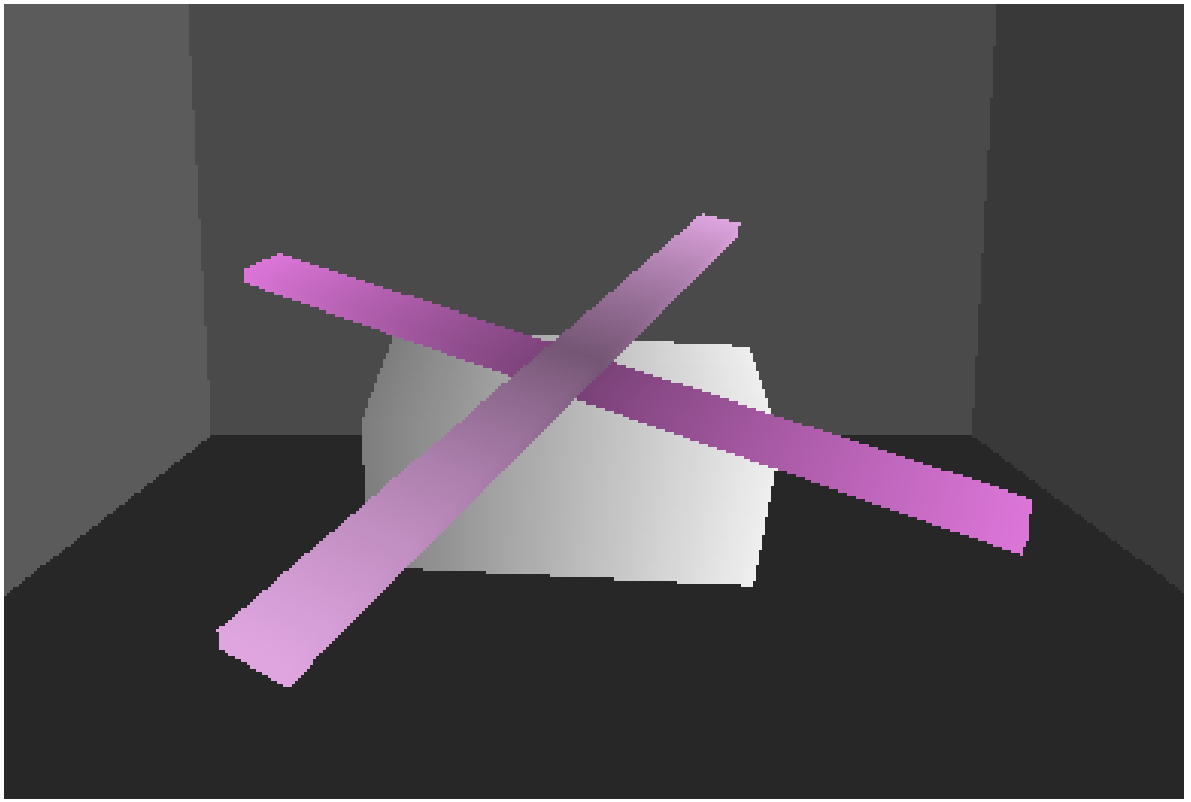
Fragment Shader
Calculate correct color values

Visibility Tests
Blending

Is the fragment visible?
Blend together multiple fragments

More Granular Surface Color

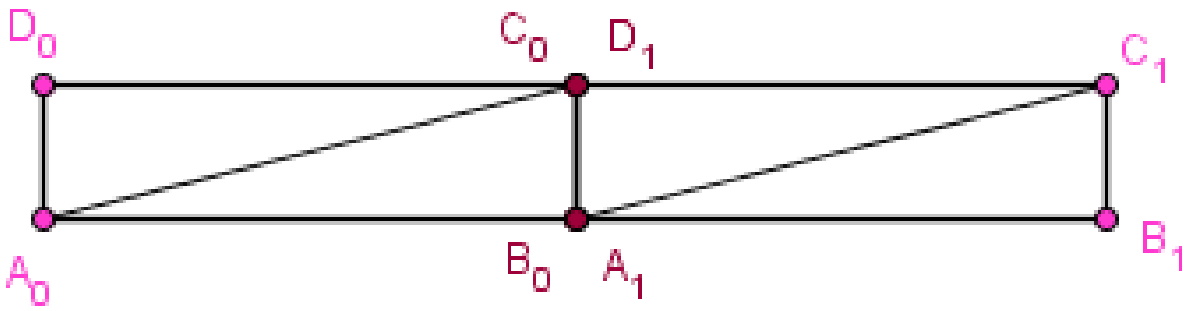
- Blades – 4 different meshes:
  - 2 blades
  - Each blade consists of two parts



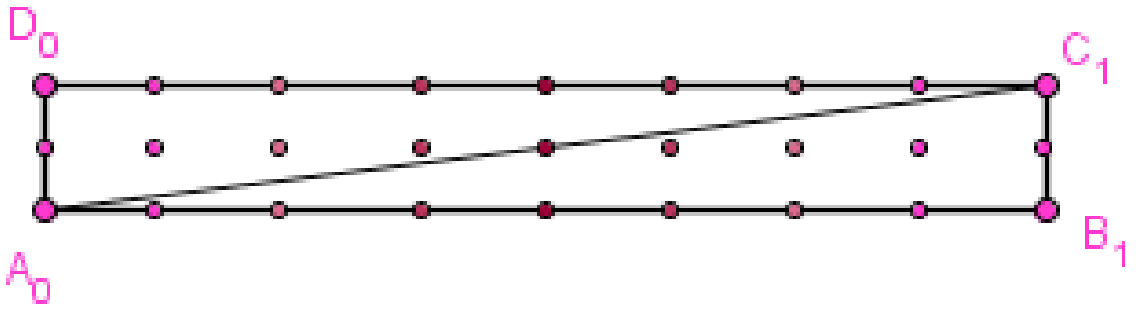
Chopper by Annika Hansalu

More Granular Surface Color

- Extra vertices and faces that all need parsing

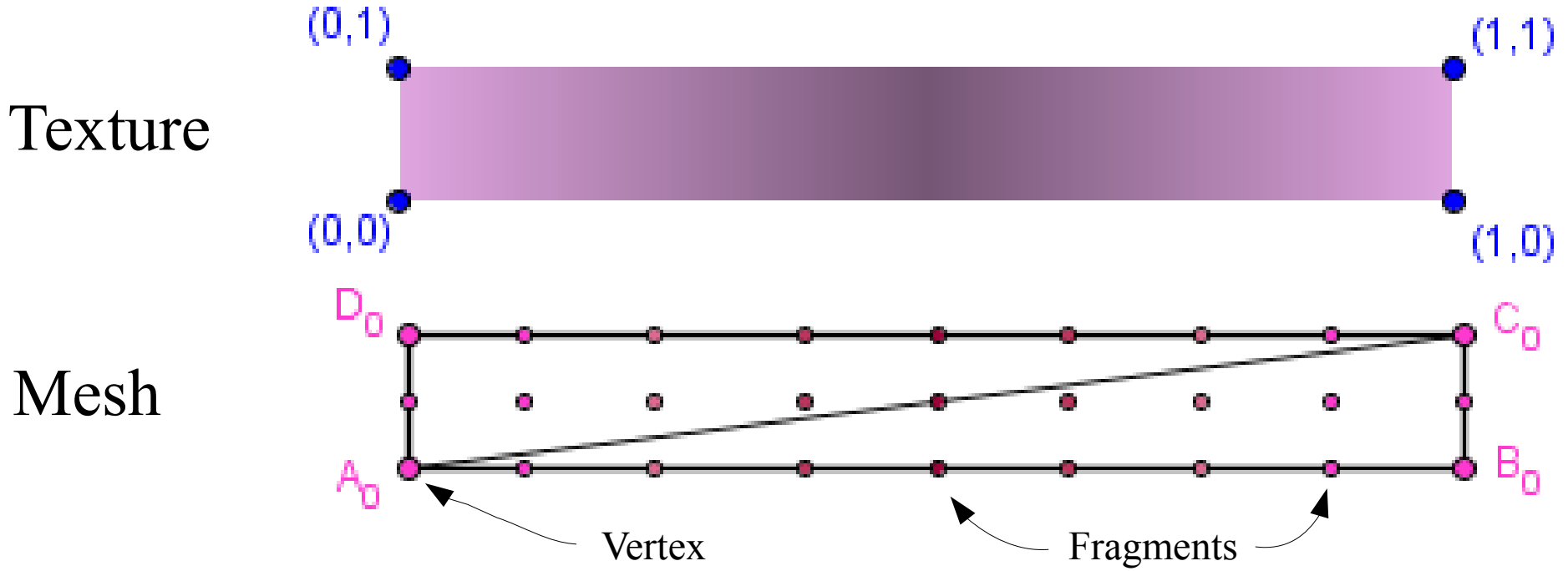


- Could we get the same result with only 4 vertices?



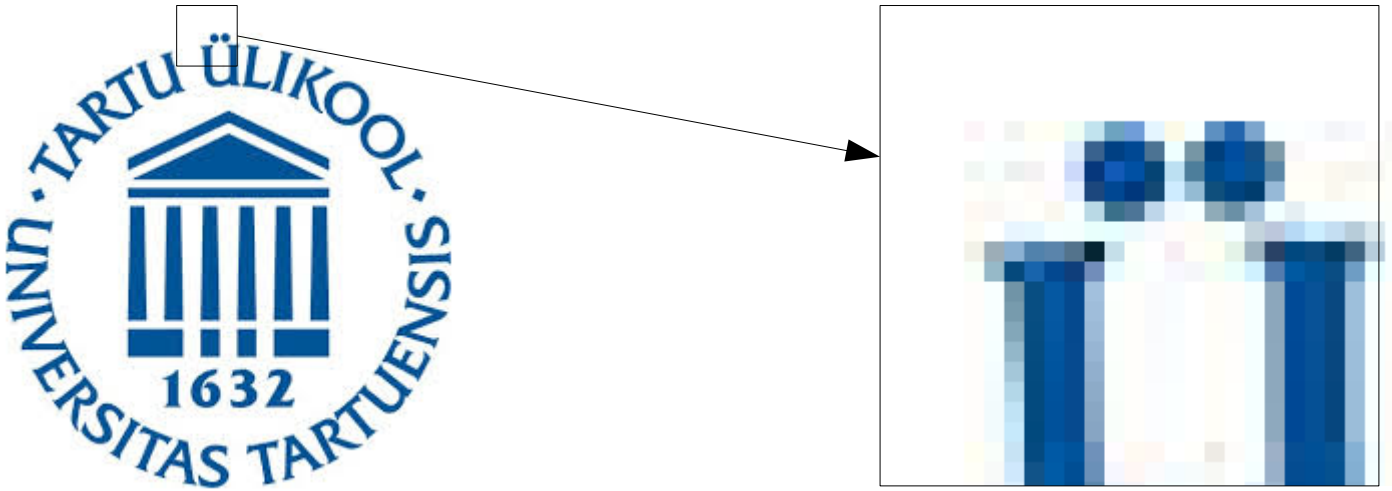
More Granular Surface Color

- We would need to specify at which fragment we take which color.
- We can no longer interpolate the color, but should somehow specify a mapping.



(Raster) Image

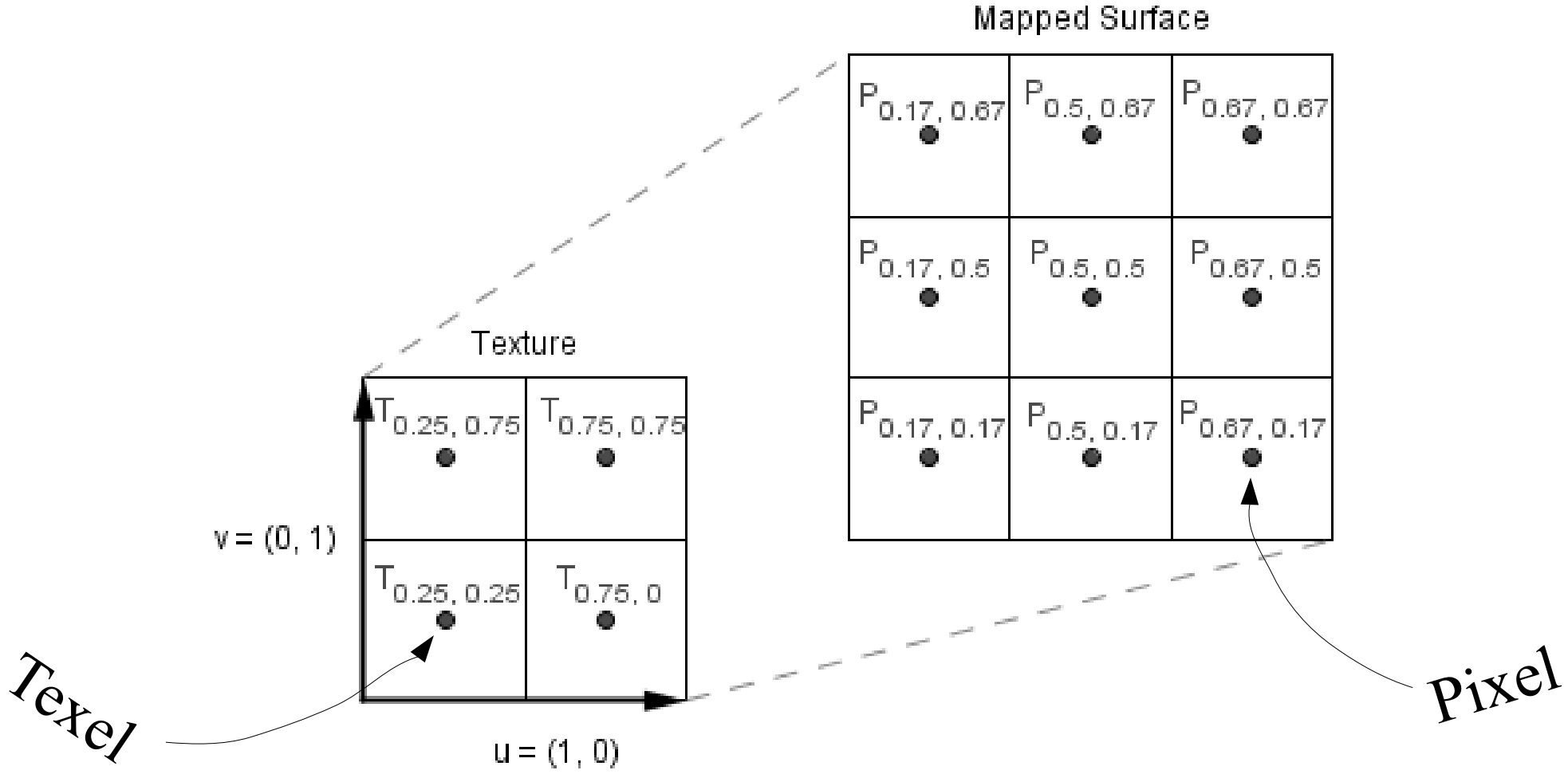
- Image is a matrix of point values.



- But, our 3D surface is continuous, we may rasterize a varying amount of points in a face.

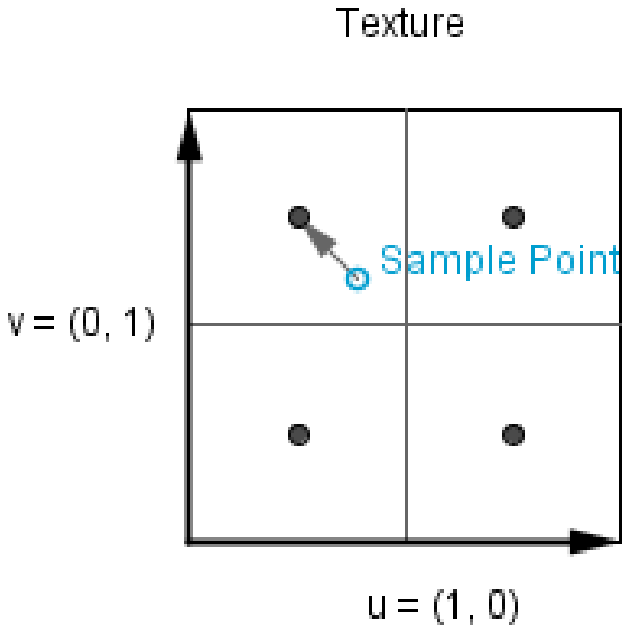
Upscale

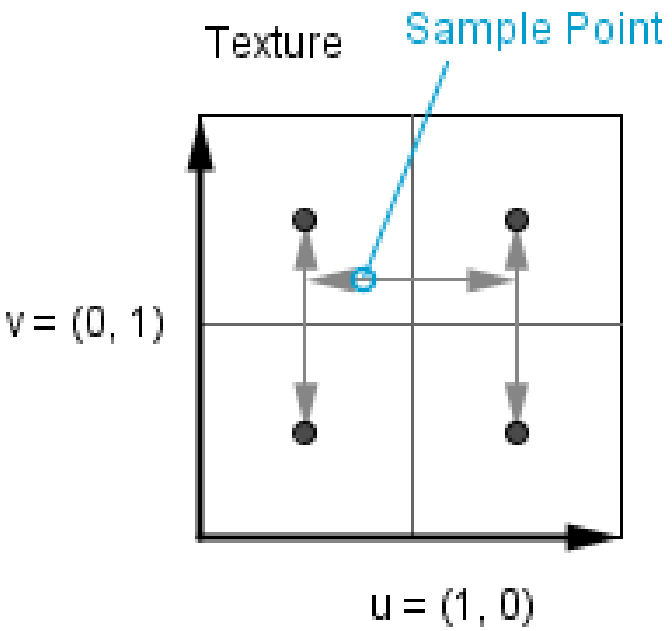
- Sometimes we want to see the surface in more detail than there are point values in the image.

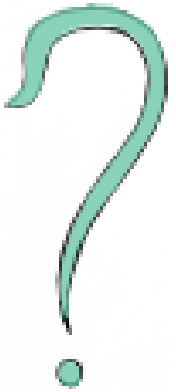


Upscale

- For a single point in the larger surface, we usually have 4 neighbours in the texture.
- What could be the exception?
- What possibilities we have to find a value?

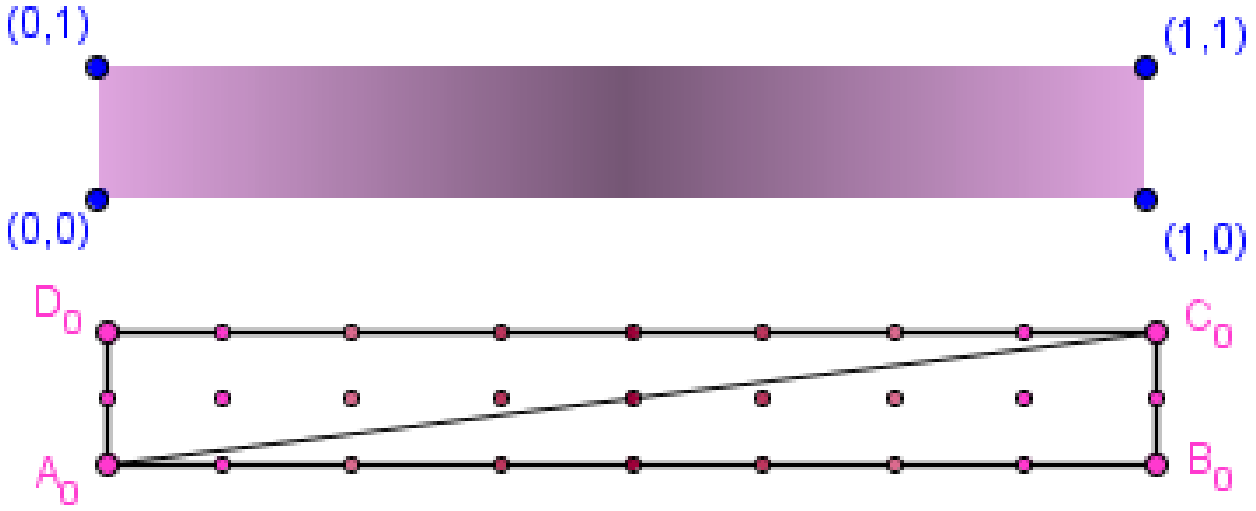






Upscale

- With that in mind, what would be a smallest texture we need for the chopper blade here?

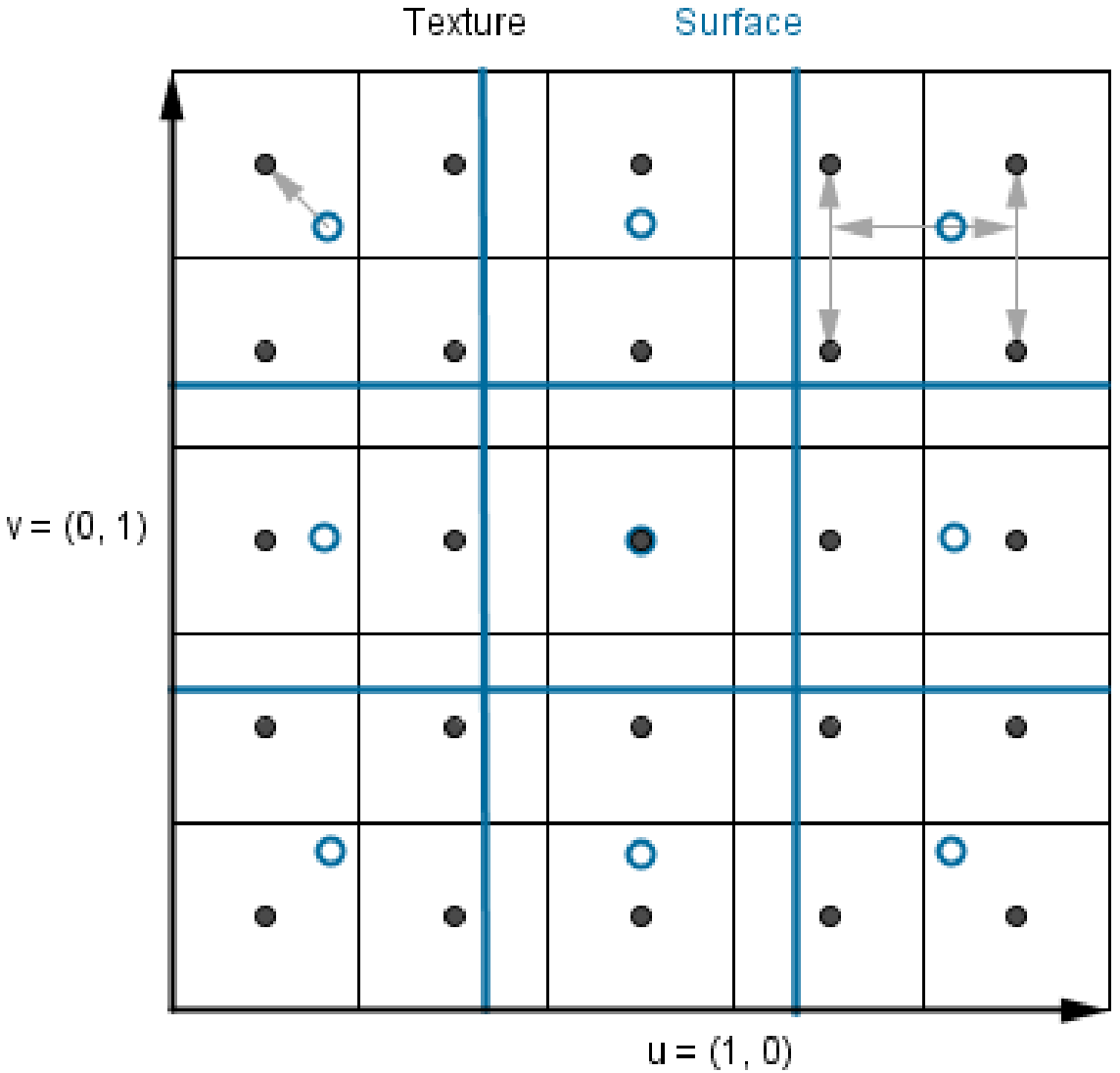


Upscale

- Given a texture with some *width*×*height*, how to find the nearest, or 4 nearest texels?

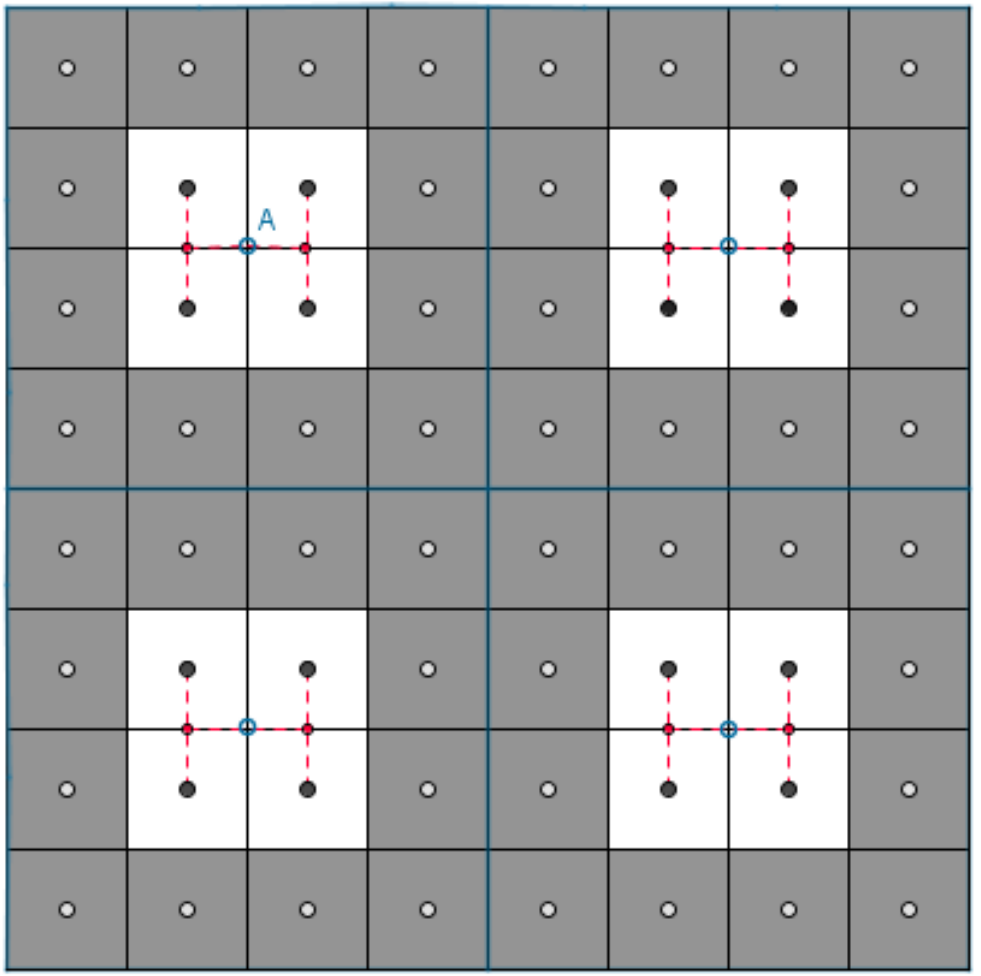
Downscale

- We can do the same interpolation for the downscale.

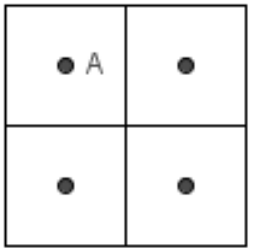


Downscale

- What can go wrong?



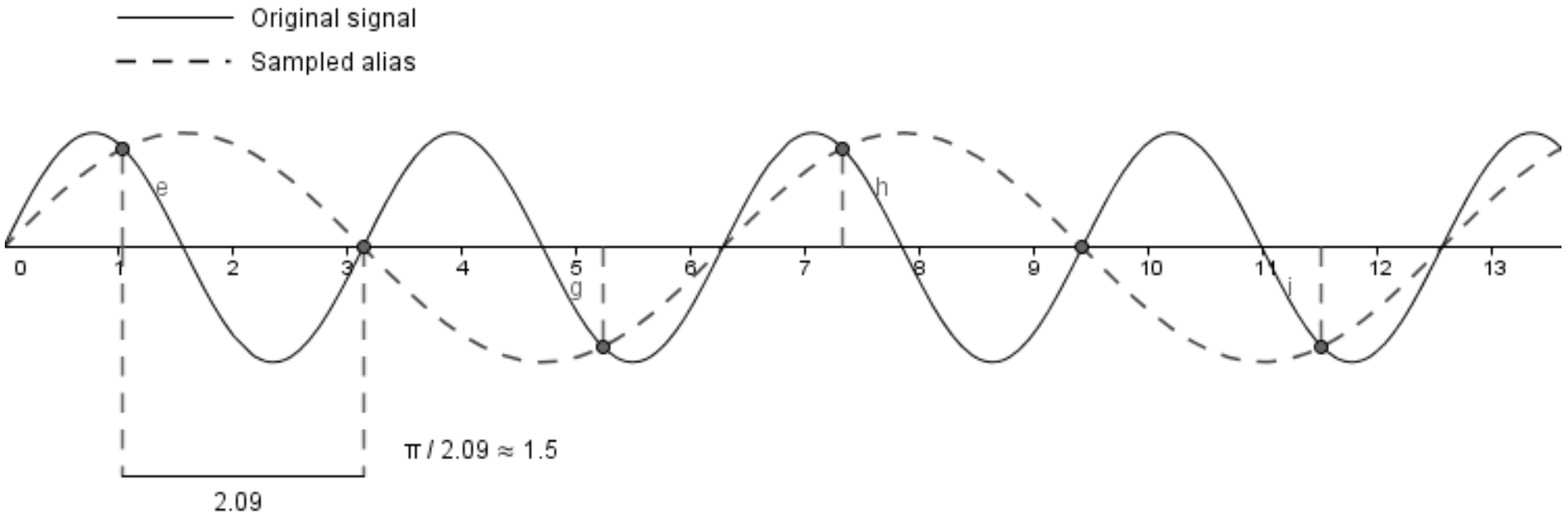
Texture



Downscaled

Nyquist–Shannon Sampling Theorem

- In order to reconstruct a band-limited signal, one has to sample with sampling rate more than twice the highest frequency.



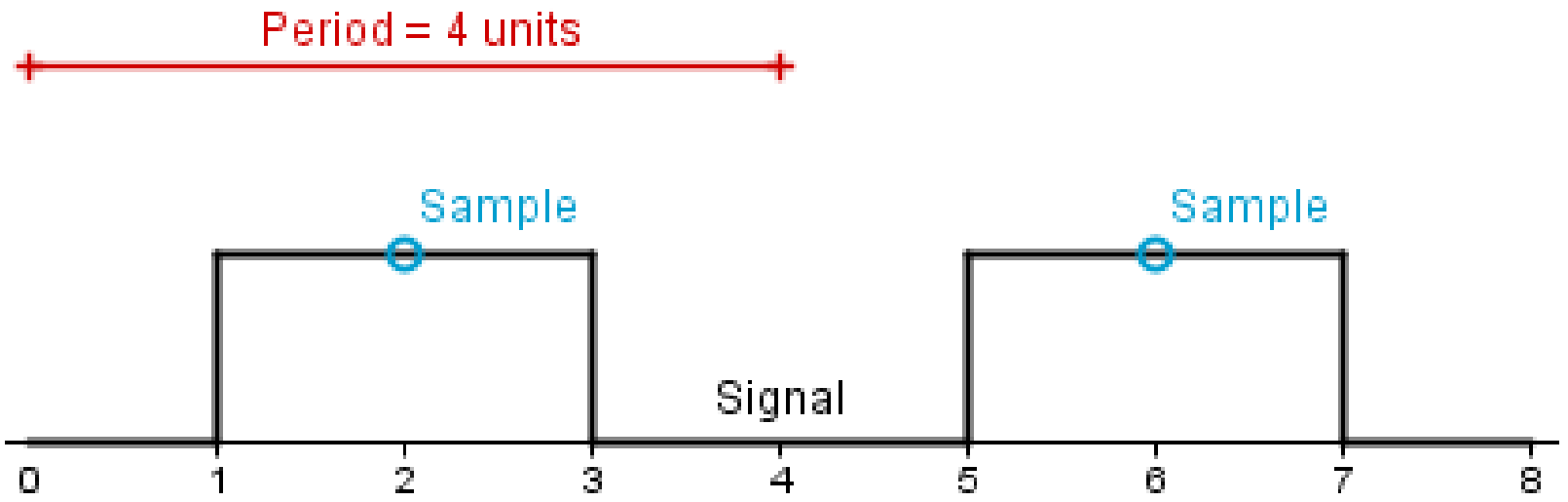
This means more than 2 samples per period, every period.

Nyquist–Shannon Sampling Theorem

- Band-limited signal – there is a fixed highest frequency in the signal.
- The signals in real life are not band-limited.
- Reconstruction is possible only when we know the shape of the signal.
- Sampling less frequently, we produce an alias – signal with a lower frequency.
- Usually assumes samples are taken over a length of time.
- More info: Http://www.skillbank.co.uk/SignalConversion/rate.htm
  http://blogs.msdn.com/b/shawnhar/archive/2011/04/29/texture-aliasing.aspx

Downscale

- So, what is happening in our example?



$$period = 4 \Rightarrow frequency = \frac{1}{4}$$

$$frequency_{Nyquist} = \frac{2}{4} = \frac{1}{2} \qquad frequency_{Us} = \frac{1}{4} < \frac{1}{2}$$

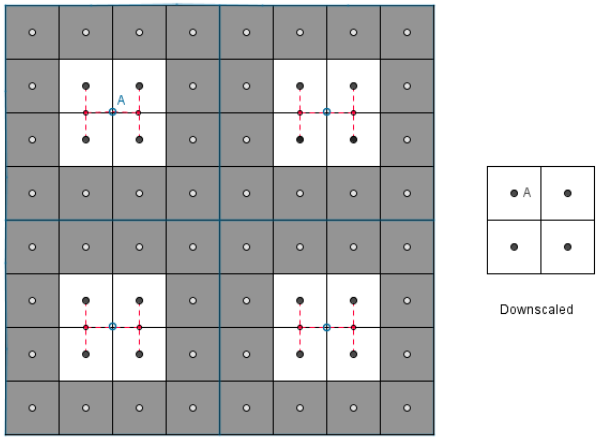
We need more than 1 sample per two units.

Downscale

- We need more than 1 sample per 2 units.
- Is this even possible, if we want to downscale from 8×8 to 2×2?

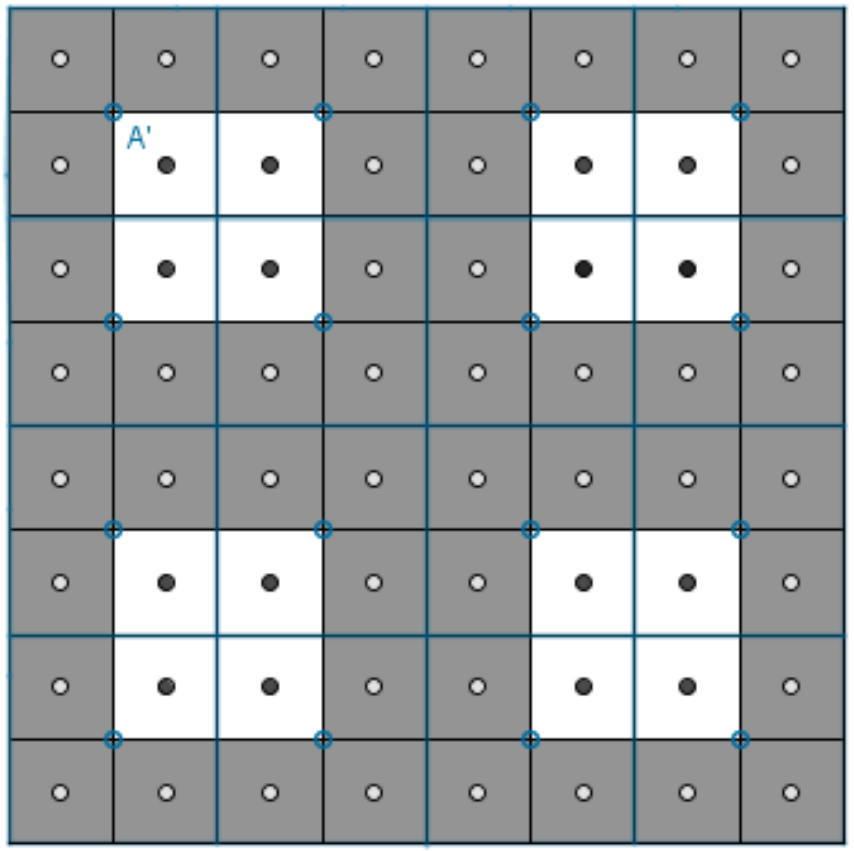
Downscale

- But we do not want to create Moire aliasing either.
- Our texture is not white, a 2×2 downscale should not be white either.
- One unit in the result covers 16 units in the texture. How to represent all those 16 values?



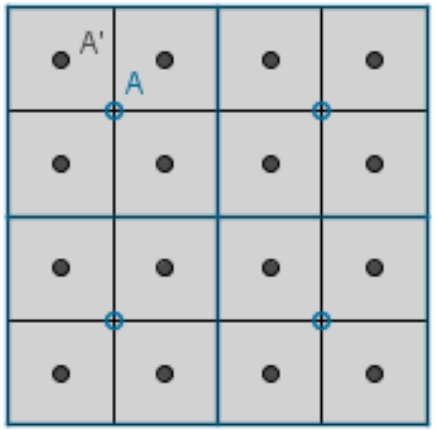
Mipmapping

- In order not to take that many samples each time for downscaling, we take them beforehand.



Texture 8×8

Mipmap 4×4



Mipmap 2×2 = Downscaled

Mipmapping

- What if we have a texture that is 10×10.
  - The first mipmap is the image itself – 10×10.
  - Then we take half the size – 5×5.
  - Next we take half the size – 2.5... Uh-oh.
- The last mipmap we could create is 5×5.
- For a smaller downscale (eg 2×2, 1×1) we still need to sample more than the 4 neighbouring pixels.
- How not to have that problem?

Mipmapping

- Assume we have mipmaps 8×8, 4×4, 2×2, 1×1.
- We want to show our texture on a 6×6 area.
- Which mipmap should we sample?

Filtering

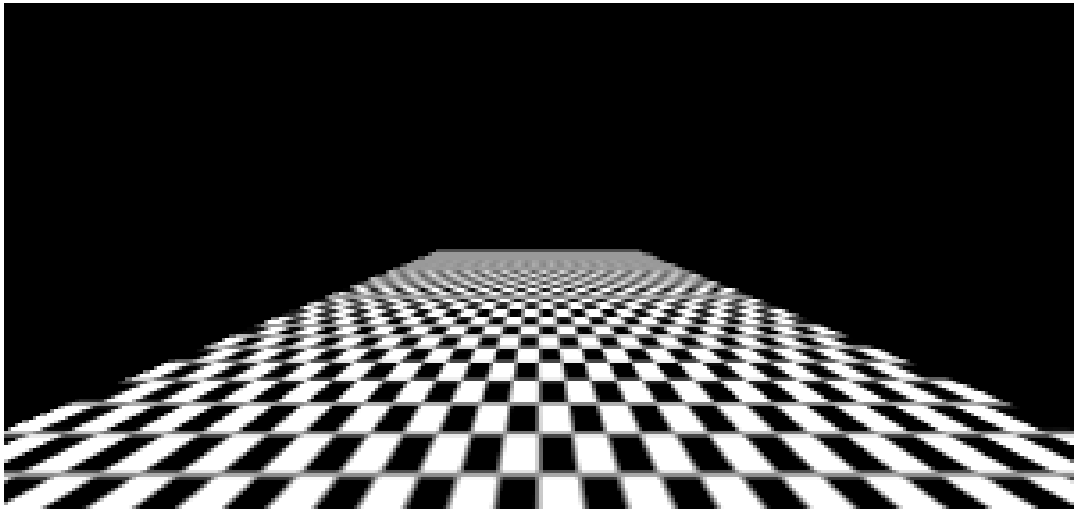
- We have seen several ways to sample the texture.
- Upscale (magnification filtering):
  - Nearest neighbour
  - Bilinear
- Downscale (minification filtering):
  - Nearest neighbour (mipmap: no, NN, linear)
  - Bilinear (mipmap: no, NN, linear)

Also called trilinear

Questions?

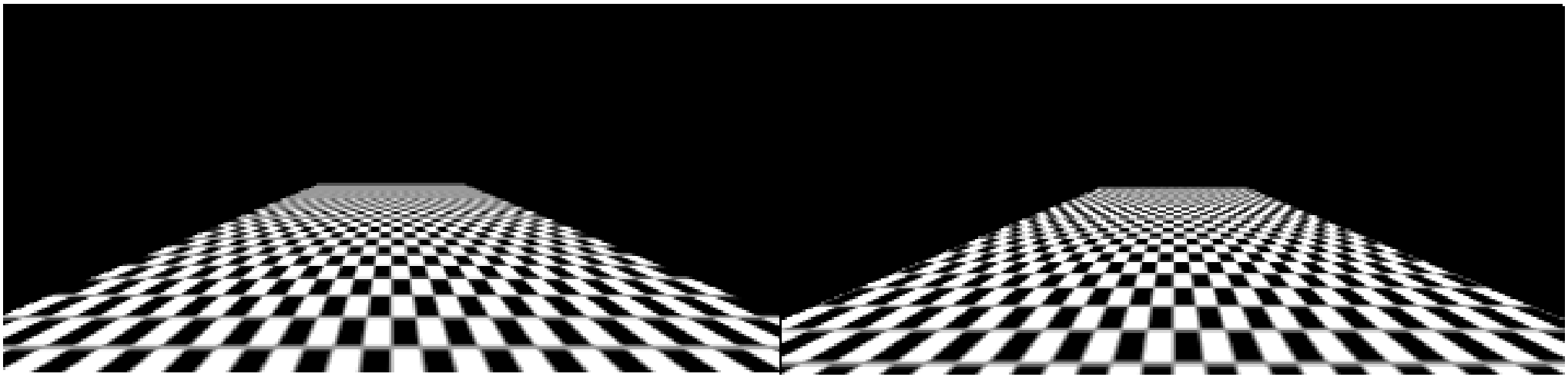
Anisotropic Filtering

- We assumed that the result we are showing our texture on is shown as a square. This is usually not the case.
- If we rotate our quad around the x-axis for example, then we might get that the texture needs to be shown on a 10×5 area instead of 10×10.



Anisotropic Filtering

- We have more resolution in width then in height. It is unfair to average both dimensions equally.
- Anisotropic filtering will use the higher mipmap and take more samples along the denser direction.

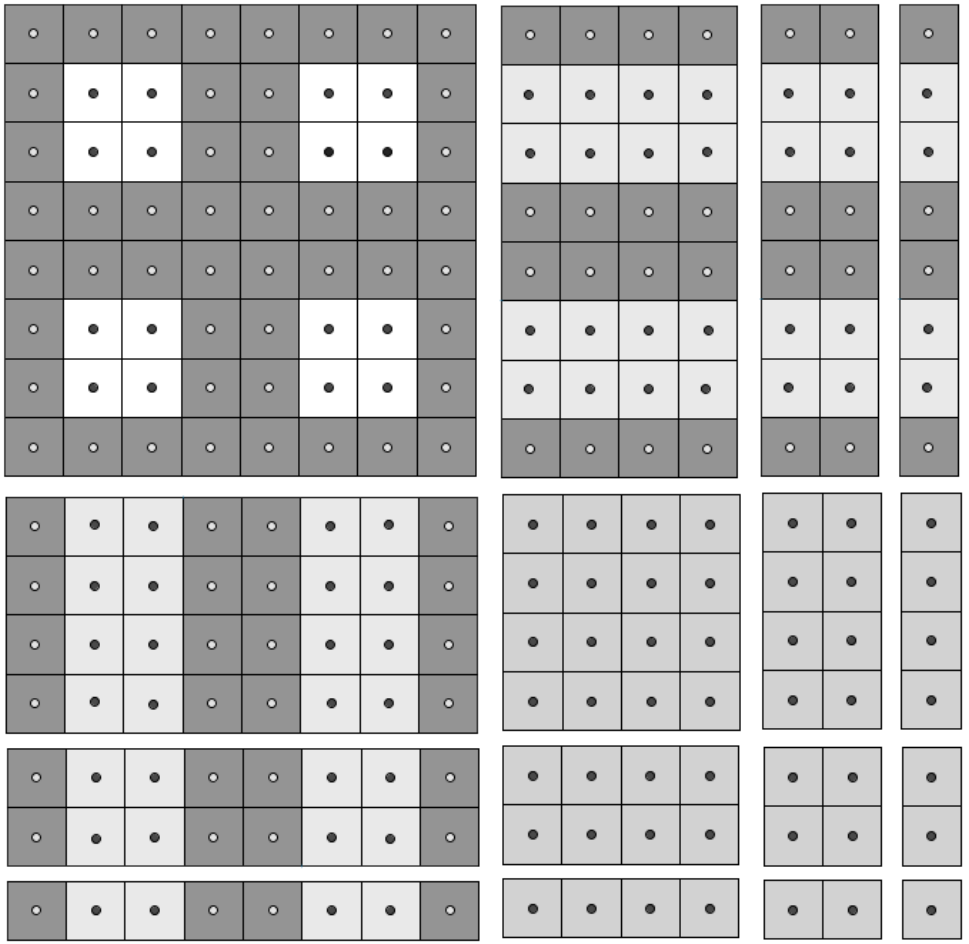


No anisotropic filtering

16x anisotropic filtering

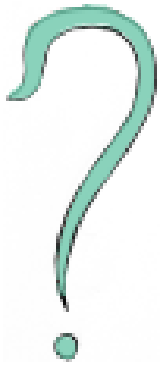
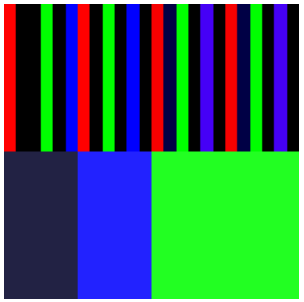
Anisotropic Filtering

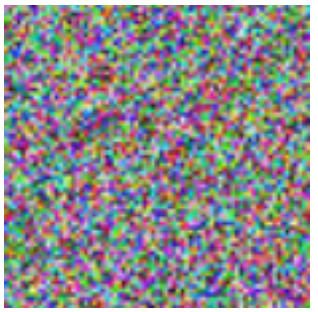
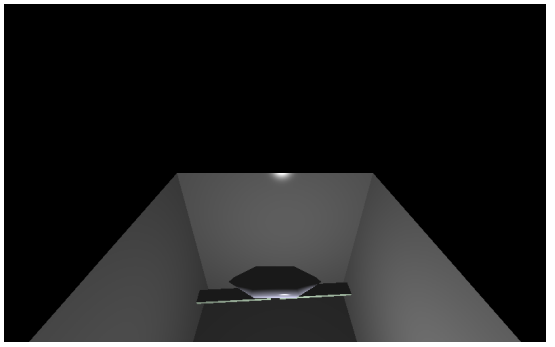
- Actual implementations are vendor dependant.
- One way would be to just create anisotropic mipmaps.



Textures

- There are more uses for textures than just storing granular color of a material.
  - Data textures – we can hold other data like normals or other values with 3 (or 4) coordinates.
  - Noise texture – we can store samples of a random function in a texture to procedurally generate things like the Perlin noise.
  - Render target – we could also render the current framebuffer to a texture.

What did you learn today?

What more would you like to know?

Next time

Blending – *Jaanus Jaggo*