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

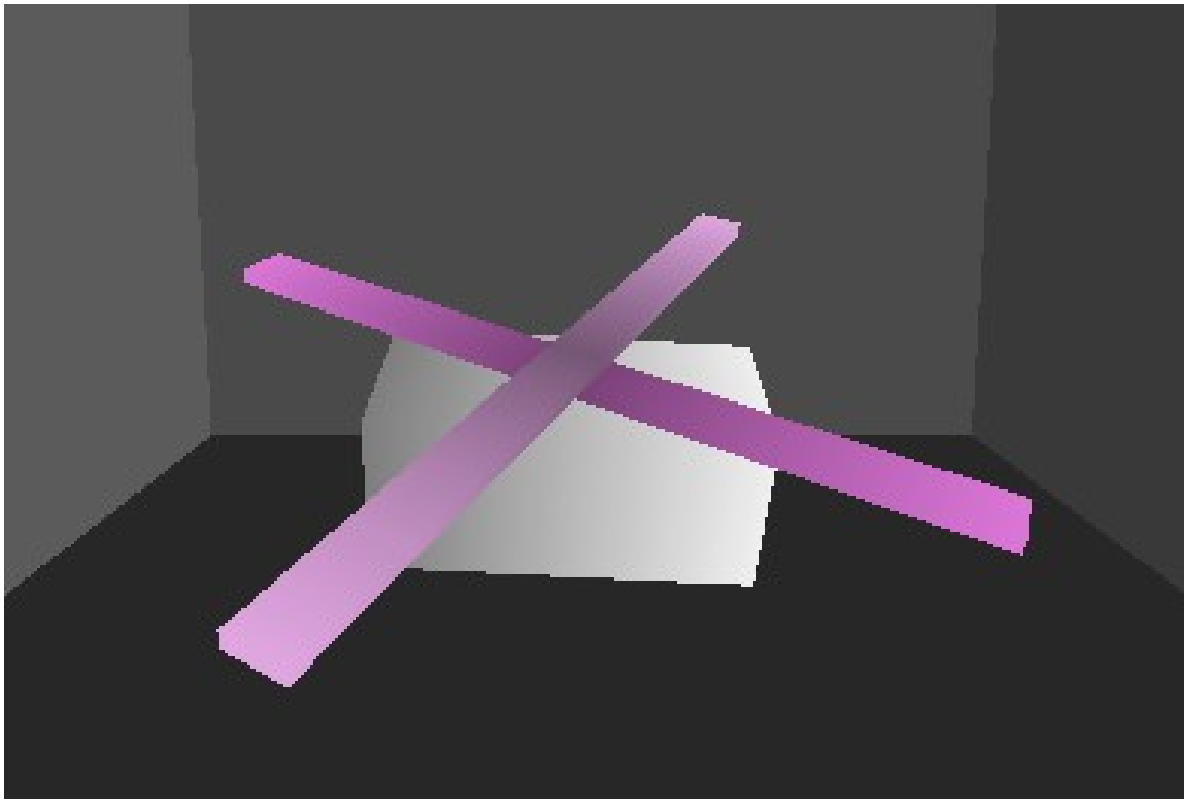
Fragment Shading

Fragment Shader
Calculate correct color values

Visibility Tests
Blending

Is the fragment visible?
Blend together multiple fragments

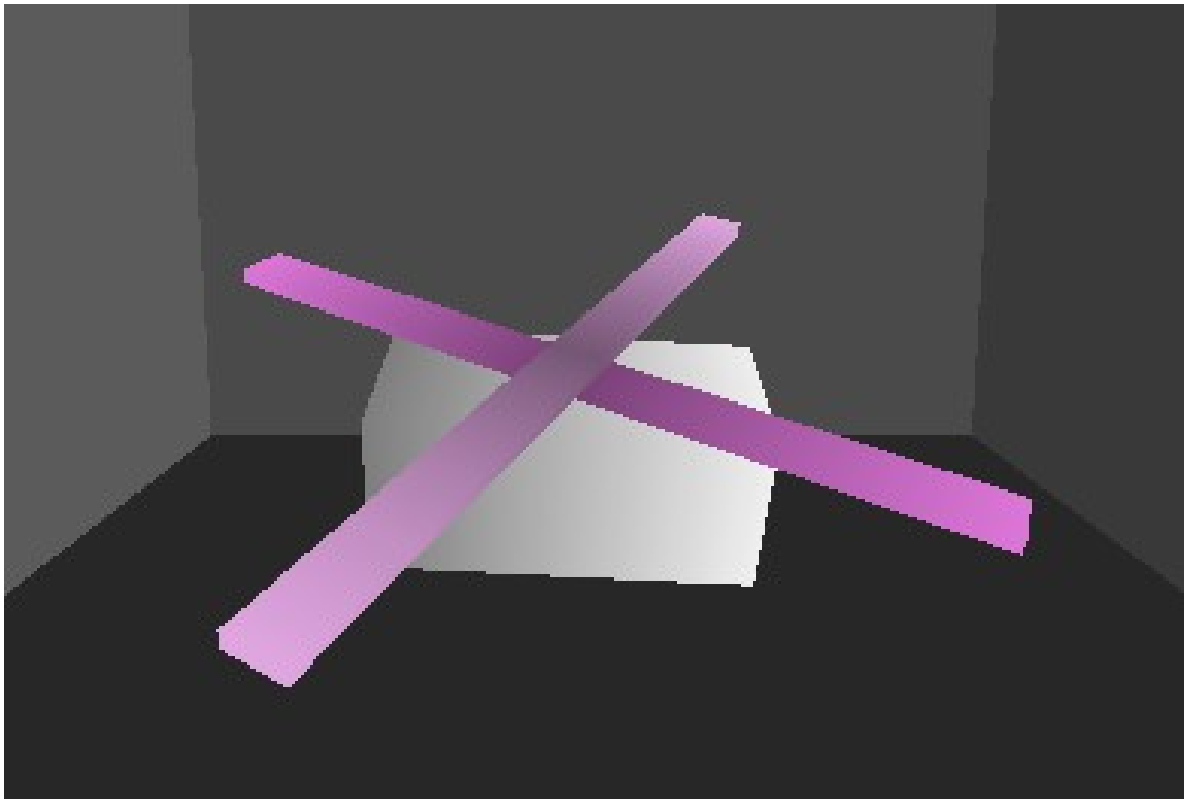
More Granular Surface Color



Chopper by Annika Hansalu

More Granular Surface Color

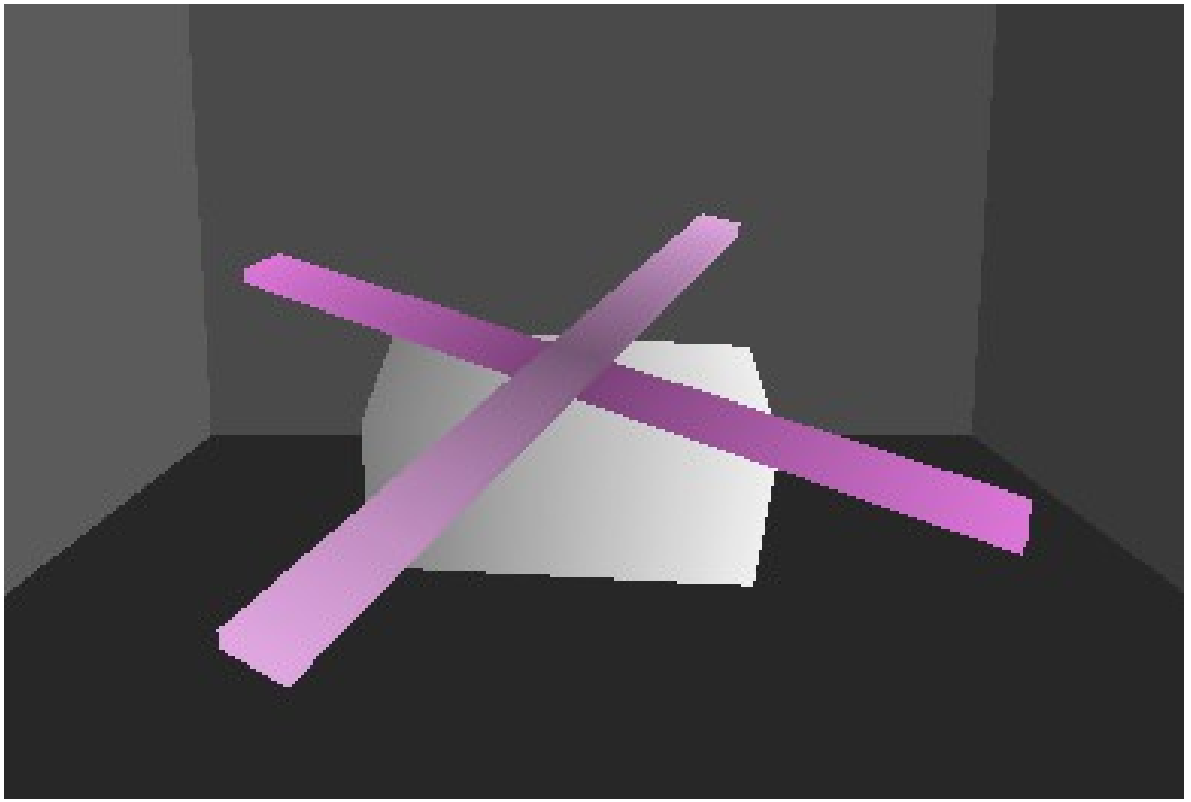
- Blades – 4 different meshes



Chopper by Annika Hansalu

More Granular Surface Color

- Blades – 4 different meshes:
  - 2 blades



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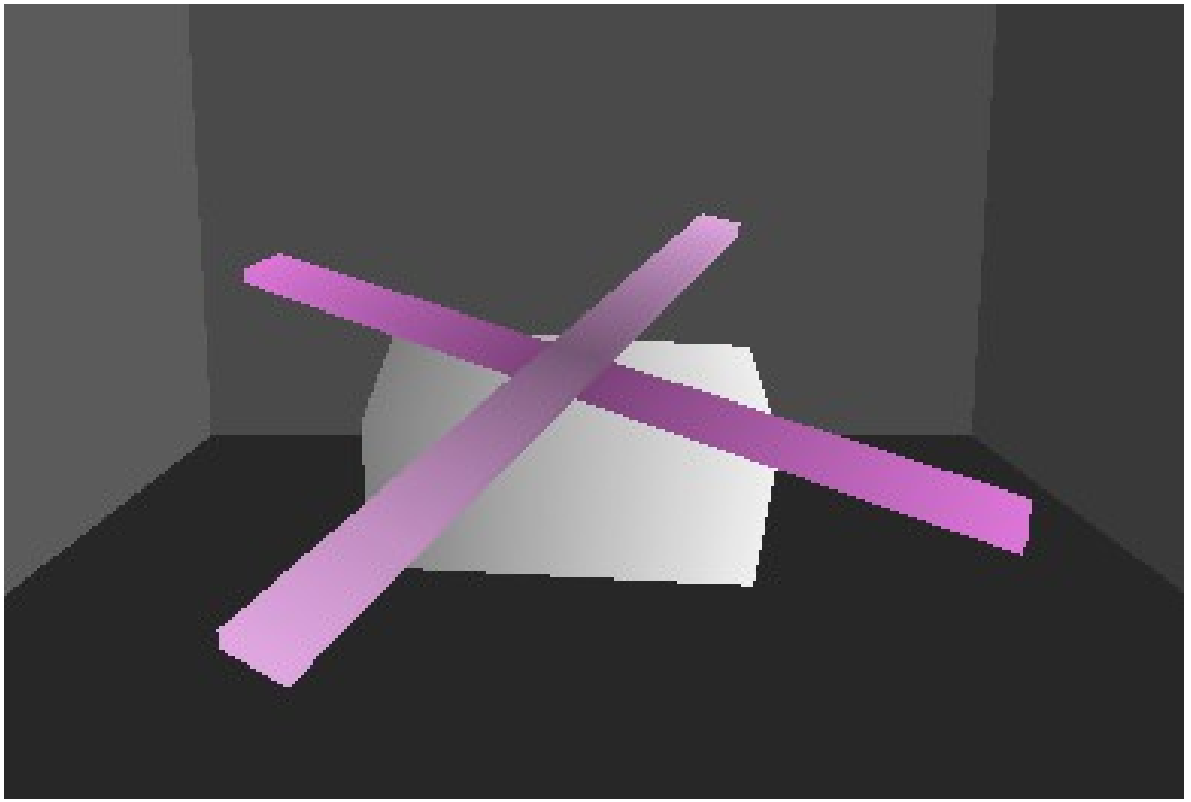
More Granular Surface Color

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



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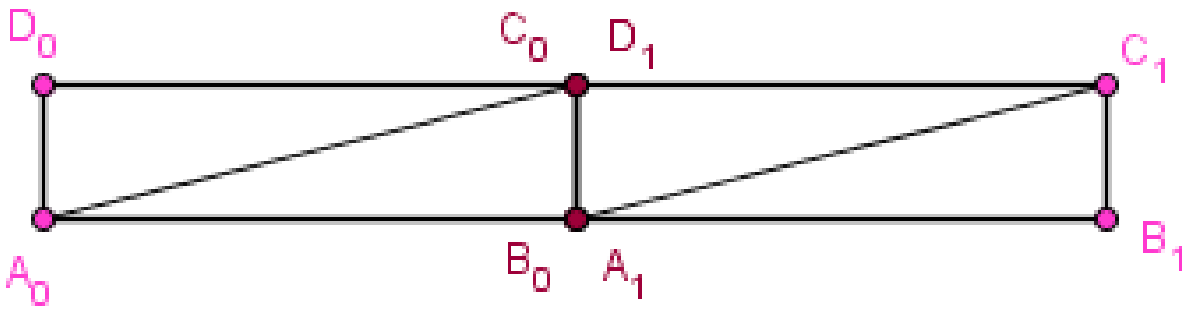
More Granular Surface Color

- Extra vertices and faces that all need parsing



More Granular Surface Color

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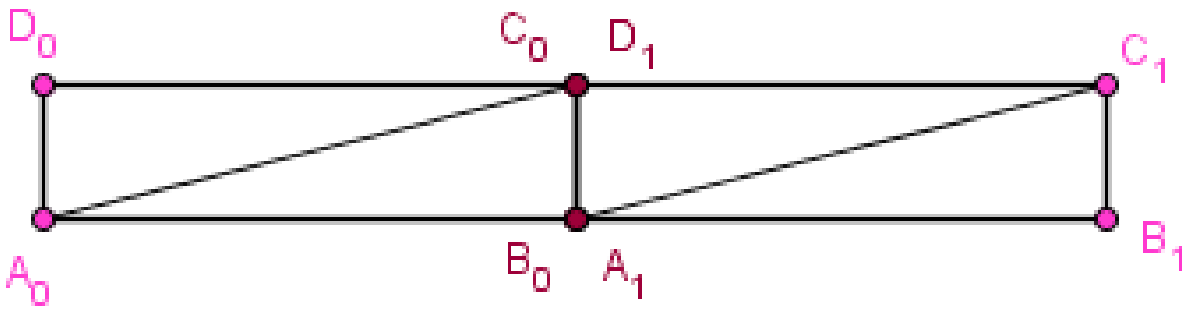
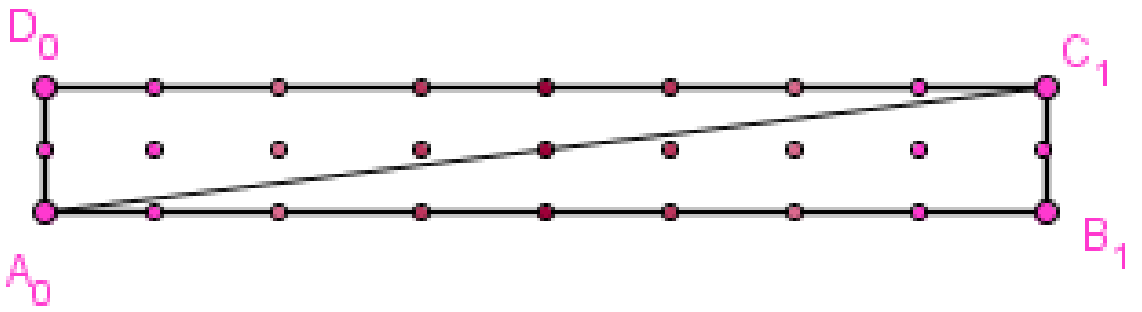


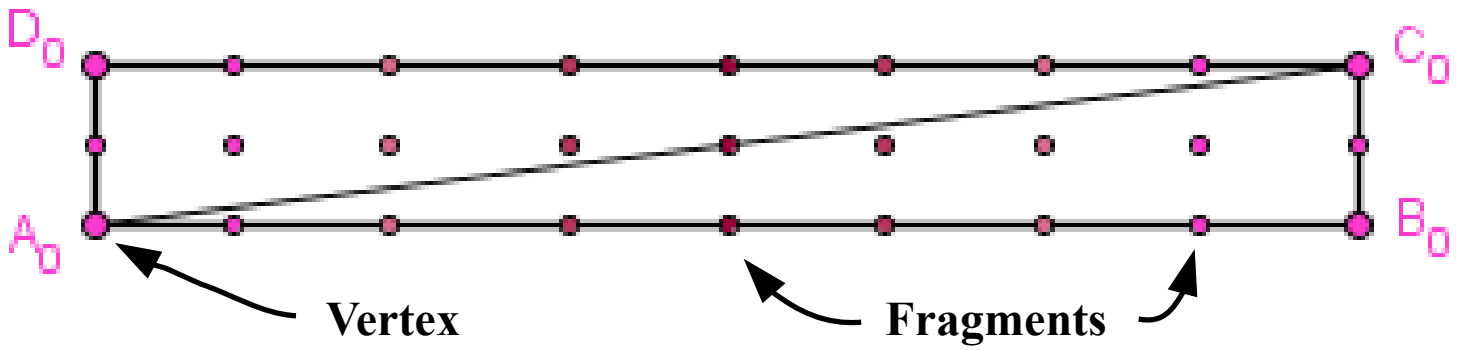
- Could we get the same result with only 4 vertices?



More Granular Surface Color

- We need to specify at which fragment we take which color.

Mesh

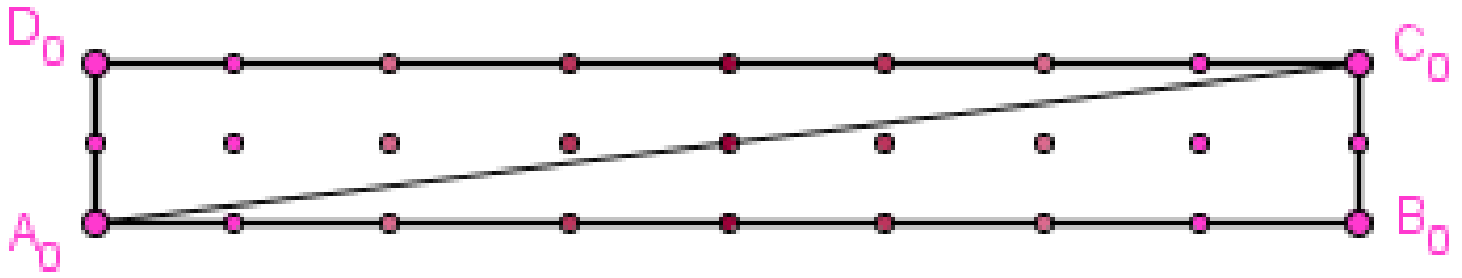


More Granular Surface Color

- We need **an image** to specify at which fragment we take which color.

Texture

Mesh

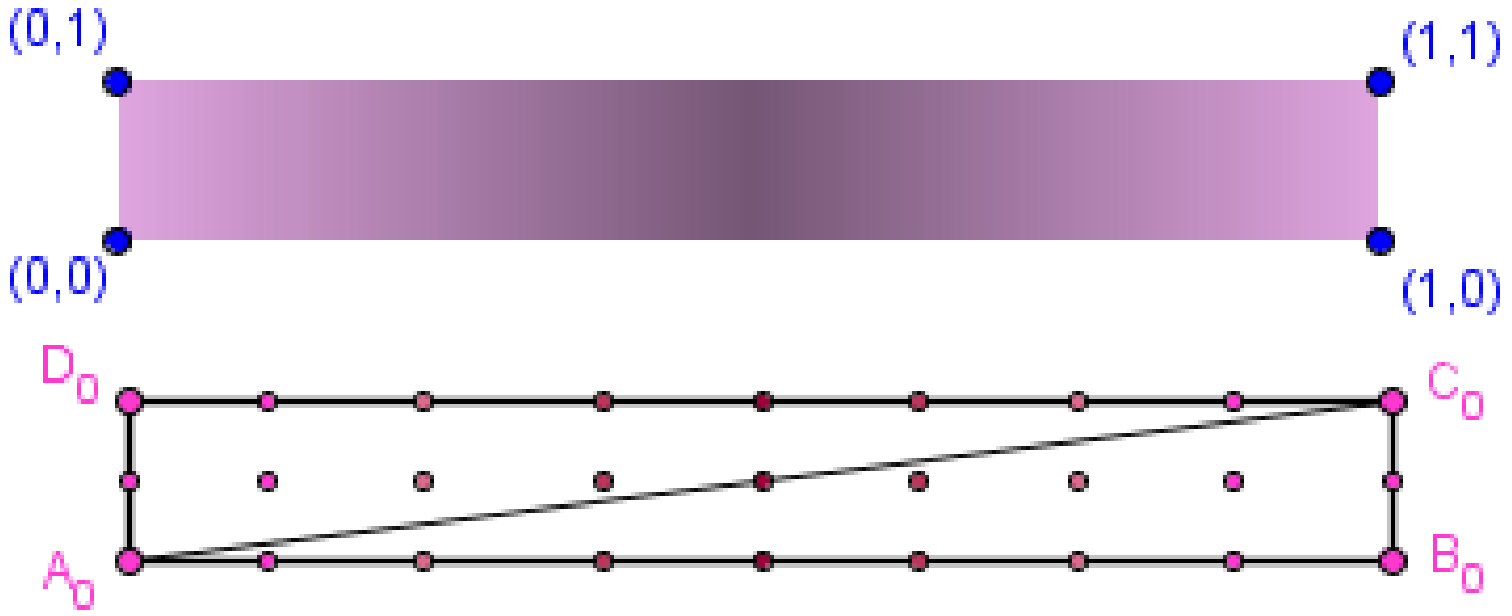


More Granular Surface Color

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

Texture

Mesh



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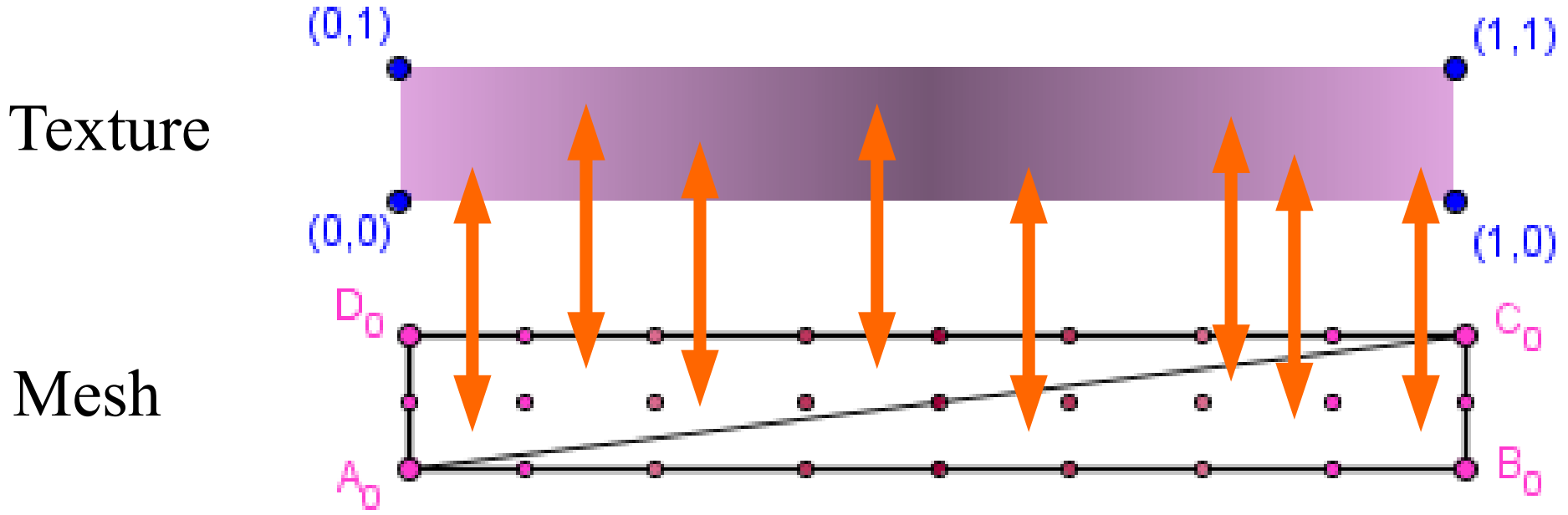

More Granular Surface Color

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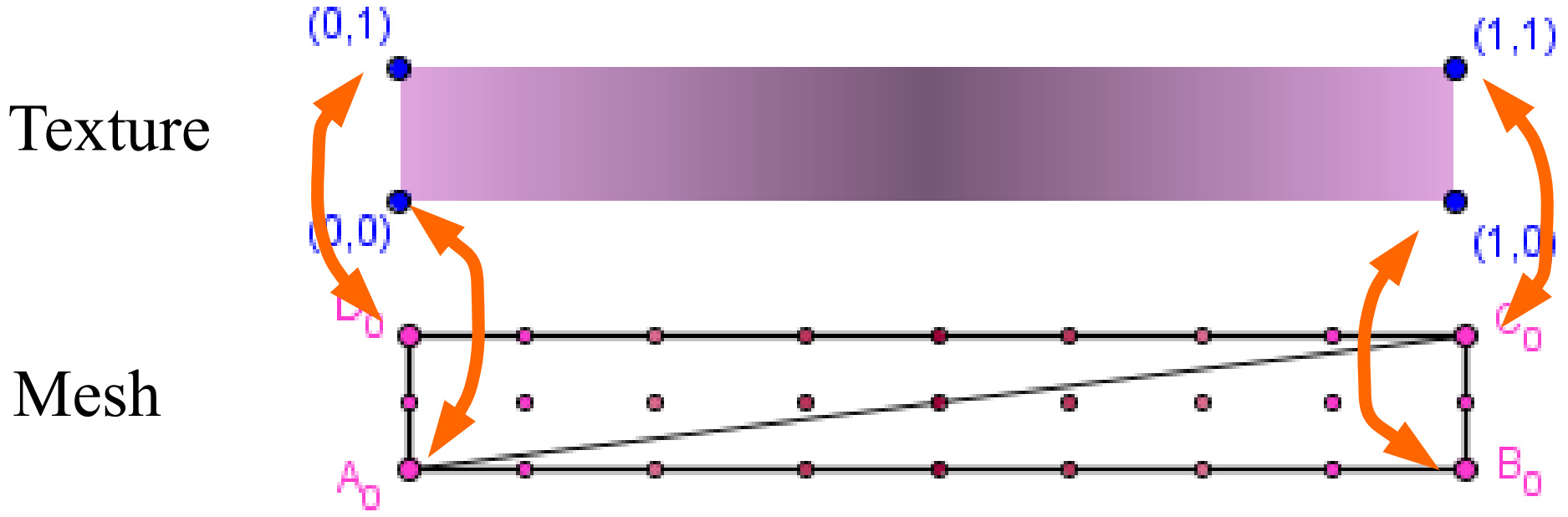
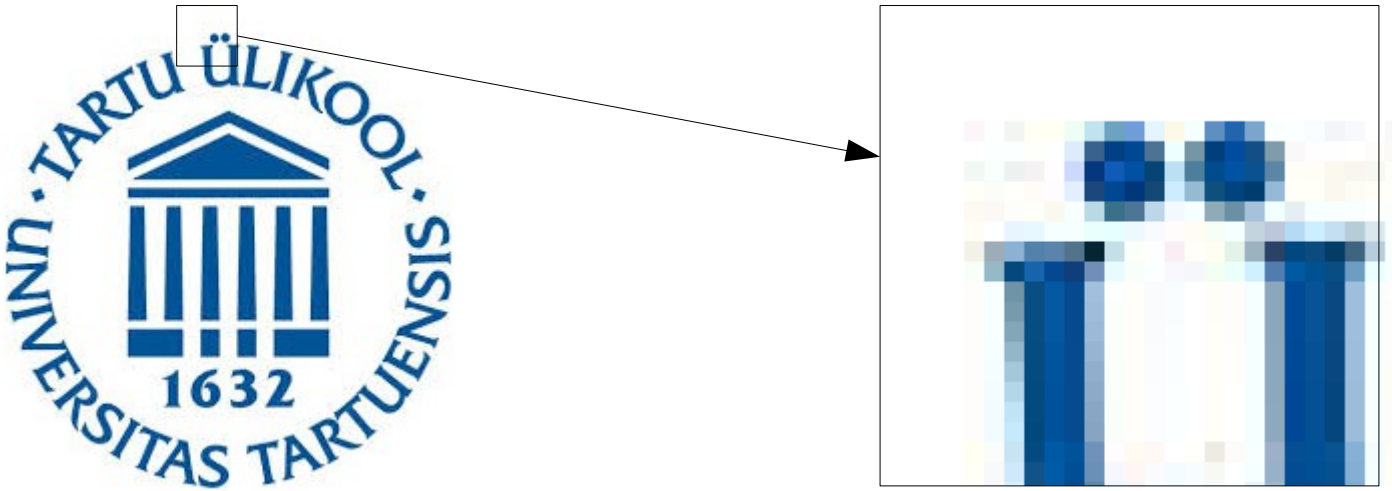


(Raster) Image

- Image is a matrix of point values.



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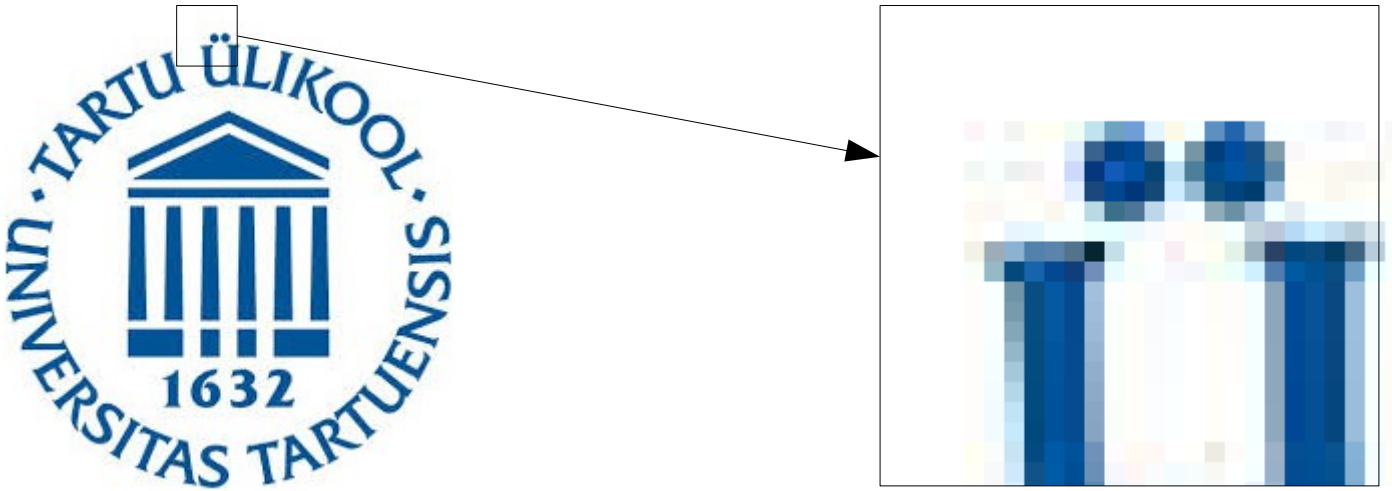

- Our 3D surface is **continuous**, we may rasterize a **varying amount** of points for a face.

Upscale

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

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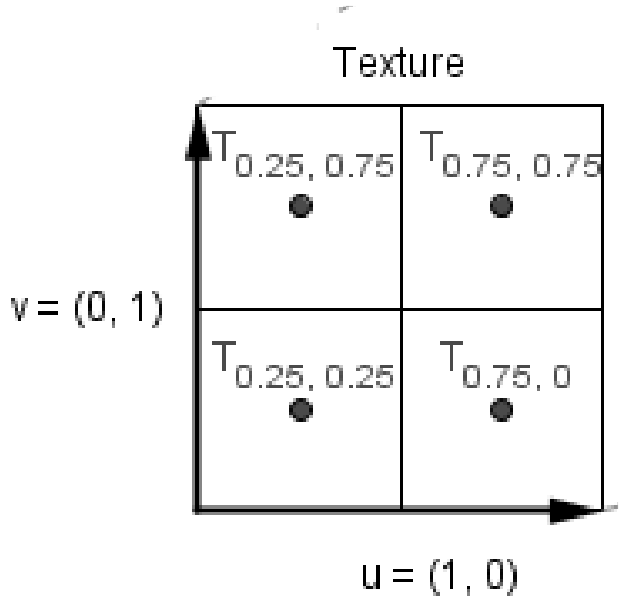

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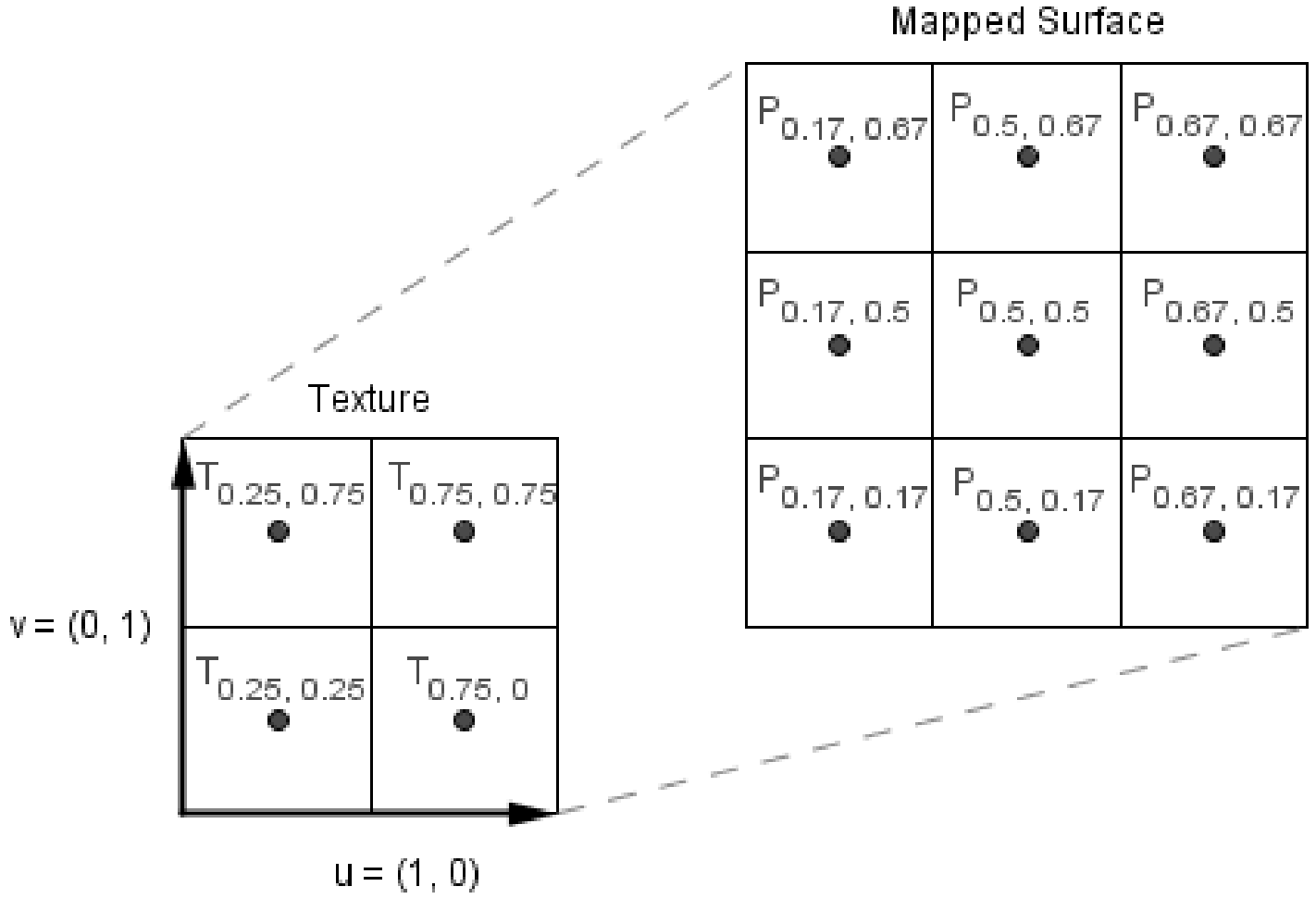

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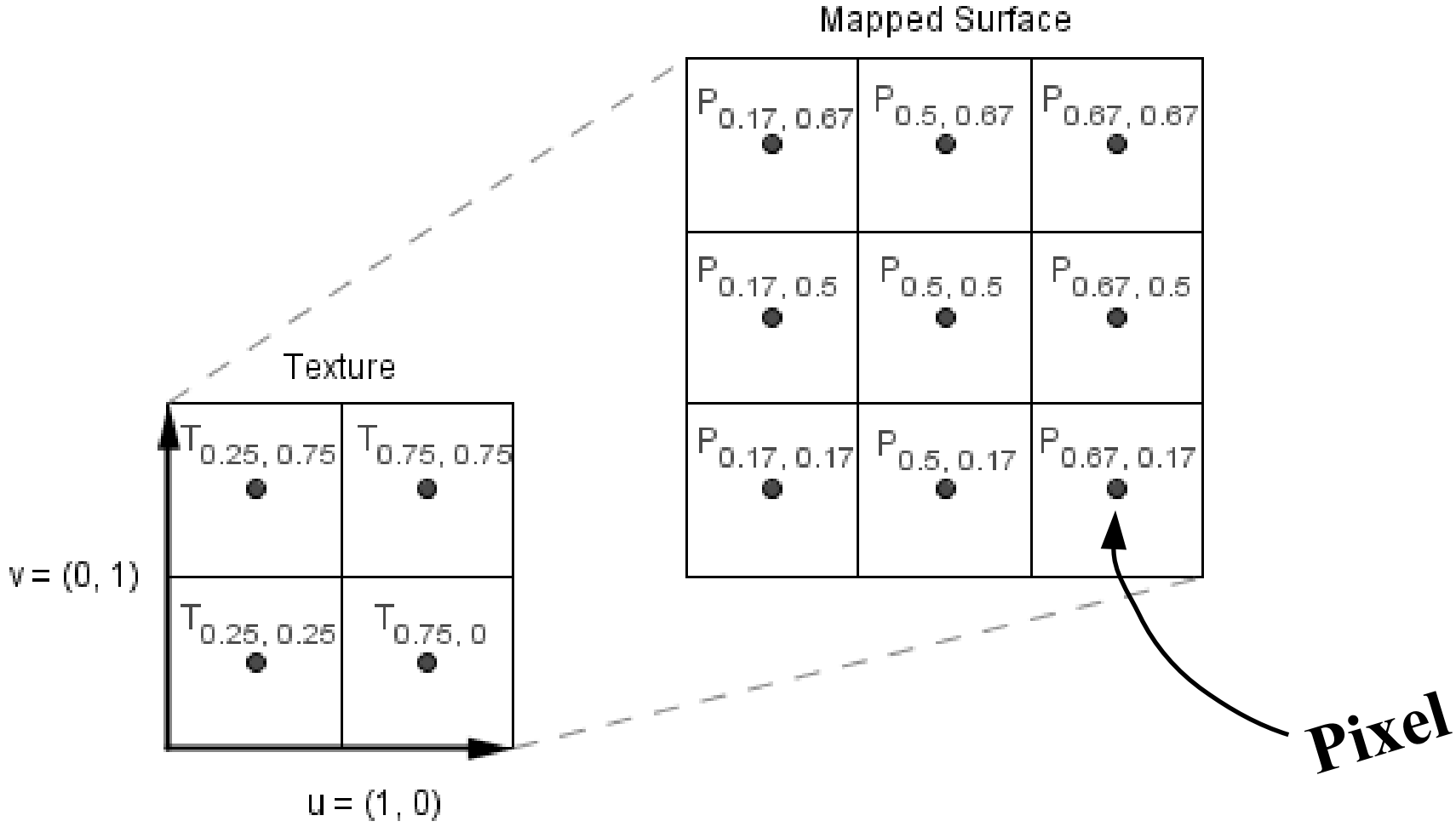

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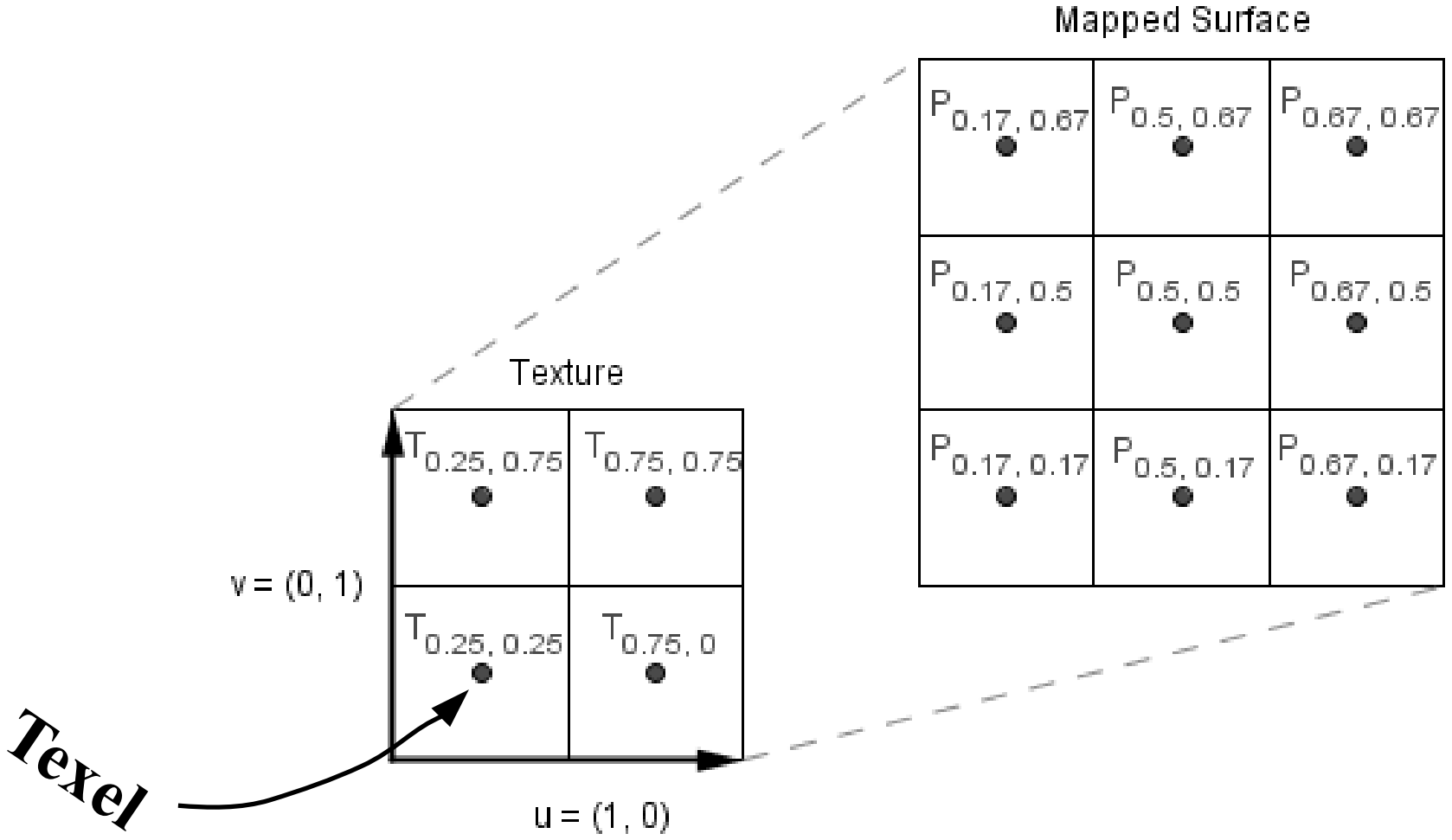
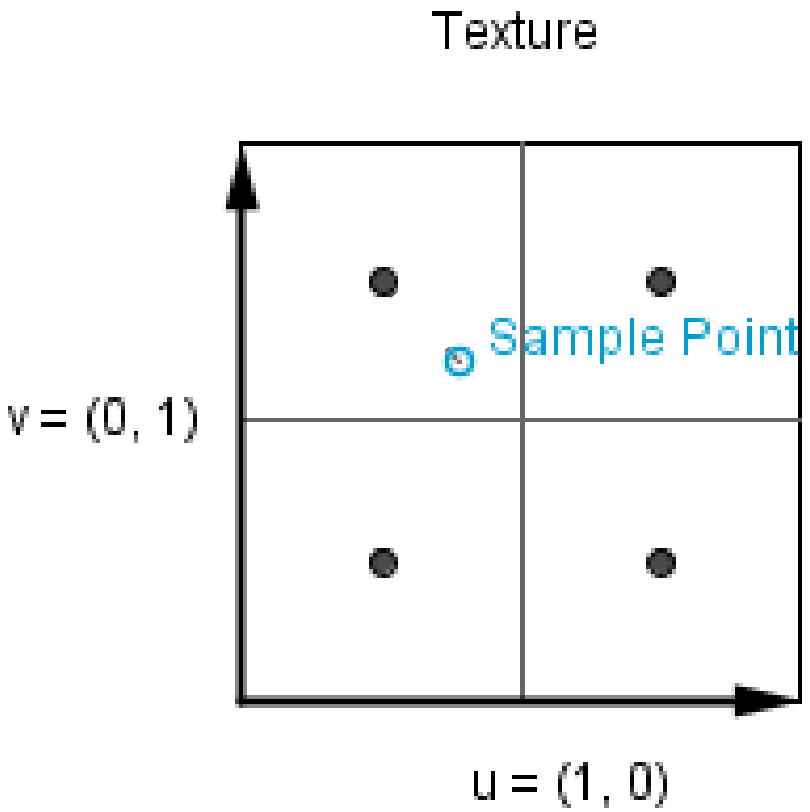


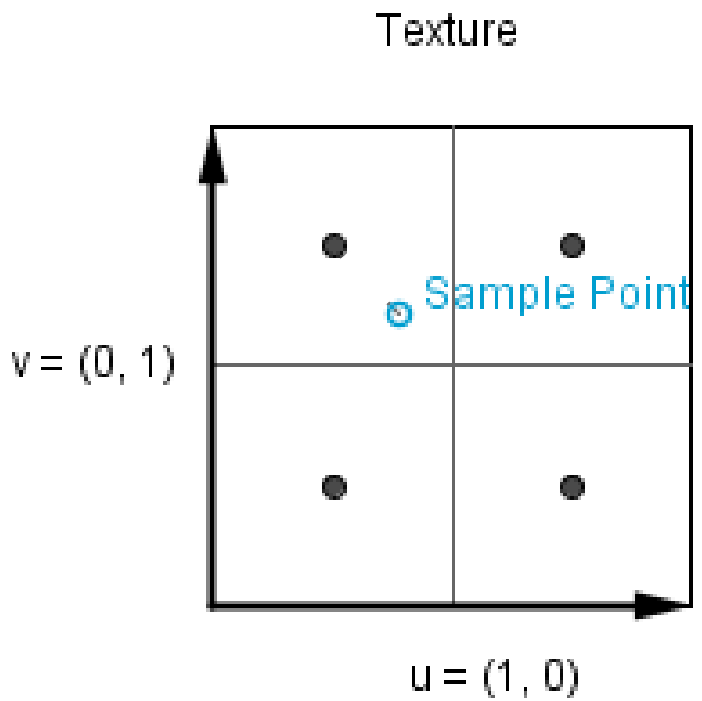
Upscale

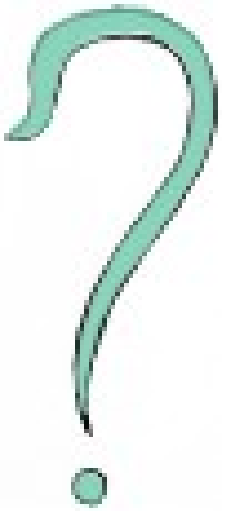
- For a single point in the larger surface, we usually have **4 neighbours in the texture**.



Upscale

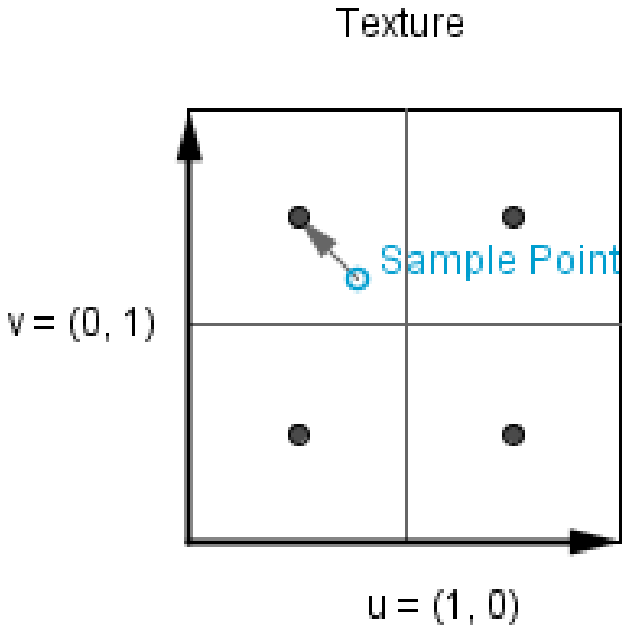
- For a single point in the larger surface, we usually have **4 neighbours in the texture**.
- What are the exceptions?

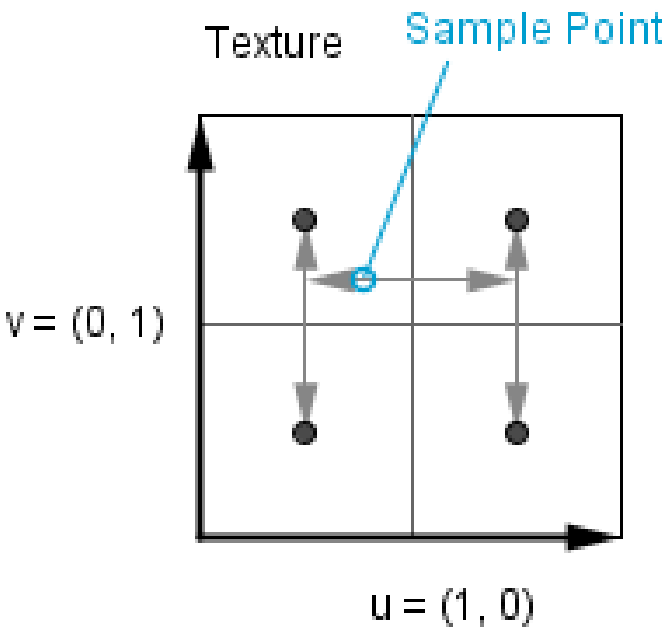


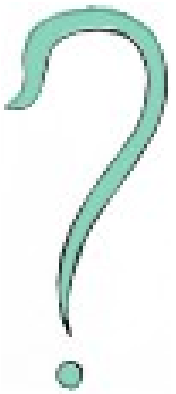


Upscale

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







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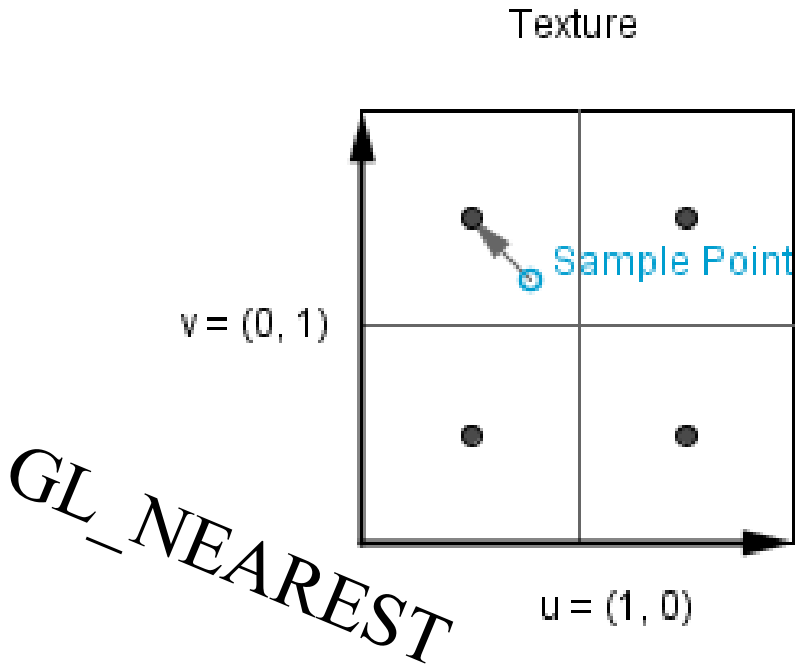
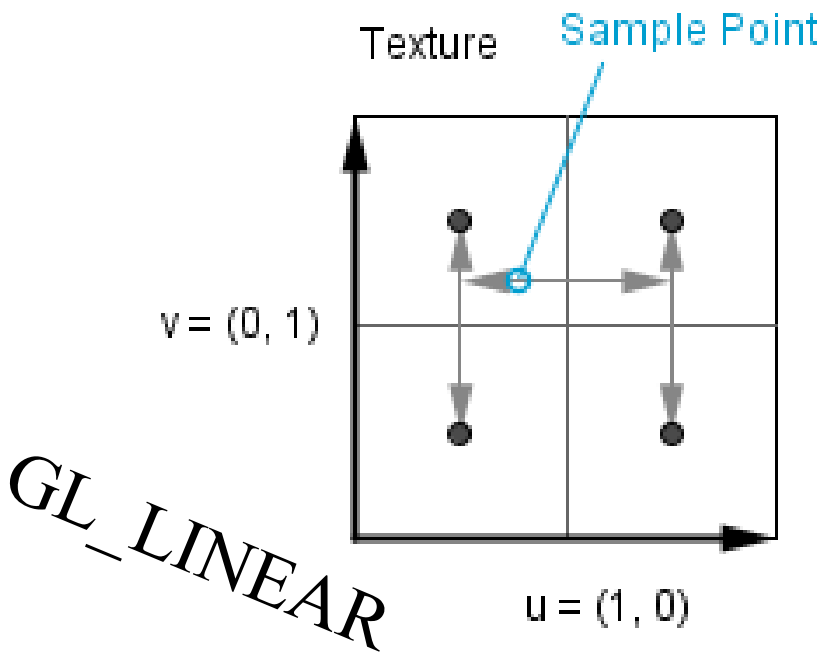
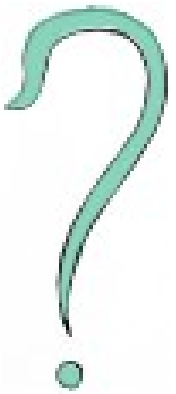
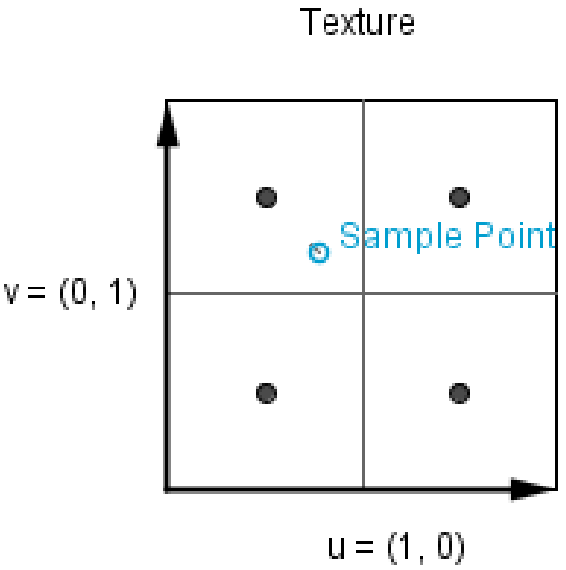






What do these do?

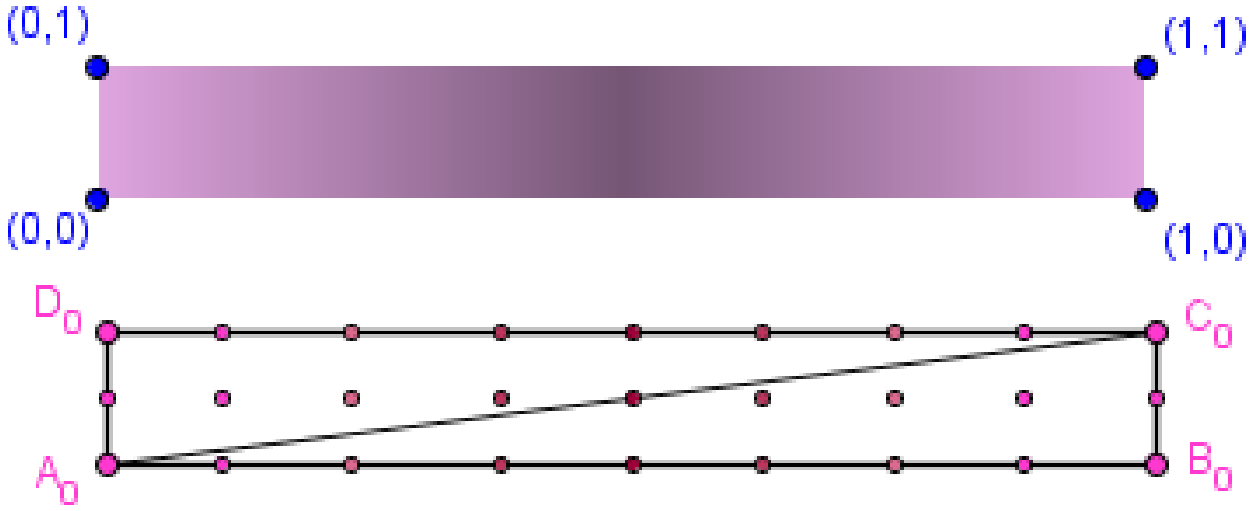
- GL_CLAMP_TO_EDGE
- GL_CLAMP_TO_BORDER
- GL_MIRRORED_REPEAT
- GL_REPEAT



https://www.khronos.org/registry/OpenGL-Refpages/gl4/html/glTexParameter.xhtml

Upscale

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

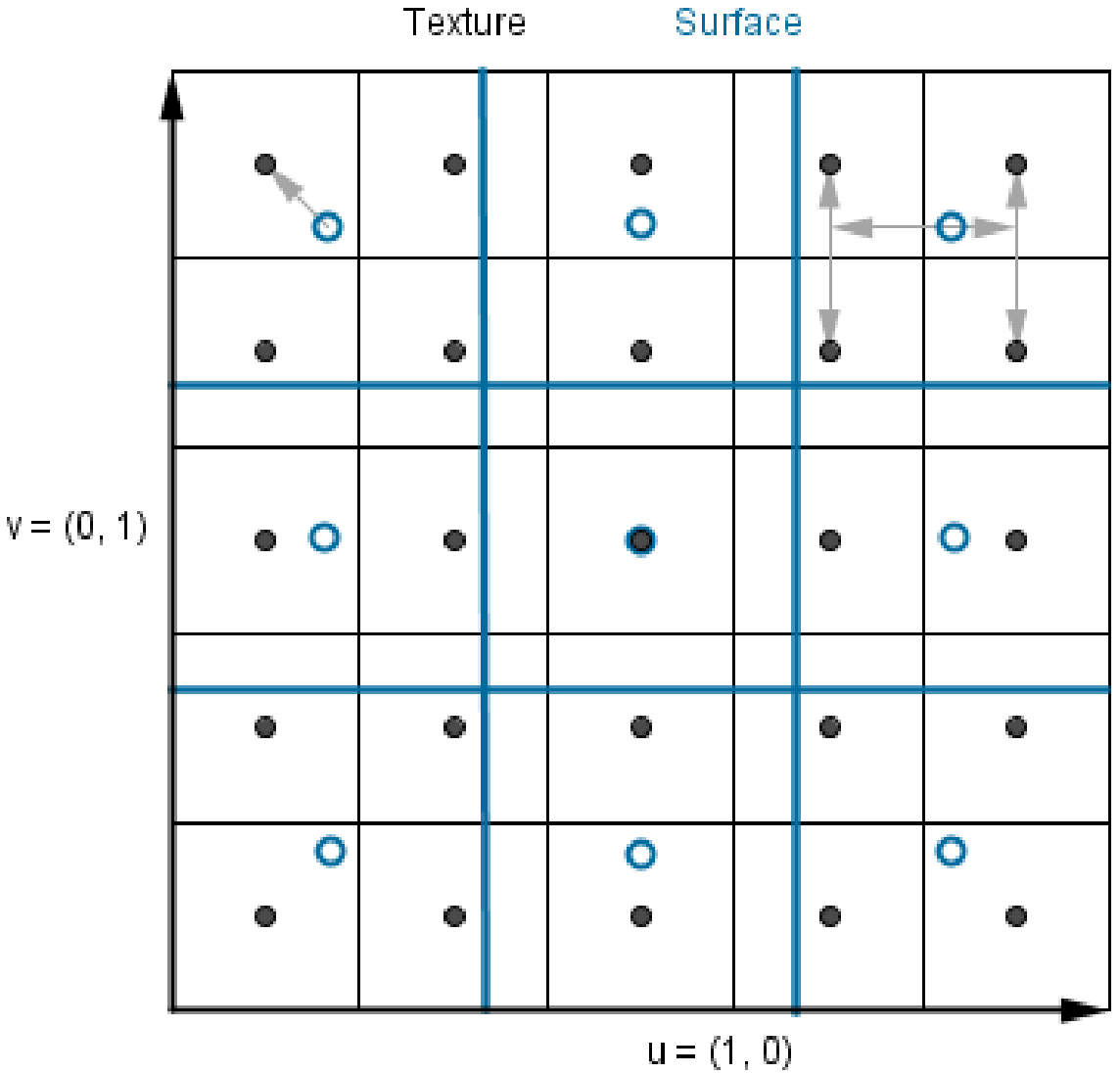


Upscale

- Given a texture with some *width*×*height*, how to find the nearest texels of an UV sample?

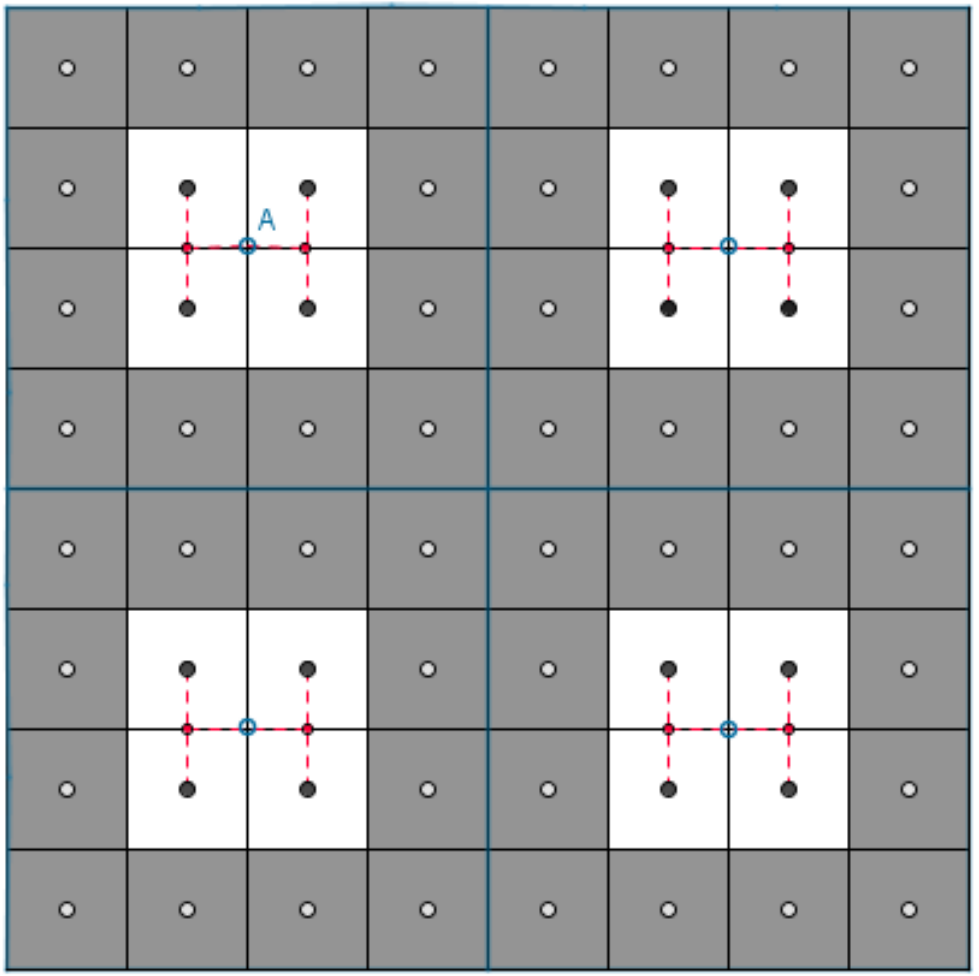
Downscale

- We can do the same interpolation for the downscale.

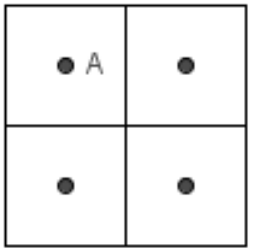


Downscale

- What can go wrong?



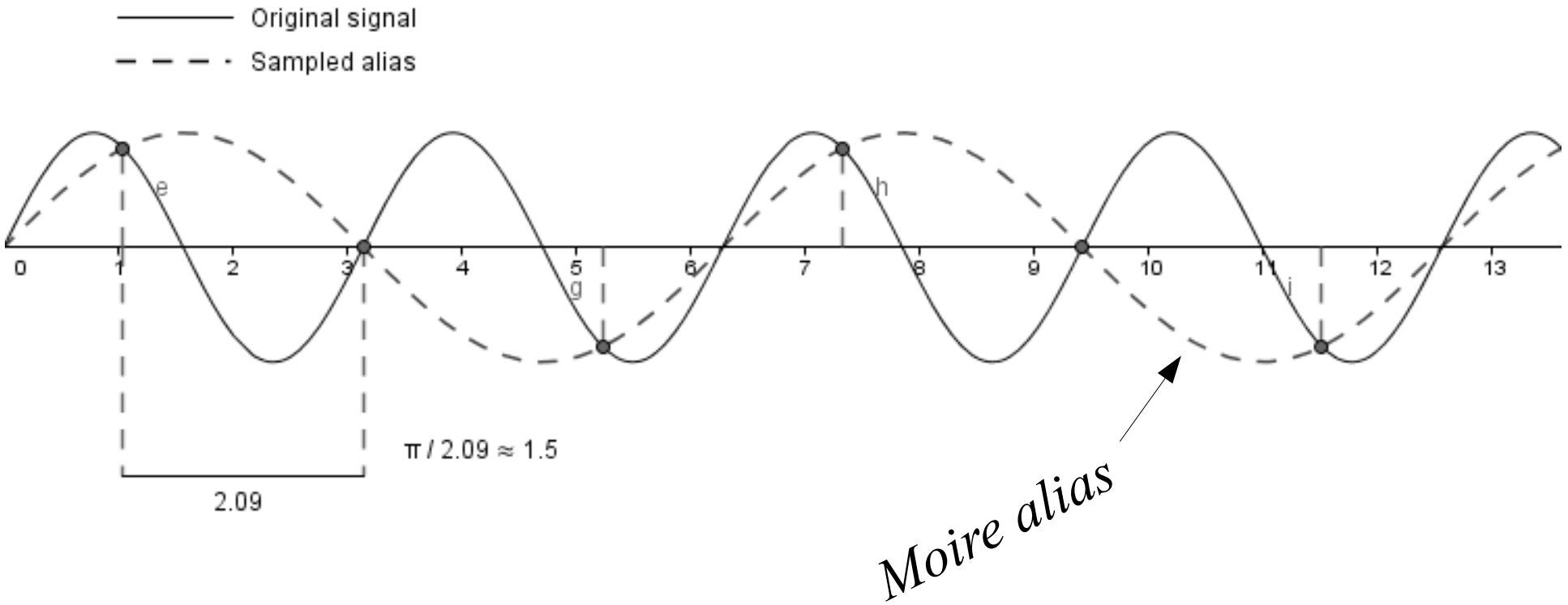
Texture



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.*



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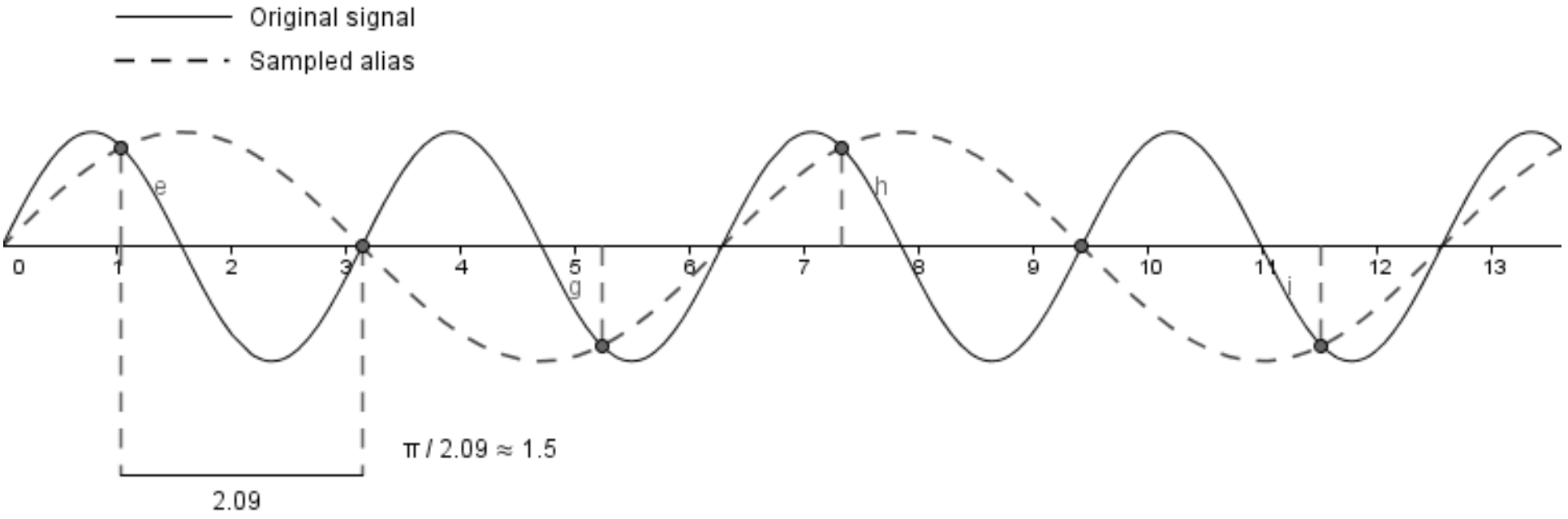

This means more than 2 samples per period, every period.

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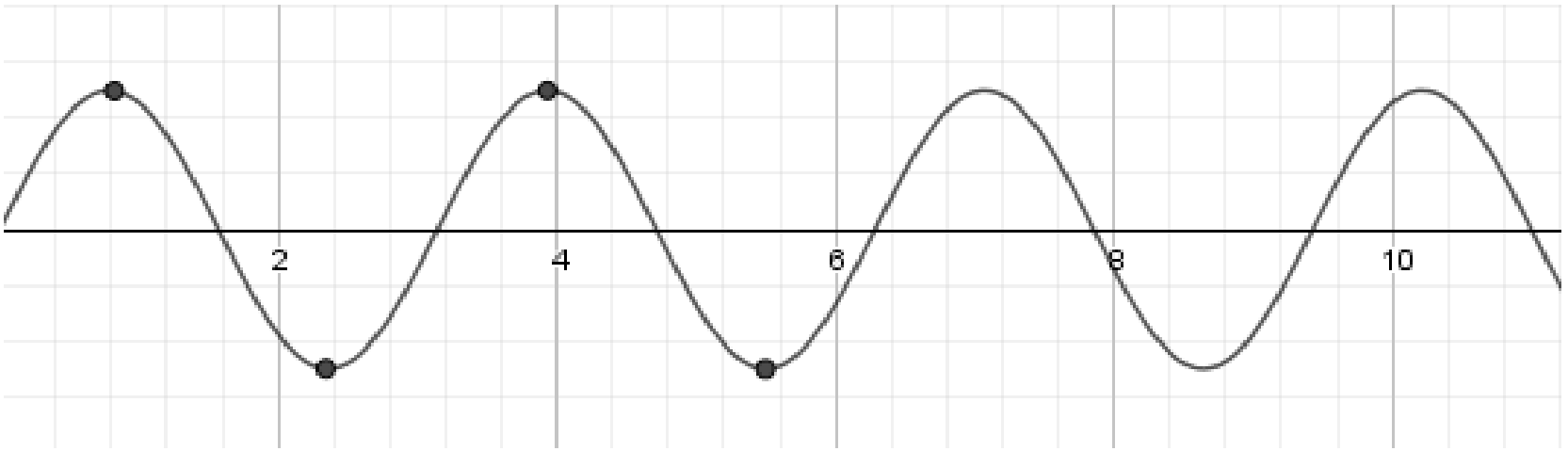

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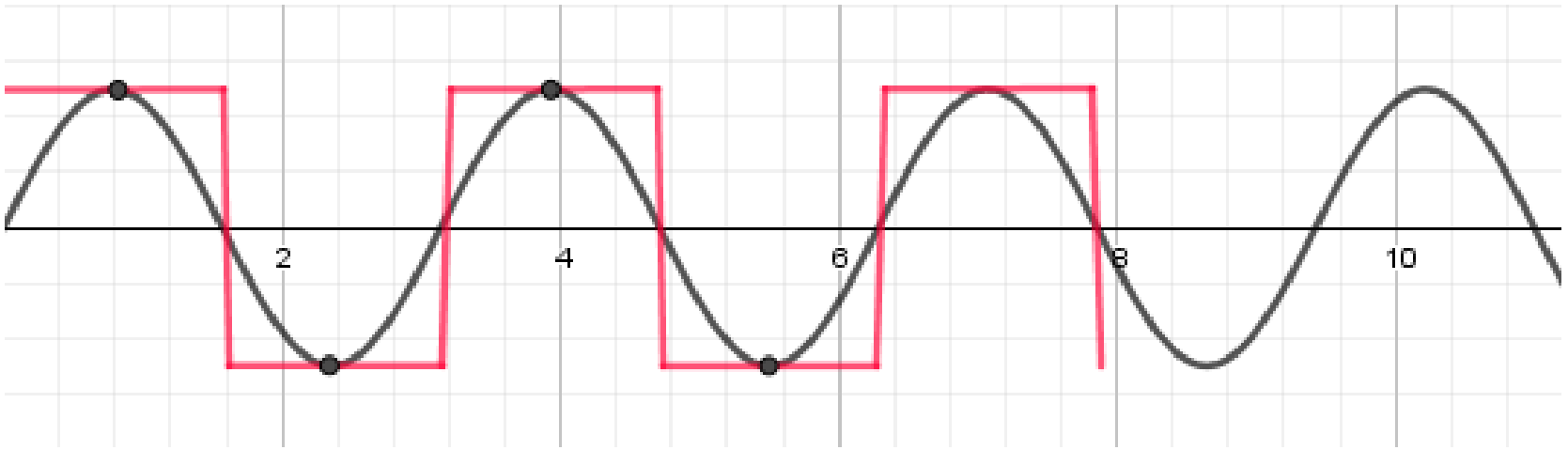

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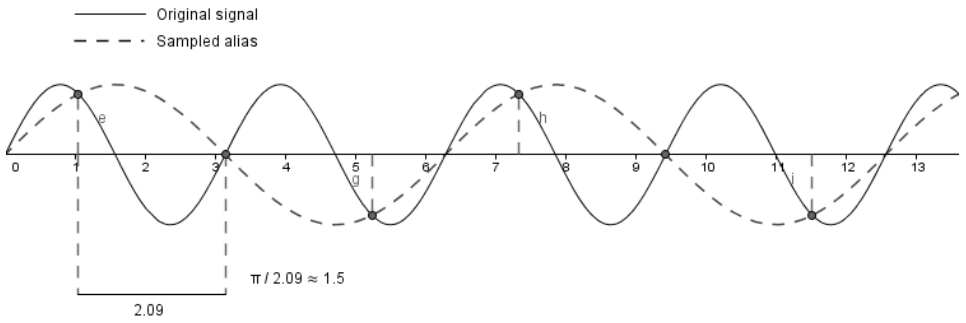

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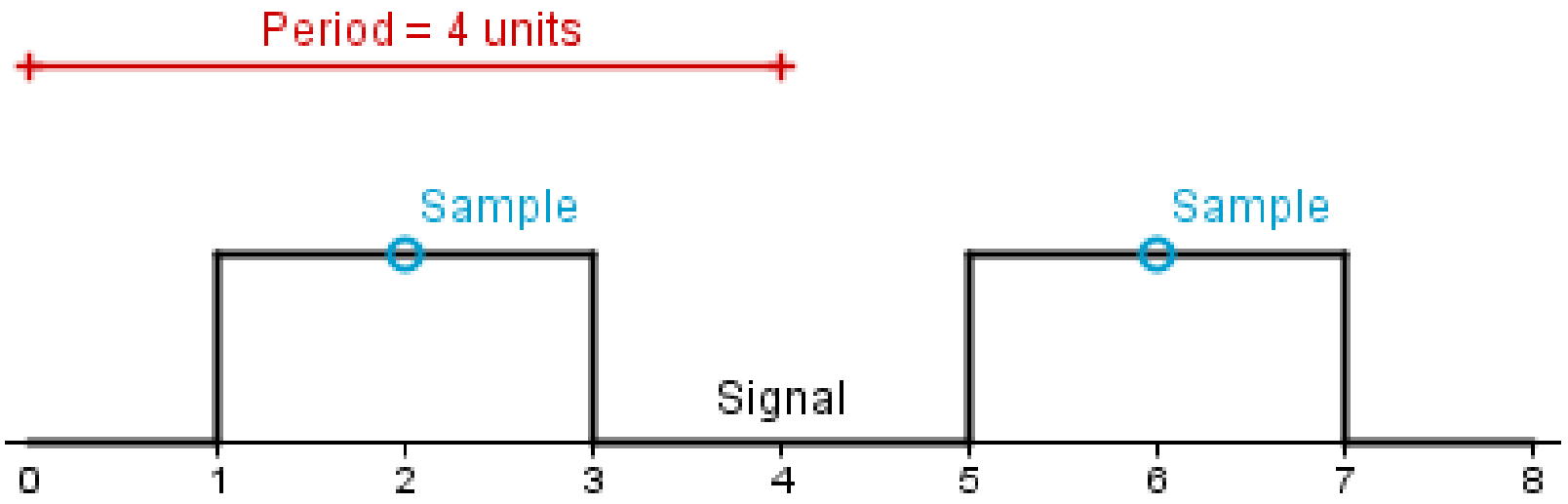
- More info: Http://www.skillbank.co.uk/SignalConversion/rate.htm
  http://blogs.msdn.com/b/shawnhar/archive/2011/04/29/texture-aliasing.aspx

Downscale

- So, what is happening in our example?



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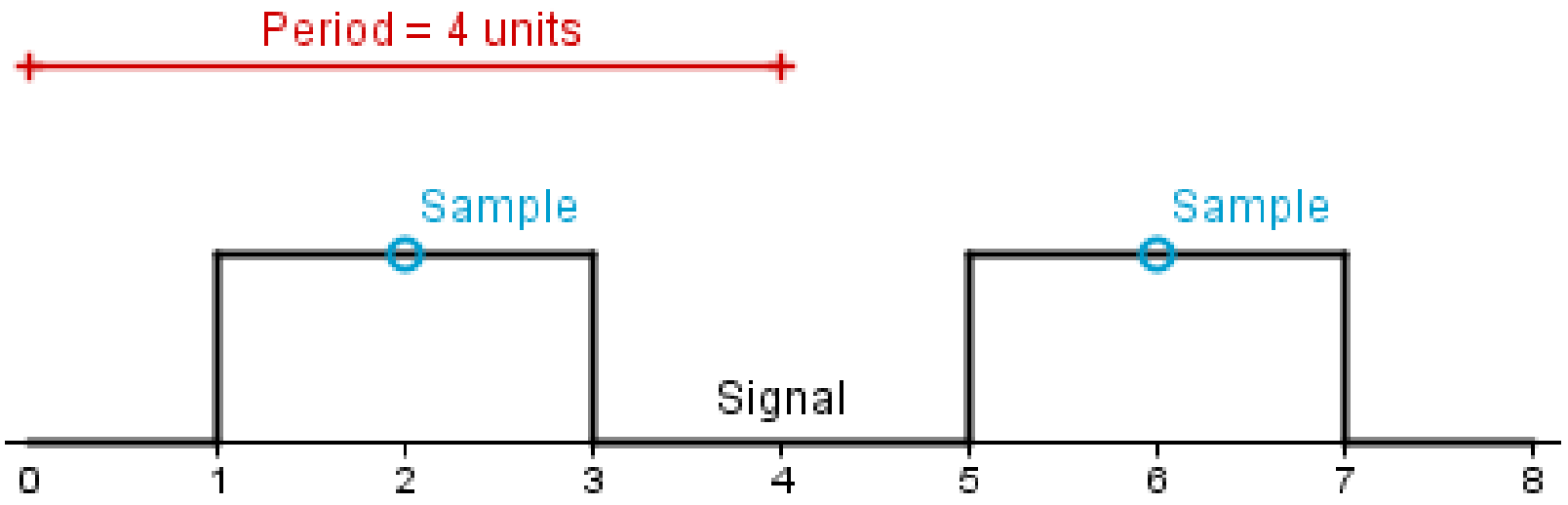

$$period = 4 \Rightarrow frequency = \frac{1}{4}$$

Downscale

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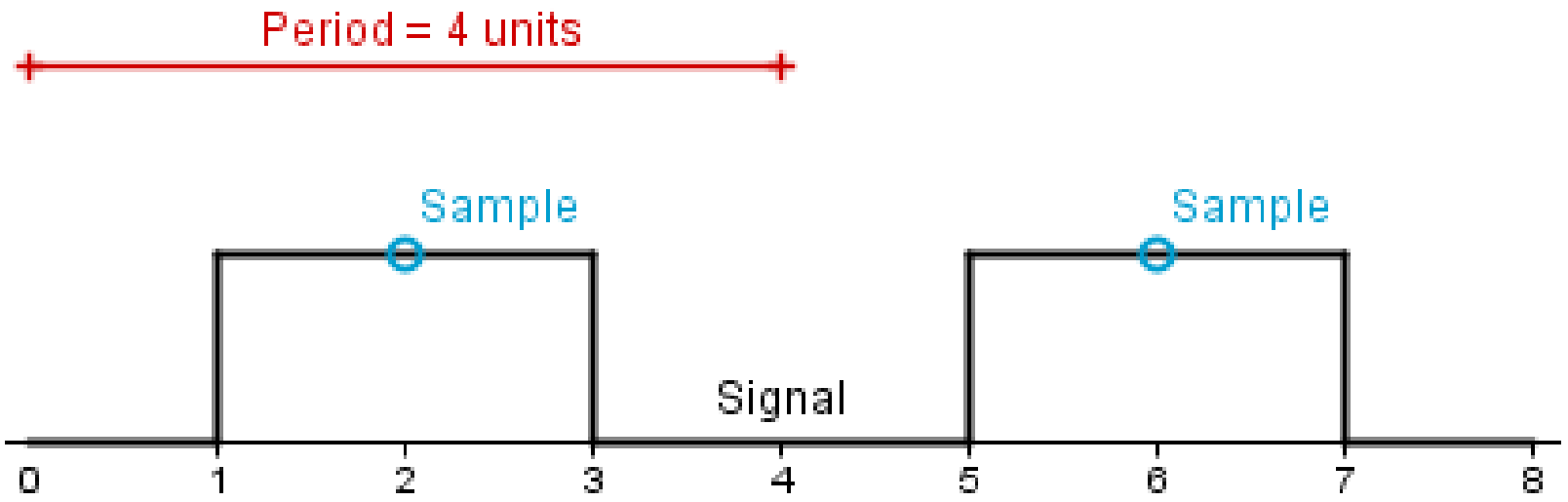

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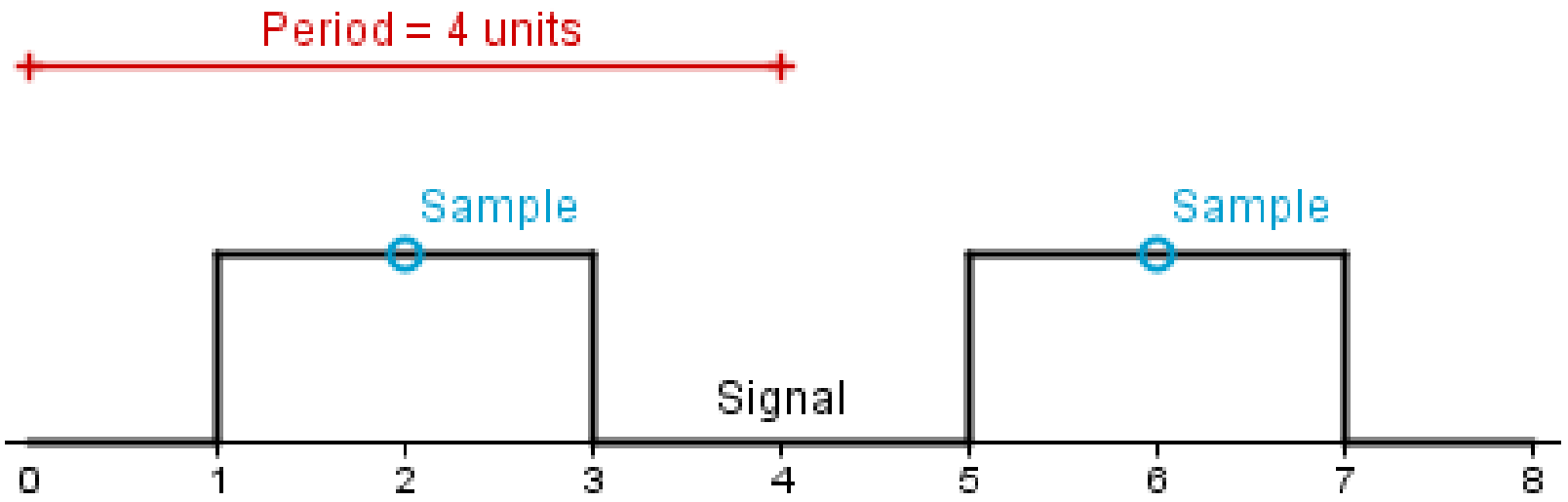

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We need more than 1 sample per two units.

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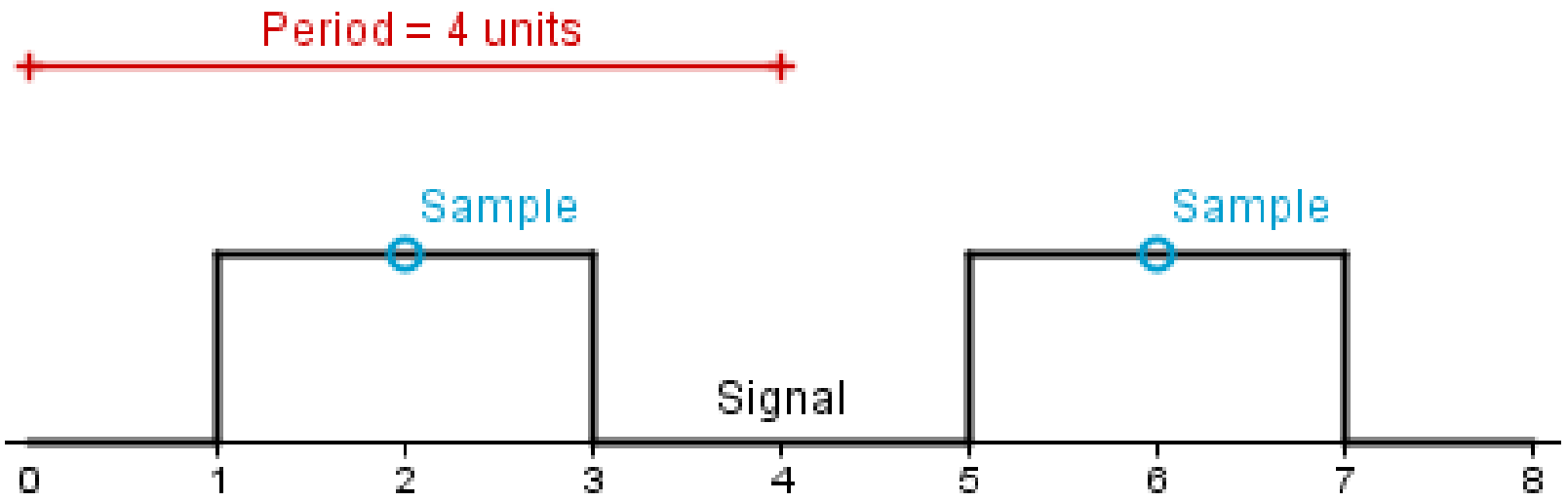

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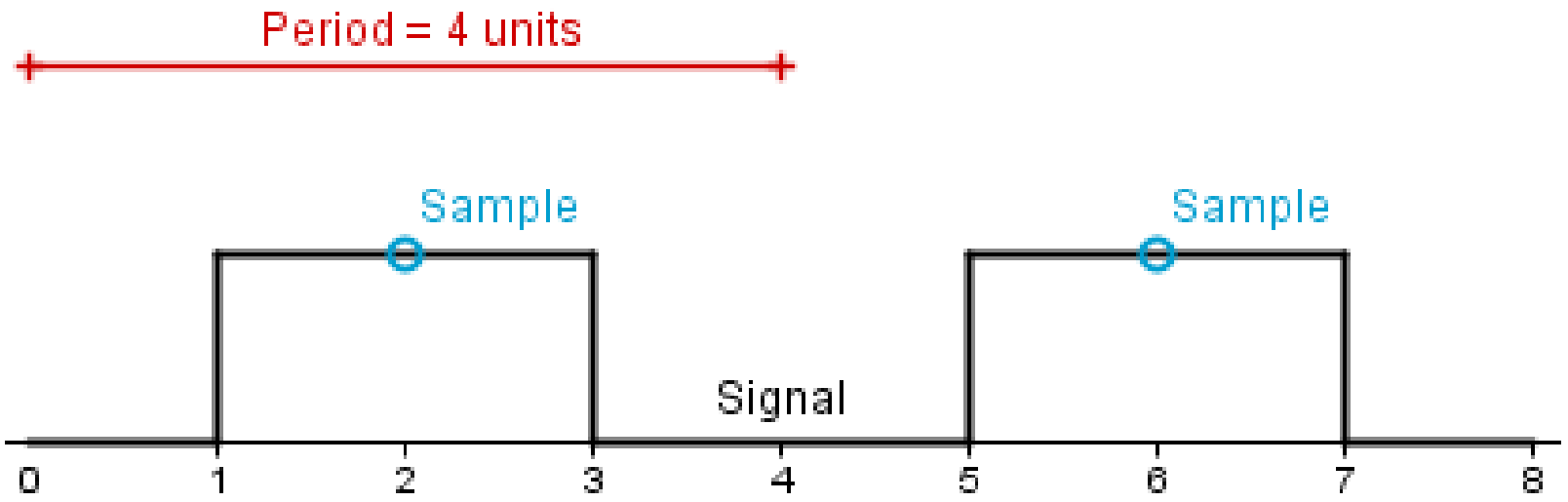


$$period = 4 \Rightarrow frequency = \frac{1}{4}$$

Aliasing

$$frequency_{Nyquist} = \frac{2}{4} = \frac{1}{2}$$

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

We need more than 1 sample per two units.

Downscale

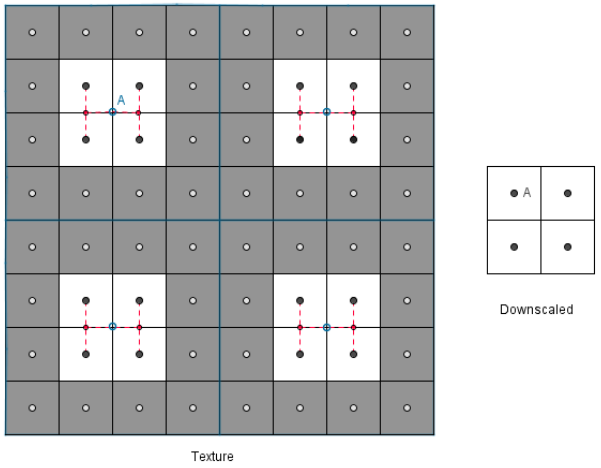
- We need more than 1 sample per 2 units.

Downscale

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

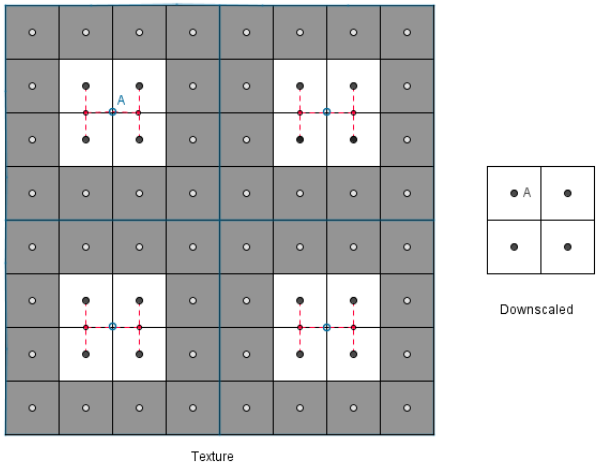
Downscale

- We do not want to create *Moire aliasing*.



Downscale

- We do not want to create *Moire aliasing*.
- Our texture is not white, a 2×2 downscale should not be white either.



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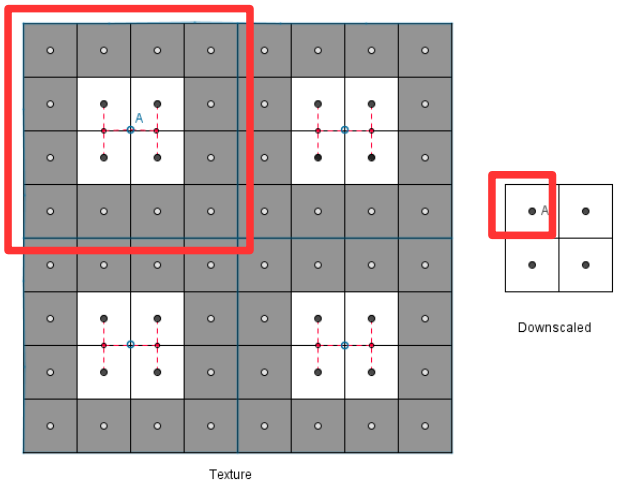
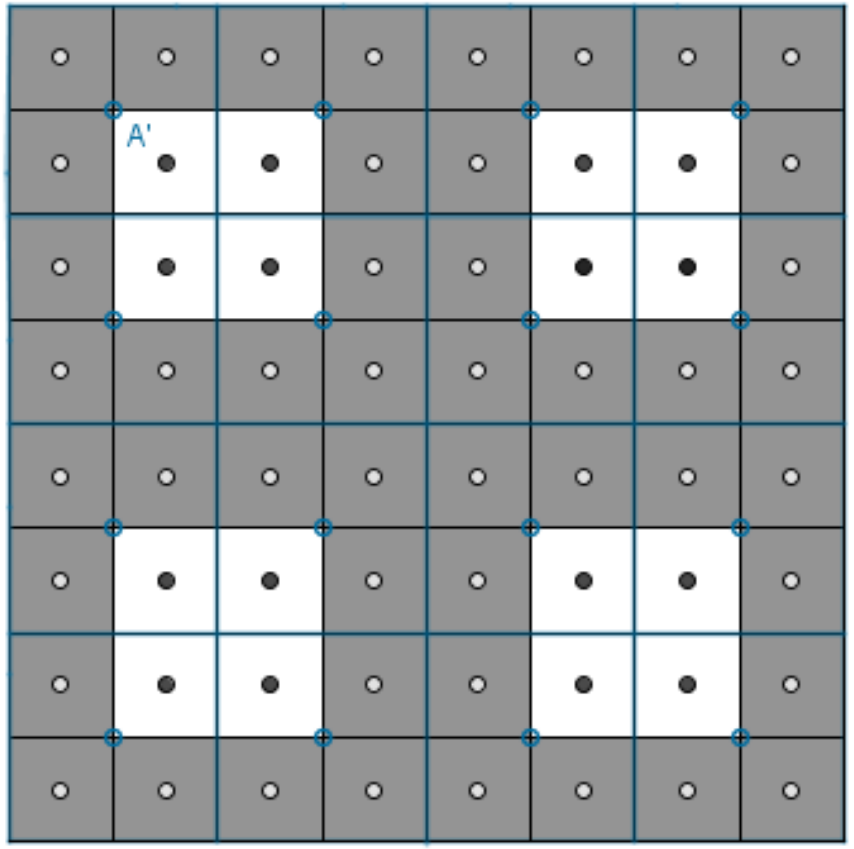
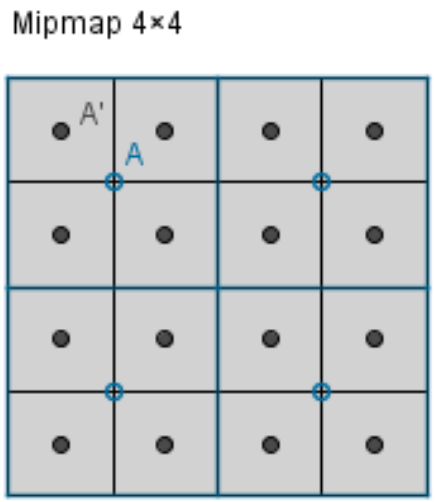
- We do not want to create *Moire aliasing*.
- Our texture is not white, a 2×2 downscale should not be white either.
- One unit in the result covers 16 units in the texture. How to represent all those 16 values?

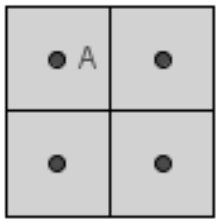


Mipmapping

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







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- **How not to have that problem?**

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- **Which mipmap should we sample?**

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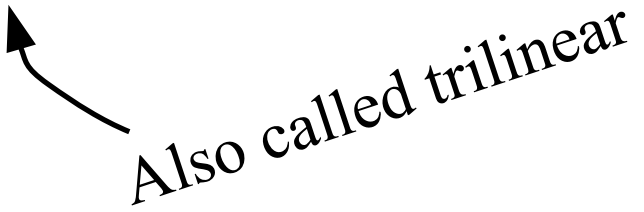

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Questions?

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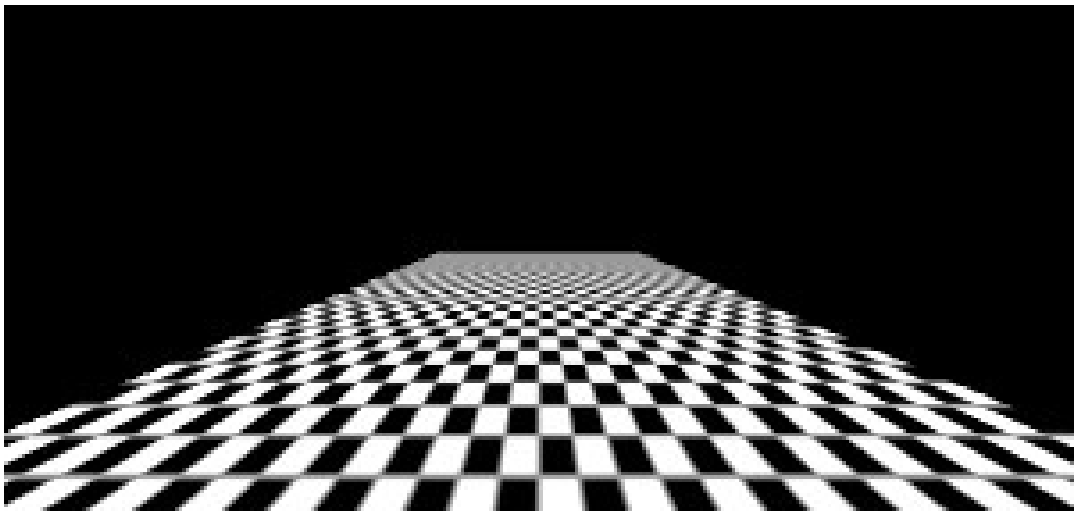
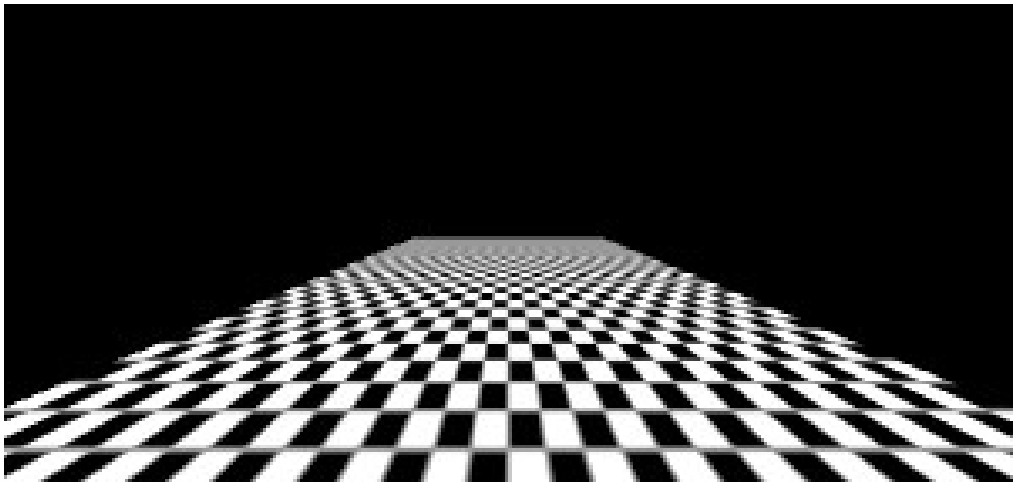
Anisotropic Filtering

- 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

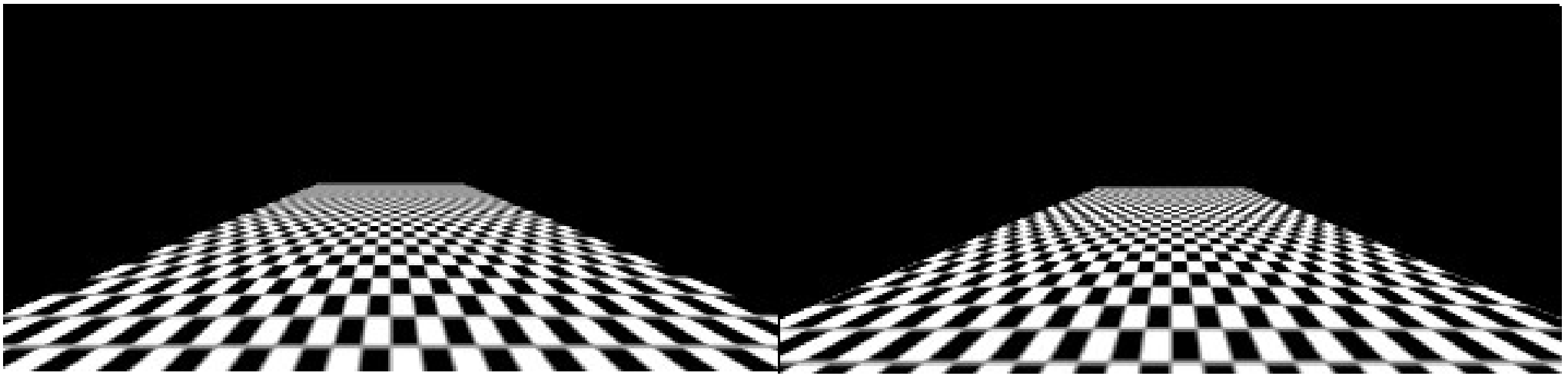
- We have more resolution in width then in height. It is unfair to average both dimensions equally.



No anisotropic filtering

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.

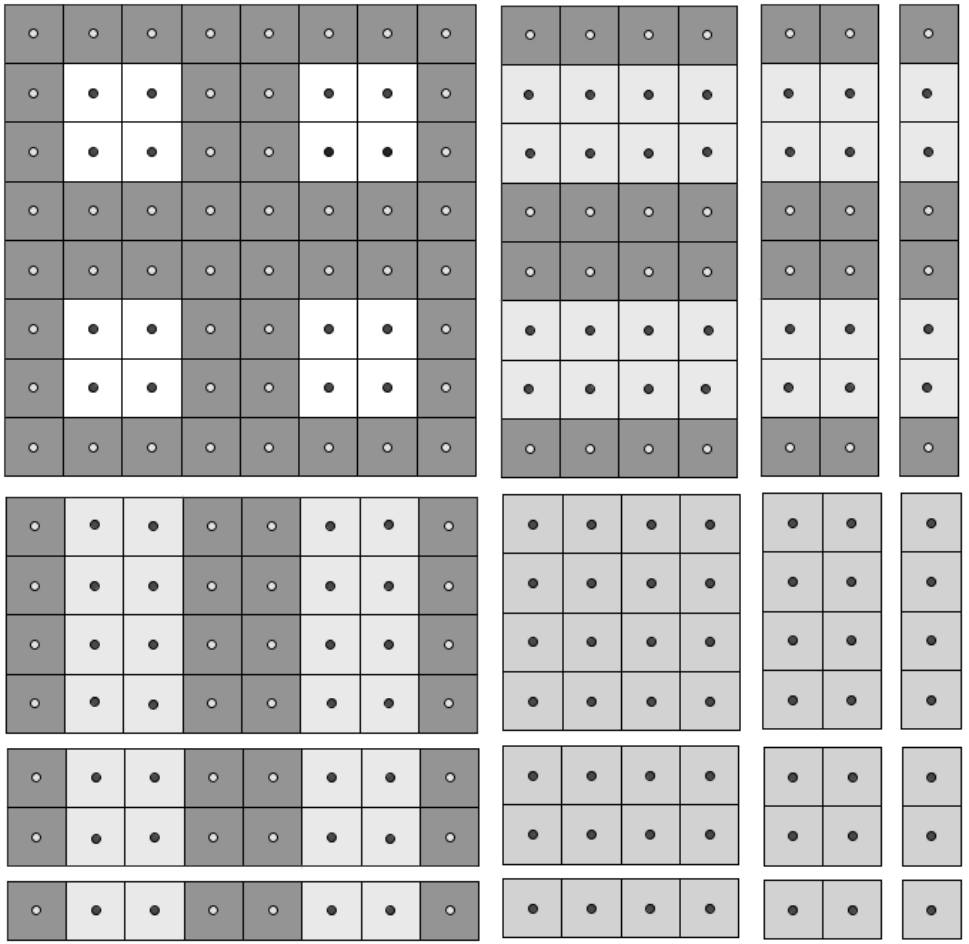


No anisotropic filtering

16x anisotropic filtering

Anisotropic Filtering

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



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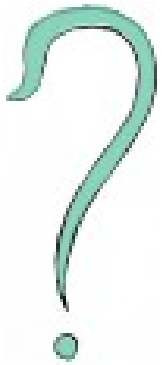
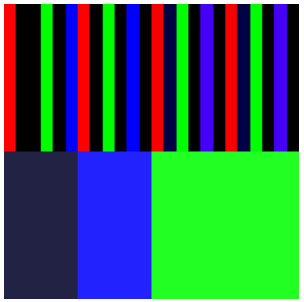

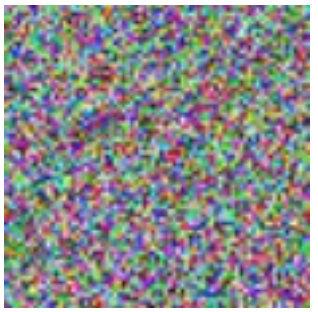
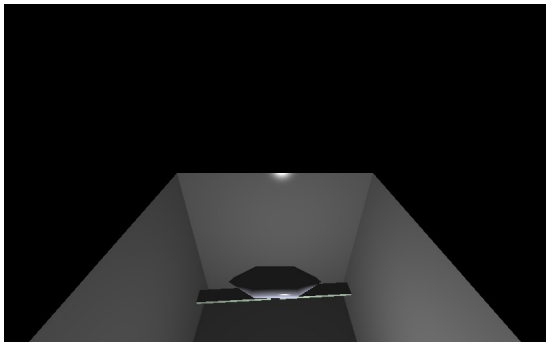

What seemed useful today?

What more would you like to know?

Next time

Blending – *Jaanus Jaggo*