Computer Graphics (COMP0027) 2022/23

Texturing

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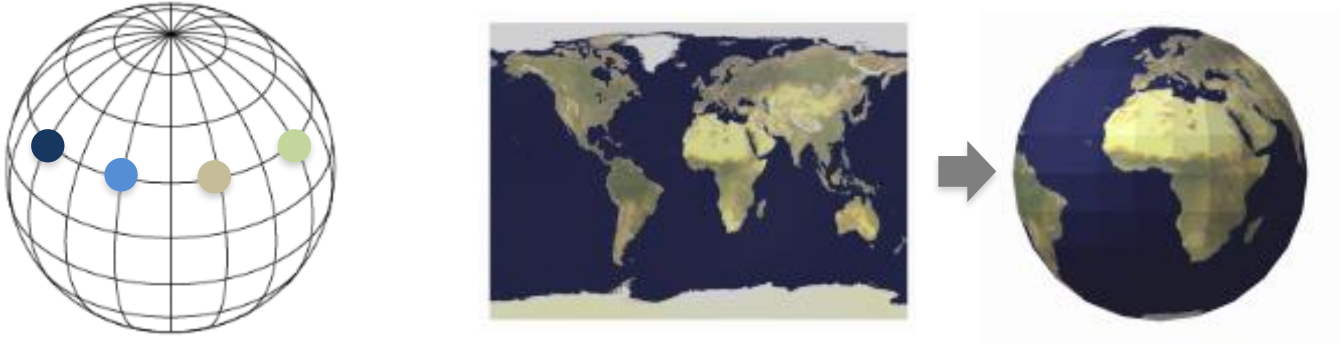
UCL

Texture Mapping

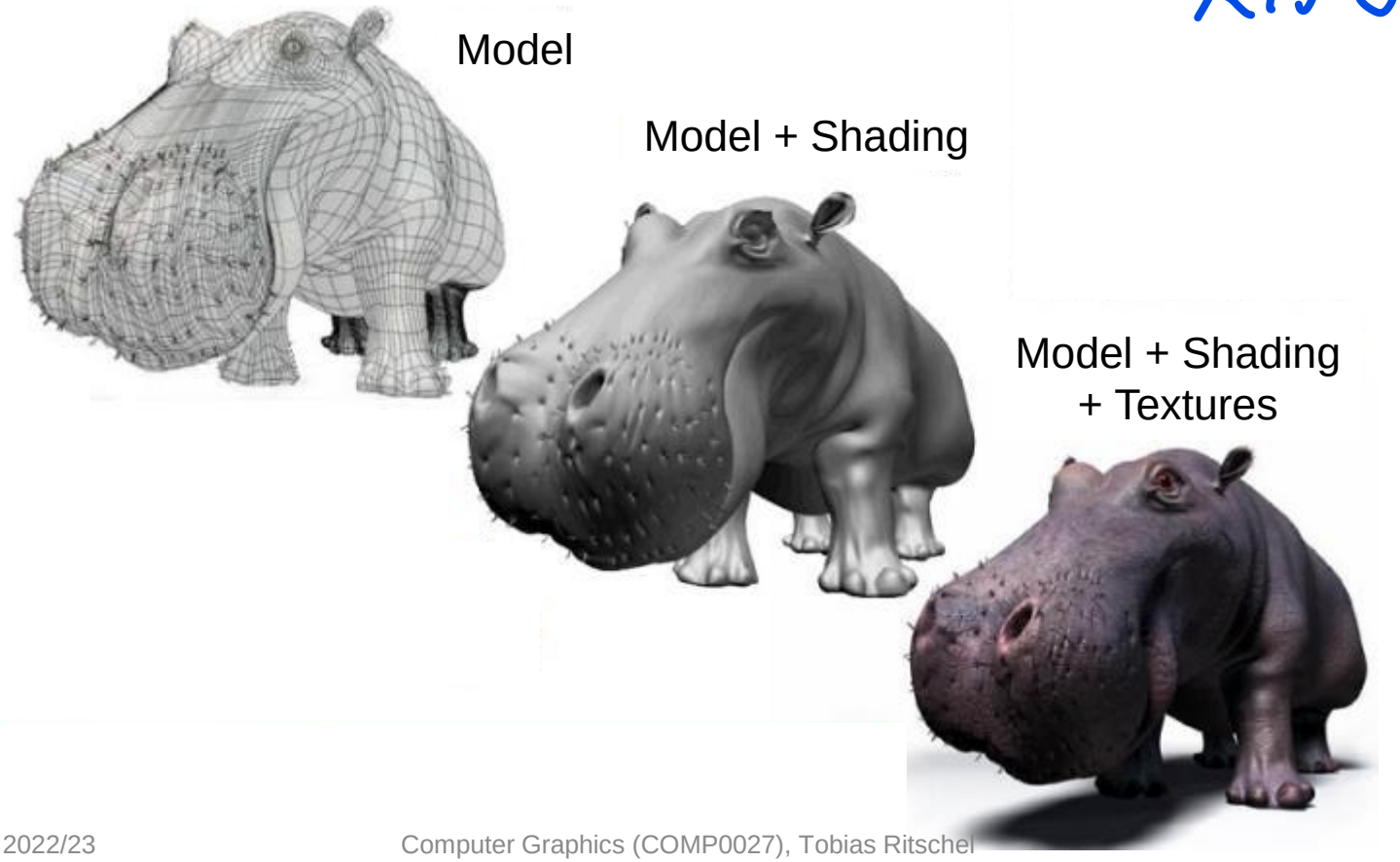
- Have seen: colour can be assigned to vertices
- But: don’t want to represent all this detail with geometry

Texture Mapping

- Considering small details
  - We may not want to add polygons to represent every detail
  - Instead, prefer to keep a large polygon and use an *image* to represent the details

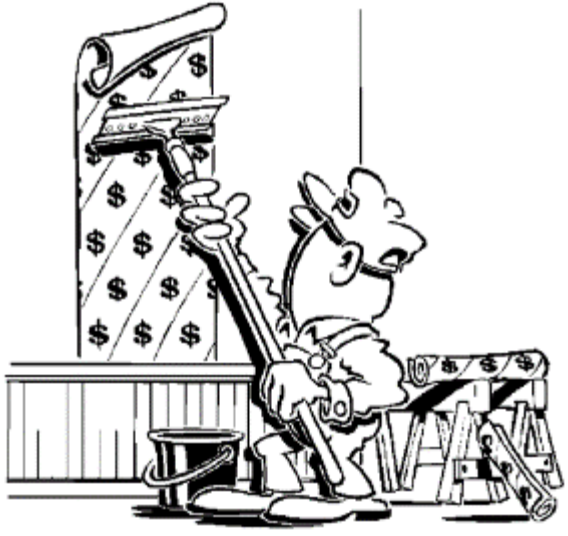


The Quest for Visual Realism

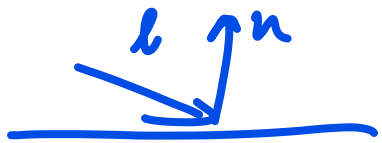


Texture Mapping

- Increase the apparent complexity of simple geometry
- Efficient packing of flat detail
- Like wallpapering or gift-wrapping with stretchy paper



Texture Mapping

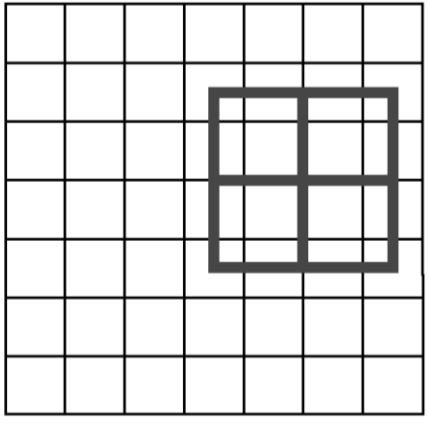


- Standard texture mapping modifies diffuse component k_{d}
  - Pasting a picture onto the polygon

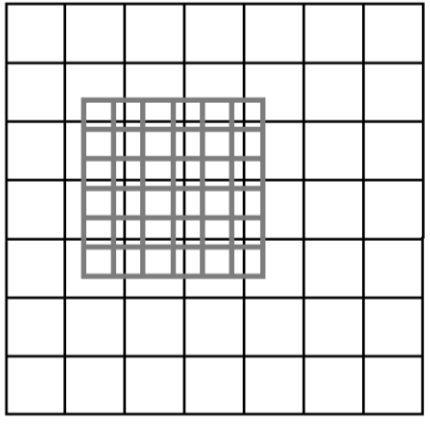
- A texture is a 2D array of texels storing RGB (or RGBA) components

Difference between pixels and texels

There can be a different match between the pixels of the framebuffer and the texels of the texture



Magnification



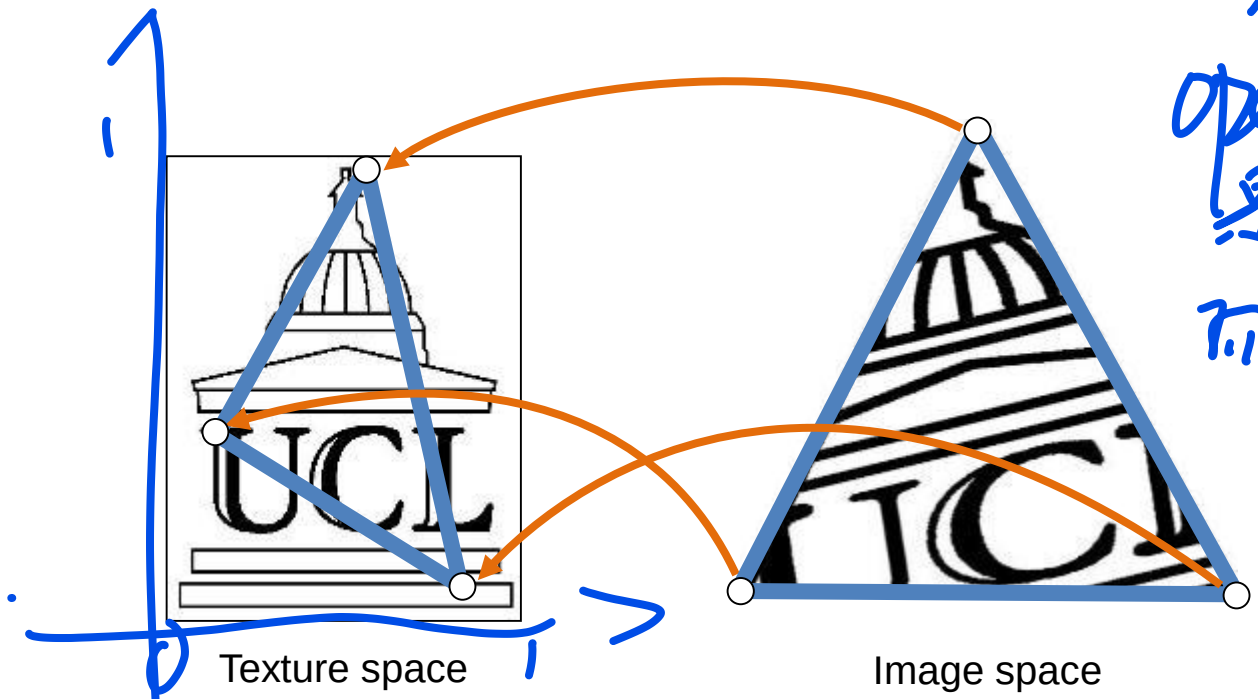
Minification

Overview

- Texture mapping
  - Inverse and Forward Mapping
  - Bilinear interpolation
  - Perspective correction
- Mipmapping
- Other forms of mapping
  - Environment
  - Bump mapping

Texture coordinates

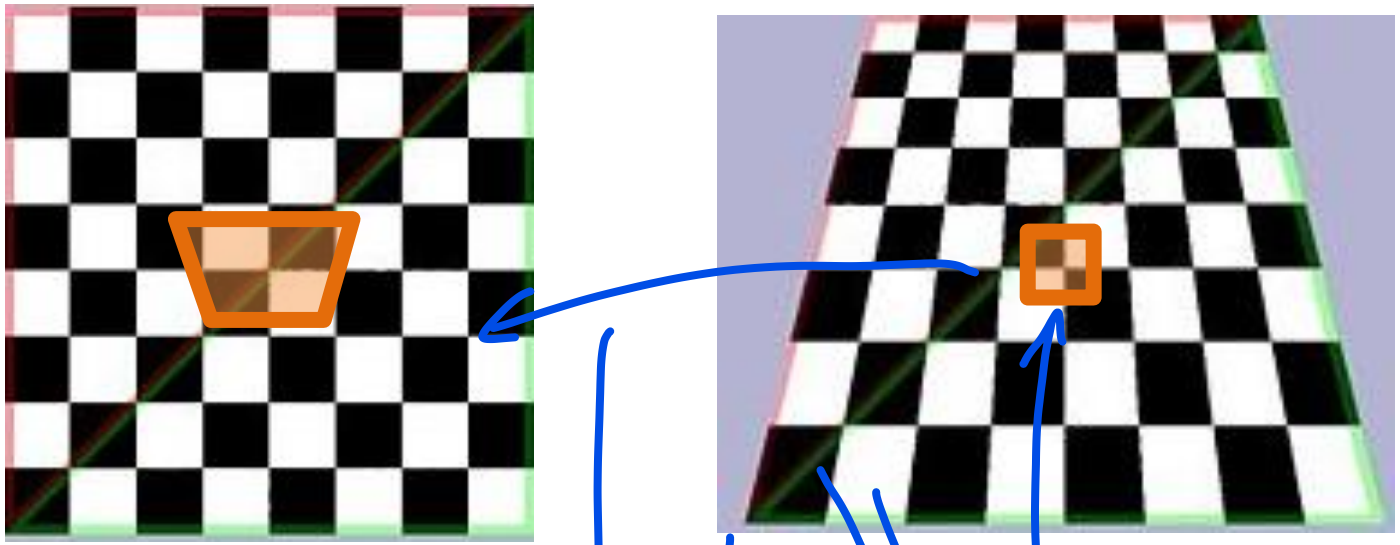
Each vertex is associated with a point on an image (s, t)



Forward Mapping

- For points in the texture, map onto the polygon
  - much harder to implement correctly, and harder to model
- Inverse mapping is much more commonly used
  - Most 3D modelers output u, v co-ordinates for texture application

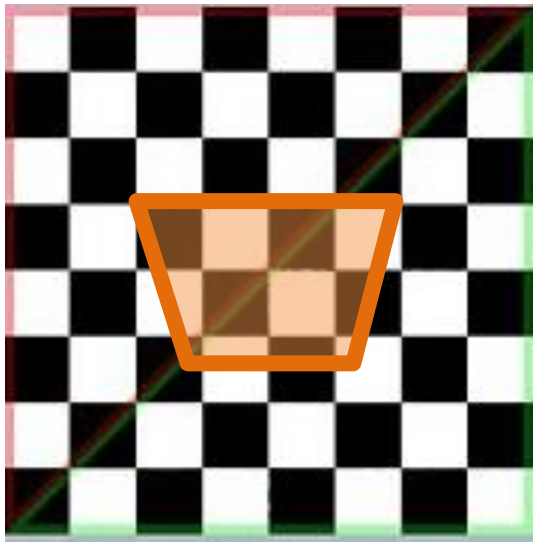
Pixels and texels

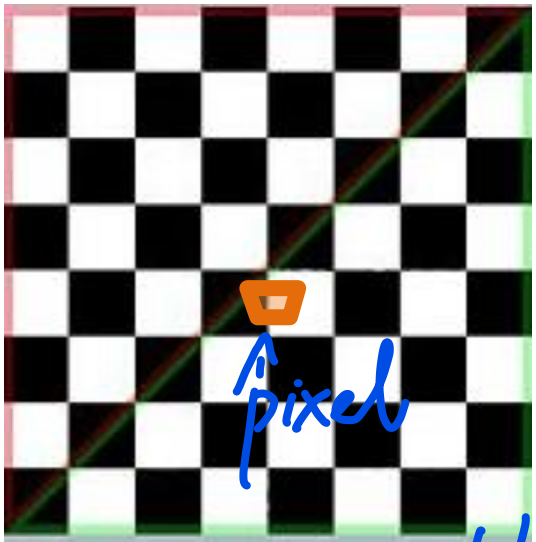


Sampling

- A pixel maps to a non-rectangular region
- Usually only perform map on centre of pixel
- Problem: Under and over-sampling

Oversampling

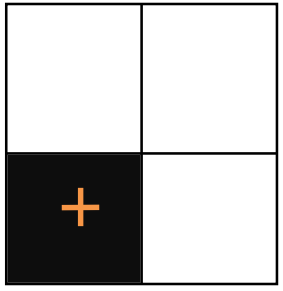




Undersampling

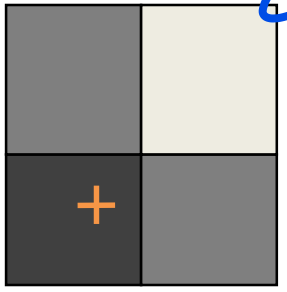
Undersampling solution: Filtering

Nearest neighbour



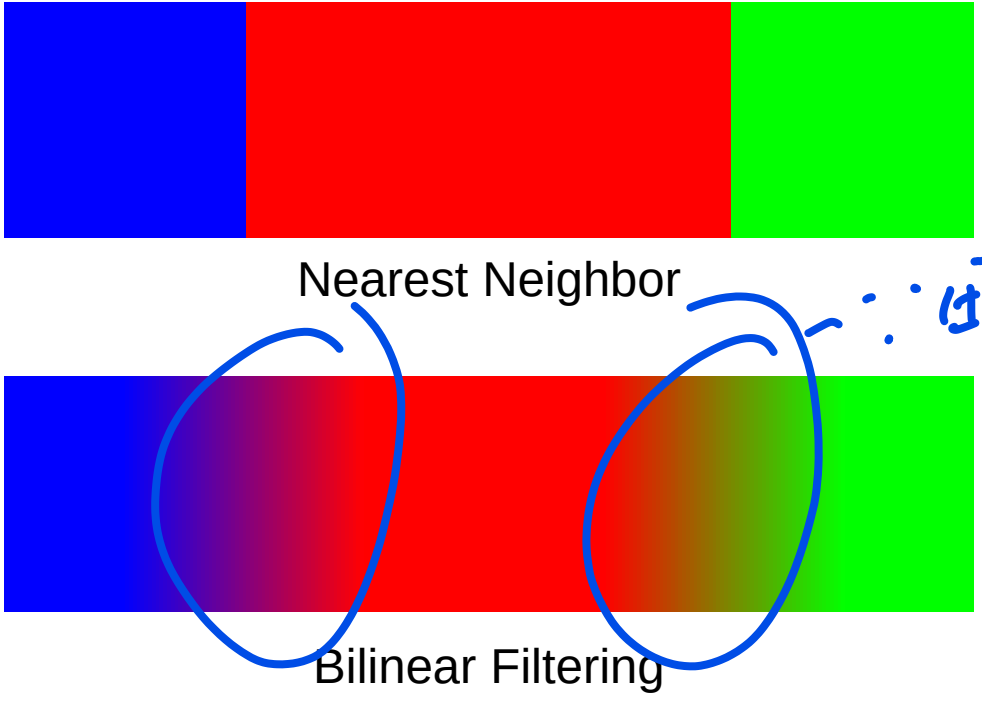
Pick texel with closest centre

Bilinear



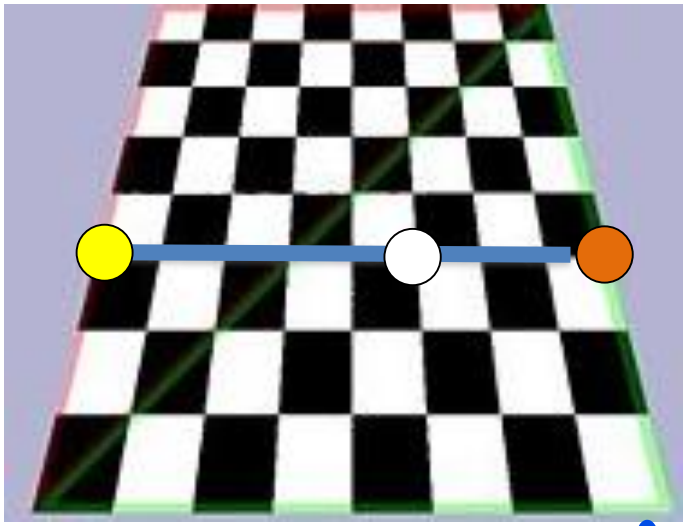
Weighted average based on distance to texel centre

Filtering examples



Filtering

- Bilinear filtering (partially) solves the undersampling problem since it provides smooth shading between texels



(Mine Craft)

MIP-Mapping

- When oversampling we use **MIP-mapping**
- Resample image at lower resolution
- Create a “pyramid” of textures.
- Interpolate texture between two adjacent layers

Texture Pyramid

128x128

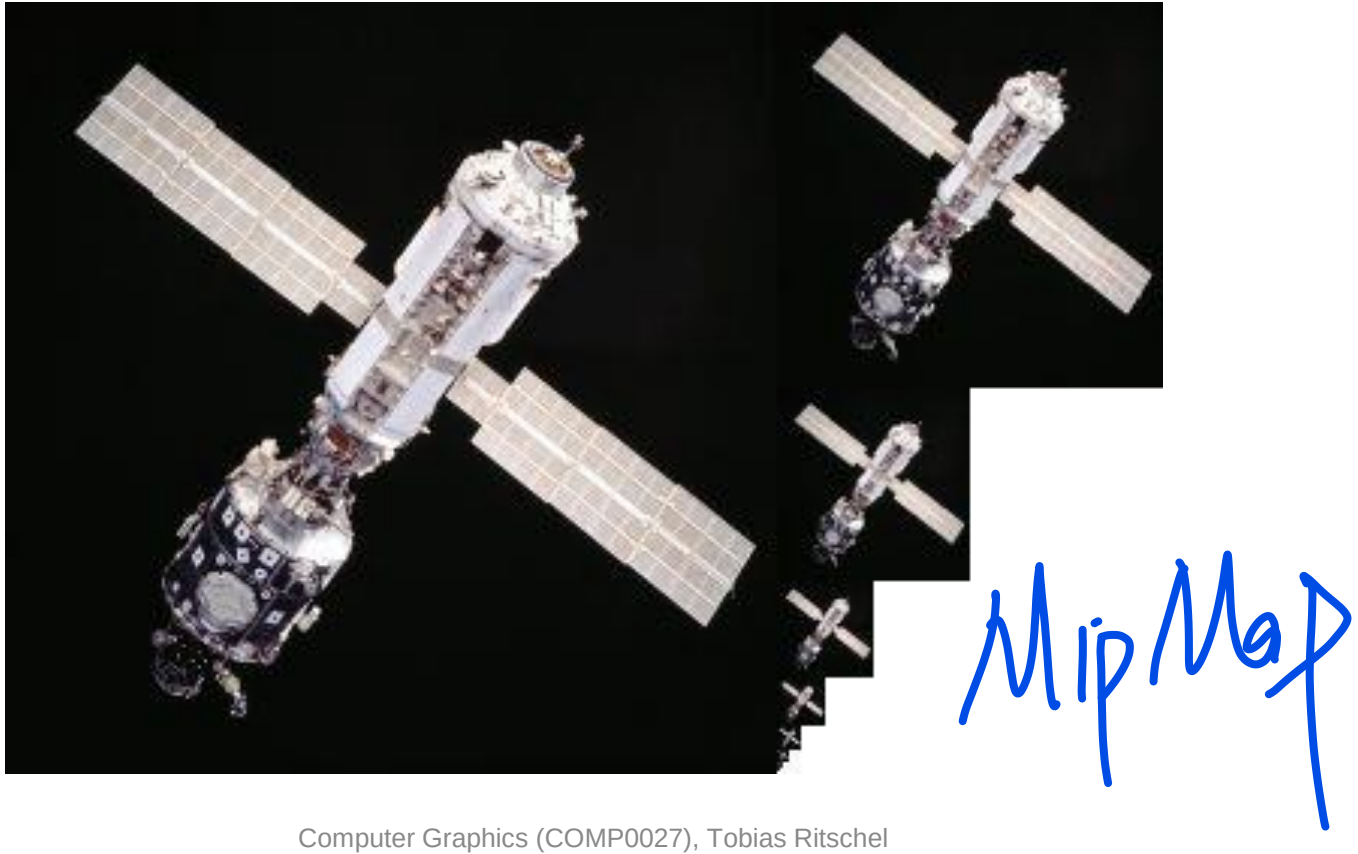
64x64

32x32

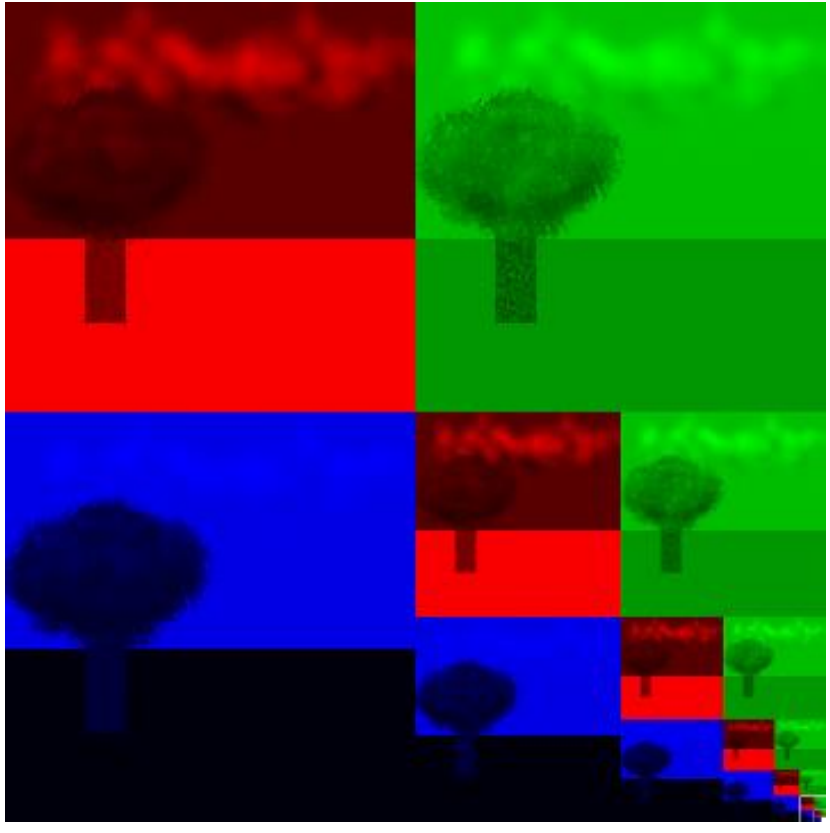
...

1x1

Efficient spatial layout



Efficient RGB channel layout



interesting.

Linear MIP Sampling

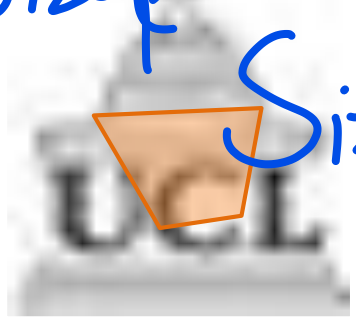
- Choose the level of the MIP-map based on the du and dv for dx and dy are closest to 1 pixel

Texel

Pixel

Texel

Pixel



Texel

Pixel

Tri-linear MIP Sampling

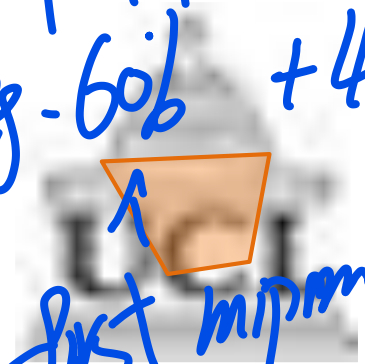
- Choose two level and after interpolating within the levels, interpolate between the outcome

Texel

Pixel

Texel

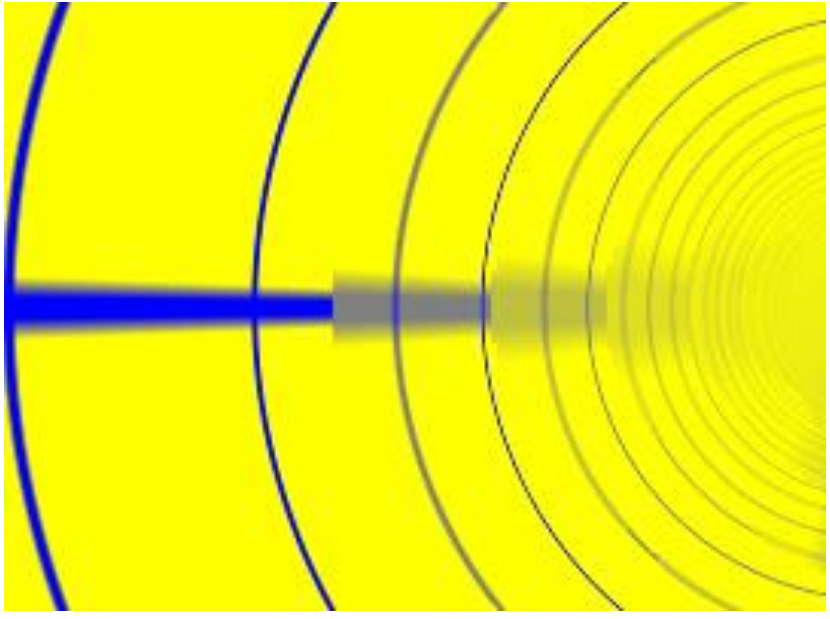
Pixel



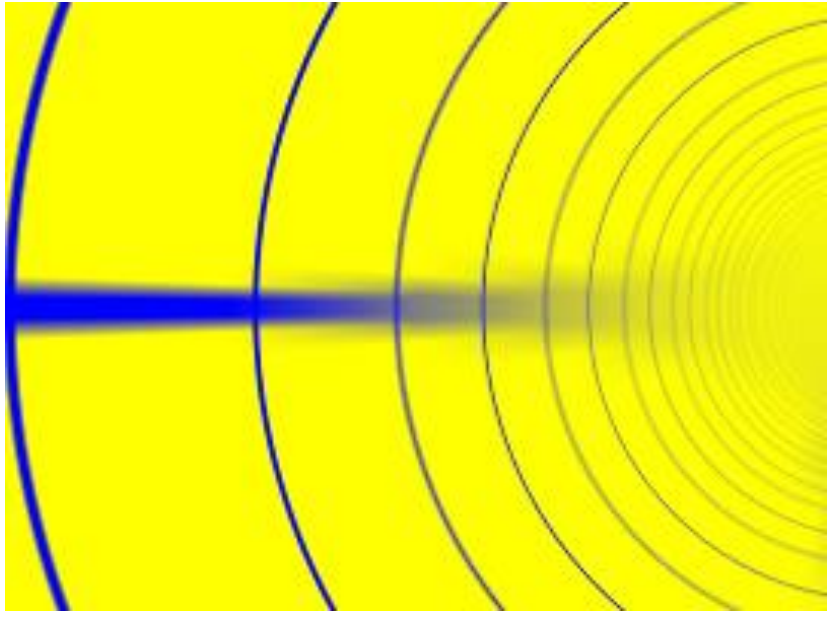
Texel

Pixel

MIP Mapping Examples

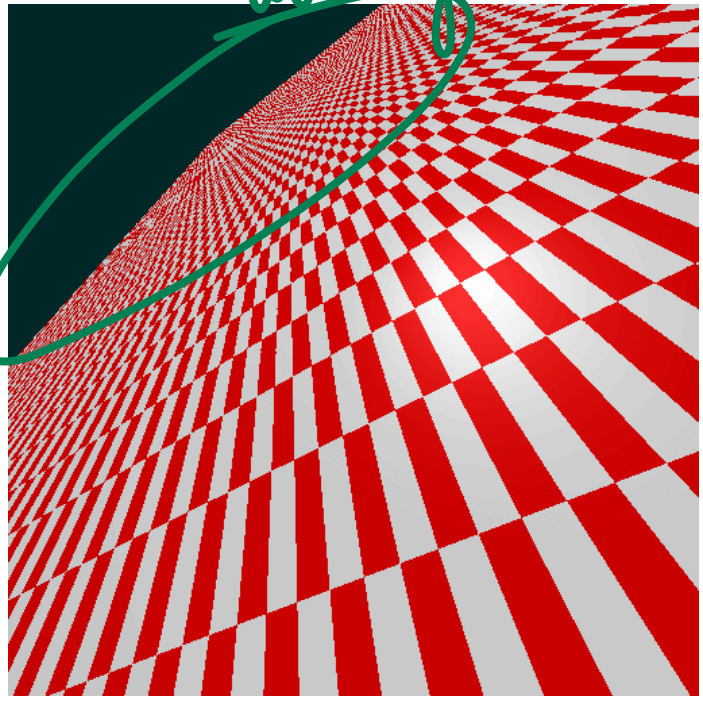


Bilinear Filtering
(distinct MIP map levels)

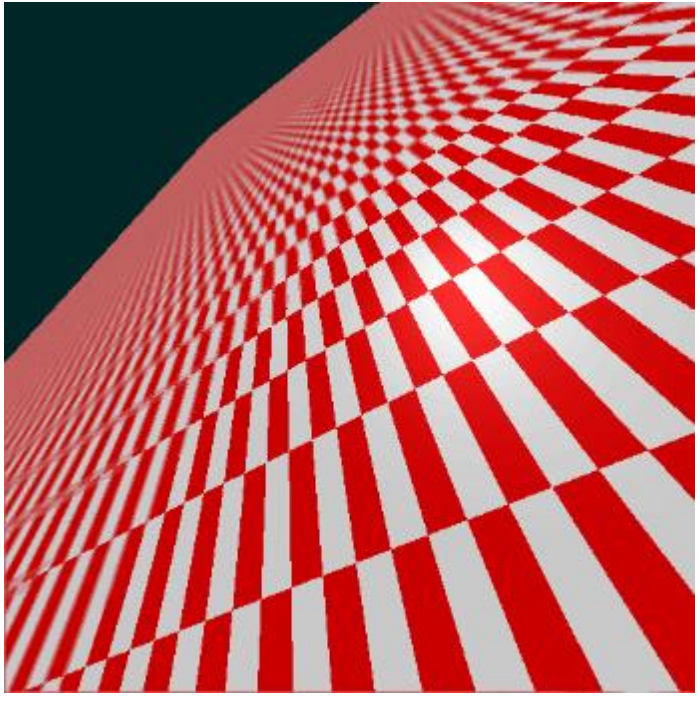


Trilinear Filtering
(MIP mapping)

More Examples



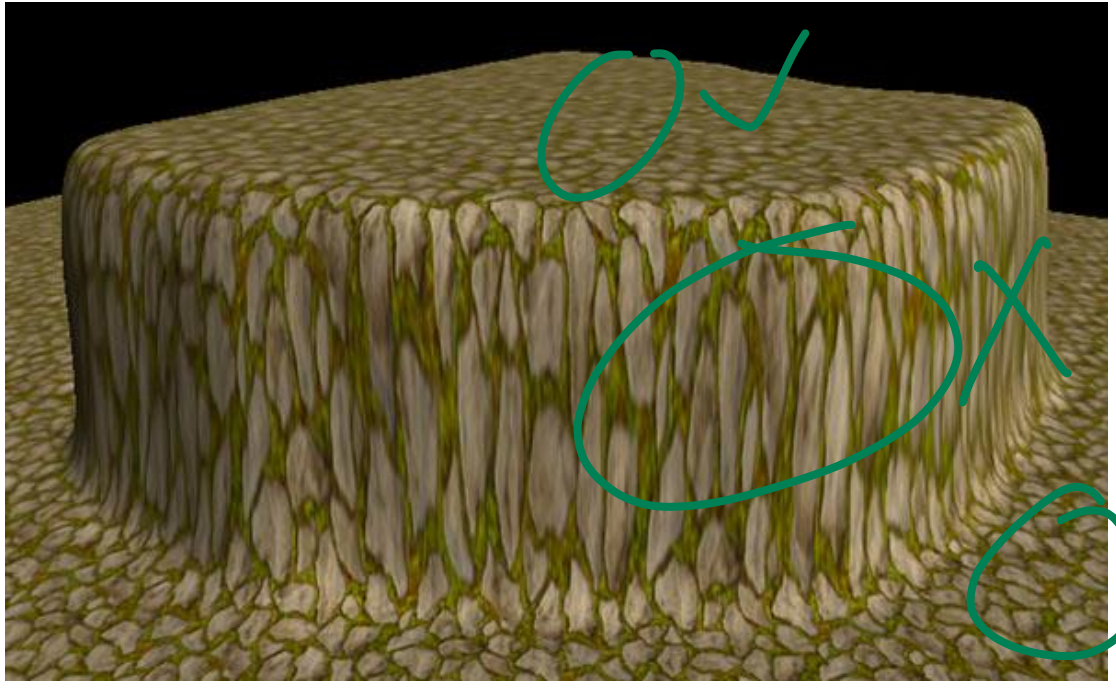
Nearest Neighbor



MIP Mapping

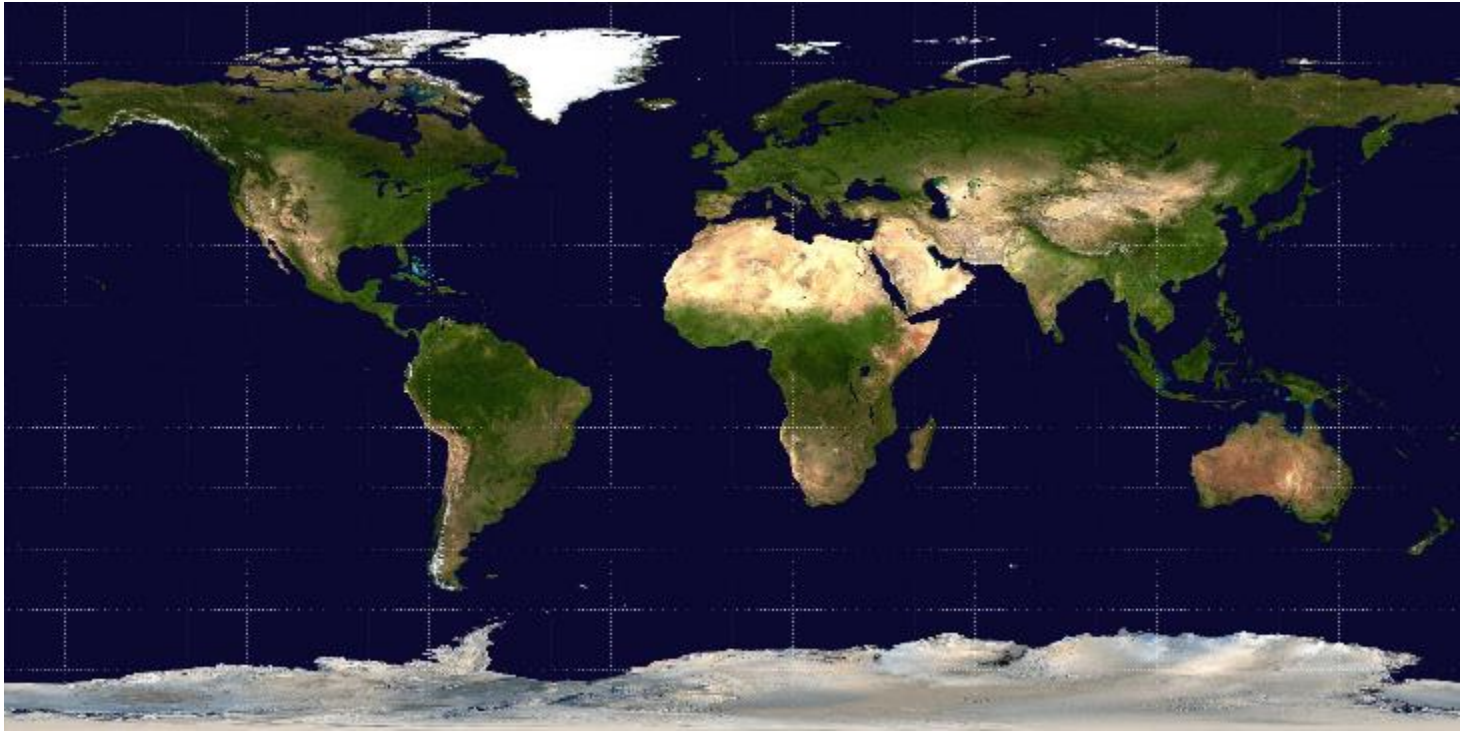
Parametrization 参数化

Where does u, v come from?



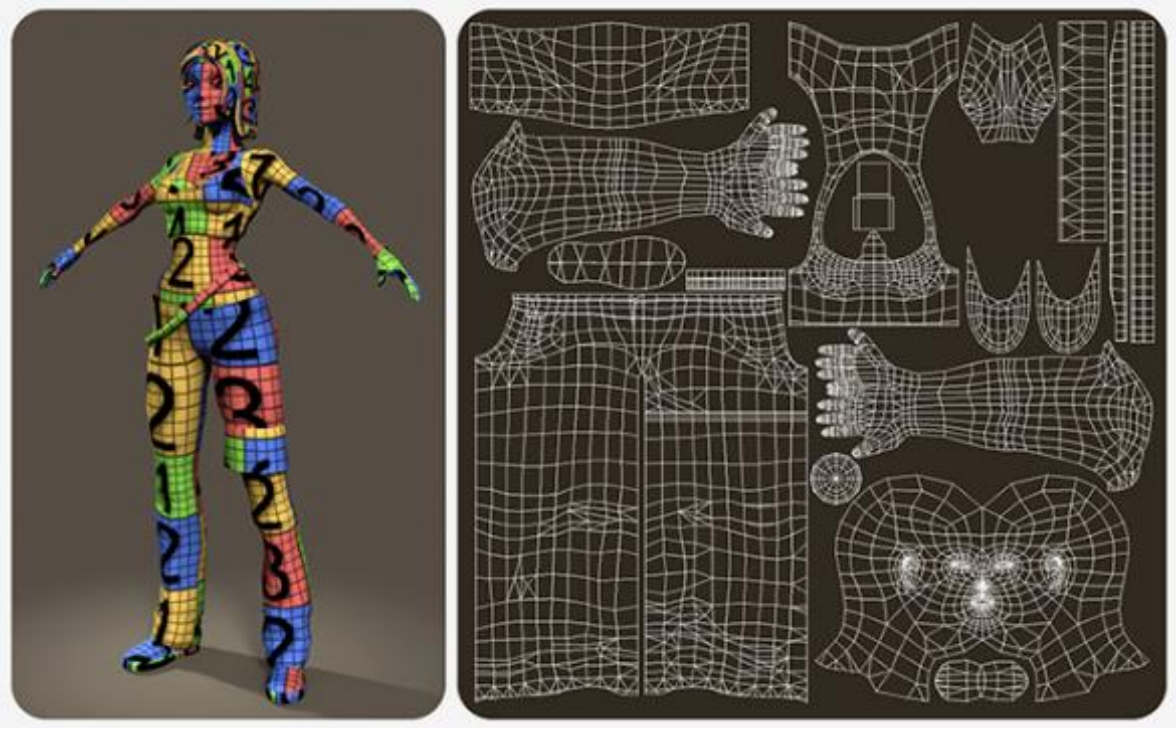
Planar projection

Where does u, v come from?



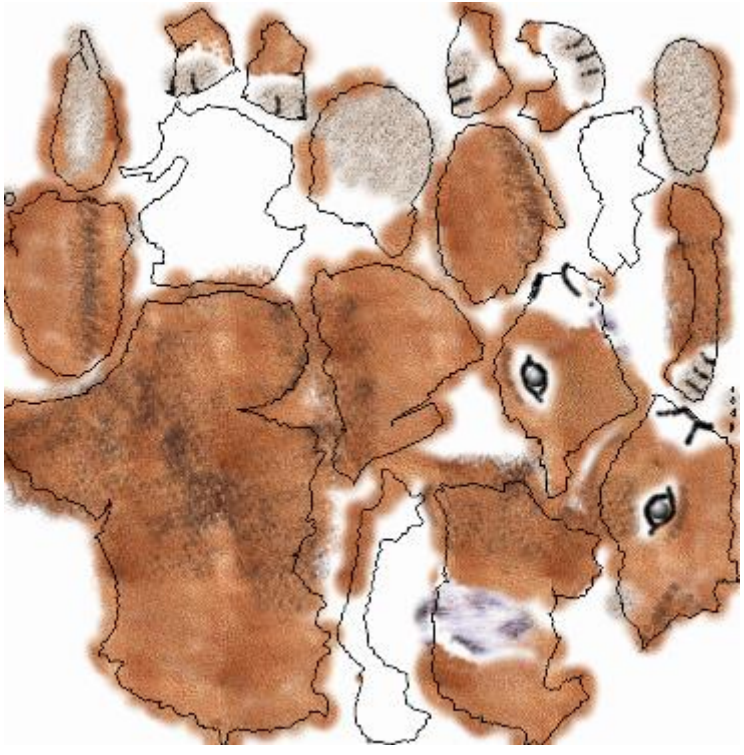
Spherical projection

Where does u, v come from?



Charts, done manually

Where does u, v come from?



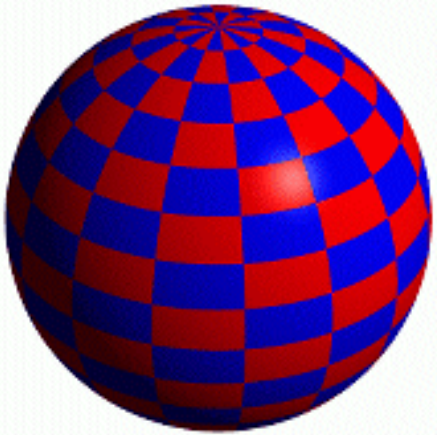
Charts, done automatically

Other Forms of Texture Mapping

1. Bump Mapping
2. Displacement Mapping
3. Environment Mapping

Bump Mapping

- Use textures to alter the surface normal
  - Does not change the actual shape of the surface
  - Just shaded as if it were a different shape



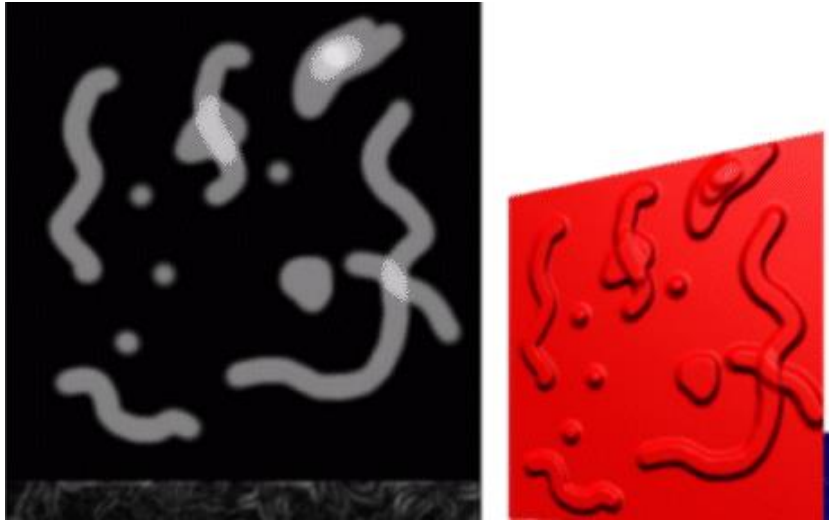
Sphere w/Diffuse Texture

Swirly Bump Map

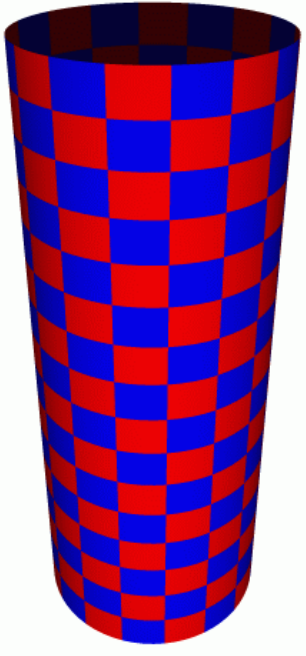
Sphere w/Diffuse Texture & Bump Map

Bump Mapping

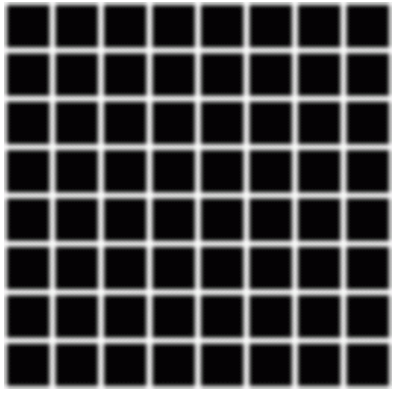
- Treat the texture as a single-valued height function
- Compute the normal from the partial derivatives in the texture



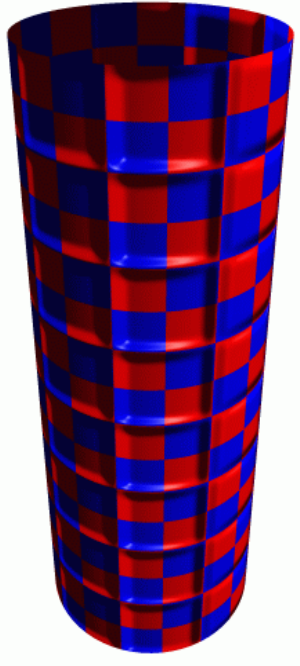
Another Bump Map Example



Cylinder w/Diffuse Texture Map



Bump Map

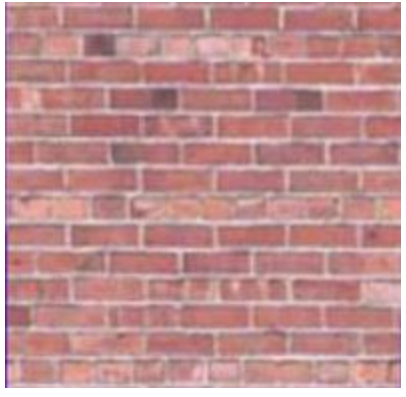


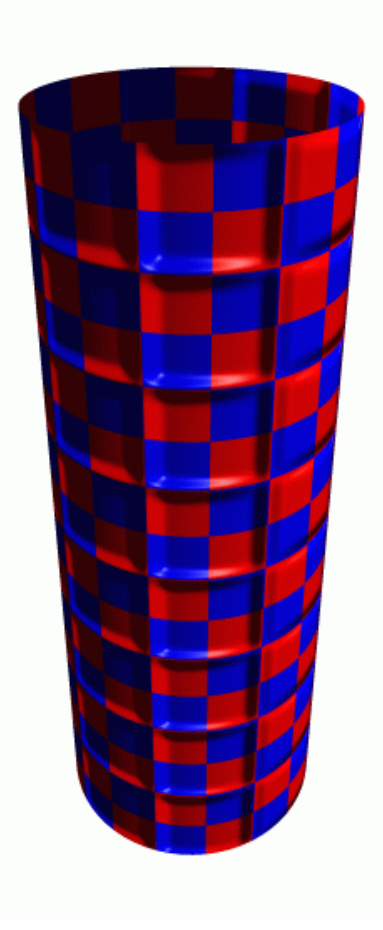
Cylinder w/Texture Map & Bump Map

What's Missing?

- There are no bumps on the silhouette of a bump-mapped object

- Bump maps don’t allow self-occlusion or self-shadowing

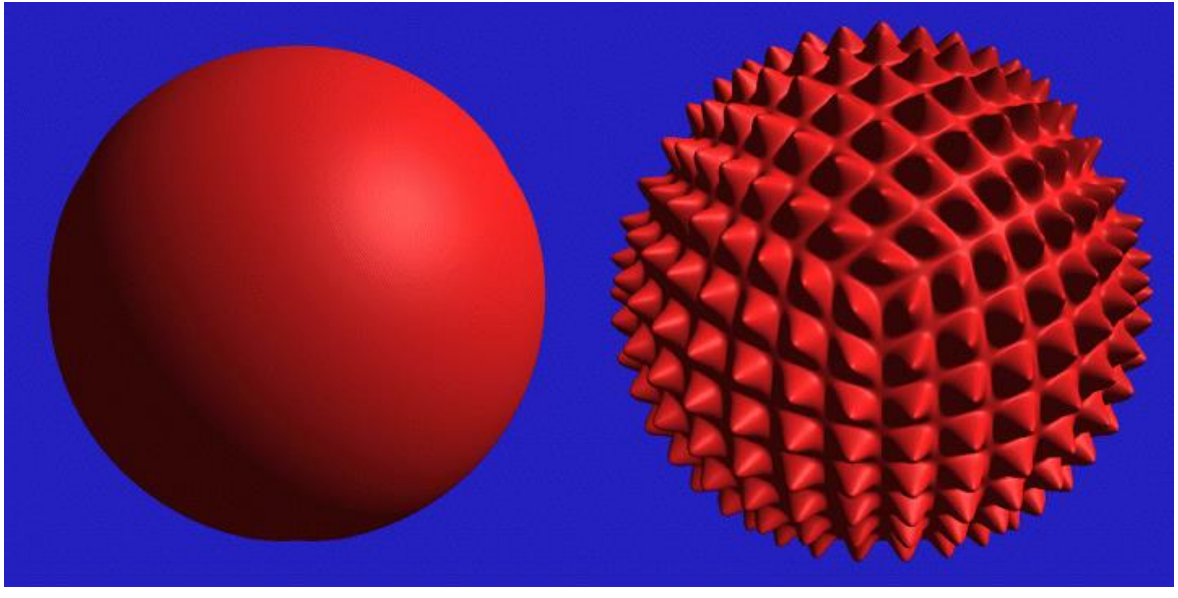




Displacement Mapping

move Vertices

- Use the texture map to actually move the surface point
- The geometry must be displaced before visibility is determined



Displacement Mapping

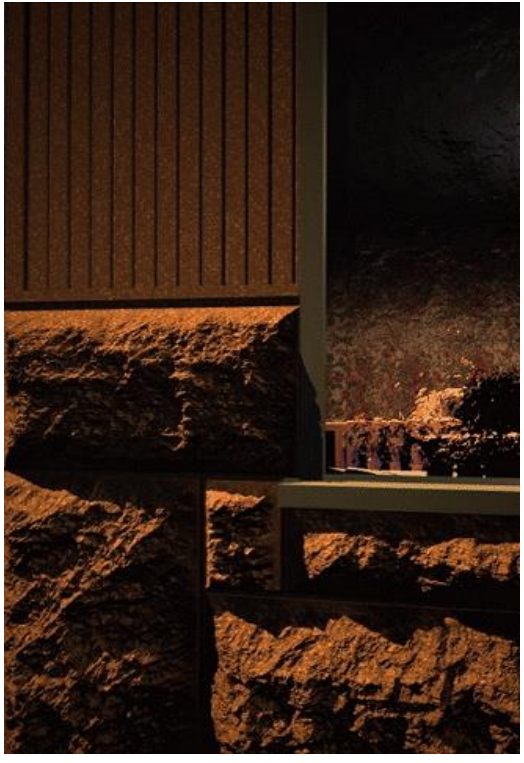


Image from:

Geometry Caching for Ray-Tracing Displacement Maps

by Matt Pharr and Pat Hanrahan.

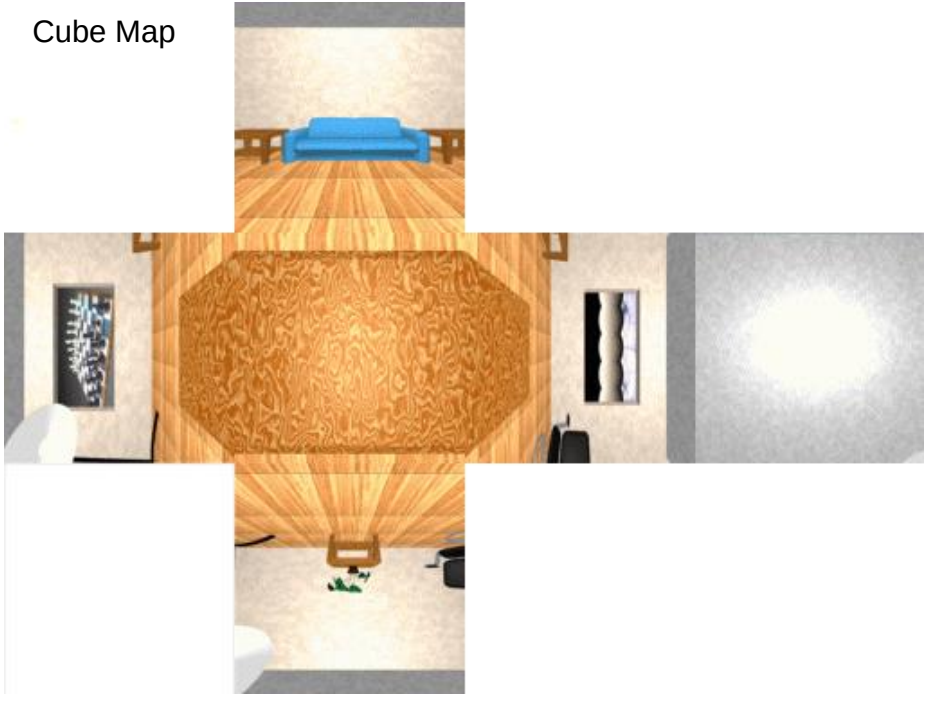
Note the detailed shadows cast by the stones

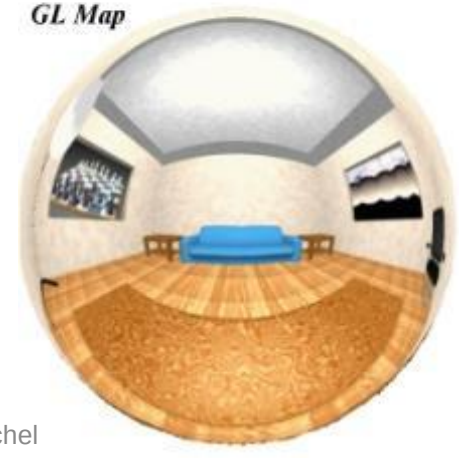
Environment Maps

- We can simulate reflections by using the direction of the reflected ray to index a spherical texture map at "infinity".
- Assumes that all reflected rays begin from the same point.

What's the Best Layout?

Cube Map





Environment Mapping Example

Terminator II

Recap

- Texture Mapping adds detail to otherwise simple geometry
- “Texture” can mean different modifications to the calculation of lighting, or can even displace geometry locally
- Sampling issues are very important
- To some extent current graphics cards are built around attempting to do texturing efficiently.