Computer Graphics (COMP0027) 2022/23
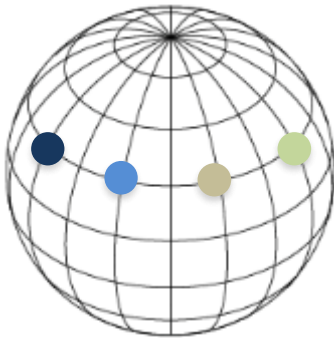
# **Texturing**

Tobias Ritschel

# Texture Mapping

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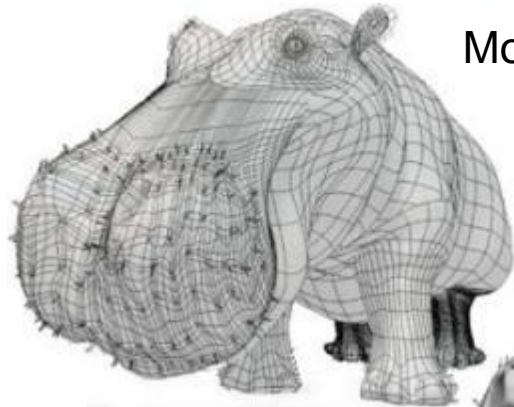- But: don't want to represent all this detail with geometry

# 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
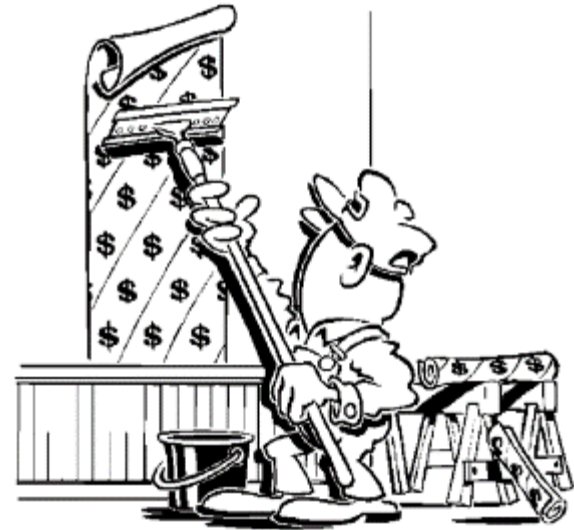
# The Quest for Visual Realism

Model

Model + Shading

Model + Shading
+ Textures

# Texture Mapping

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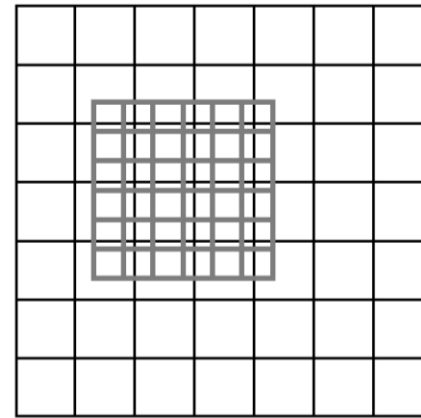
# Texture Mapping

- Standard texture mapping modifies diffuse component $k_\mathrm{d}$
  - 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
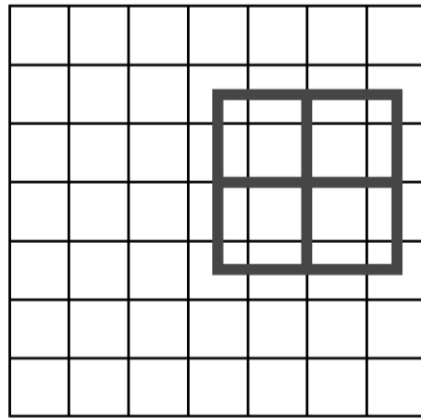

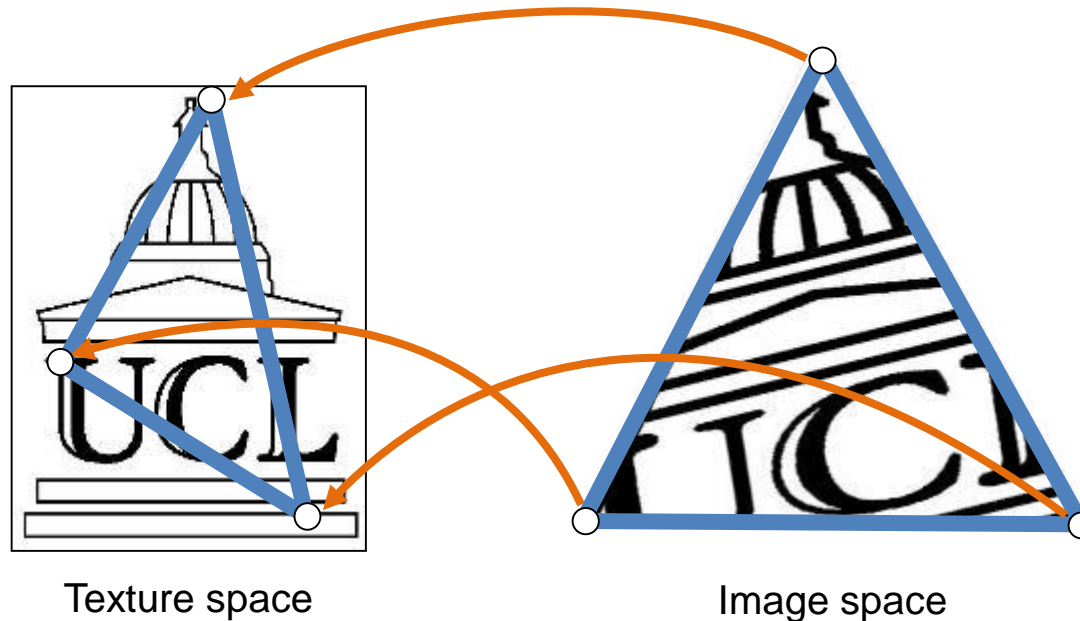
Magnification

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 $(s, t)$



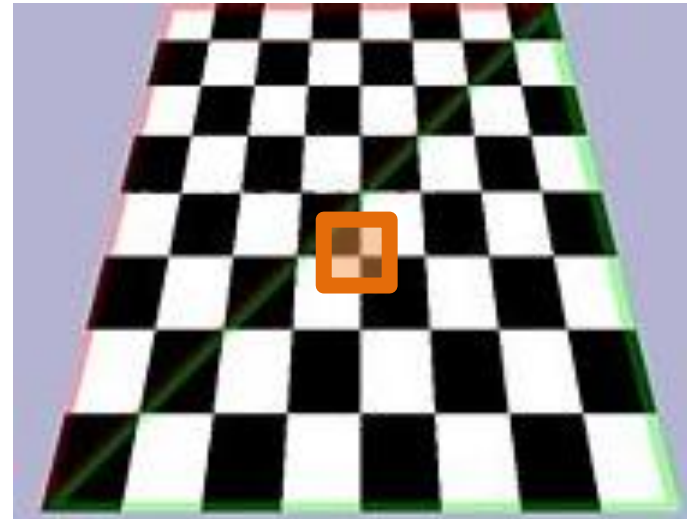Texture space                    Image space

# 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



Texture

3D view

# Sampling

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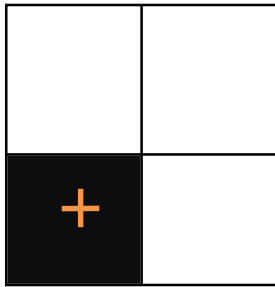- Problem: Under and over-sampling
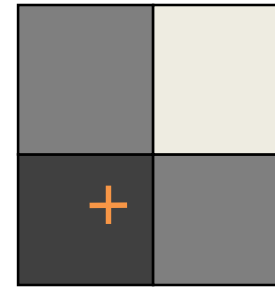


Oversampling

Undersampling

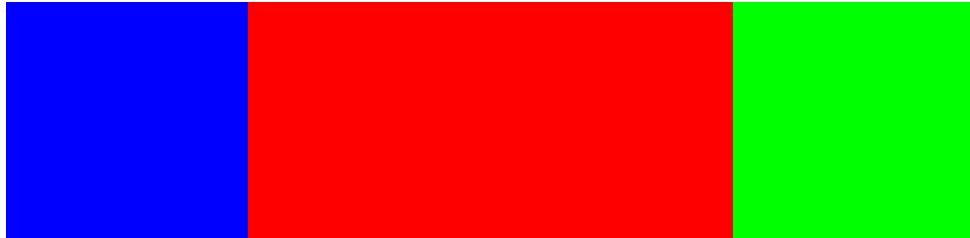# Undersampling solution: Filtering

Nearest neighbour
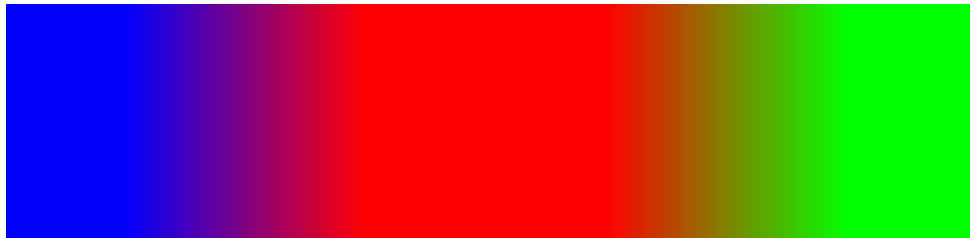


Pick texel with closest
centre

Bilinear



Weighted average
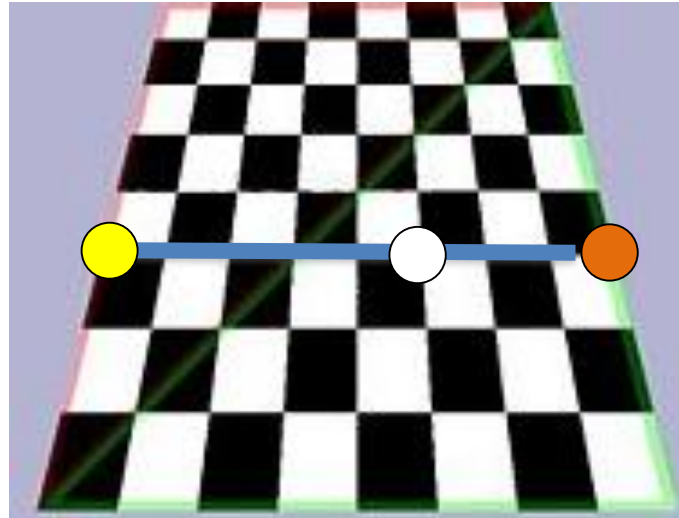based on distance to
texel centre

# Filtering examples

Nearest Neighbor

Bilinear Filtering

# Filtering

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

# 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
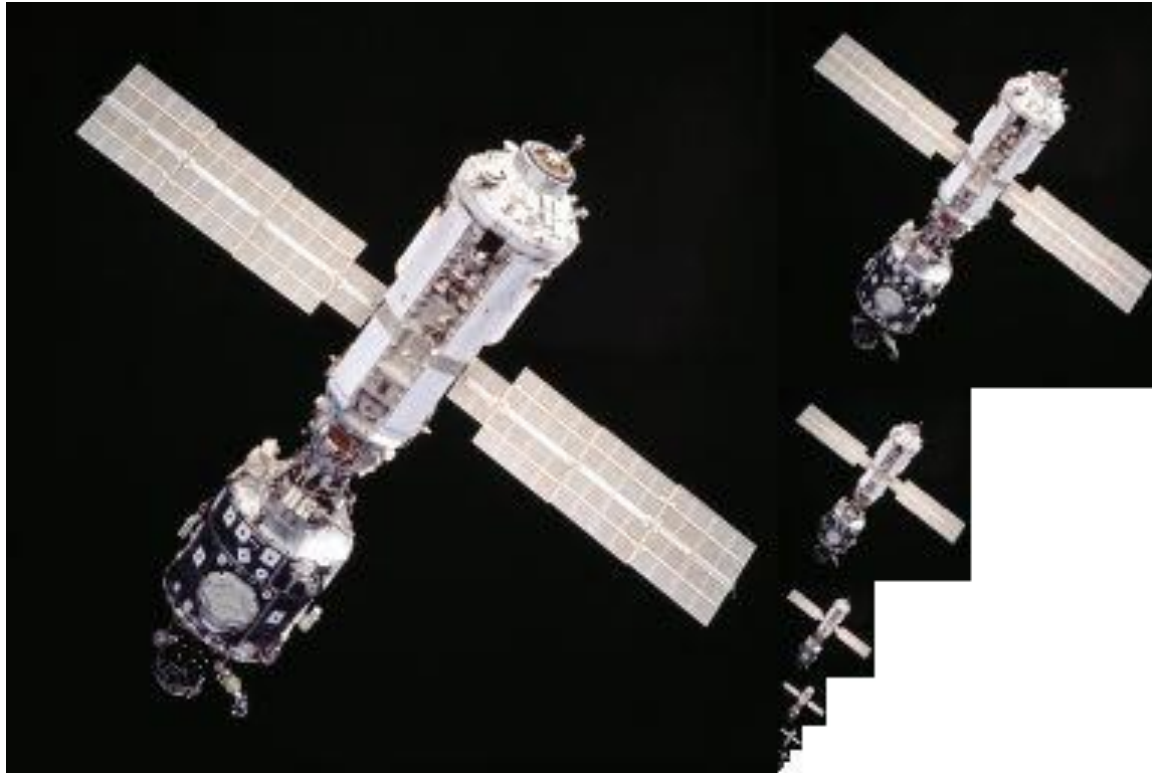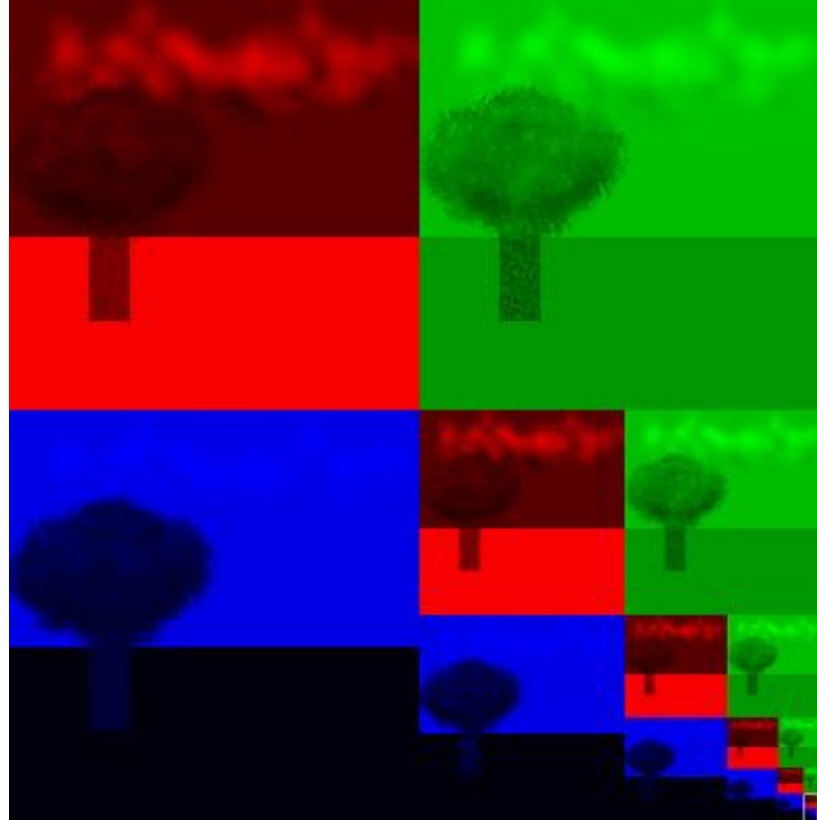


128x128          64x64          32x32          1x1

# Efficient spatial layout
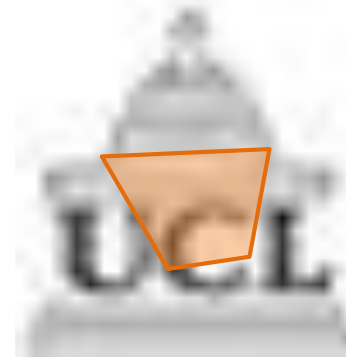
# Efficient RGB channel layout

# 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



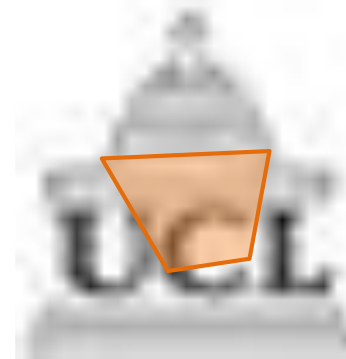| | Texel | | Texel | | Texel |
| --- | --- | --- | --- | --- | --- |
| | Pixel | | Pixel | | Pixel |

# Tri-linear MIP Sampling

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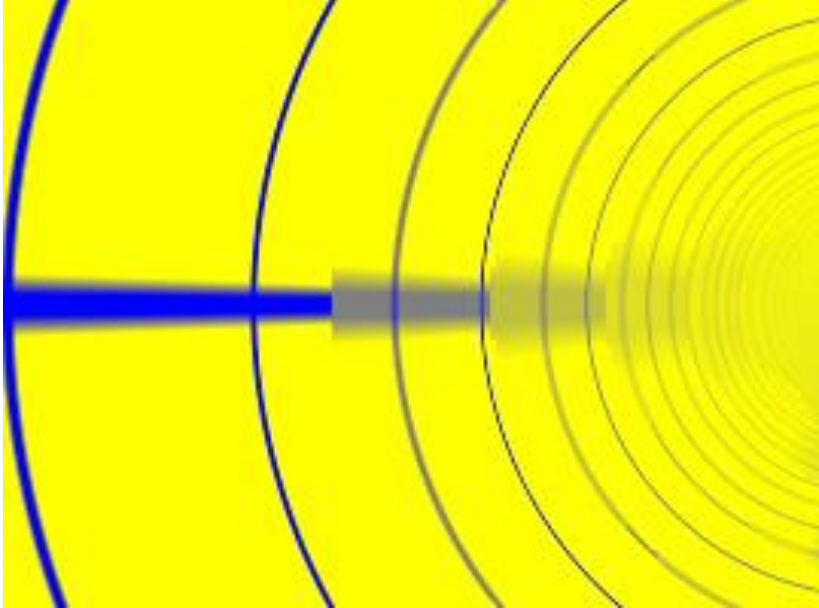


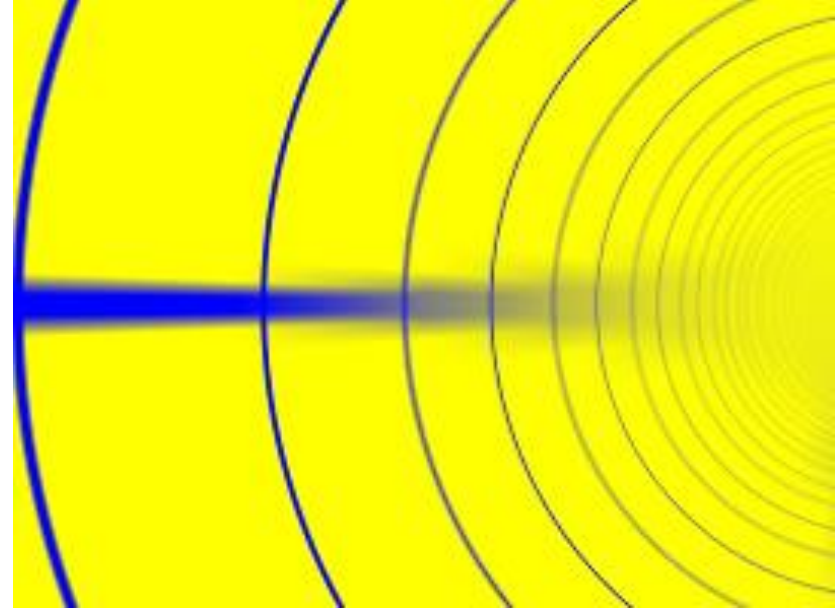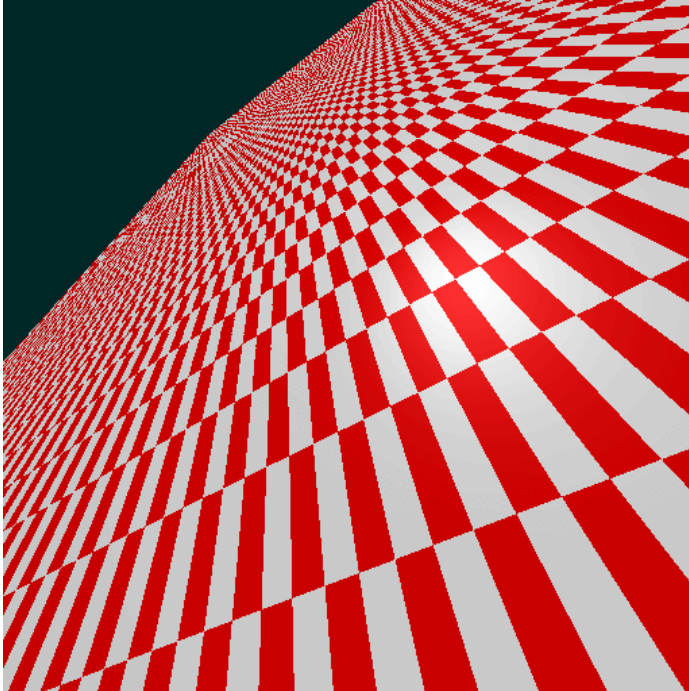| —— Texel | —— Texel | —— Texel |
| —— Pixel | —— Pixel | —— Pixel |

# MIP Mapping Examples
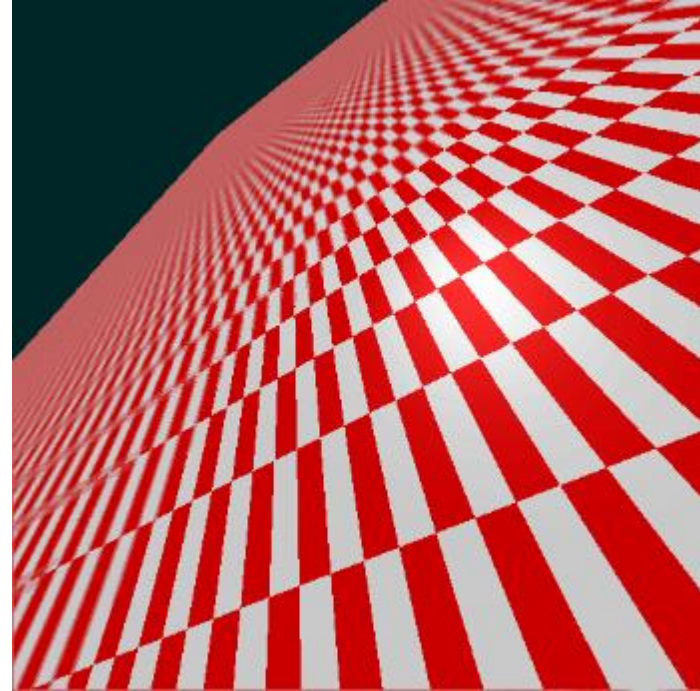


Bilinear Filtering
(distinct MIP map levels)

Trilinear Filtering
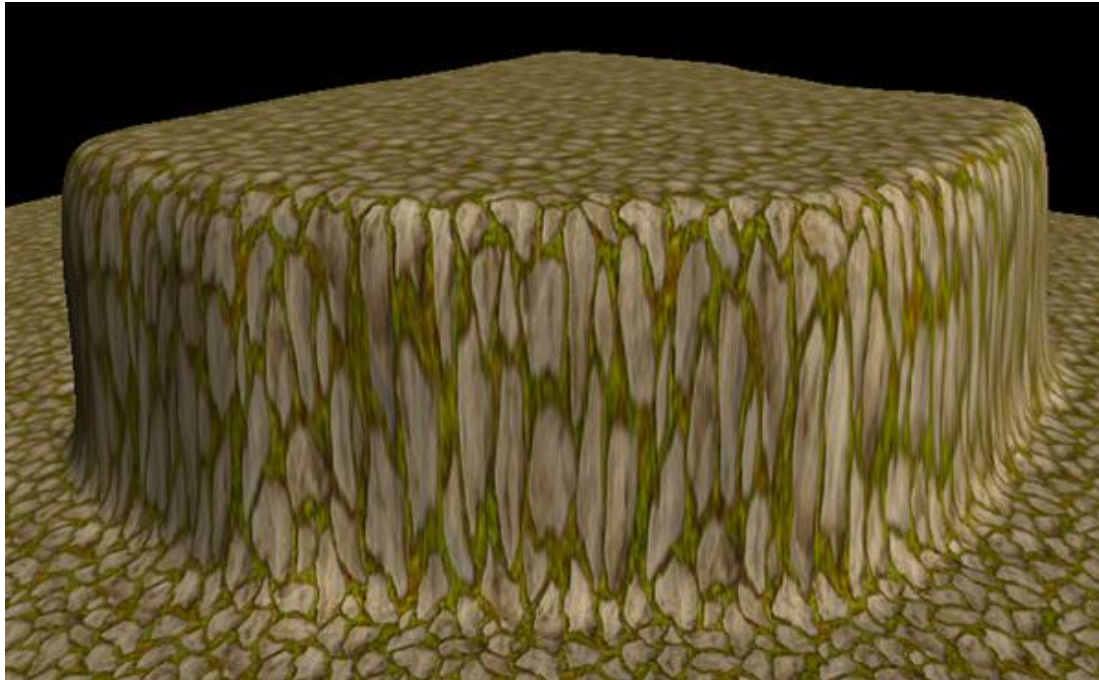(MIP mapping)

# More Examples

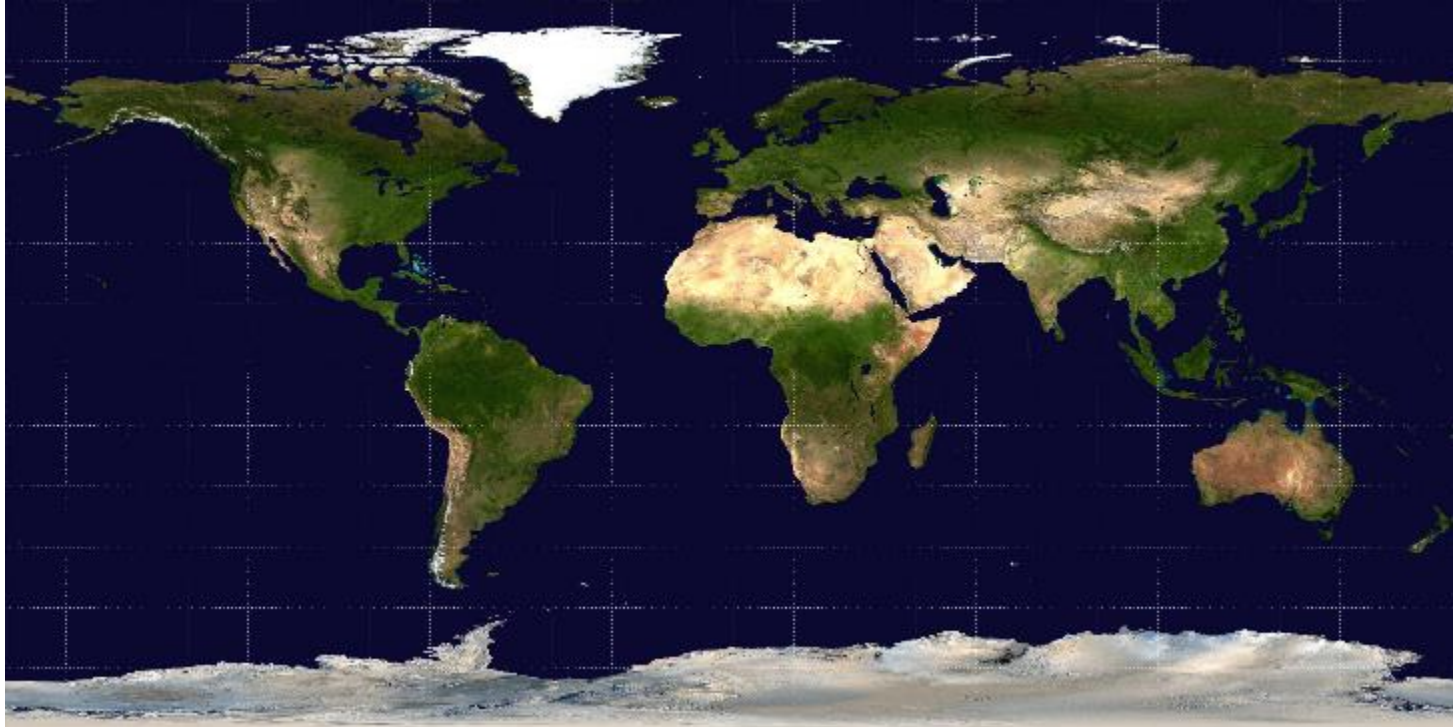

Nearest Neighbor



MIP Mapping
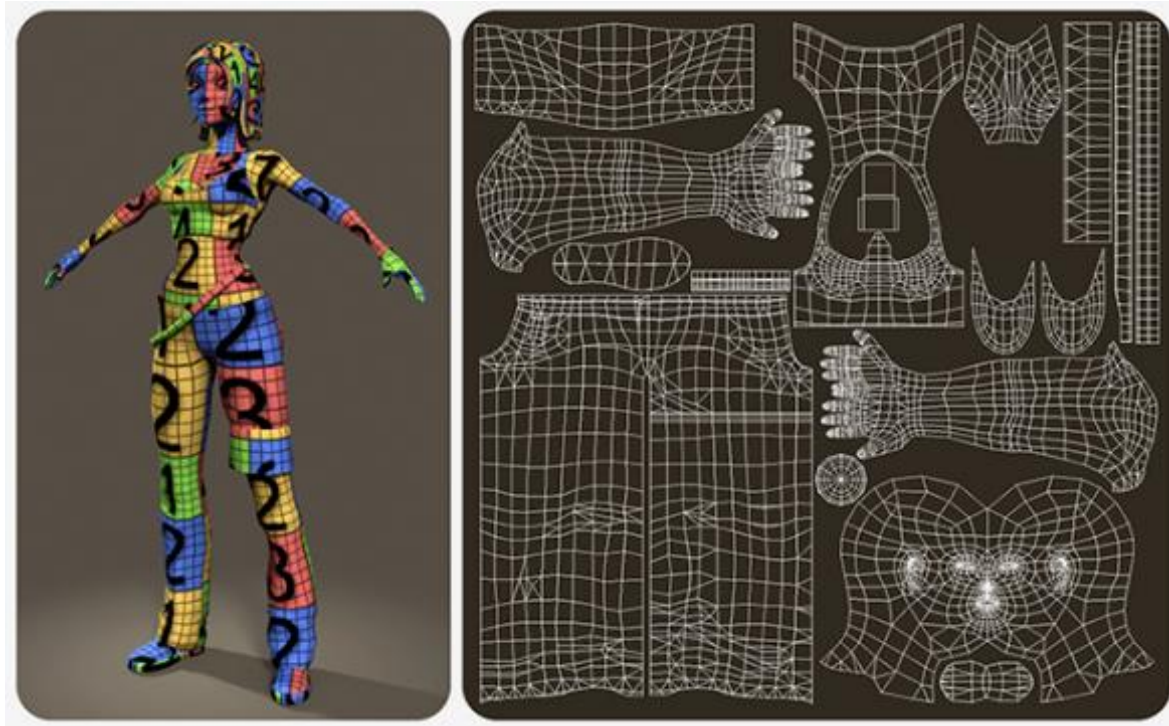
# Parametrization

# 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?
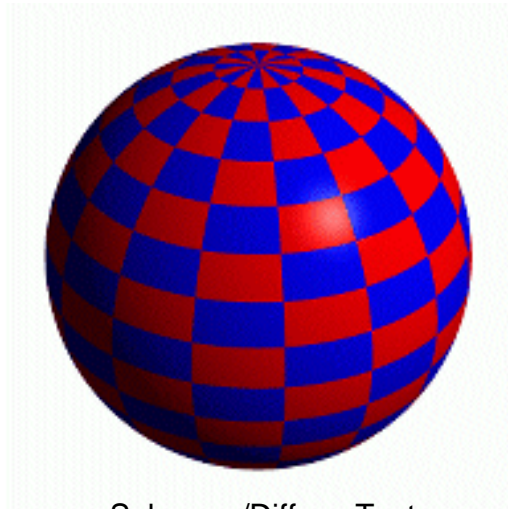


Charts, done automatically

# Other Forms of Texture Mapping

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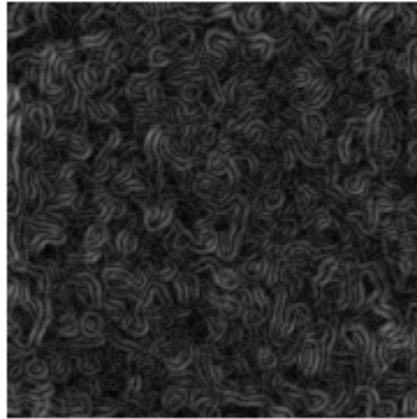2. Displacement Mapping
3. Environment Mapping
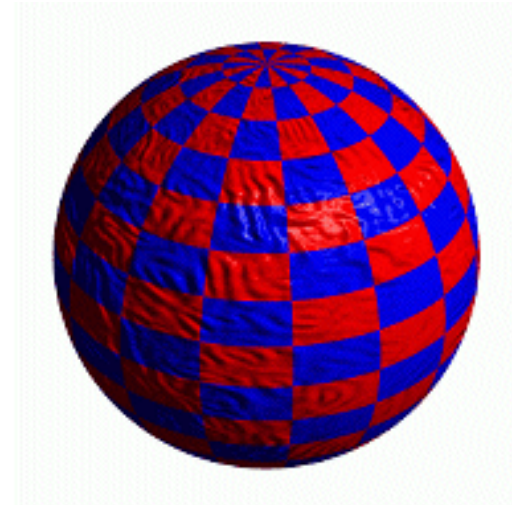
# Bump Mapping

- 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



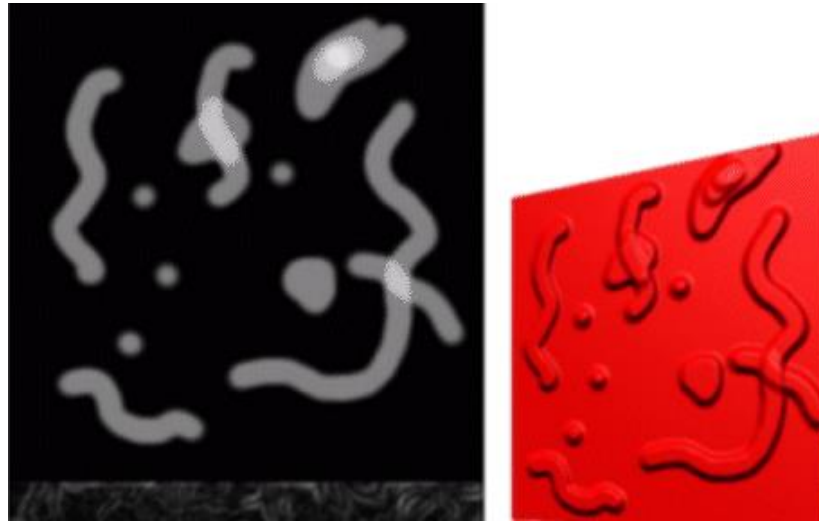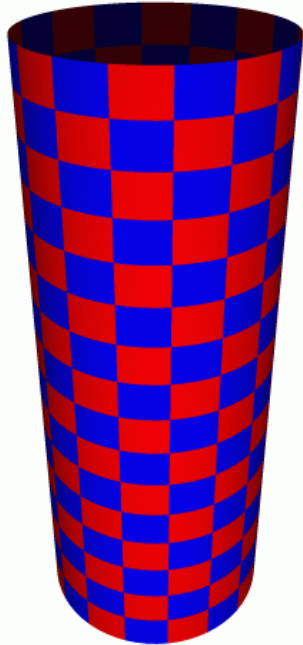Sphere w/Diffuse Texture      Swirly Bump Map      Sphere w/Diffuse Texture & Bump Map
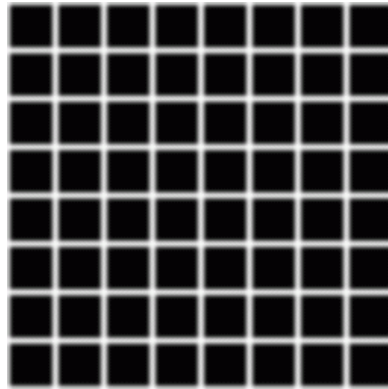
# Bump Mapping

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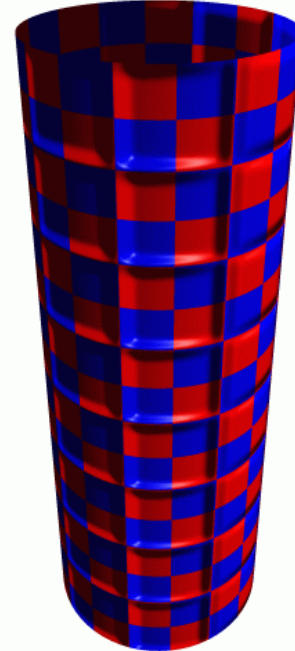- Compute the normal from the partial derivatives in the texture

# Another Bump Map Example


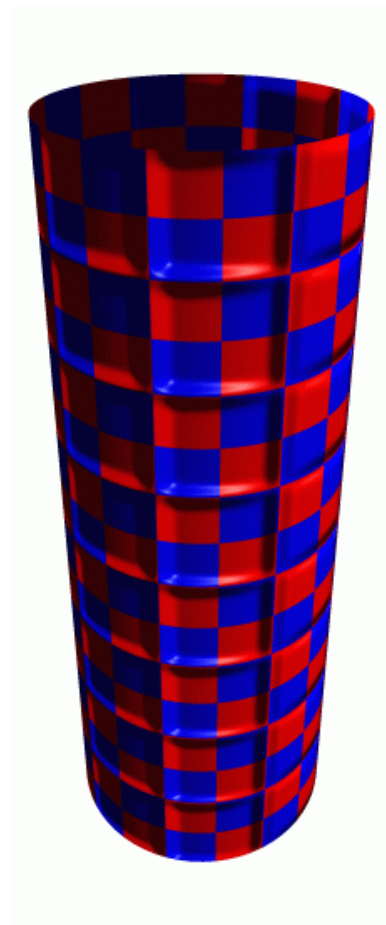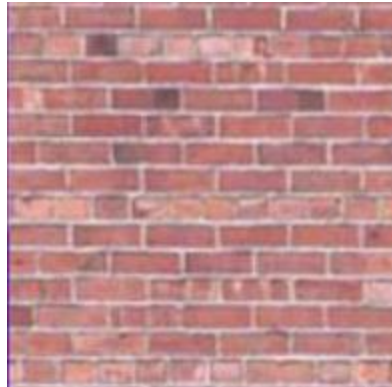
Cylinder w/Diffuse Texture Map
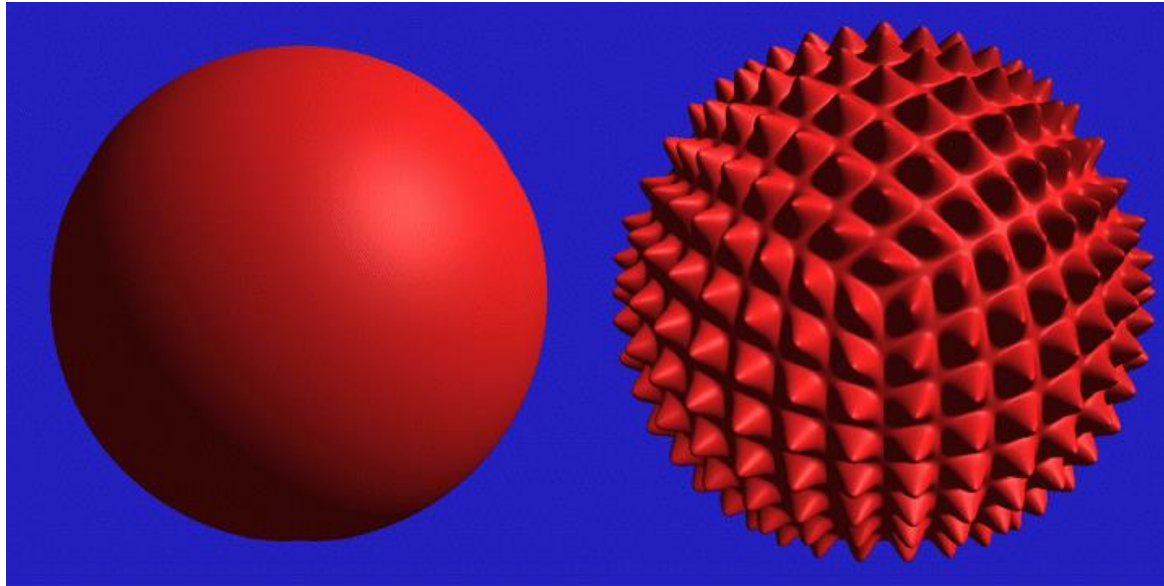
Bump Map

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

- 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.

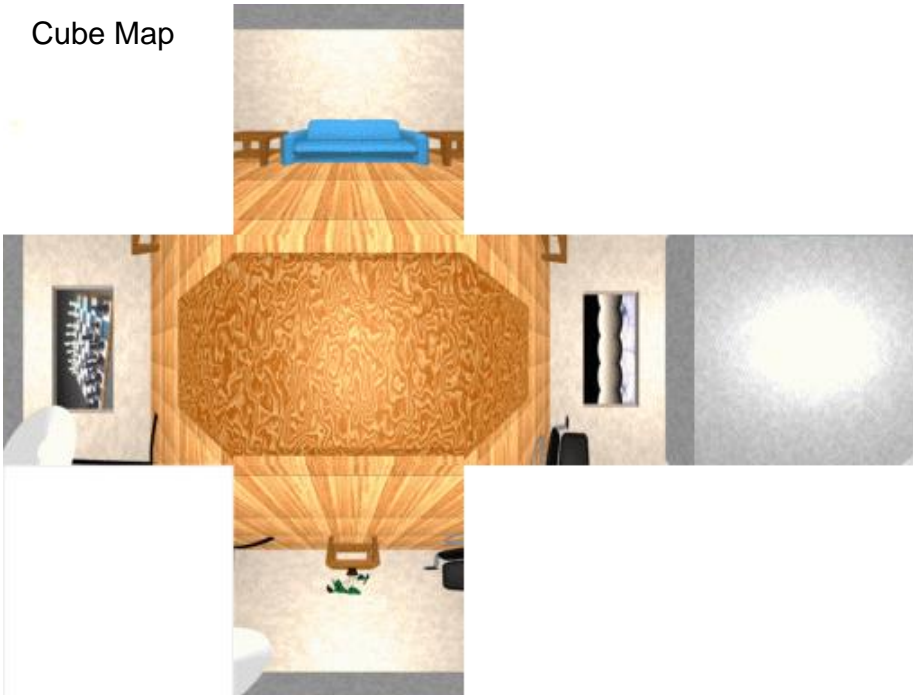Note the detailed shadows cast by the stones

# 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.
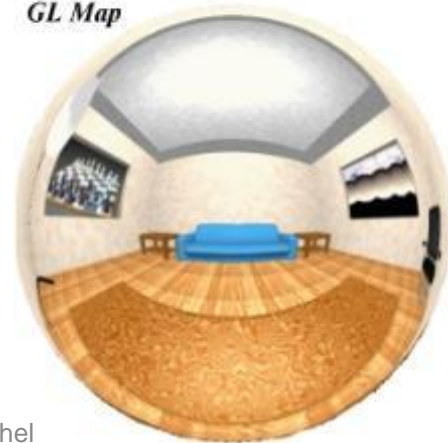
# What's the Best Layout?

Cube Map

Lattitude Map

GL 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.