Texture Mapping

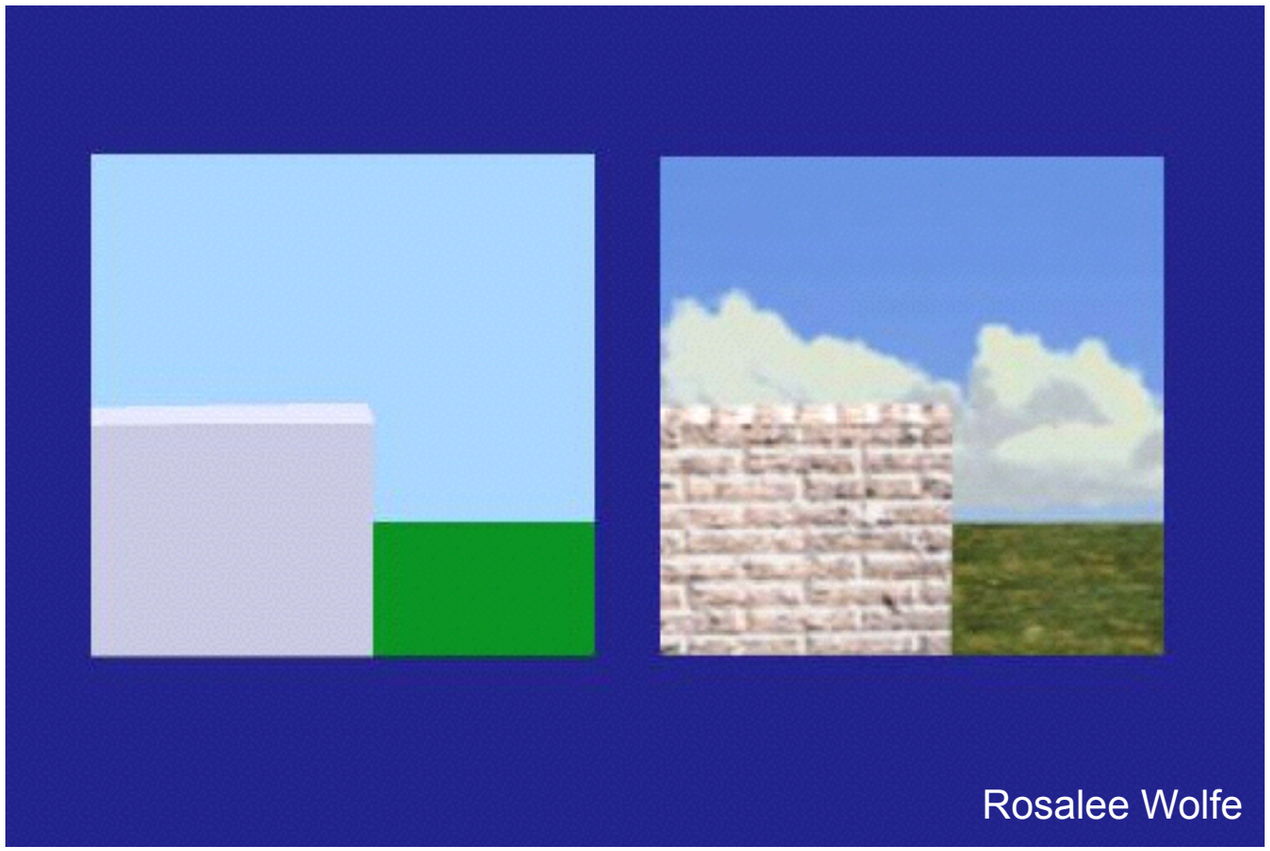
There are limits to geometric modeling

http://www.beinteriordecorator.com

National Geographic

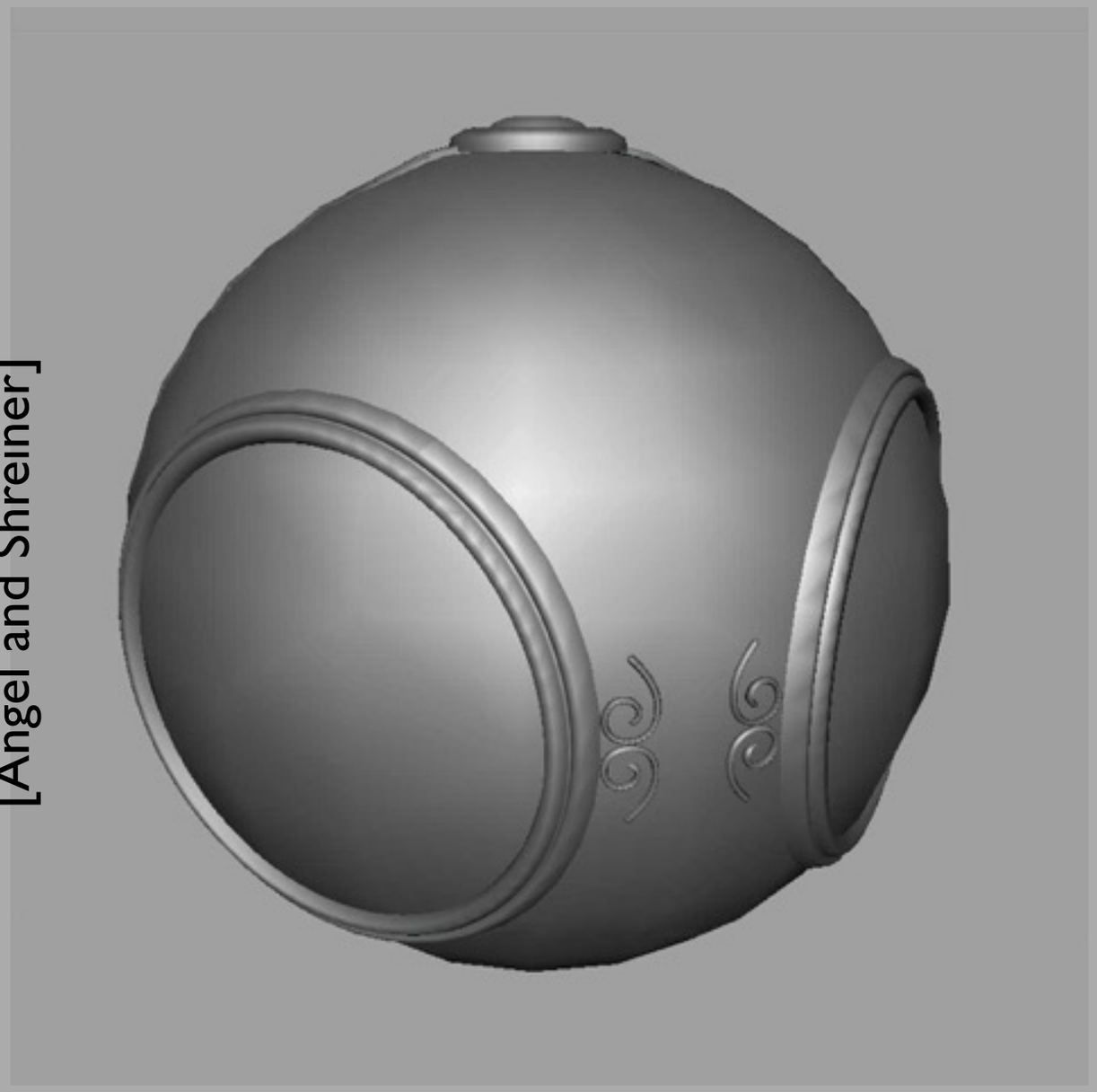
Although modern GPUs can render millions of triangles/sec, that's not enough sometimes...

Use texture mapping to increase realism through detail

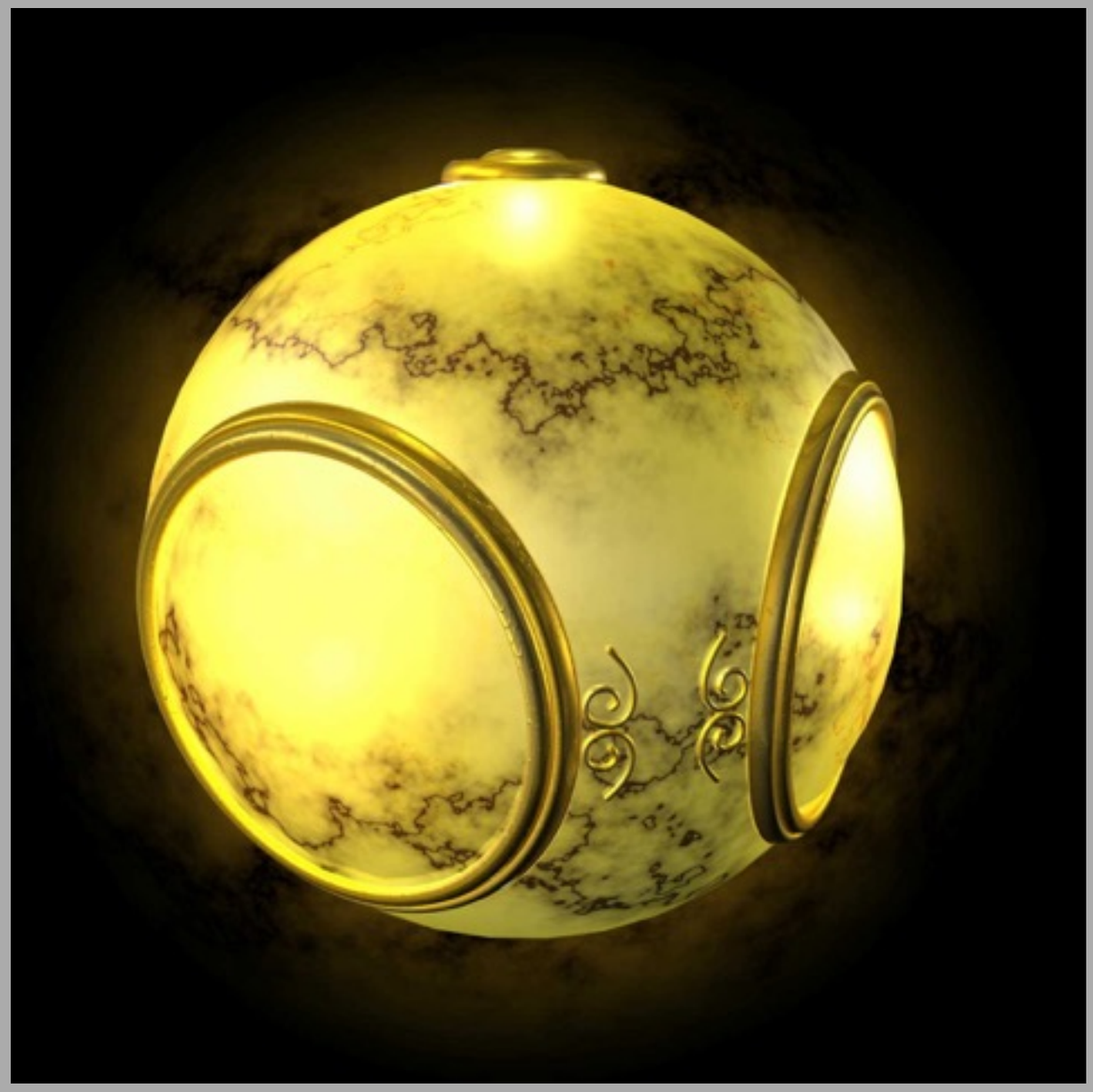


This image is just 8 polygons!

[Angel and Shreiner]



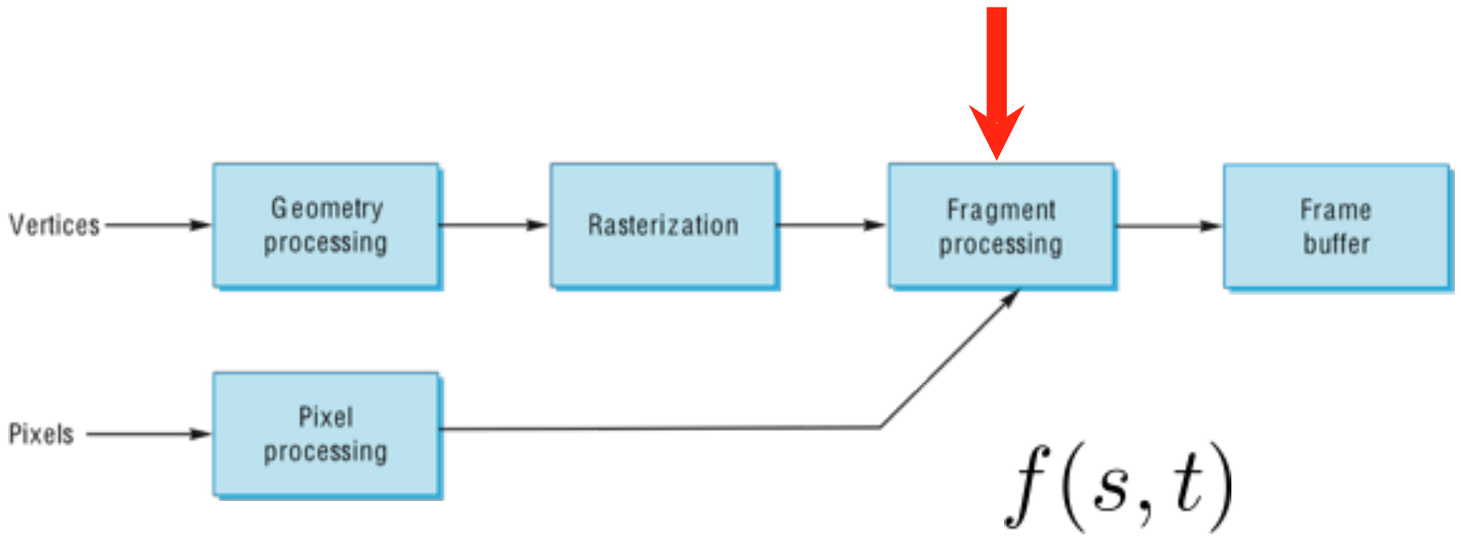
No texture

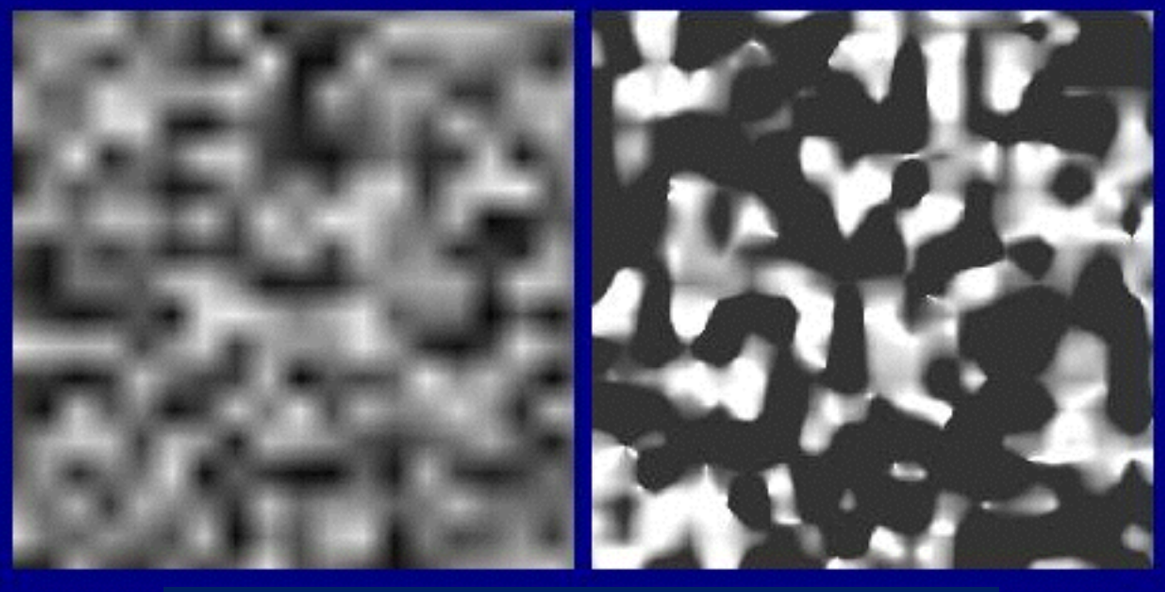


With texture

Pixar - Toy Story

Store 2D images in buffers and lookup pixel reflectances



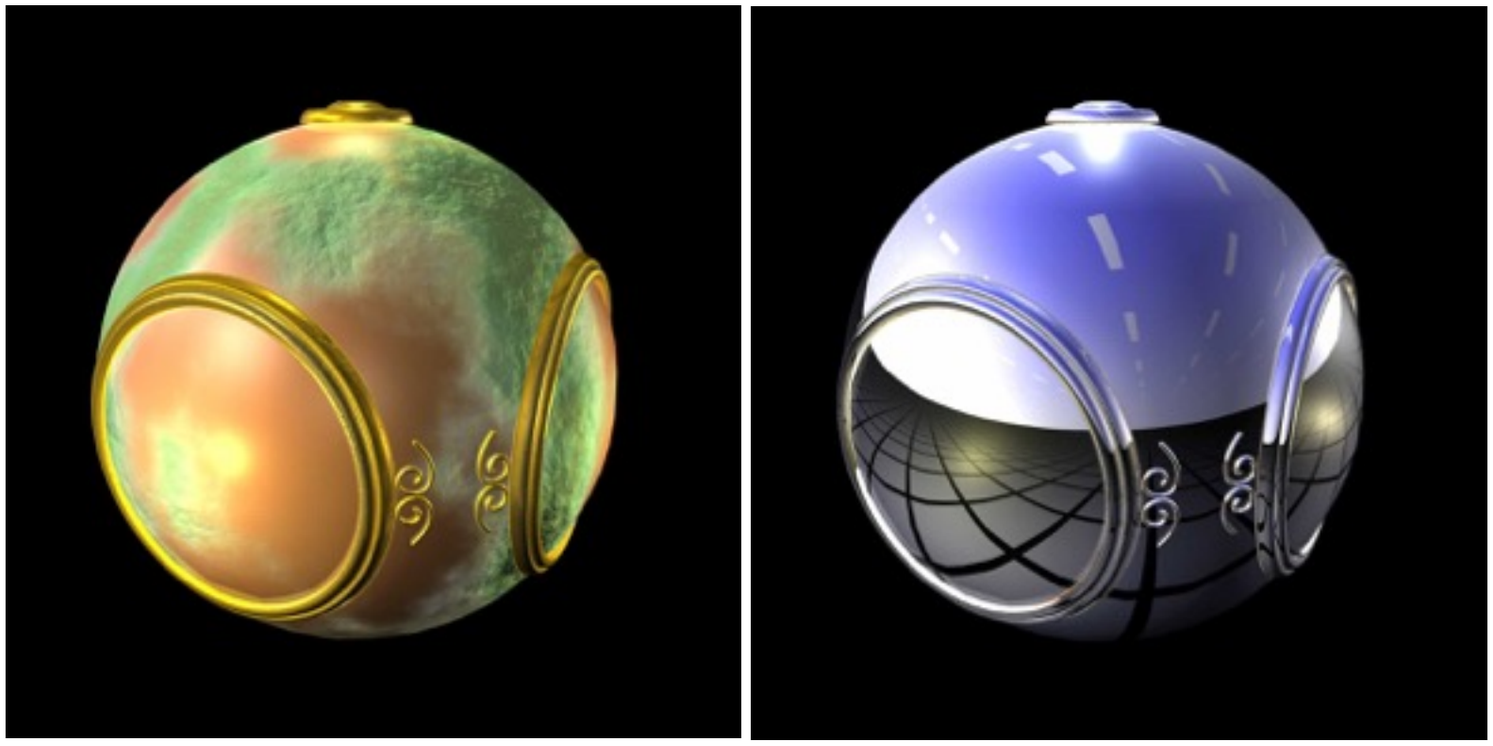


procedural

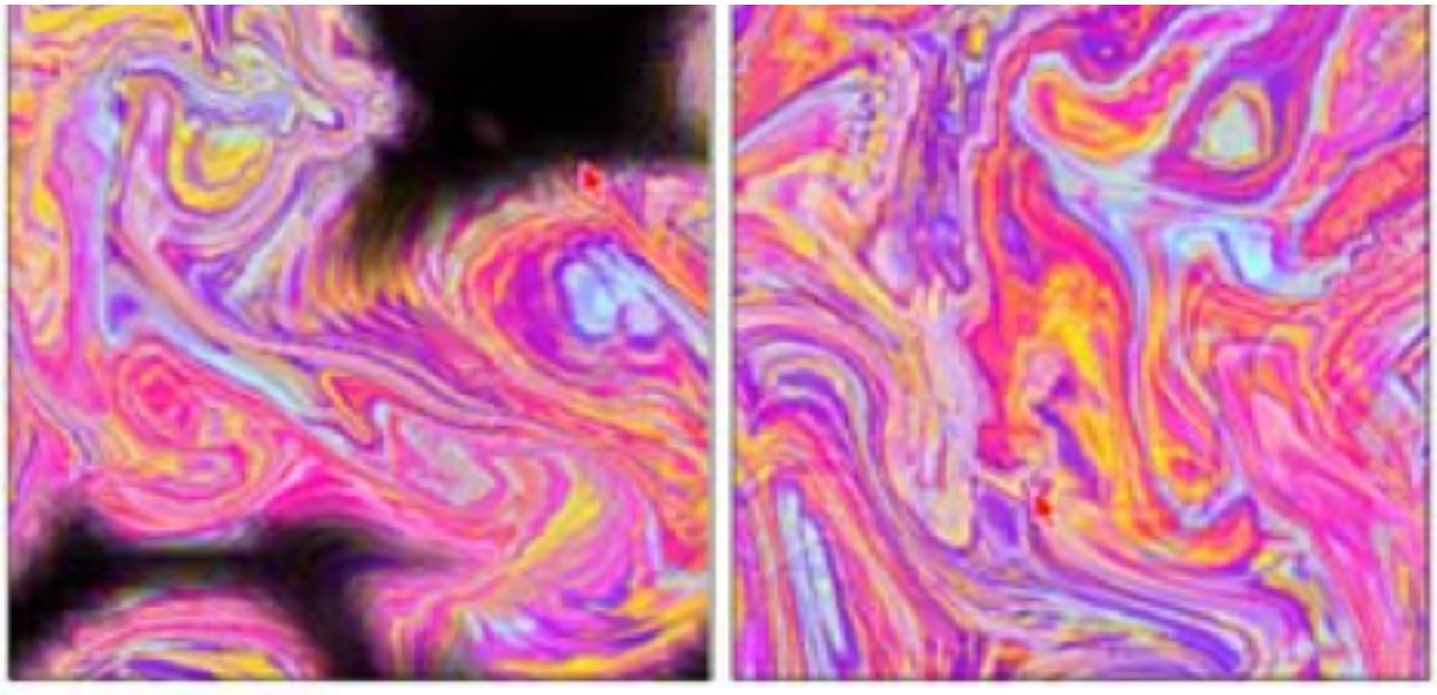
photo

Other uses of textures...

Light maps
Shadow maps
Environment maps
Bump maps
Opacity maps
Animation

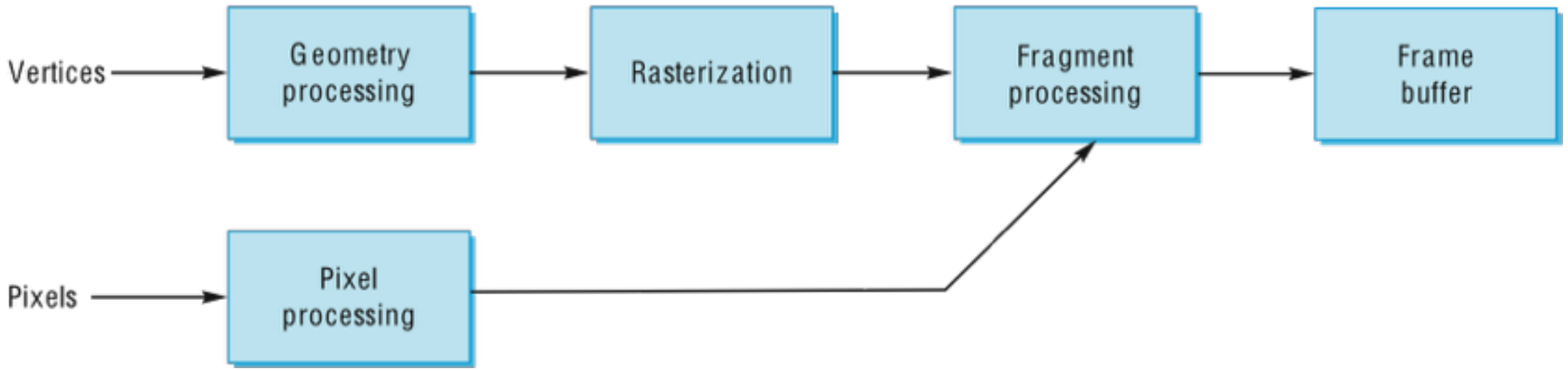


[Angel and Shreiner]



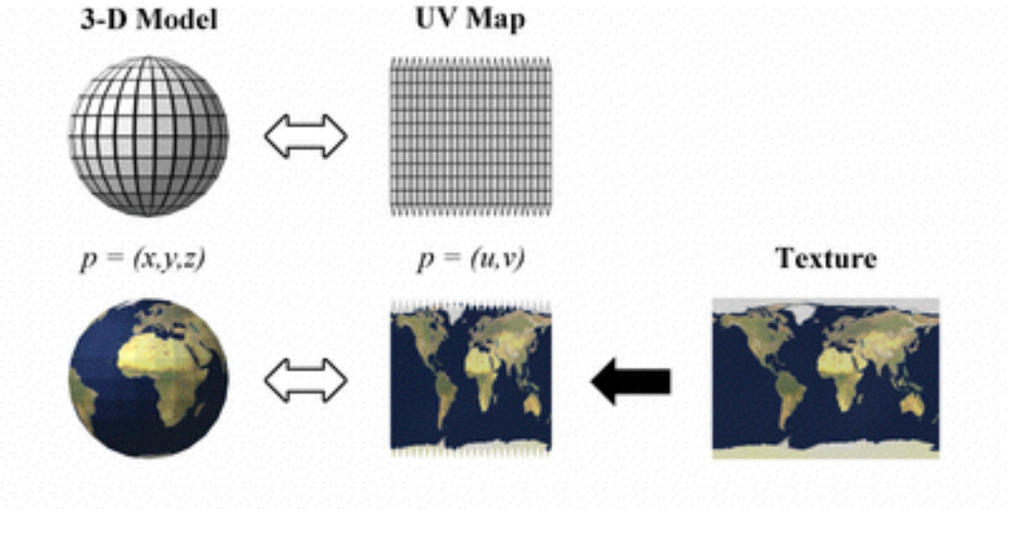
[Stam 99]

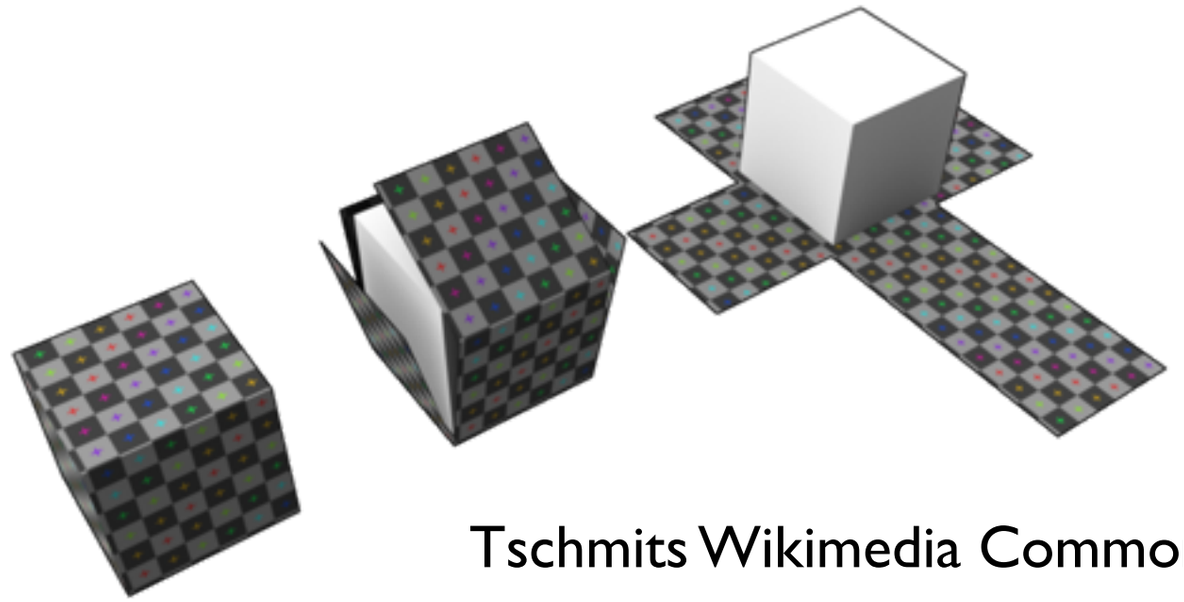
Texture mapping in the OpenGL pipeline



- Geometry and pixels have separate paths through pipeline
- meet in **fragment processing** - where textures are applied
- texture mapping applied at end of pipeline - efficient since relatively few polygons get past clipper

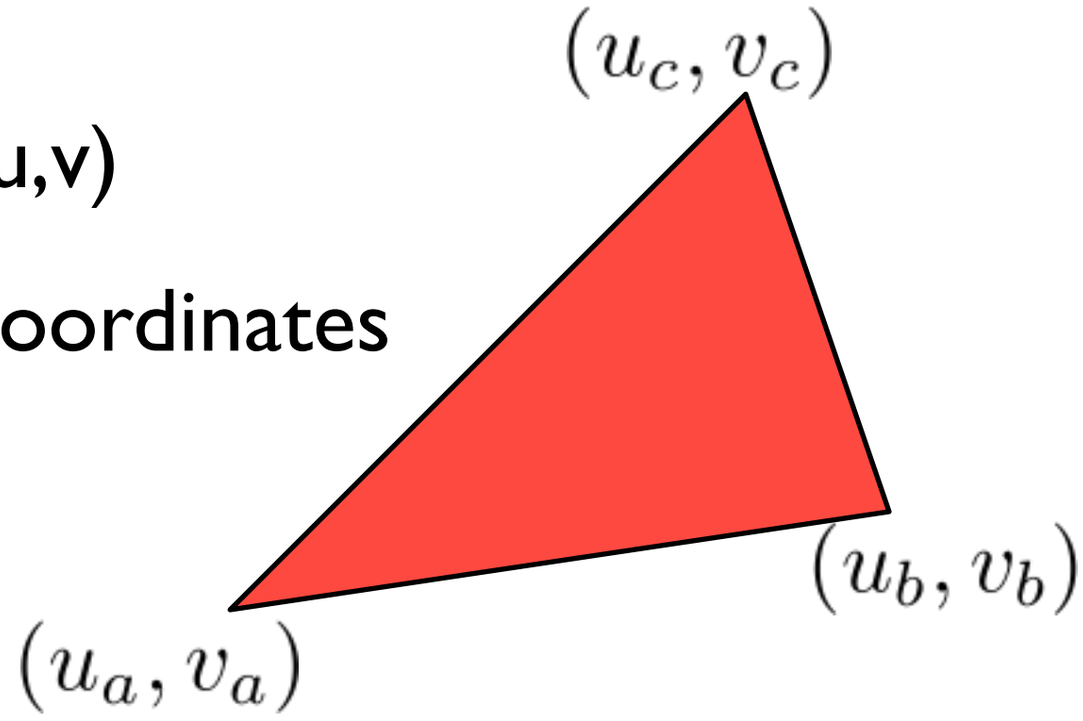
uv Mapping

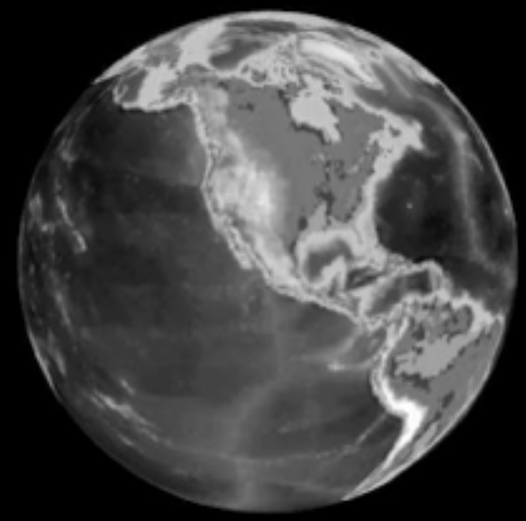


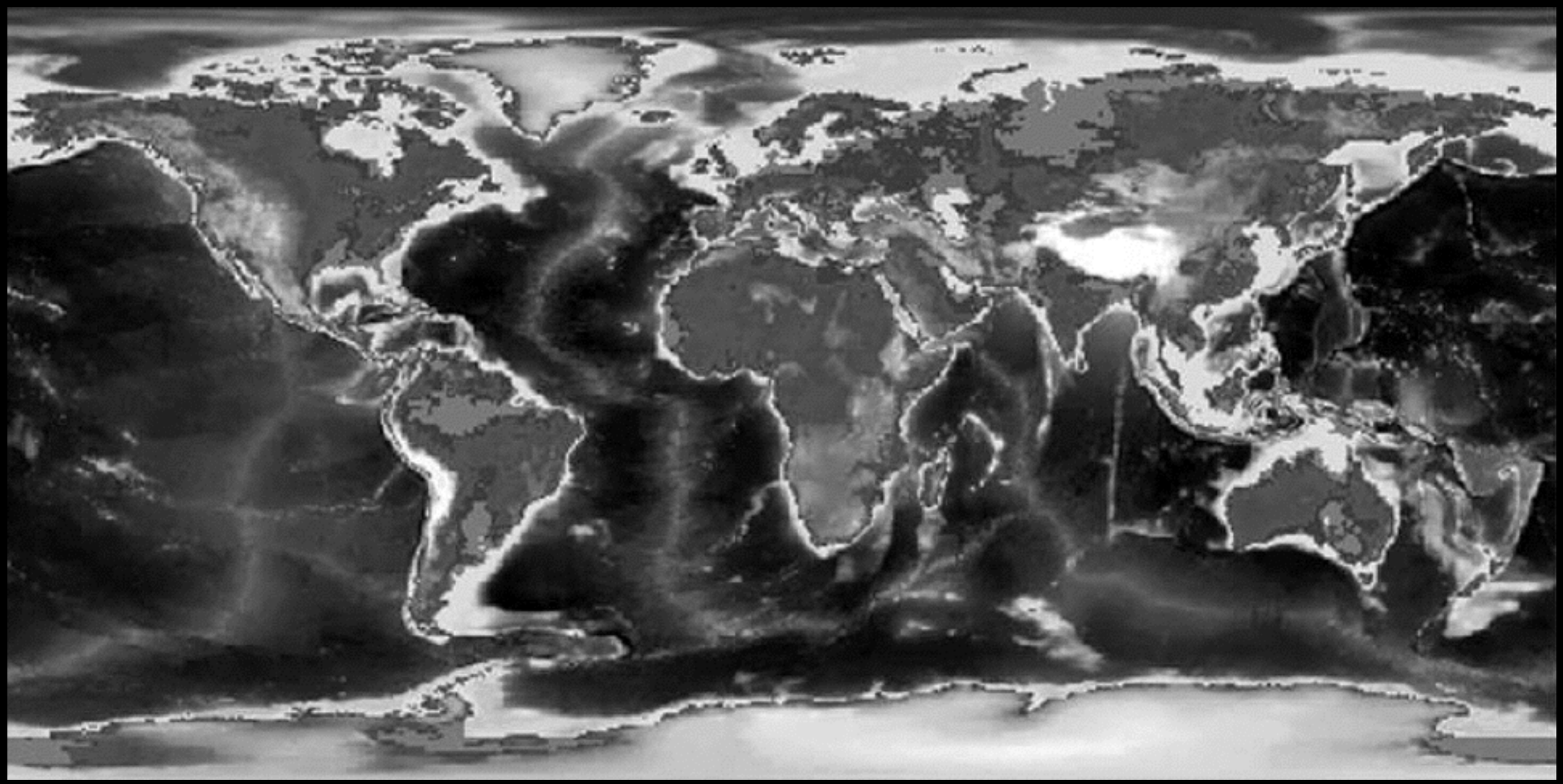


Tschmits Wikimedia Commons

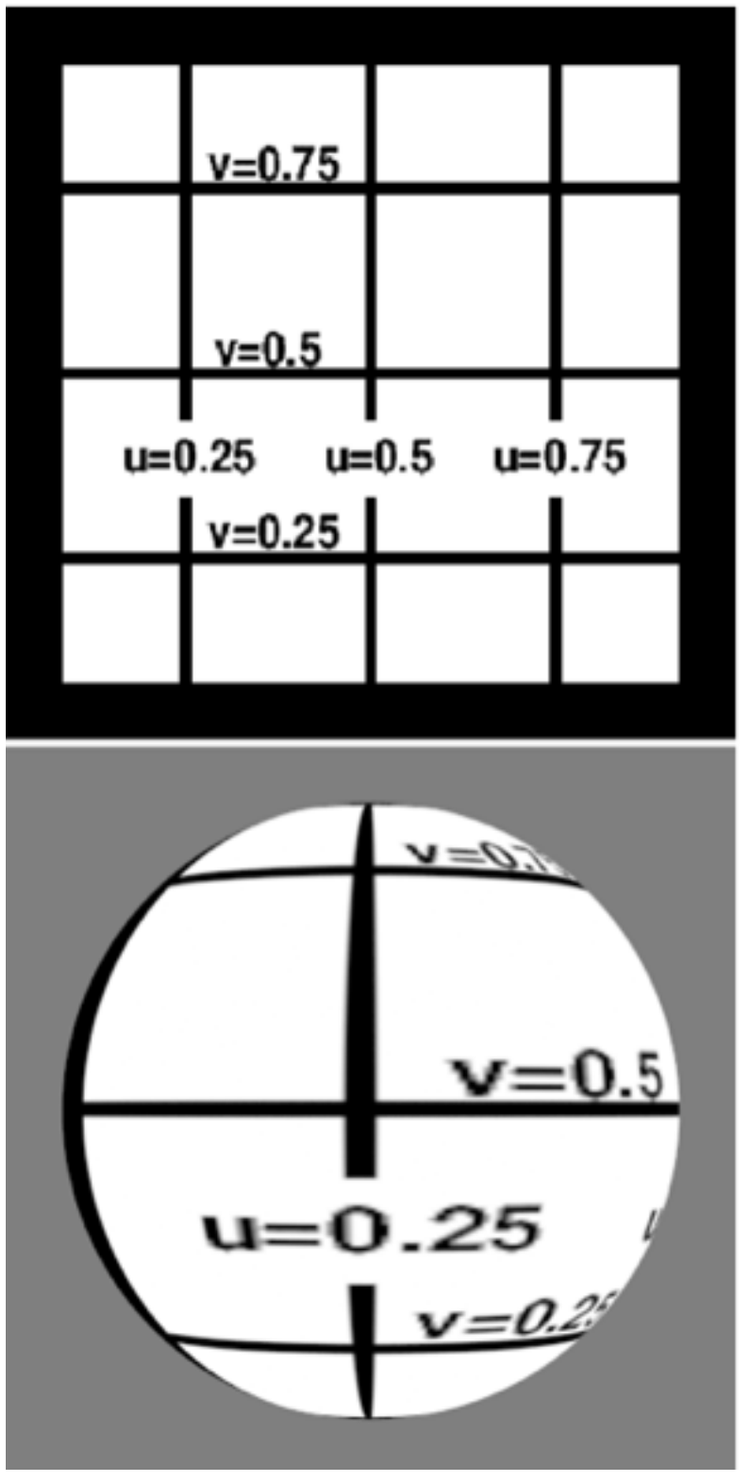
- 2D texture is parameterized by (u,v)
- Assign polygon vertices texture coordinates
- Interpolate within polygon

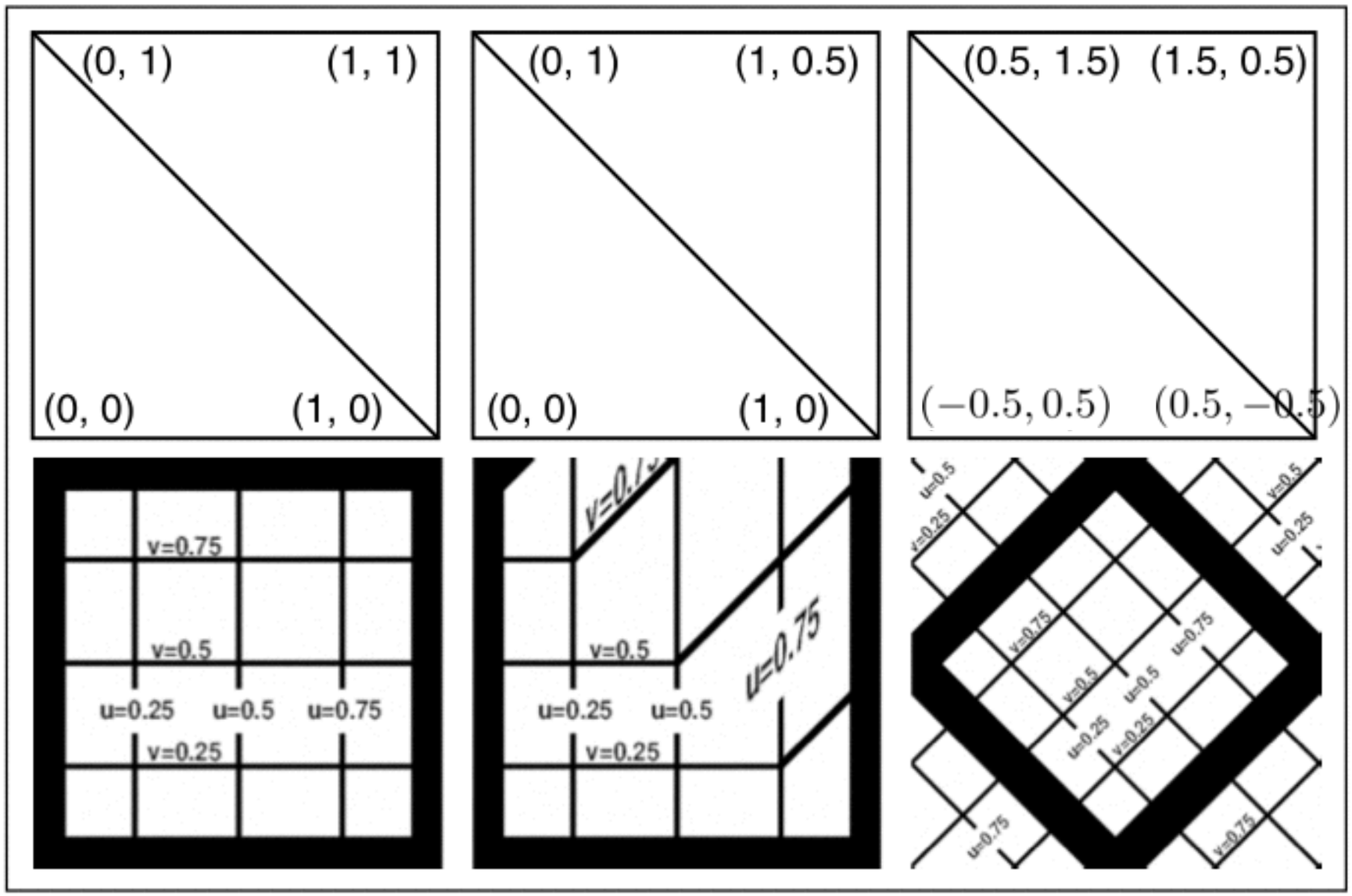






Texture Calibration

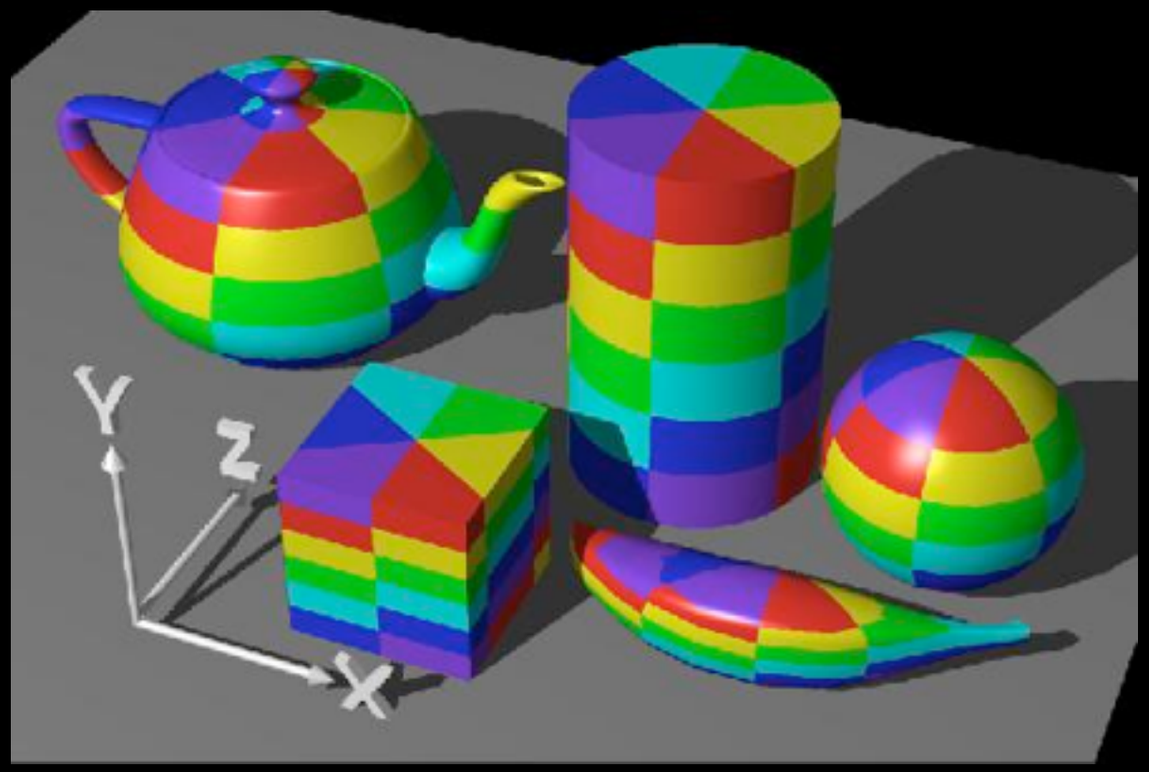


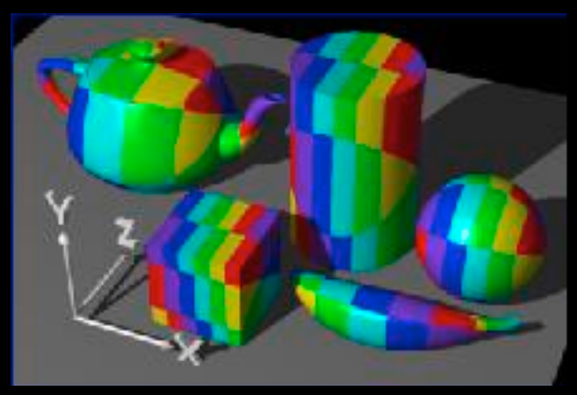


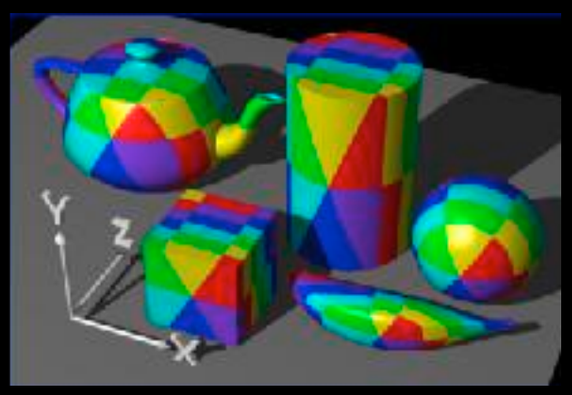
Cylindrical mapping

(x,y,z) -> (theta, h) -> (u,v)

[Rosalee Wolfe]

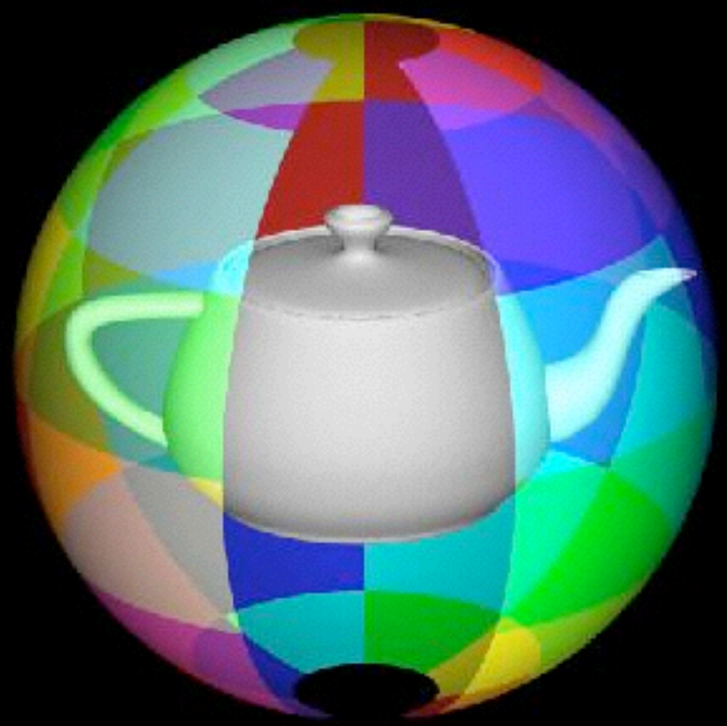




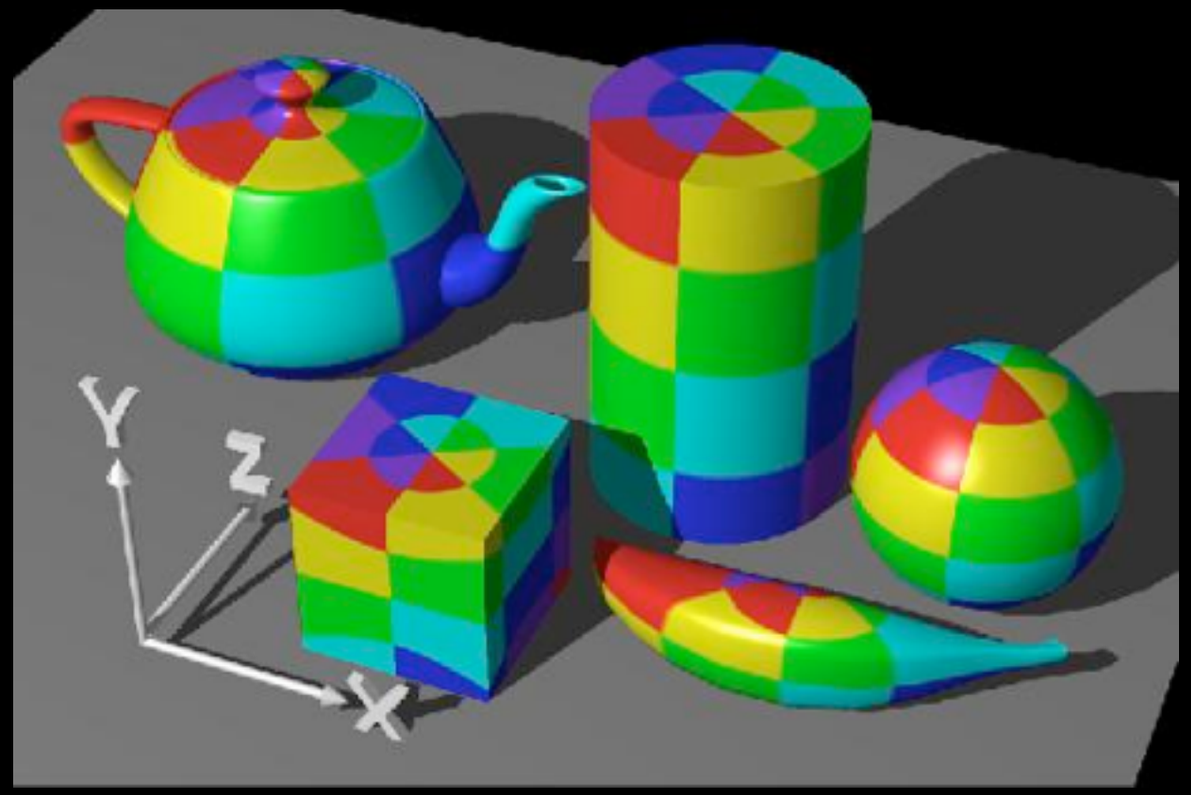


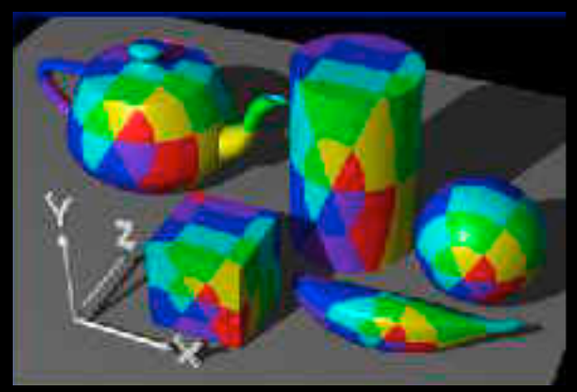
Spherical Mapping

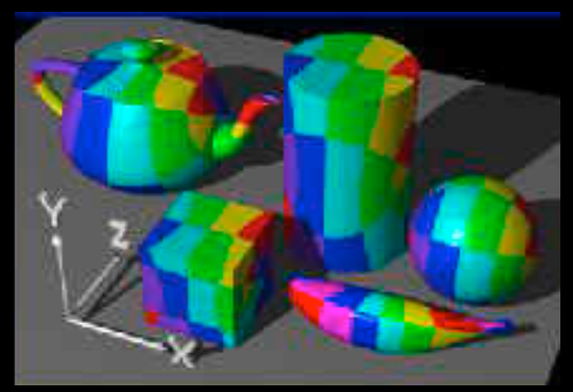
(x,y,z) -> (latitude,longitude)
-> (u,v)



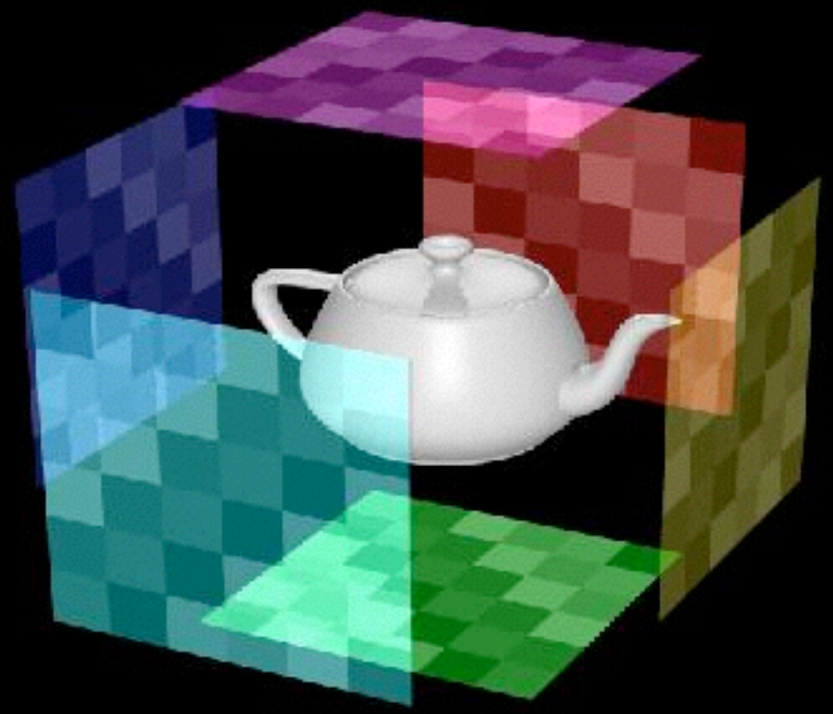
[Rosalee Wolfe]



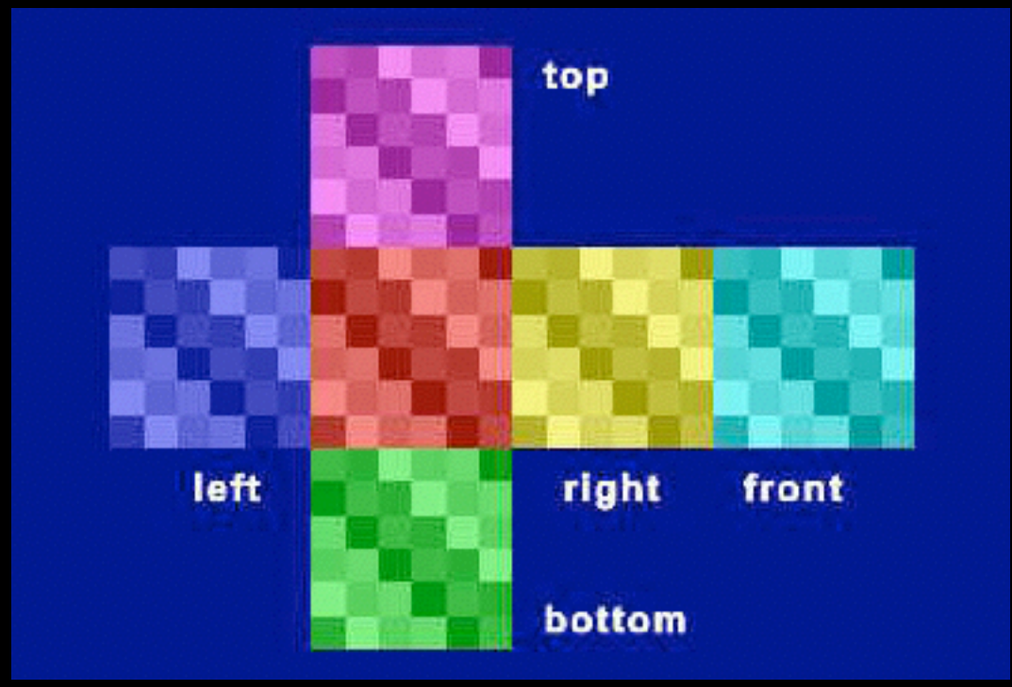


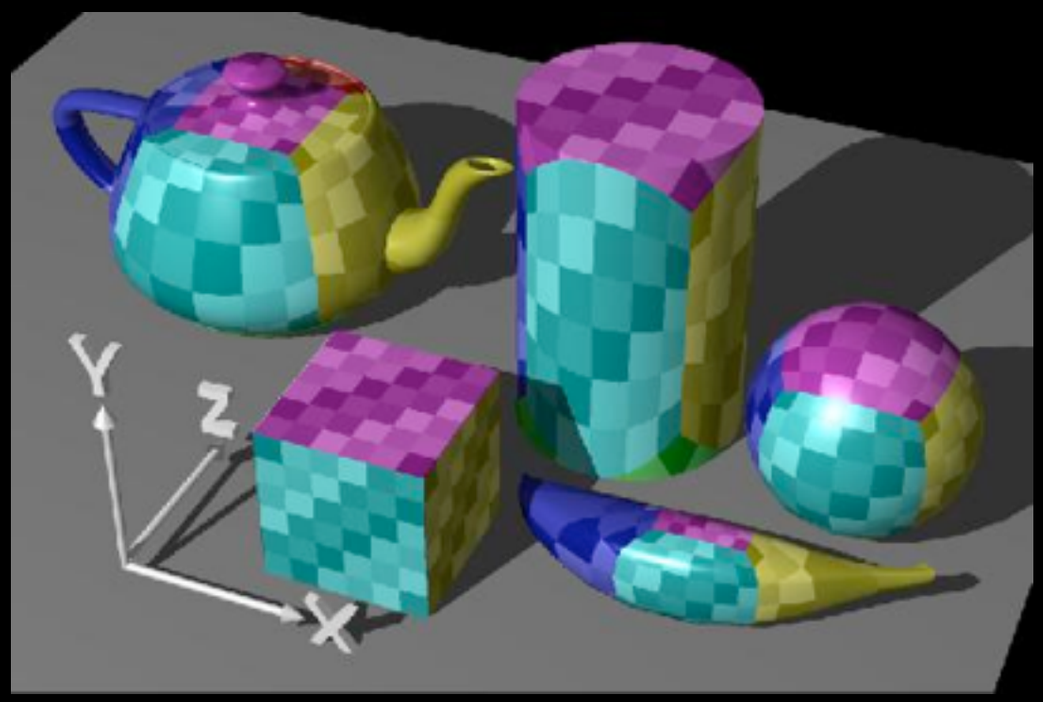


Box Mapping

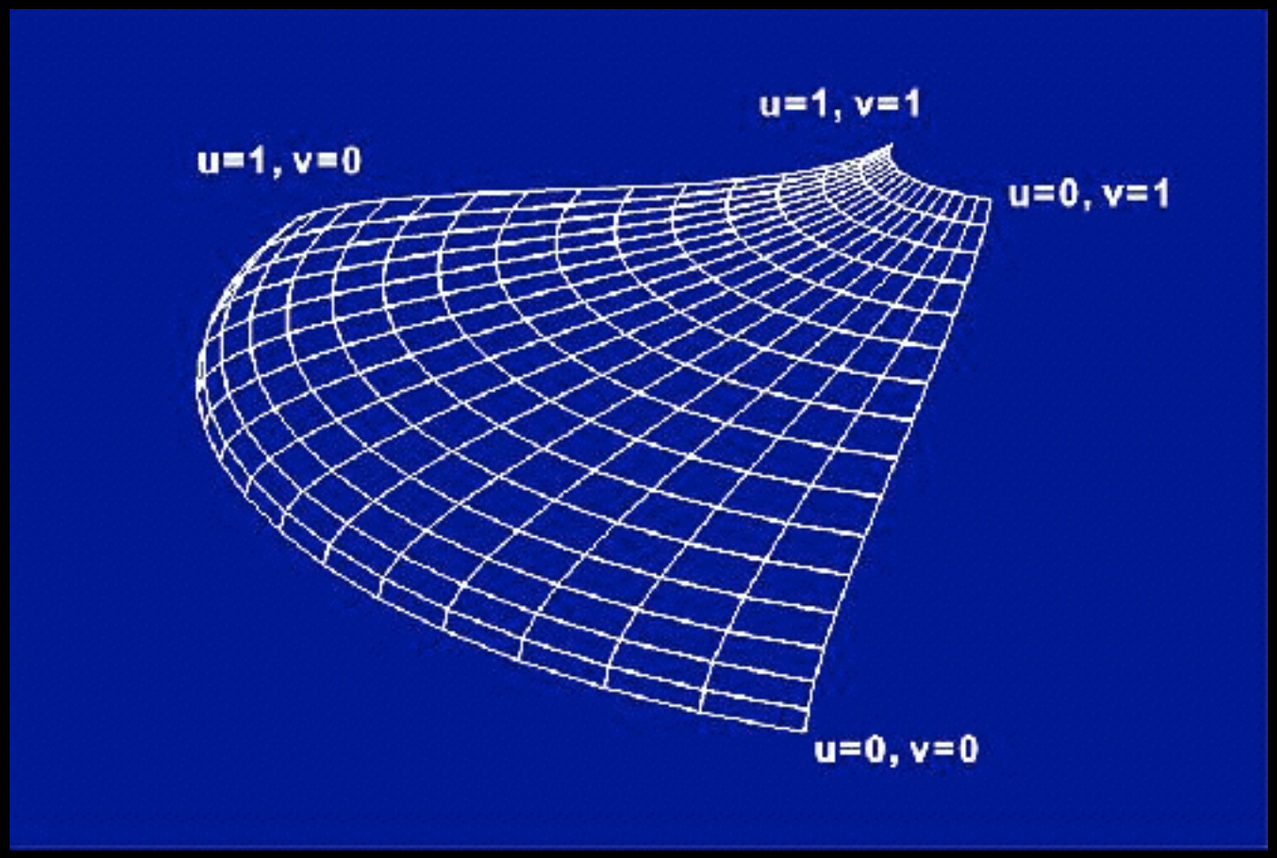


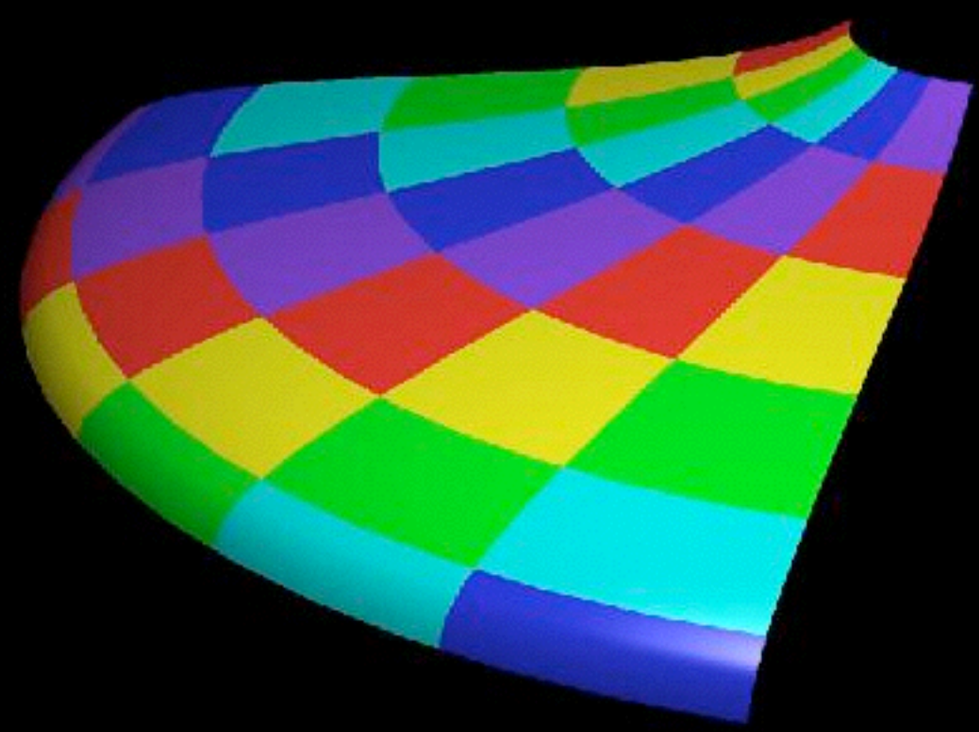
[Rosalee Wolfe]



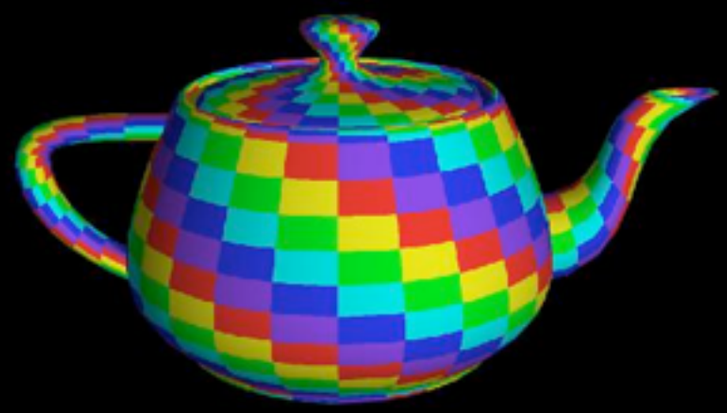


Parametric Surfaces





32 parametric patches

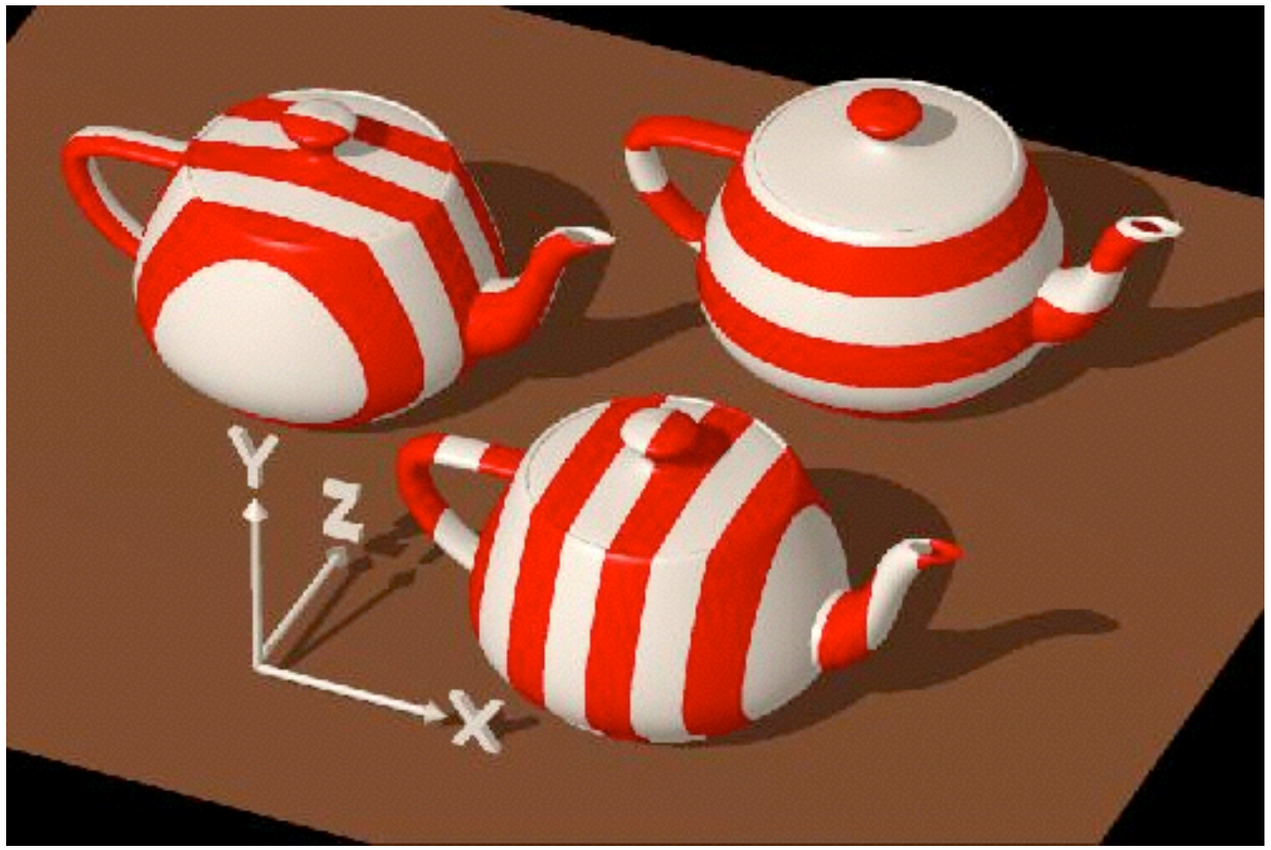


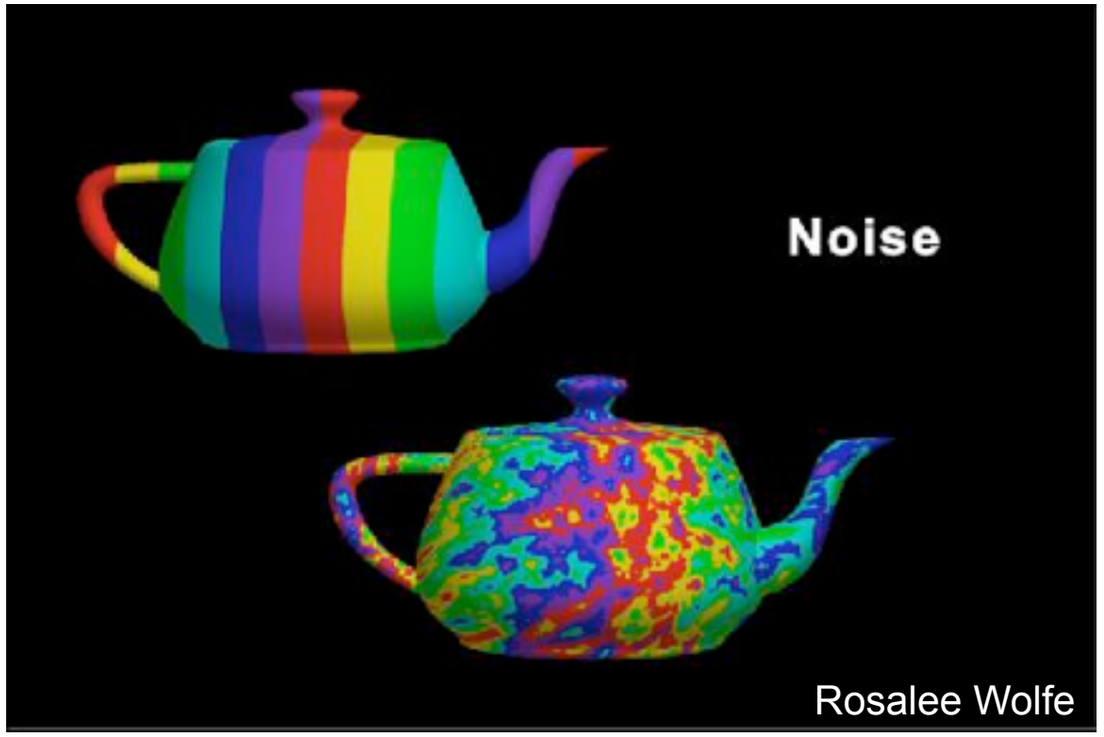
3D solid textures

[Dong et al., 2008]

can map object (x,y,z) directly to texture (u,v,w)

Procedural textures



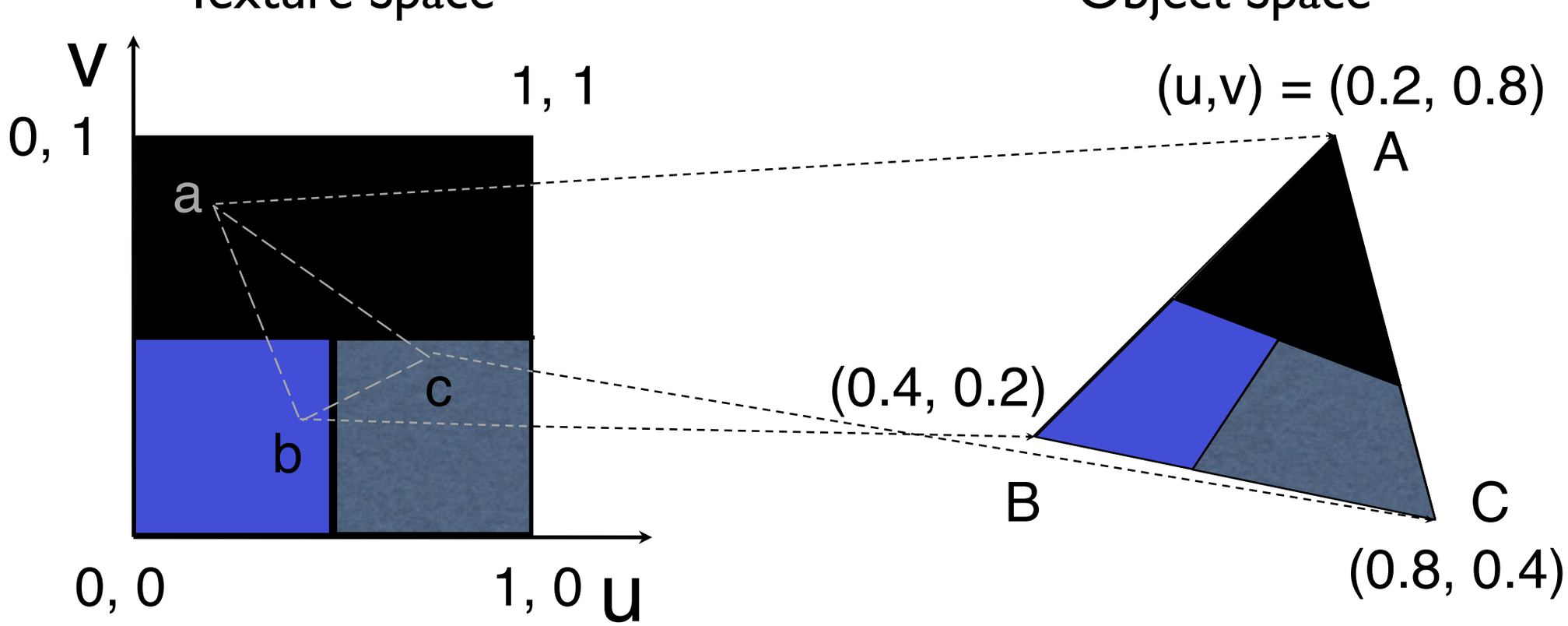


e.g., Perlin noise

Triangles

Texturing triangles

- Store (u,v) at each vertex
- interpolate inside triangles using barycentric coordinates



[Angel and Shreiner]

Texturing triangles

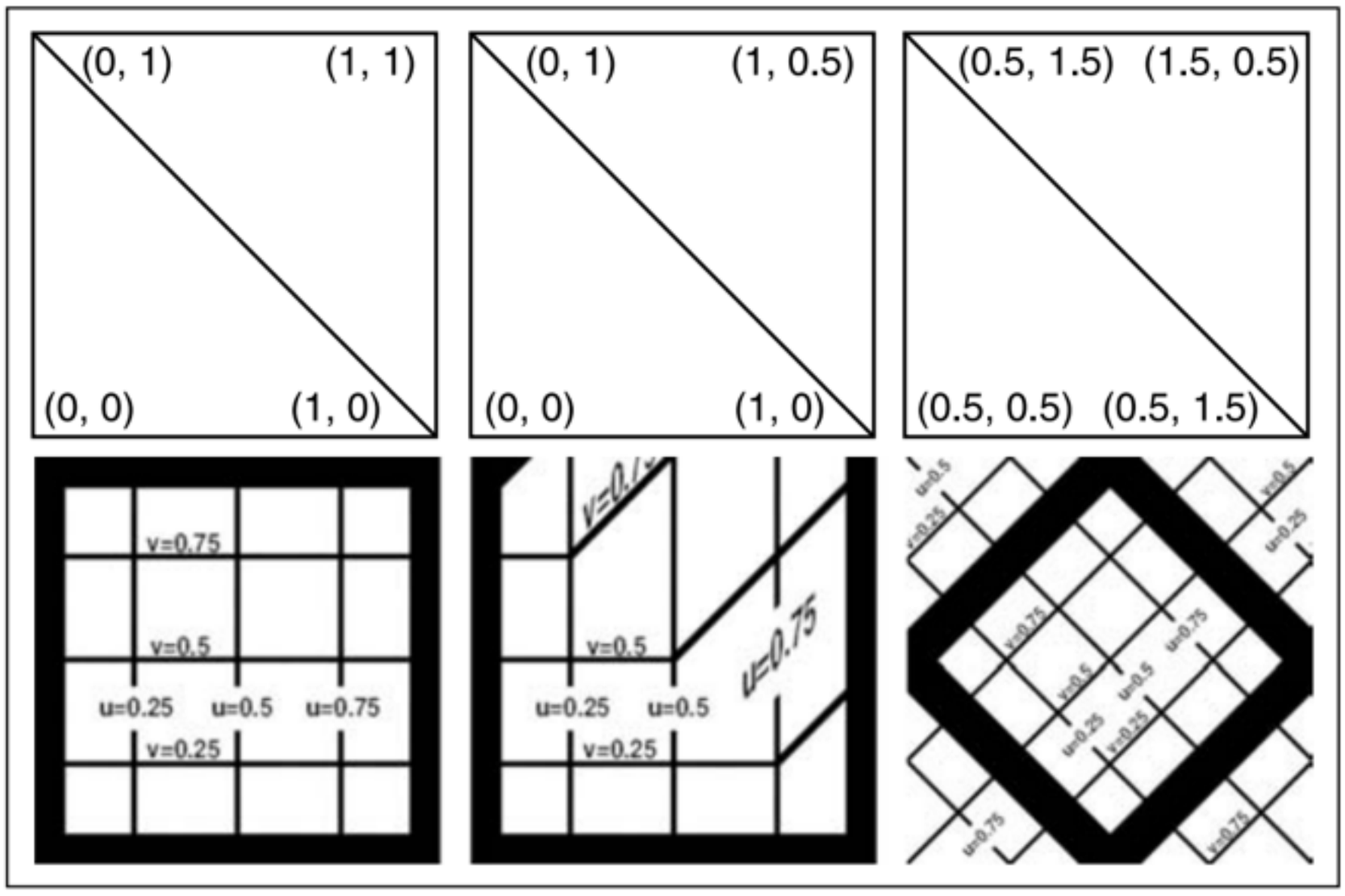
- Store (u,v) at each vertex
- interpolate inside triangles using barycentric coordinates

$$\mathbf{p}(\beta,\gamma) = \mathbf{a} + \beta(\mathbf{b}-\mathbf{a}) + \gamma(\mathbf{c}-\mathbf{a}).$$

$$u(\beta,\gamma) = u_a + \beta(u_b - u_a) + \gamma(u_c - u_a),$$
$$v(\beta,\gamma) = v_a + \beta(v_b - v_a) + \gamma(v_c - v_a).$$

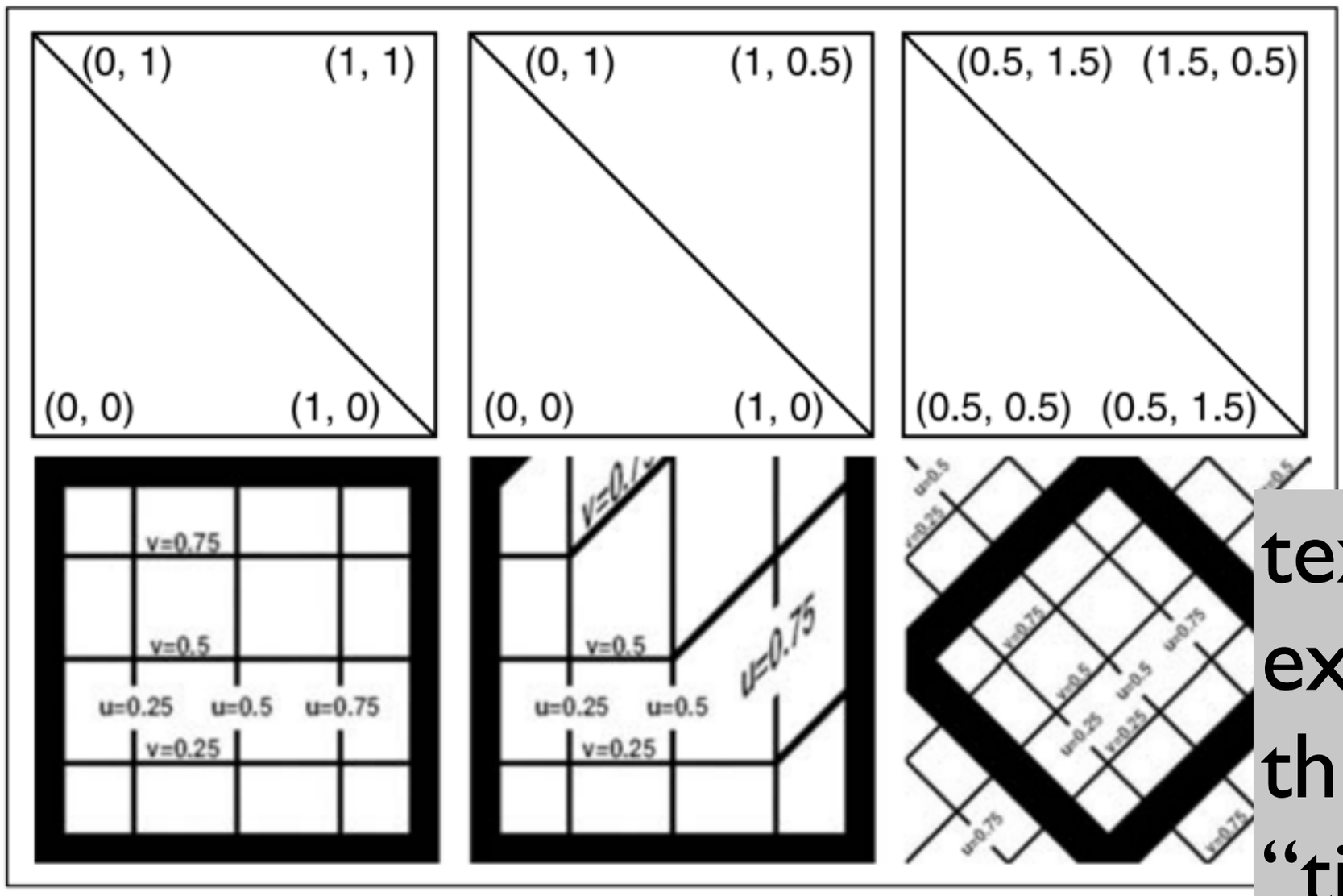
Texturing triangles

Choice of (u,v) makes big difference



Texturing triangles

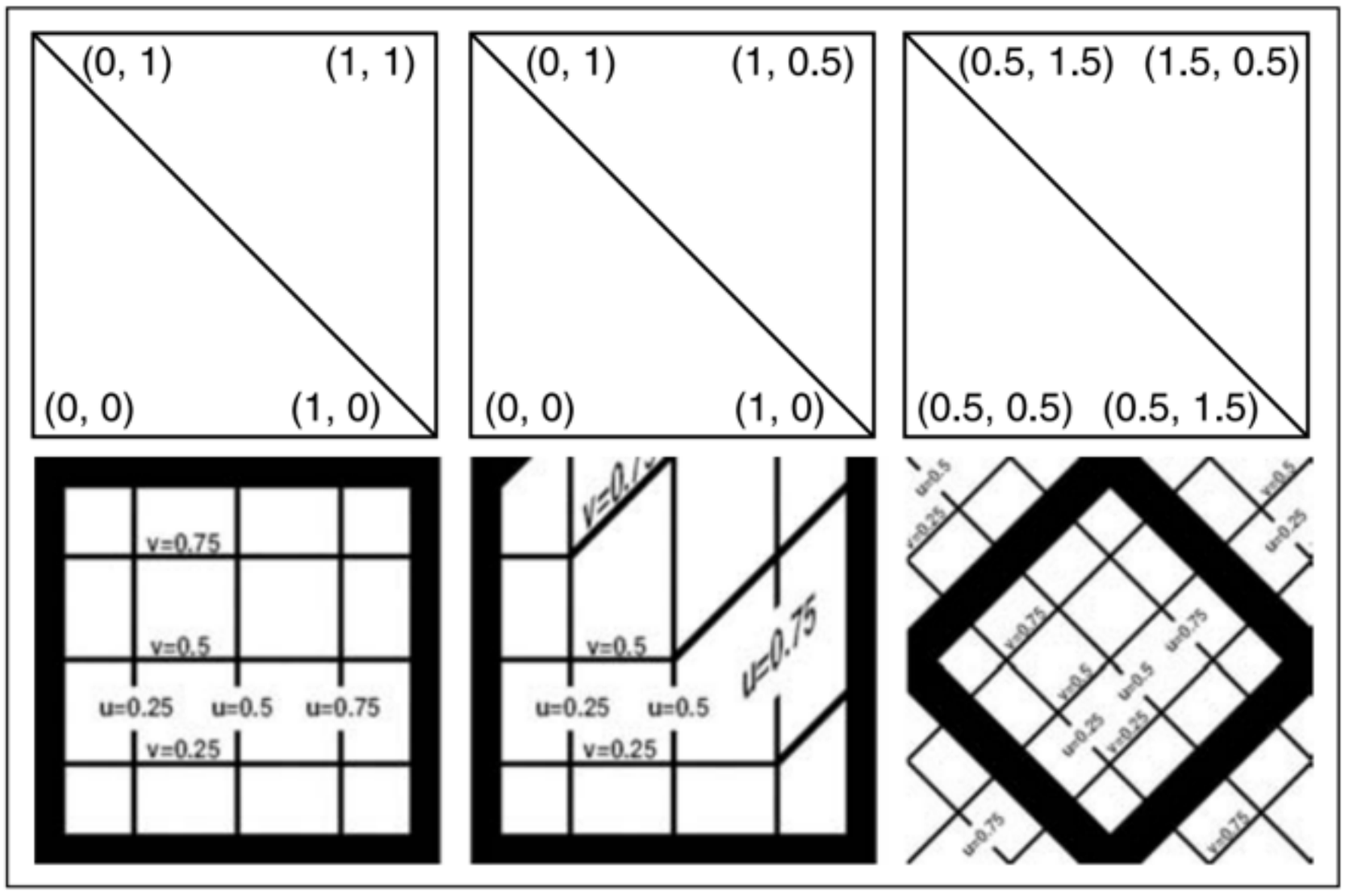
Choice of (u,v) makes big difference



texture extended through "tiling"

Texturing triangles

Choice of (u,v) makes big difference

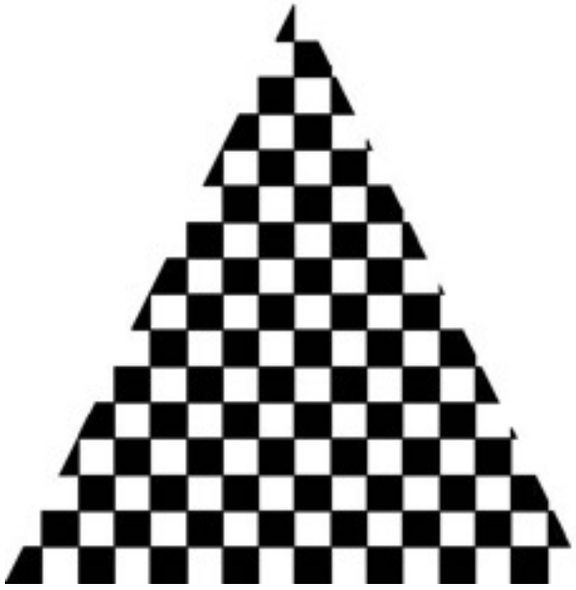


Textures in OpenGL

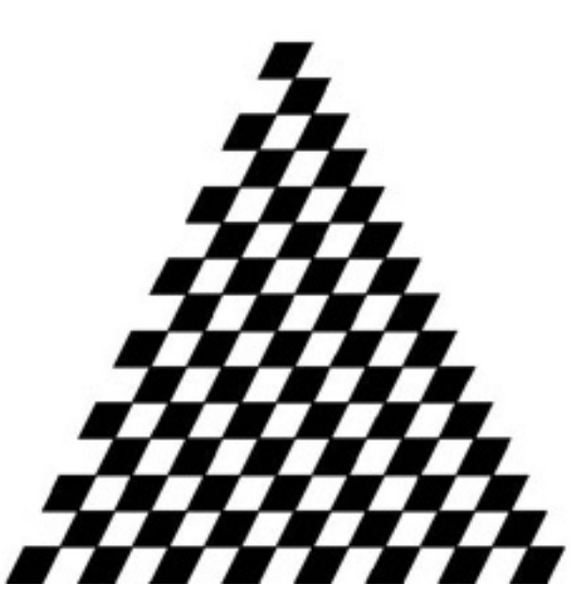
- Assign (u,v) to vertices

`glTexCoord*()`

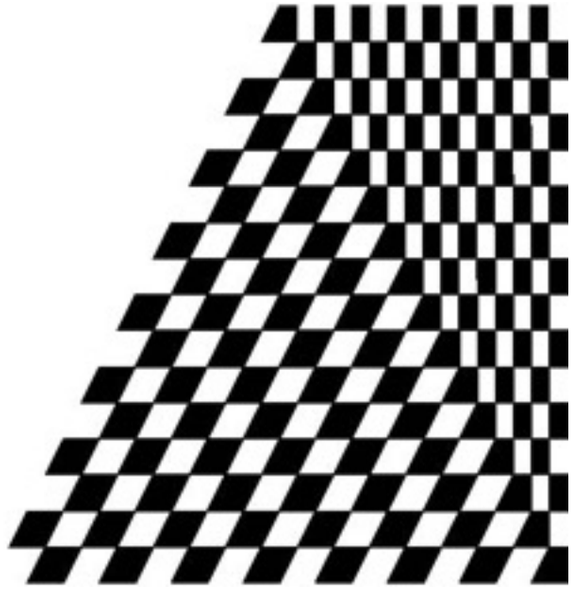
- OpenGL then uses interpolation for triangle interior



good selection
of tex coordinates

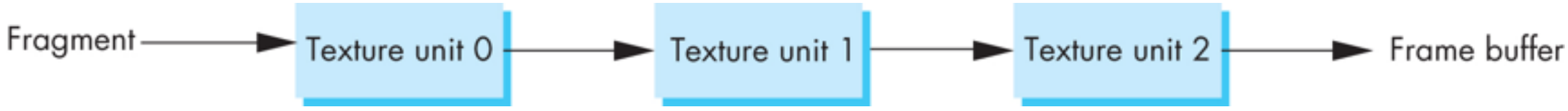


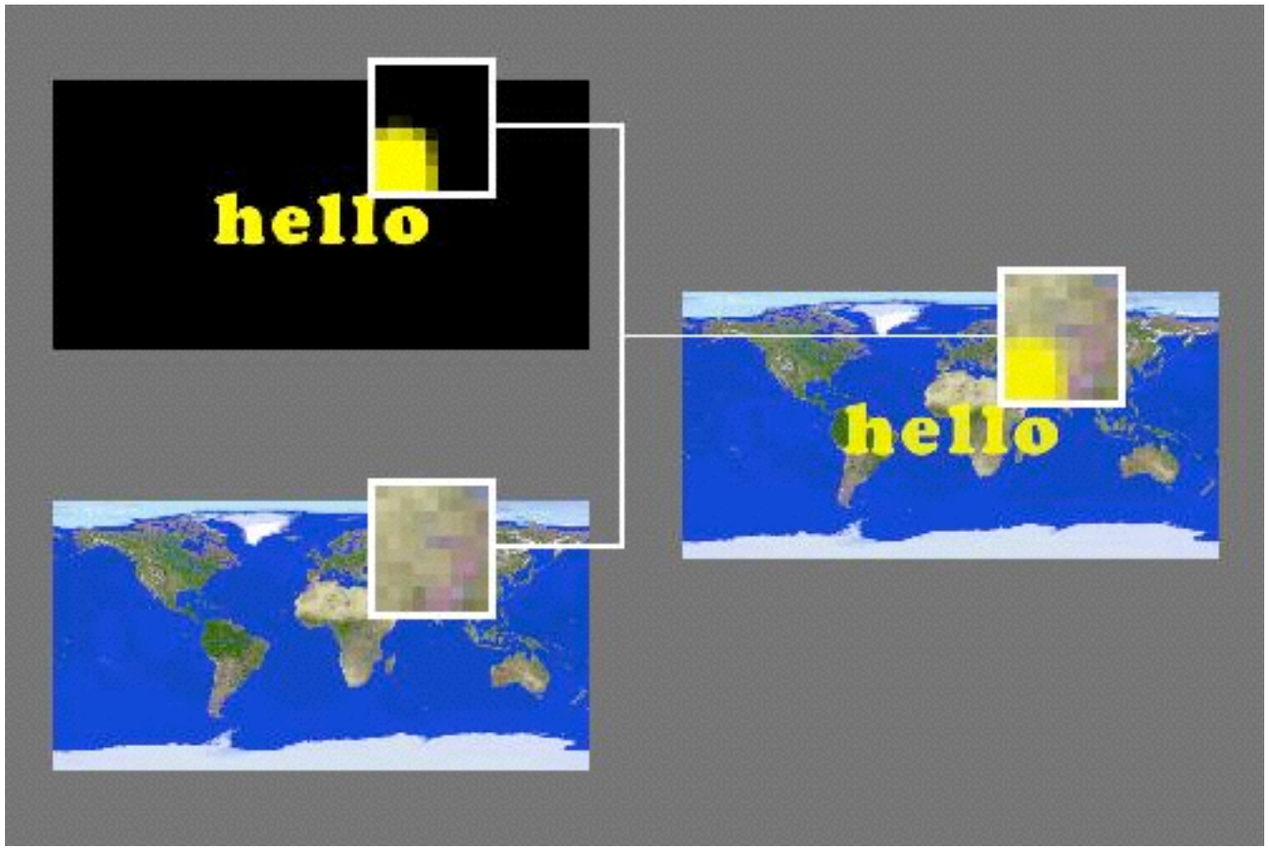
poor selection
of tex coordinates



texture stretched
over trapezoid
showing effects of
bilinear interpolation

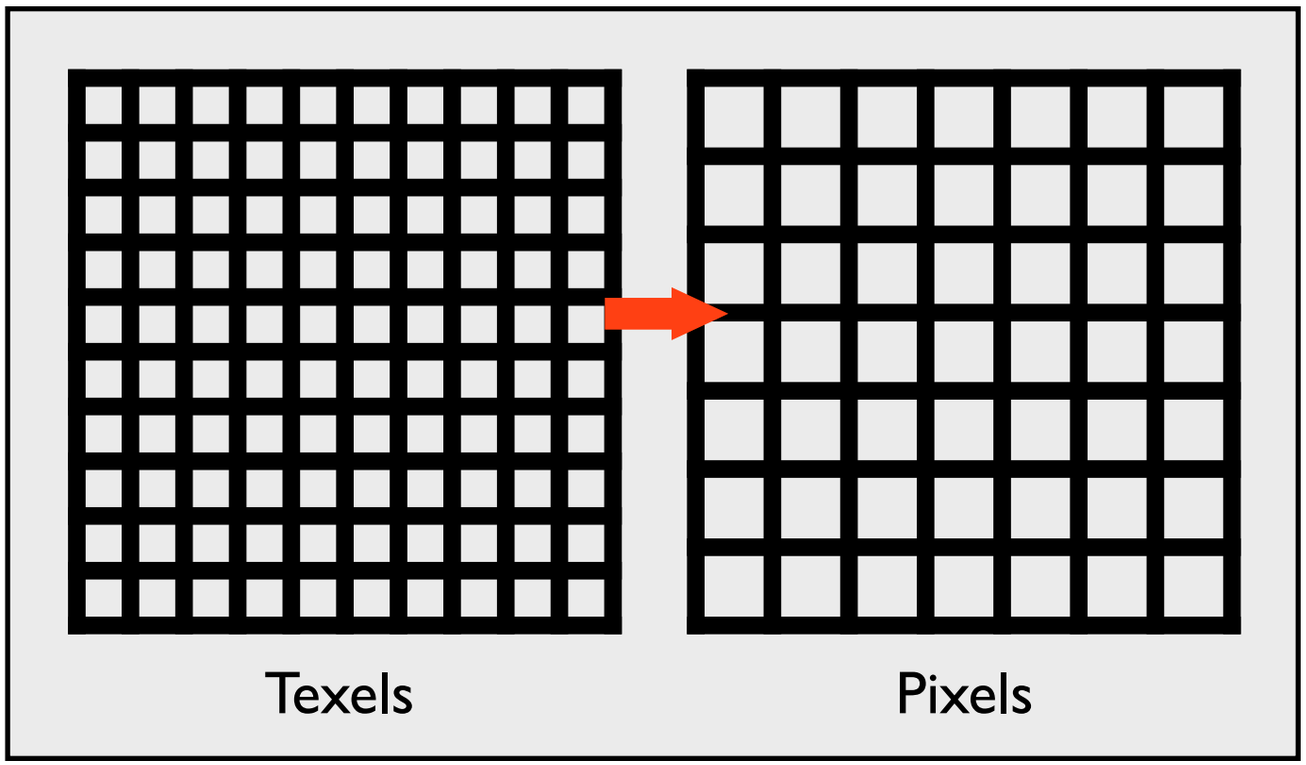
Multitexturing

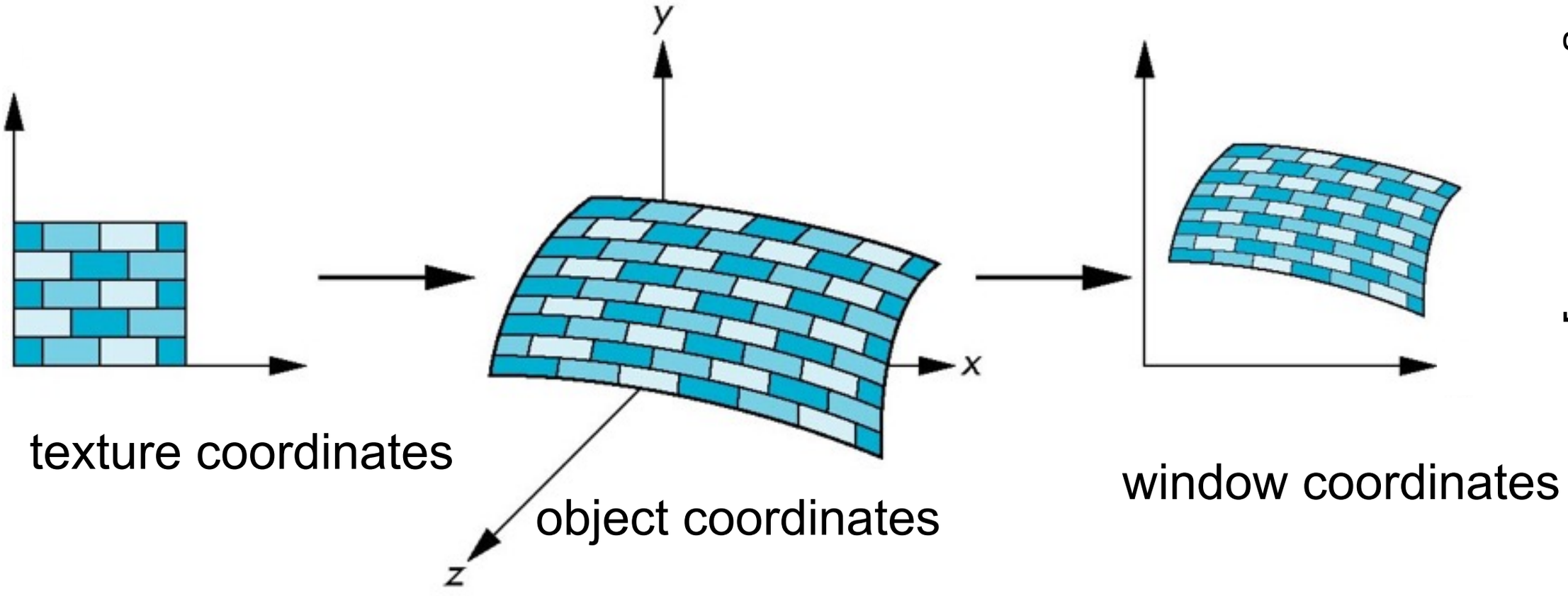




Texture Sampling

Texture Mapping

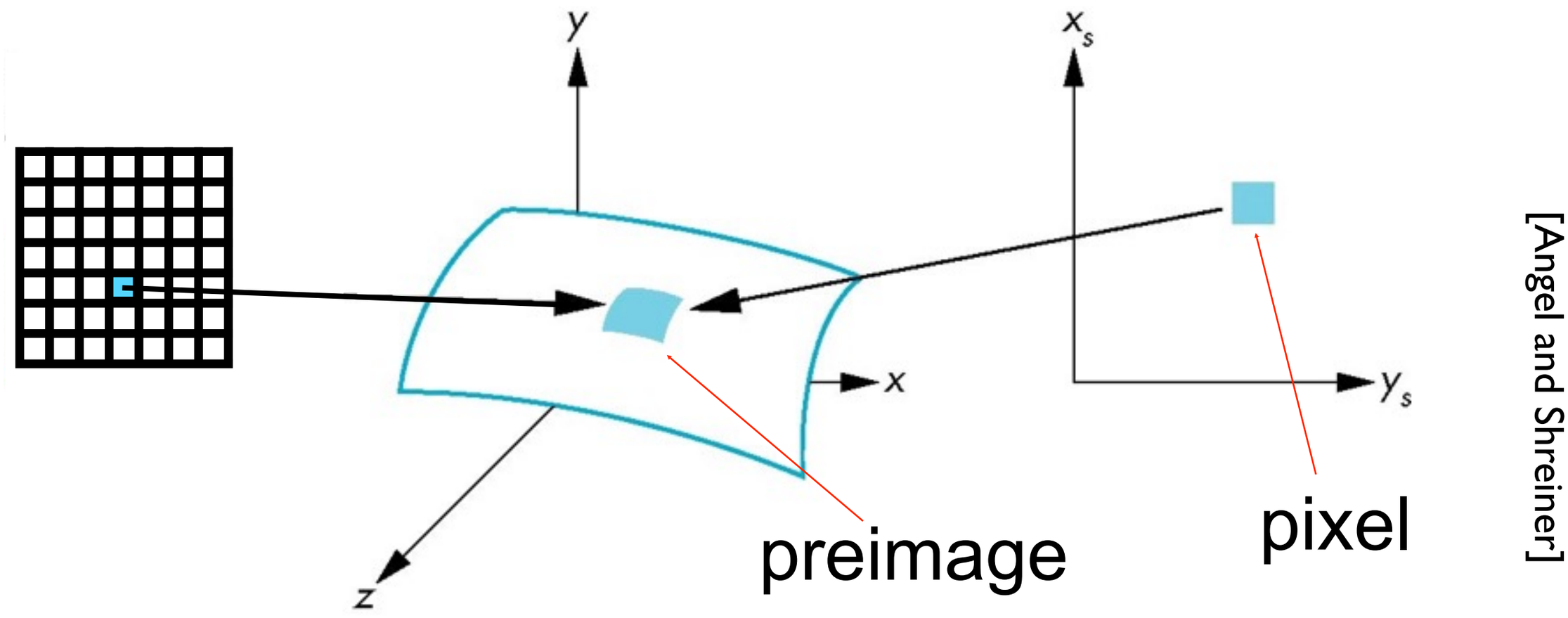




[Angel and Shreiner]

Point Sampling

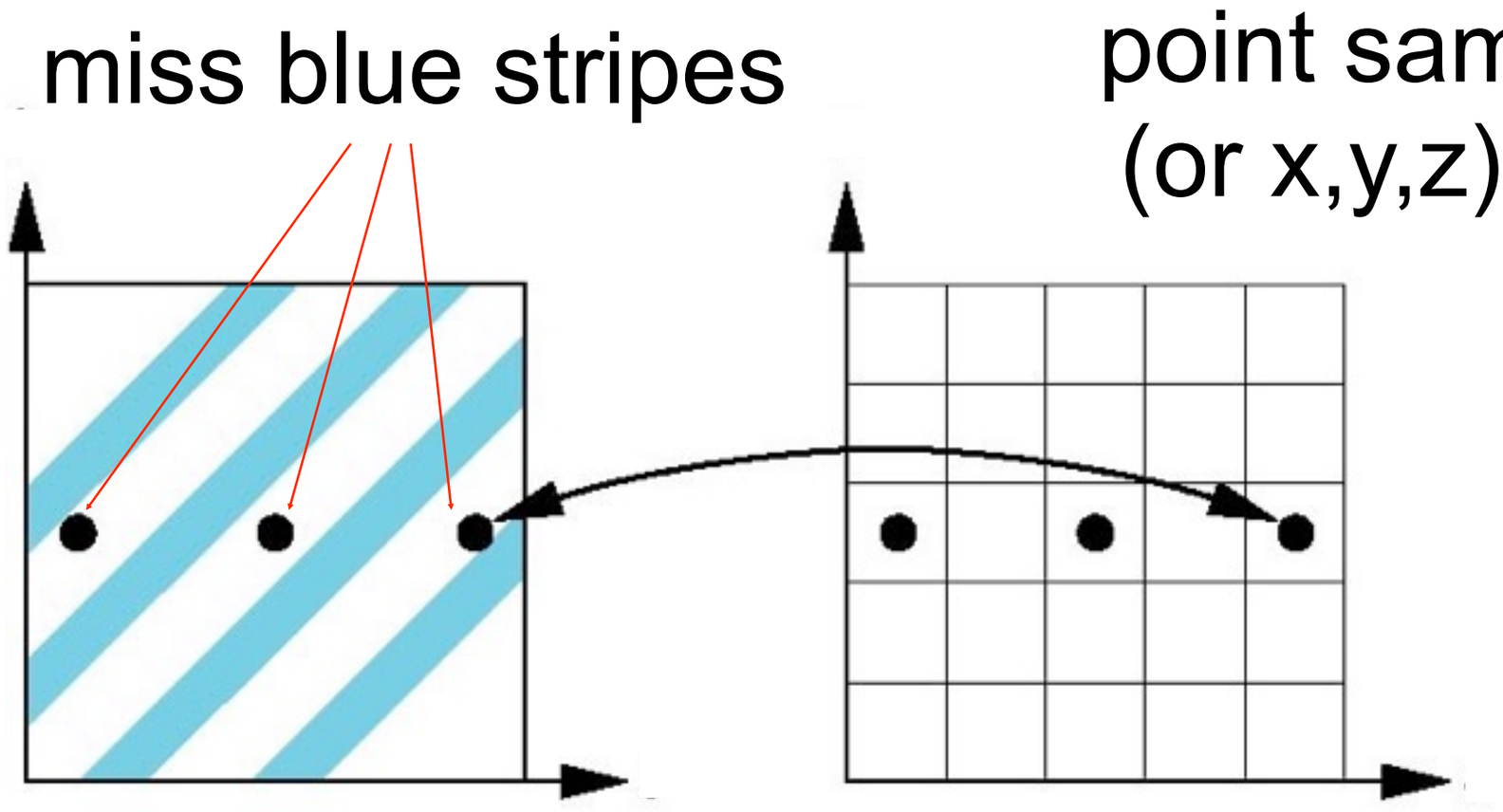
Map back to texture image and use the **nearest texel**



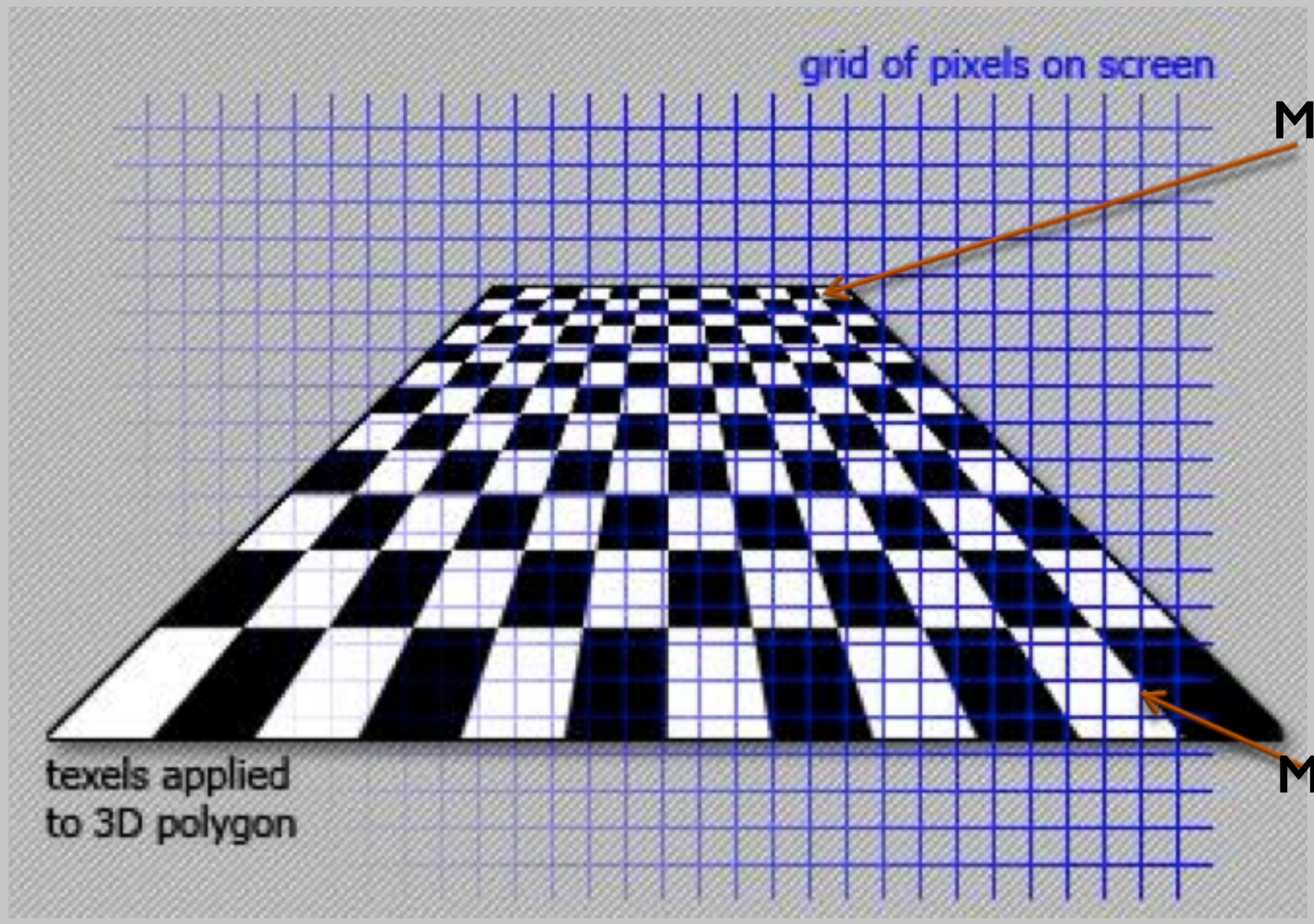
[Angel and Shreiner]

Aliasing

Point sampling of the texture can lead to aliasing artifacts



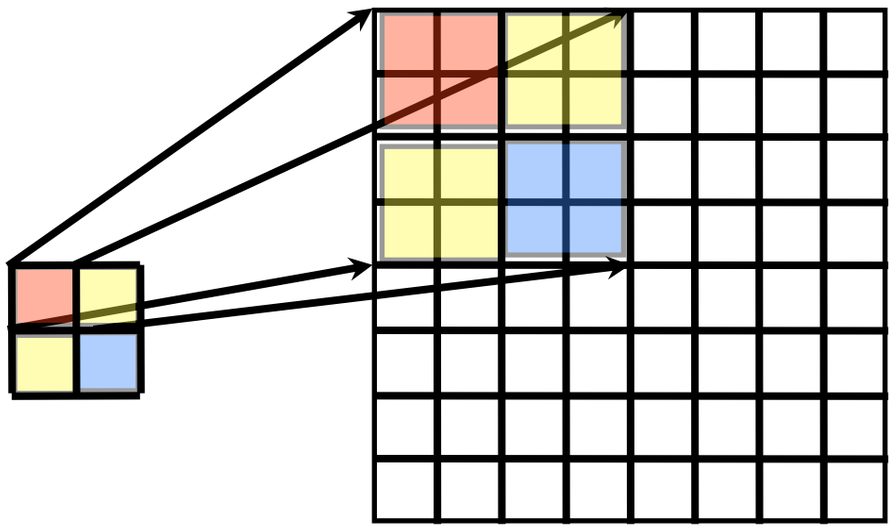
Magnification and Minification



Magnification and Minification

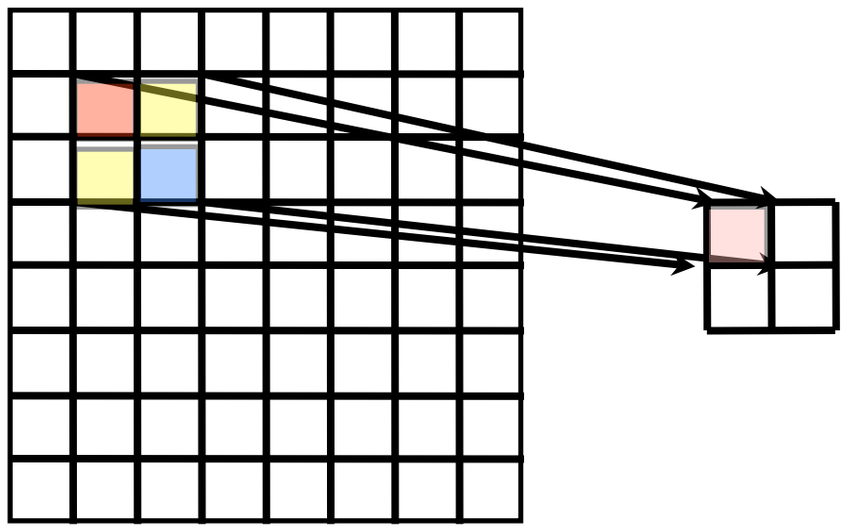
More than one texel can cover a pixel (*minification*) or
more than one pixel can cover a texel (*magnification*)

Can use point sampling (nearest texel) or linear filtering
(2 x 2 filter) to obtain texture values



Texture Pixels

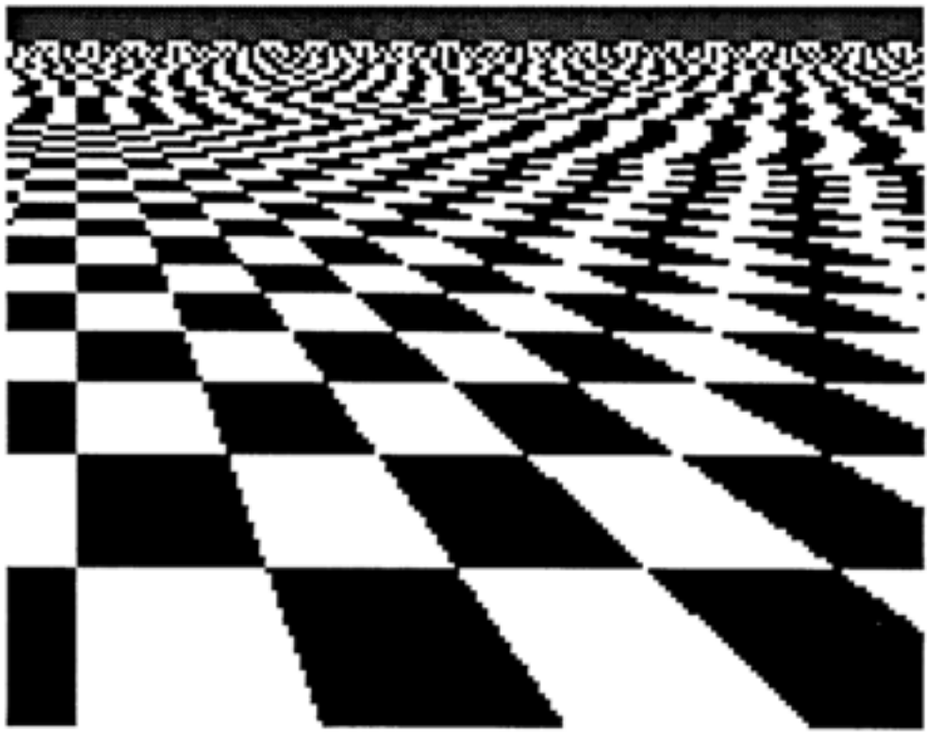
Magnification

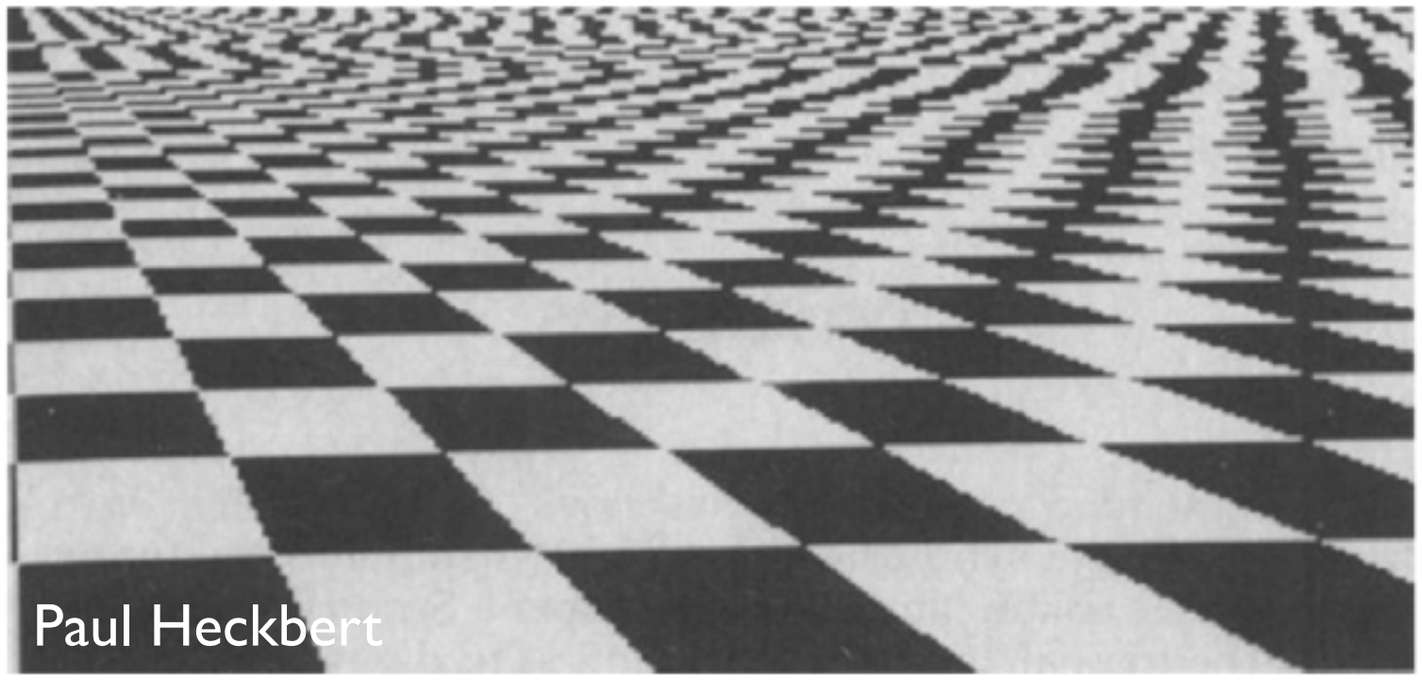


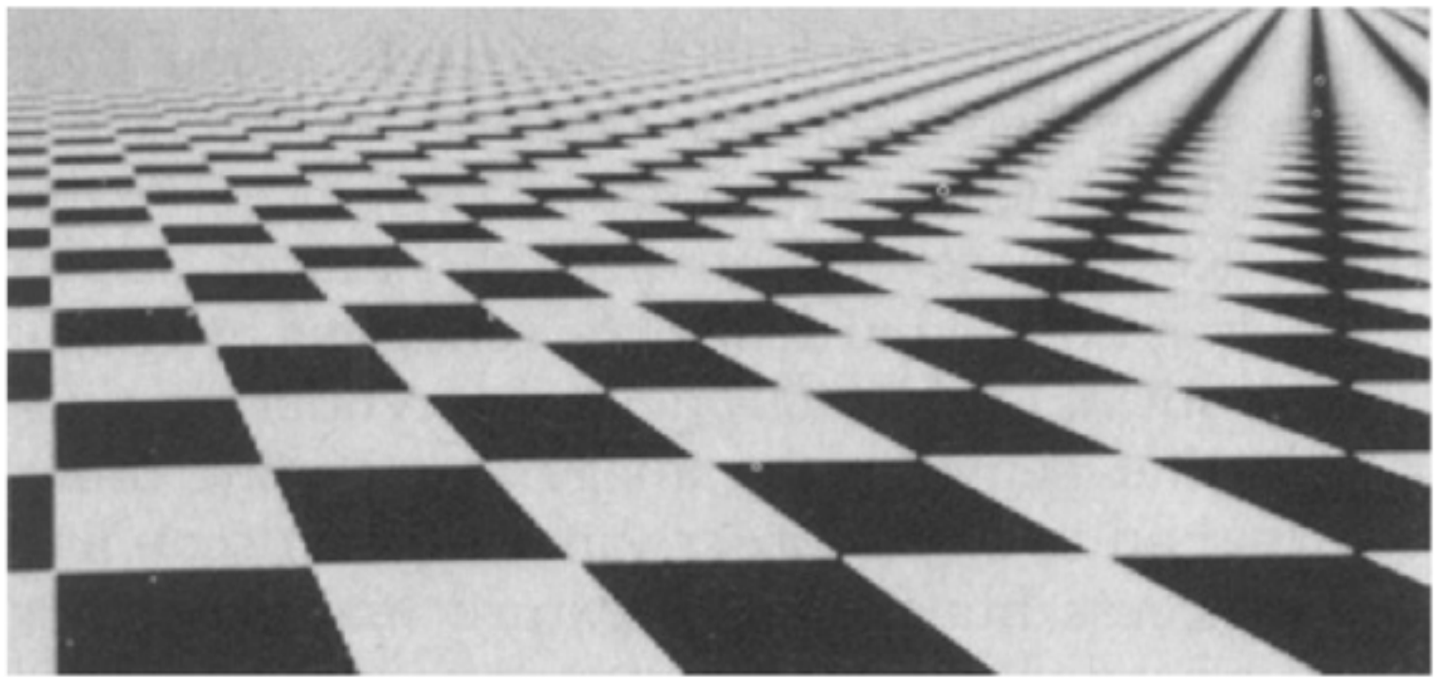
Texture Pixels

Minification

Aliasing artifacts



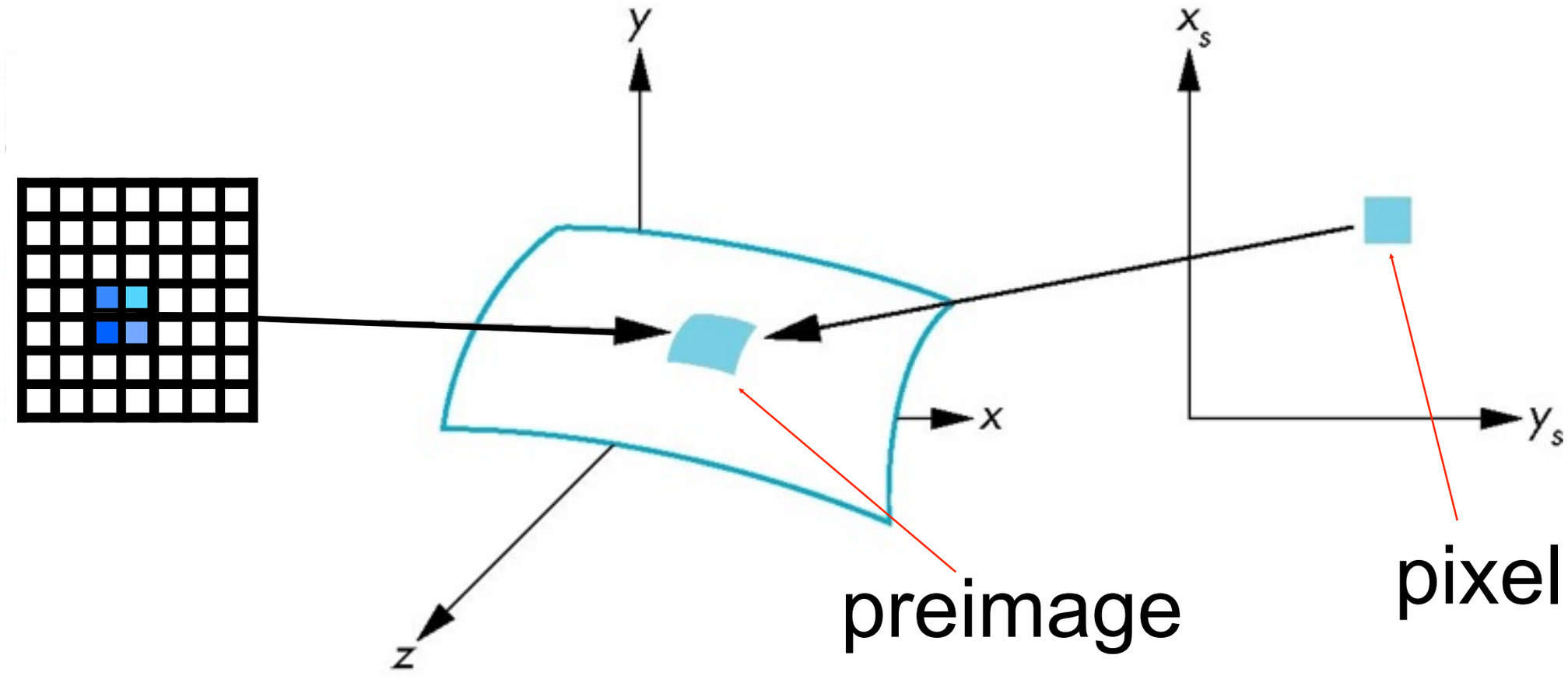




We apply **filtering** to reduce aliasing artifacts

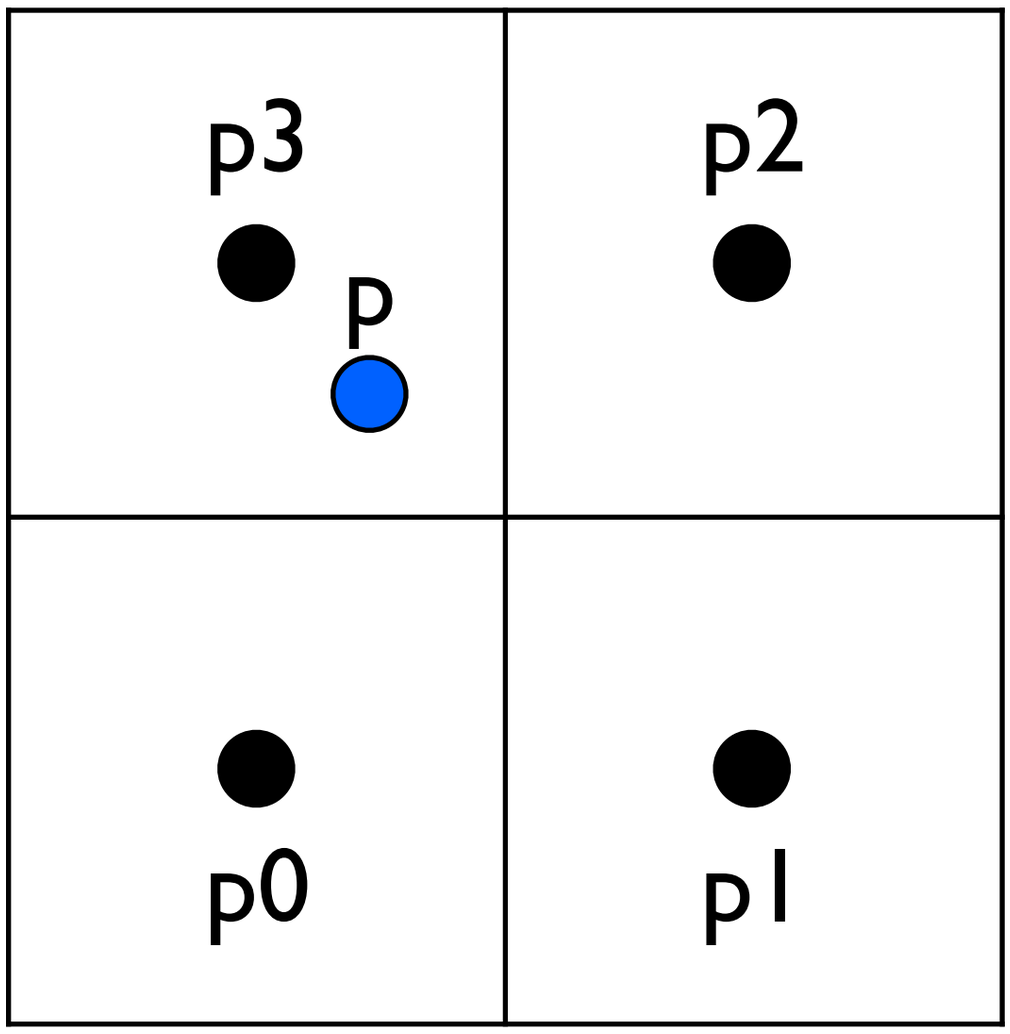
Area Averaging

A better but slower option is to use **area averaging**



[Angel and Shreiner]

Use bilinear filtering



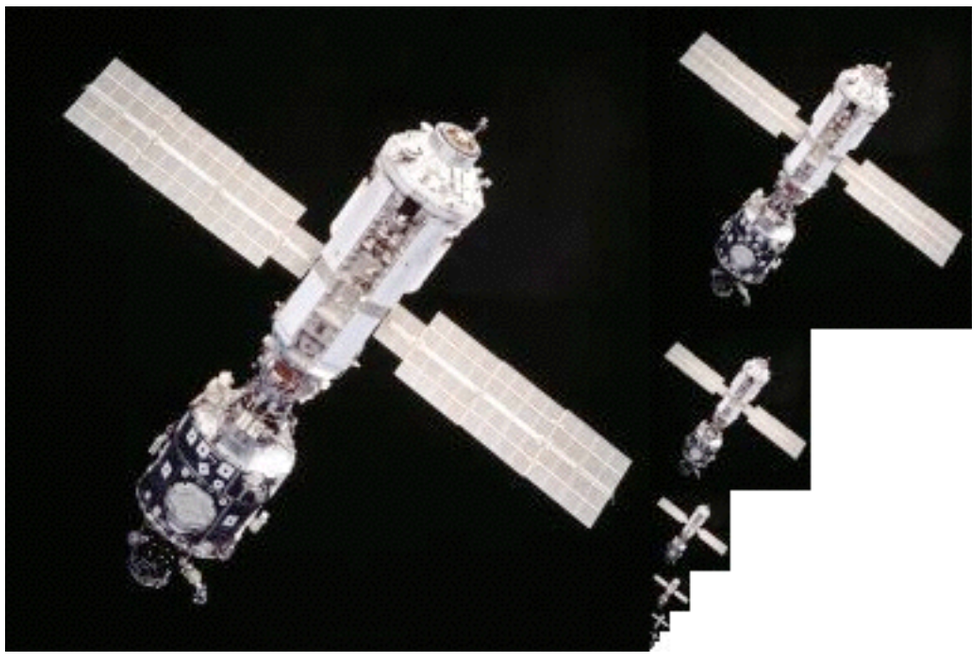
p = ?

Wikipedia

nearest neighbor **bilinear** **bicubic**

mitigate magnification artifacts

Mipmapping



Togikun, Wikimedia Commons

128×128, 64×64, 32×32, 16×16, 8×8, 4×4, 2×2, 1×1

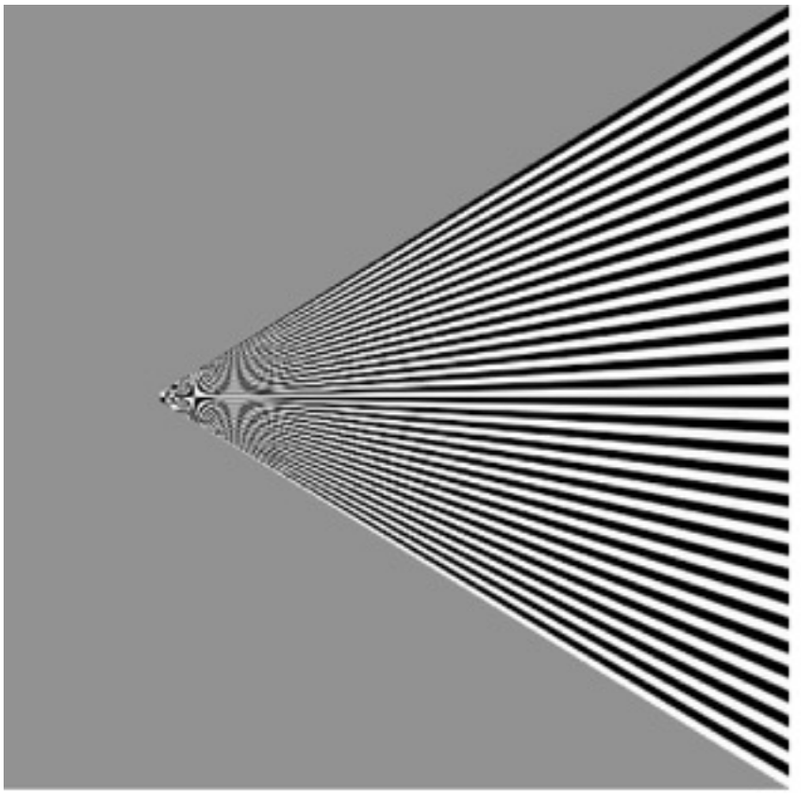
Reduce minification artifacts

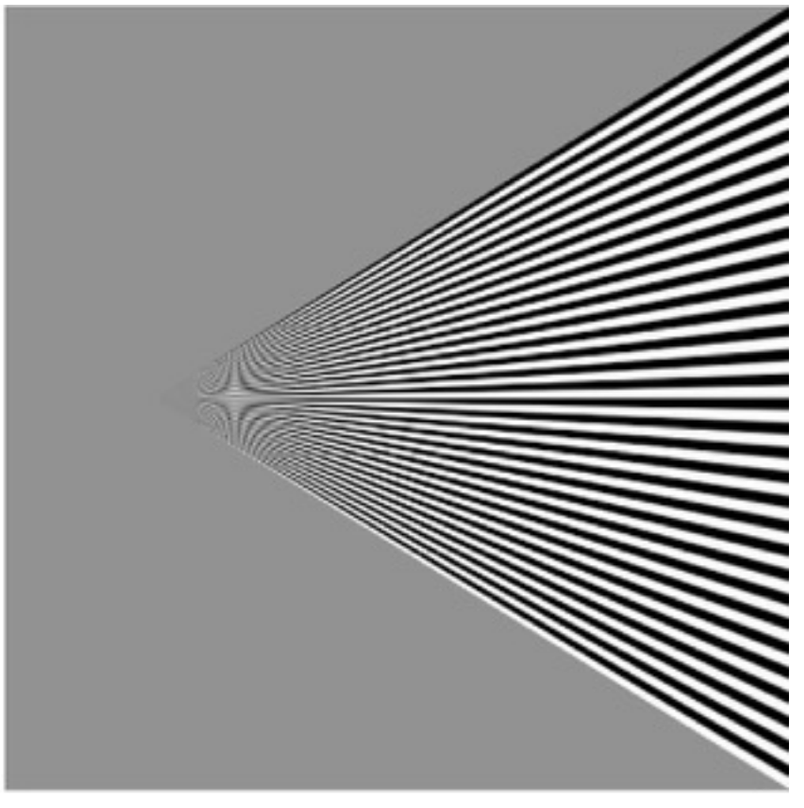
Prefilter the texture to obtain reduced resolutions

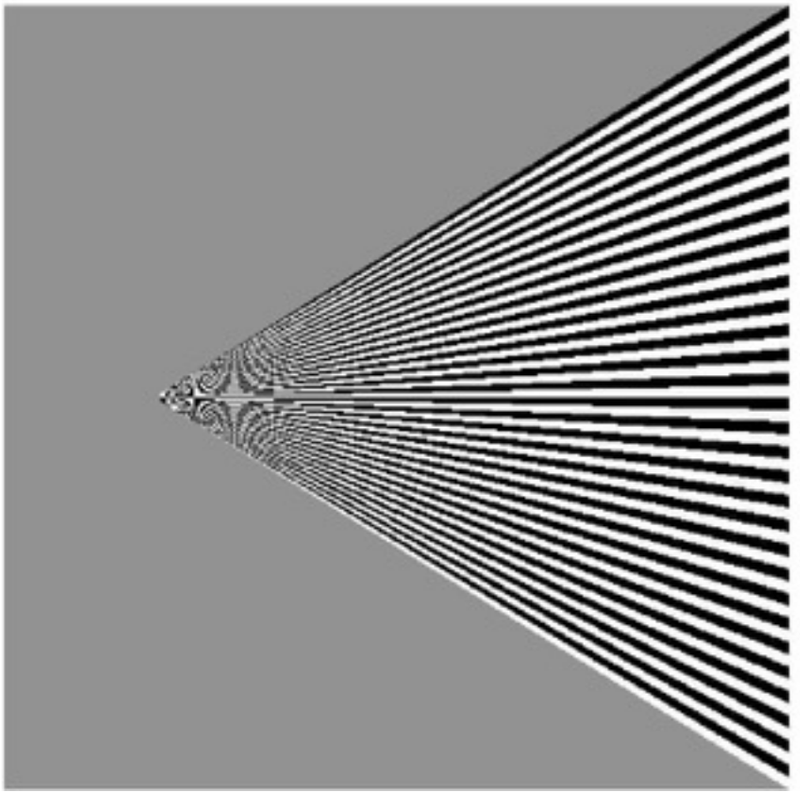
Requires 1/3 more space

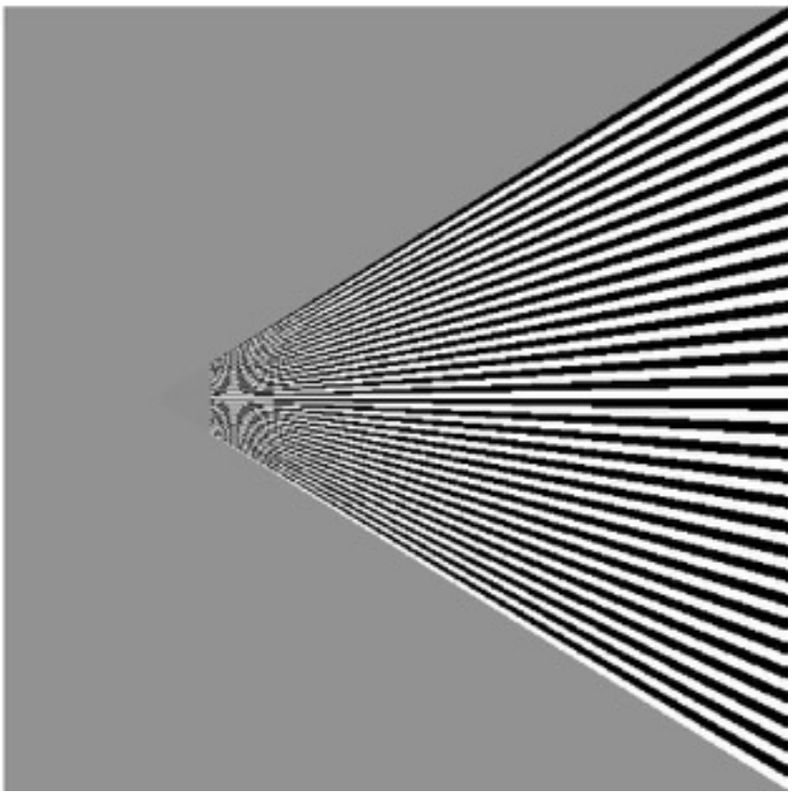
Get a texture hierarchy indexed by level

[Angel and Shreiner]

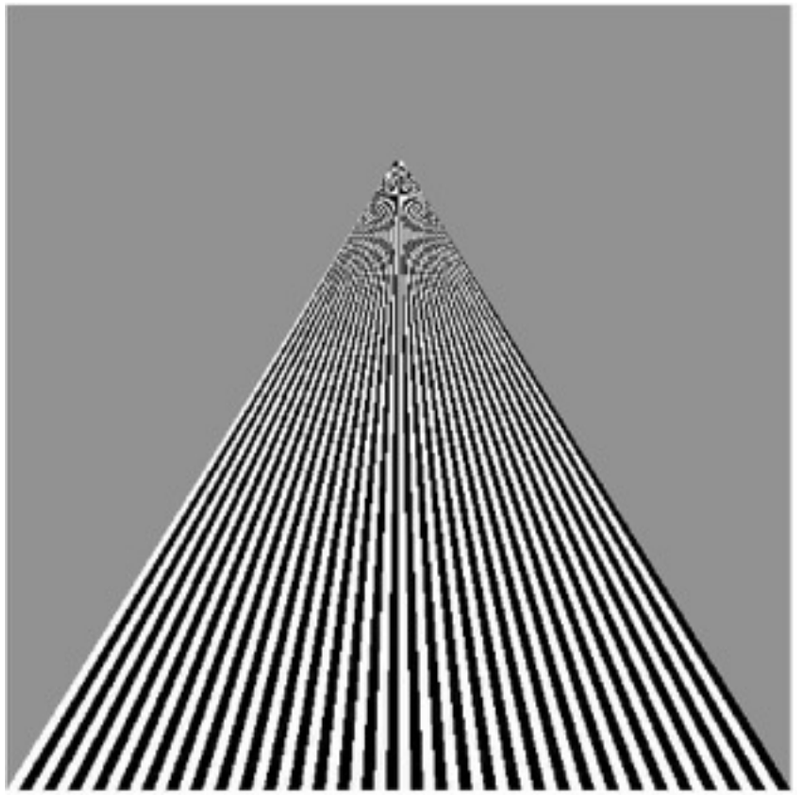




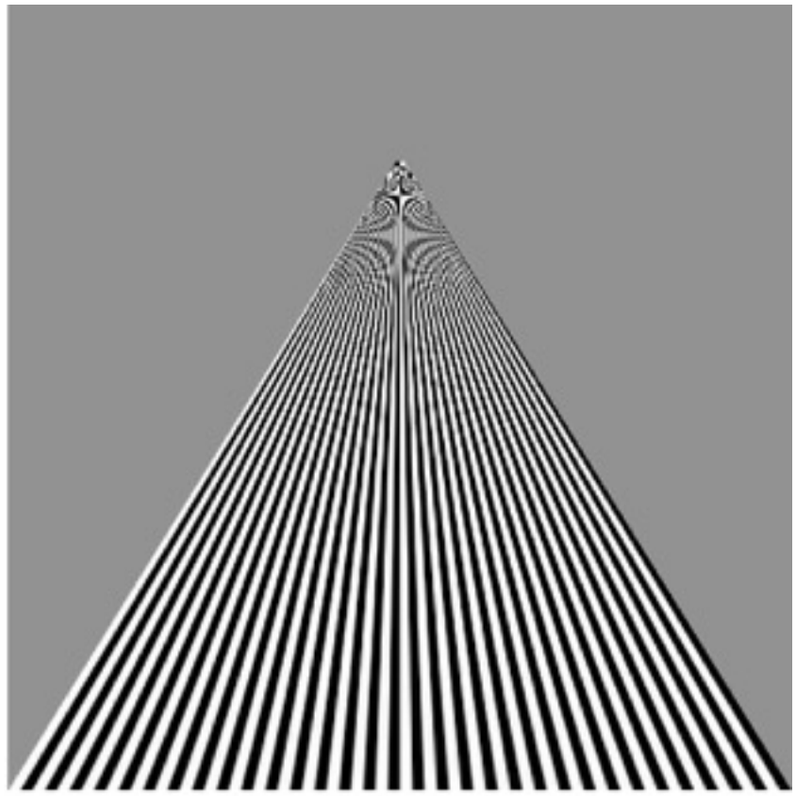




point sampling

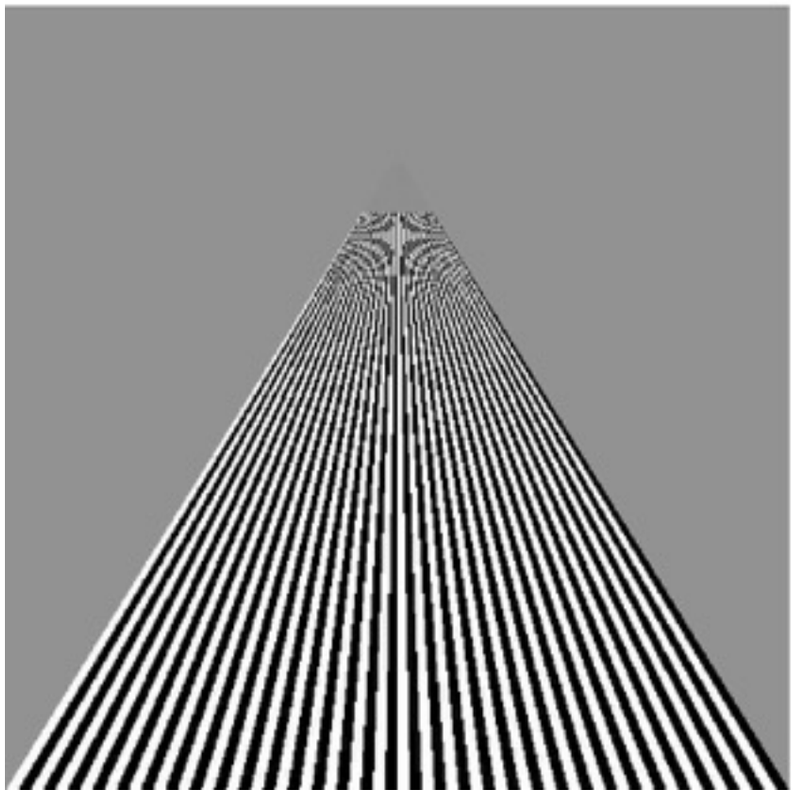


linear filtering

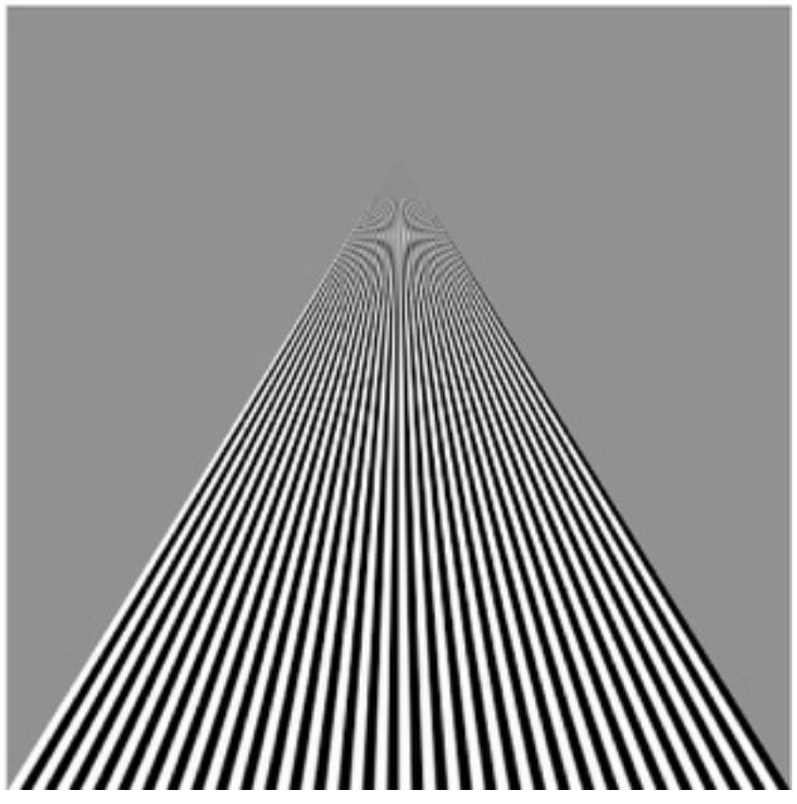


[Angel and Shreiner]

mipmapped point sampling



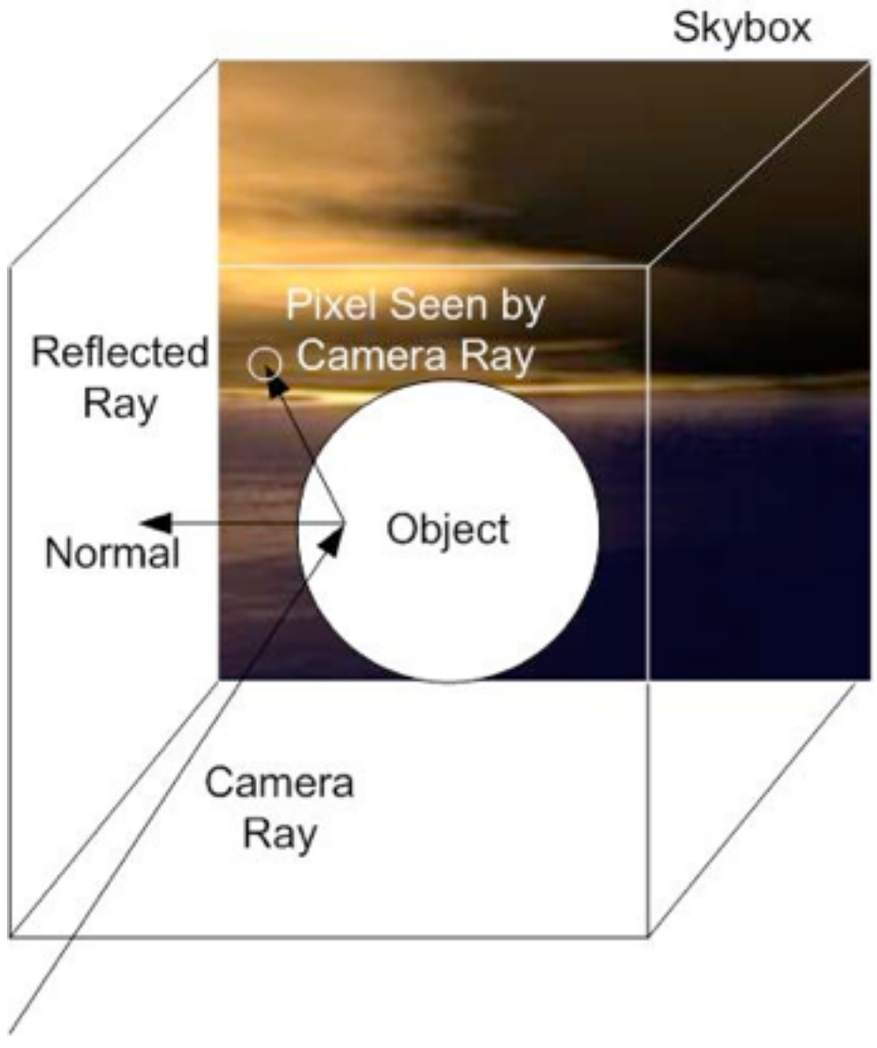
mipmapped linear filtering

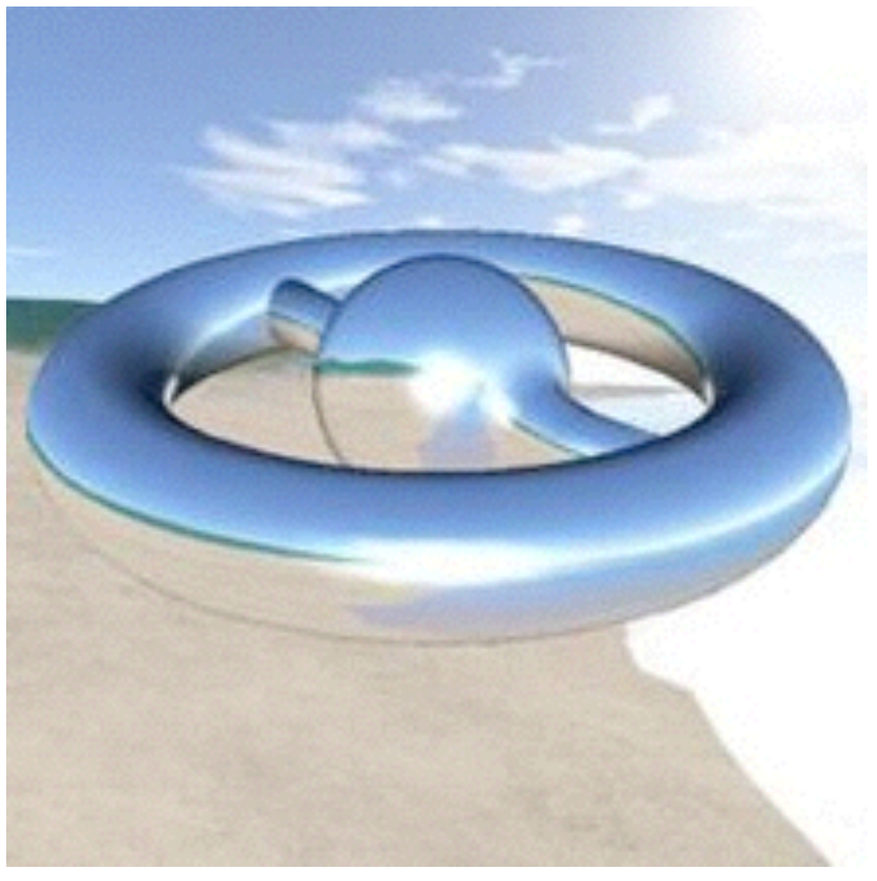


Environment mapping

Environment Mapping

Use a texture for the distant environment simulate the effect of ray tracing more cheaply





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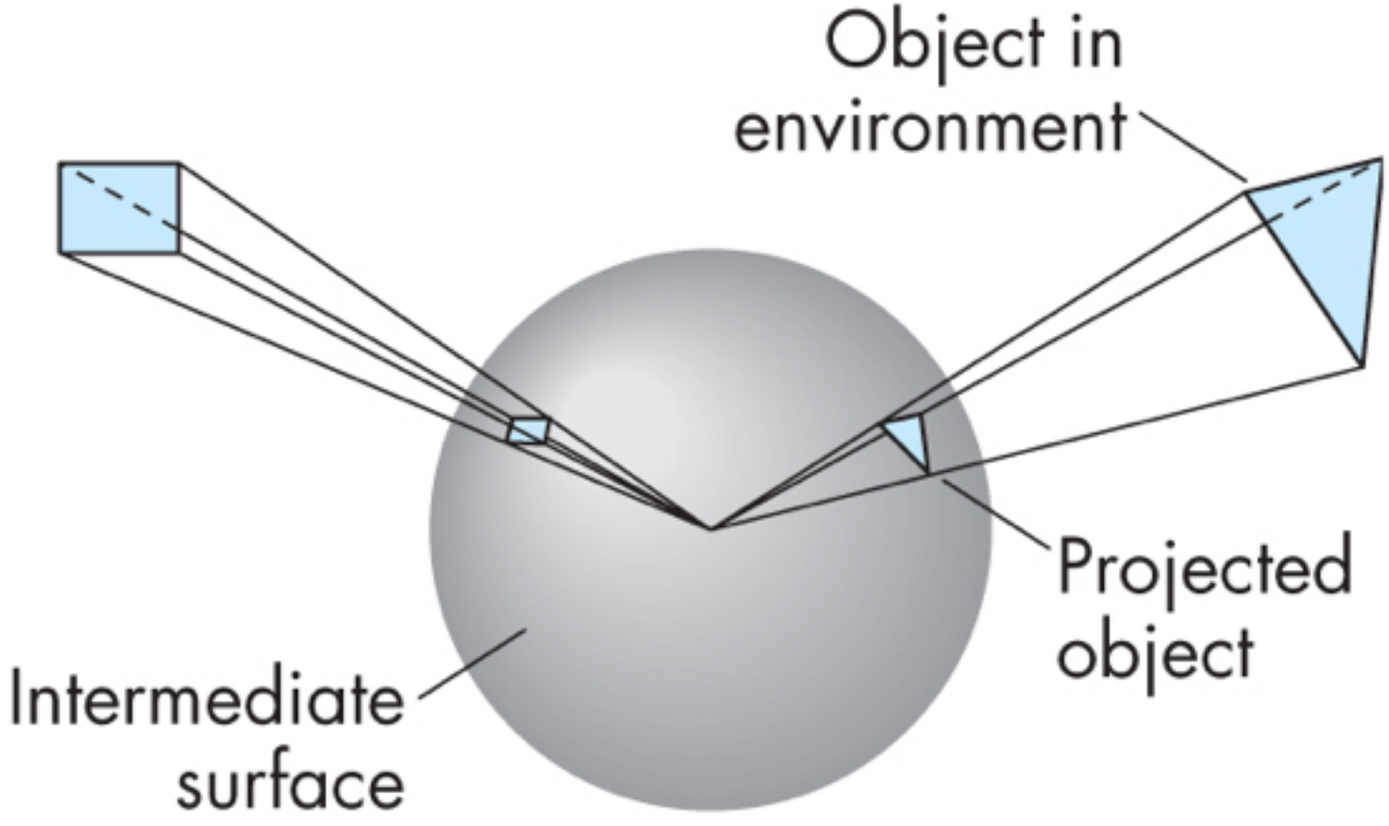
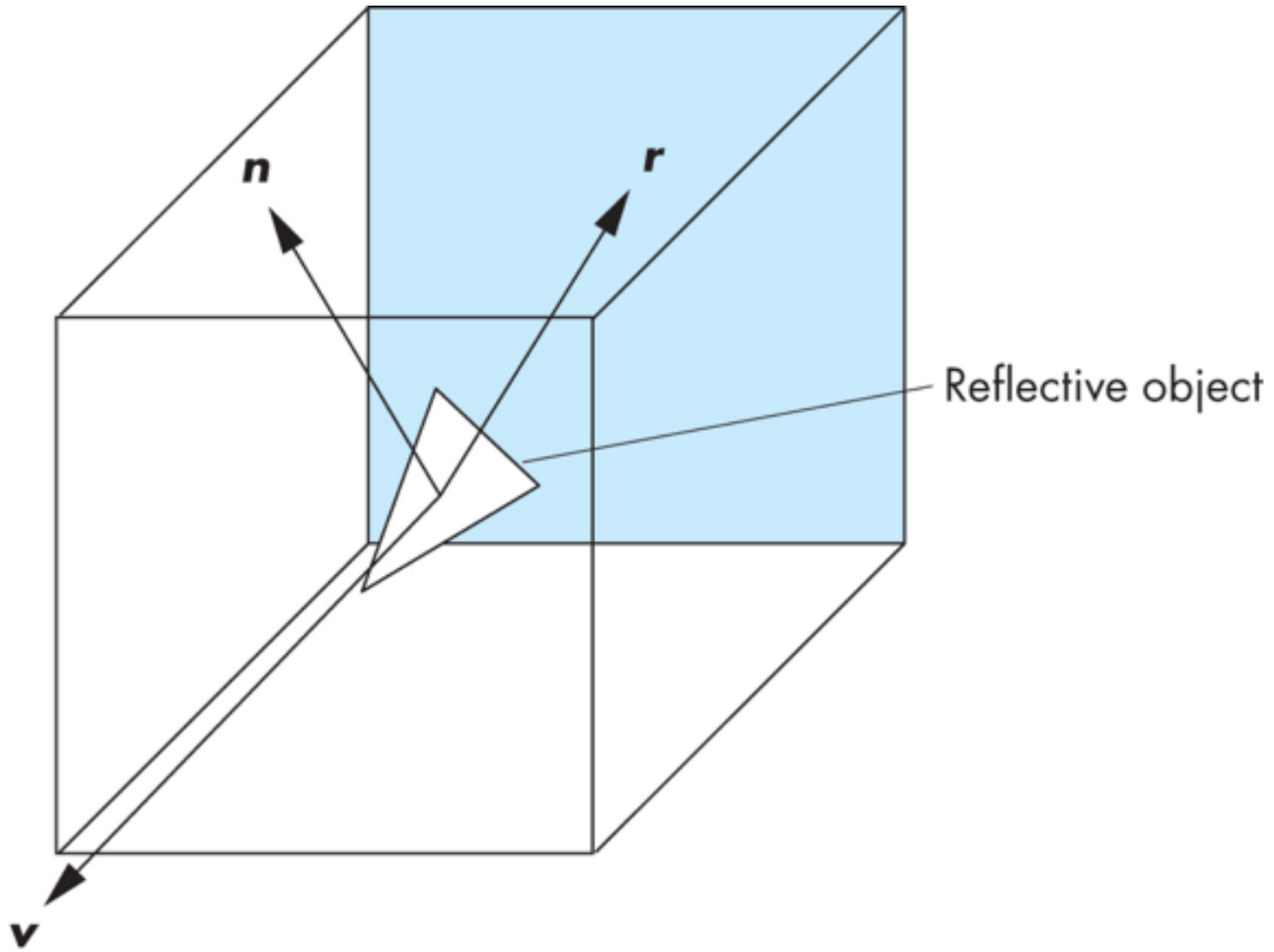
Sphere Mapping

- Project objects in the environment onto sphere centered at eye
- unwrap and store as texture
- use reflection direction to lookup texture value

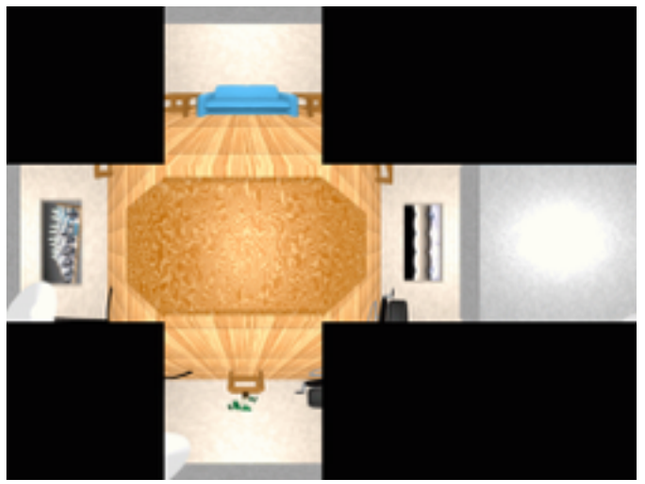


Cube Mapping

- Compute six projections, one for each wall
- store as texture
- use reflection direction to lookup texture value



Different environment maps



www.reindelsoftware.com

Blinn/Newell latitude mapping

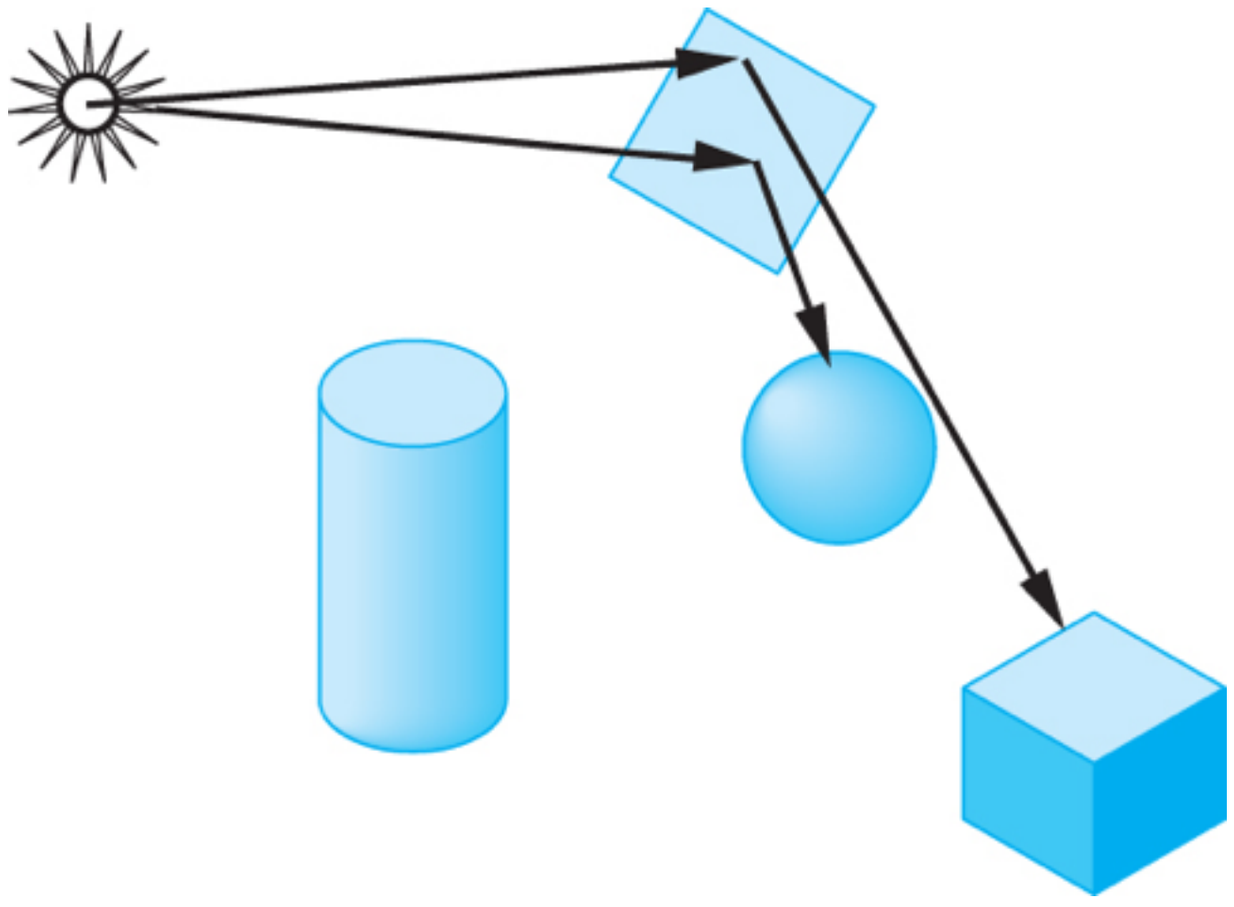
OpenGL spherical mapping

Cube mapping

Environment Mapping

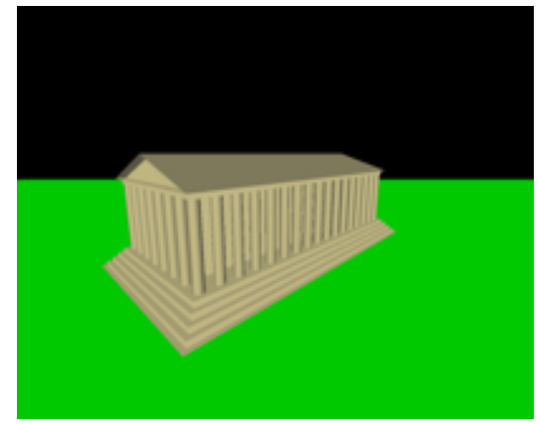
Create the effect of a mirror with two-pass rendering

1. First pass: render the scene from the perspective of the mirror
2. Second pass: render from original pov; use the first image as a texture for the mirror



Shadow Mapping

first pass from light's perspective



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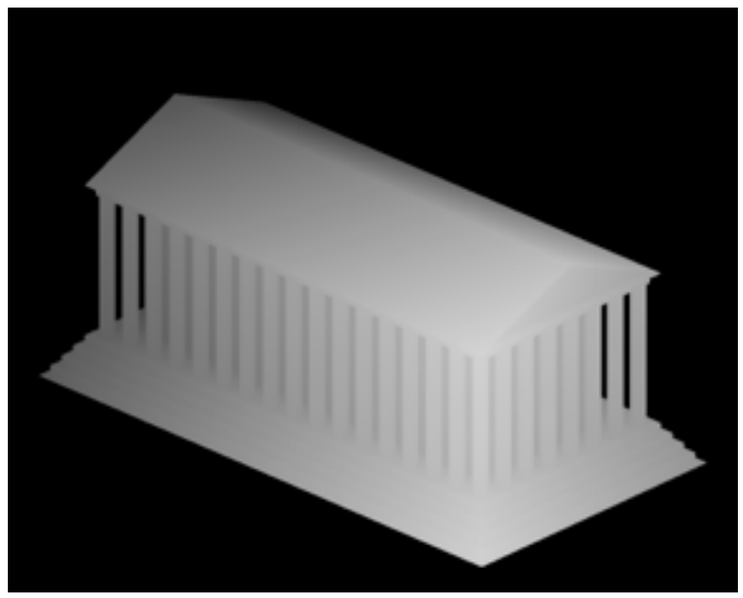
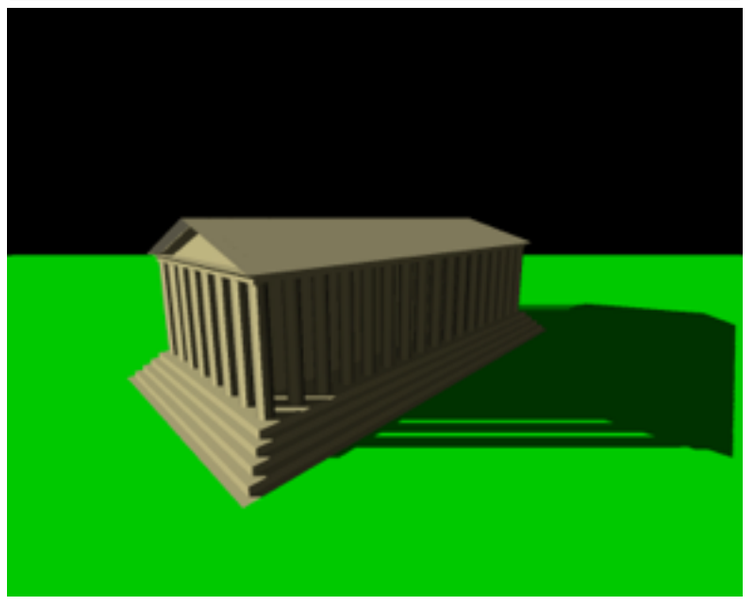
1. render scene from pov of light and store z-buffer in a texture



2. when rendering scene from desired pov, also render from light pov and test pixel against stored texture



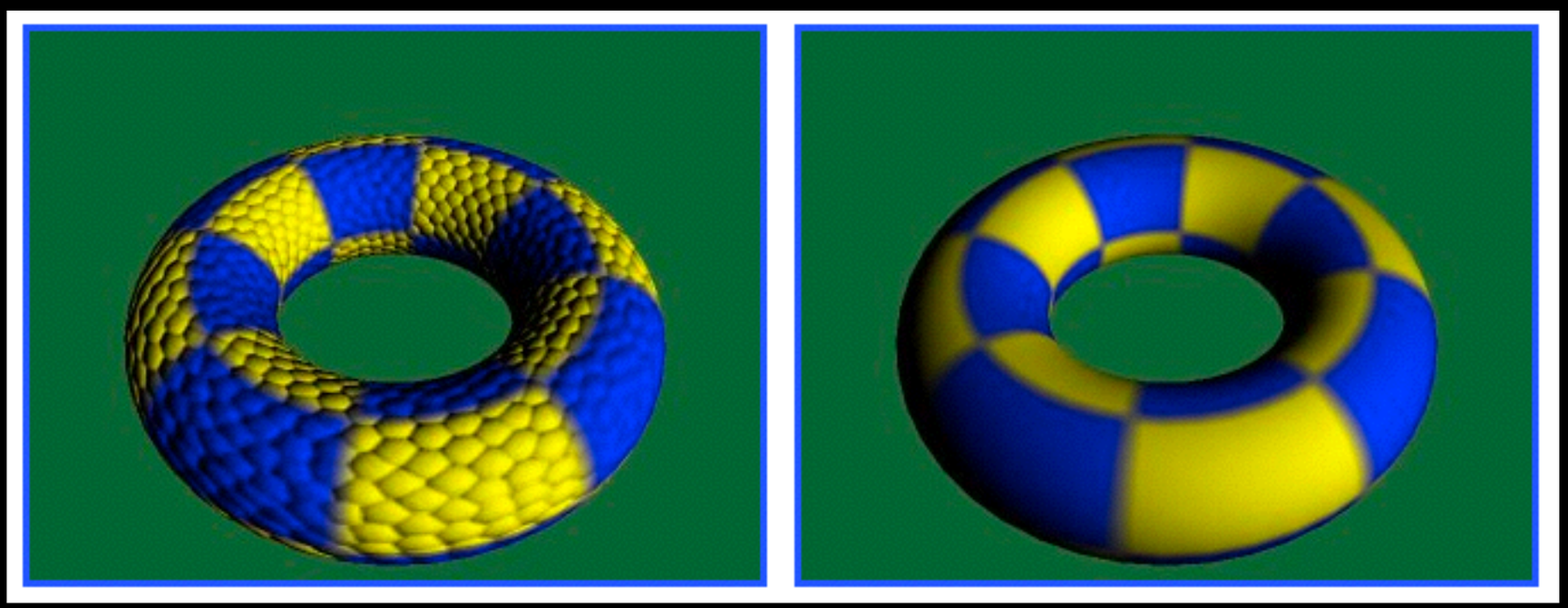
Bump Mapping

perturb
normal
vectors

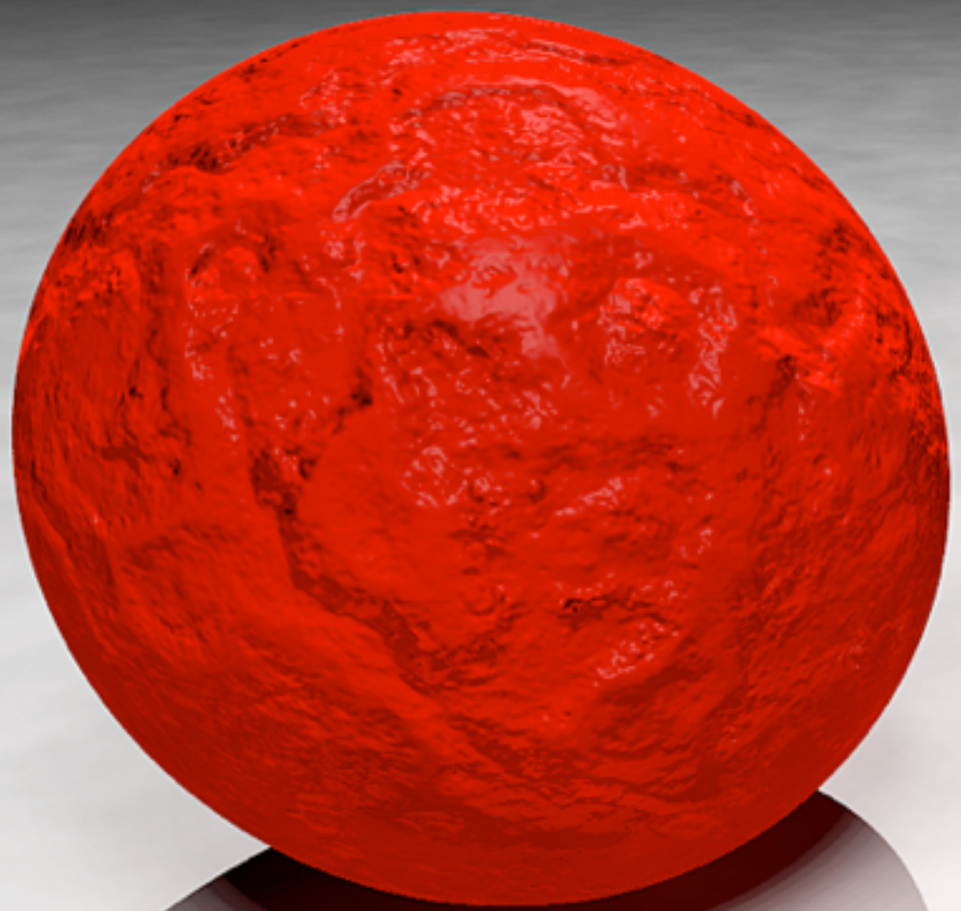
doesn't
affect
silhouette

[DirectXTutorial.com]

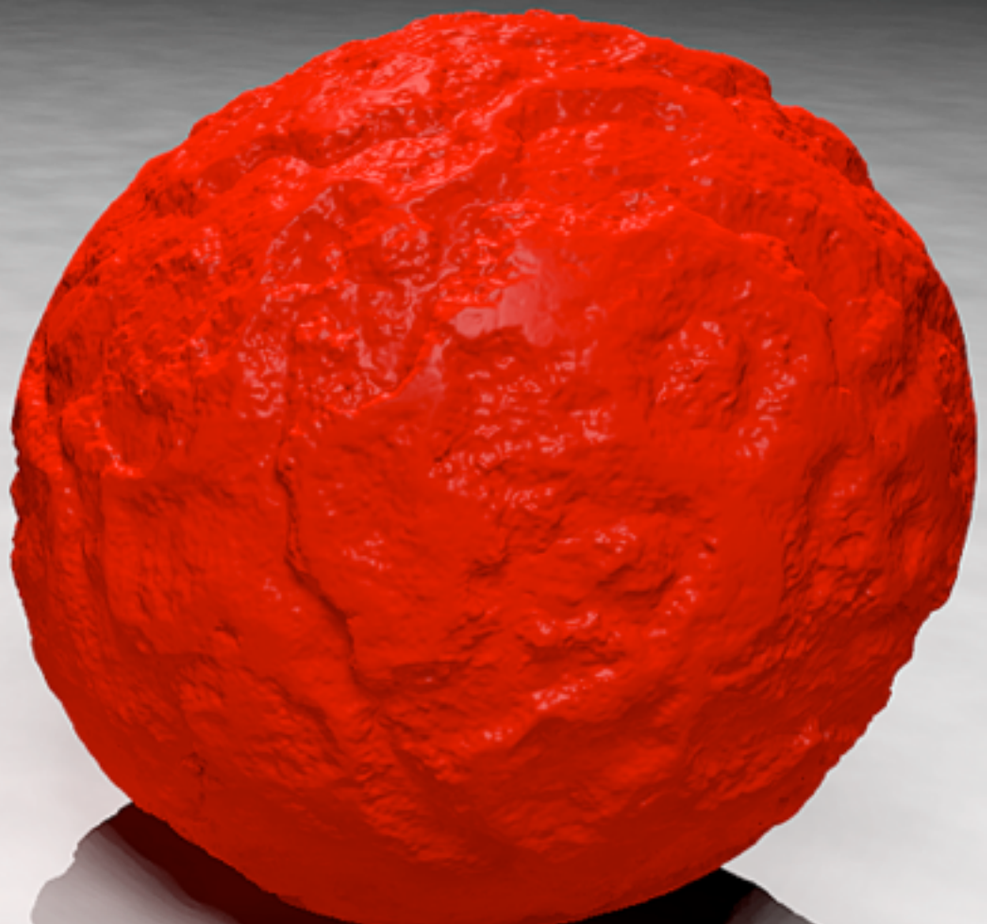
http://www.lg.clanhost.cz



http://www.paulsprojects.net/tutorials/simplebump/simplebump.html



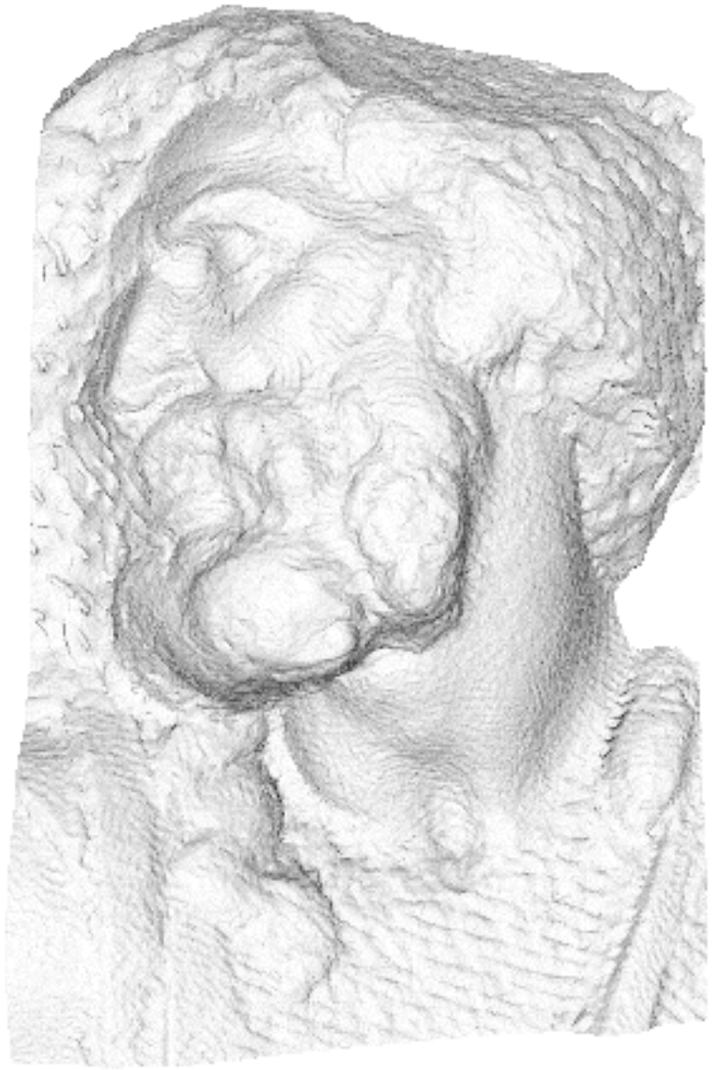
bump mapping



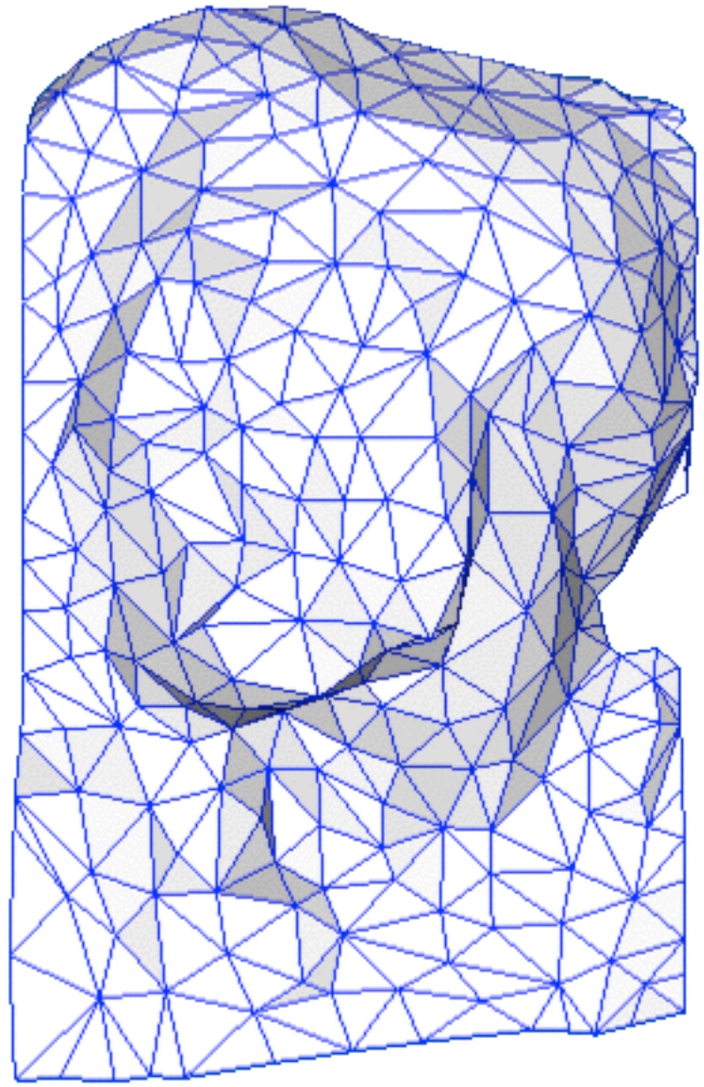
geometric detail

Wikimedia Commons

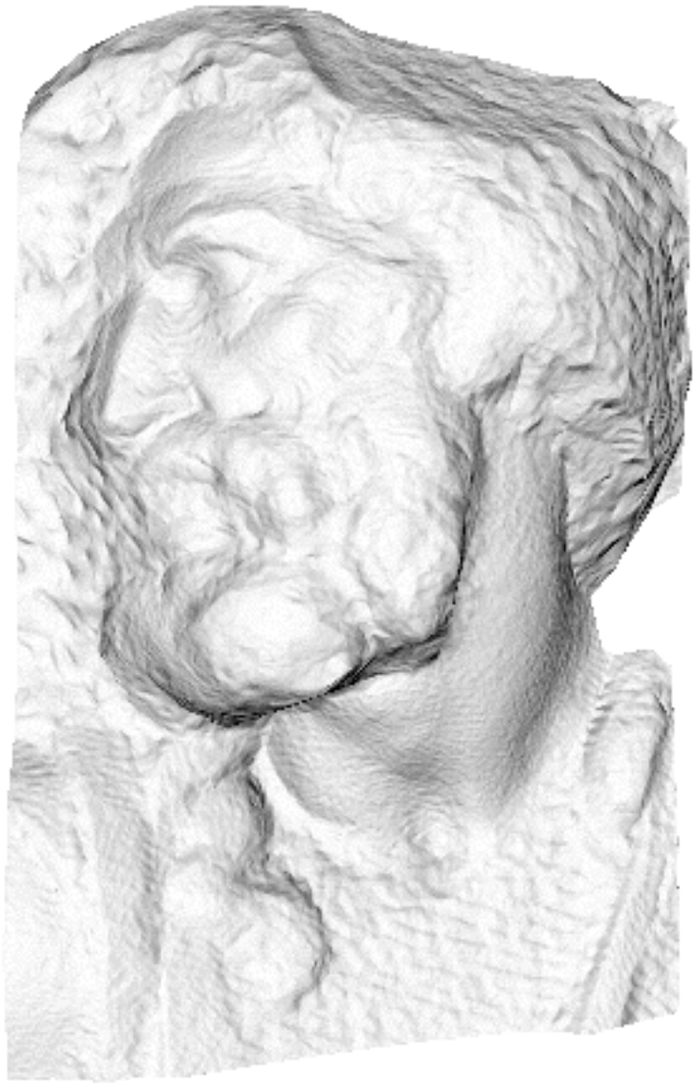
Normal Mapping



original mesh
4M triangles



simplified mesh
500 triangles



simplified mesh
and normal mapping
500 triangles

Wikimedia Commons