CS130 : Computer Graphics

Texture Mapping

Tamar Shinar
Computer Science & Engineering
UC Riverside

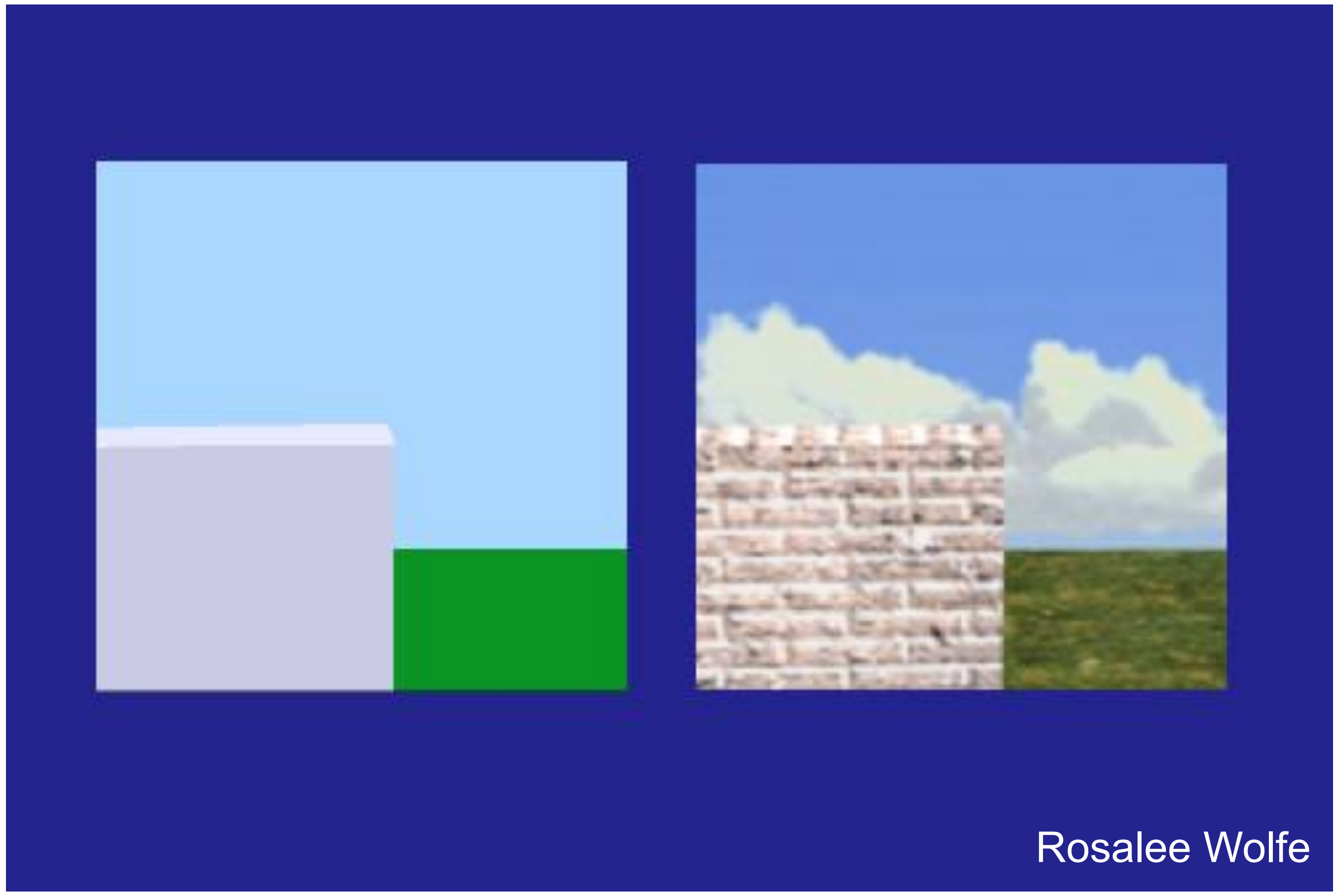
There are limits to geometric modeling

http://www.beinteriordecorator.com

National Geographic

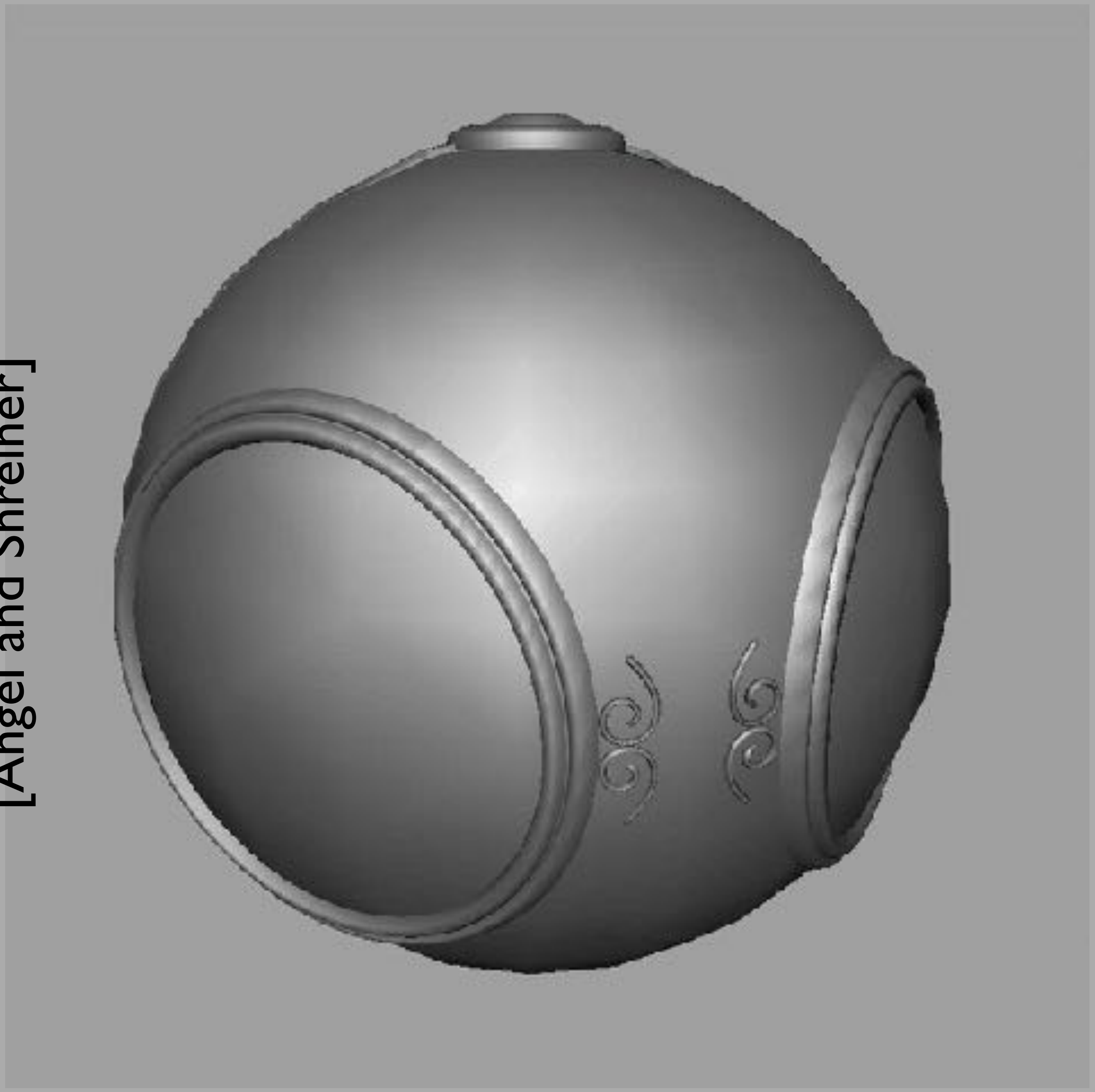
Although modern GPUs can render millions of triangles/sec, that's not enough sometimes...

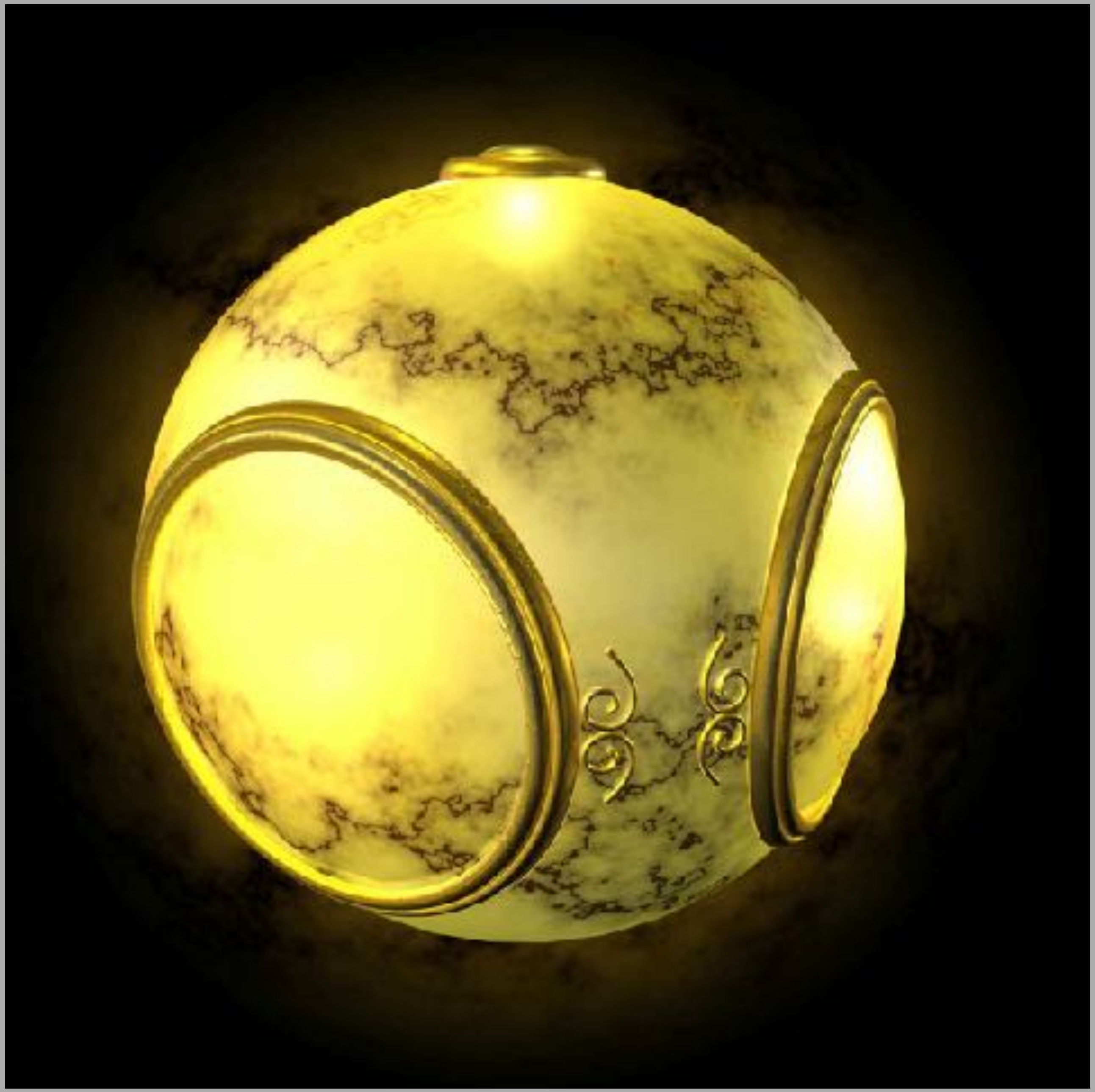
Use texture mapping to increase realism through detail



This image is just 8 polygons!

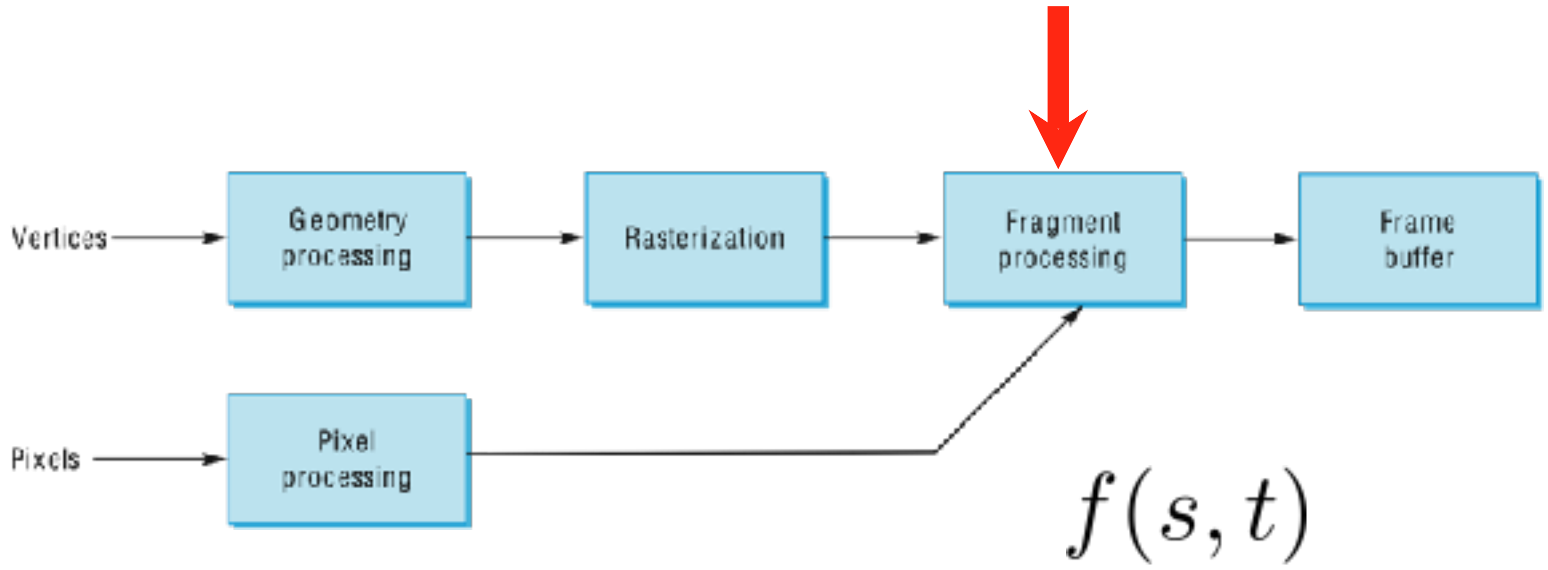
[Angel and Shreiner]


No texture

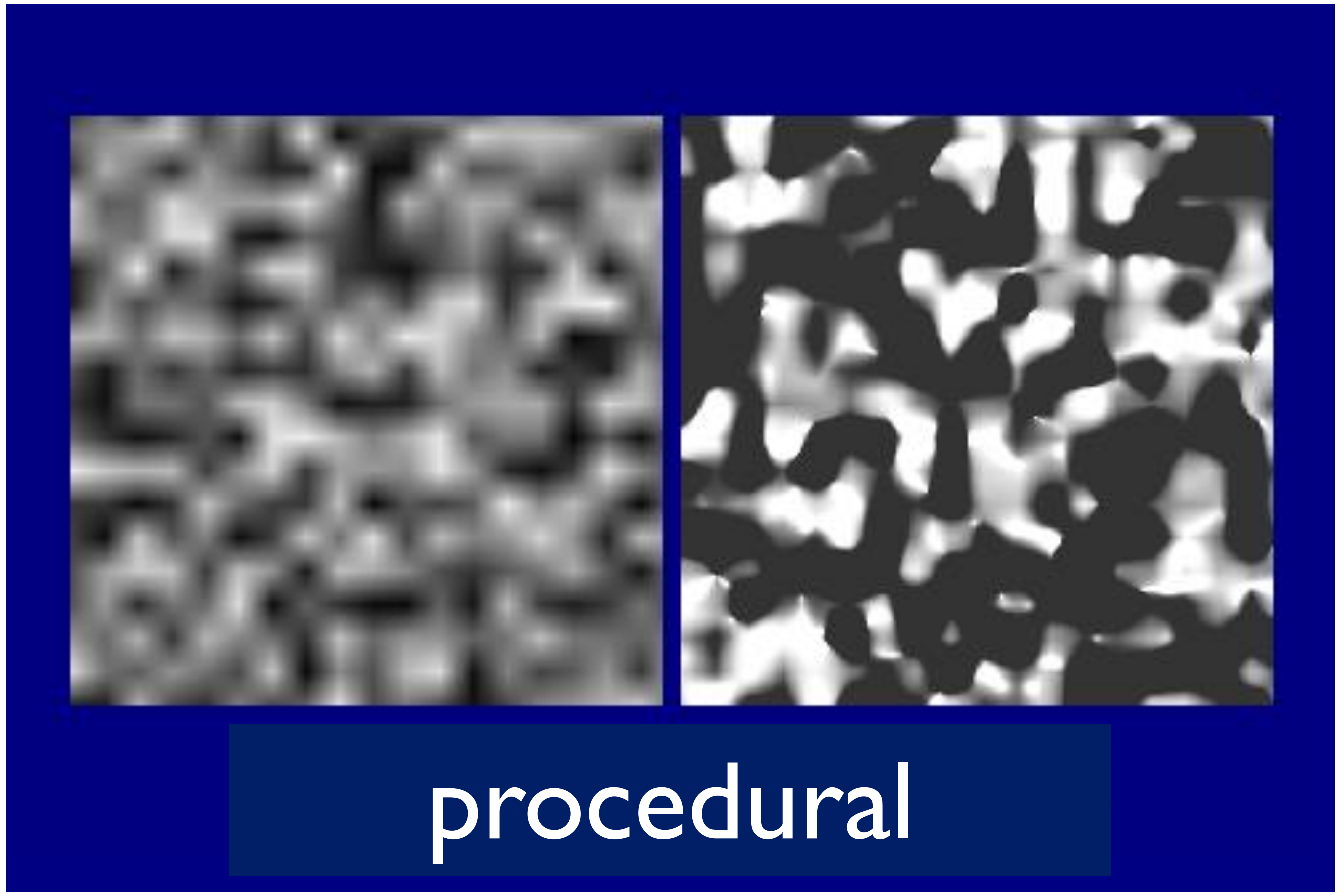

With texture

Pixar - Toy Story

Store 2D images in buffers and lookup pixel reflectances

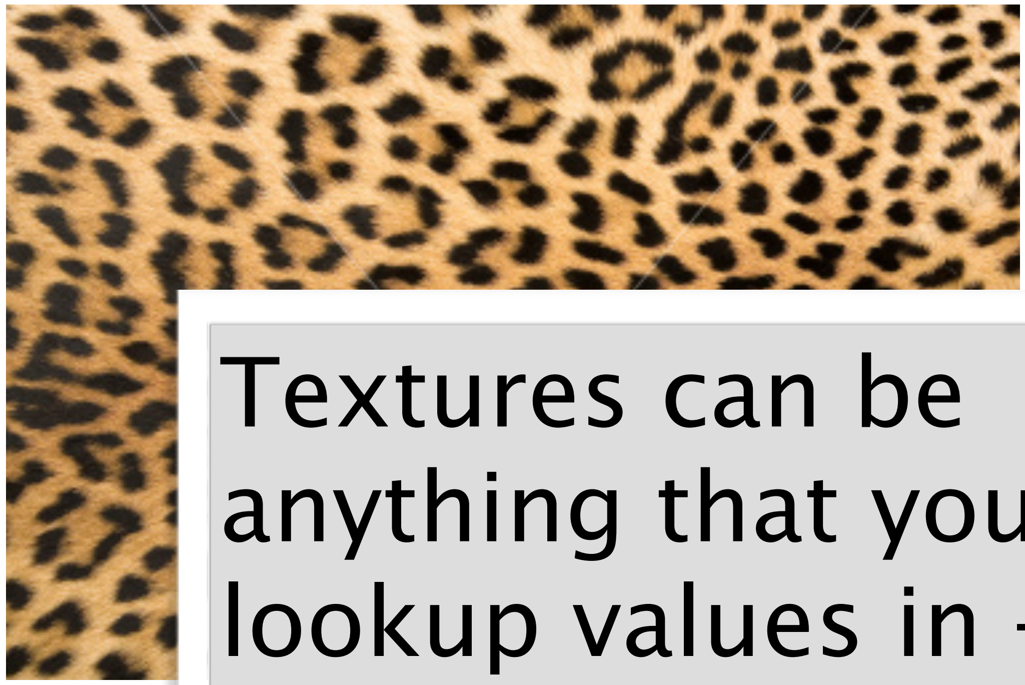


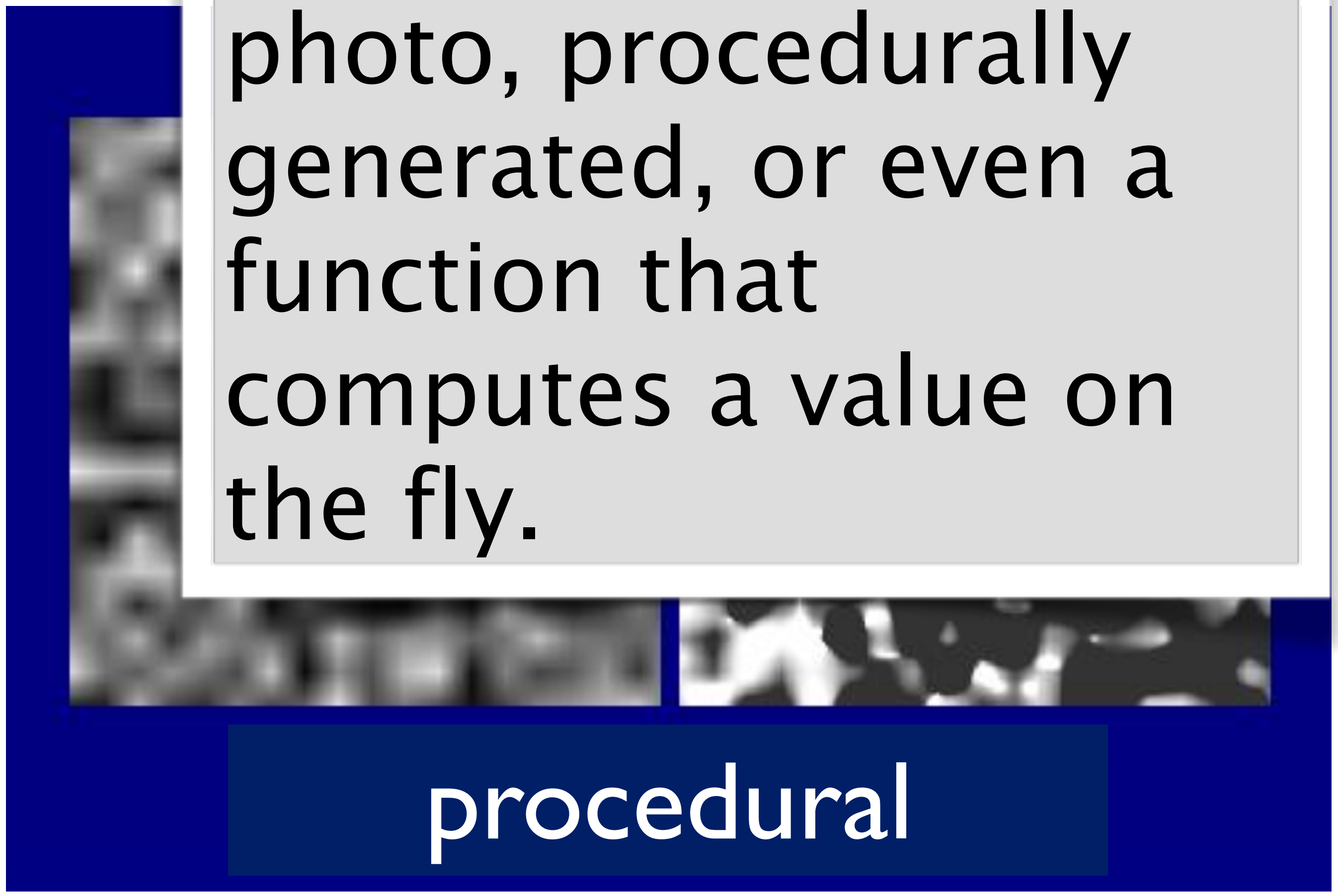
$f(s,t)$



photo

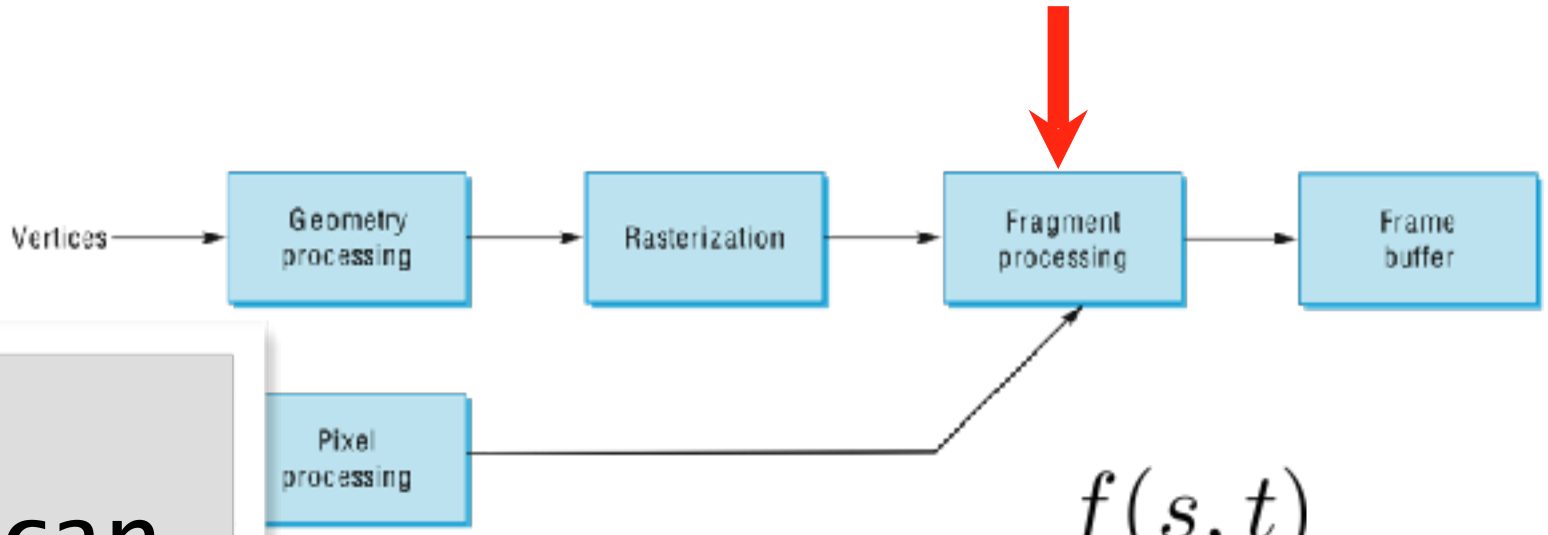
Store 2D images in buffers and lookup pixel reflectances





Textures can be anything that you can lookup values in — photo, procedurally generated, or even a function that computes a value on the fly.

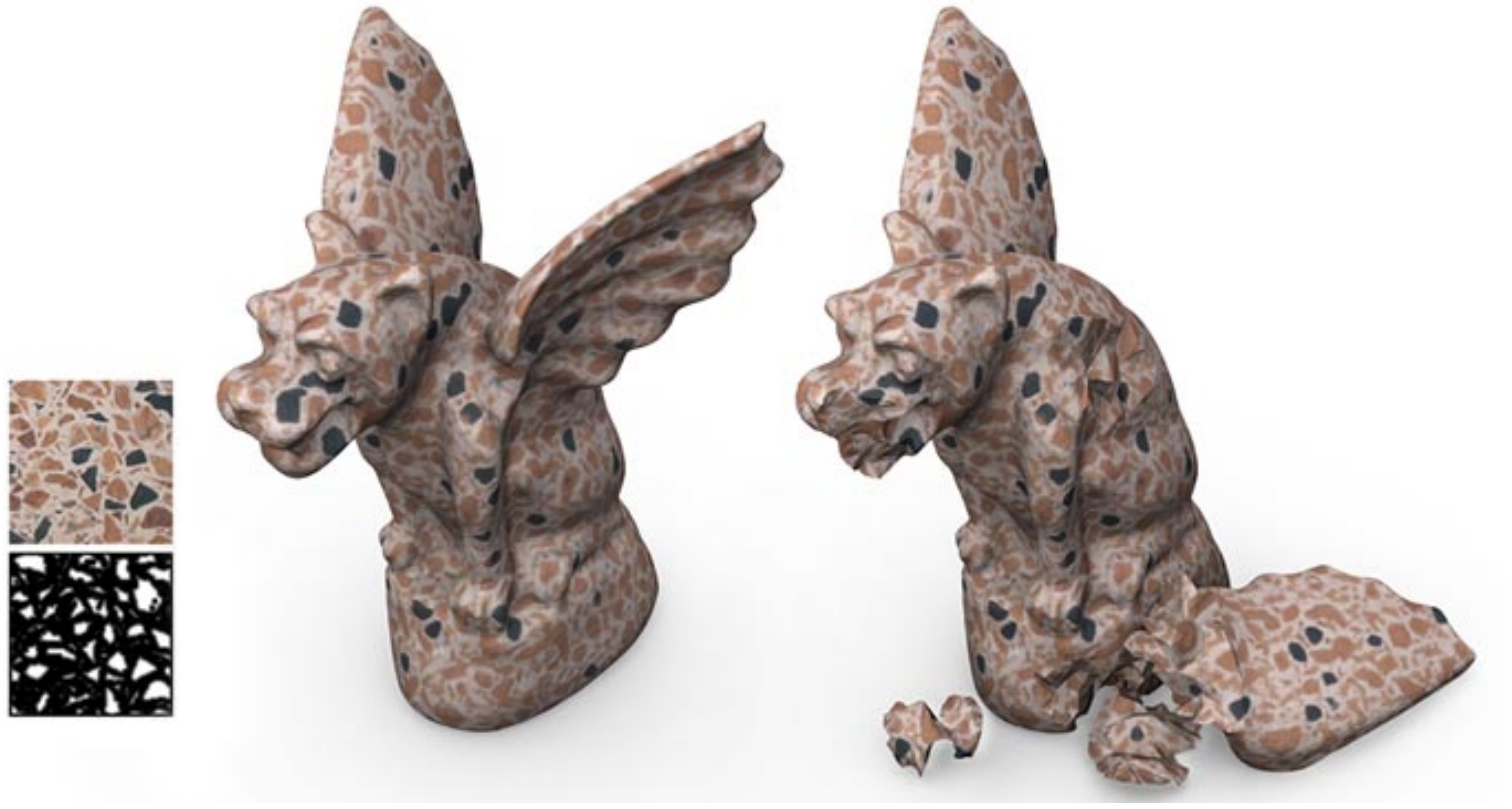
procedural



$f(s,t)$

photo

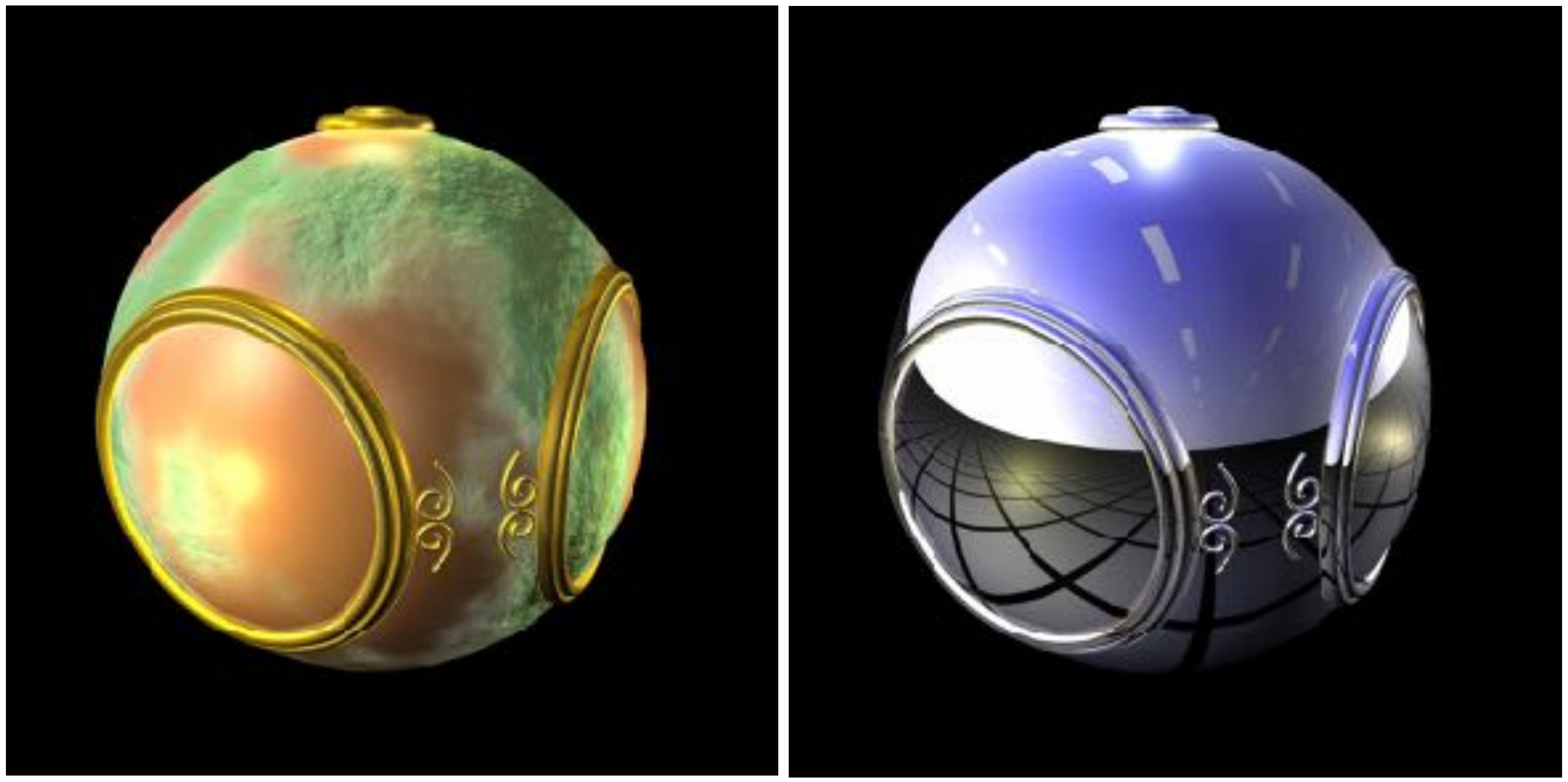
3D solid textures

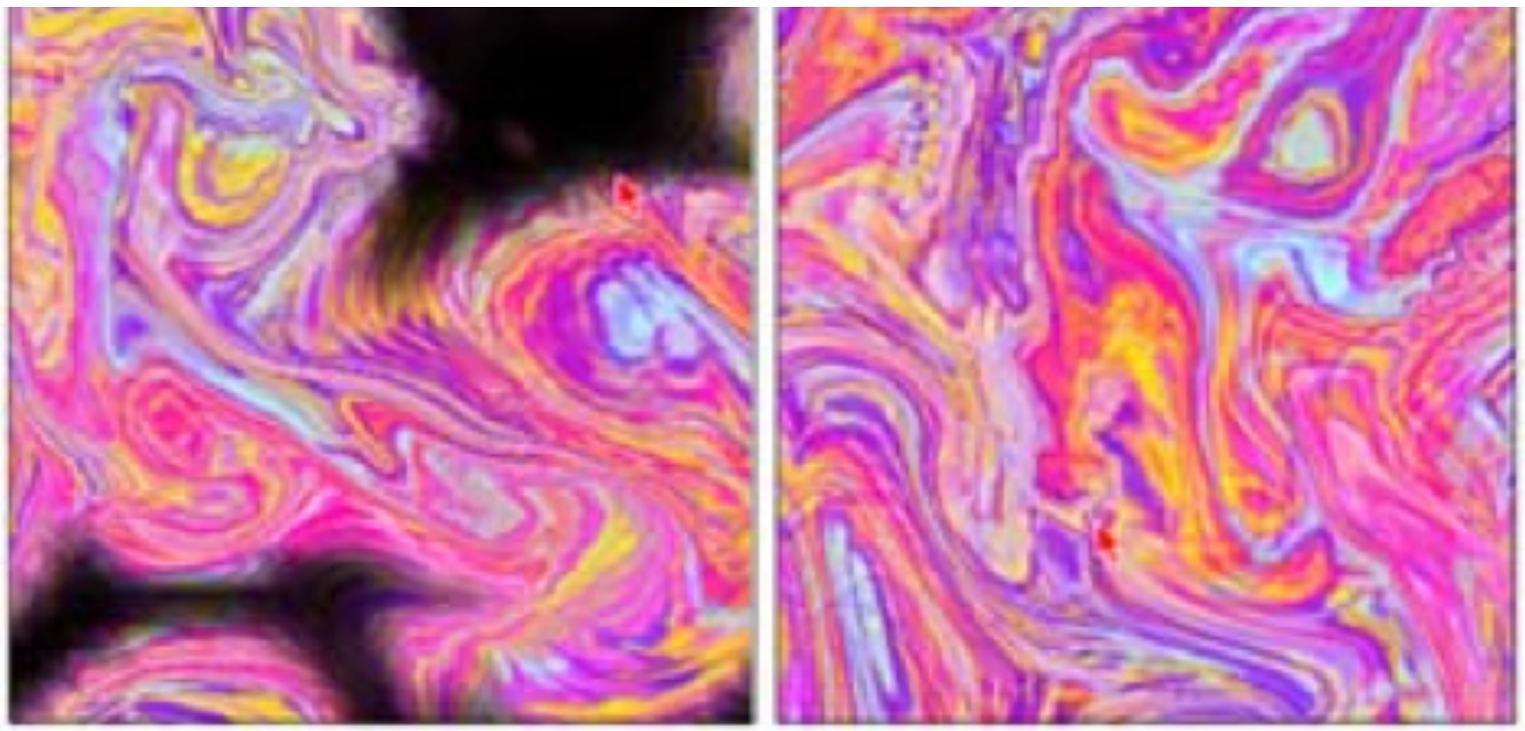


[Dong et al., 2008]

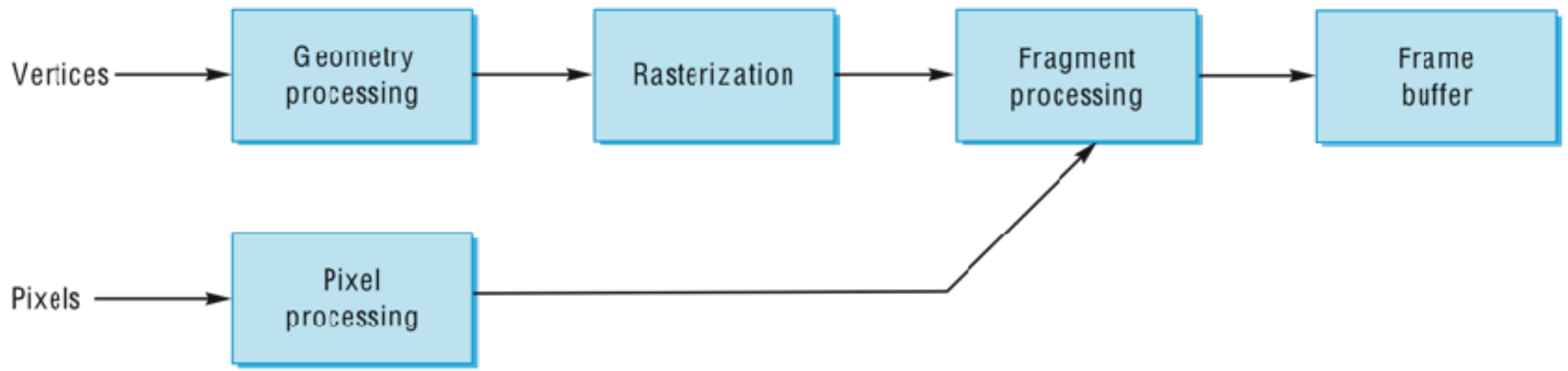
Other uses of textures...

Light maps
Shadow maps
Environment maps
Bump maps
Opacity maps
Animation


[Angel and Shreiner]

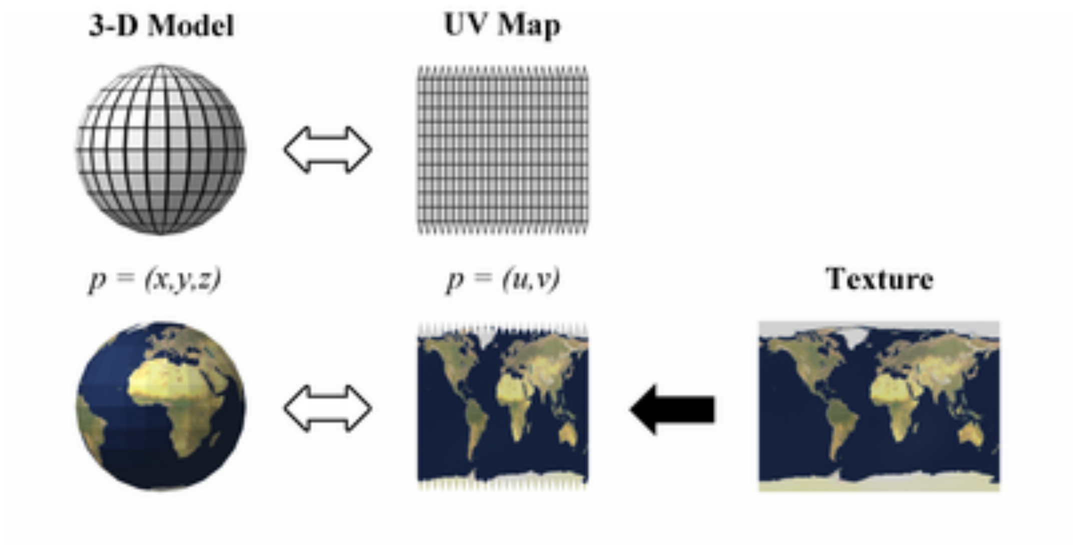

[Stam 99]

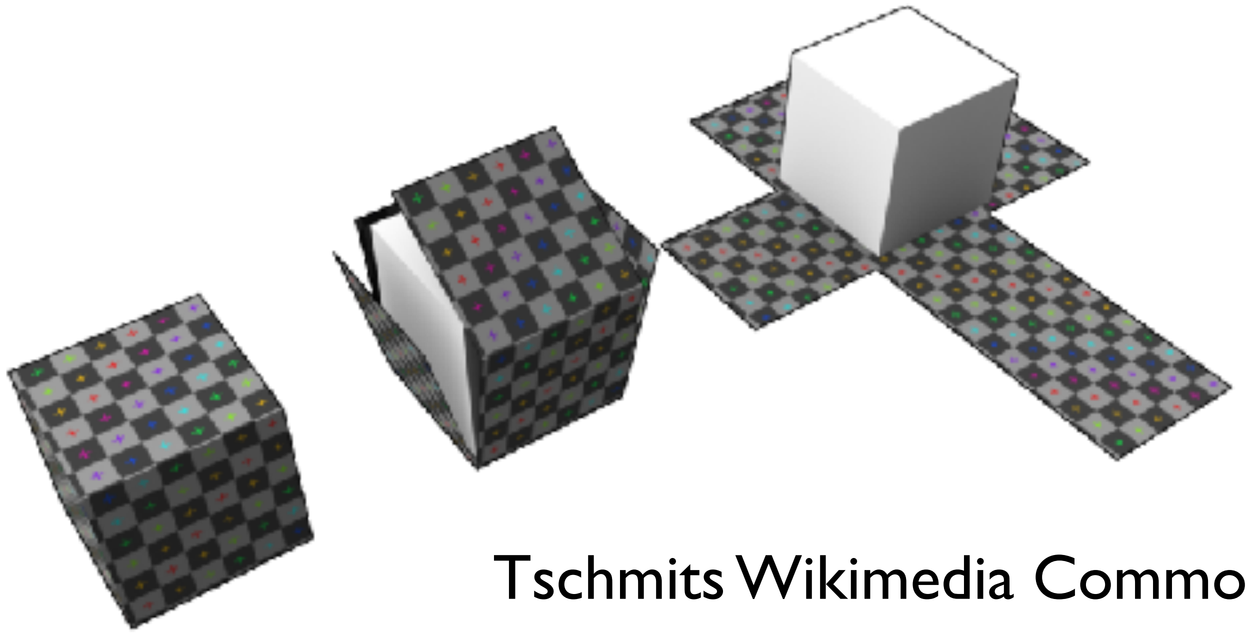
Texture mapping in the OpenGL pipeline



- 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

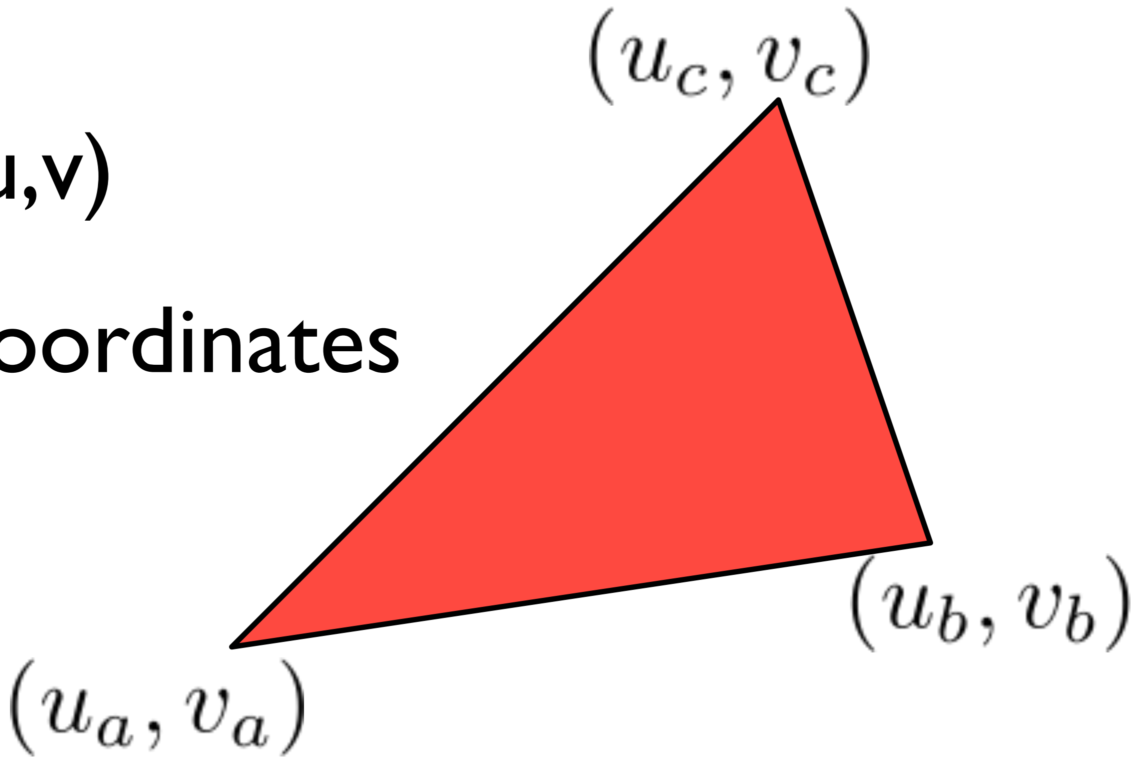
uv Mapping

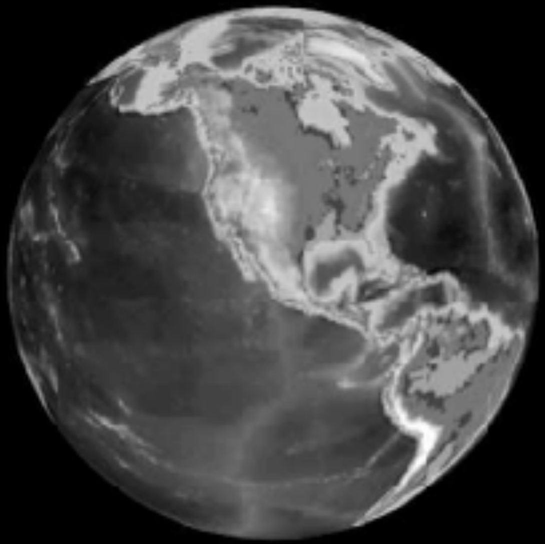
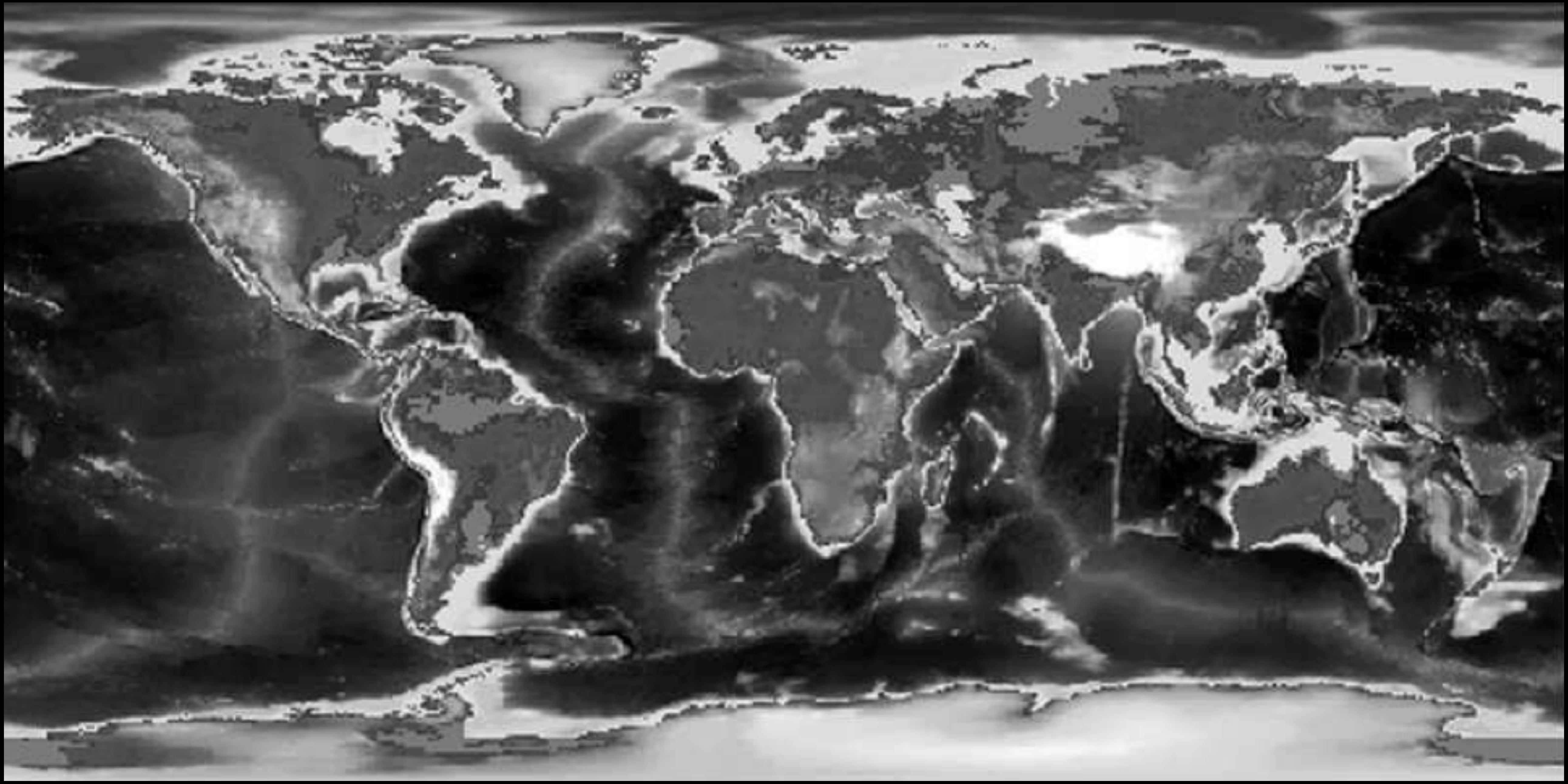




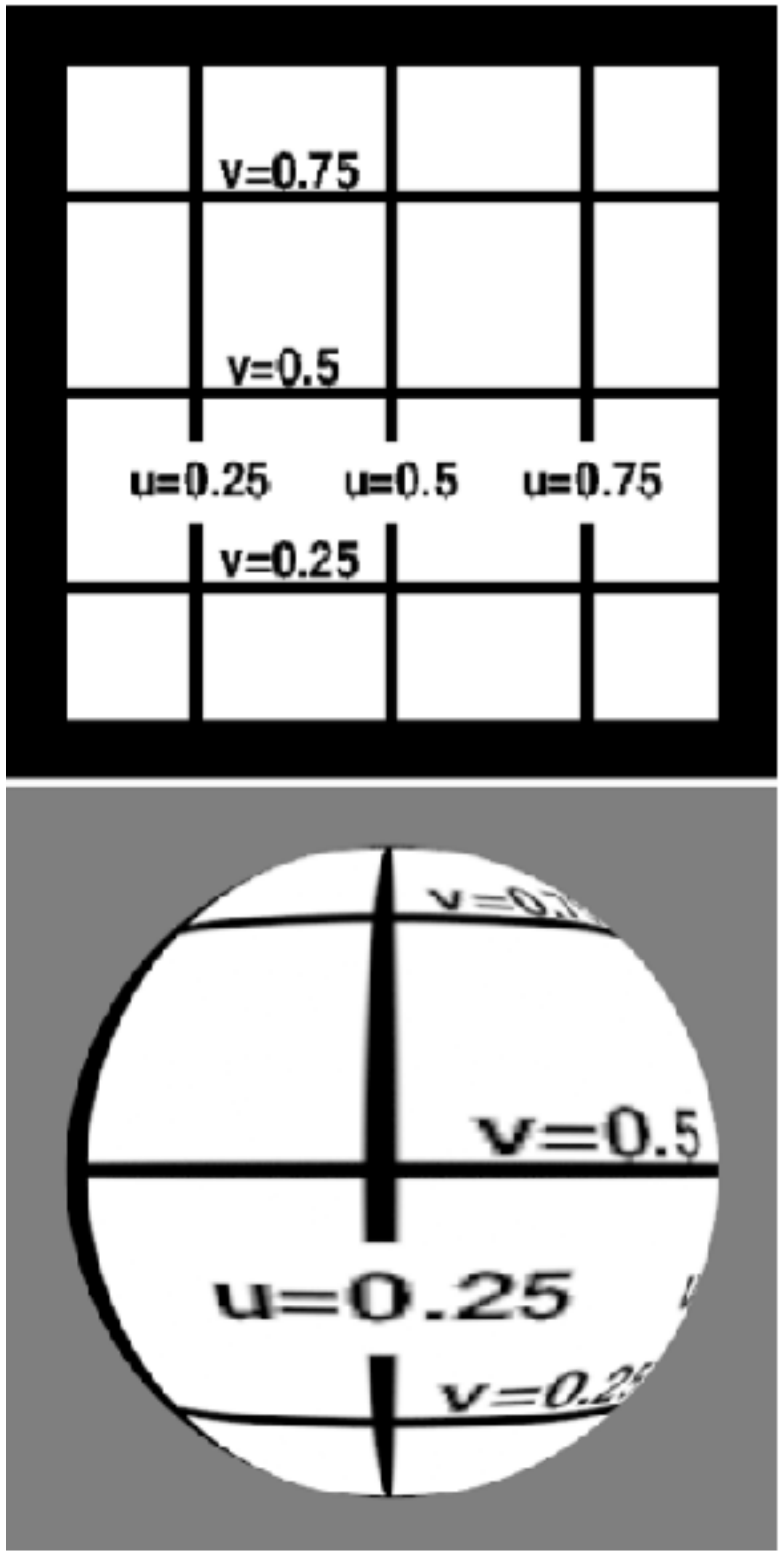
Tschmits Wikimedia Commons

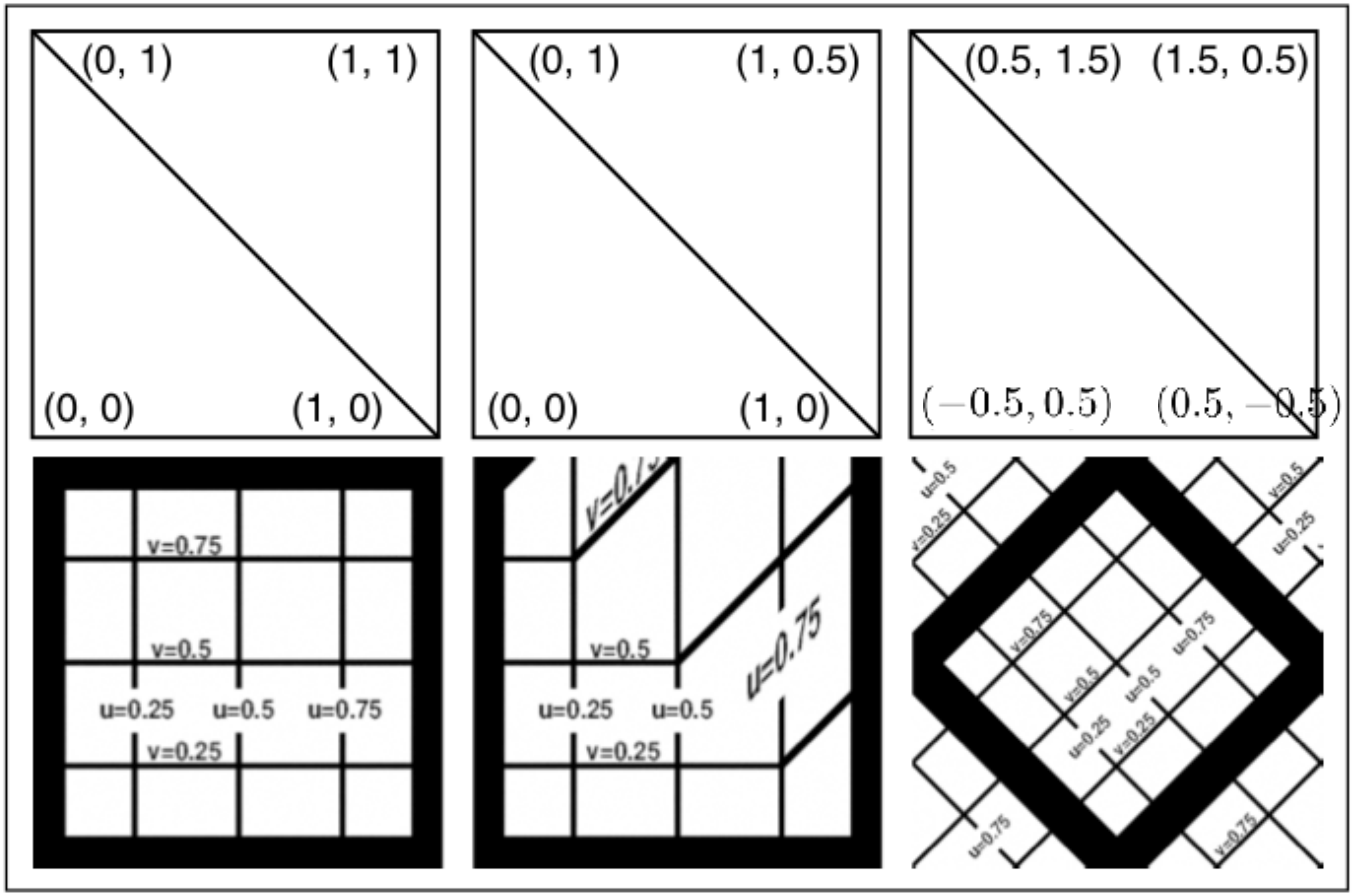
- 2D texture is parameterized by (u,v)
- Assign polygon vertices texture coordinates
- Interpolate within polygon



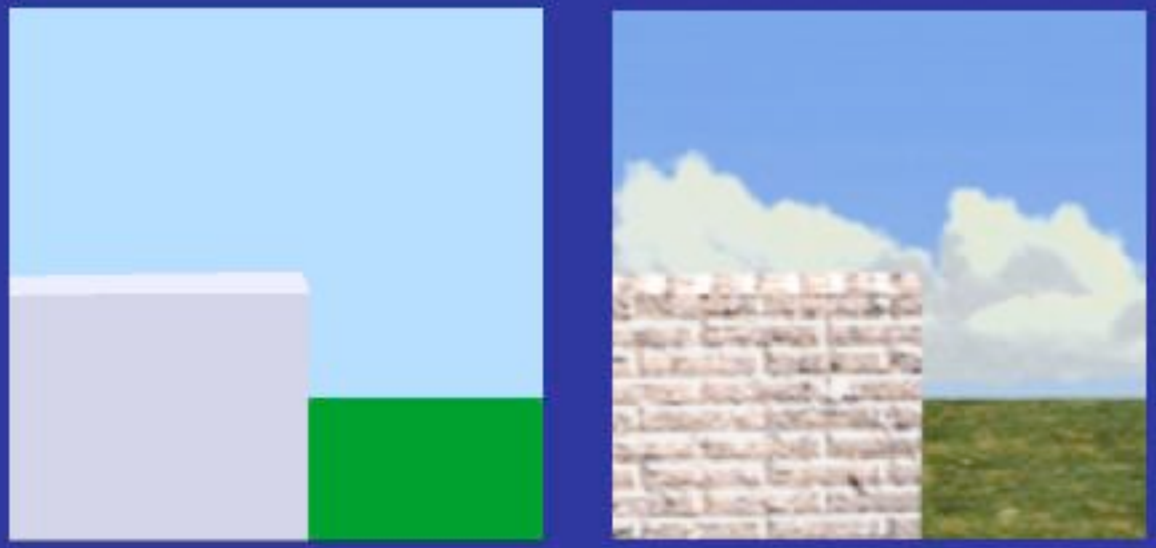
Texture Calibration

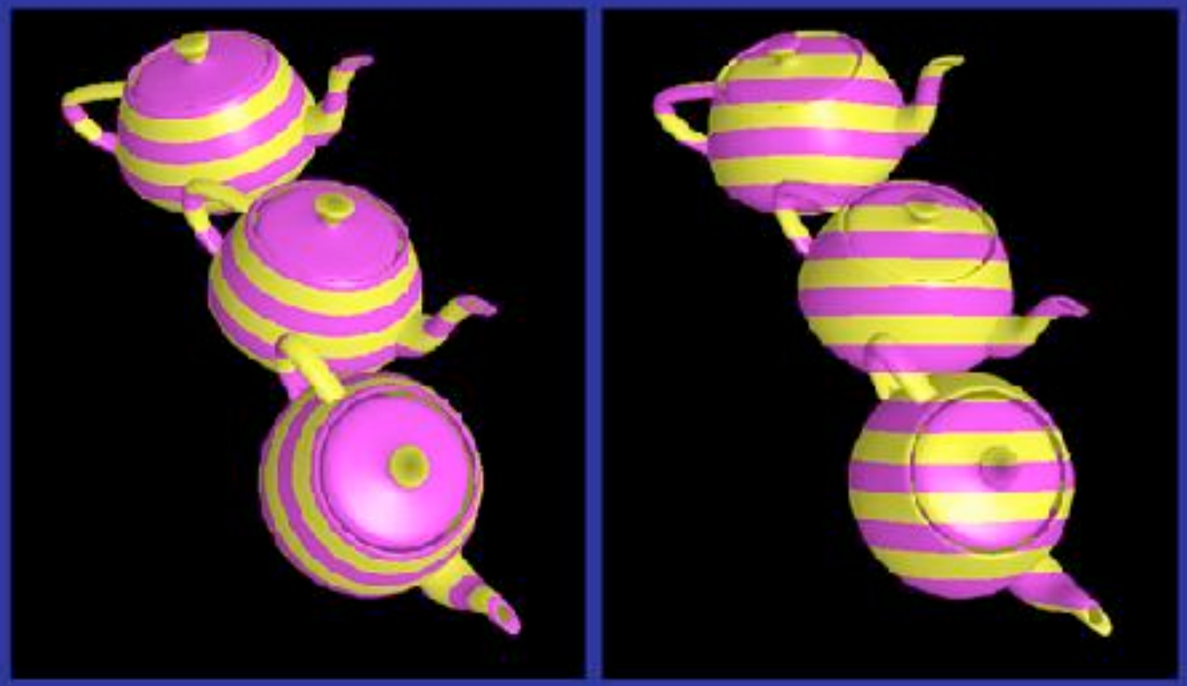




The major issues in texture mapping...

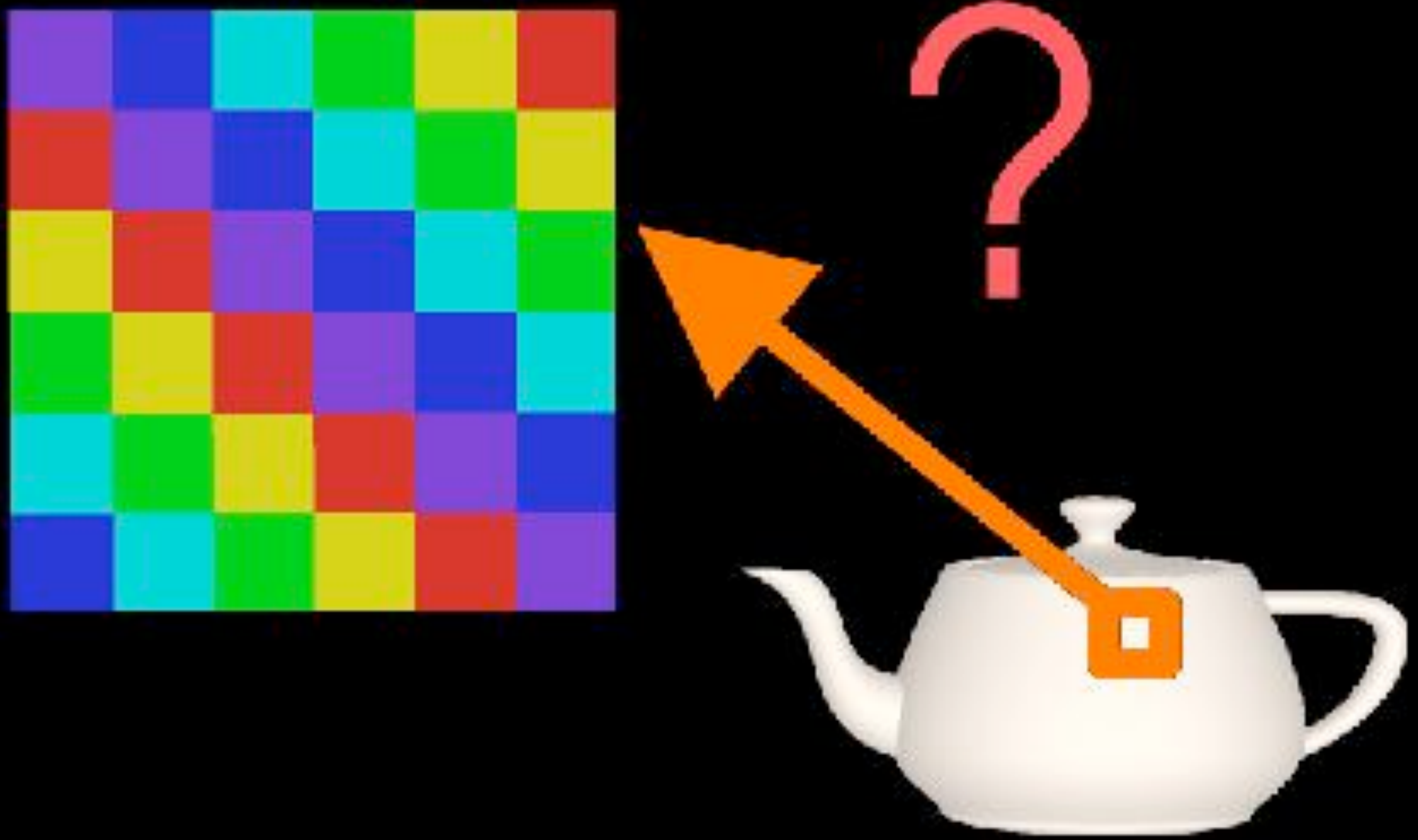
- What should the actual mapping be?


easy: flat surface


[Rosalee Wolfe]

harder: curved surface

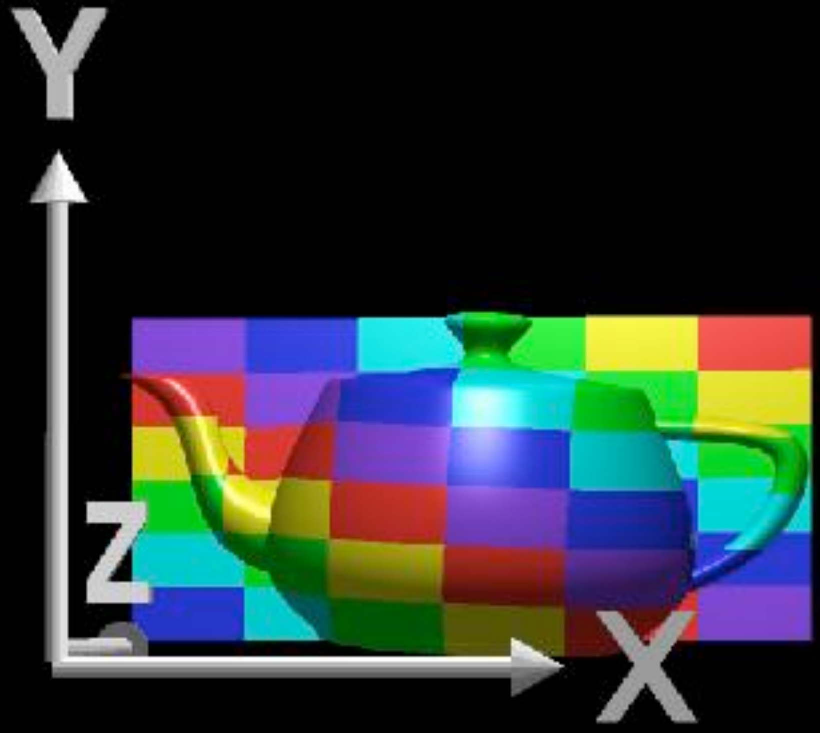
Given a point on the object **(x,y,z)**, what point **(u,v)** in the texture we use?

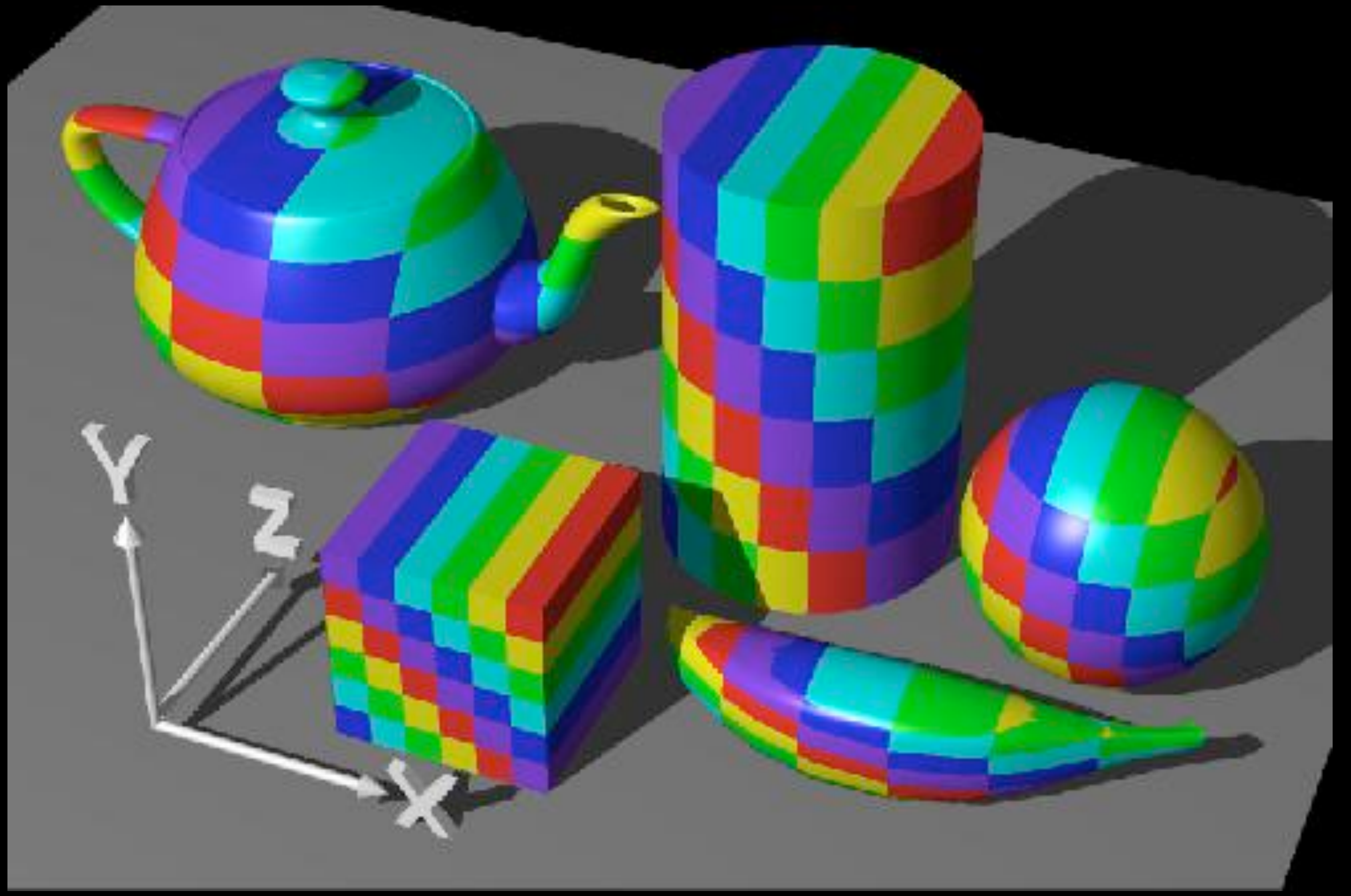


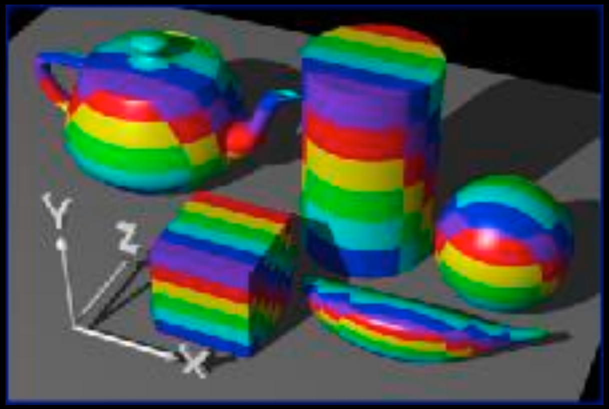
[Rosalee Wolfe]

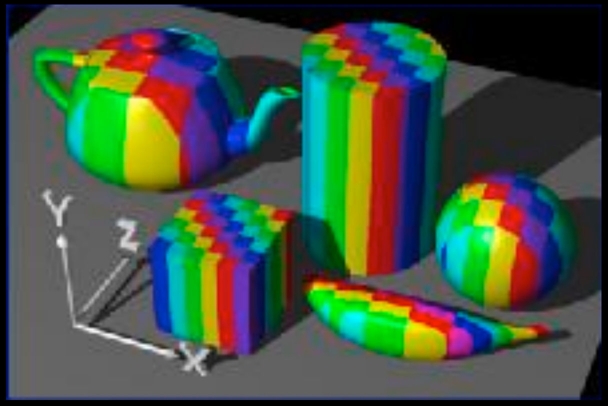
Example: planar mapping

[Rosalee Wolfe]



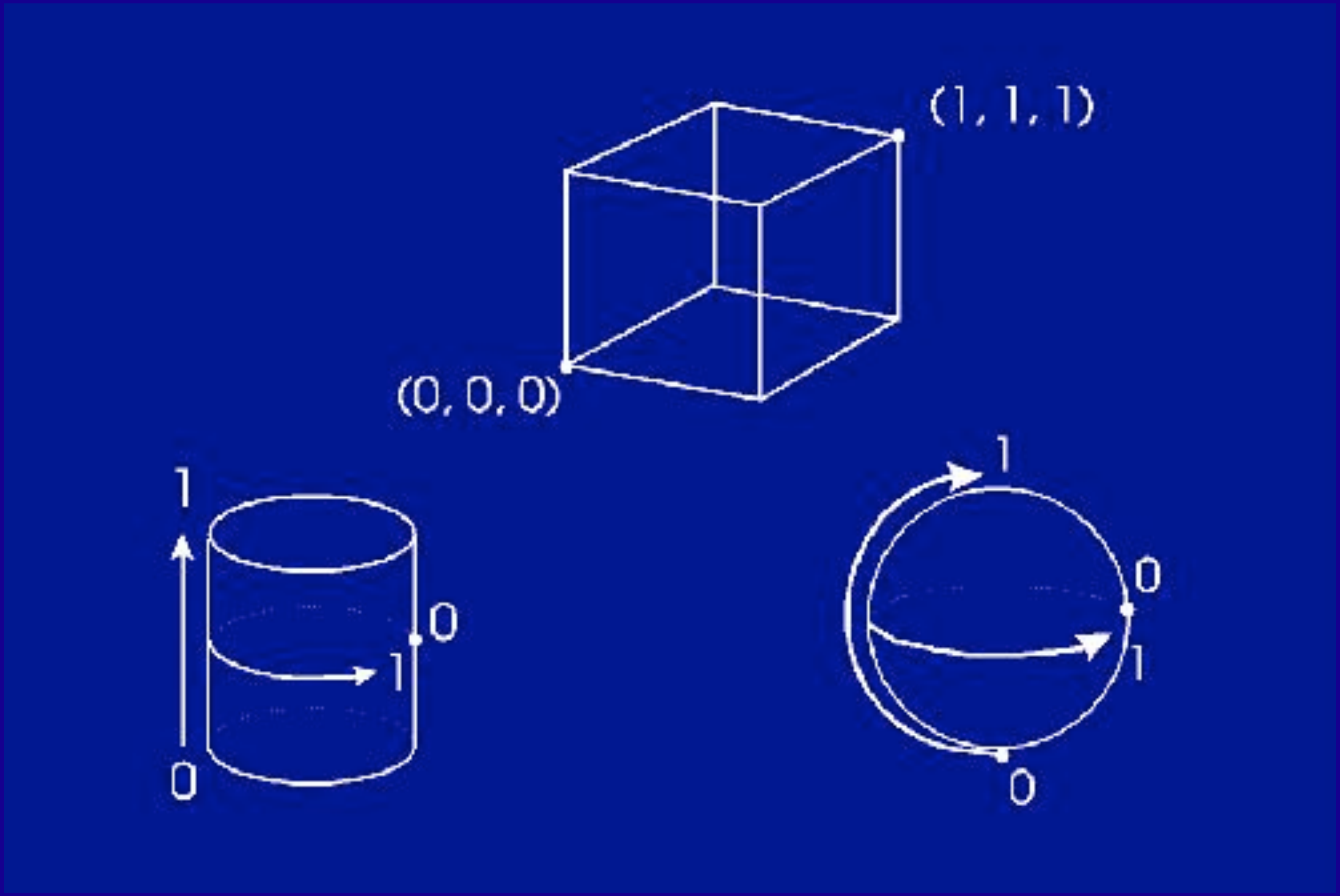






Intermediate surfaces

First map the texture to a simpler, intermediate surface

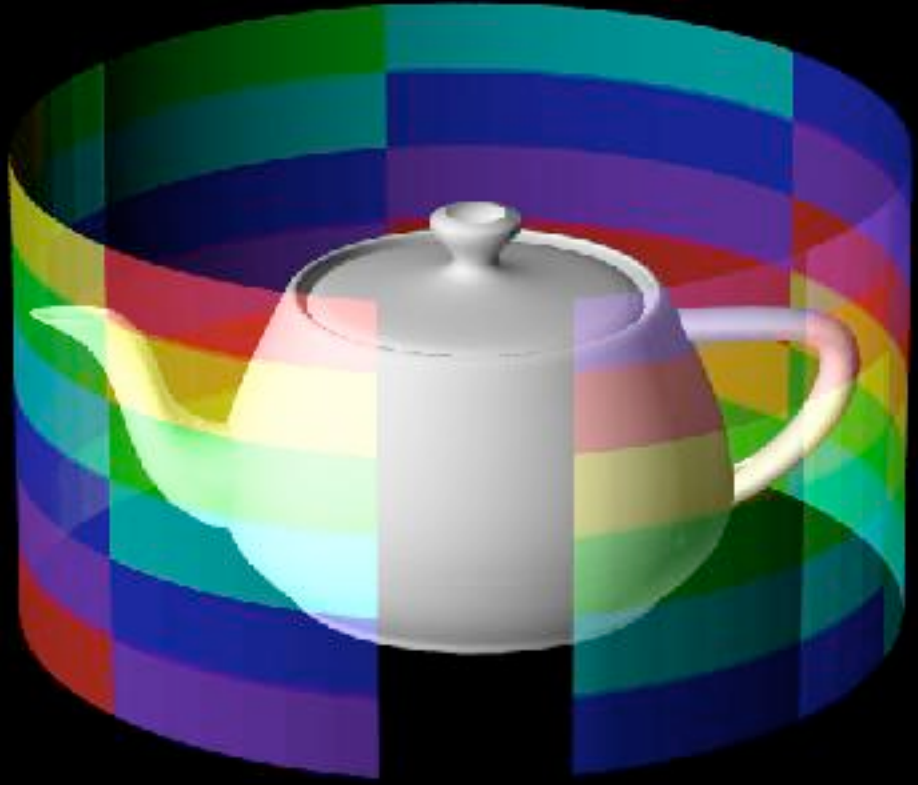


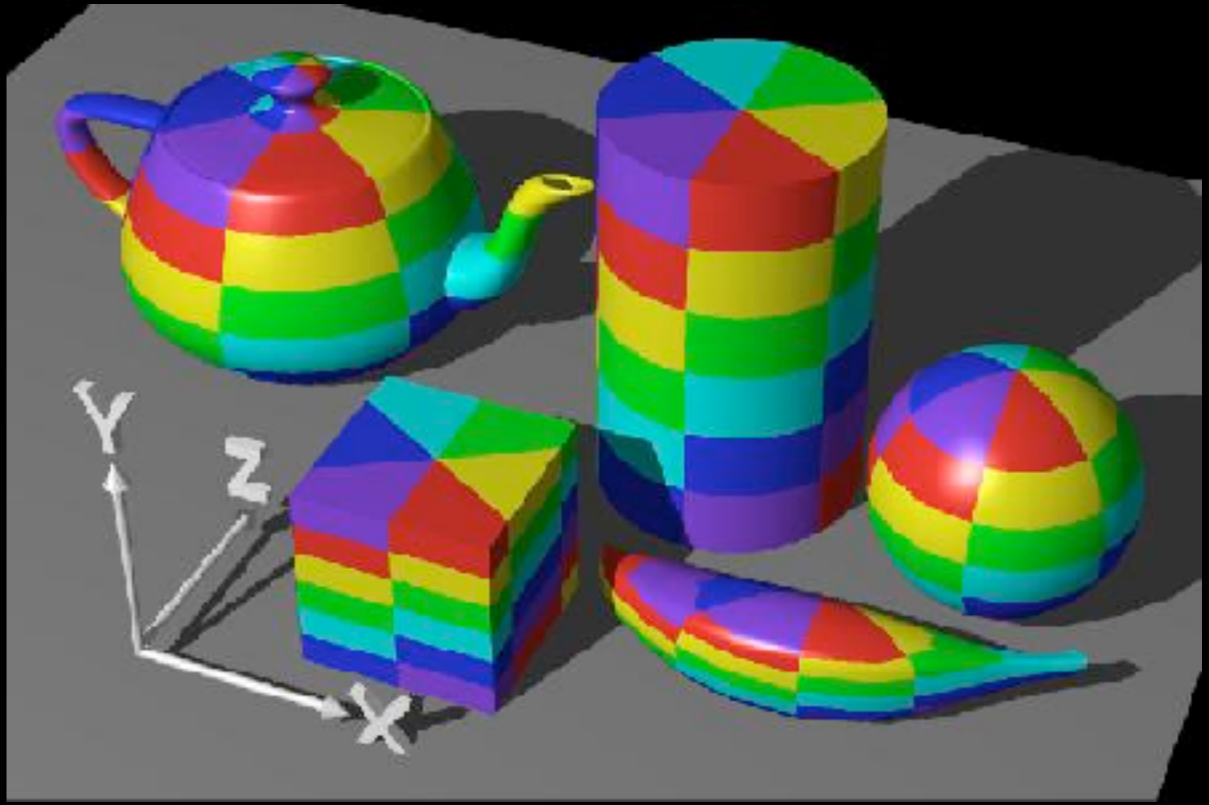
[Rosalee Wolfe]

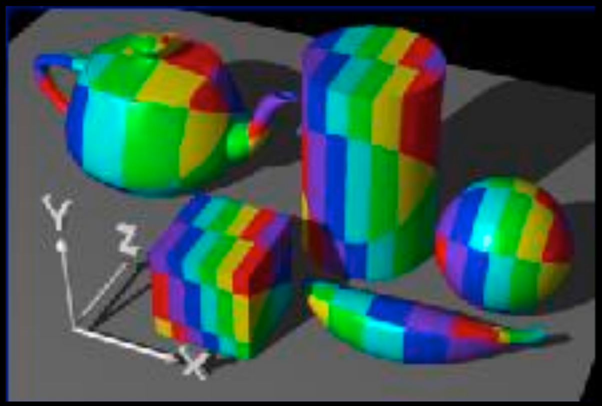
Cylindrical mapping

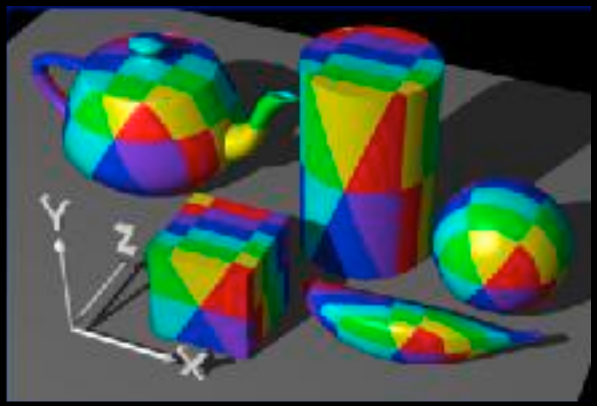
(x,y,z) -> (theta, h) -> (u,v)

[Rosalee Wolfe]





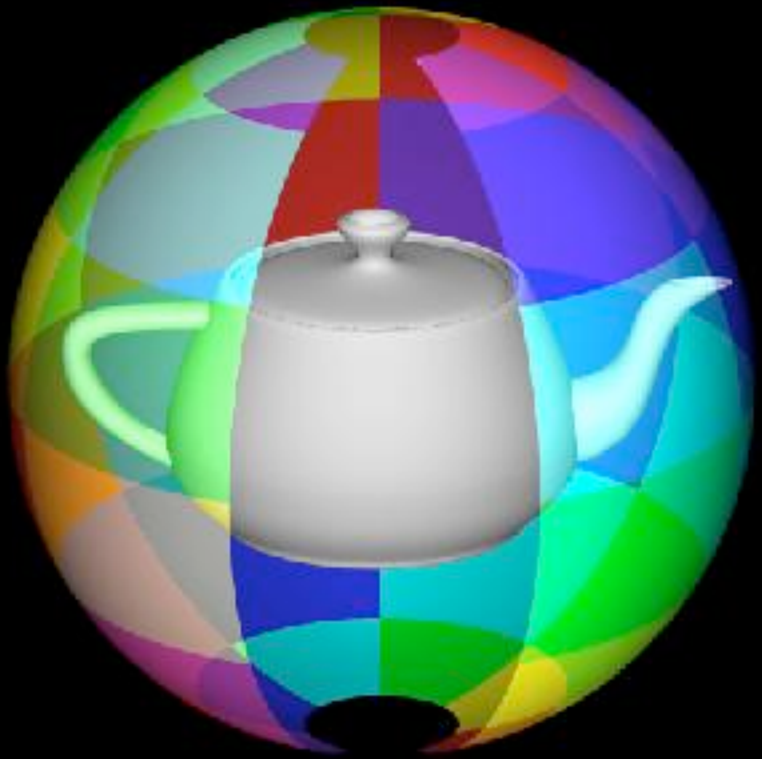


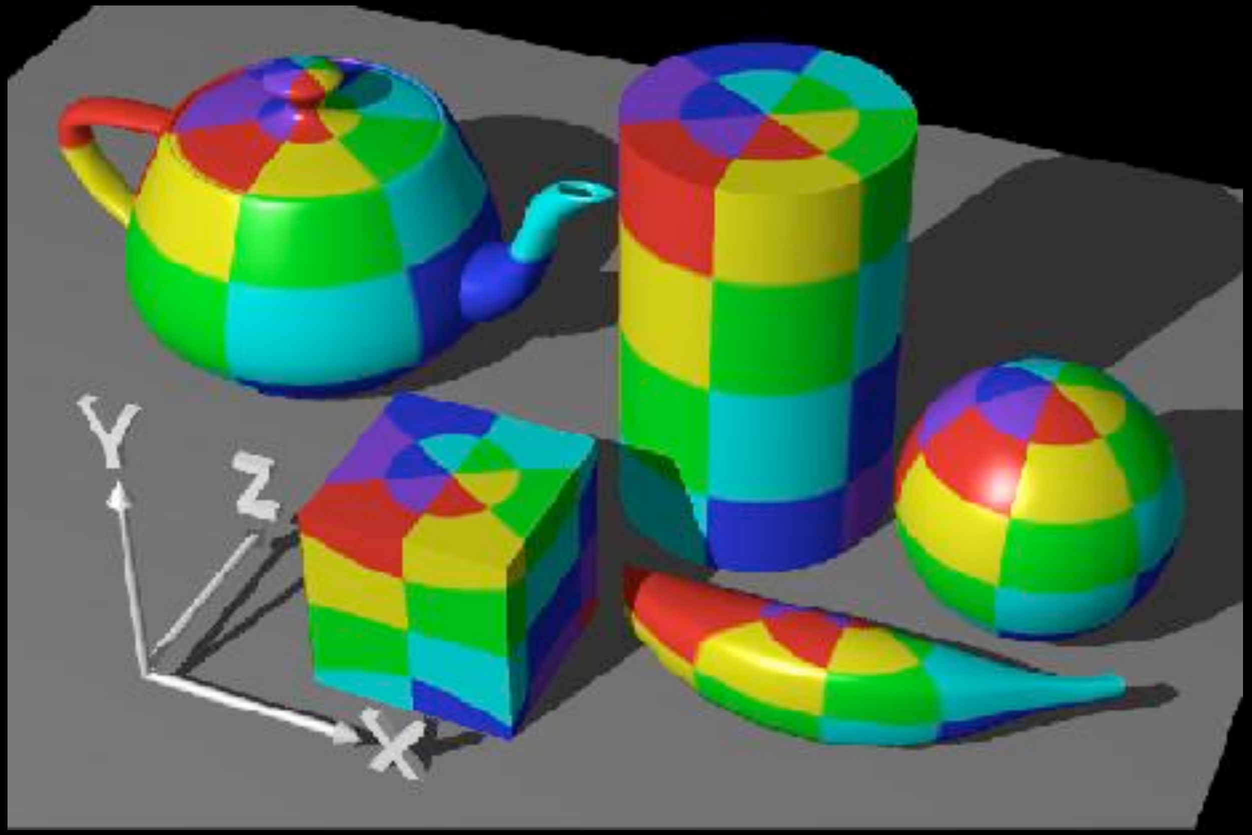


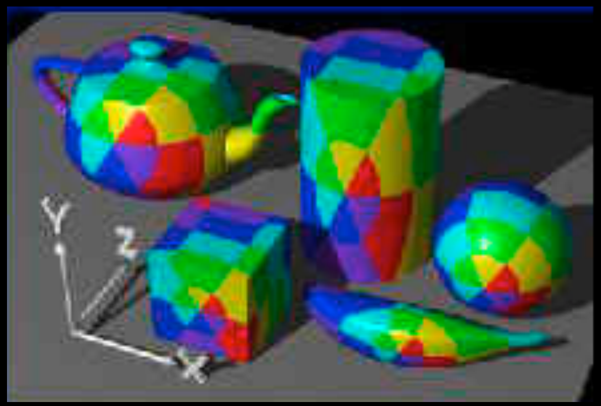
Spherical Mapping

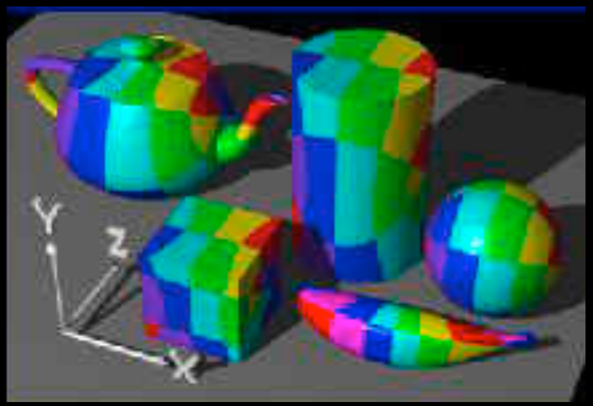
(x,y,z) -> (latitude,longitude)
-> (u,v)

[Rosalee Wolfe]

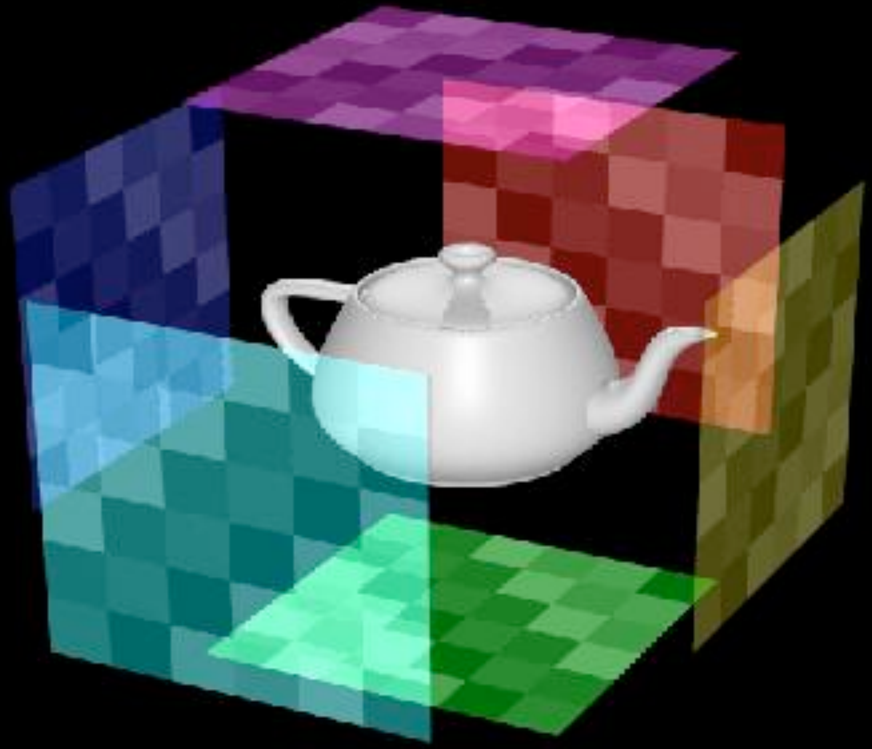


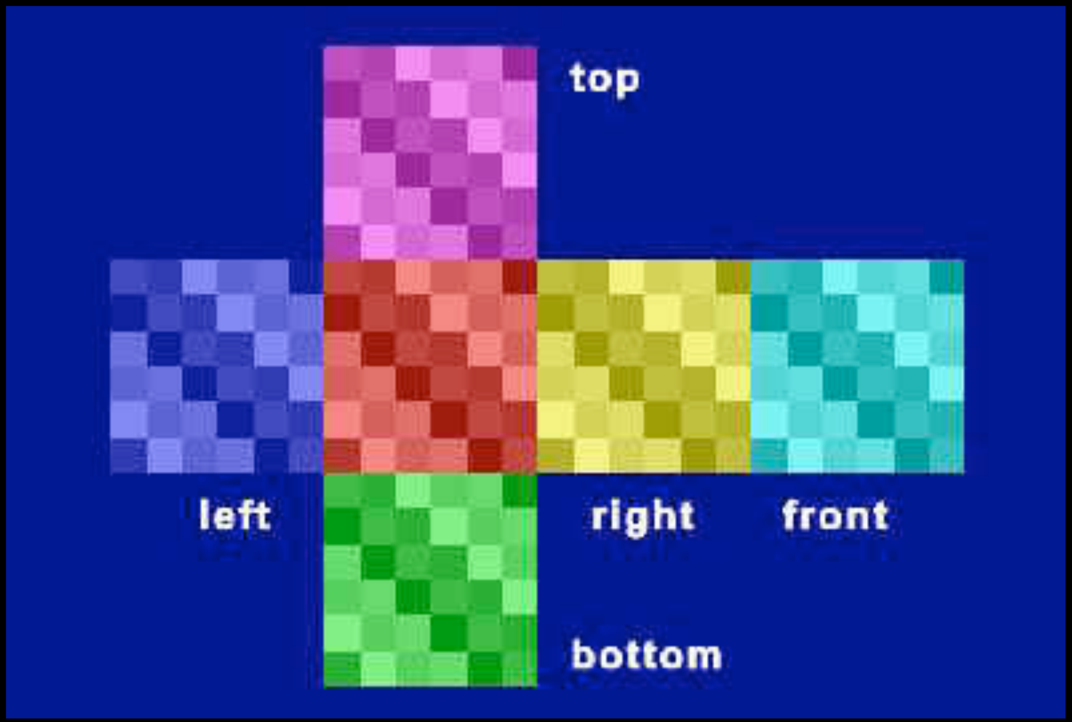


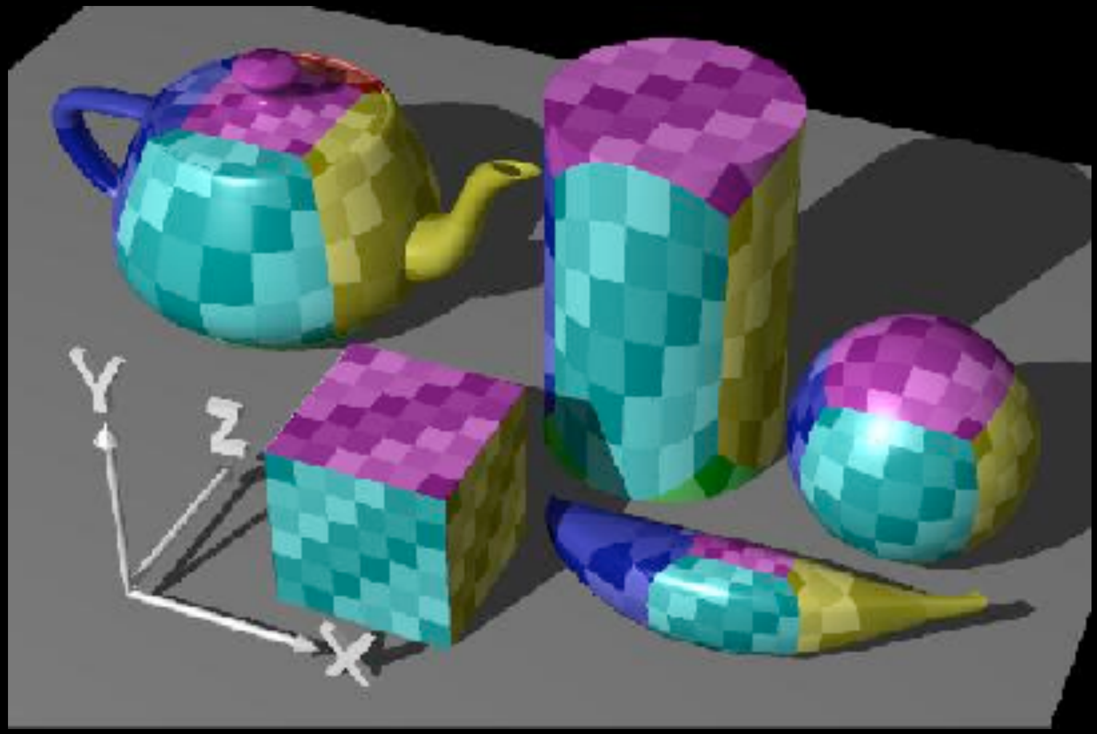




Box Mapping

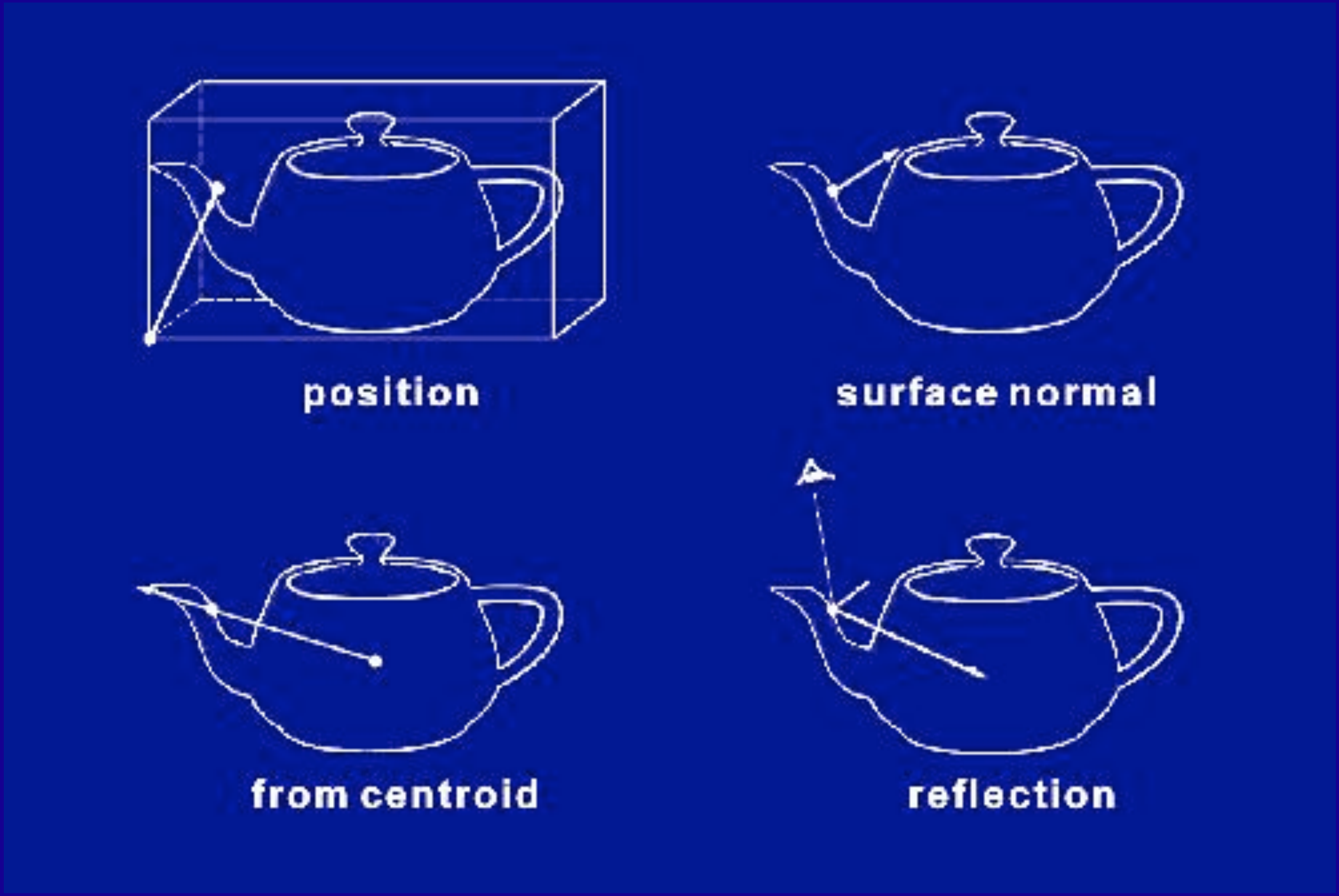






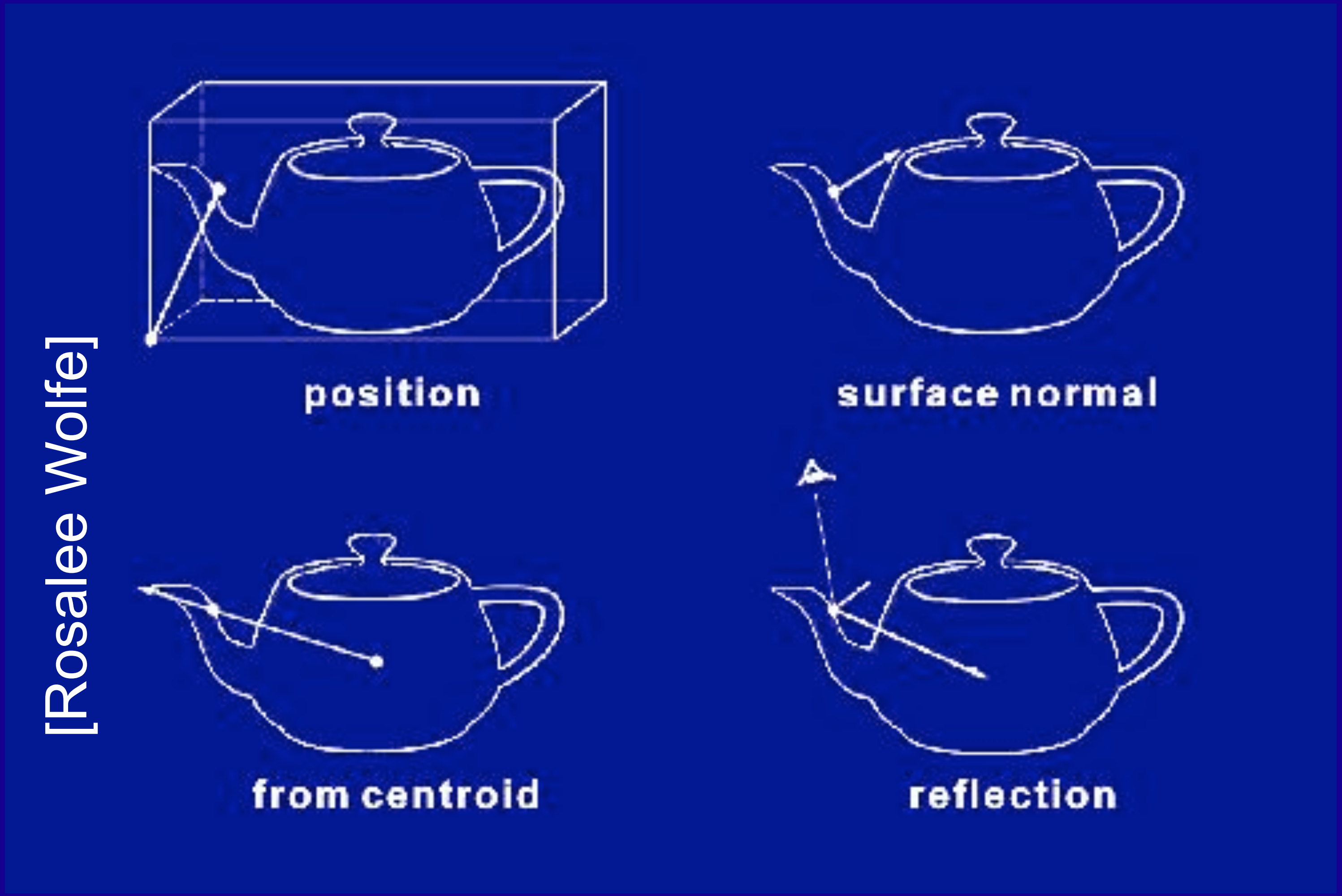
[Rosalee Wolfe]

How do we map between intermediate and actual objects?

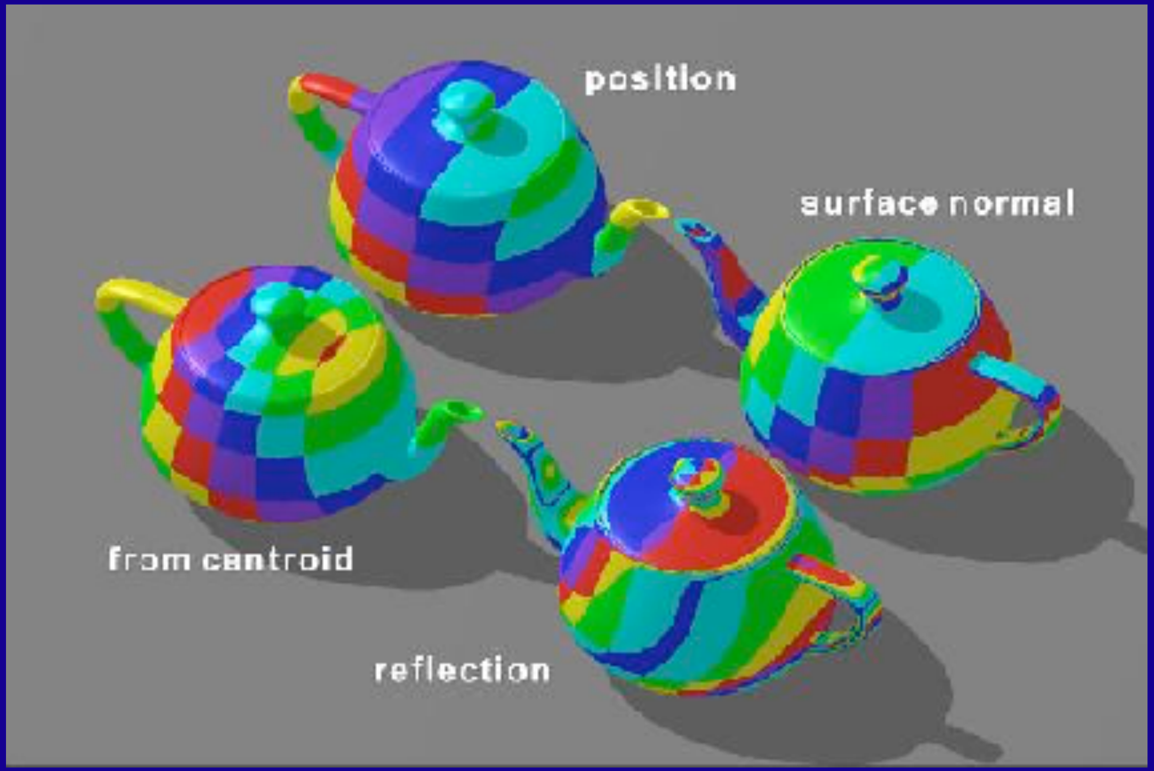


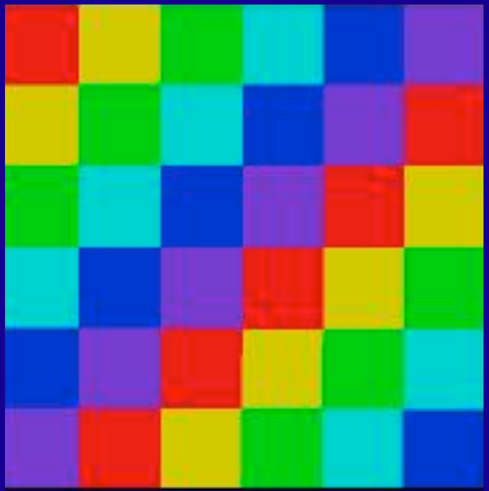
[Rosalee Wolfe]

How do we map between intermediate and actual objects?

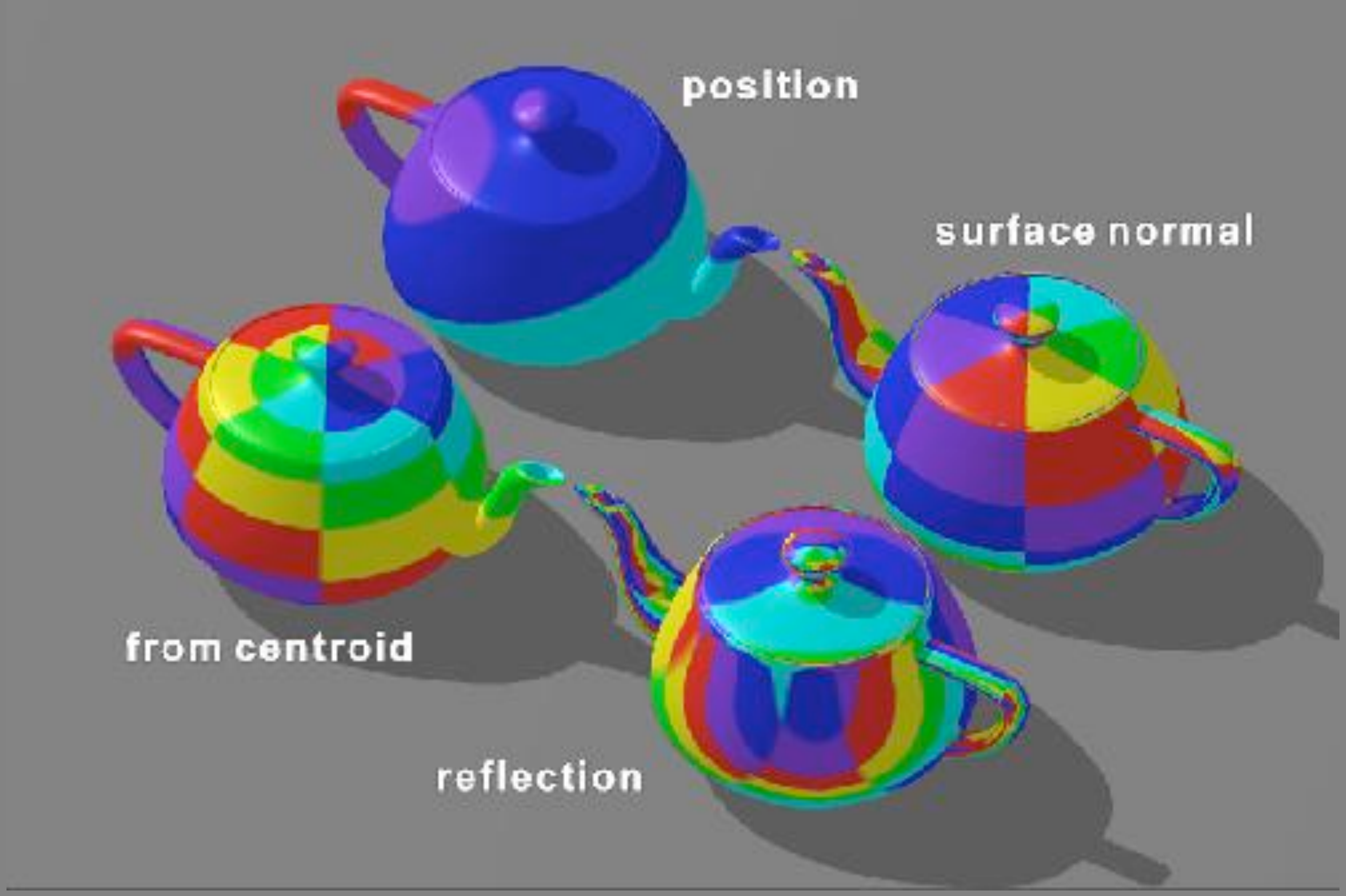


[Rosalee Wolfe]

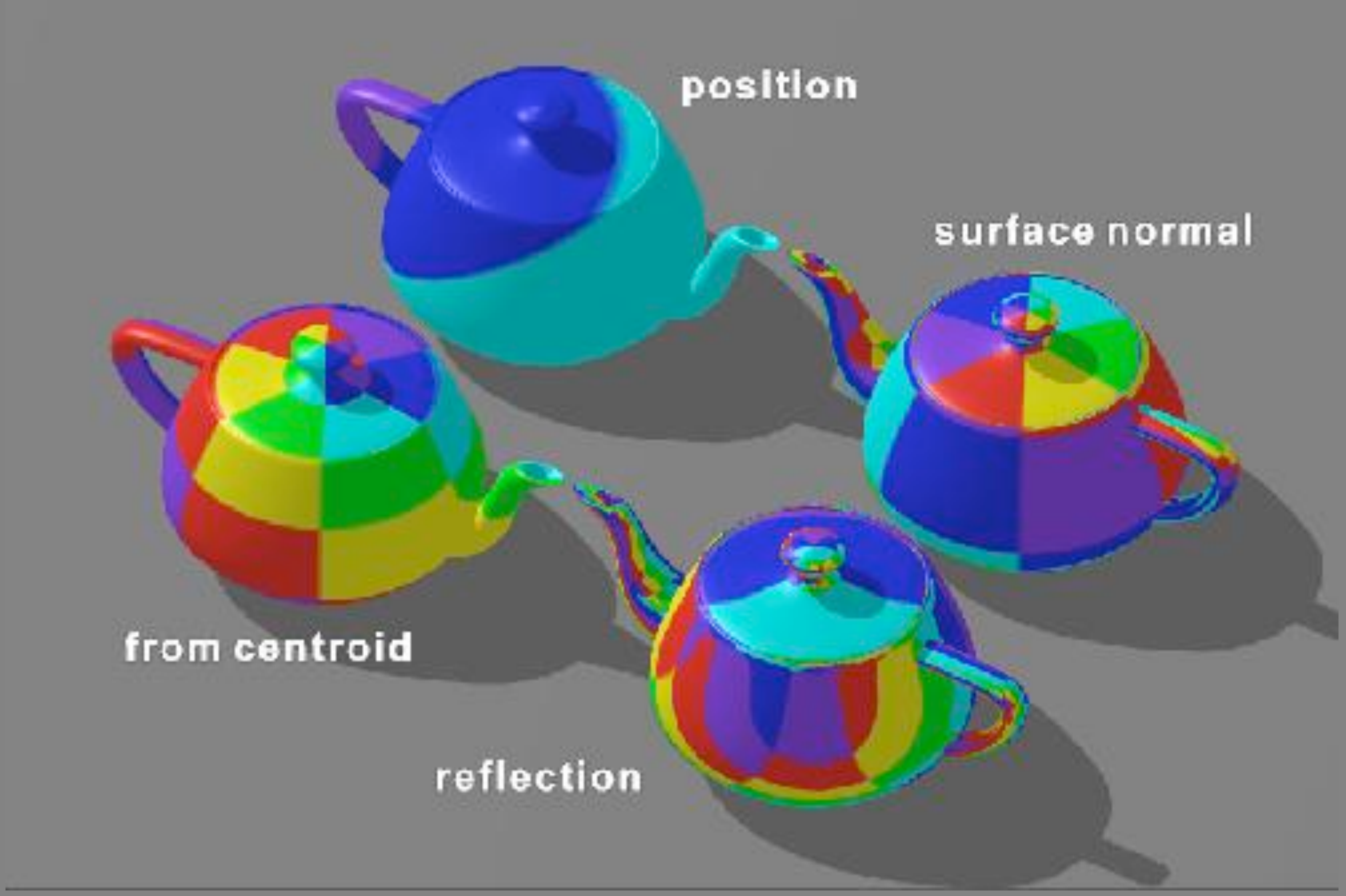




What intermediate shape was used here?

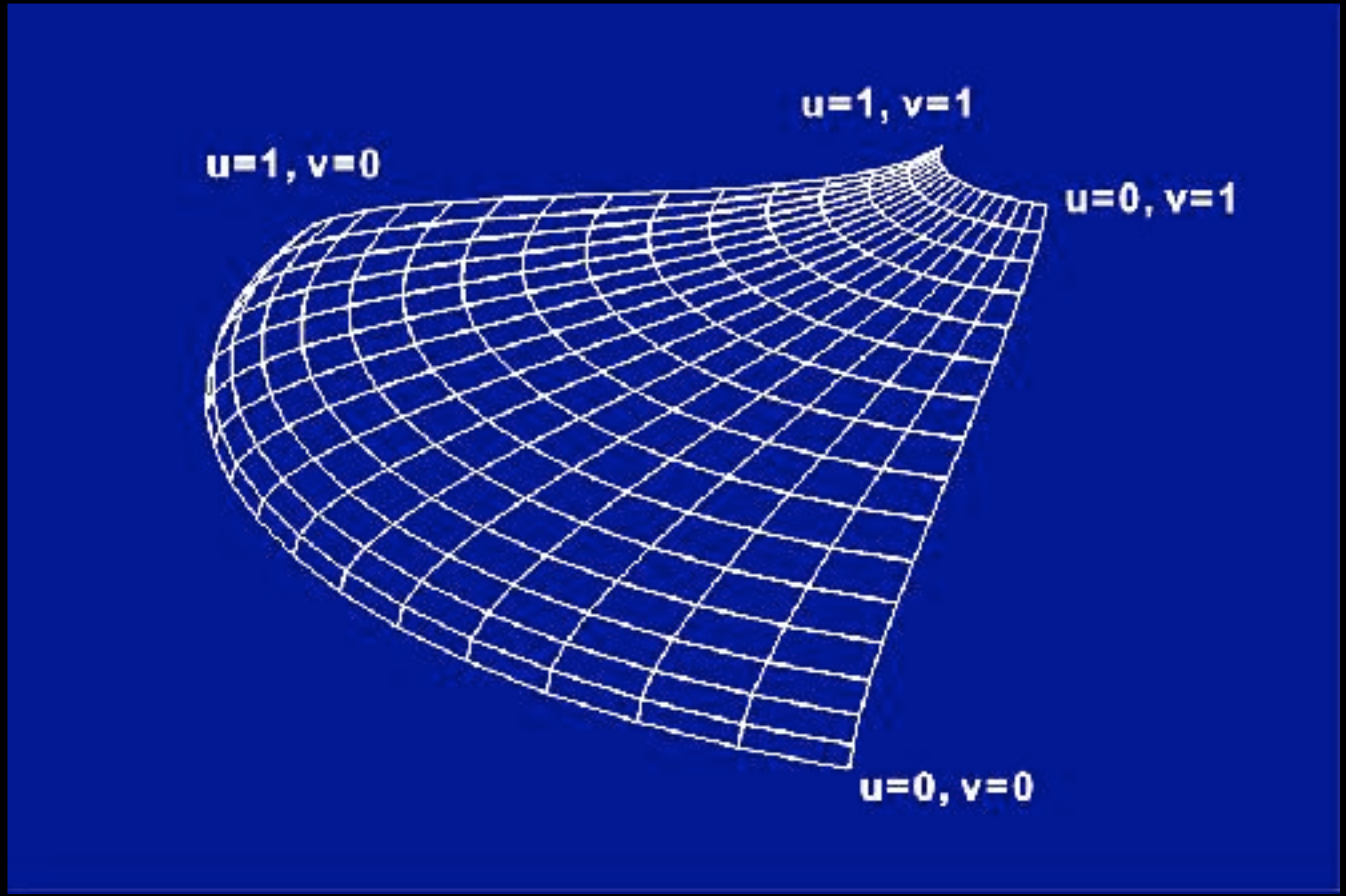


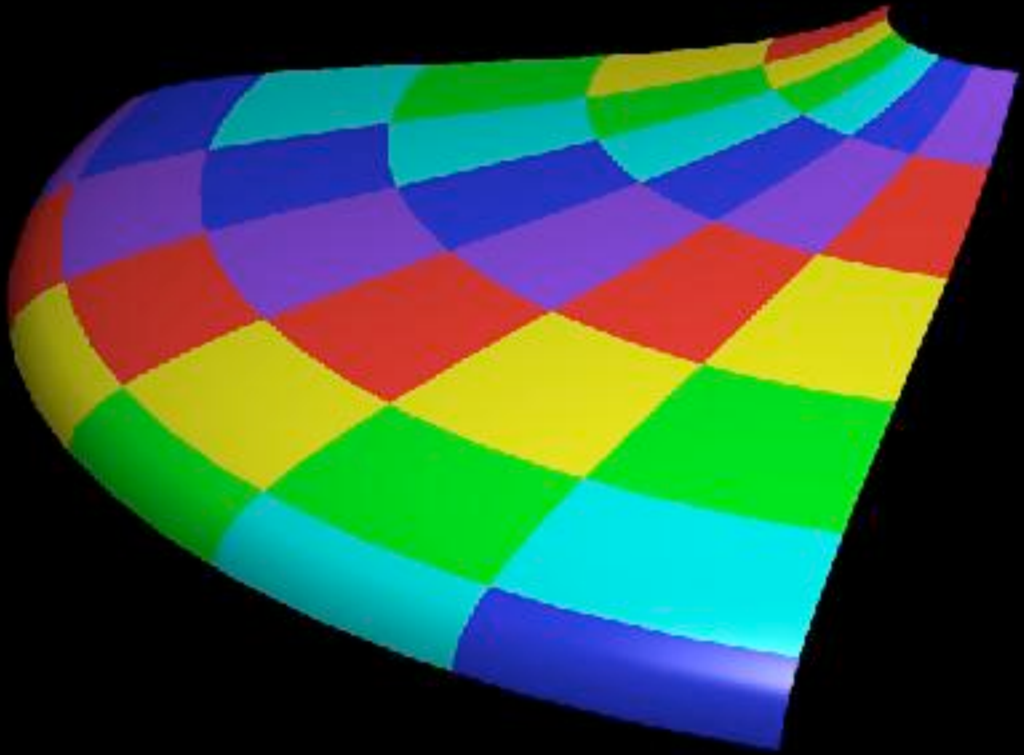
Cylindrical



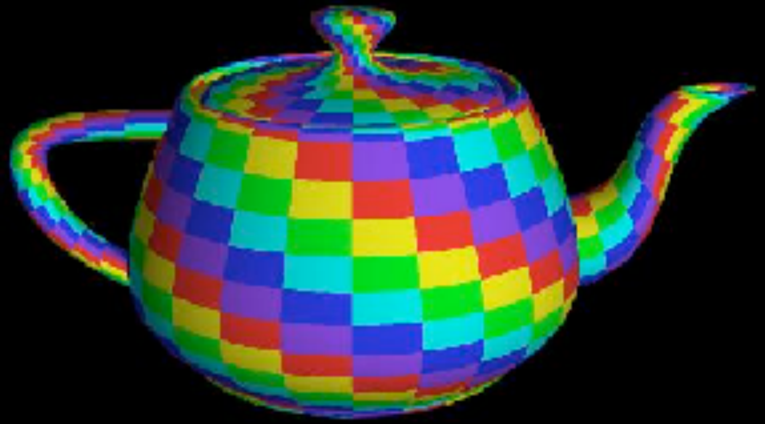
Spherical

Parametric Surfaces

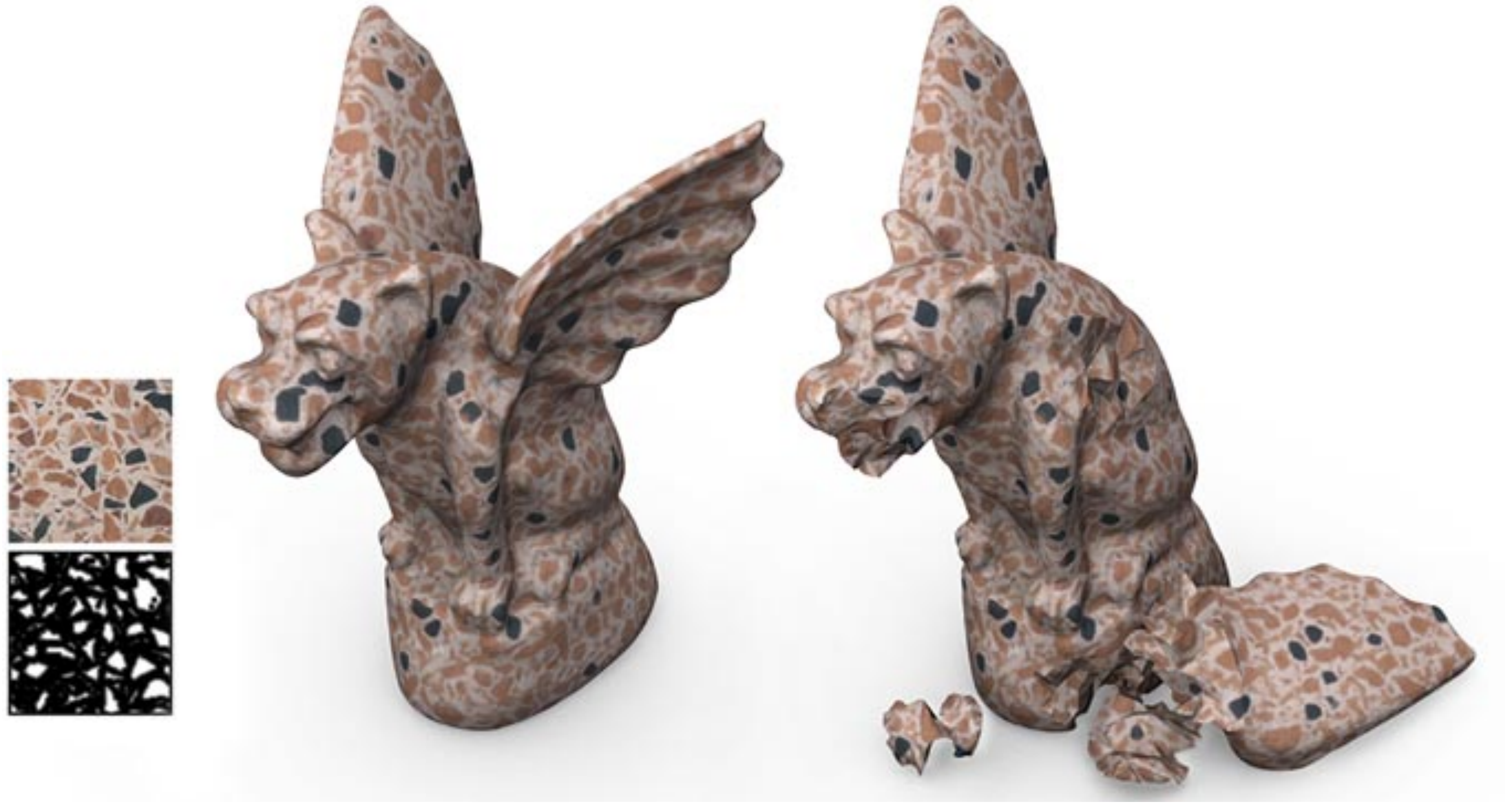




32 parametric patches



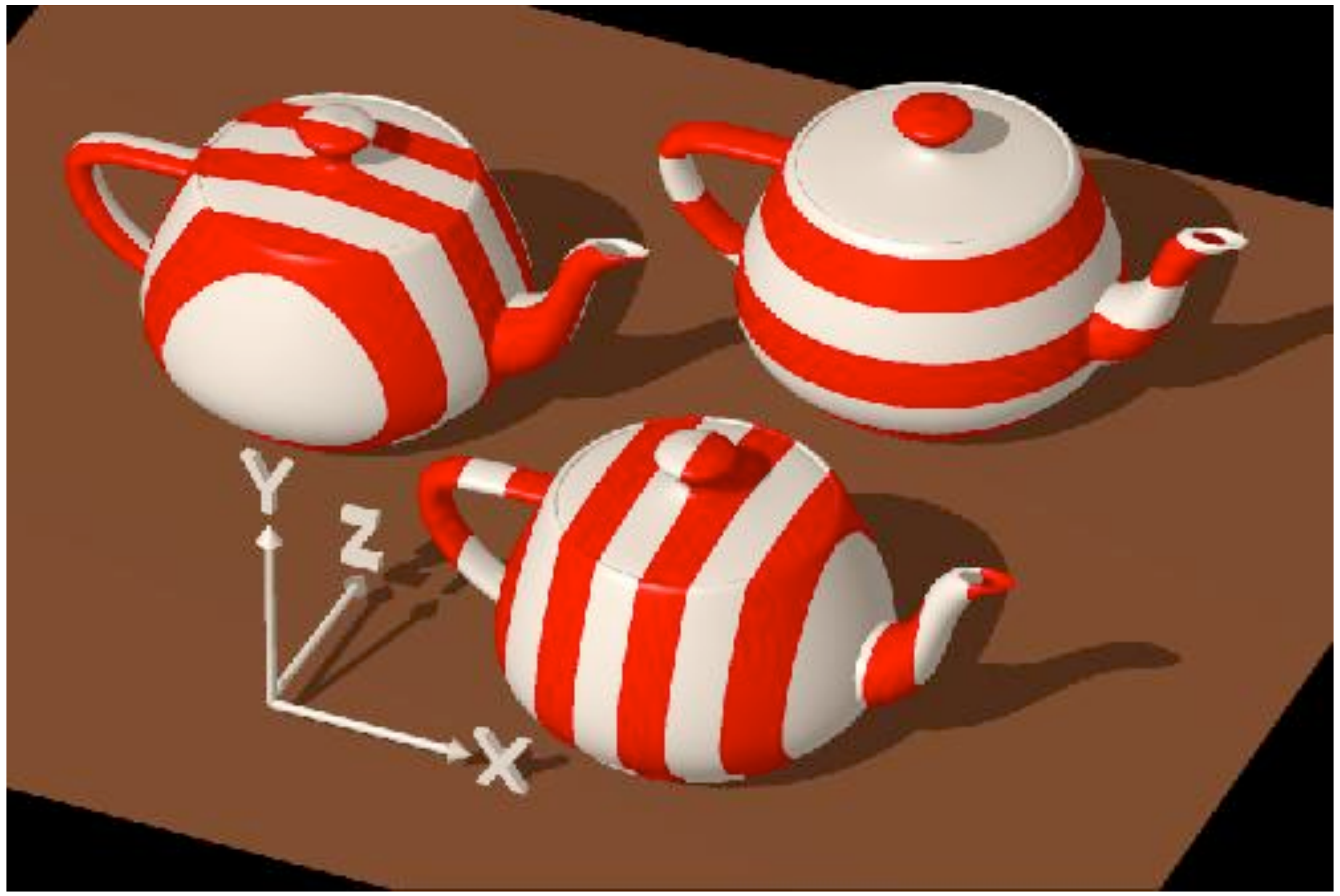
3D solid textures

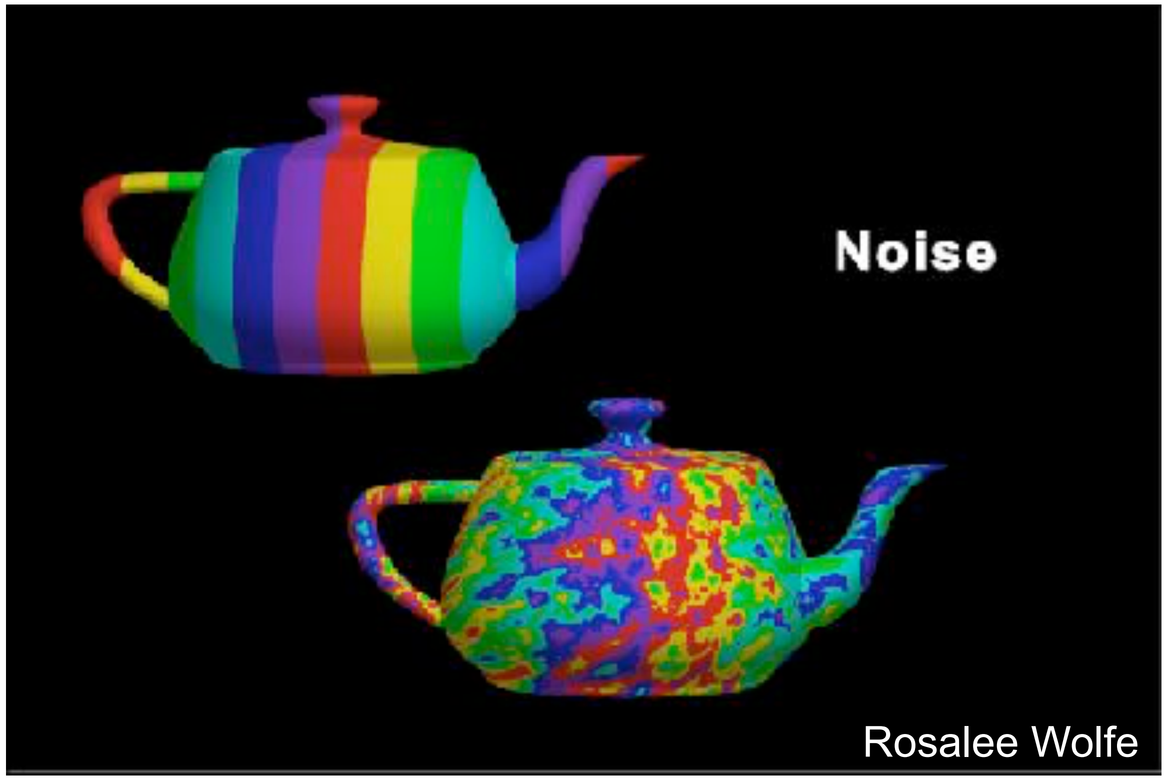


[Dong et al., 2008]

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

Procedural textures

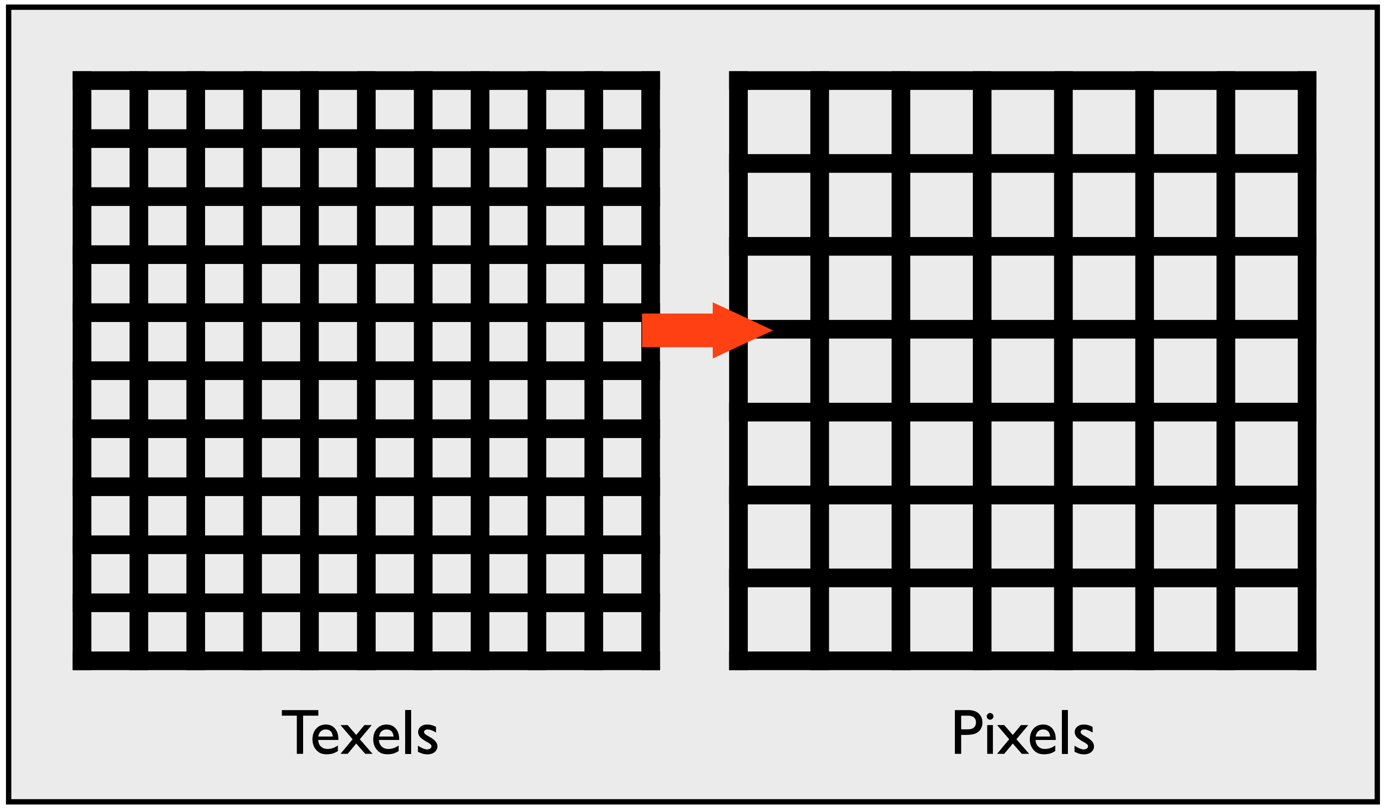


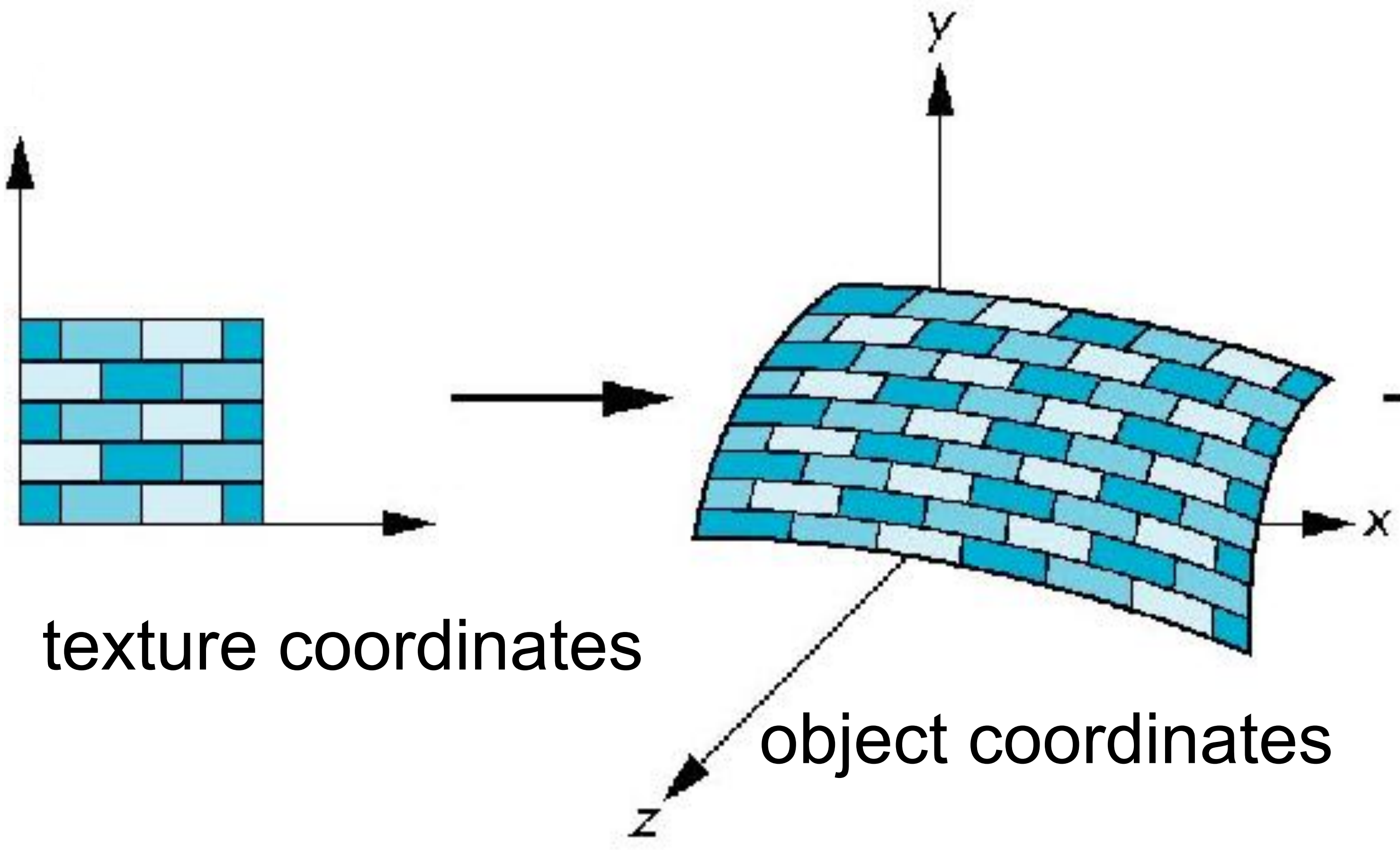


e.g., Perlin noise

Texture Sampling

Texture Mapping





texture coordinates

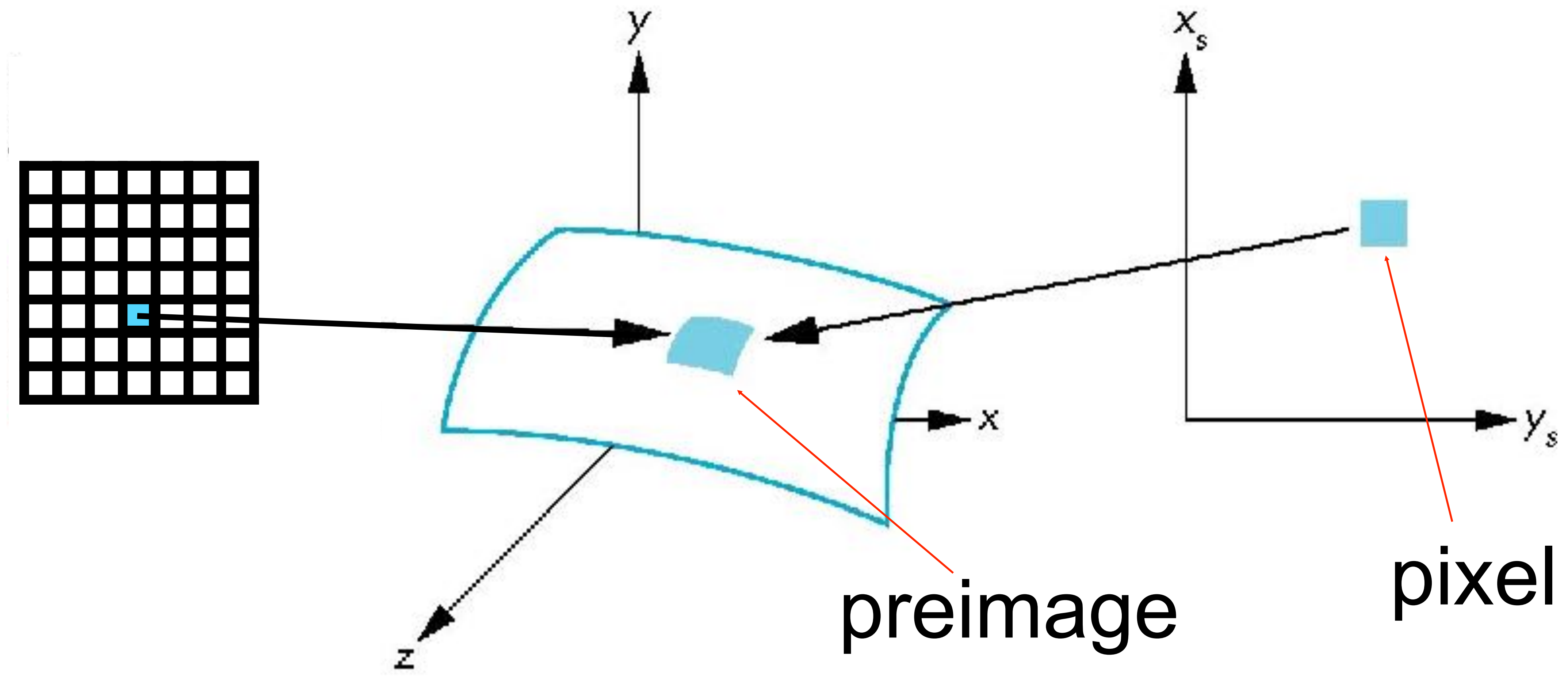
object coordinates

window coordinates

[Angel and Shreiner]

Point Sampling

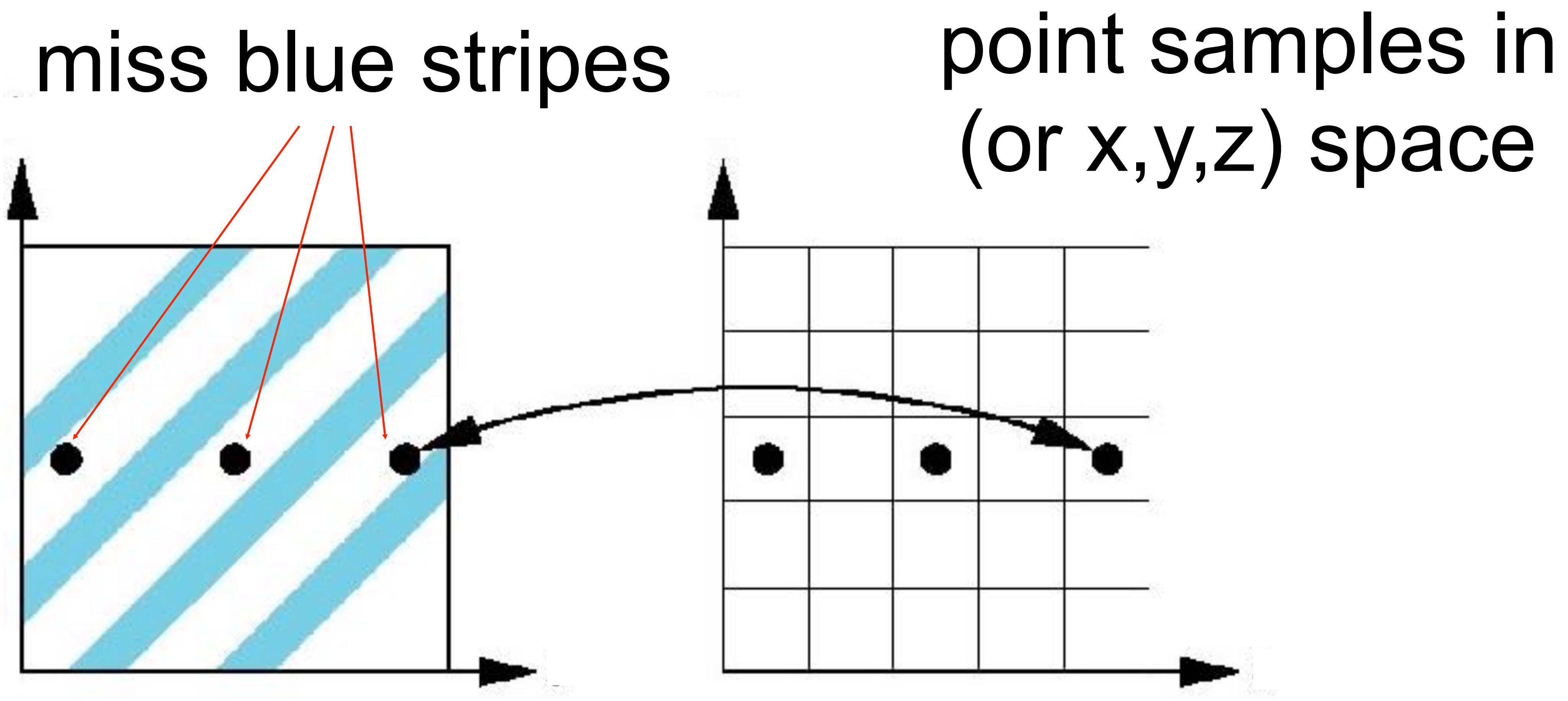
Map back to texture image and use the **nearest texel**



[Angel and Shreiner]

Aliasing

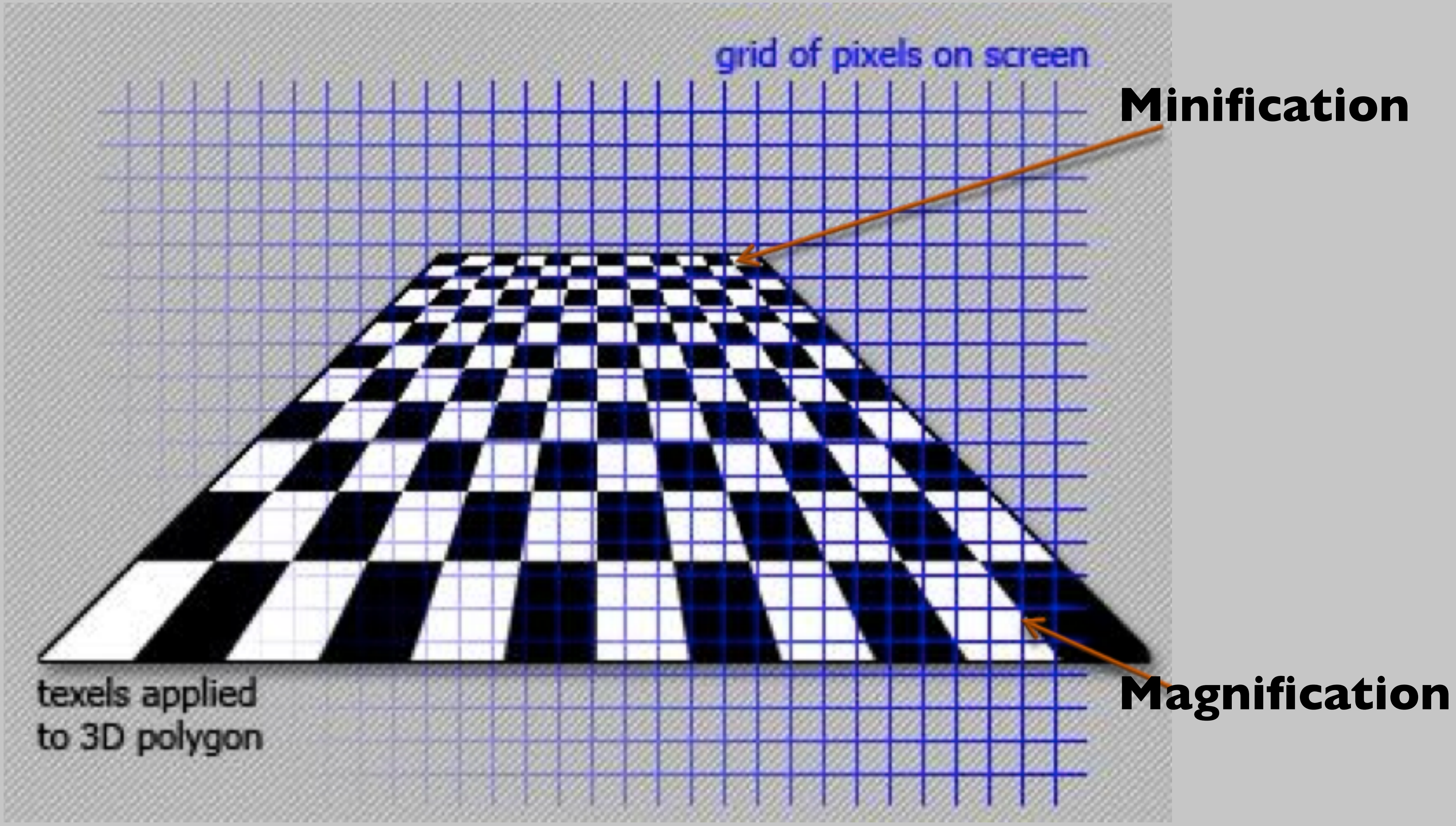
Point sampling of the texture can lead to aliasing artifacts



point samples in texture space

[Angel and Shreiner]

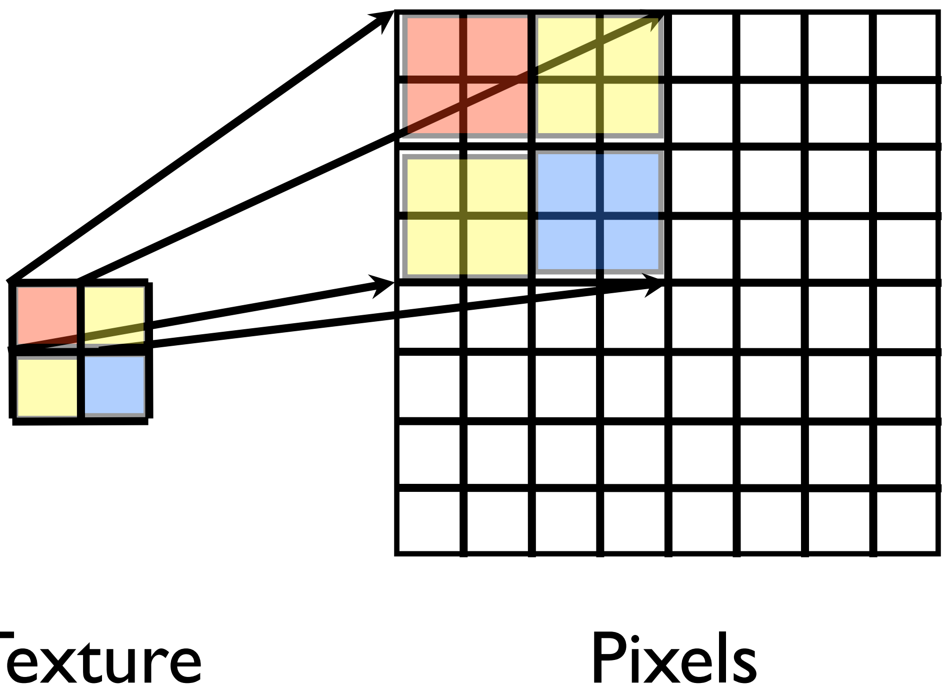
Magnification and Minification



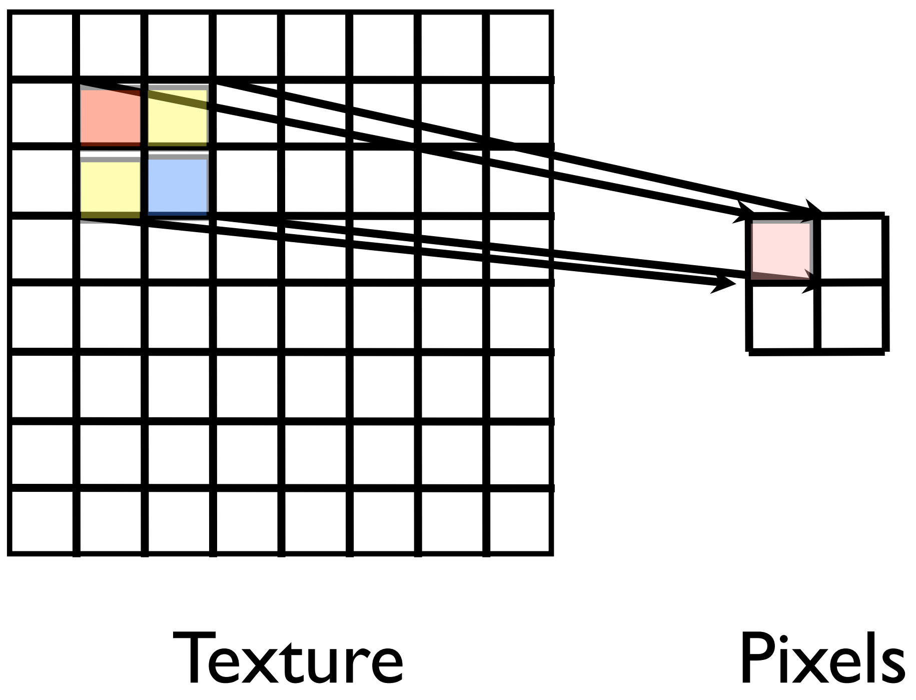
Magnification and Minification

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

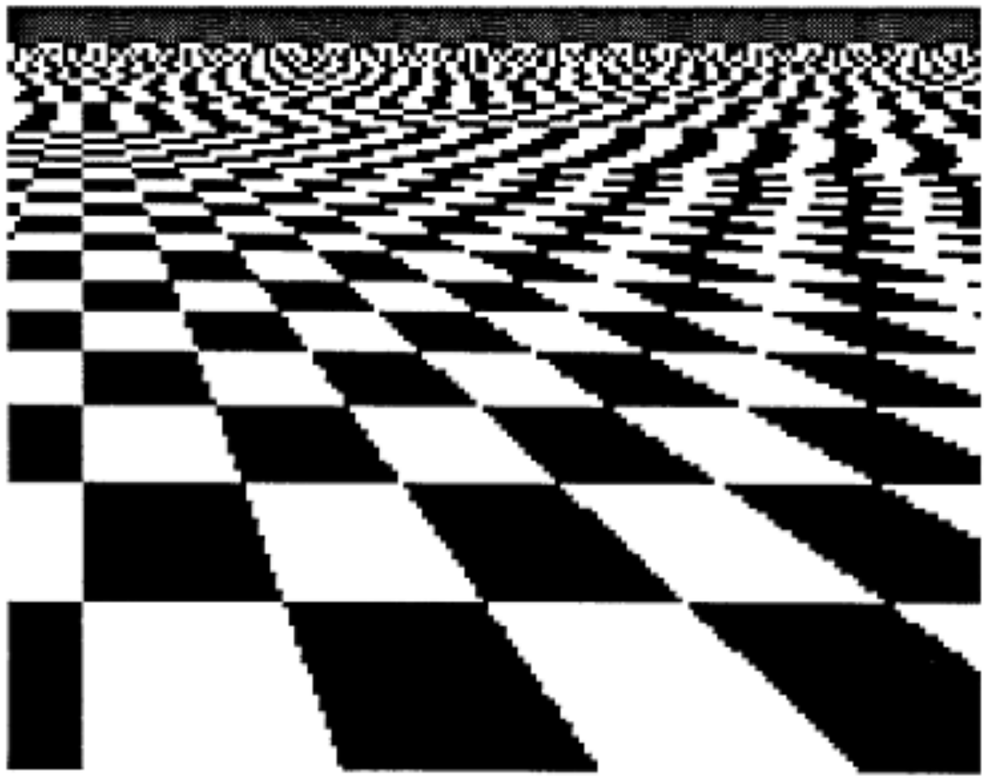


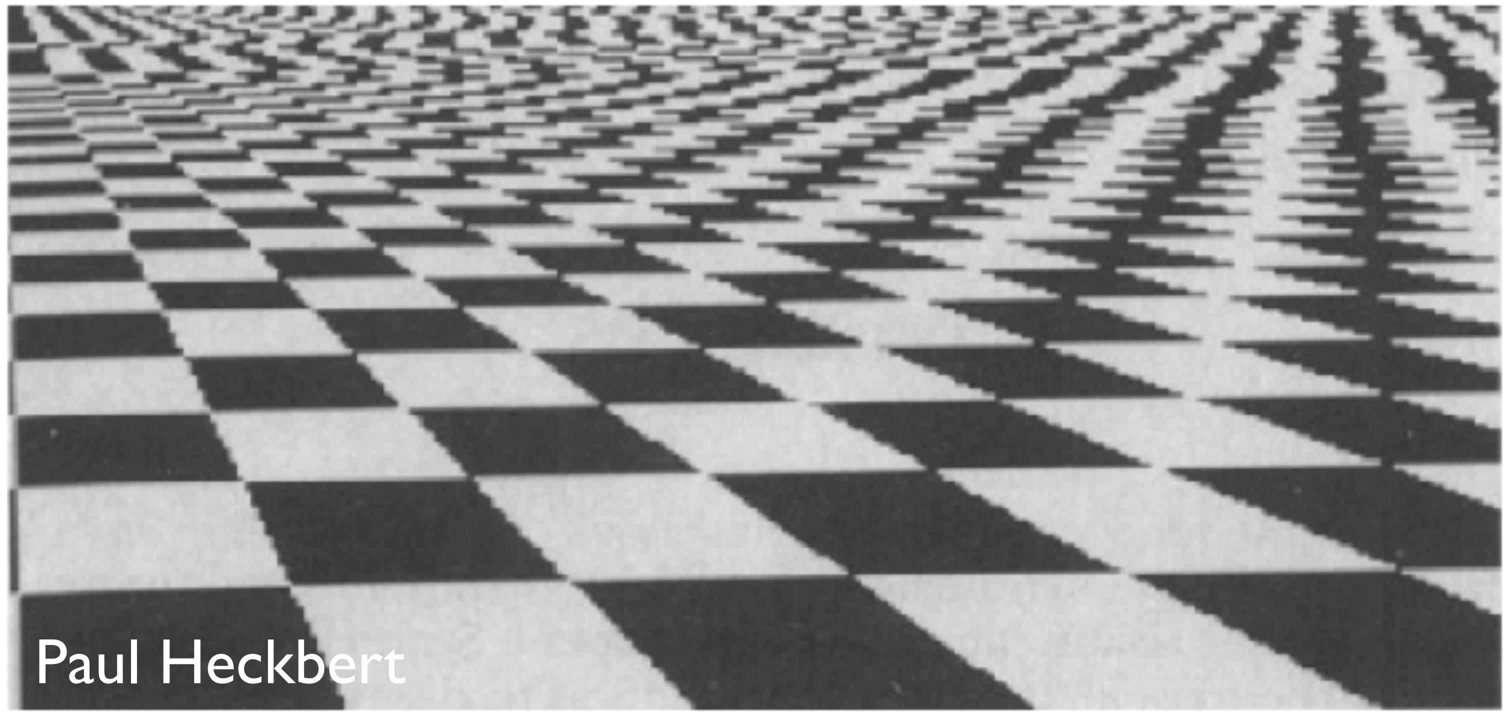
Magnification

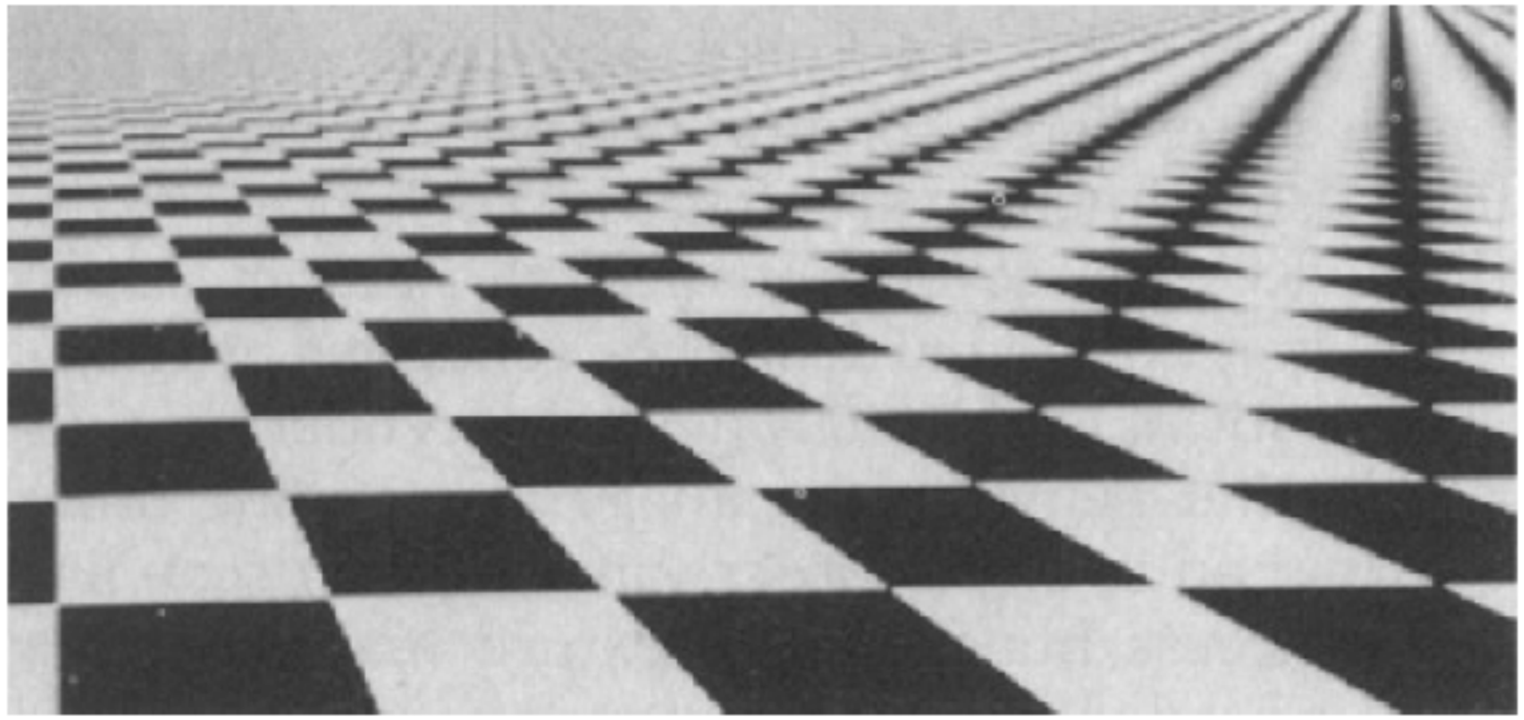


Minification

Aliasing artifacts



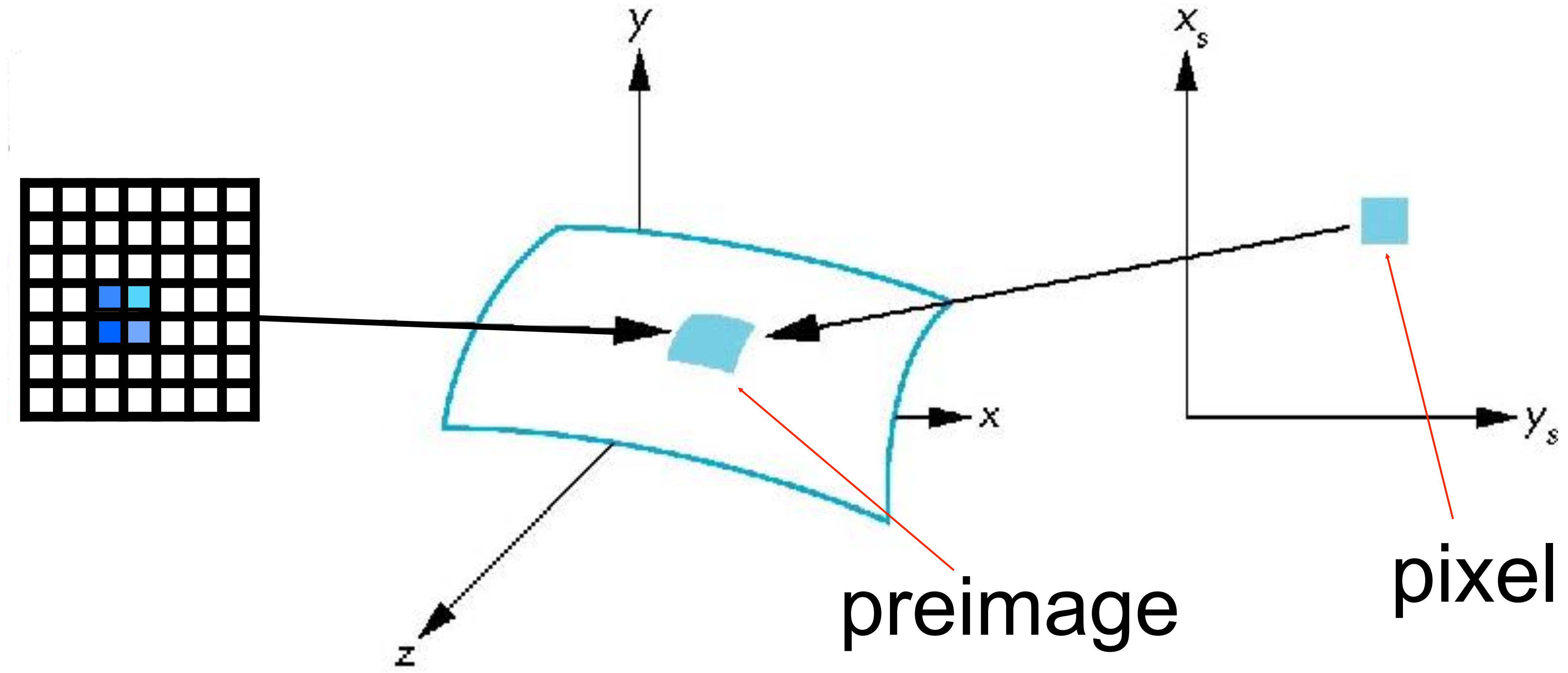




We apply **filtering** to reduce aliasing artifacts

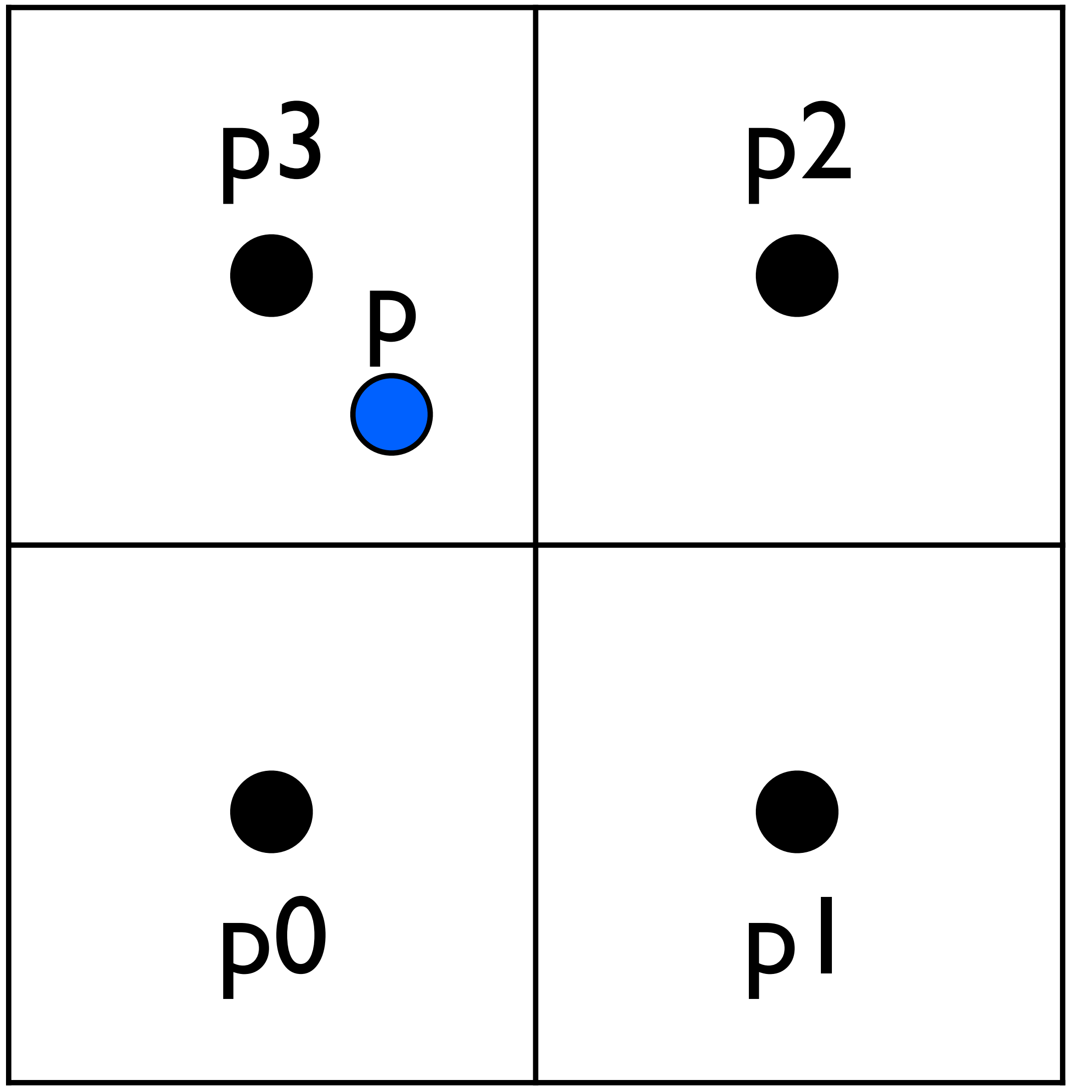
Area Averaging

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

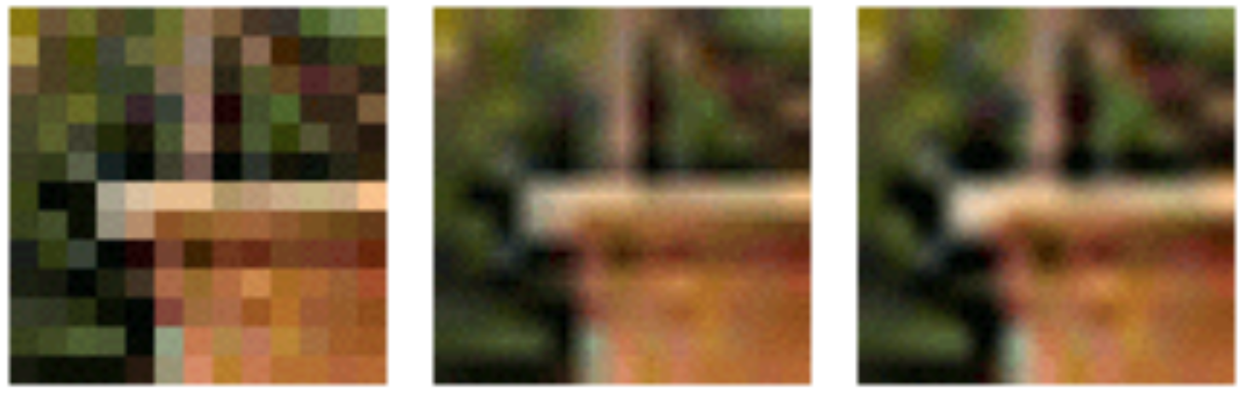


[Angel and Shreiner]

Use bilinear filtering



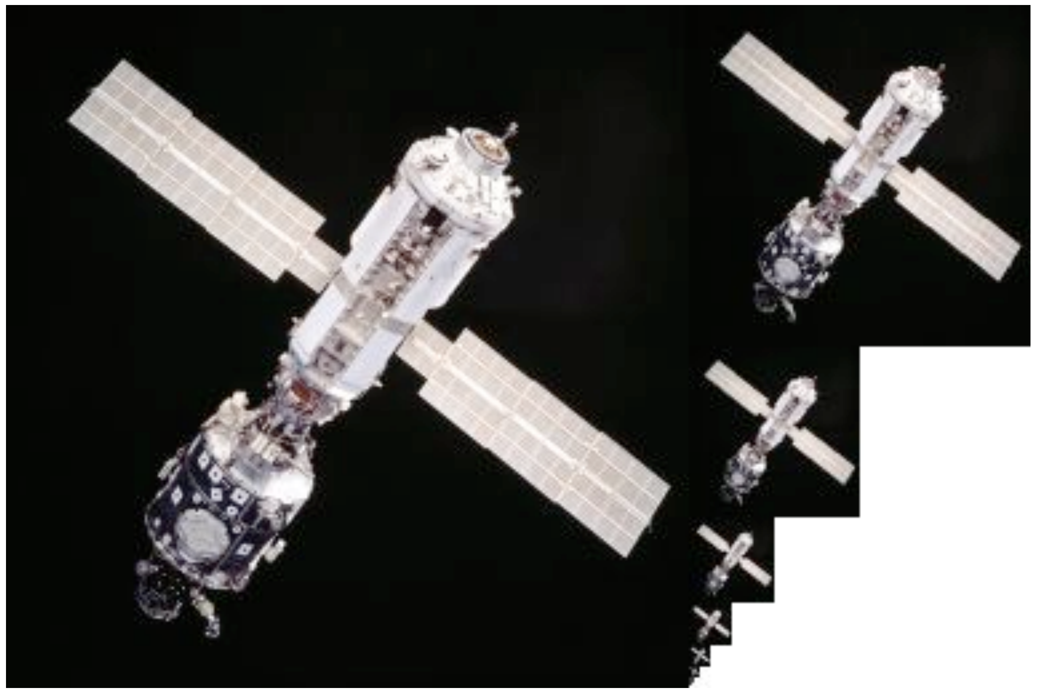
p = ?



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

mitigate magnification artifacts

Mipmapping



Togikun, Wikimedia Commons

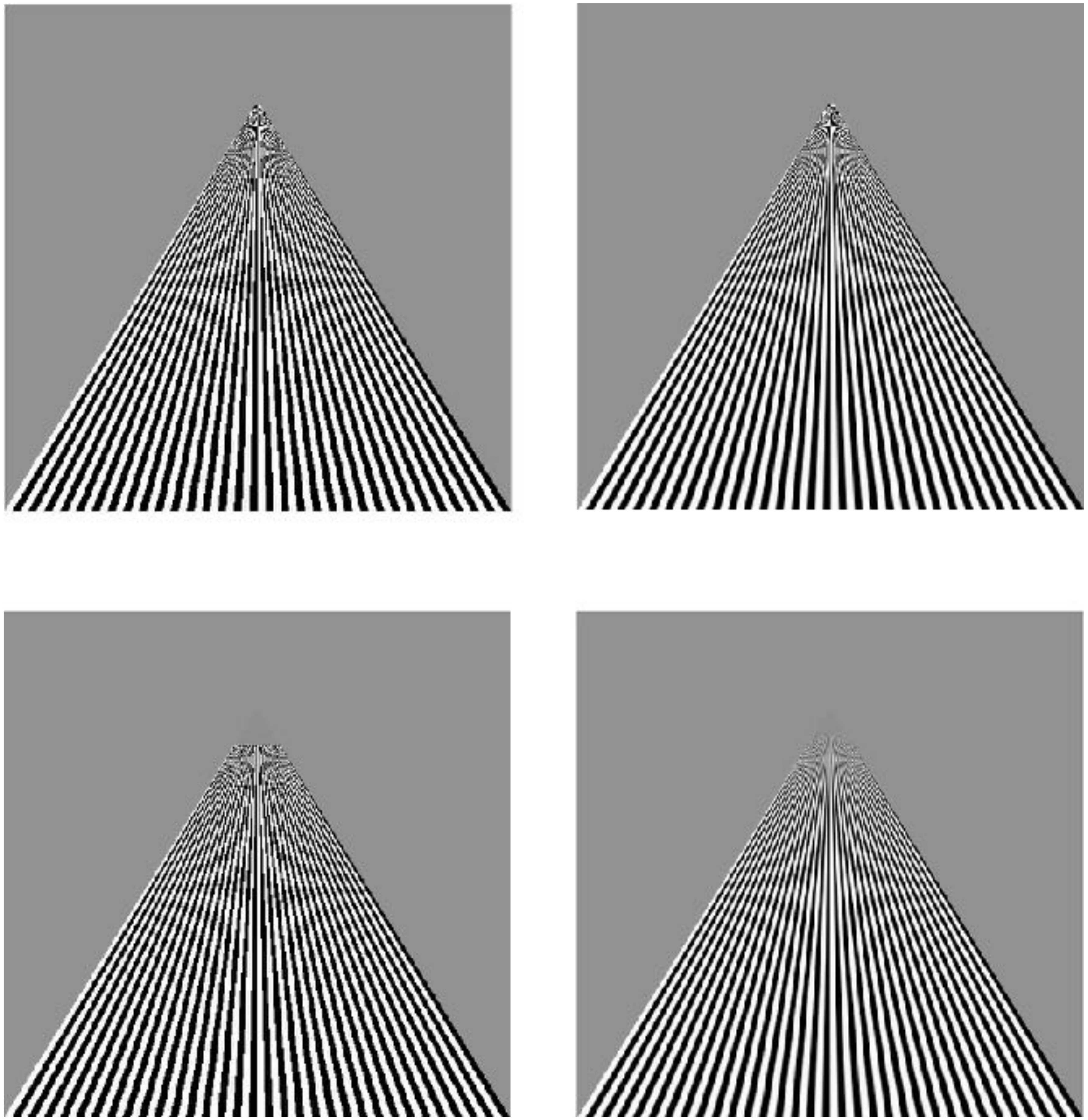
128×128, 64×64, 32×32, 16×16, 8×8, 4×4, 2×2, 1×1

Reduce minification artifacts

Prefilter the texture to obtain reduced resolutions

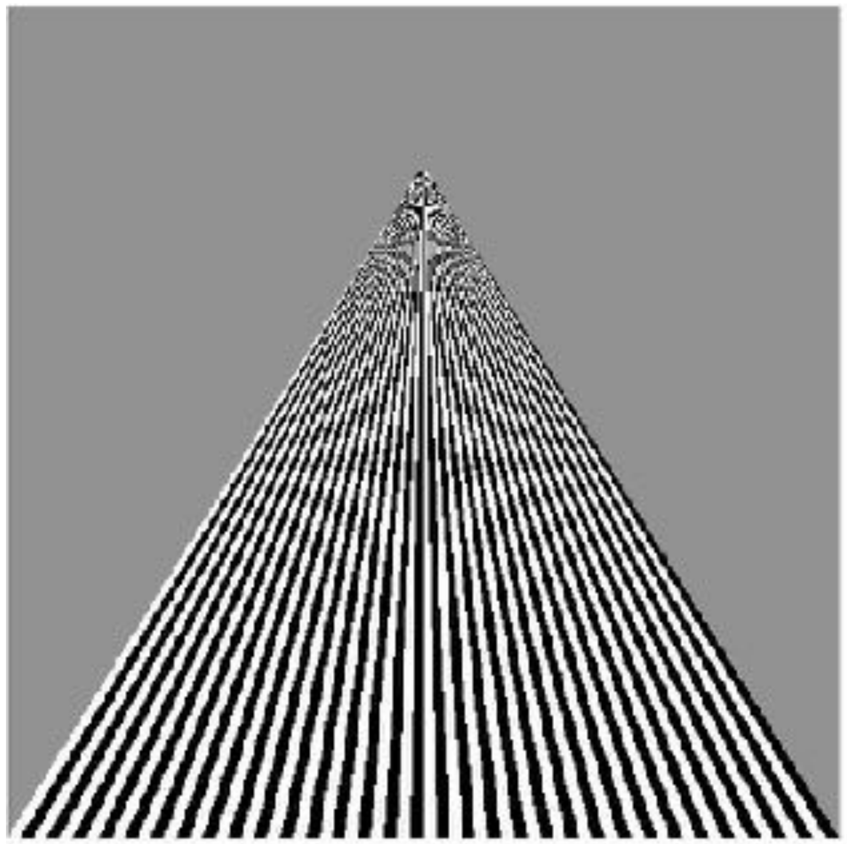
Requires 1/3 more space

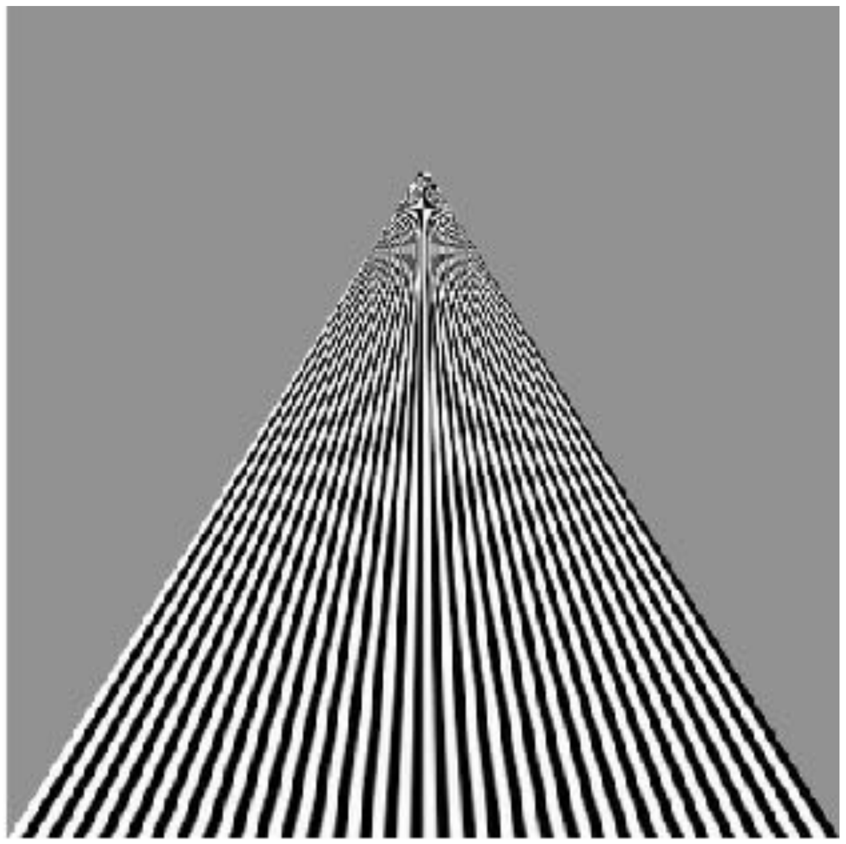
Get a texture hierarchy indexed by level



[Angel and Shreiner]

point
sampling

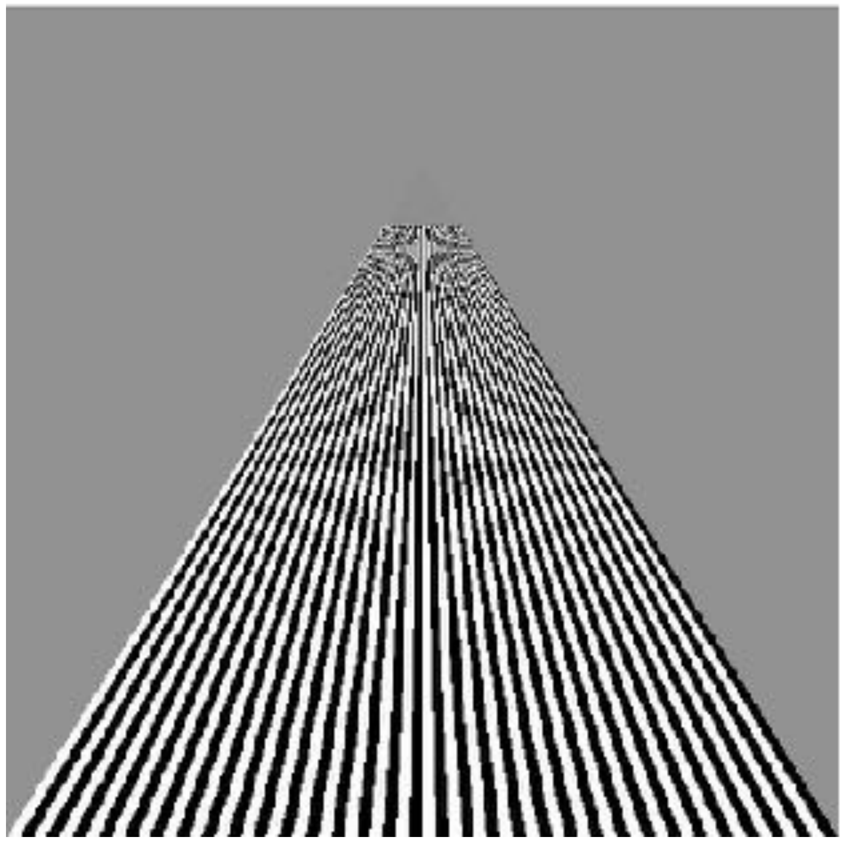


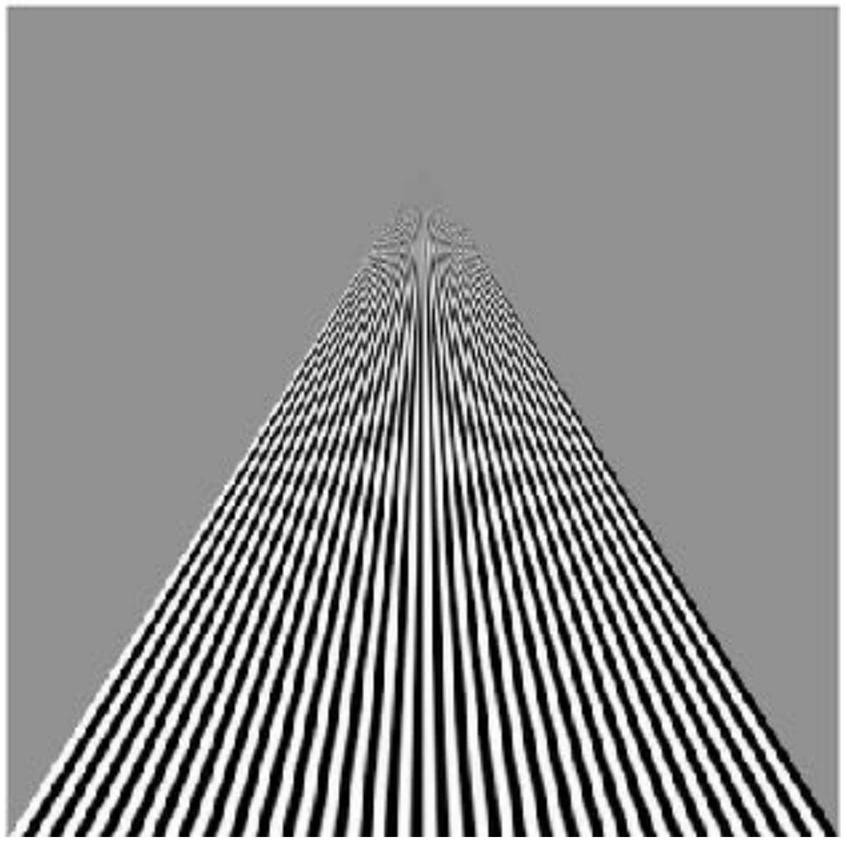


linear
filtering

[Angel and Shreiner]

mipmapped
point
sampling



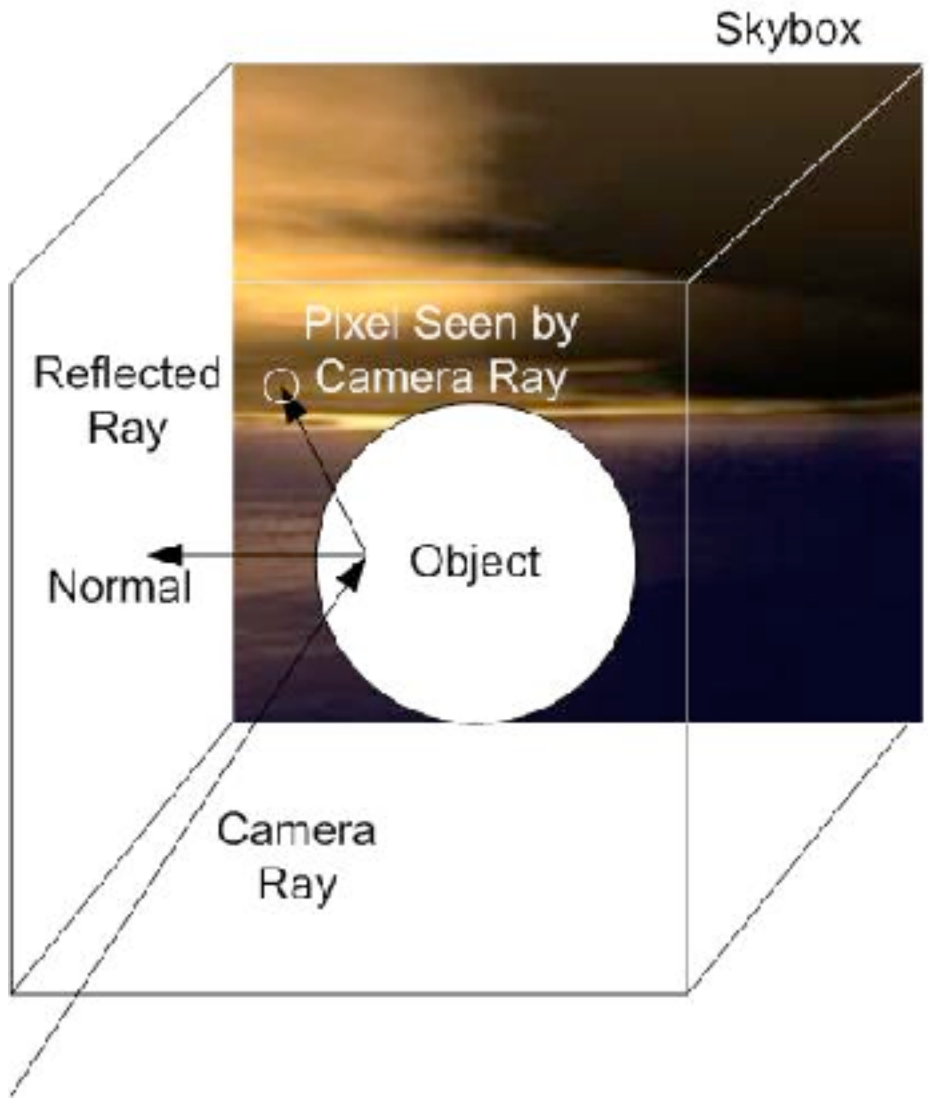


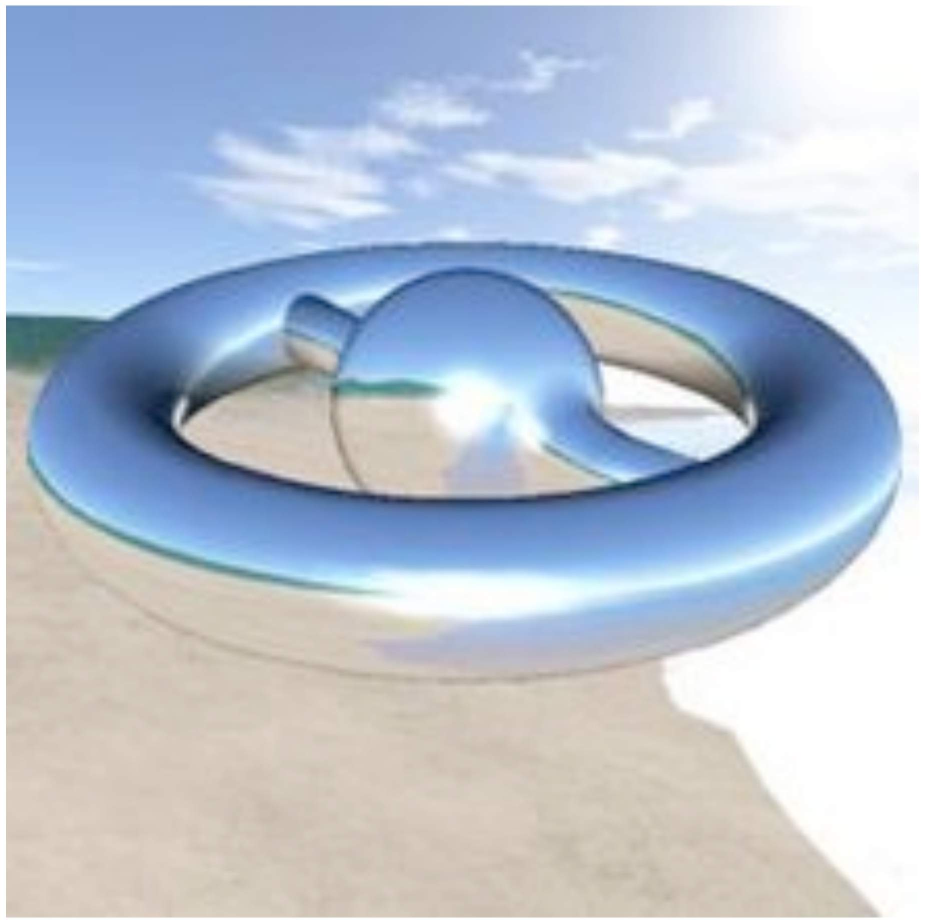
mipmapped
linear
filtering

Environment mapping

Environment Mapping

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

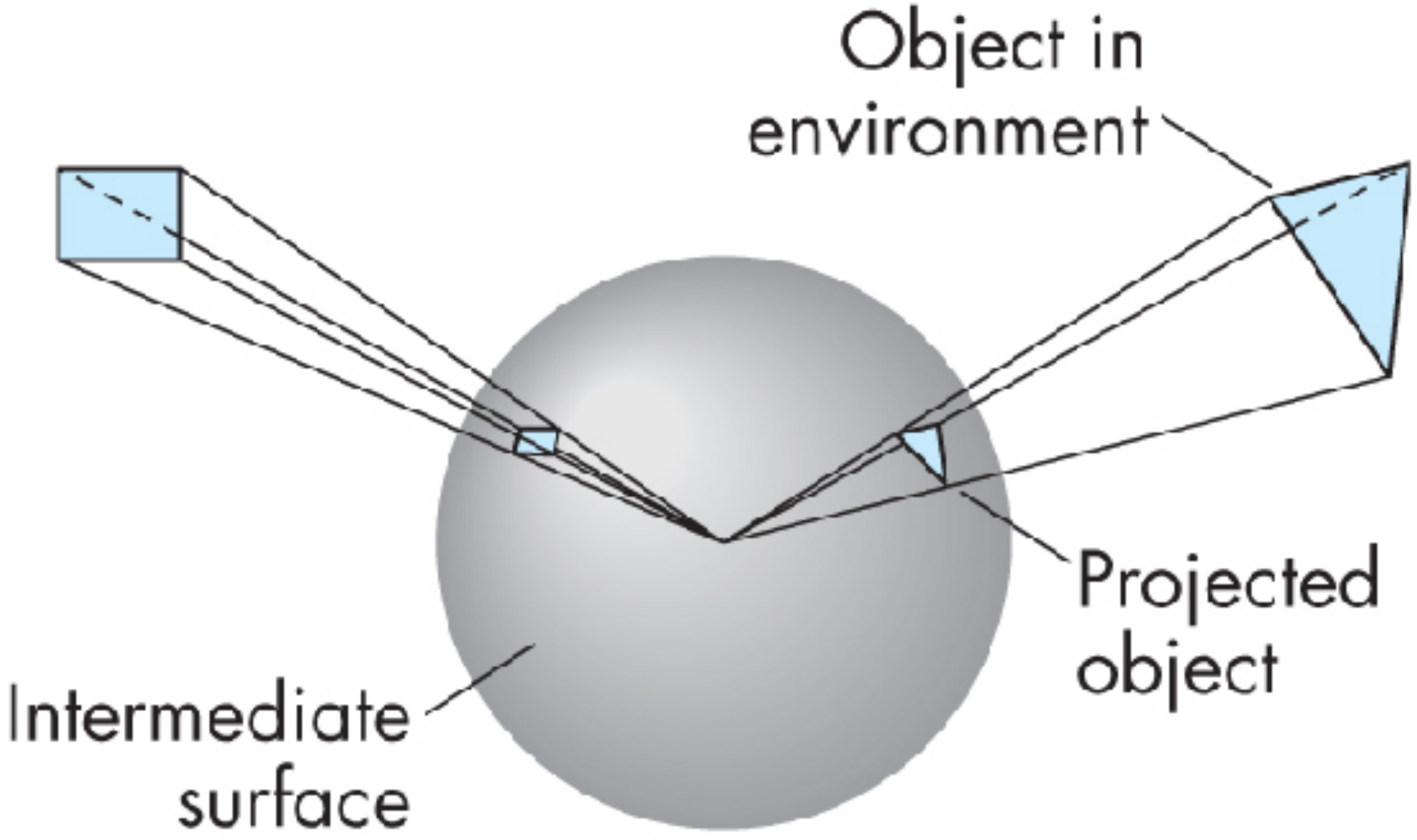




Wikimedia Commons

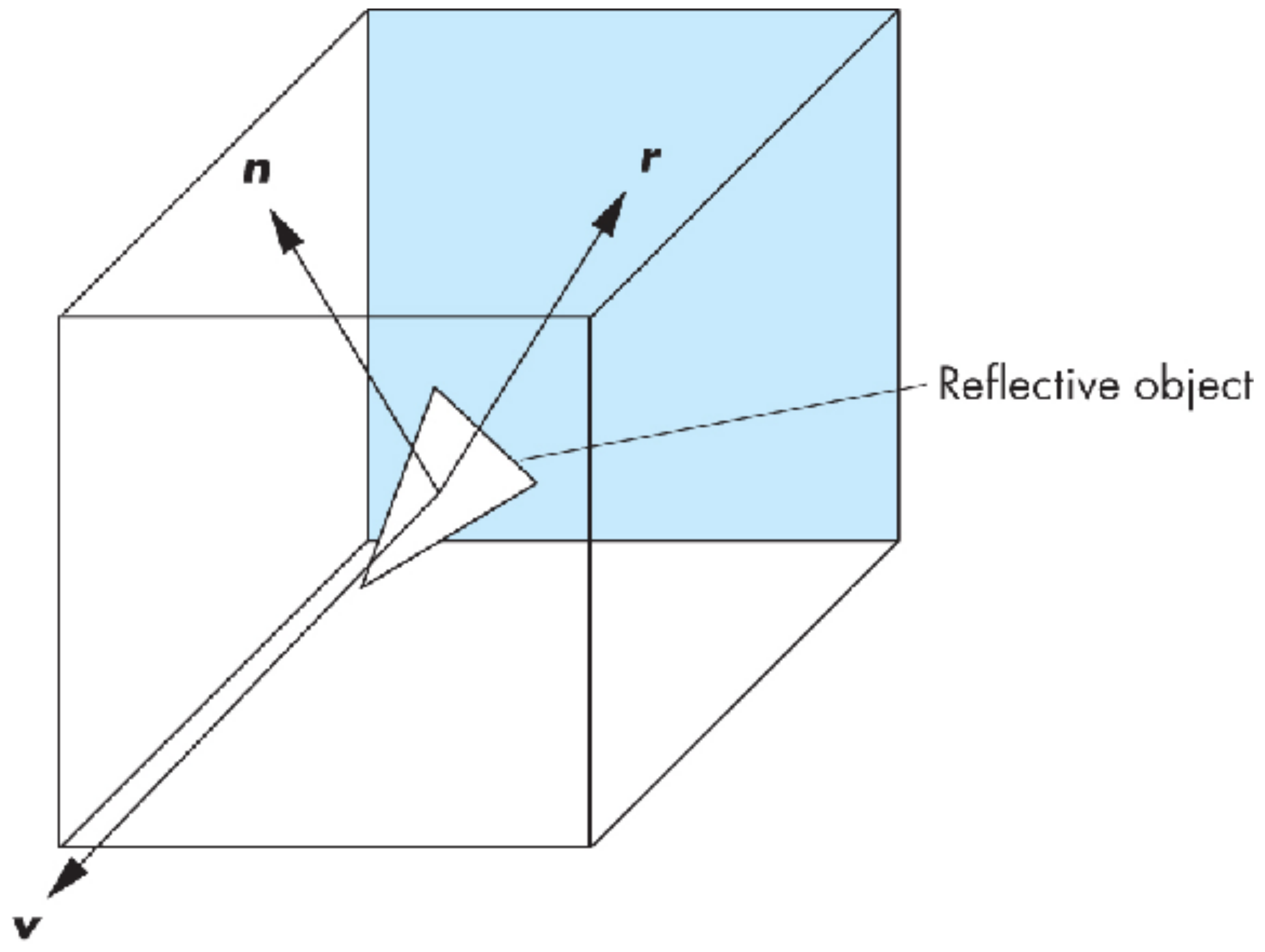
Sphere Mapping

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

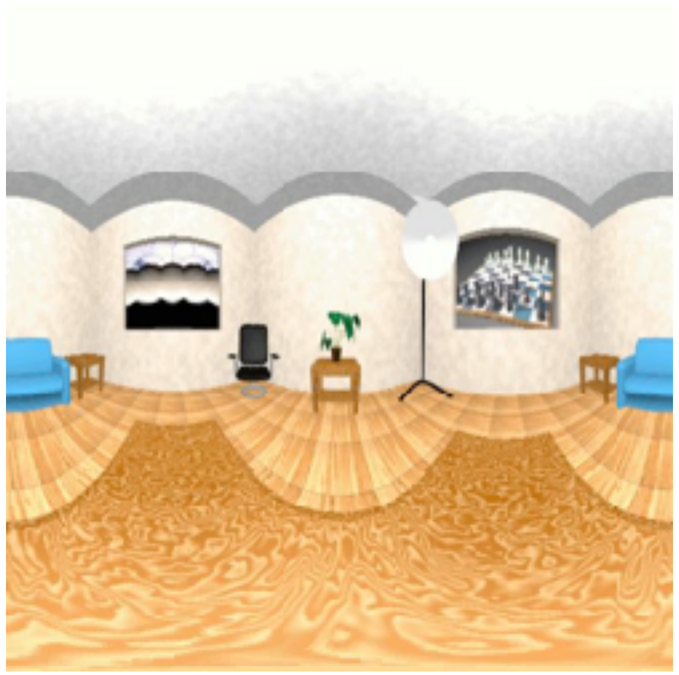


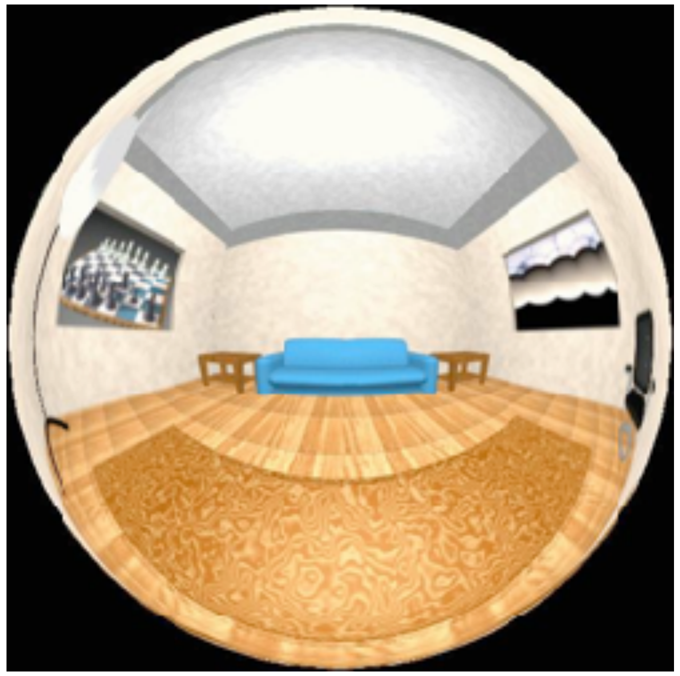
Cube Mapping

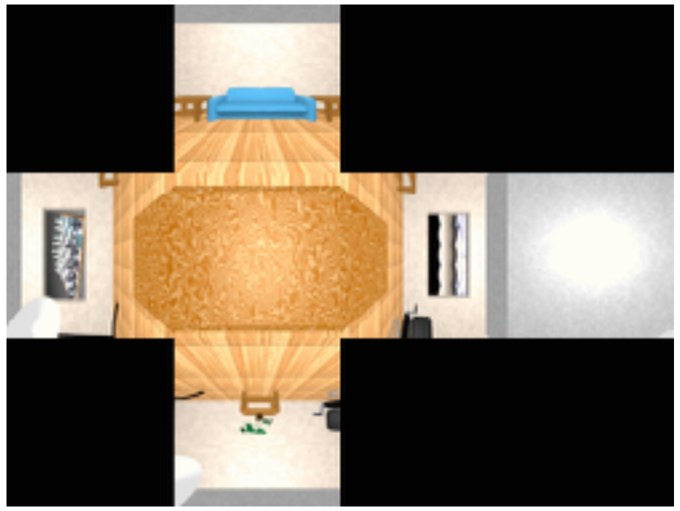
- Compute six projections, one for each wall
- store as texture
- use reflection direction to lookup texture value



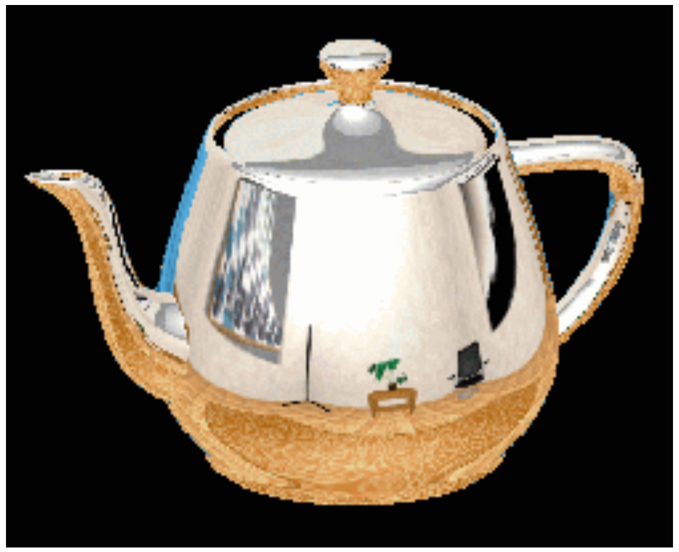
Different environment maps

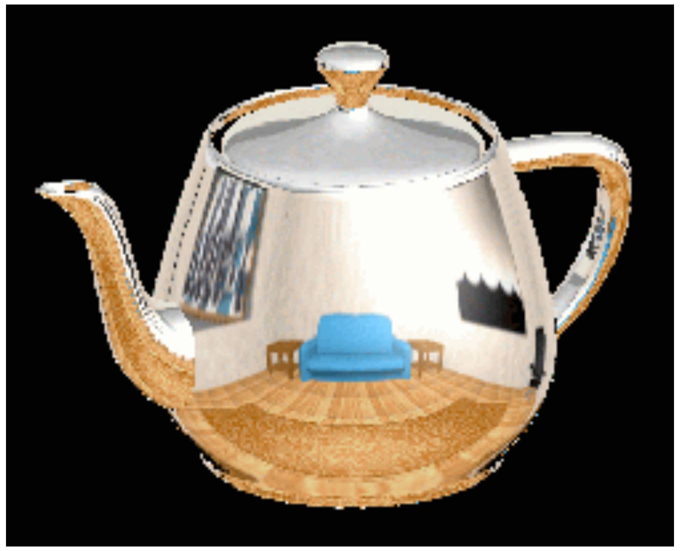


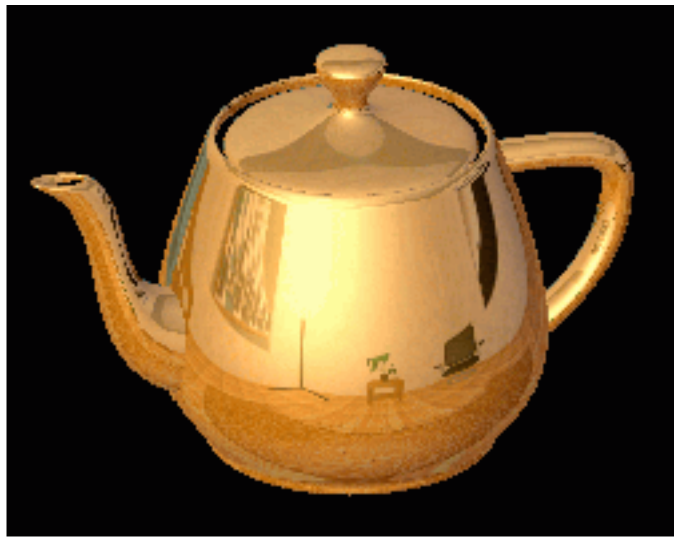




www.reindelsoftware.com







Blinn/Newell latitude mapping

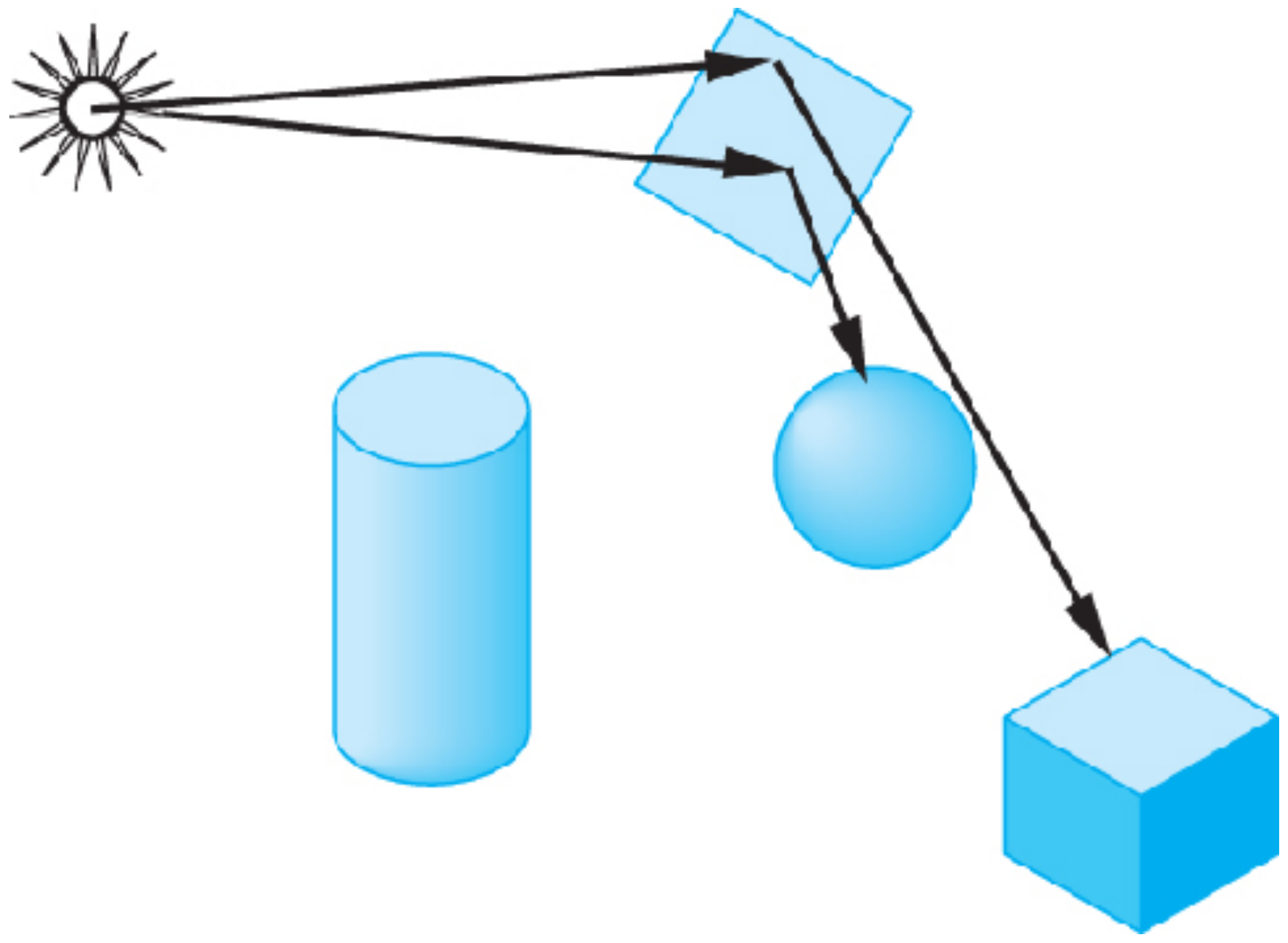
OpenGL spherical mapping

Cube mapping

Environment Mapping

Create the effect of a mirror with two-pass rendering

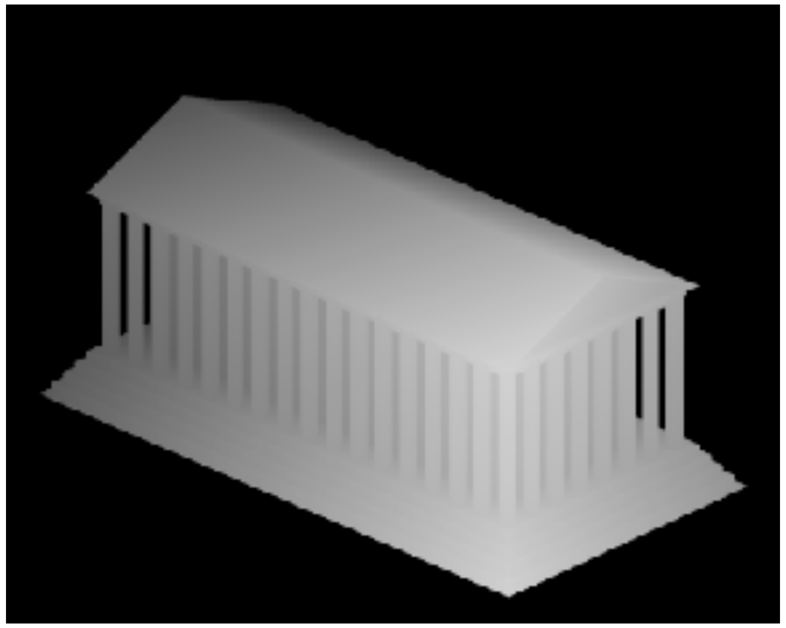
1. First pass: render the scene from the perspective of the mirror
2. Second pass: render from original pov; use the first image as a texture for the mirror

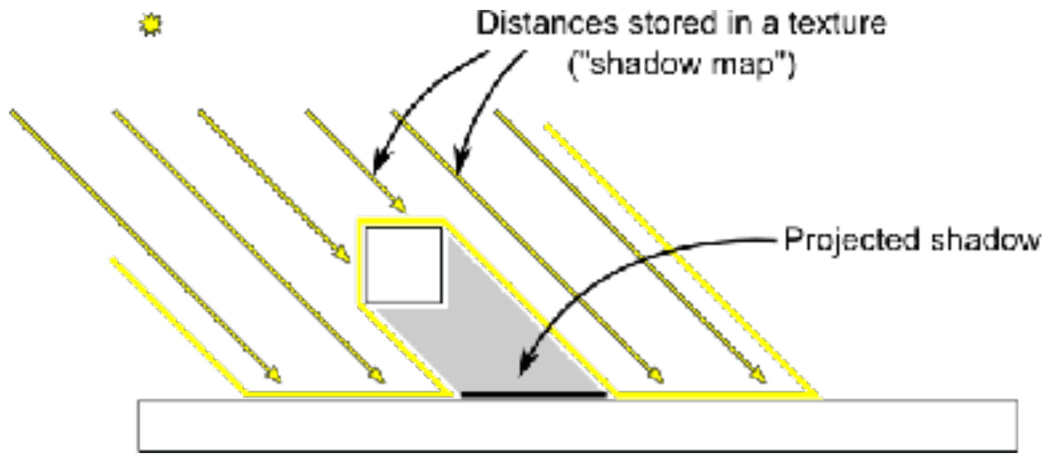


Shadow Mapping

2 passes:

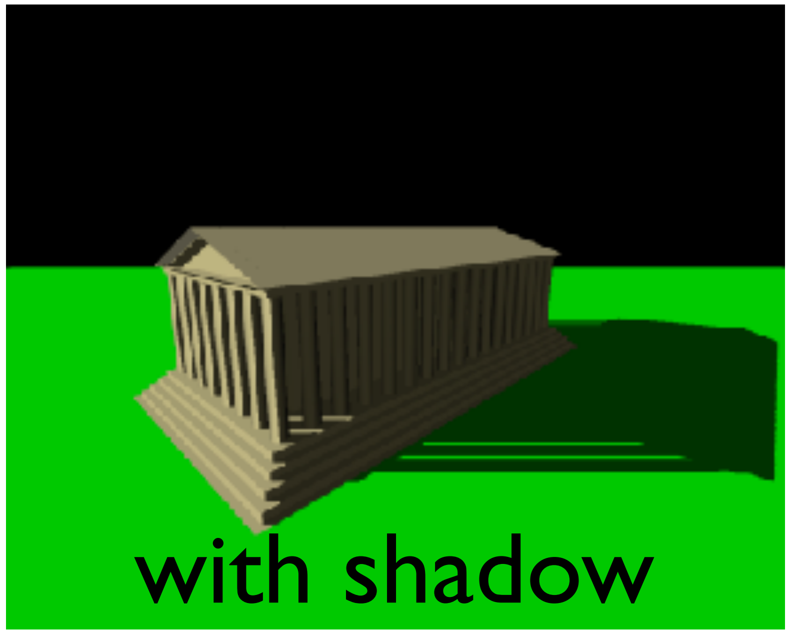
1. render scene from pov of light and store z-buffer in a texture

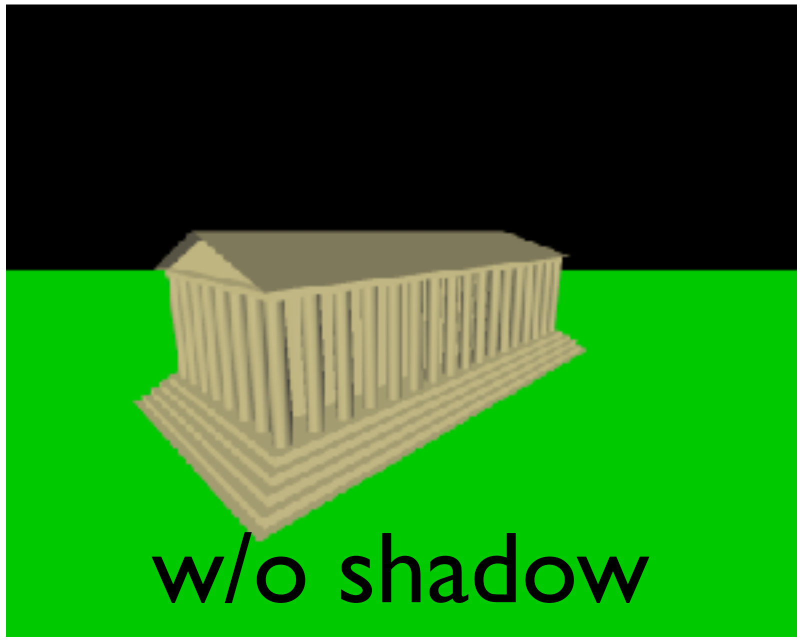




http://www.opengl-tutorial.org/intermediate-tutorials/tutorial-16-shadow-mapping/

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



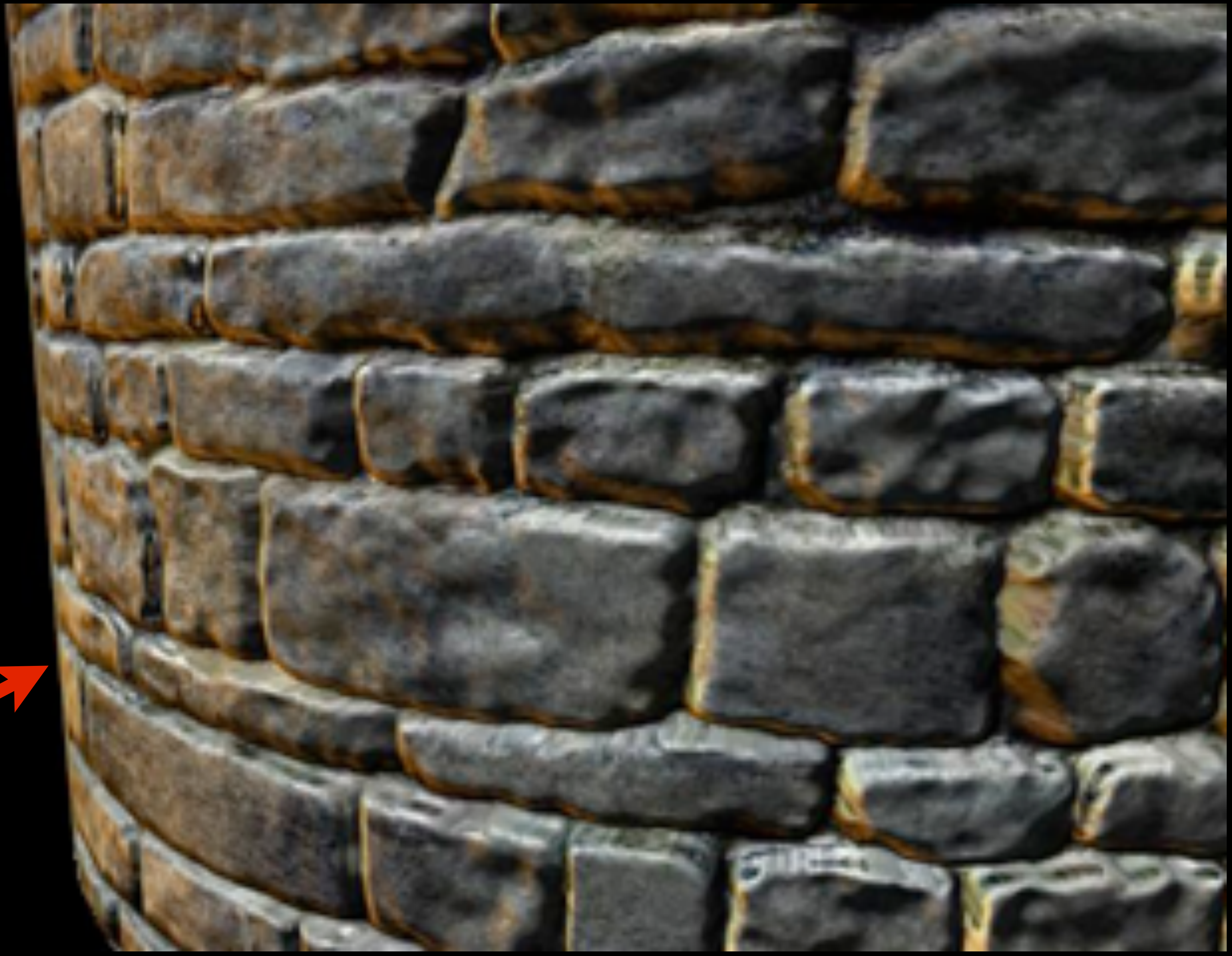


Wikimedia Commons

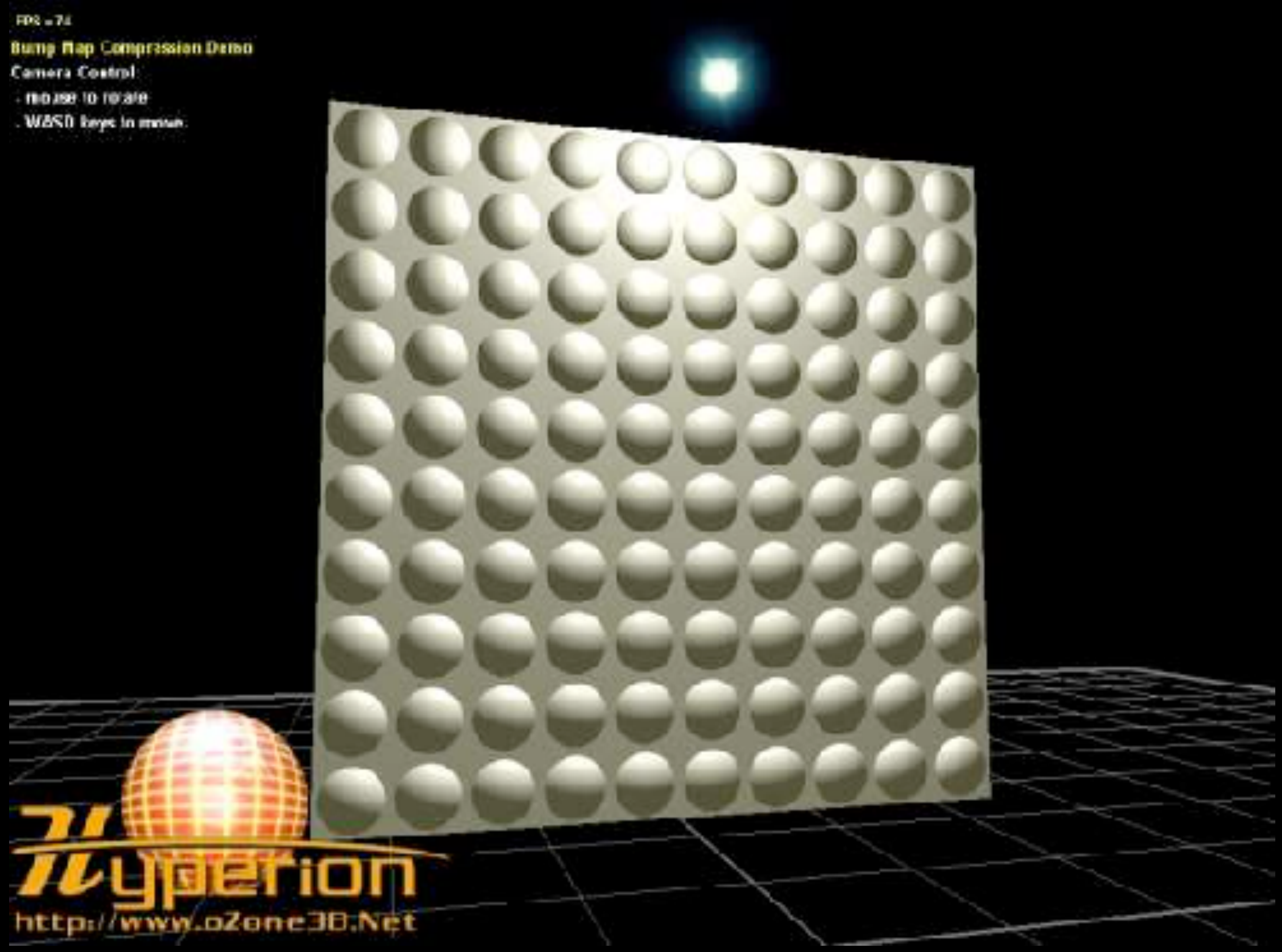
Bump Mapping

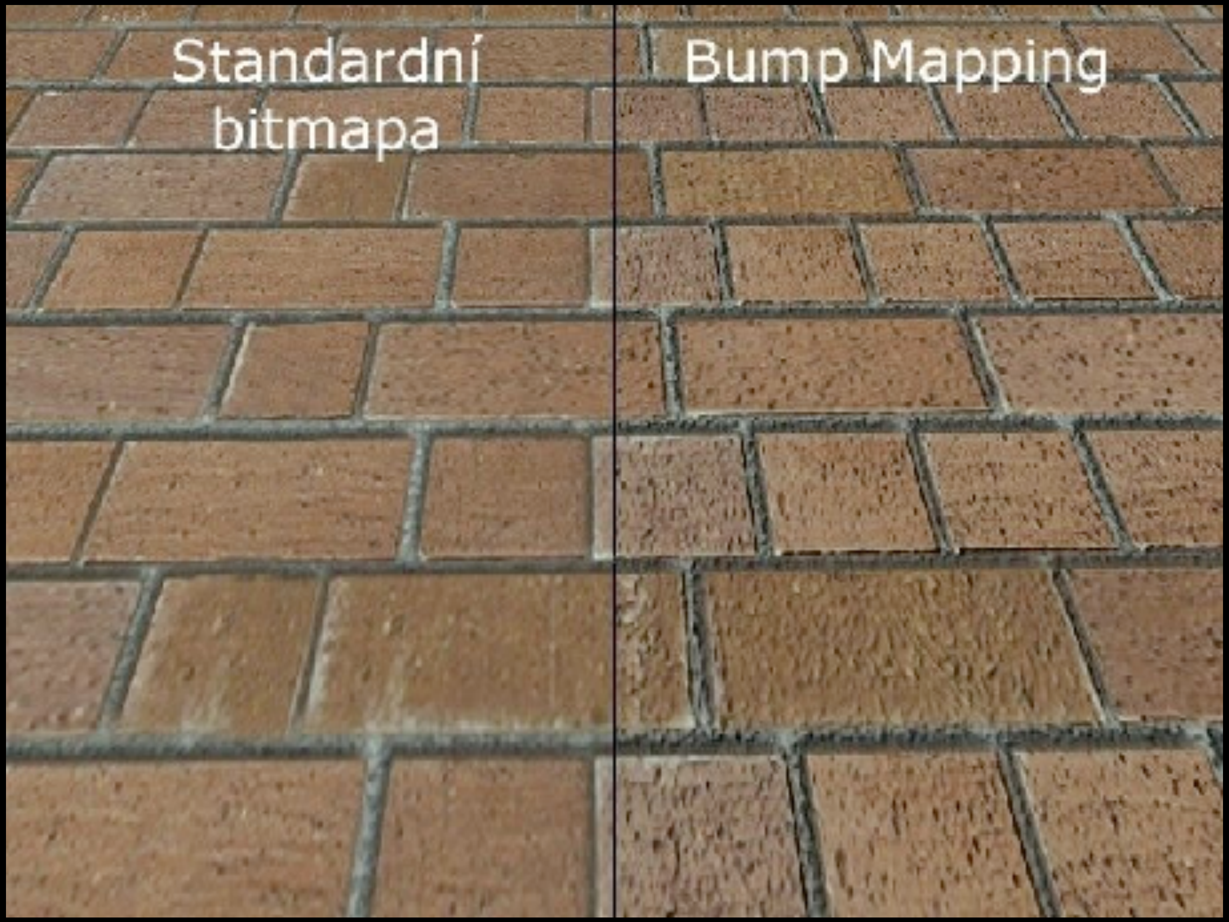
perturb
normal
vectors

doesn't
affect
silhouette

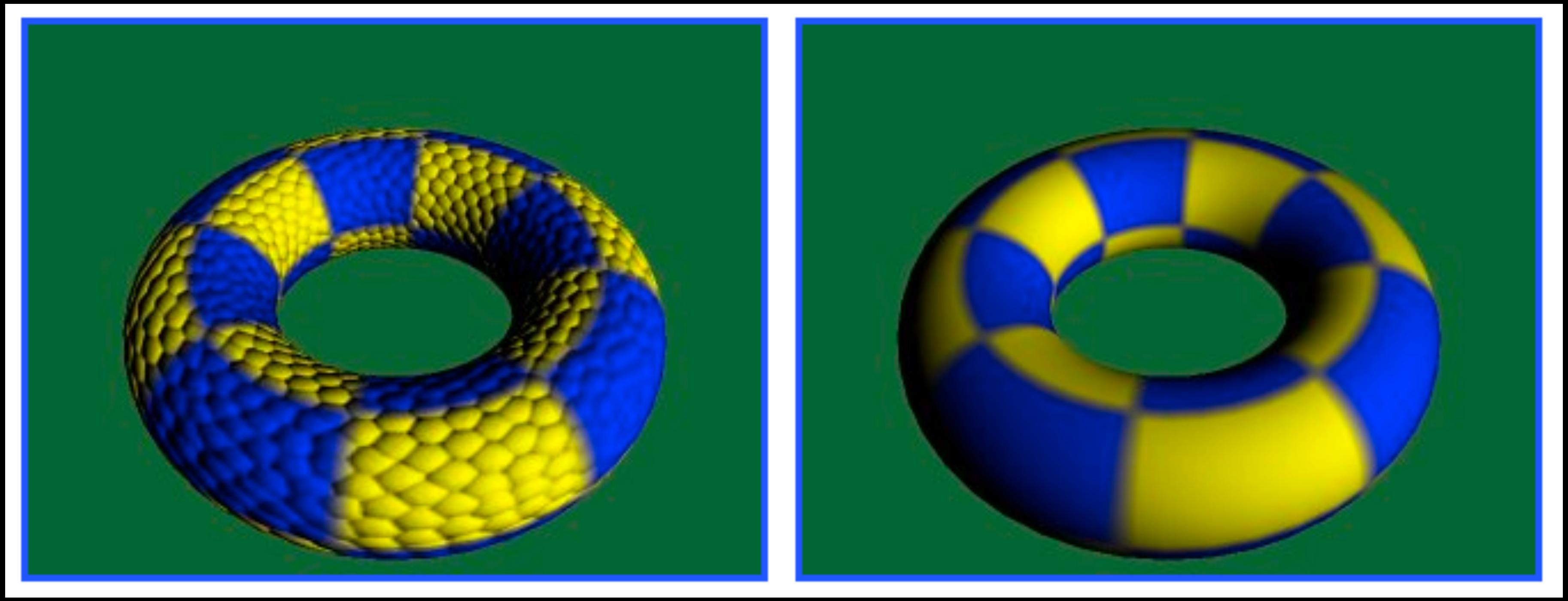


[DirectXTutorial.com]

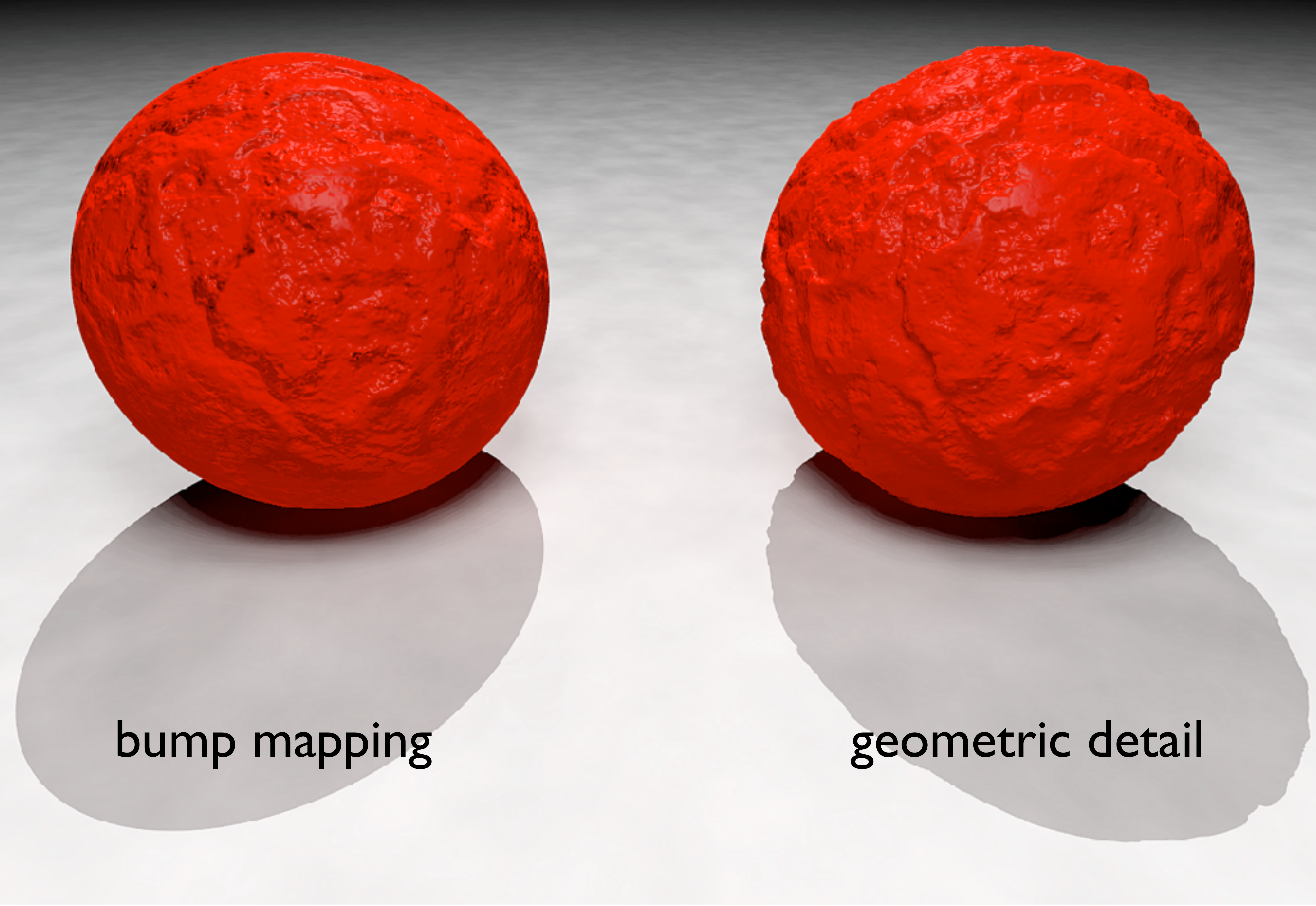




http://www.lg.clanhost.cz

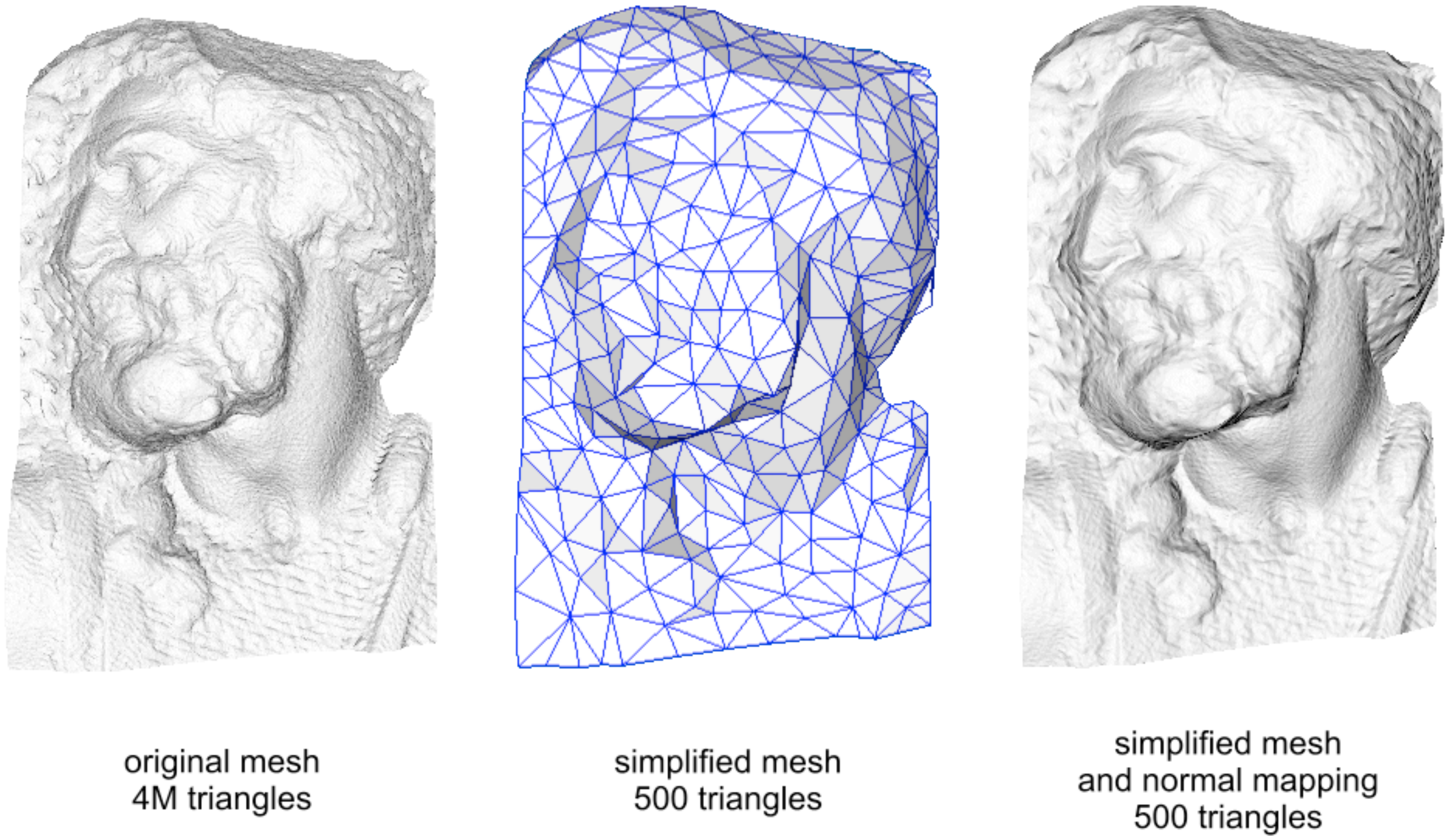


http://www.paulsprojects.net/tutorials/simplebump/simplebump.html



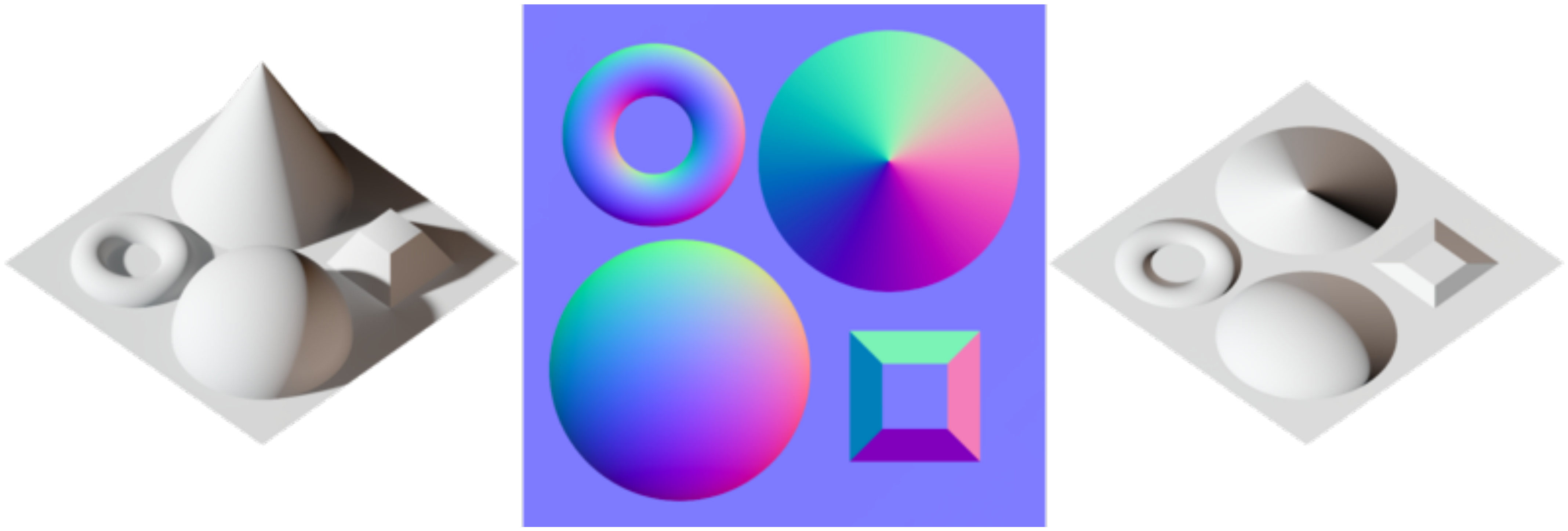
Wikimedia Commons

Normal Mapping



Wikimedia Commons

Normal Mapping



Wikimedia Commons

Example of a normal map (center) with the scene it was calculated from (left) and the result when applied to a flat surface (right).