CS130 : Computer Graphics

Texture Mapping

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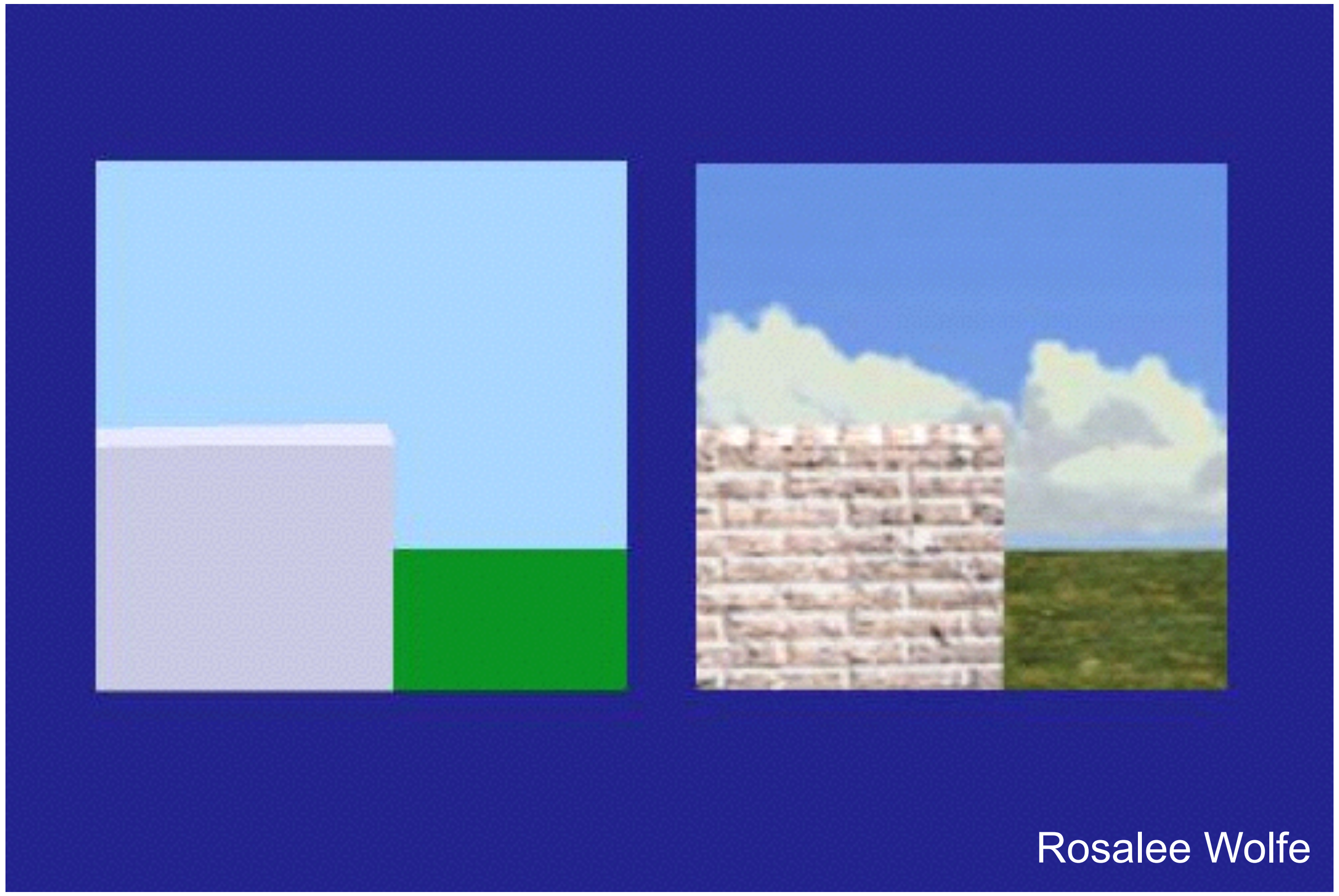
There are limits to geometric modeling

http://www.beinteriordecorator.com

National Geographic

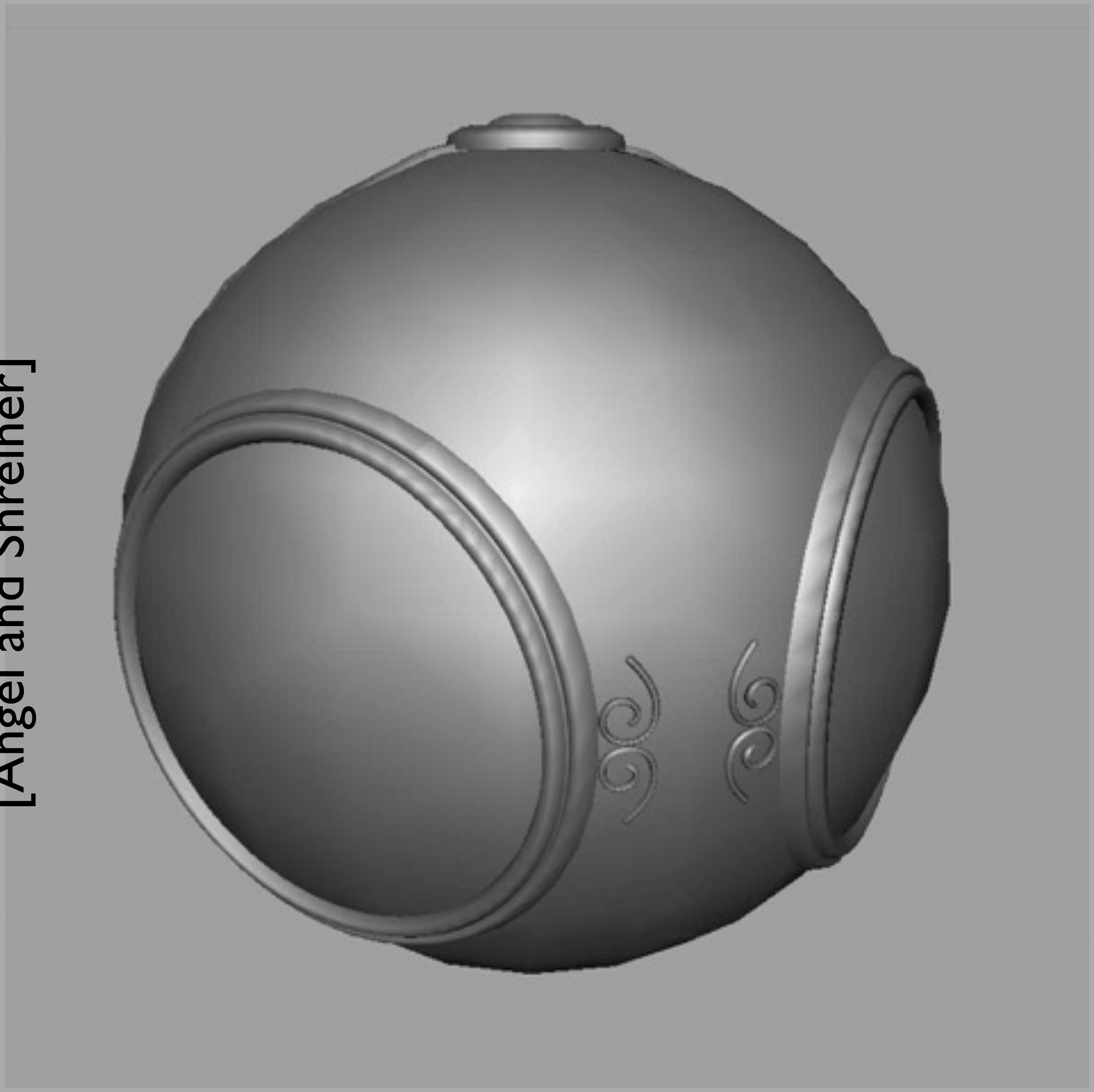
Although modern GPUs can render millions of triangles/sec, that's not enough sometimes...

Use texture mapping to increase realism through detail

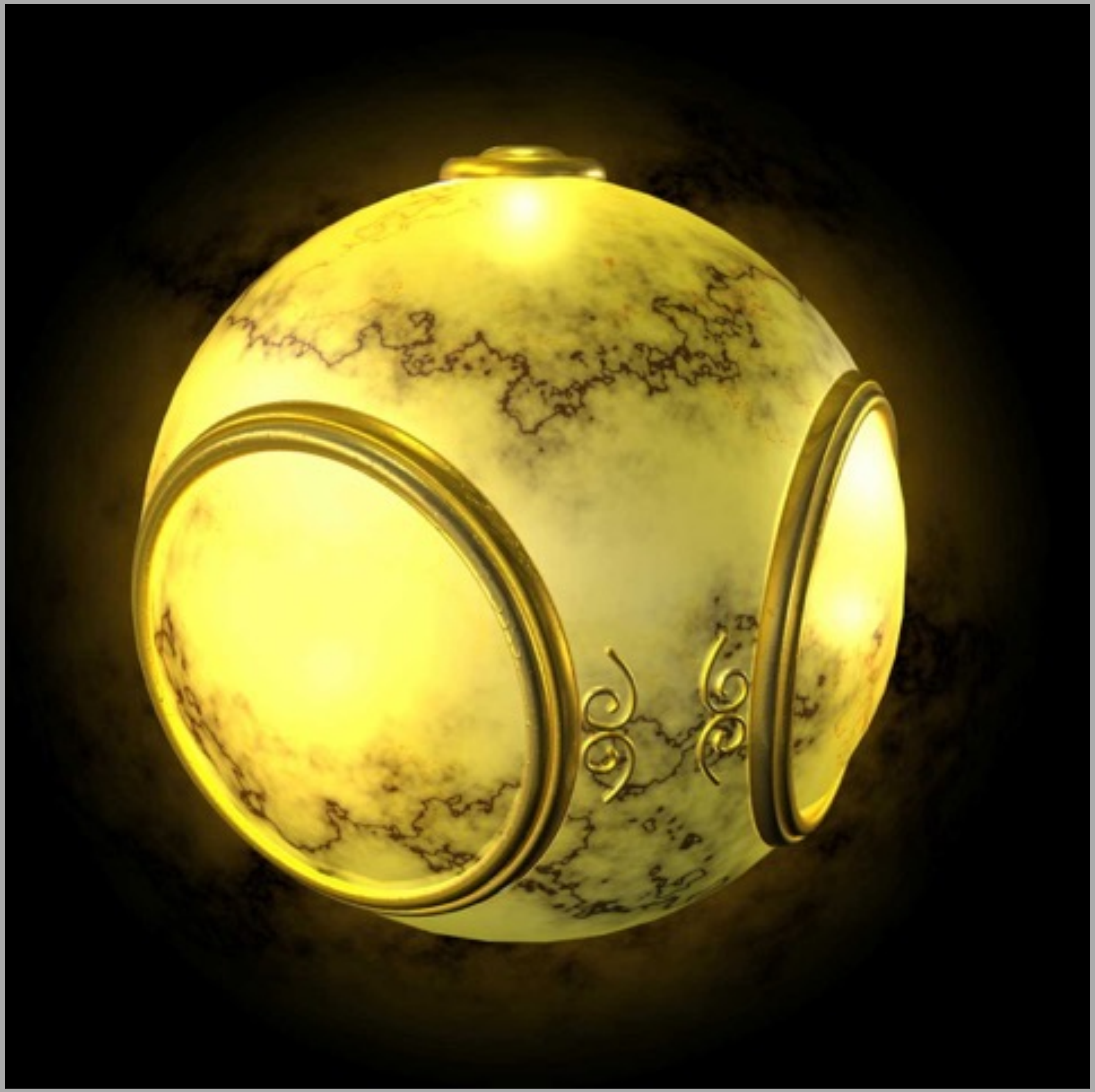


This image is just 8 polygons!

[Angel and Shreiner]



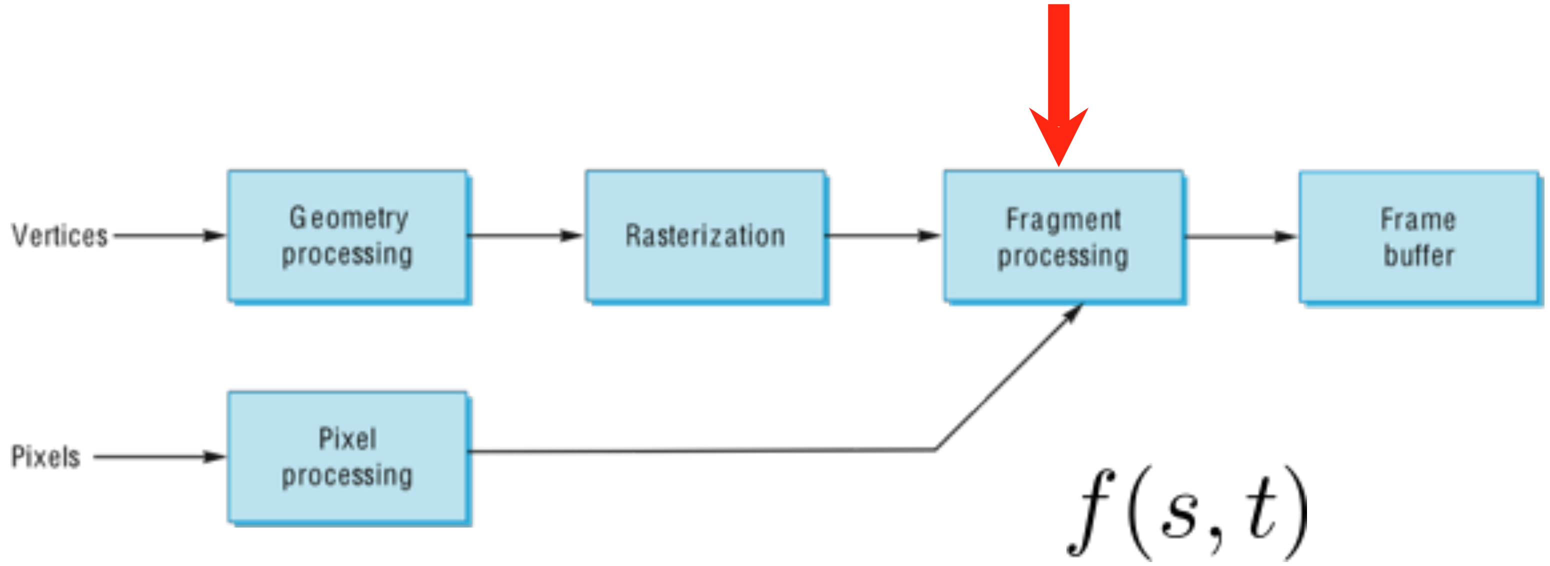
No texture



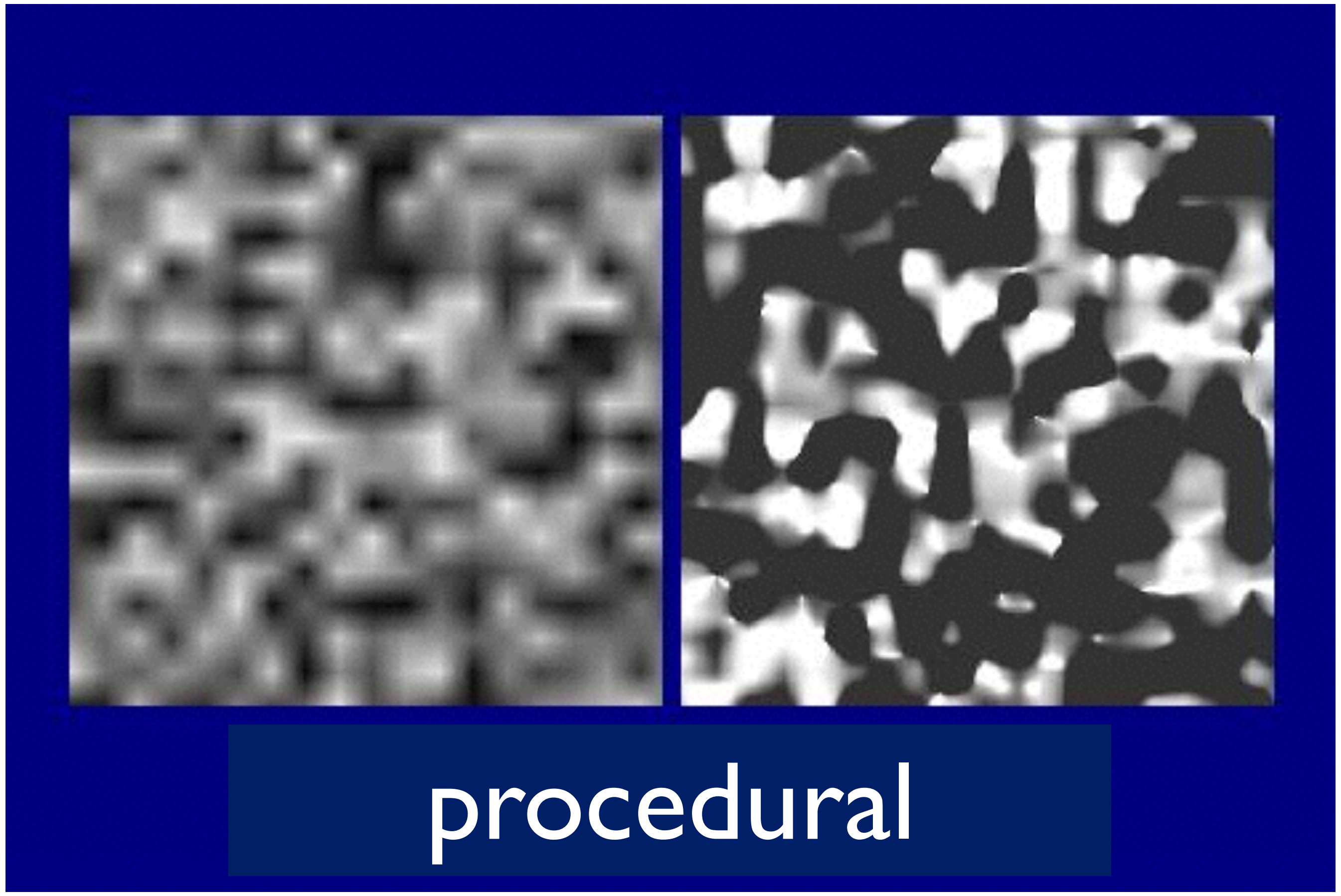
With texture

Pixar - Toy Story

Store 2D images in buffers and lookup pixel reflectances

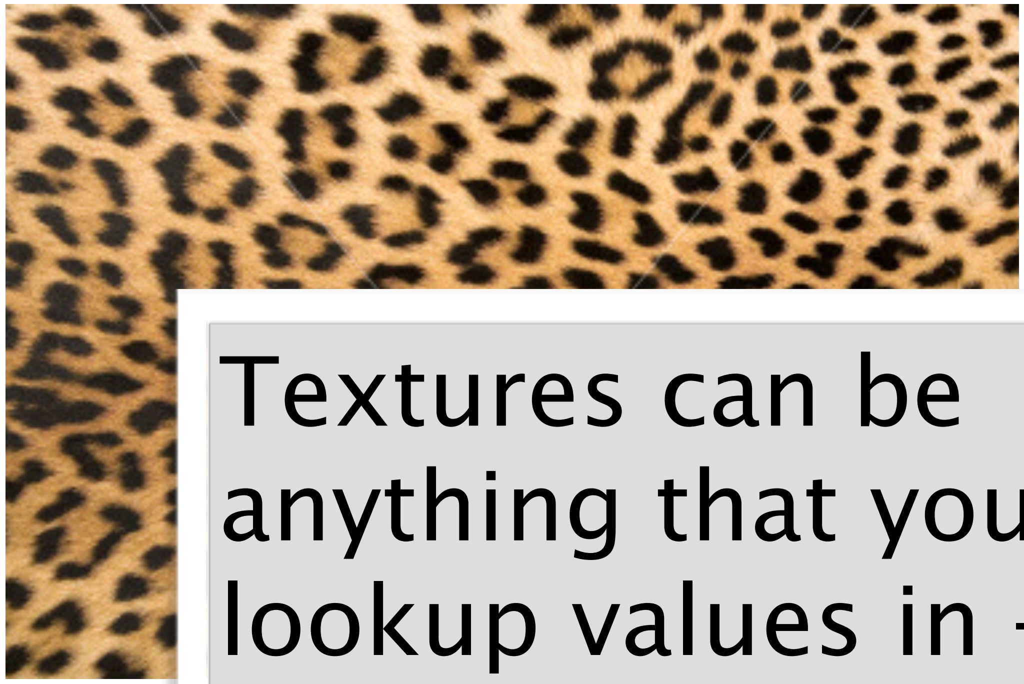


$f(s,t)$

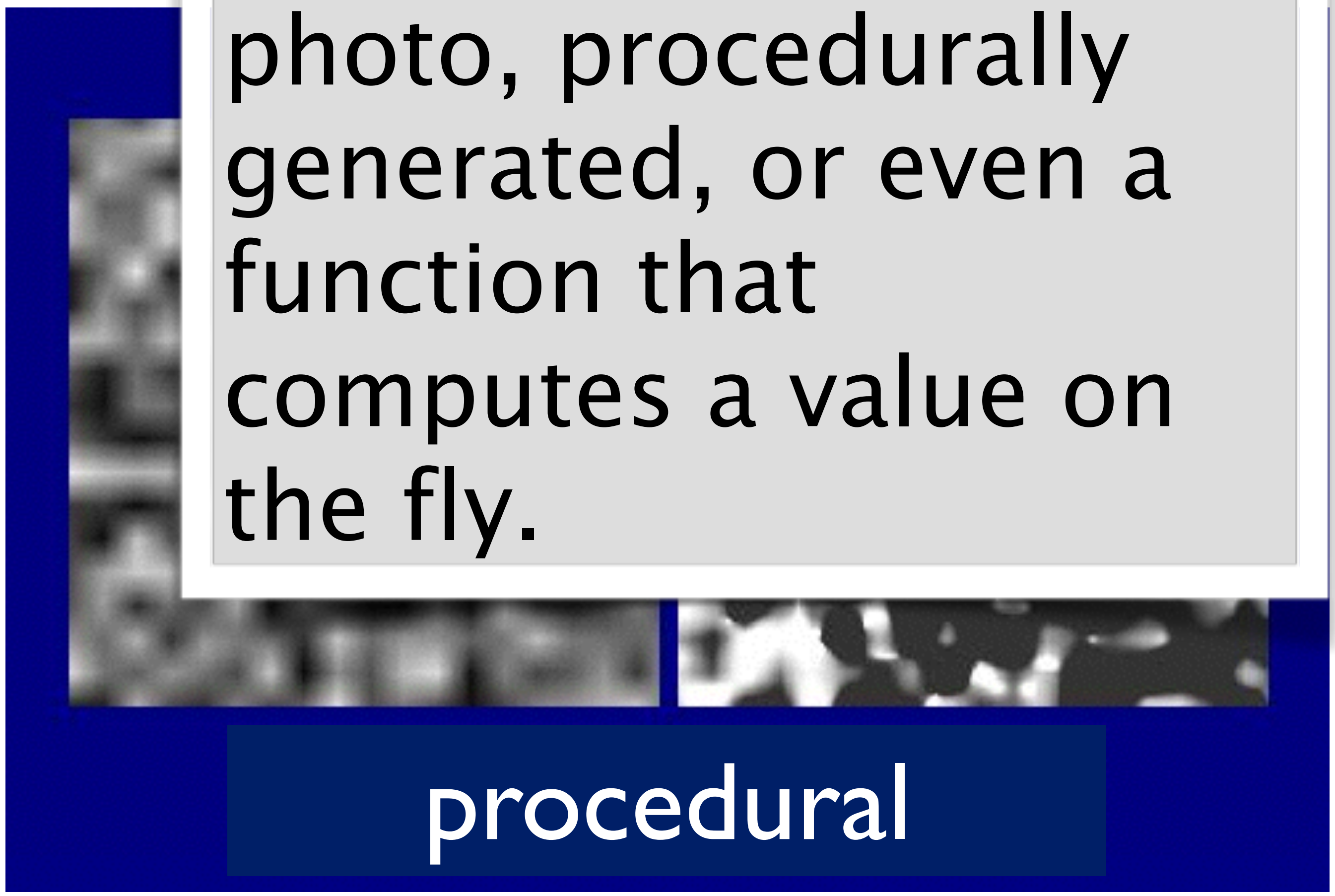

procedural

photo

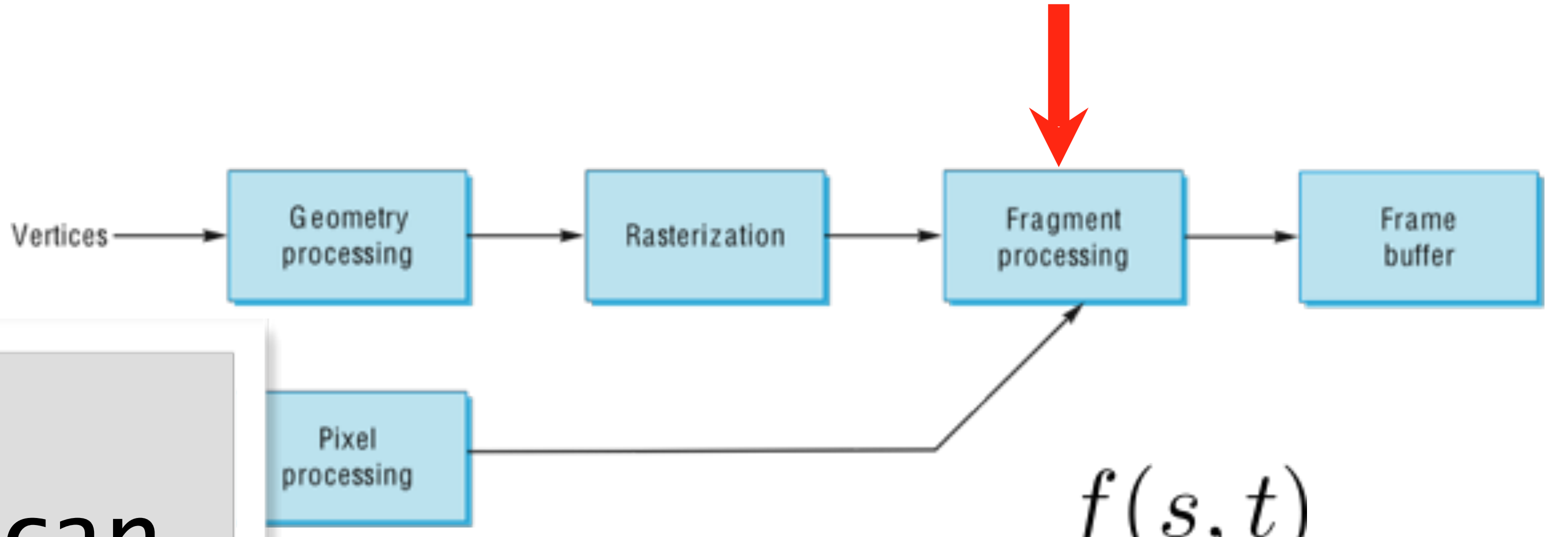
Store 2D images in buffers and lookup pixel reflectances



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



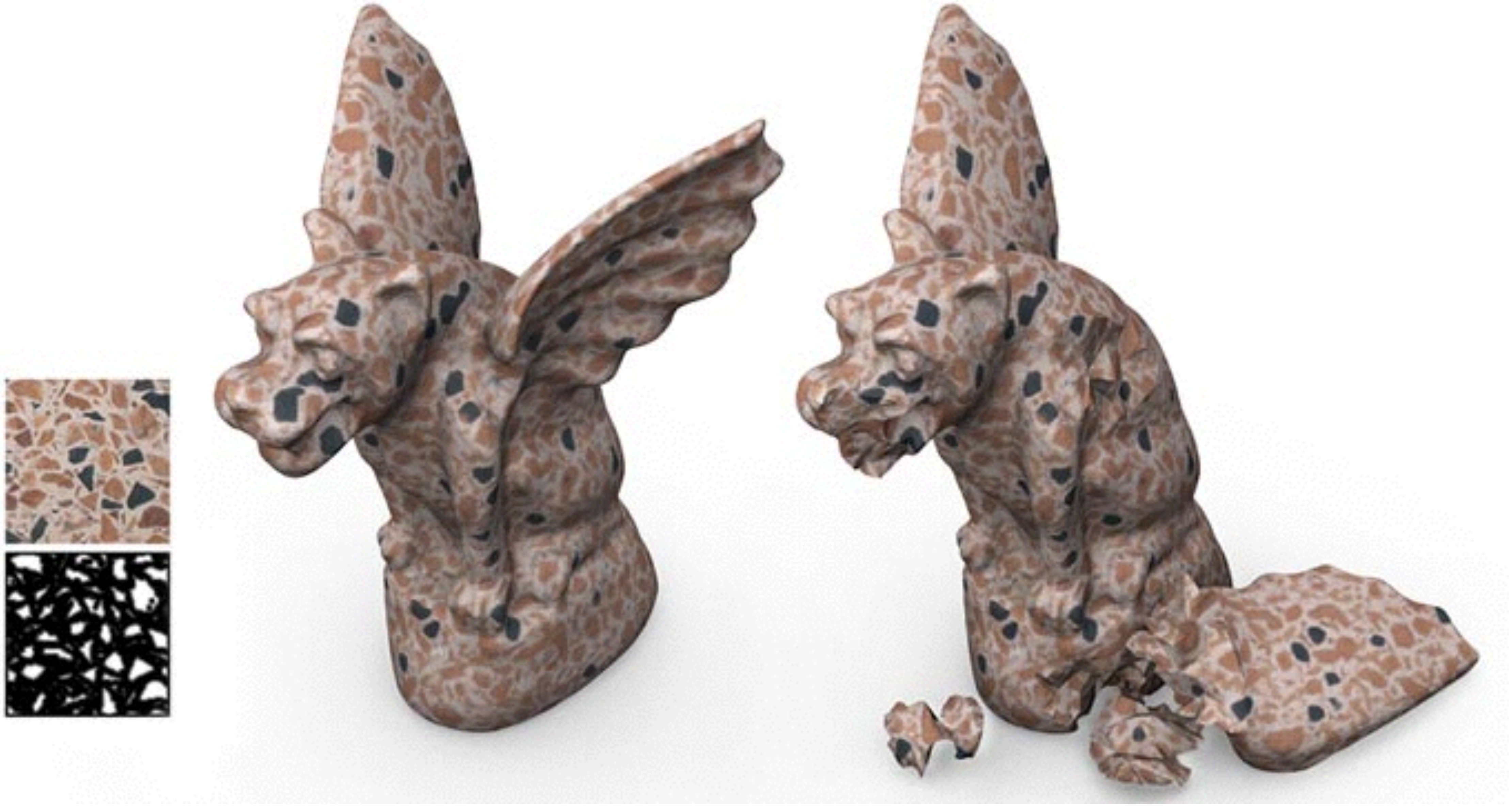
procedural



$f(s,t)$

photo

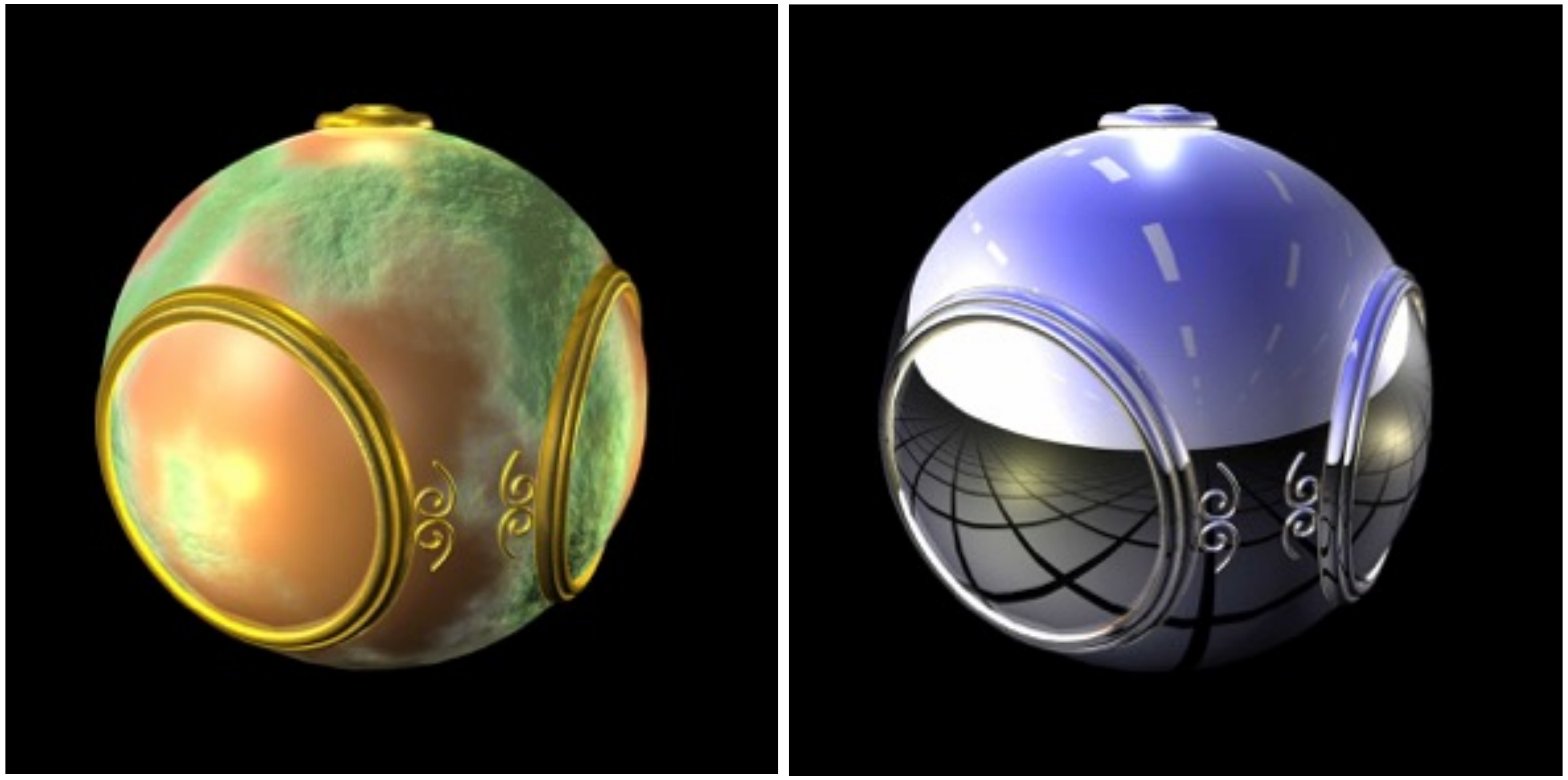
3D solid textures



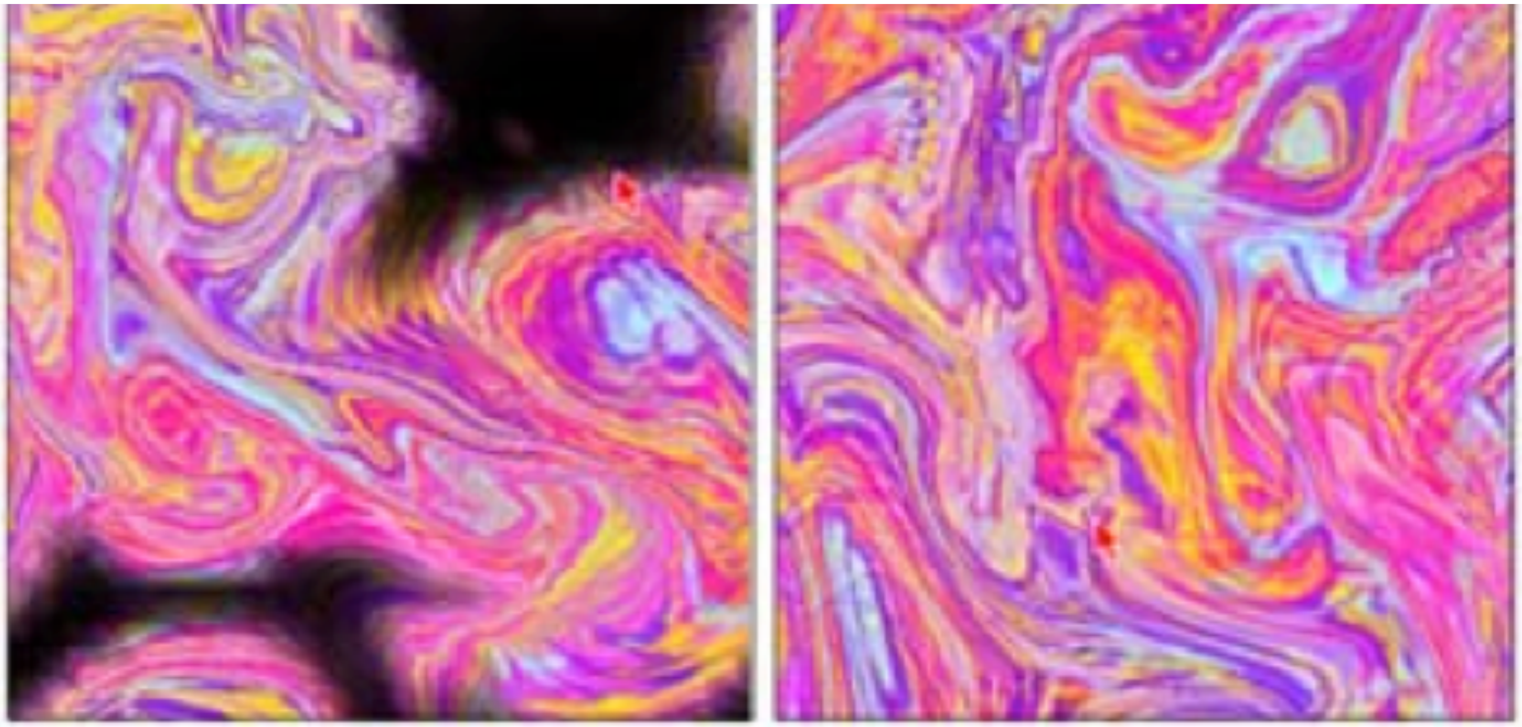
[Dong et al., 2008]

Other uses of textures...

Light maps
Shadow maps
Environment maps
Bump maps
Opacity maps
Animation

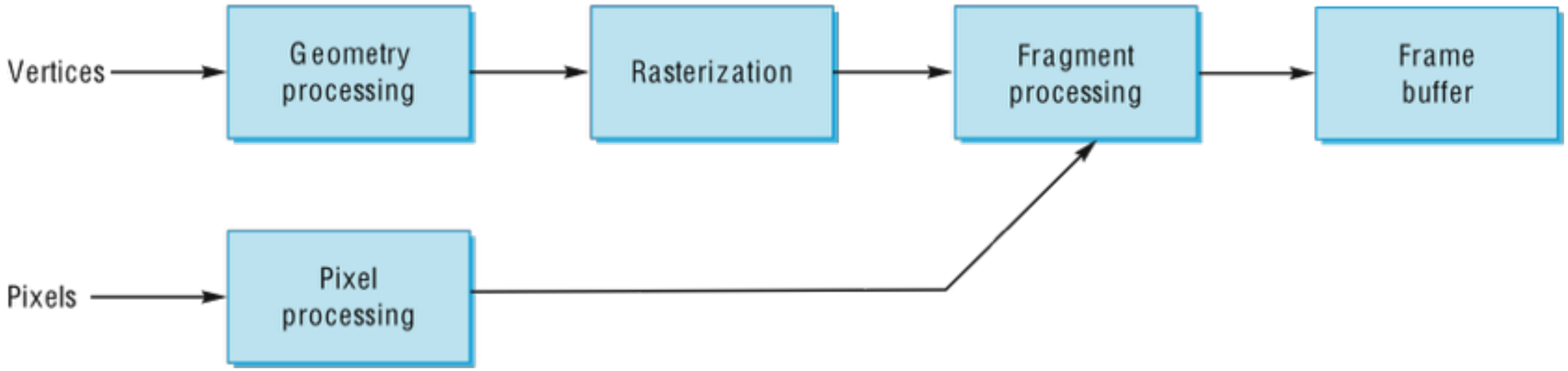


[Angel and Shreiner]



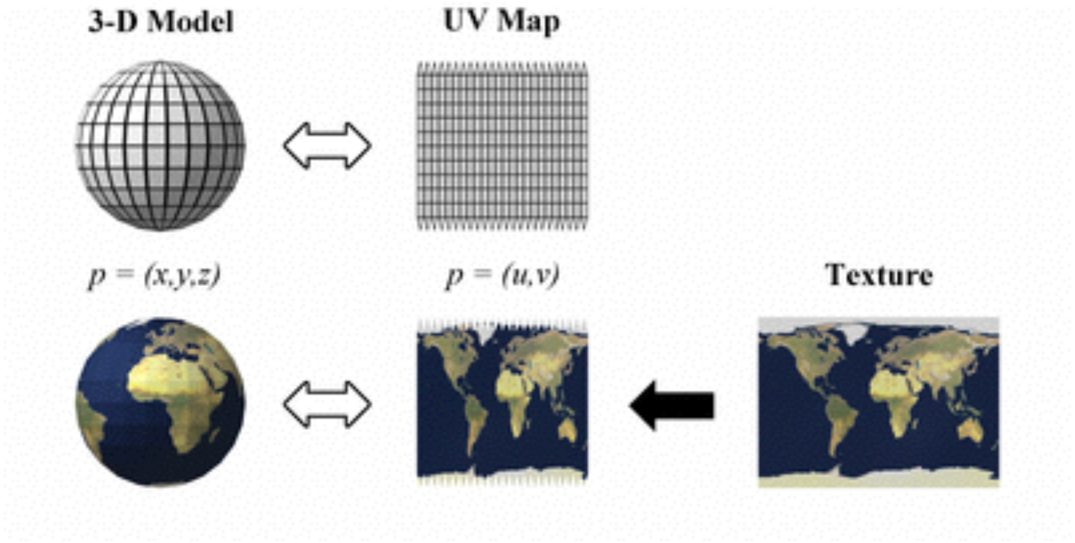
[Stam 99]

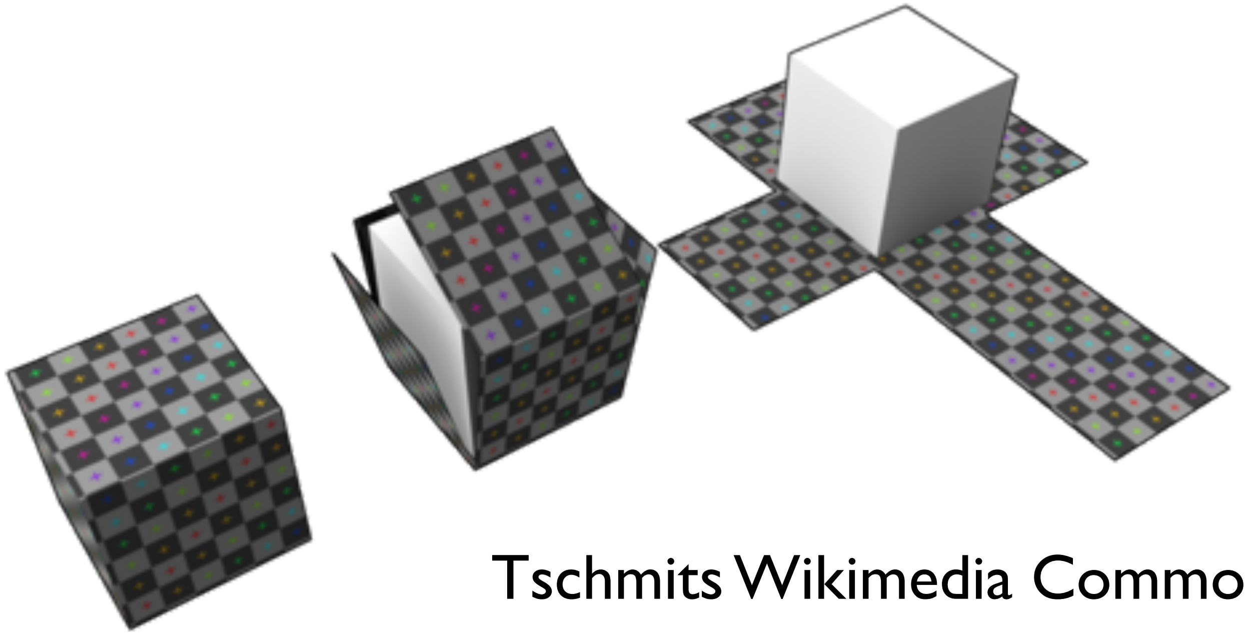
Texture mapping in the OpenGL pipeline



- 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

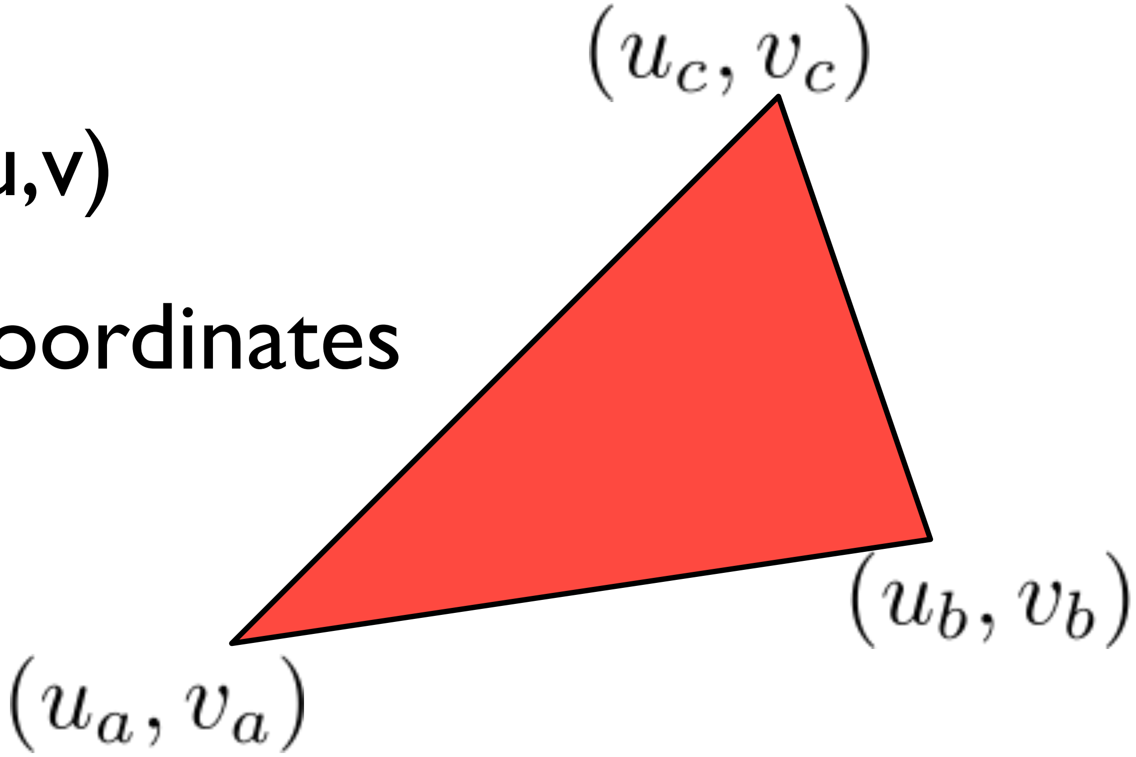
uv Mapping

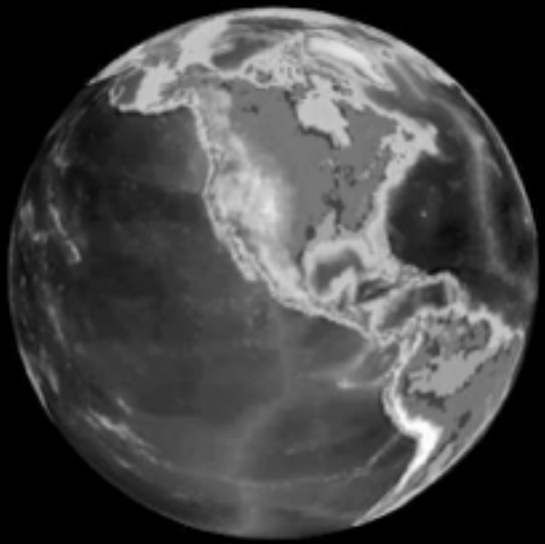


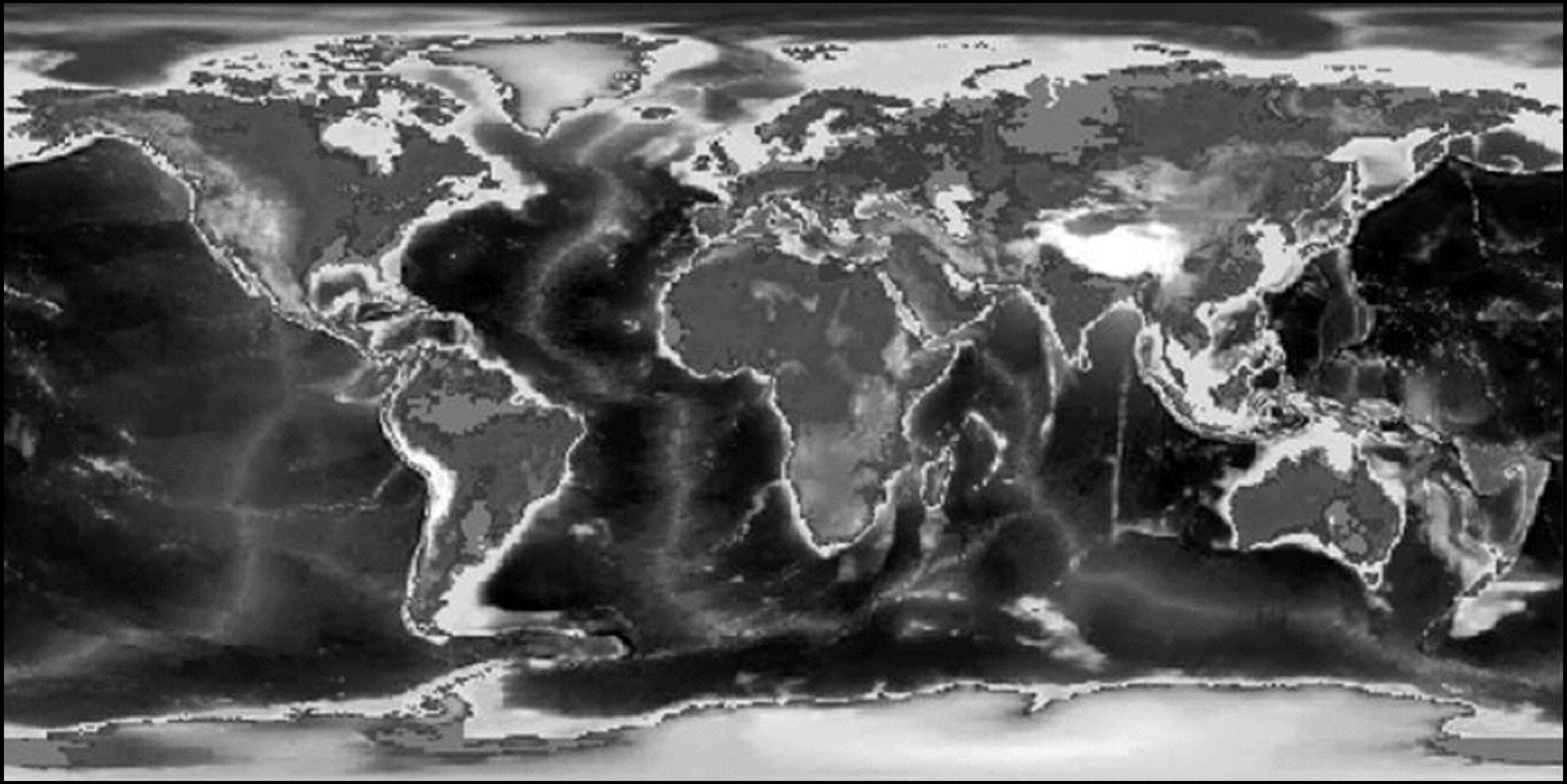


Tschmits Wikimedia Commons

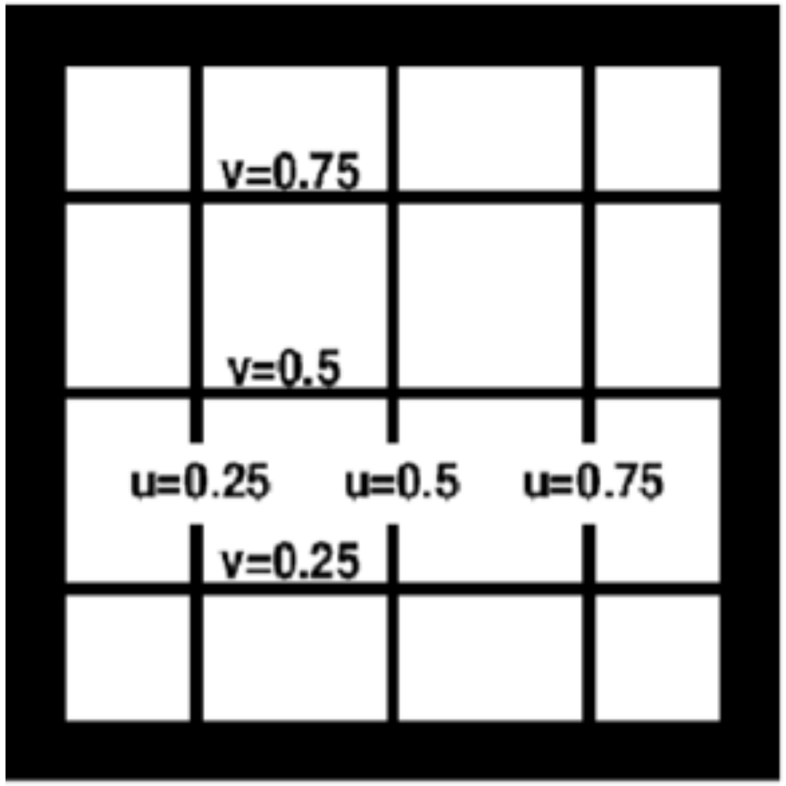
- 2D texture is parameterized by (u,v)
- Assign polygon vertices texture coordinates
- Interpolate within polygon



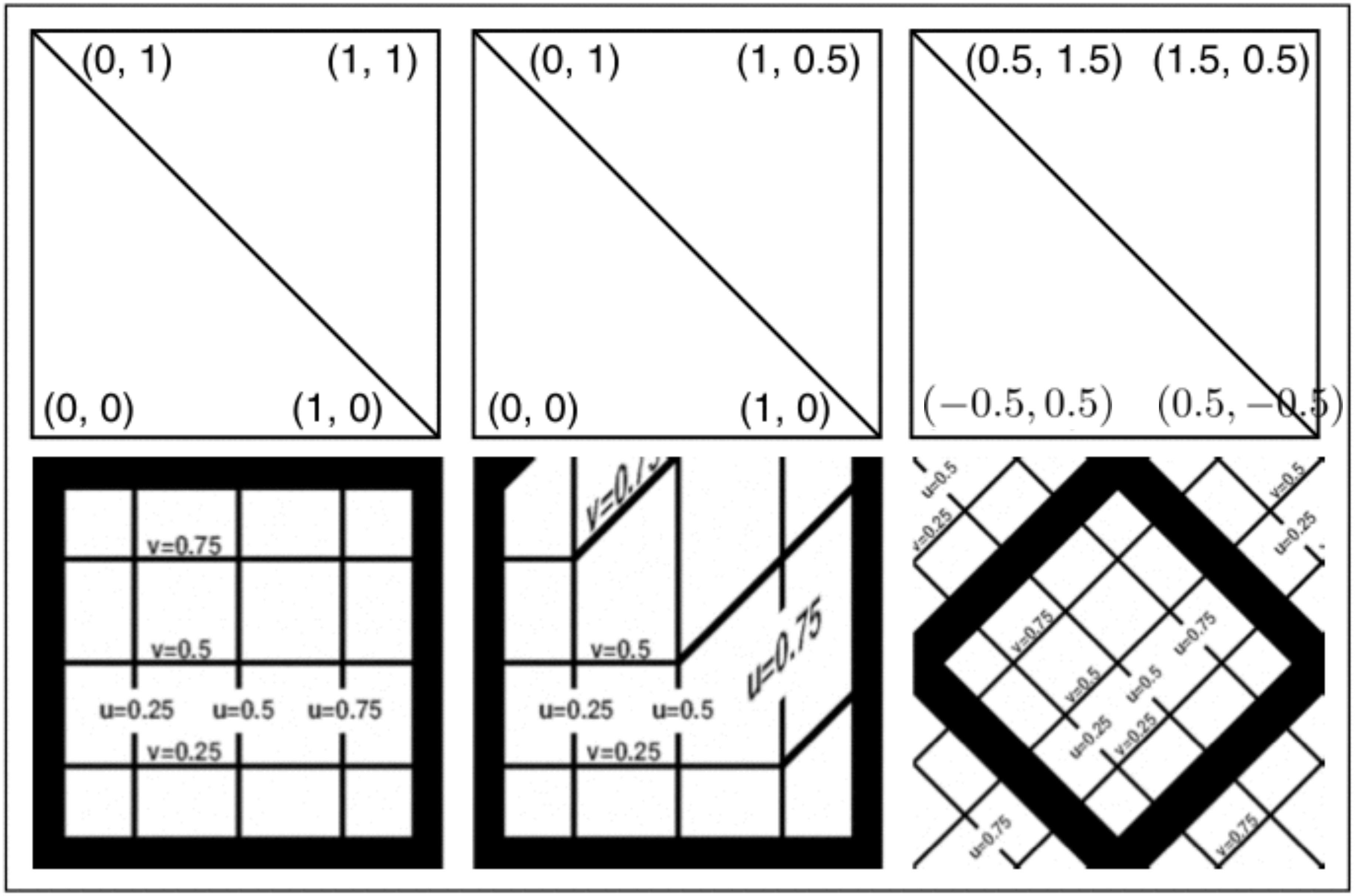




Texture Calibration

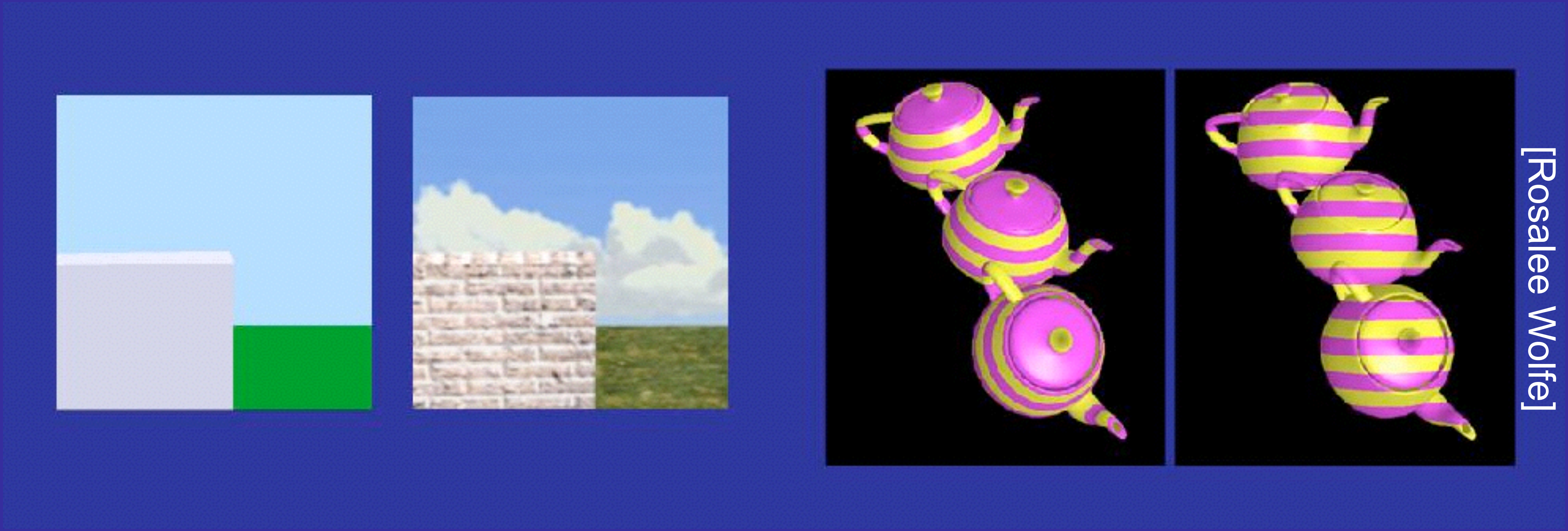


v=0.75
v=0.5
u=0.25
v=0.25



The major issues in texture mapping...

- What should the actual mapping be?

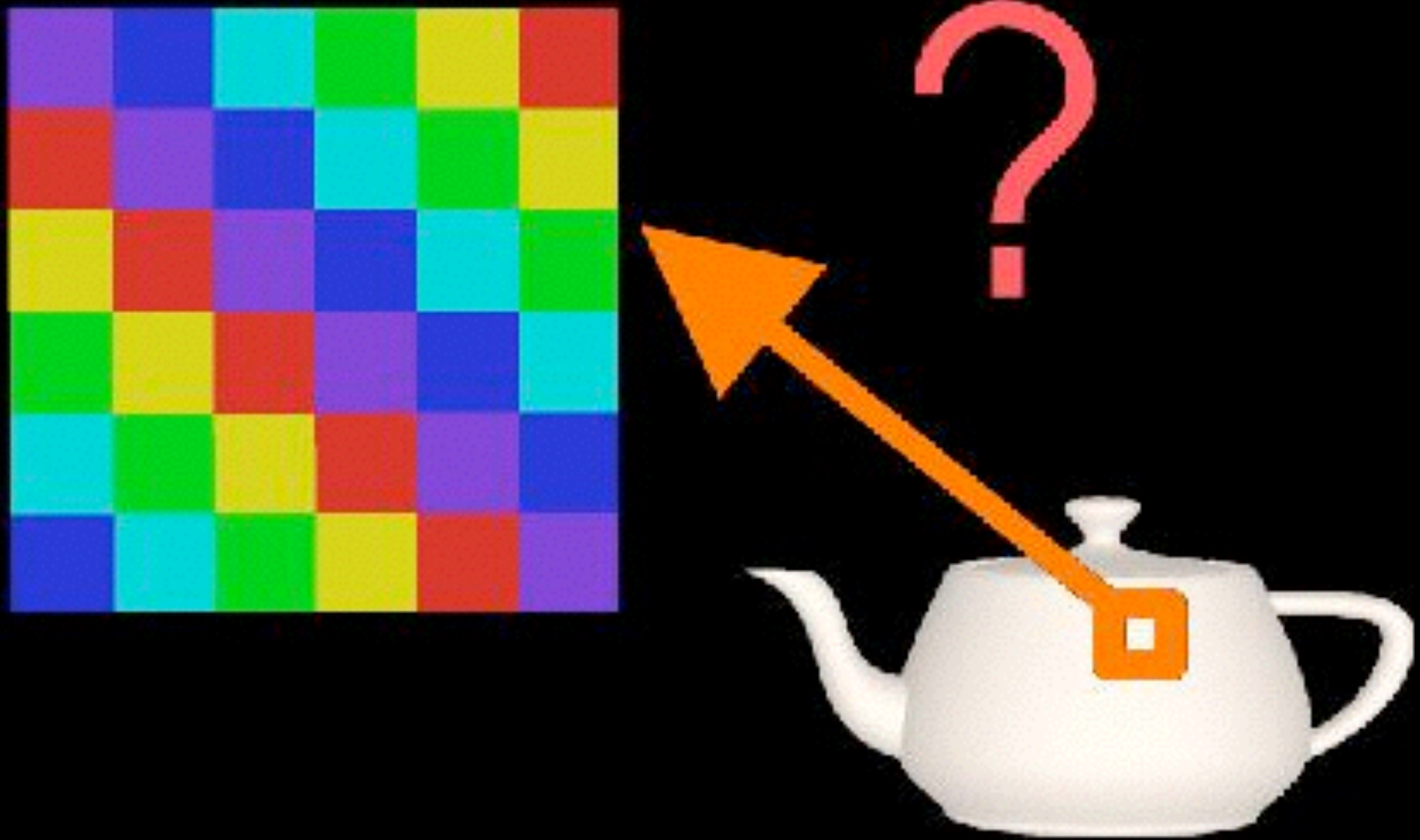


[Rosalee Wolfe]

easy: flat surface

harder: curved surface

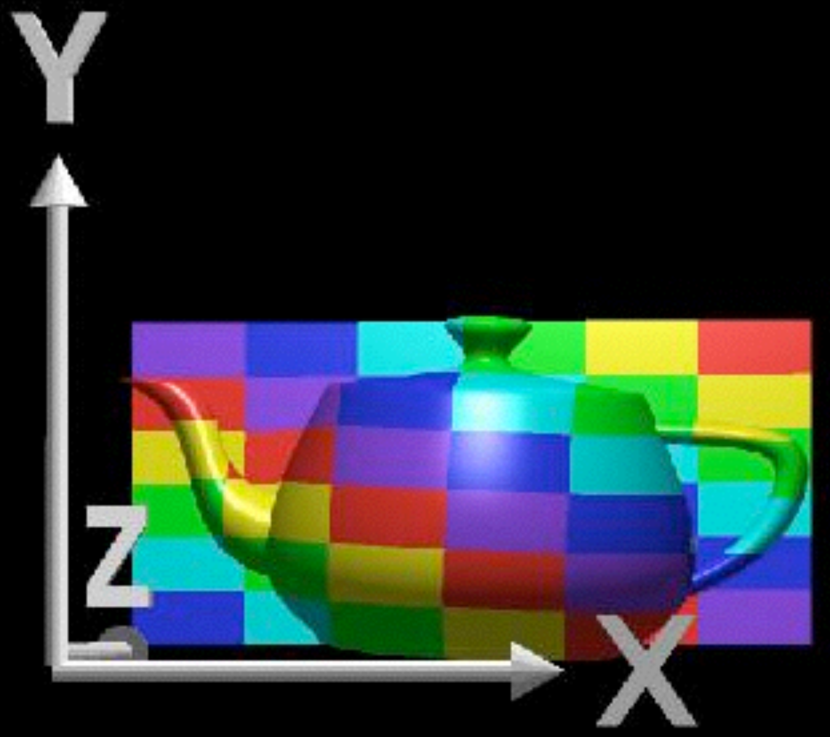
Given a point on the object **(x,y,z)**, what point **(u,v)** in the texture we use?

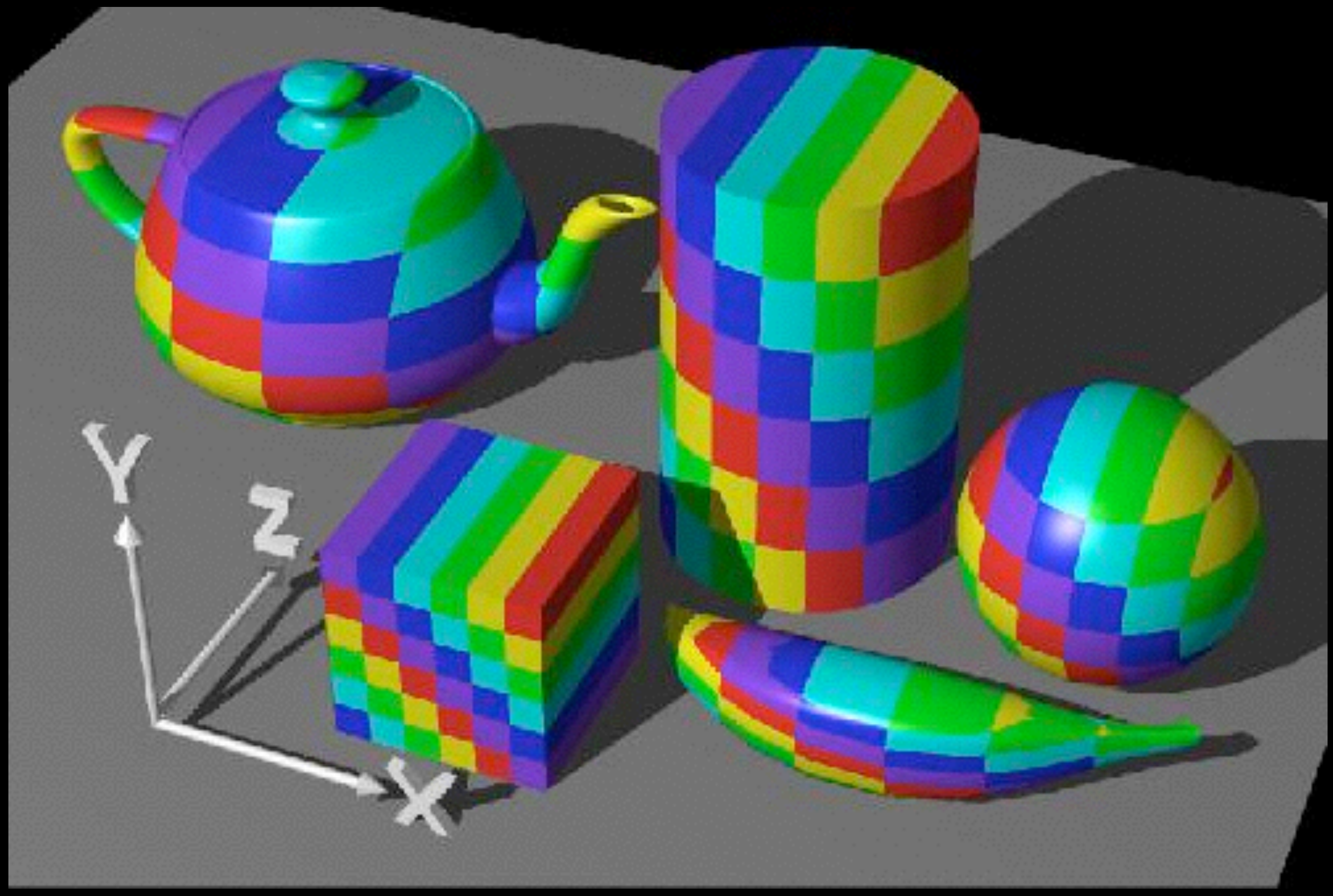


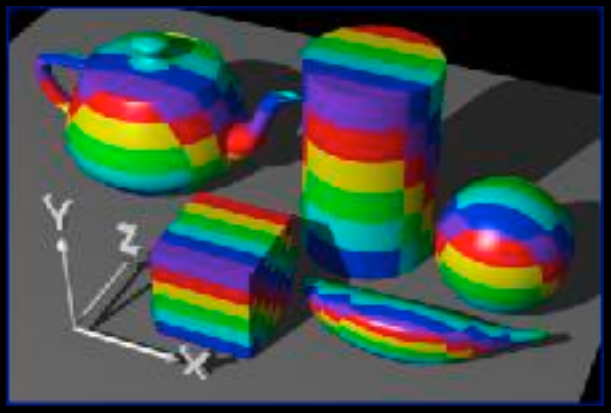
[Rosalee Wolfe]

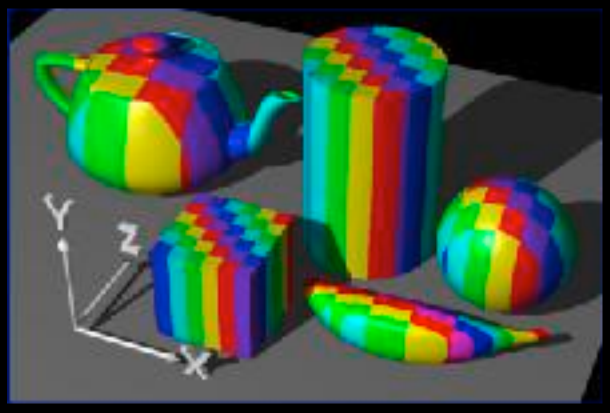
Example: planar mapping

[Rosalee Wolfe]



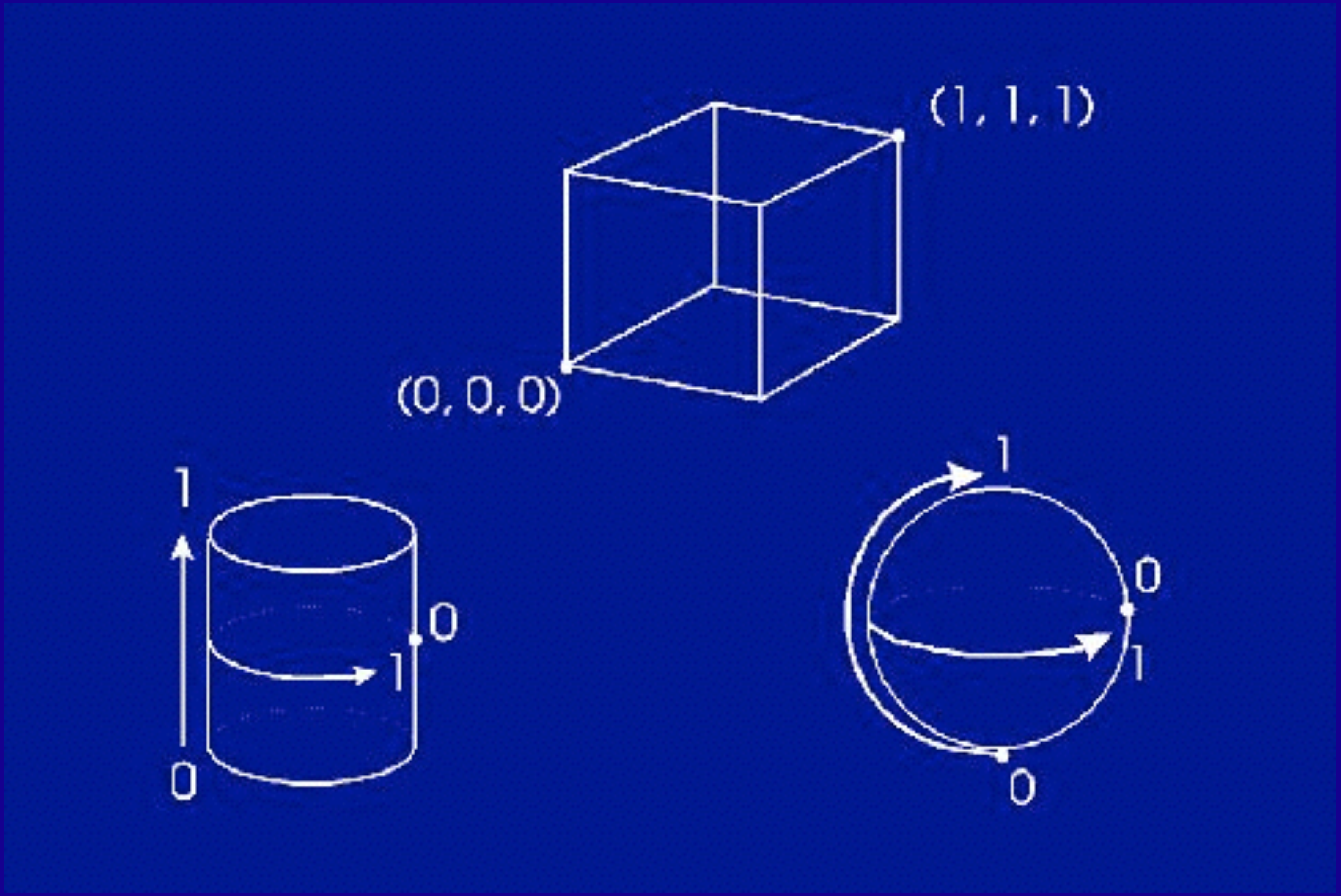






Intermediate surfaces

First map the texture to a simpler, intermediate surface

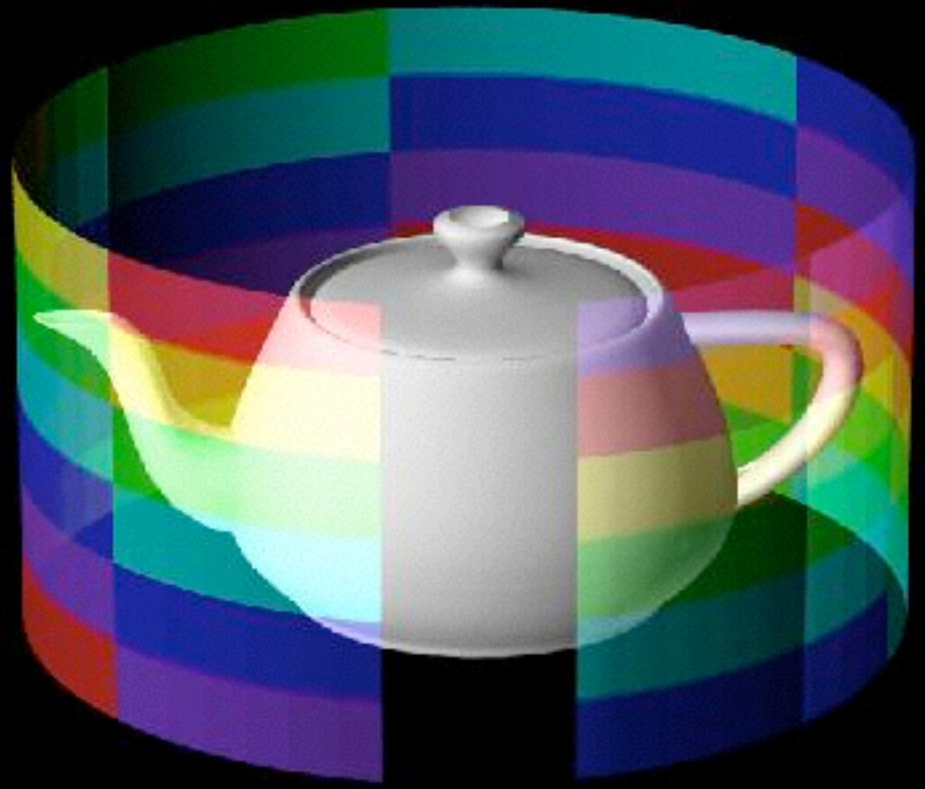


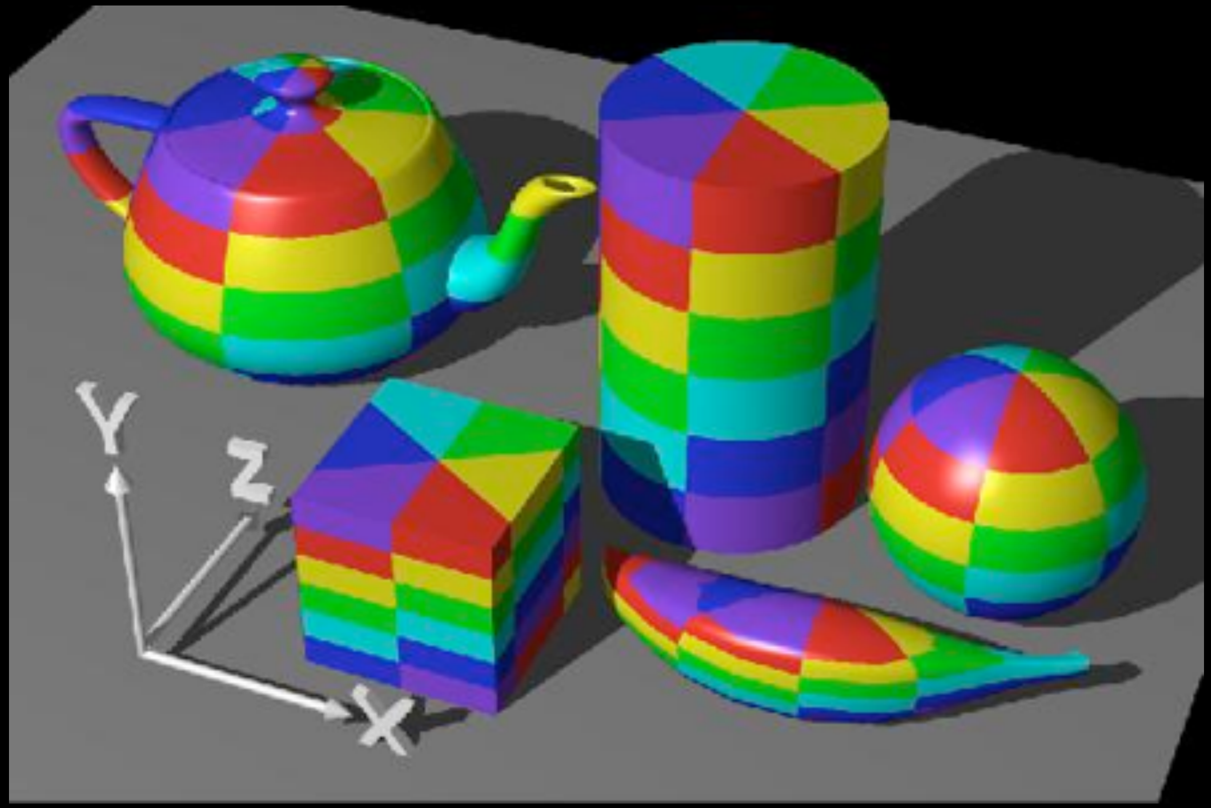
[Rosalee Wolfe]

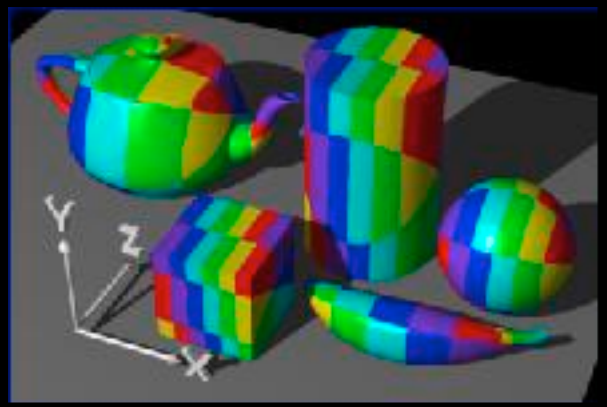
Cylindrical mapping

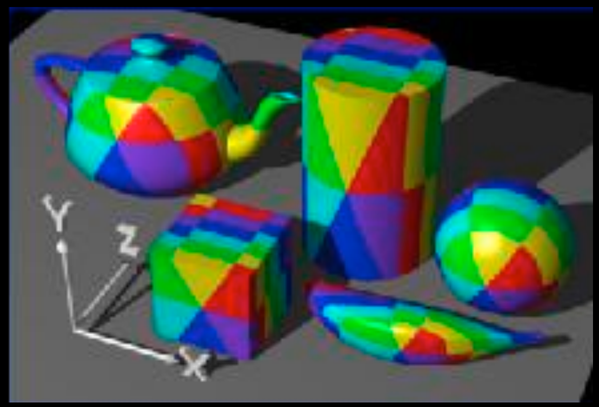
(x,y,z) -> (theta, h) -> (u,v)

[Rosalee Wolfe]





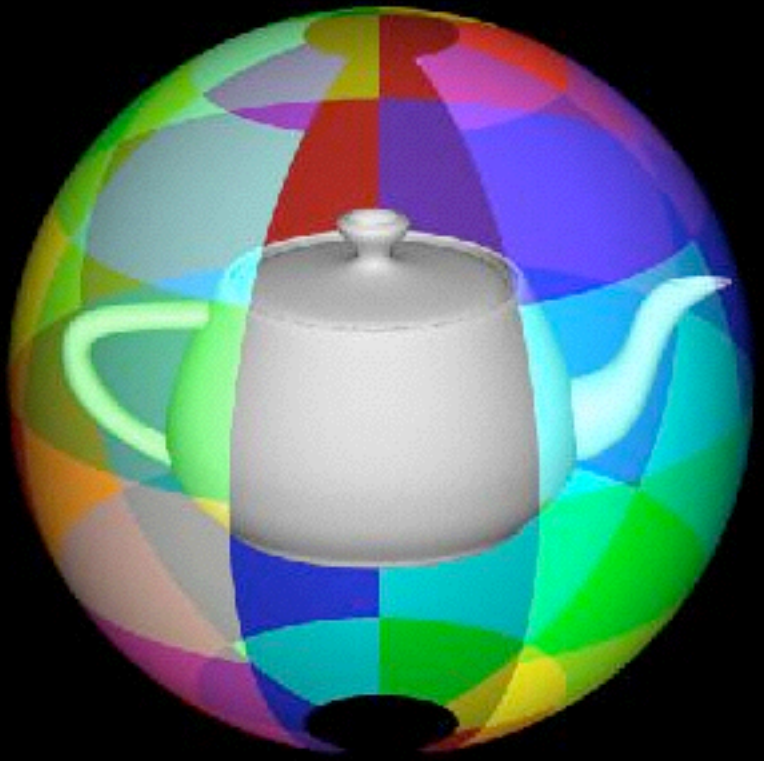


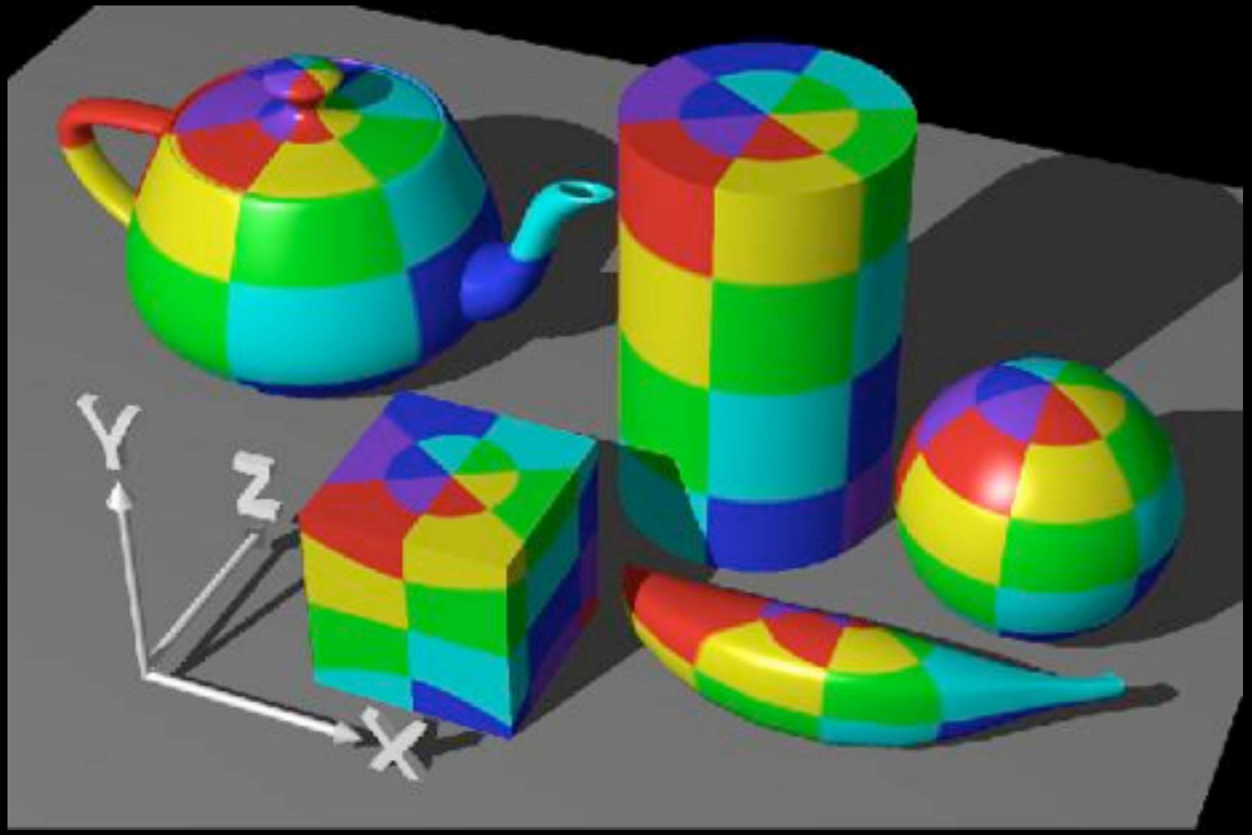


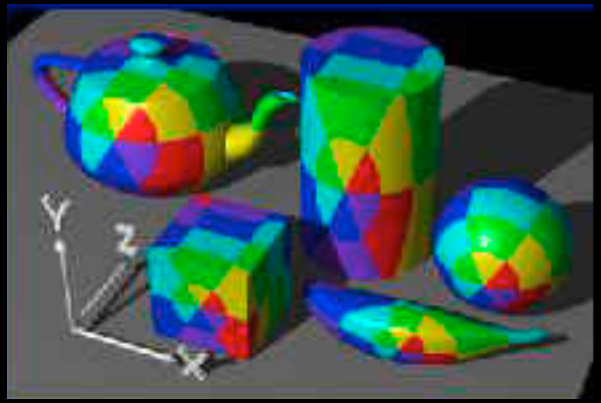
Spherical Mapping

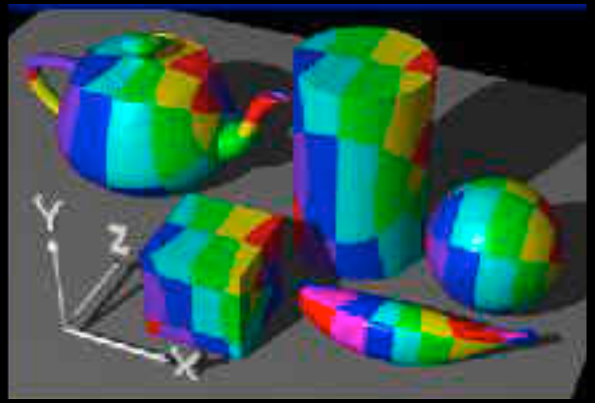
(x,y,z) -> (latitude,longitude)
-> (u,v)

[Rosalee Wolfe]

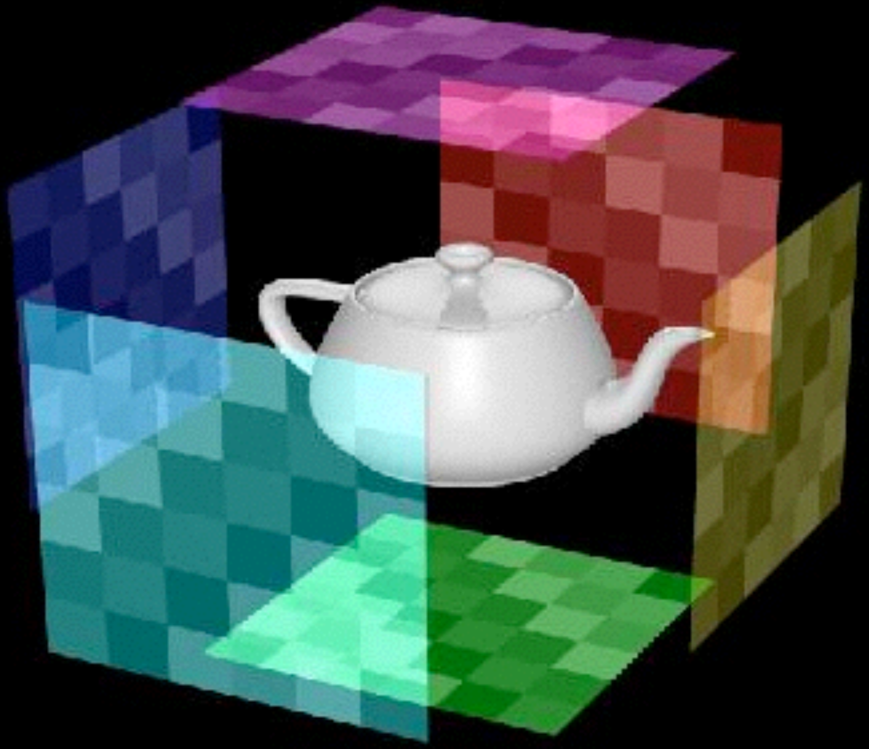


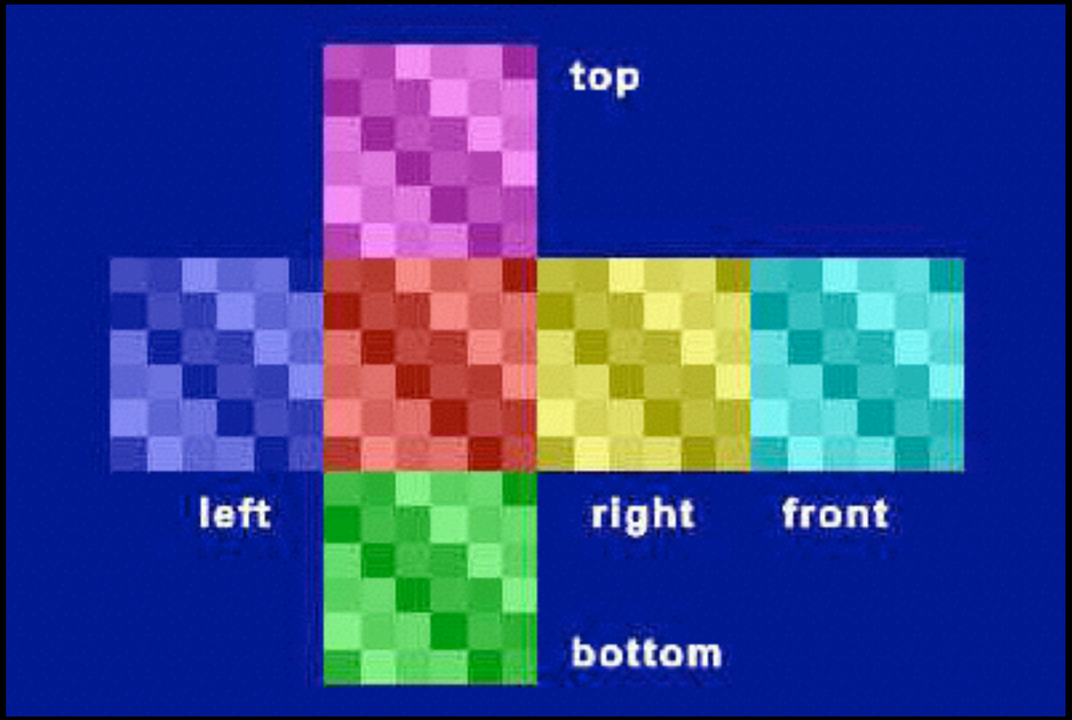


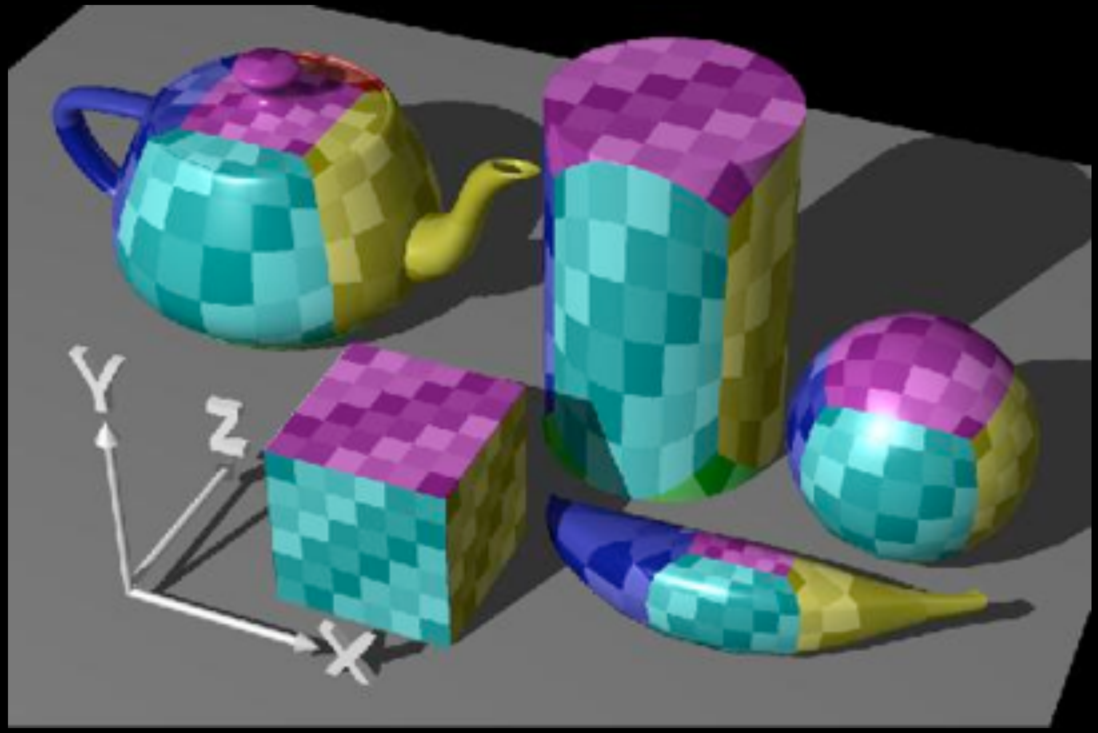




Box Mapping

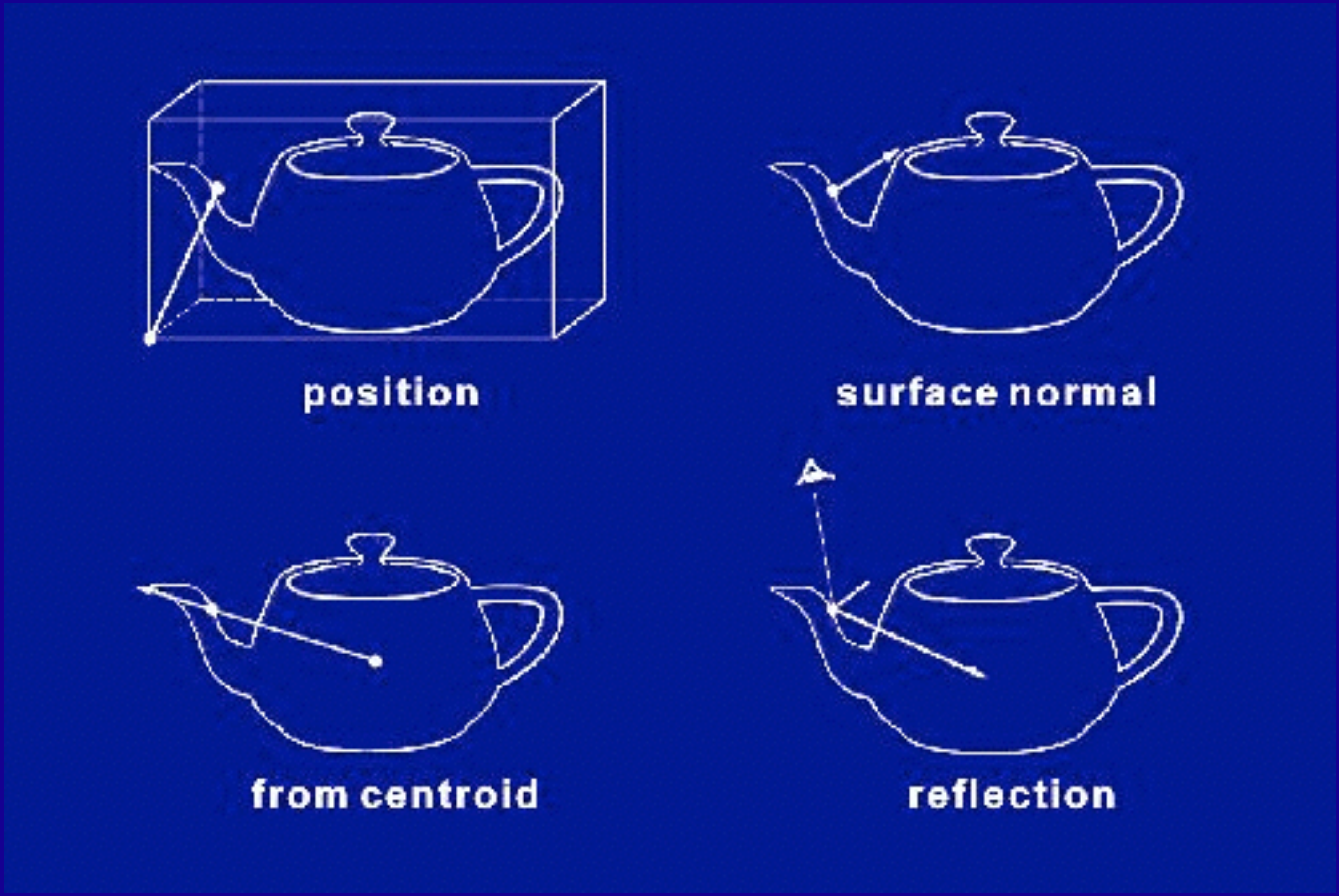






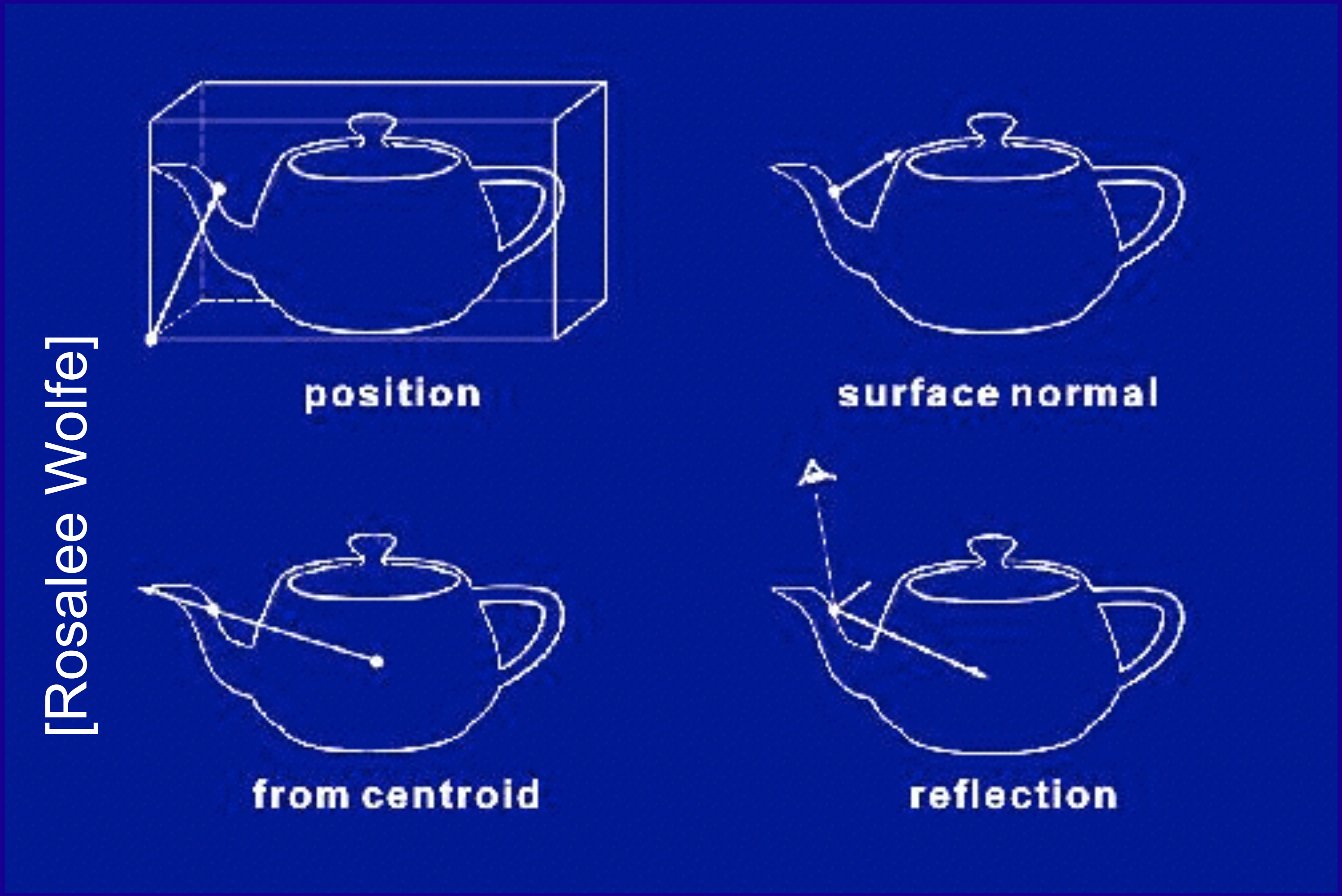
[Rosalee Wolfe]

How do we map between intermediate and actual objects?

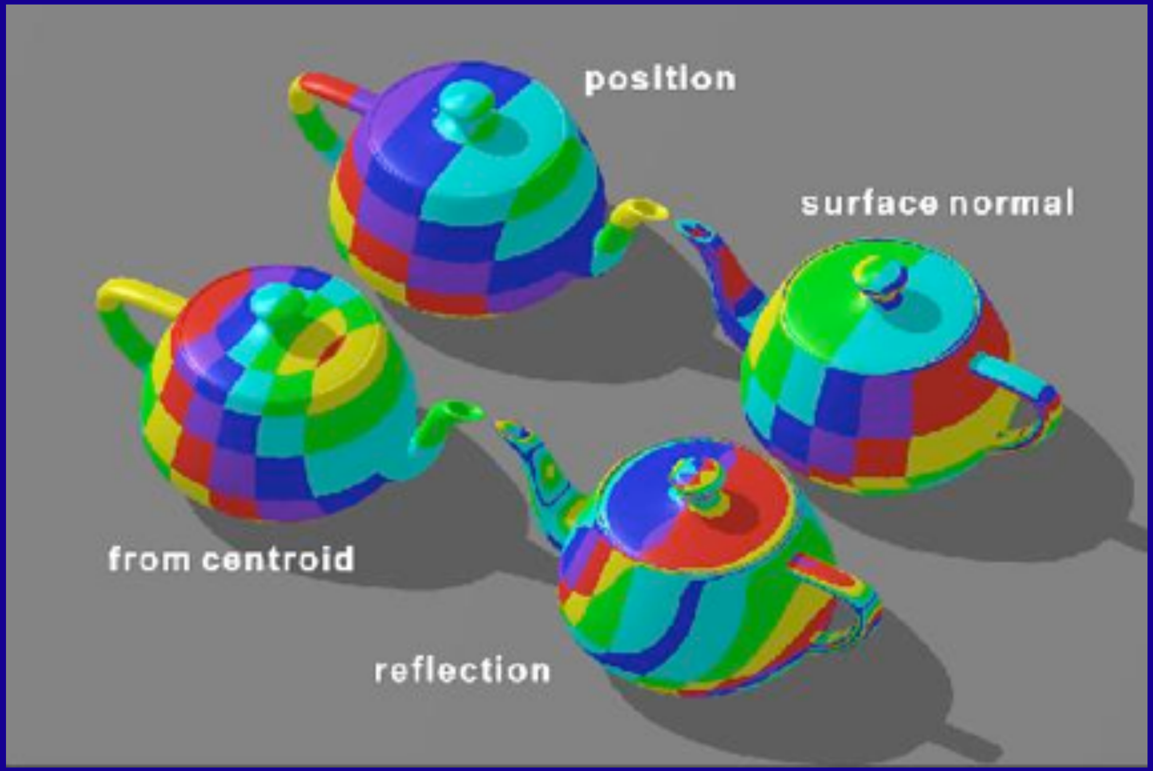


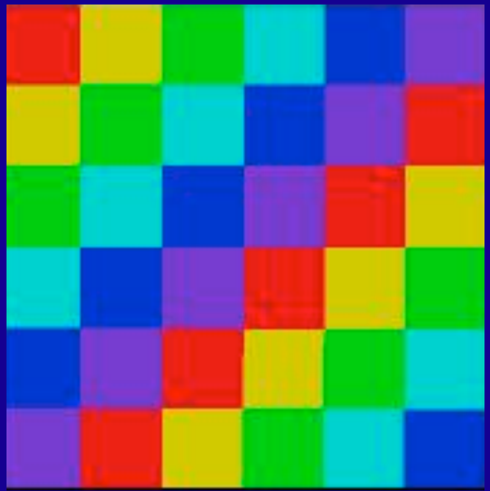
[Rosalee Wolfe]

How do we map between intermediate and actual objects?

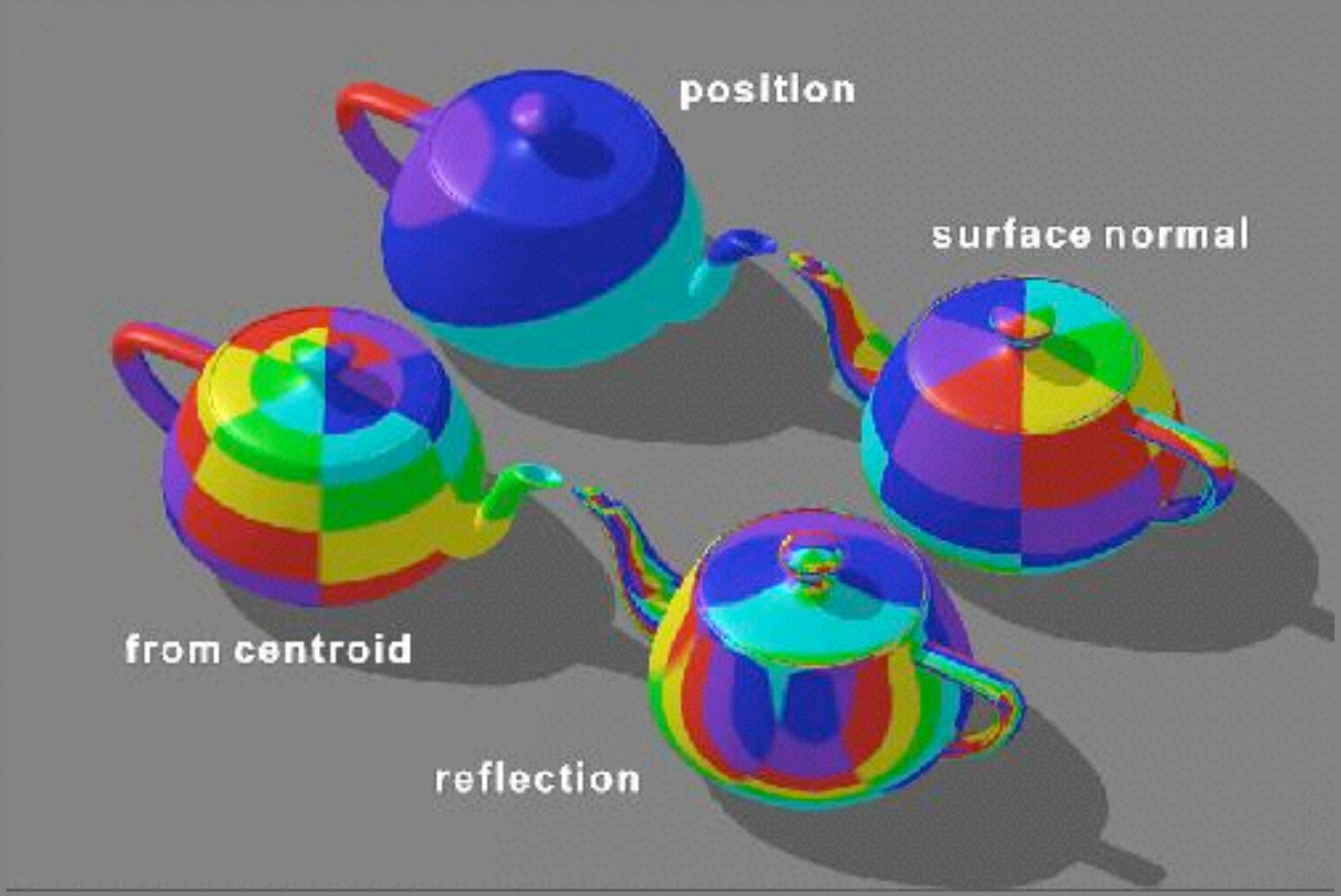


[Rosalee Wolfe]

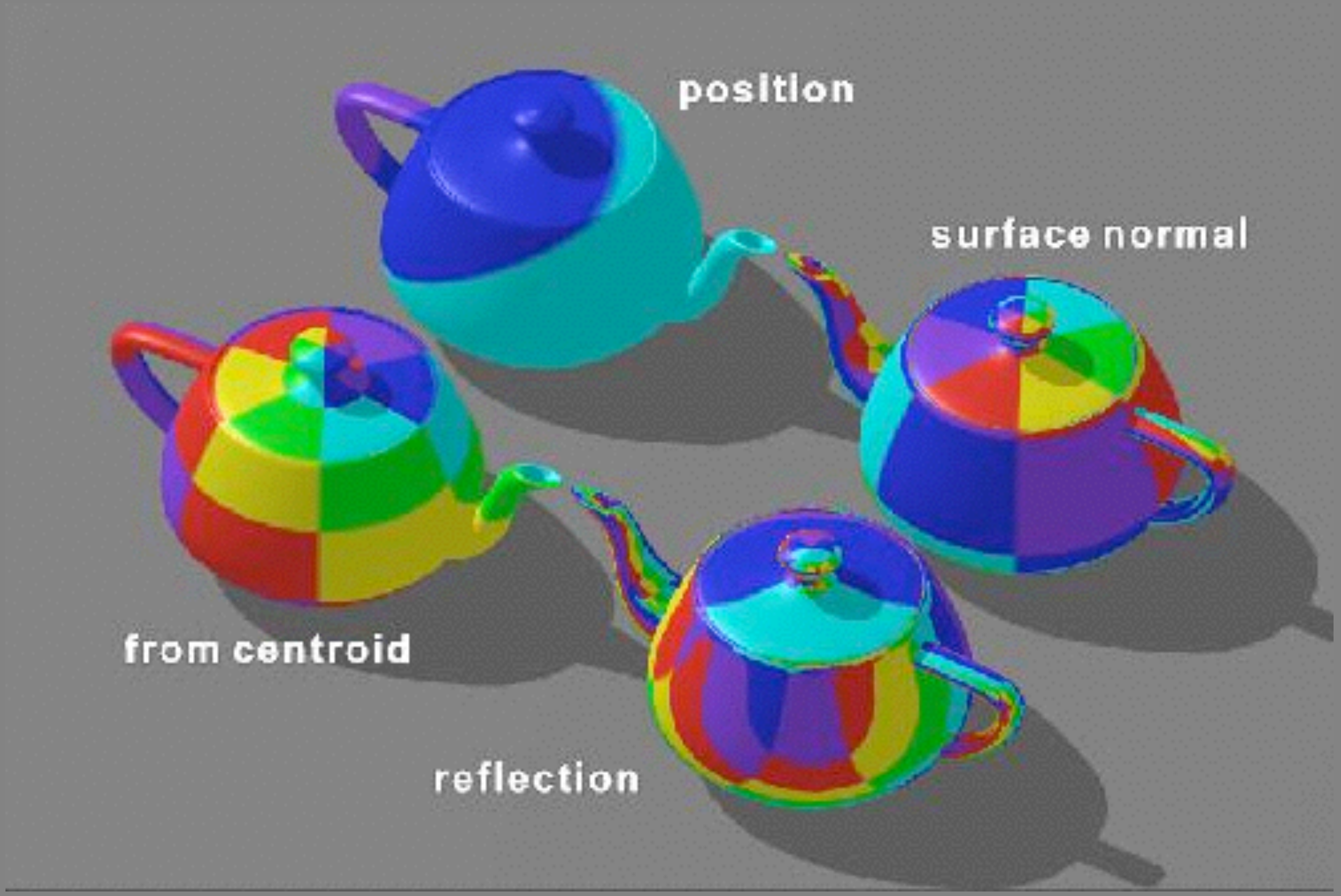




What intermediate shape was used here?

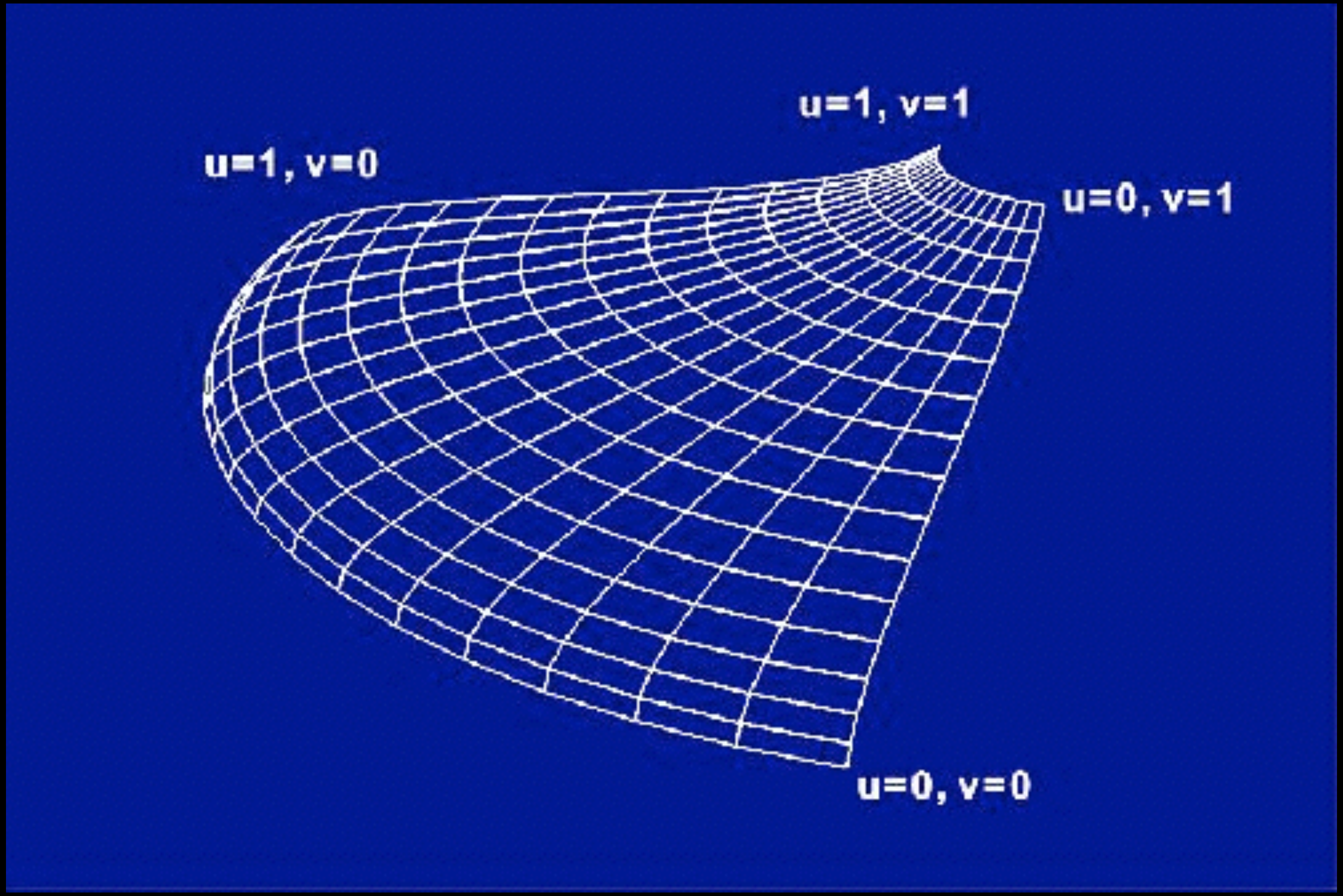


Cylindrical

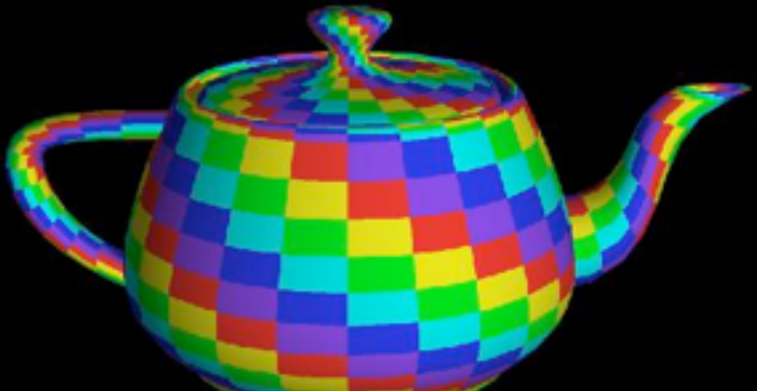


Spherical

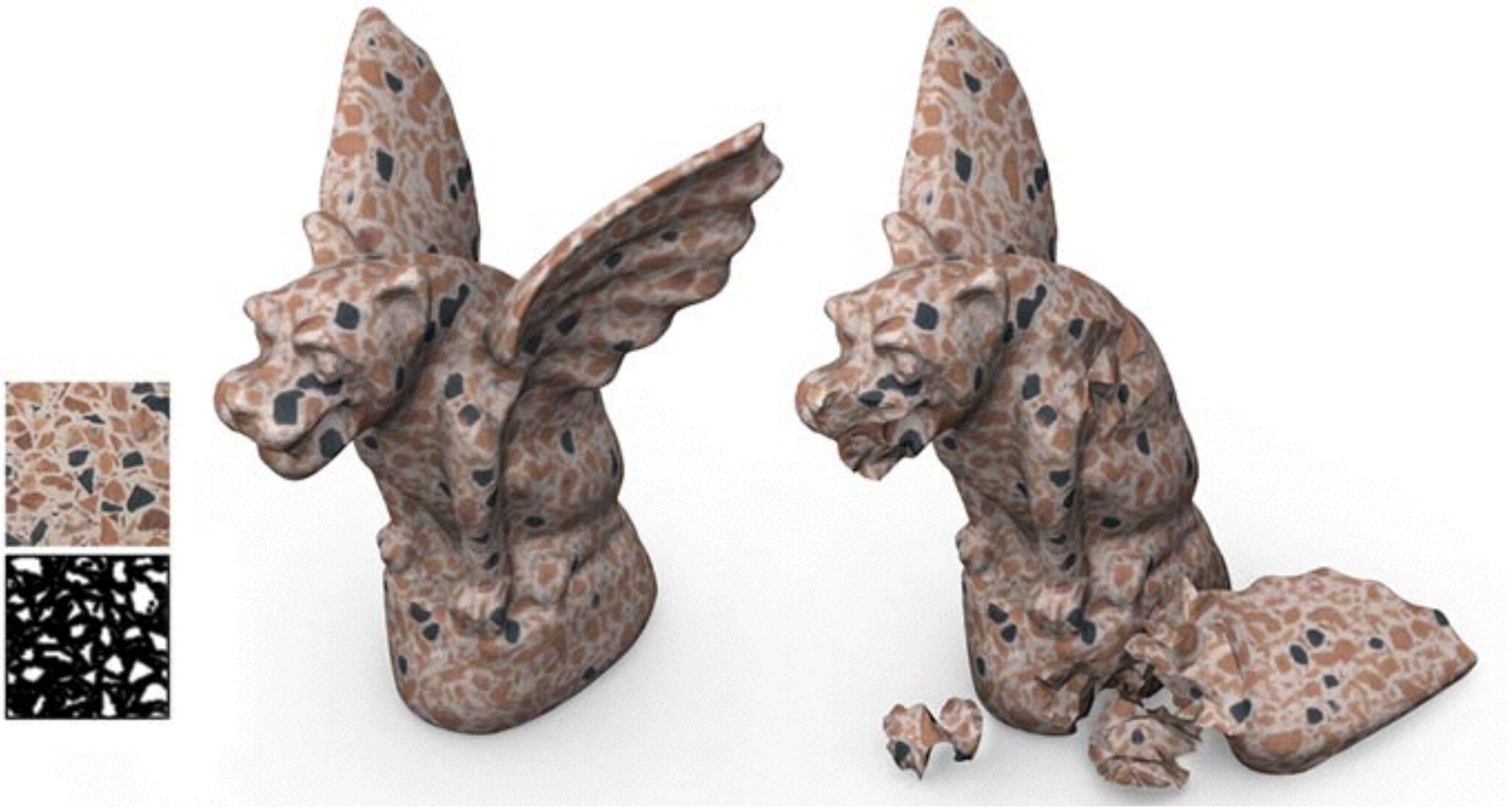
Parametric Surfaces



32 parametric patches



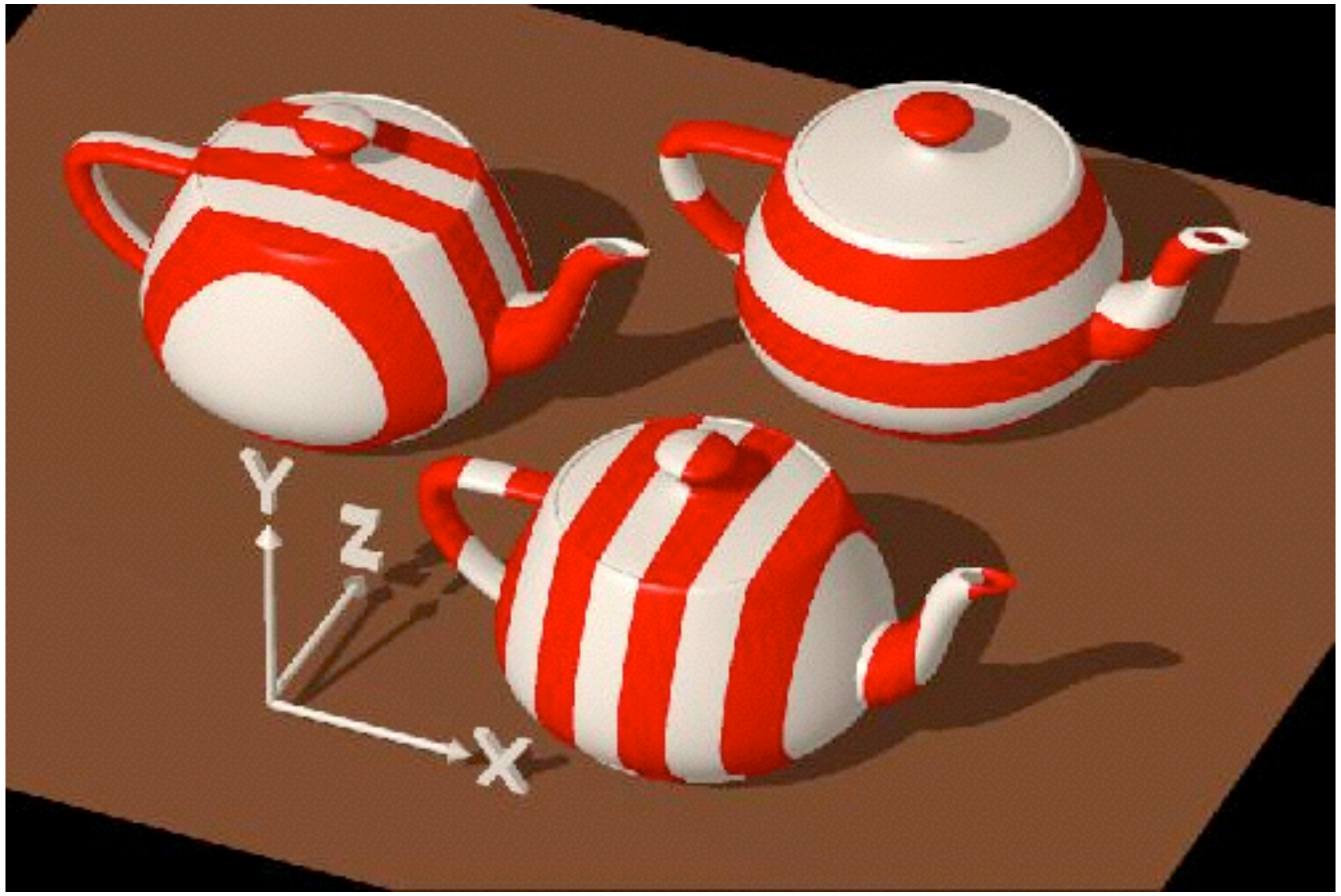
3D solid textures

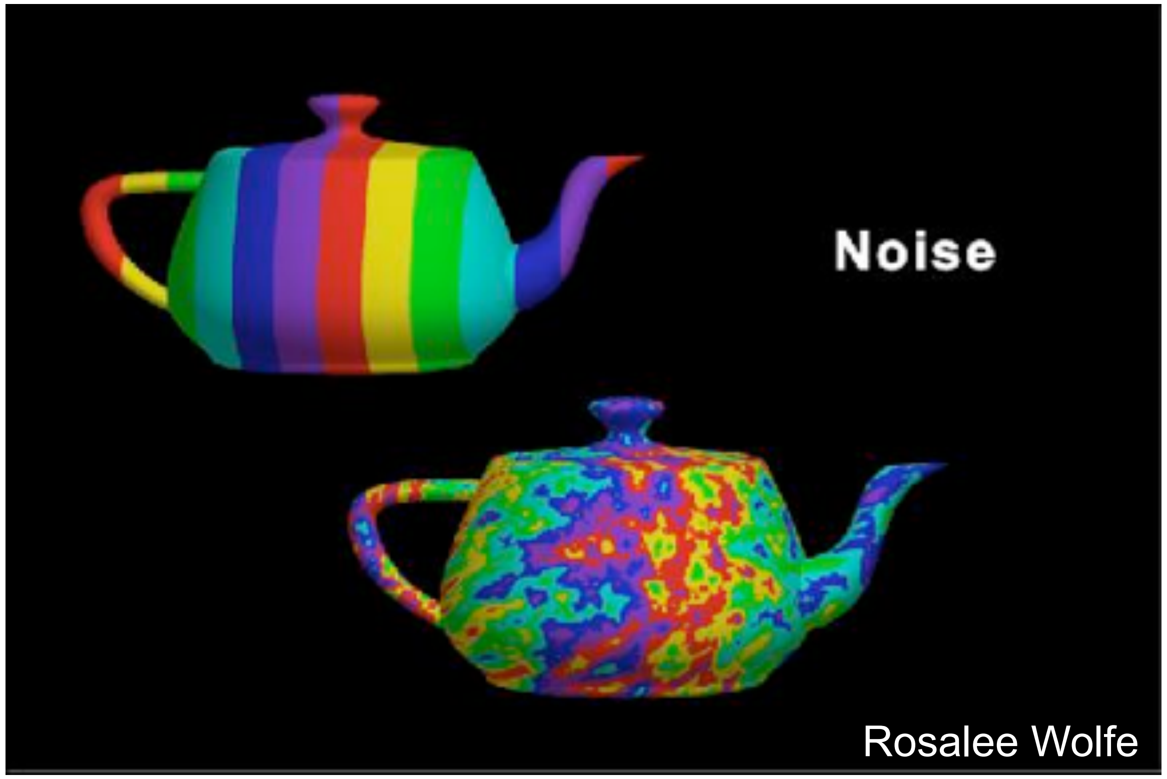


[Dong et al., 2008]

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

Procedural textures



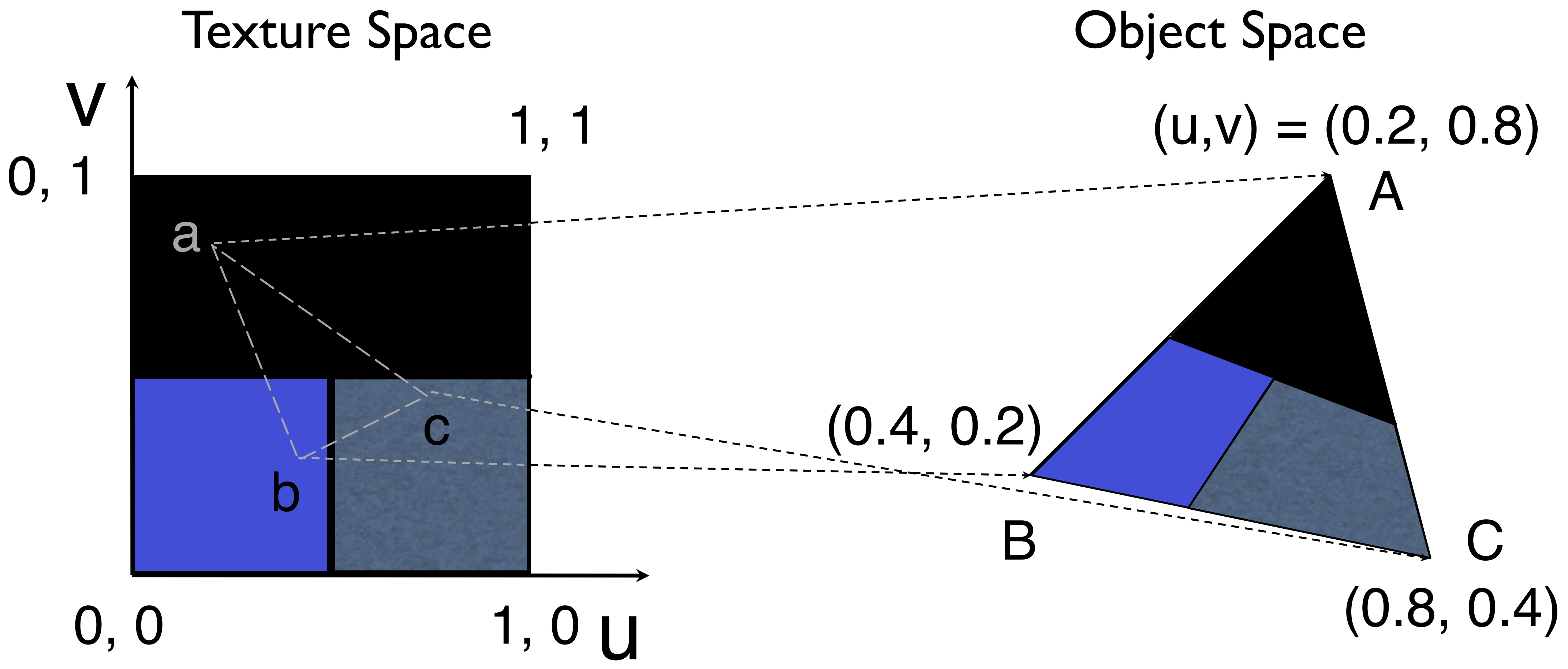


e.g., Perlin noise

Triangles

Texturing triangles

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



[Angel and Shreiner]

Texturing triangles

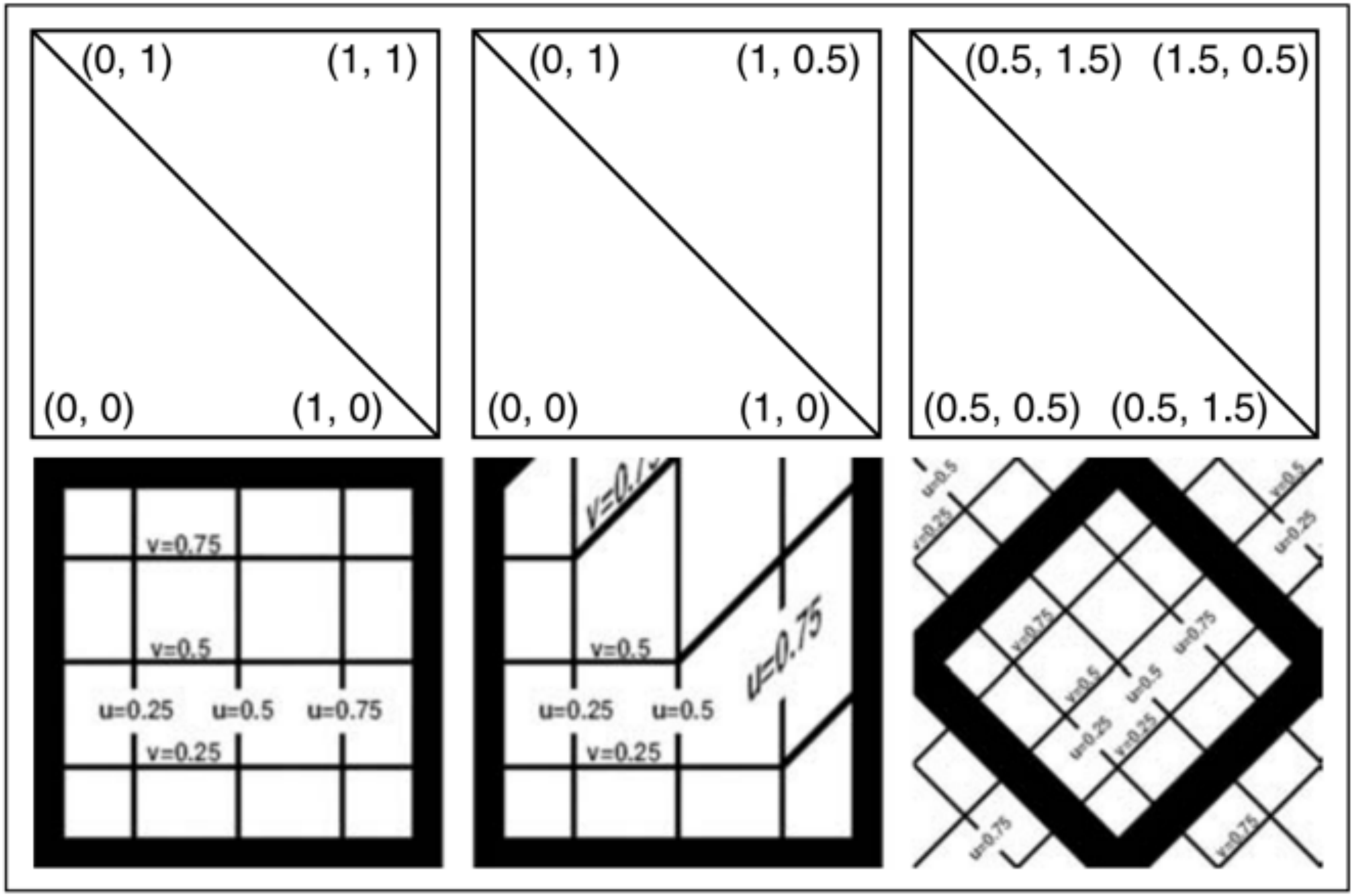
- Store (u,v) at each vertex
- interpolate inside triangles using barycentric coordinates

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

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

Texturing triangles

Choice of (u,v) makes big difference



Texturing triangles

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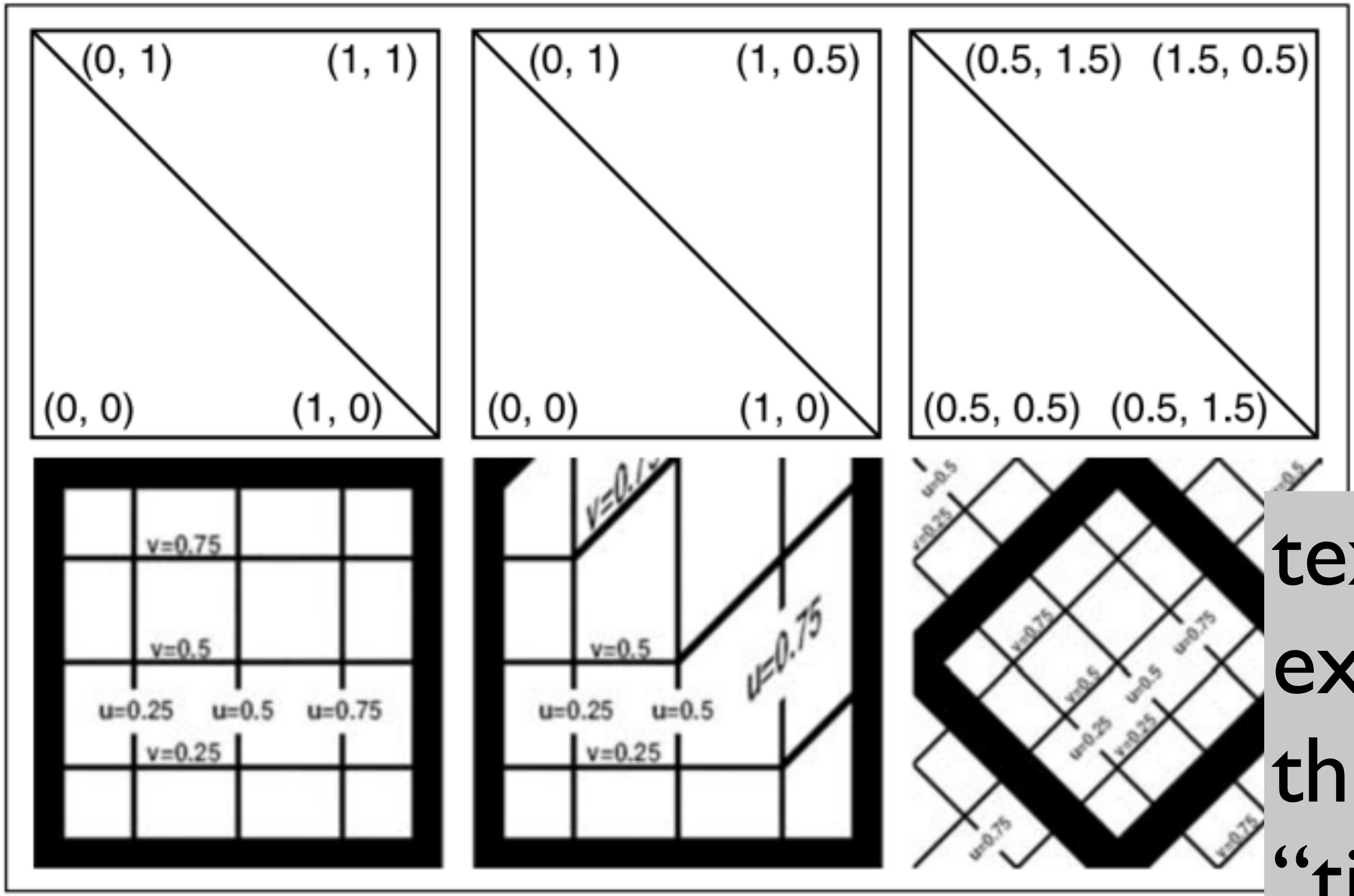
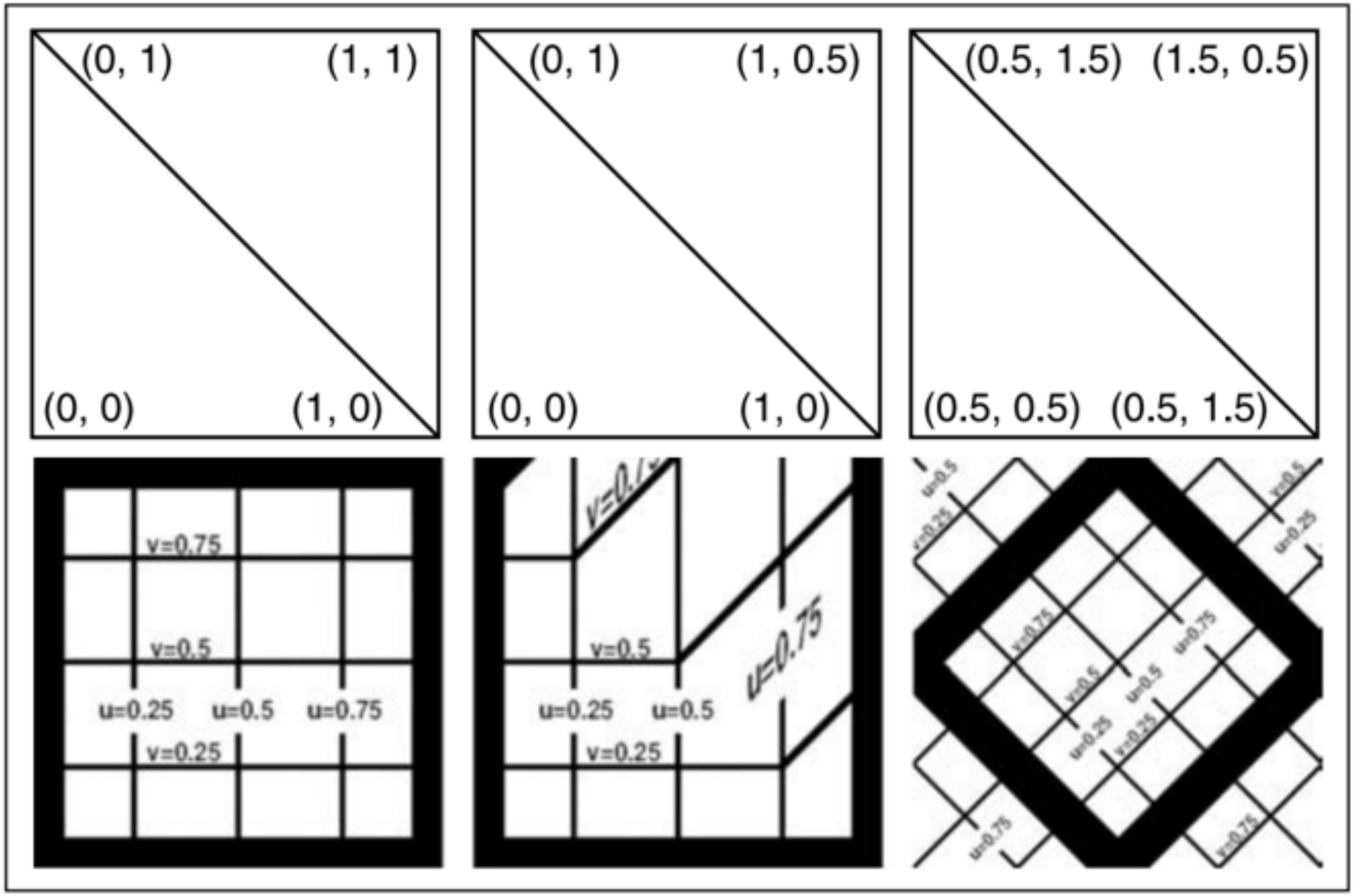


texture extended through “tiling”

Texturing triangles

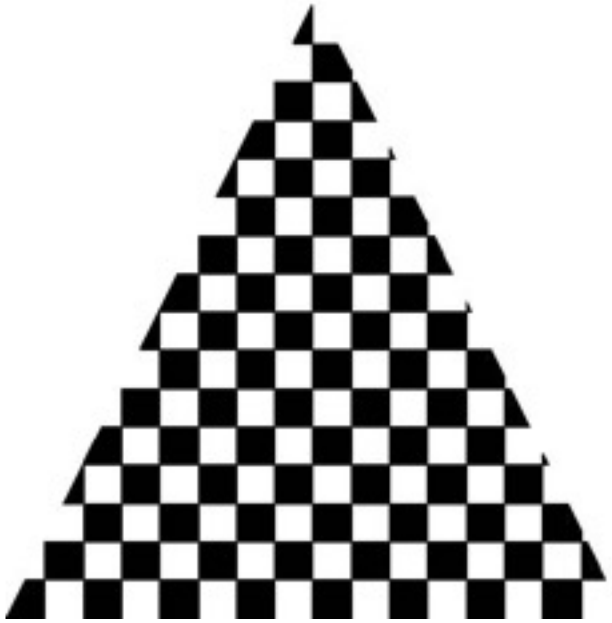
Choice of (u,v) makes big difference



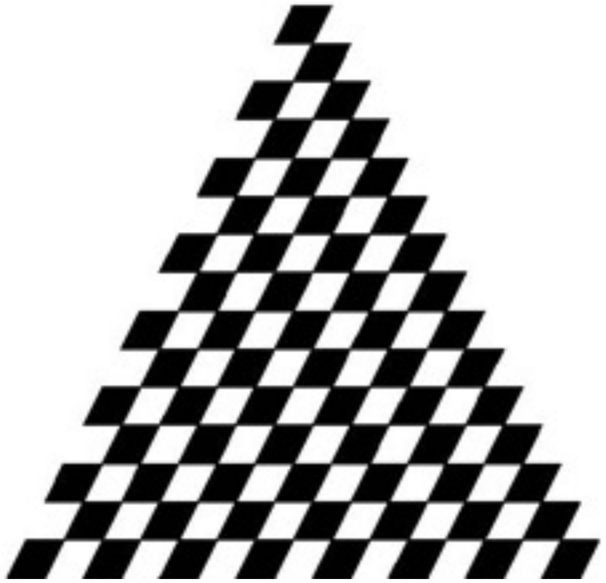
Textures in OpenGL

```
glTexCoord*()
```

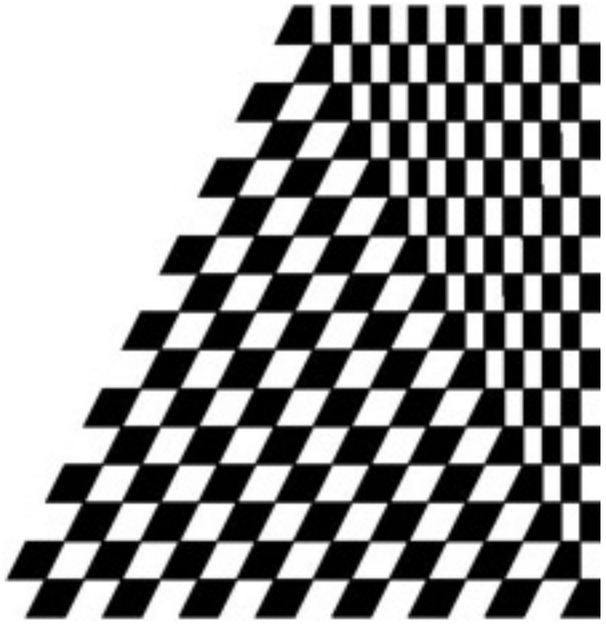
- Assign (u,v) to vertices
- OpenGL then uses interpolation for triangle interior



good selection of tex coordinates

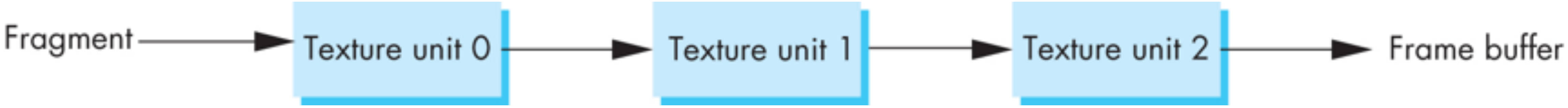


poor selection of tex coordinates

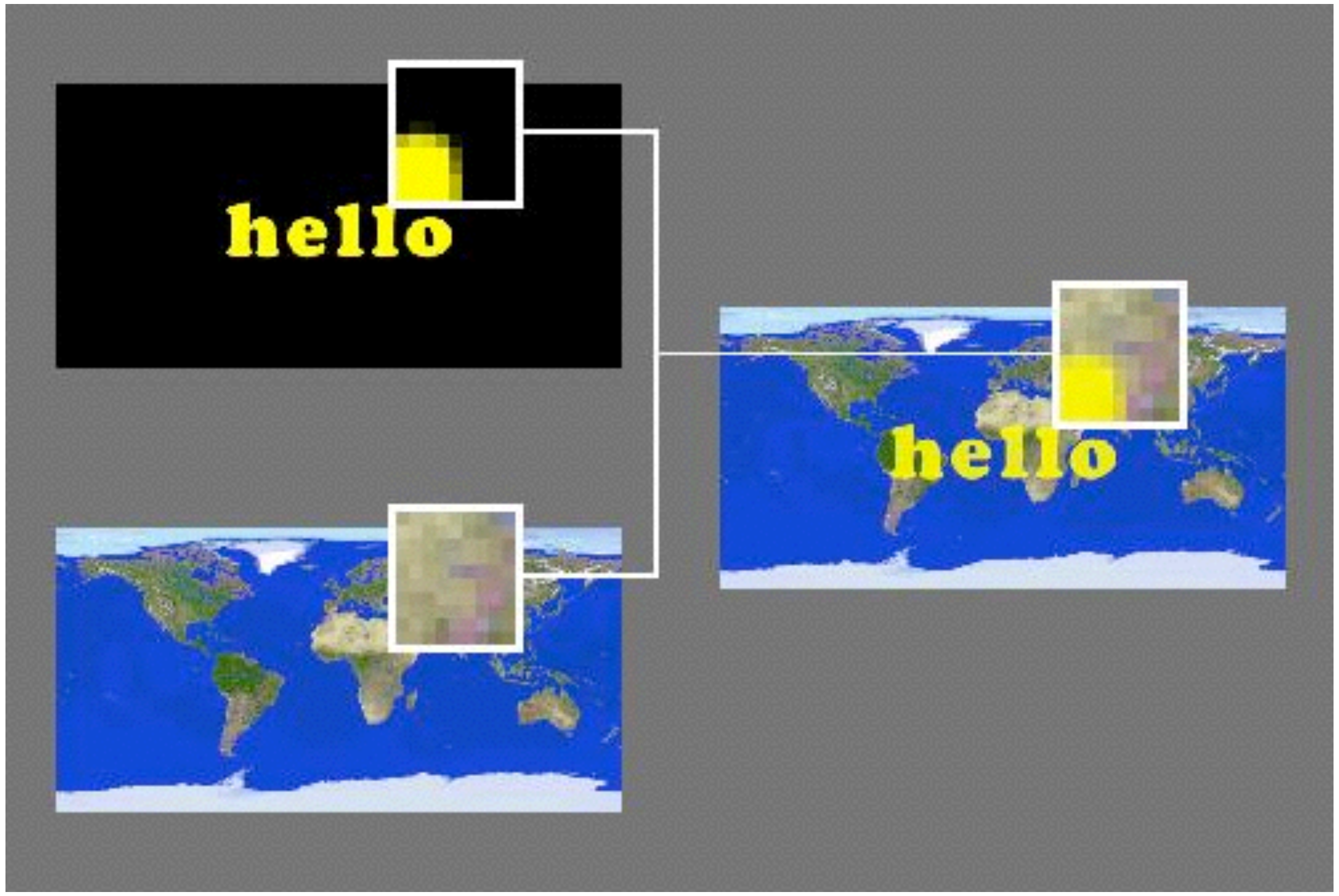


texture stretched over trapezoid showing effects of bilinear interpolation

Multitexturing



Fragment → Texture unit 0 → Texture unit 1 → Texture unit 2 → Frame buffer

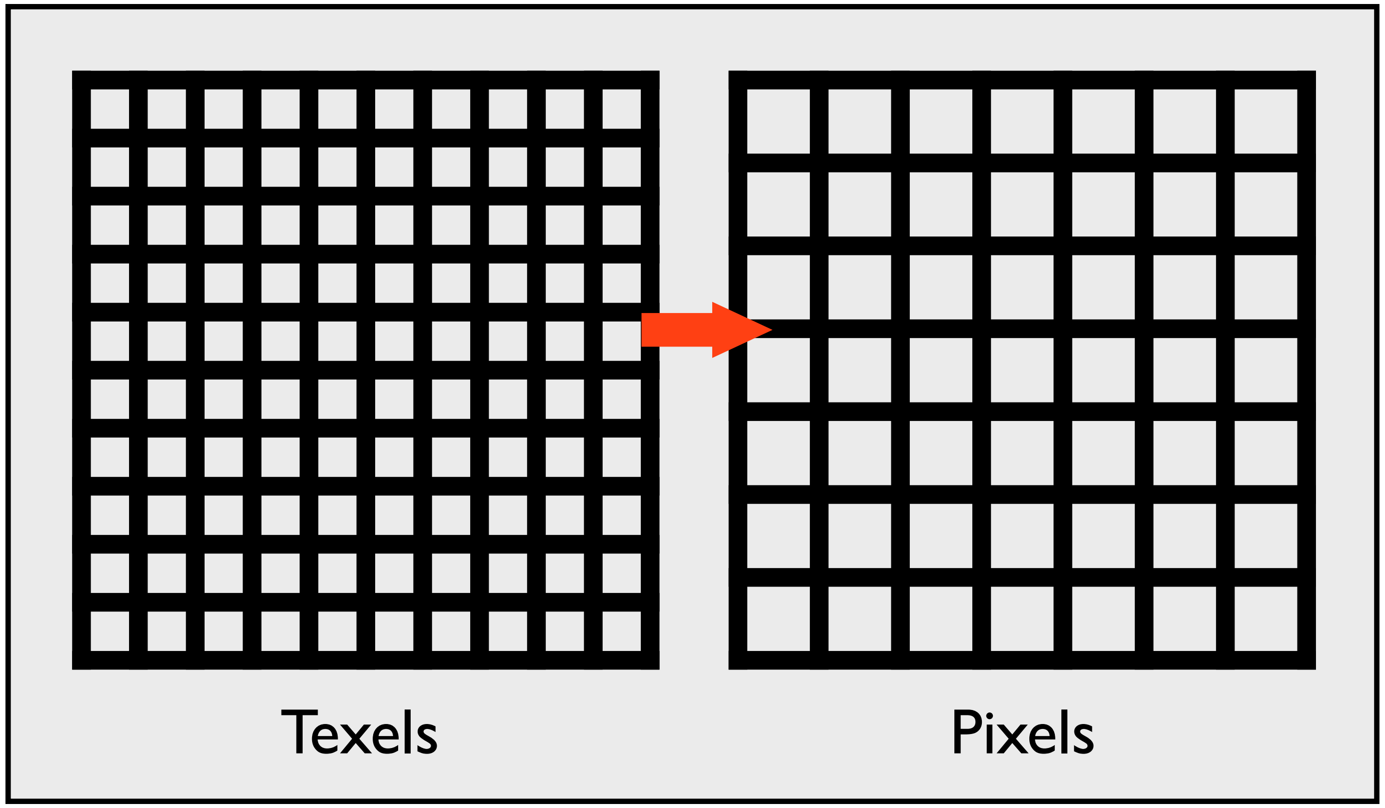


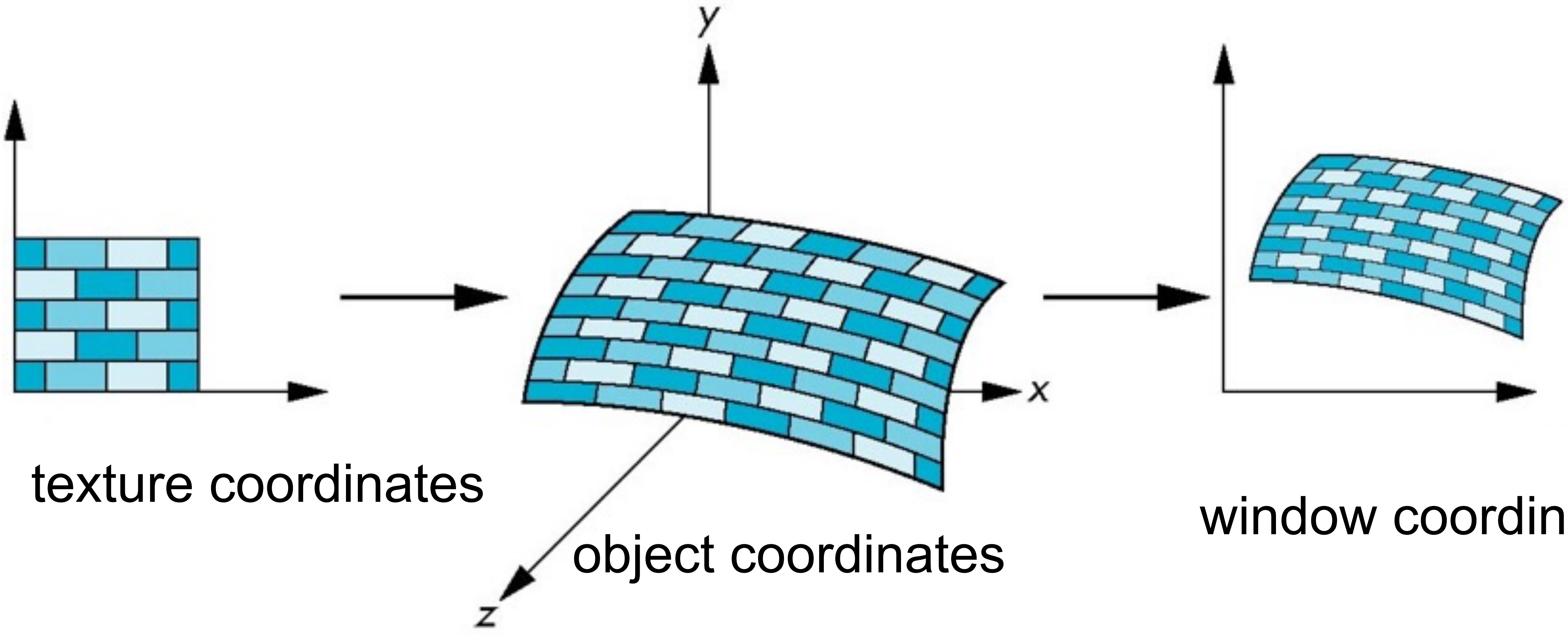
hello
ello
hello
hello

Rosalee Wolfe

Texture Sampling

Texture Mapping





texture coordinates

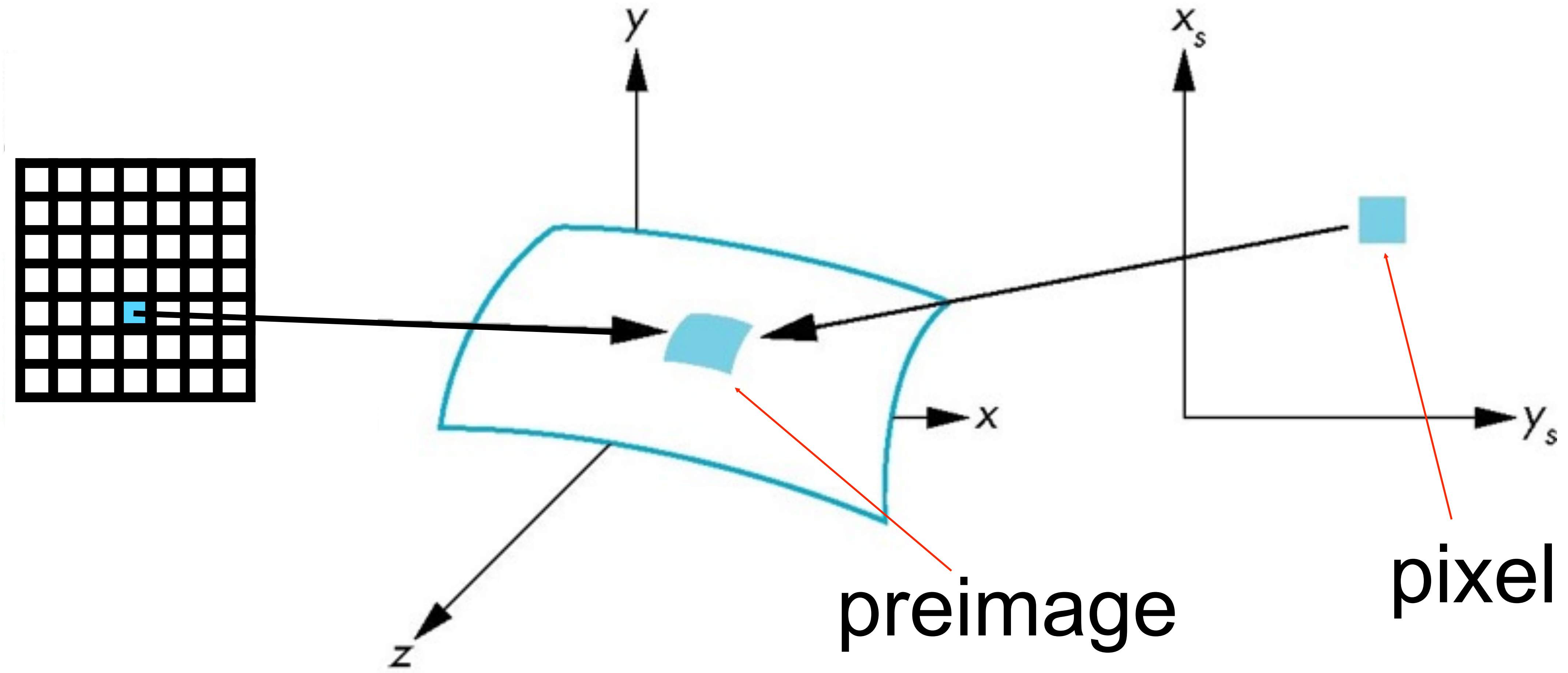
object coordinates

window coordinates

[Angel and Shreiner]

Point Sampling

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



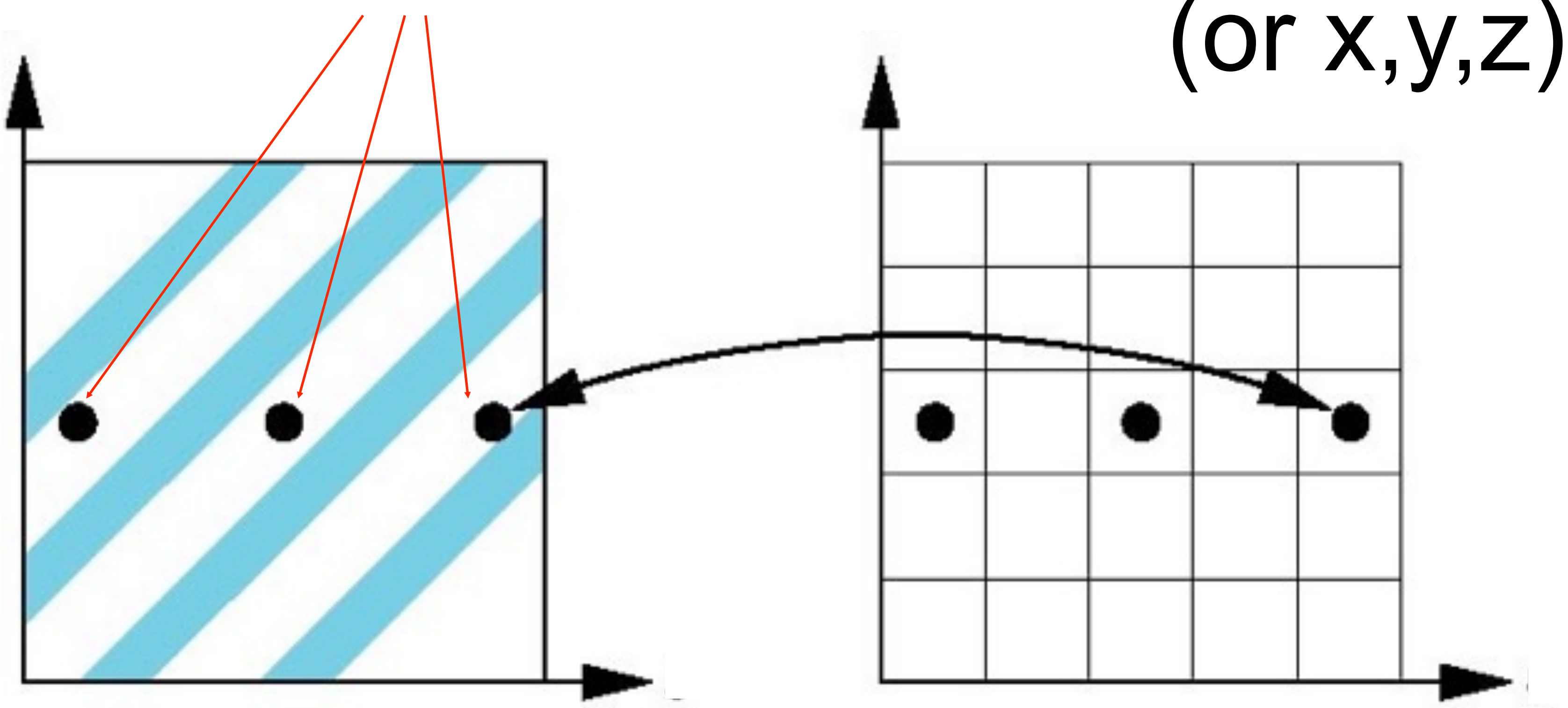
preimage

pixel

[Angel and Shreiner]

Aliasing

Point sampling of the texture can lead to aliasing artifacts



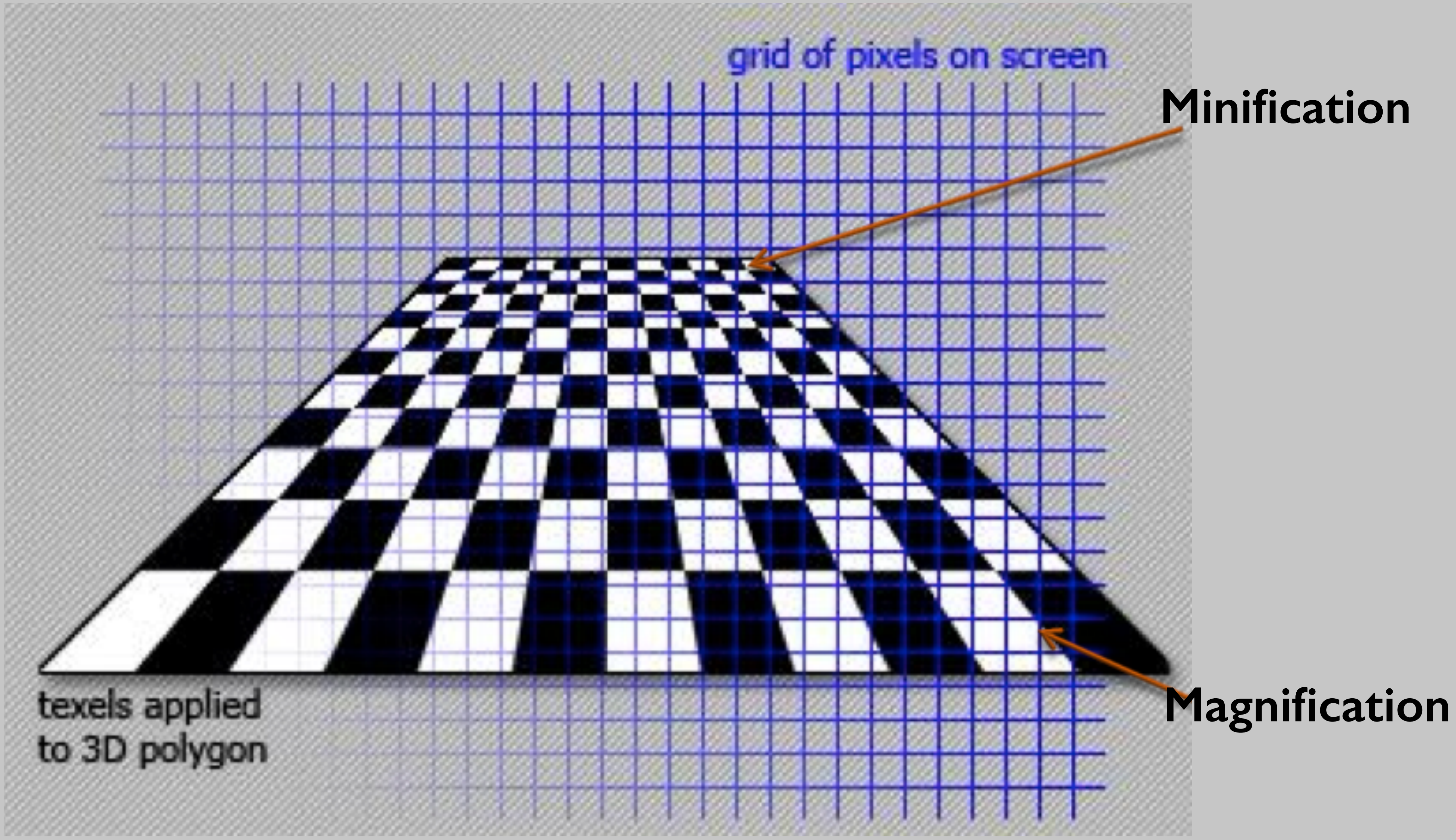
miss blue stripes

point samples in (or x,y,z) space

point samples in texture space

[Angel and Shreiner]

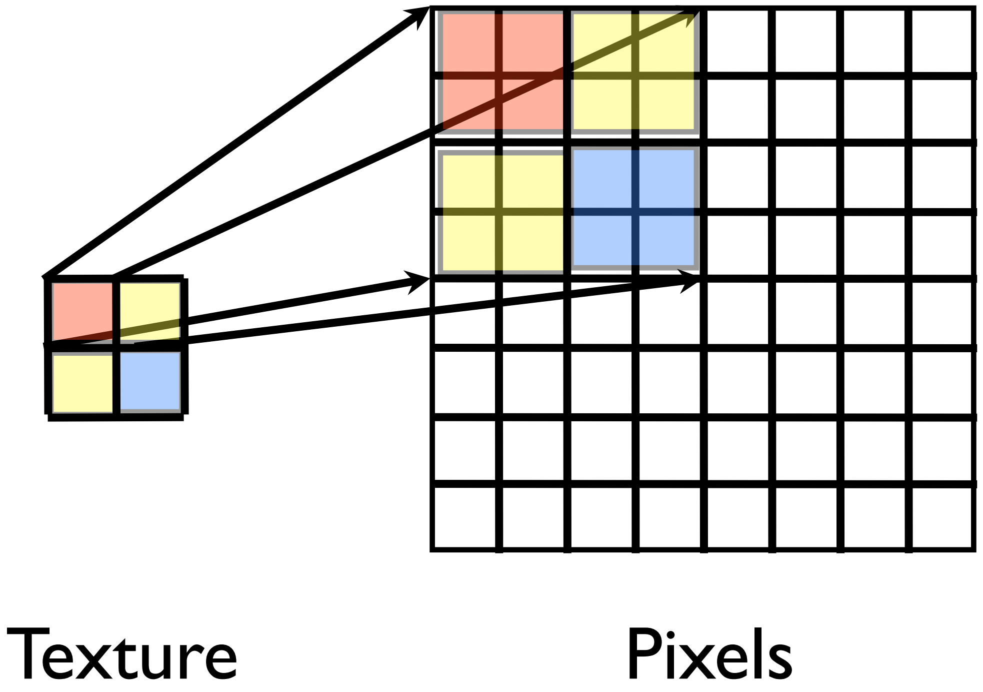
Magnification and Minification



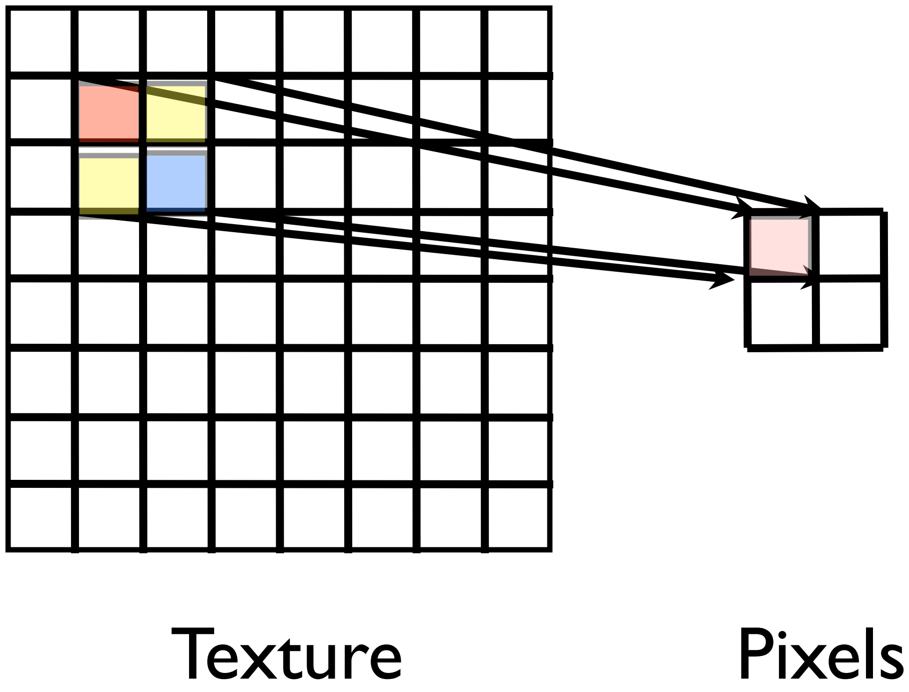
Magnification and Minification

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

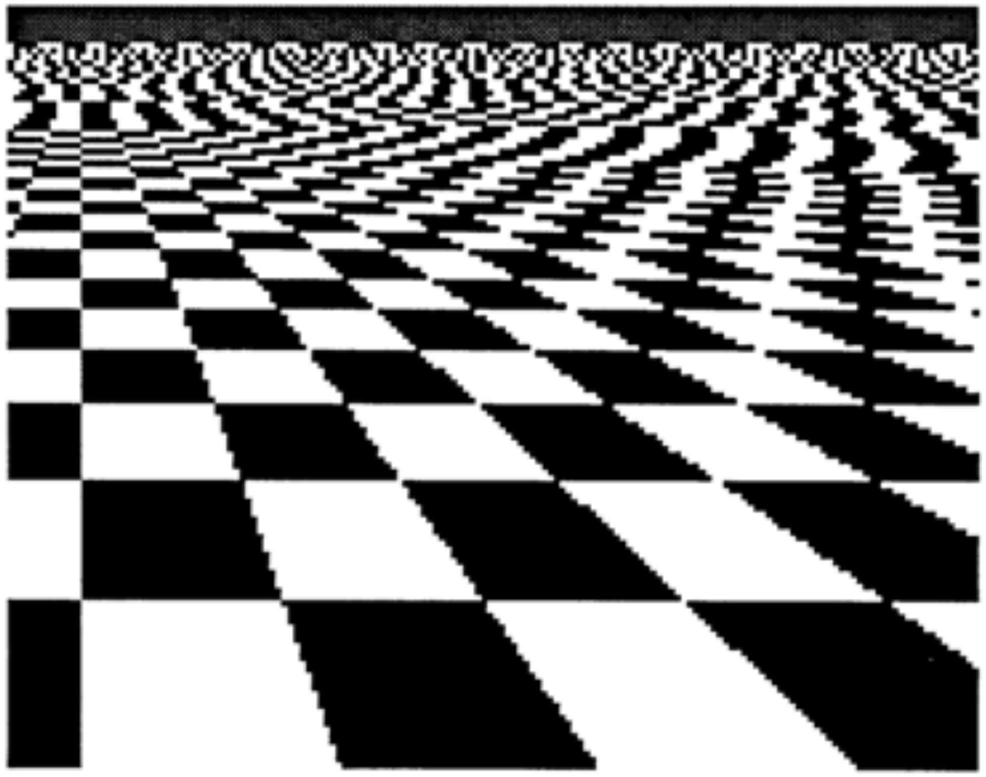


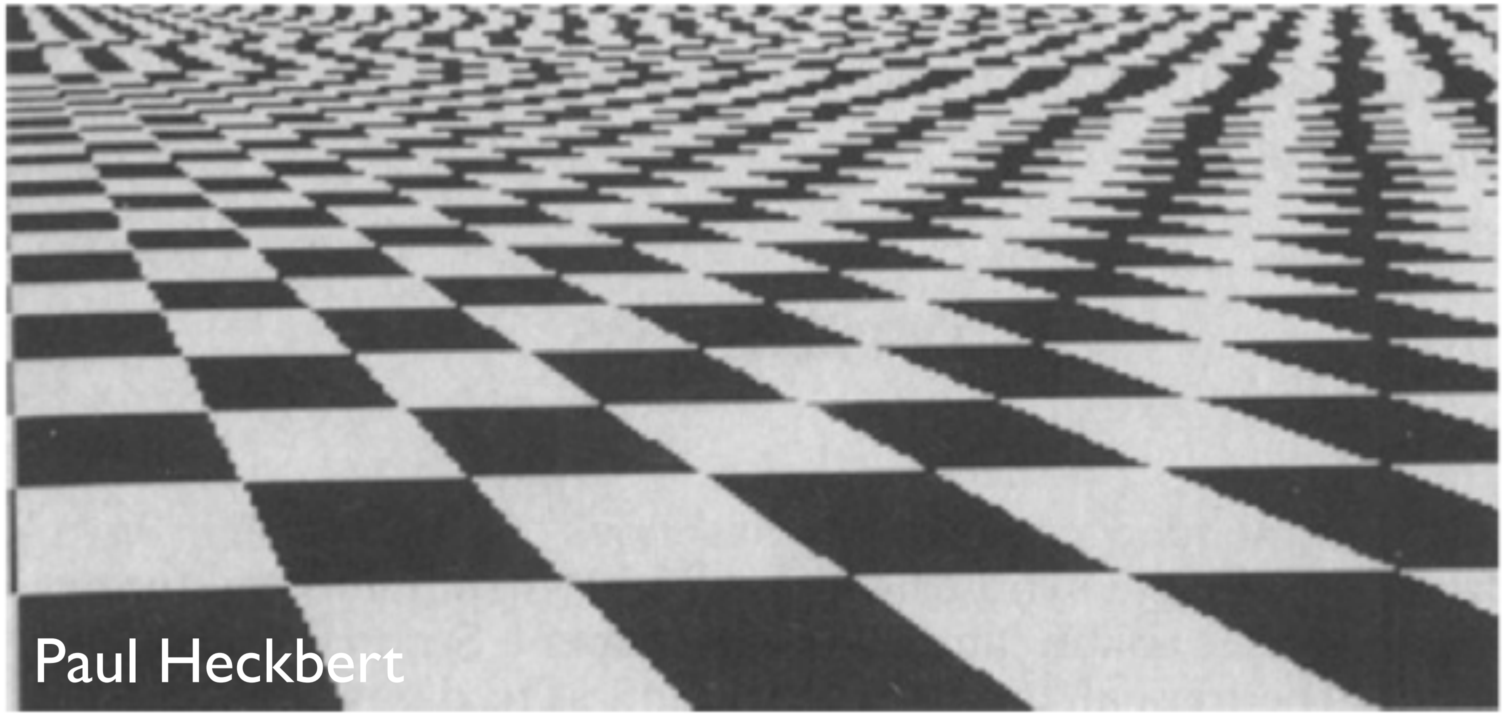
Magnification



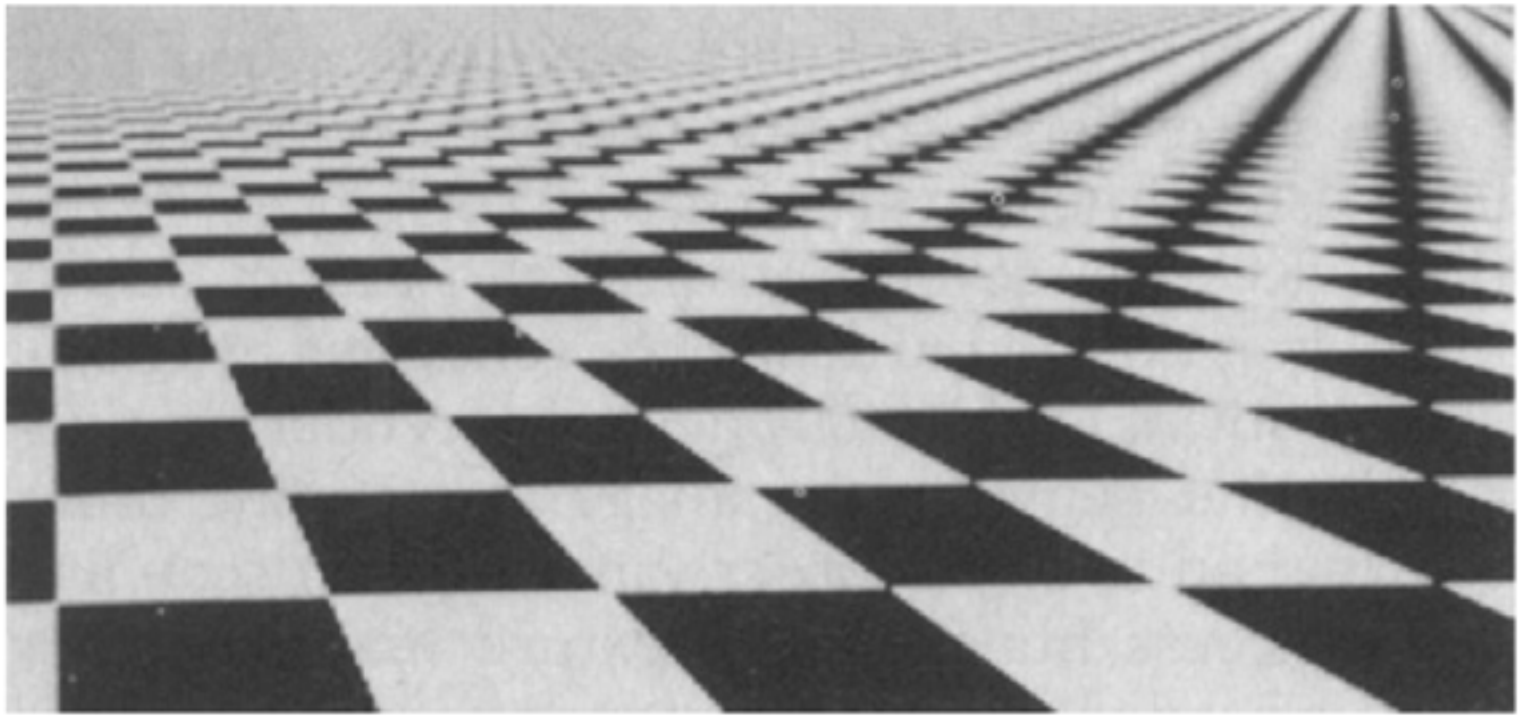
Minification

Aliasing artifacts





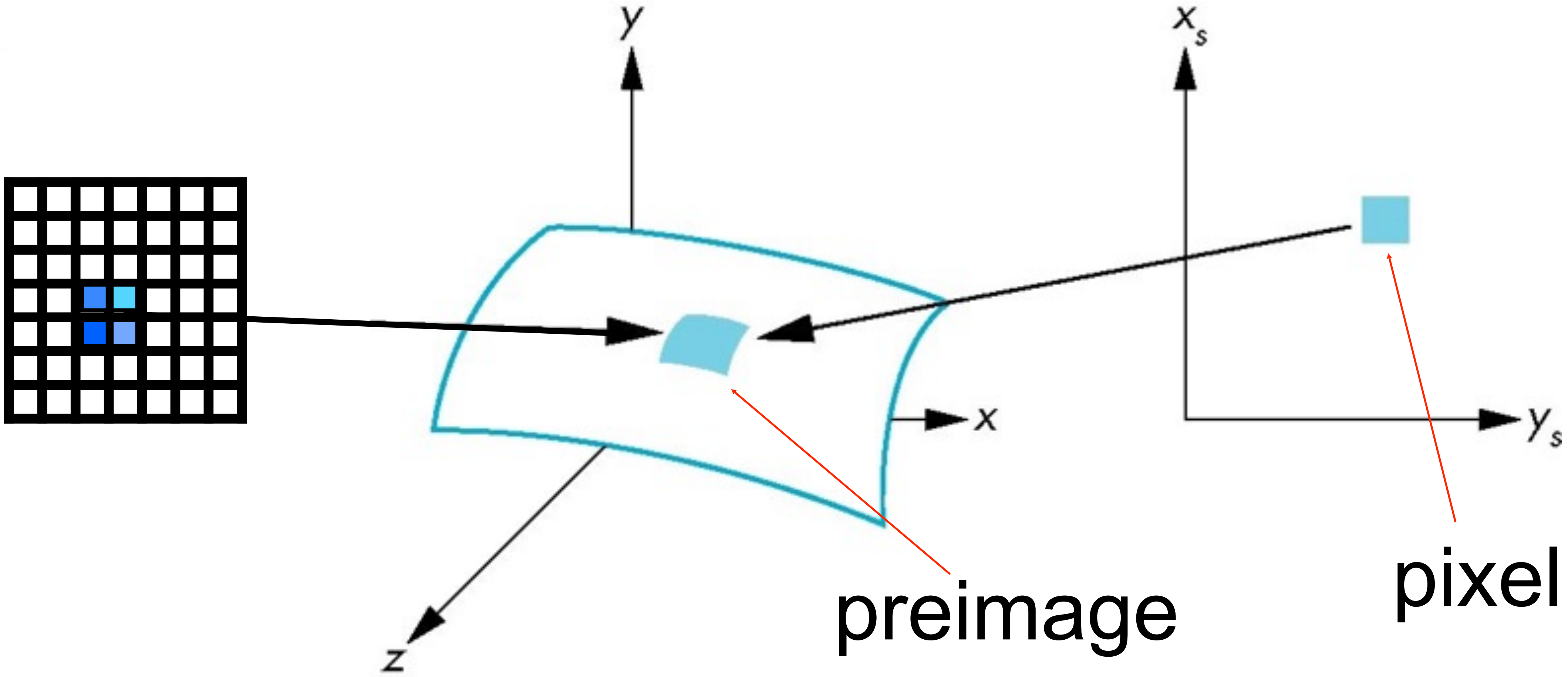
Paul Heckbert



We apply **filtering** to reduce aliasing artifacts

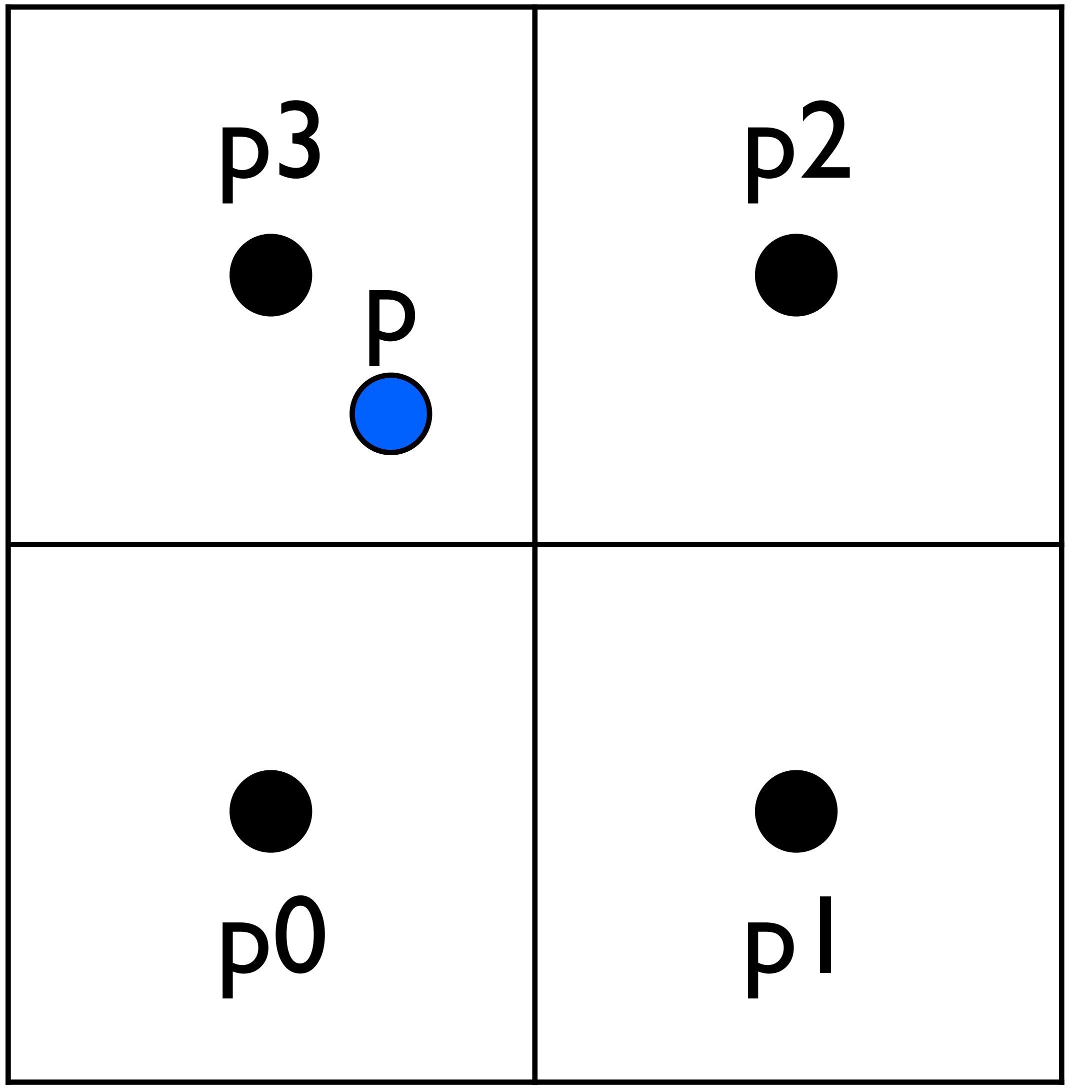
Area Averaging

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



[Angel and Shreiner]

Use bilinear filtering



nearest neighbor

bilinear

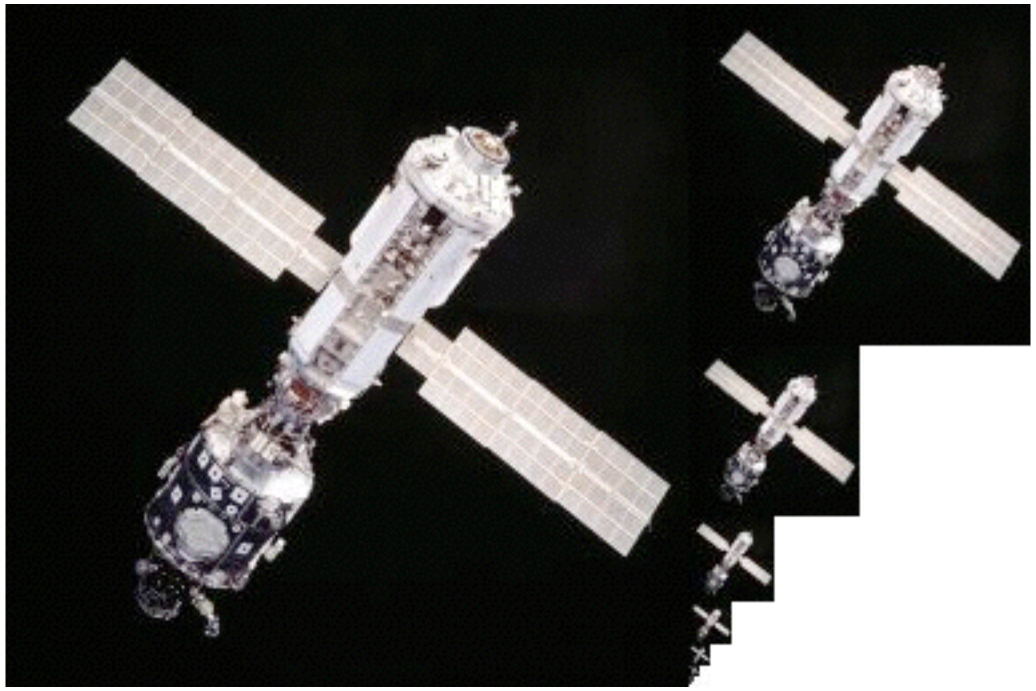
Wikipedia

bicubic

mitigate magnification artifacts

p = ?

Mipmapping



Togikun, Wikimedia Commons

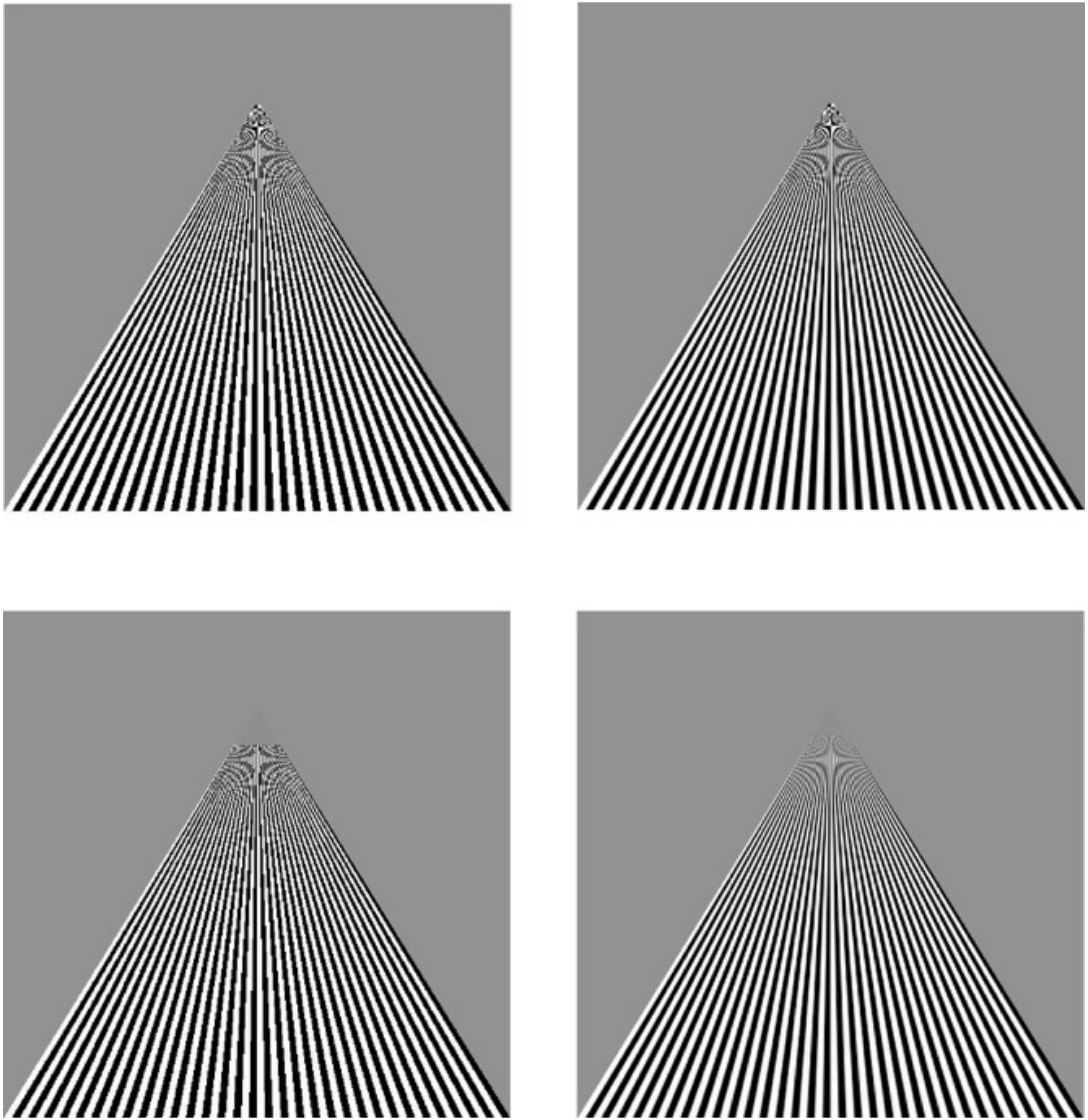
128×128, 64×64, 32×32, 16×16, 8×8, 4×4, 2×2, 1×1

Reduce minification artifacts

Prefilter the texture to obtain reduced resolutions

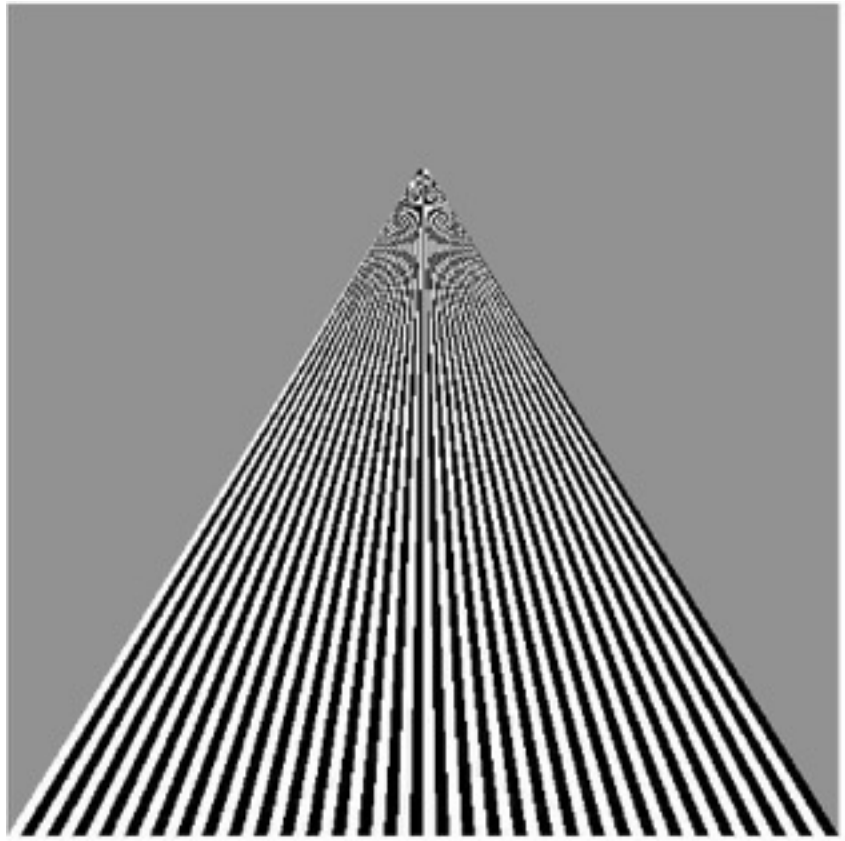
Requires 1/3 more space

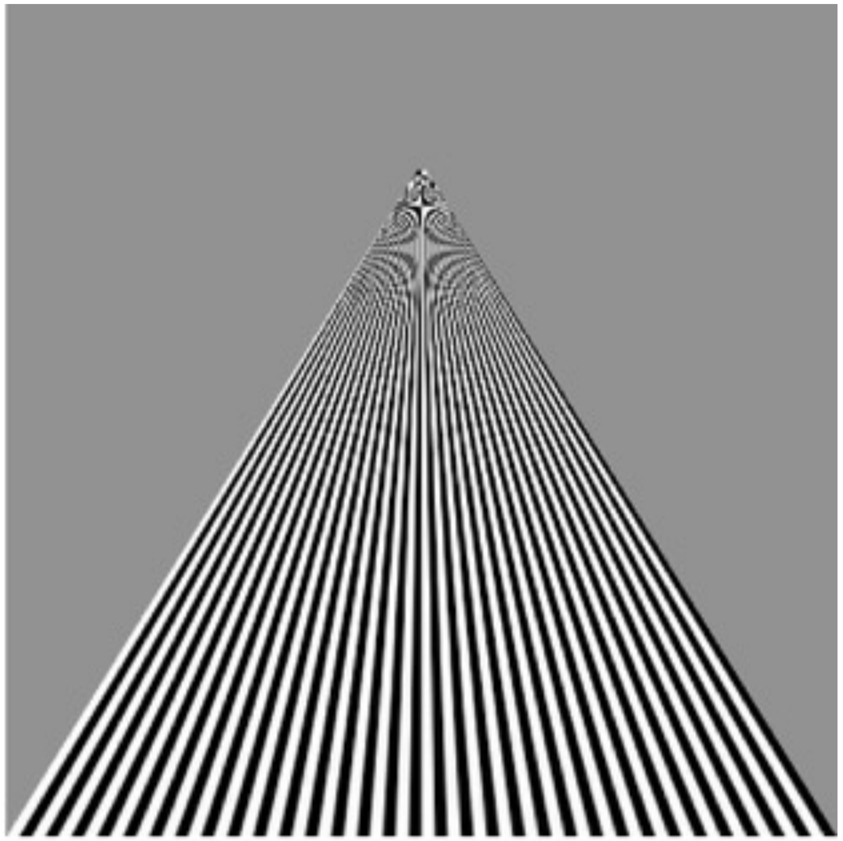
Get a texture hierarchy indexed by level



[Angel and Shreiner]

point sampling

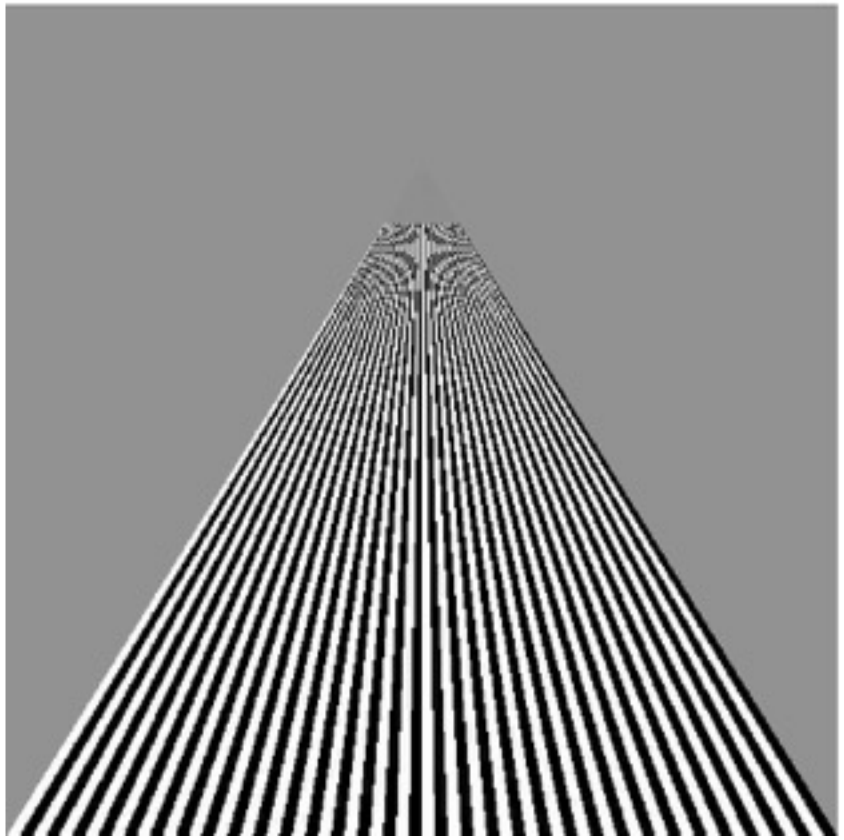


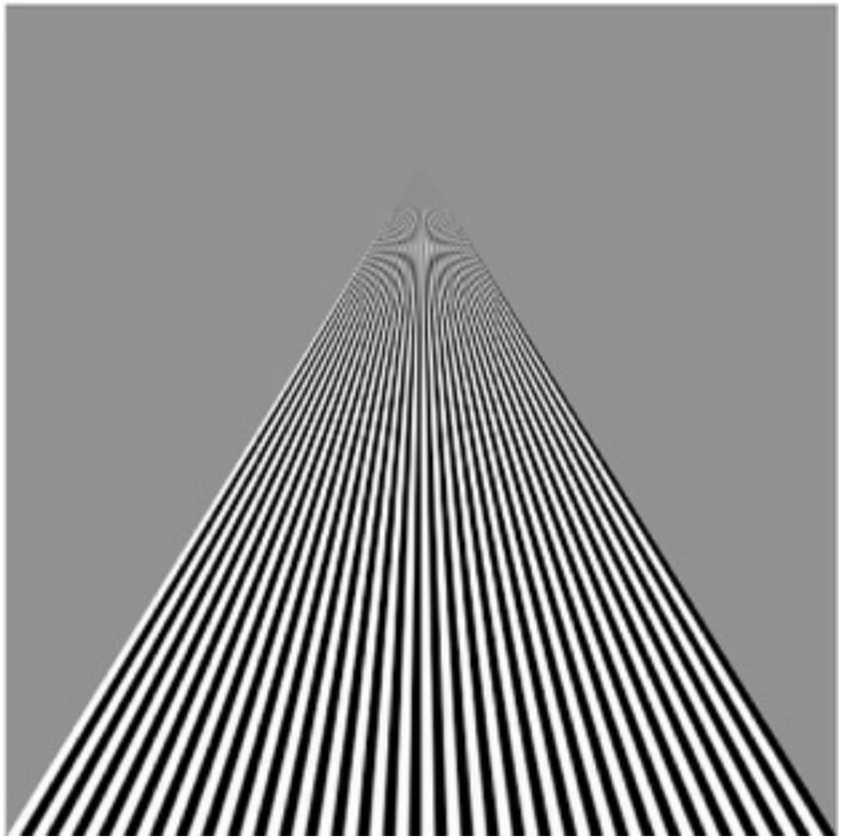


linear filtering

[Angel and Shreiner]

mipmapped point sampling





mipmapped linear filtering