# Texture Mapping

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CSE 457

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# Reading

Required

- Angel, 7.4-7.10

Recommended

- Paul S. Heckbert. Survey of texture mapping. **IEEE Computer Graphics and Applications** 6(11): 56--67, November 1986.

Optional

- Woo, Neider, & Davis, Chapter 9
- James F. Blinn and Martin E. Newell. Texture and reflection in computer generated images. **Communications of the ACM** 19(10): 542--547, October 1976.

# Texture mapping

*Texture mapping (Woo et al., fig. 9-1)*

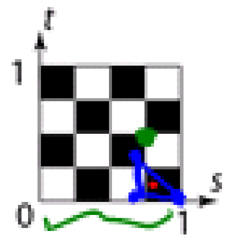
Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

- Due to Ed Catmull, PhD thesis, 1974
- Refined by Blinn & Newell, 1976

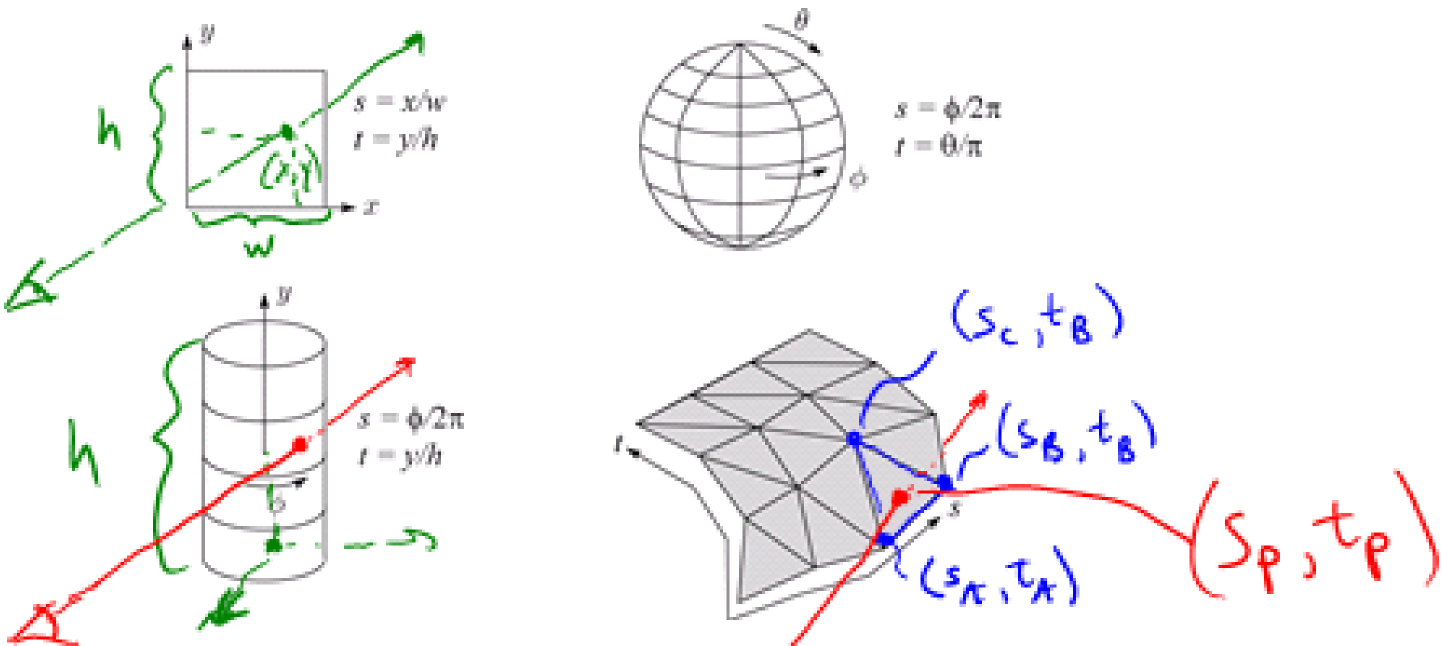
A texture can modulate just about any parameter – diffuse color, specular color, specular exponent, …

# Implementing texture mapping

A texture lives in it own abstract image coordinates paramaterized by (*s*,*t*) in the range ([0..1], [0..1]):



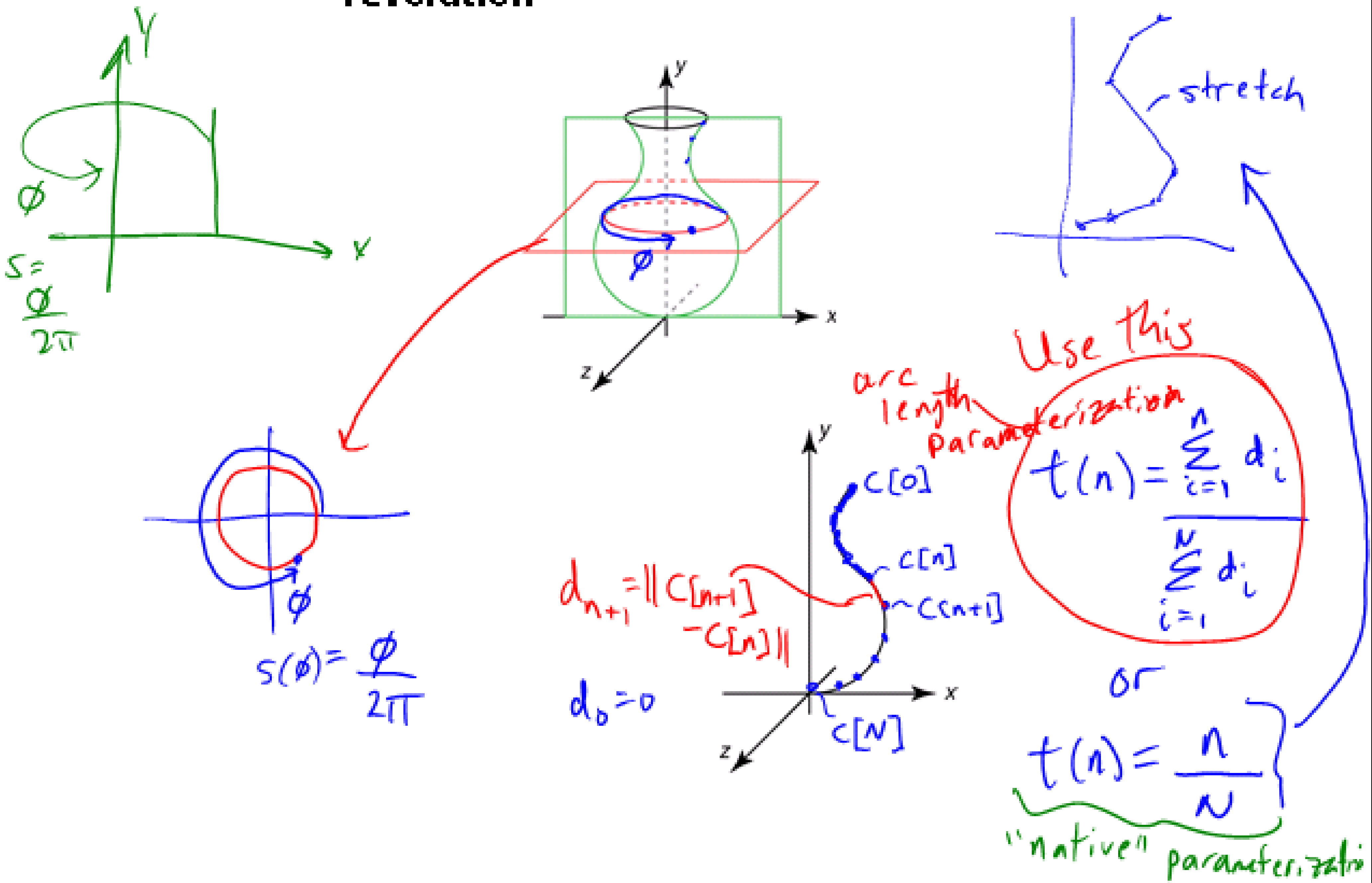

It can be wrapped around many different surfaces:




With a ray caster, we can do the sphere and cylinder mappings directly (as we will see later). For z-buffers, everything gets converted to a triangle mesh with associated (*s*,*t*) coordinates.

Note: if the surface moves/deforms, the texture goes with it.

# Texture coordinates on a surface of revolution



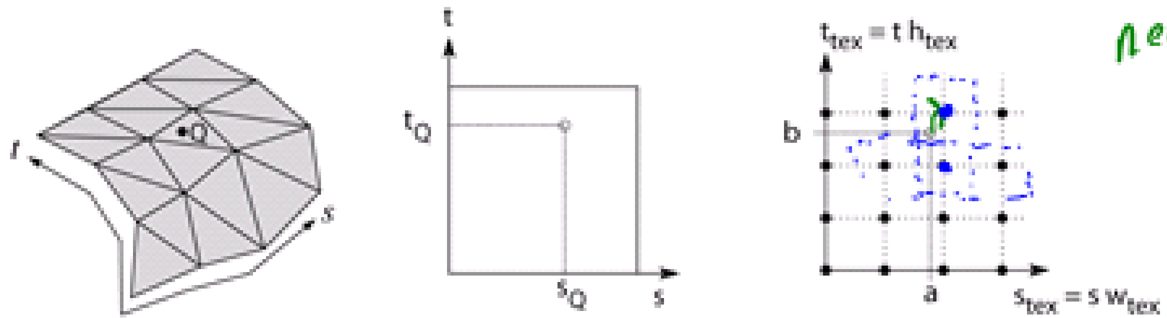
# Mapping to texture image coords

The texture is usually stored as an image. Thus, we need to convert from abstract texture coordinate:

$(s,t)$ in the range $([0..1], [0..1])$

to texture image coordinates:

$(s_{tex}, t_{tex})$ in the range $([0..\ w_{tex}], [0..\ h_{tex}])$




Point on triangle mesh

Mapping to abstract texture coords

Mapping to texture pixel coords

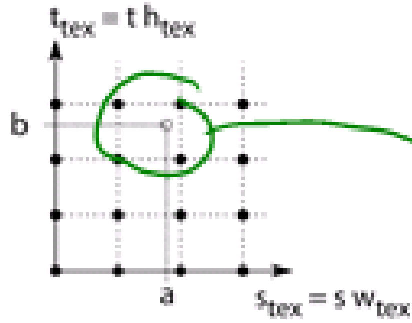
nearest neighbor interpolation

ick!

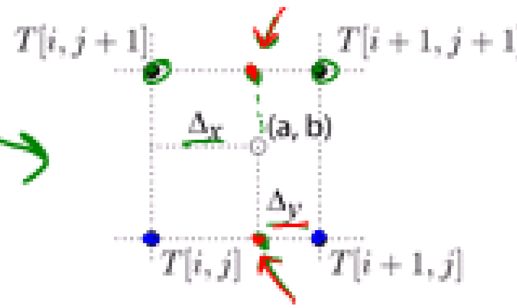
**Q**: What do you do when the texture sample you need lands between texture pixels?

# Texture resampling

We need to resample the texture:




Mapping to texture pixel coords




Close-up

$\Delta x, \Delta y \in [0, 1]$

Thus, we seek to solve for: $T(a,b) = T\left(i+\Delta_x, j+\Delta_y\right)$

A common choice is **bilinear interpolation**:

$$T(i+\Delta_x, j) = \underline{(1-\Delta_x)}\, T[i,j] \quad + \quad \underline{\Delta_x}\, T[i+1,j]$$

$$T(i+\Delta_x, j+1) = \underline{(1-\Delta_x)}\, T[i,j+1] \quad + \quad \underline{\Delta_x}\, T[i+1,j+1]$$

$$T(i+\Delta_x, j+\Delta_y) = \underline{(1-\Delta_y)}\, T(i+\Delta_x, j) \quad + \quad \underline{\Delta_y}\, T(i+\Delta_x, j+1)$$

$$= \underline{(1-\Delta_y)(1-\Delta_x)}\, T[i,j] \quad + \quad \underline{(1-\Delta_y)\Delta_x}\, T[i+1,j] \quad +$$

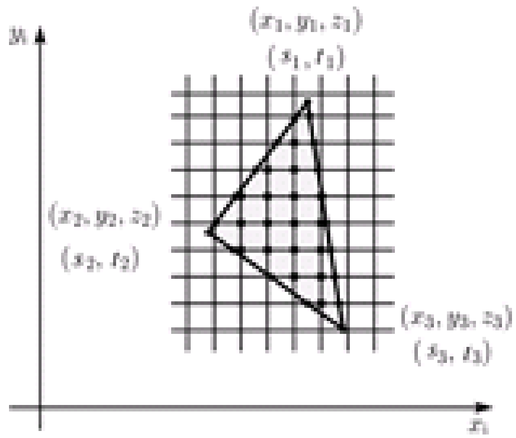
$$\underline{\Delta_y (1-\Delta_x)}\, T[i,j+1] \quad + \quad \underline{\Delta_y \Delta_x}\, T[i+1,j+1]$$

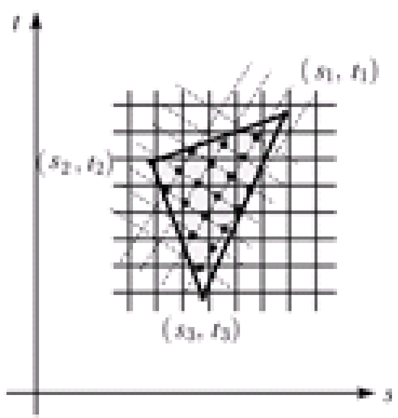
# Texture mapping and the z-buffer

Texture-mapping can also be handled in z-buffer algorithms.

Method:

- Scan conversion is done in screen space, as usual
- Each pixel is colored according to the texture
- Texture coordinates are found by Gouraud-style interpolation



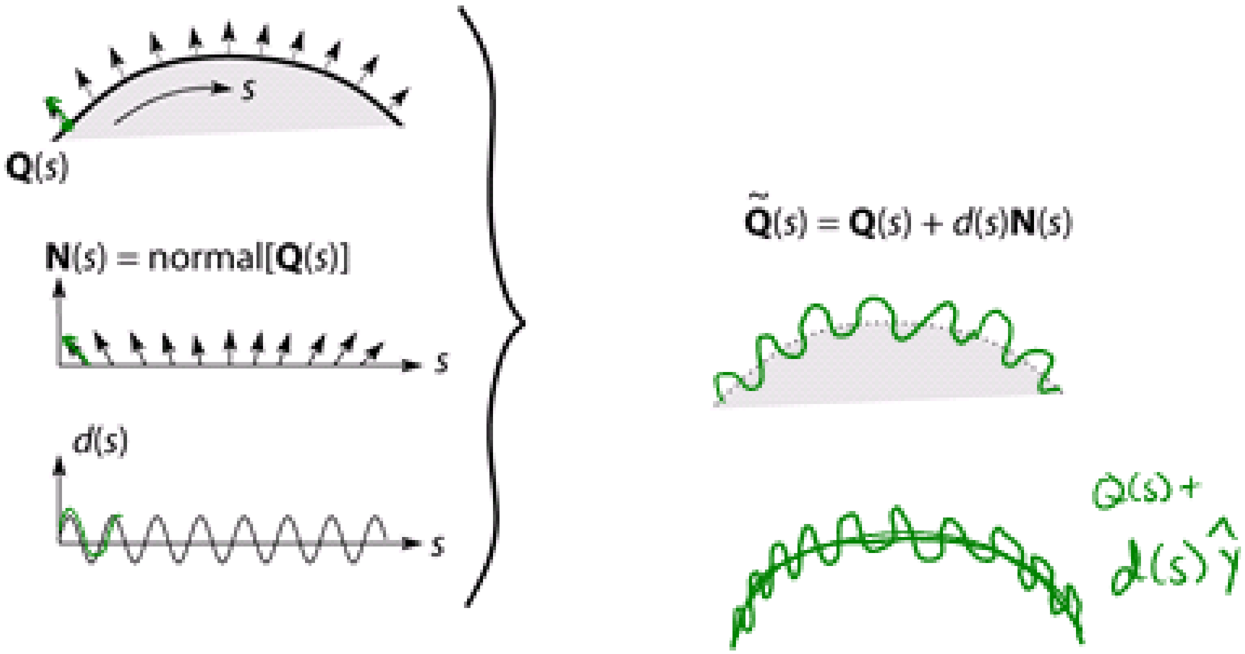


Note: Mapping is more complicated to handle perspective correctly!

# Displacement mapping

Textures can be used for more than just color.

In **displacement mapping**, a texture is used to perturb the surface geometry itself. Here's the idea in 2D:




- These displacements "animate" with the surface
- In 3D, you would of course have (s,t) parameters instead of just s.

Suppose **Q** is a simple surface, like a cube. Will it take more work to render the modified surface $\tilde{\mathbf{Q}}$?

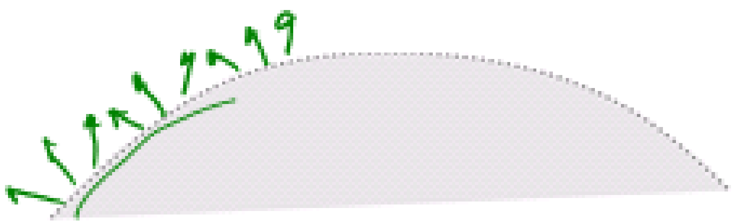
more geometry
⇒ more work

# Bump mapping

In **bump mapping**, a texture is used to perturb the normal:

- Use the original, simpler geometry, $\mathbf{Q}(s)$, for hidden surfaces
- Use the normal from the displacement map for shading:

$$\tilde{\mathbf{N}} = \text{normal}[\tilde{\mathbf{Q}}(s)]$$



$\mathbf{Q}(s)$

cast shadows wrong

What artifacts in the images would reveal that bump mapping is a fake?

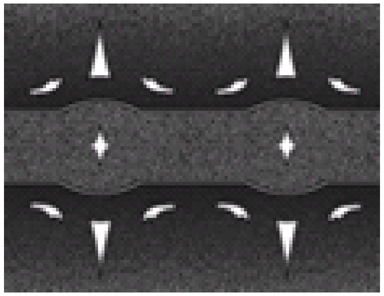
silhouettes

bumps do not occlude each other

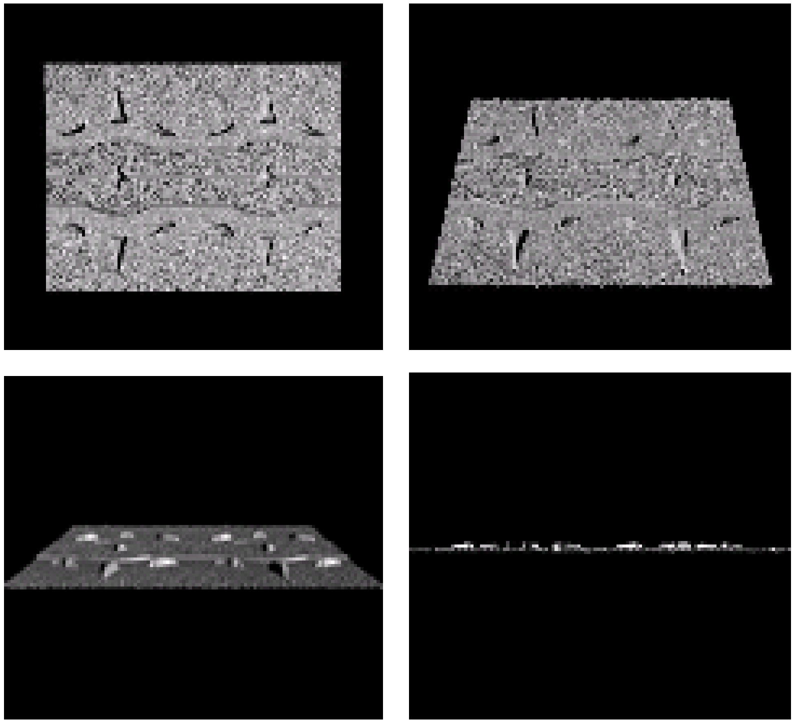
no parallax, no perspective motion

# Displacement vs. bump mapping

Input texture



Rendered as displacement map over a rectangular surface



# Displacement vs. bump mapping (cont'd)

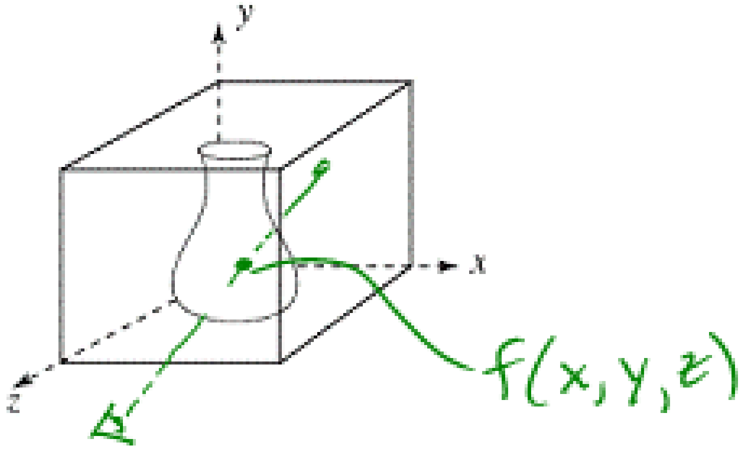
Original rendering

Rendering with bump map wrapped around a cylinder

*Bump map and rendering by Wyvern Aldinger*

# Solid textures

**Q**: What kinds of artifacts might you see from using a marble veneer instead of real marble?




One solution is to use **solid textures**:

- Use model-space coordinates to index into a 3D texture
- Like "carving" the object from the material

One difficulty of solid texturing is coming up with the textures.

# Solid textures (cont'd)

Here's an example for a vase cut from a solid marble texture:

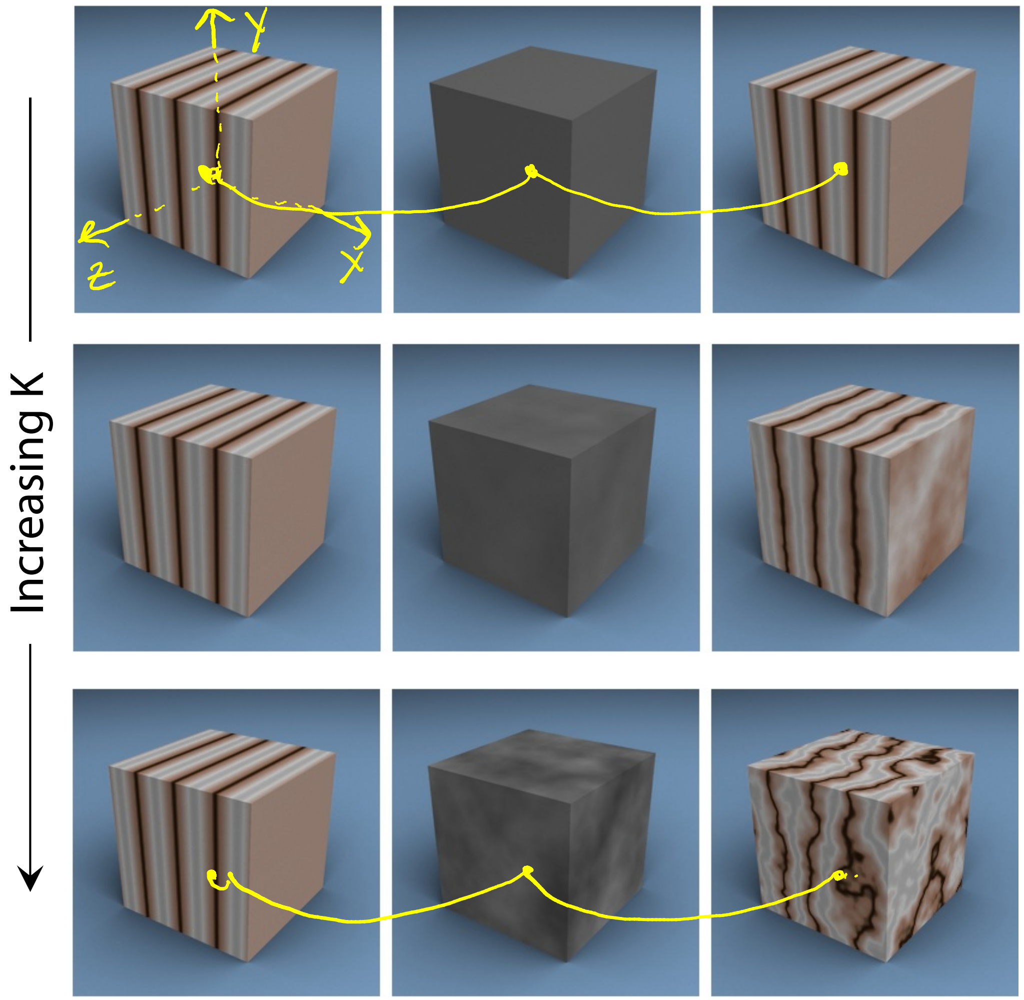
*Solid marble texture by Ken Perlin, (Foley, IV-21)*

# Solid textures (cont'd)

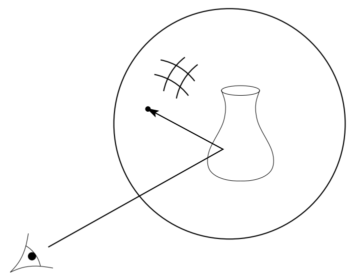
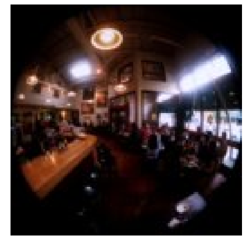
in($x,y,z$) = stripes($x$)

shift($x,y,z$) = K•noise($x,y,z$)

out($x,y,z$) = stripes($x$+shift($x,y,z$))



## Environment mapping


In **environment mapping** (also known as **reflection mapping**), a texture is used to model an object's environment:

- Rays are bounced off objects into environment
- Color of the environment used to determine color of the illumination
- Environment mapping works well when there is just a single object – or in conjunction with ray tracing

This can be readily implemented (without interreflection) using a fragment shader, where the texture is stored in a “cube map” instead of a sphere.

With a ray tracer, the concept is easily extended to handle refraction as well as reflection (and interreflection).

## Summary

What to take home from this lecture:

1. The meaning of the boldfaced terms.

2. Familiarity with the various kinds of texture mapping, including their strengths and limitations.