Texture Mapping

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CSEP 557
Winter 2013

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)

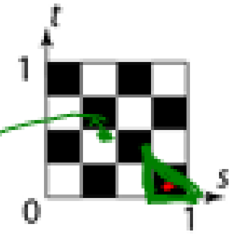
Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

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

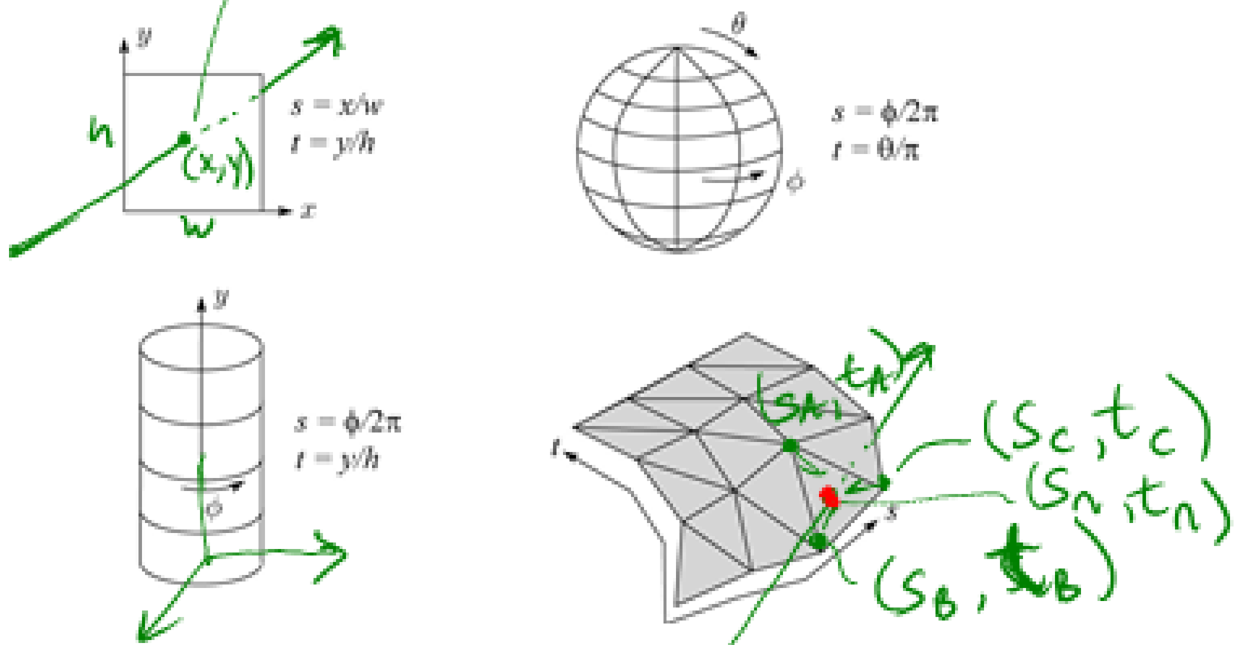
A texture can modulate just about any parameter – diffuse color, specular color, specular exponent, …

Implementing texture mapping

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



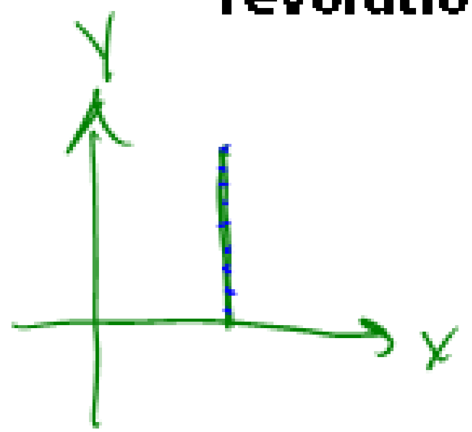
It can be wrapped around many different surfaces:

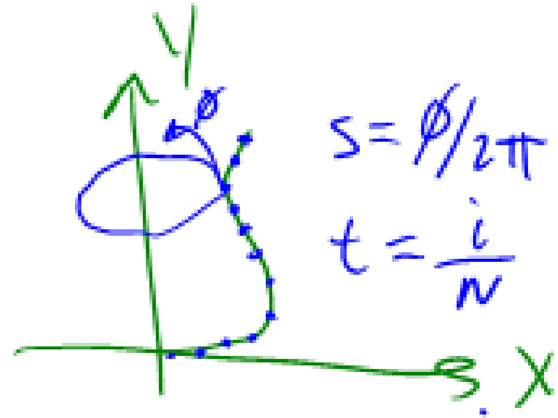


With a ray caster, we can do the sphere and cylinder mappings directly (as we will see later). For z-buffers, everything gets converted to a triangle mesh with associated (*s*,*t*) coordinates.

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

Texture coordinates on a surface of revolution





Native Parametric sampling

$s = \phi / 2\pi$

$t = \frac{i}{N}$

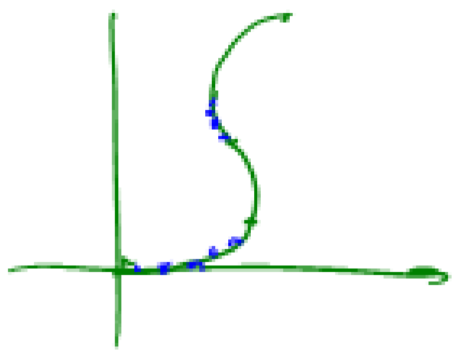
i^{th} sample

N samples

$$t = \frac{\sum_{j=1}^{i} d_{j,j-1}}{\sum_{j=1}^{N} d_{j,j-1}}$$

arc length parameterization

Do this $\Longrightarrow$



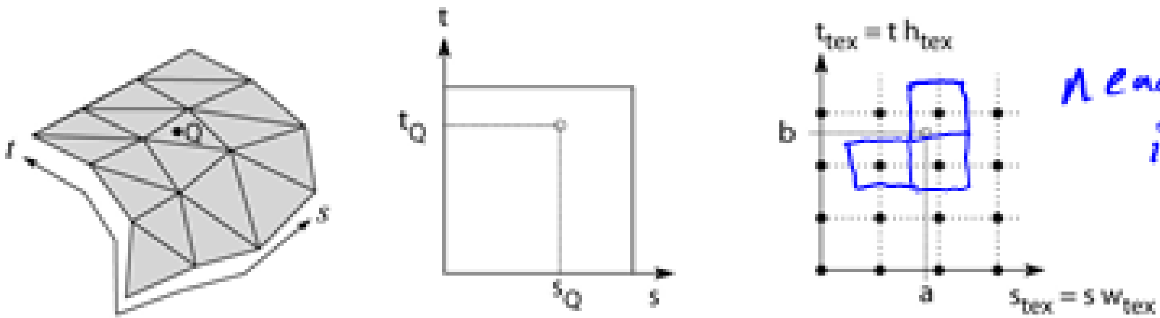
Mapping to texture image coords

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

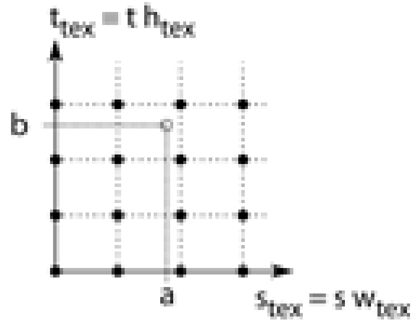
nearest neighbor interpolation = take the value of nearest texel

Ick

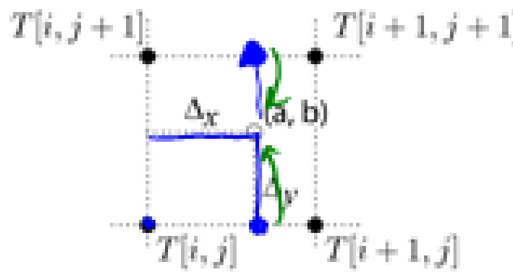
Q: What do you do when the texture sample you need lands between texture pixels?

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**:

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

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

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

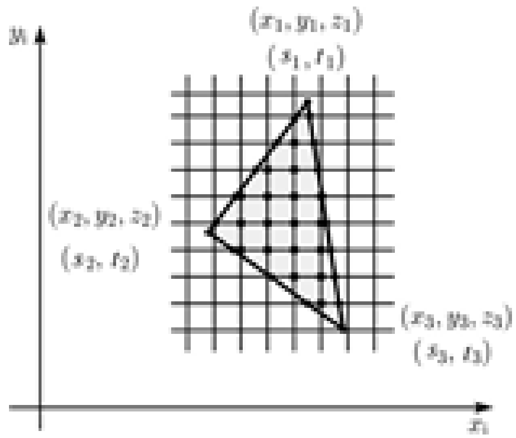
$$= \underline{(1-\Delta_x)(1-\Delta_y)}\, T[i,j] + \underline{\Delta_x(1-\Delta_y)}\, T[i+1,j] + \underline{(1-\Delta_x)\Delta_y}\, T[i,j+1] + \underline{\Delta_x \Delta_y}\, T[i+1,j+1]$$

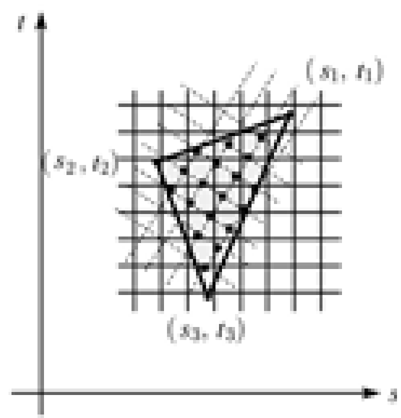
Texture mapping and the z-buffer

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



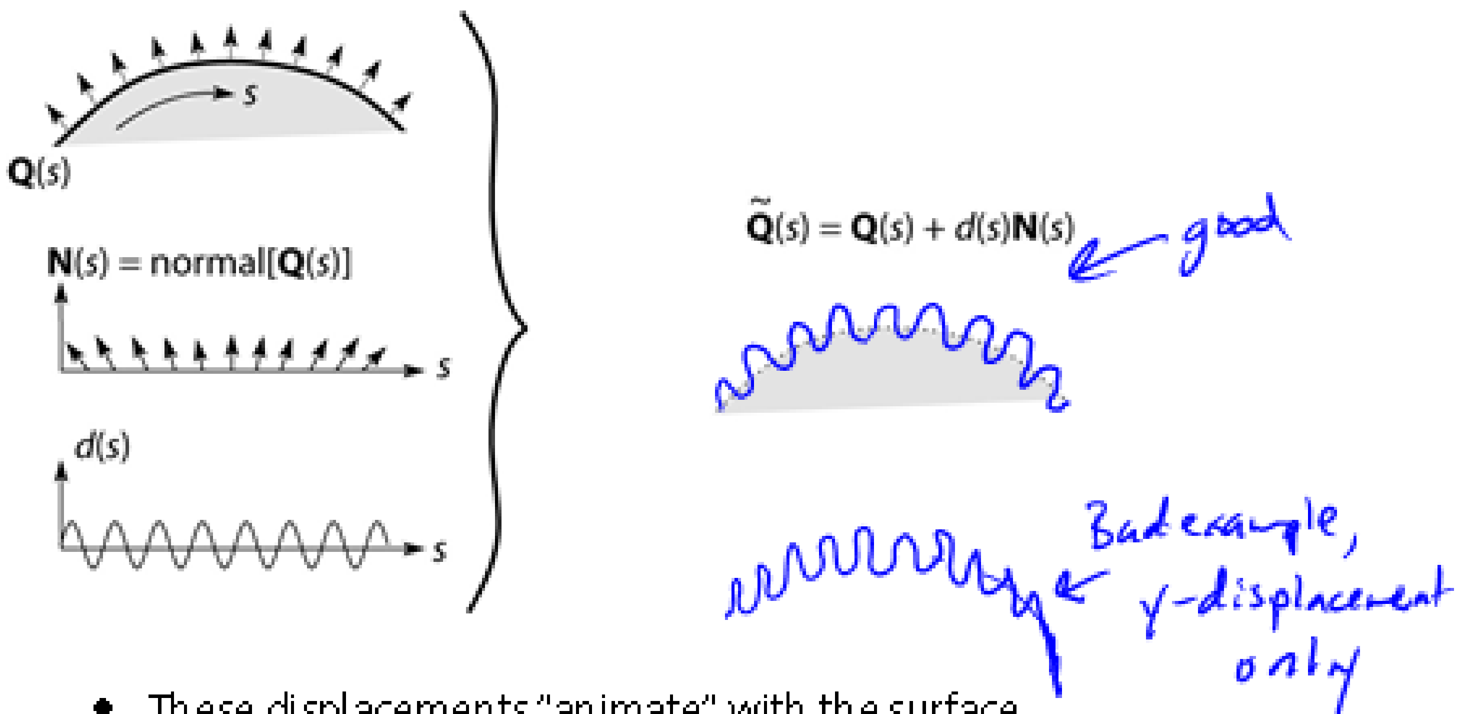


Note: Mapping is more complicated to handle perspective correctly!

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 $\tilde{\mathbf{Q}}$?

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:

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

$\mathbf{Q}(s)$

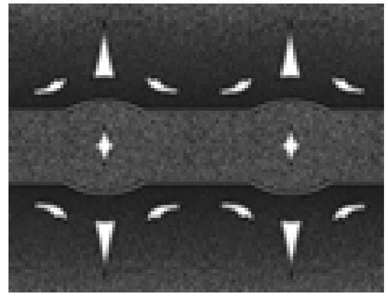
What artifacts in the images would reveal that bump mapping is a fake?

No self-occlusions of bump
silhouettes will not have bumps

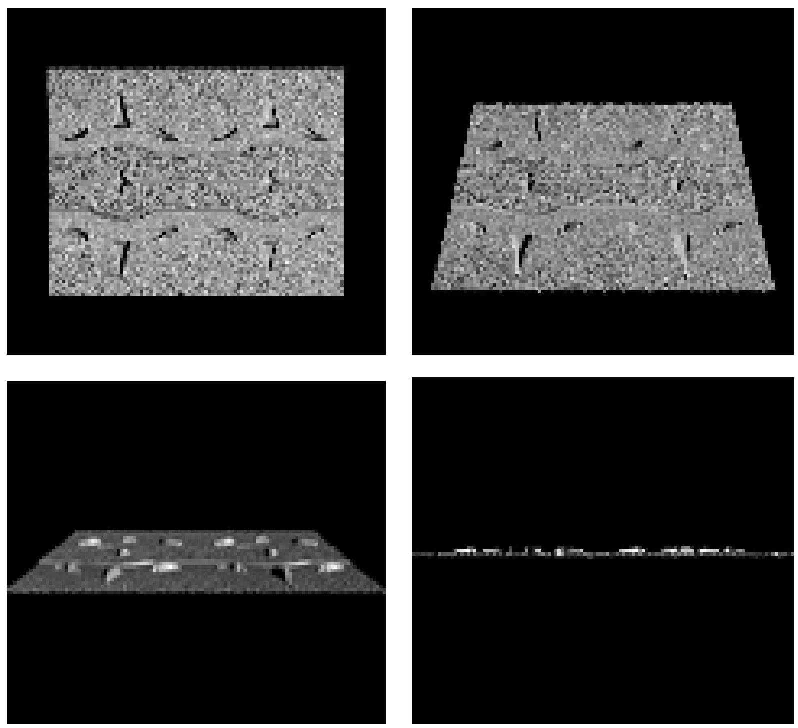
cast shadows not bumpy
perspective location of bumps will be off

Displacement vs. bump mapping

Input texture

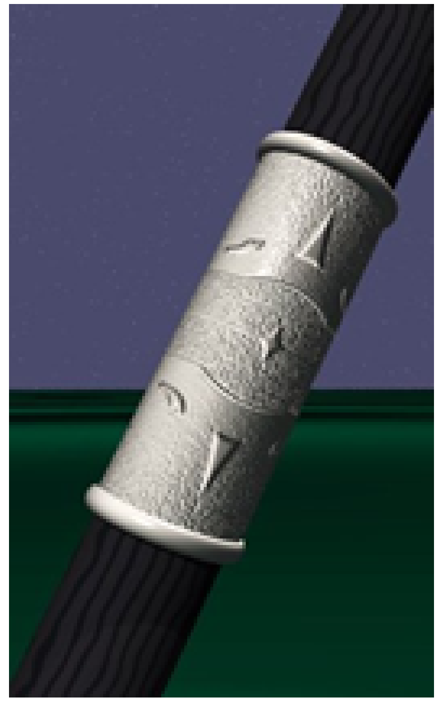


Rendered as displacement map over a rectangular surface



Displacement vs. bump mapping (cont'd)

Original rendering

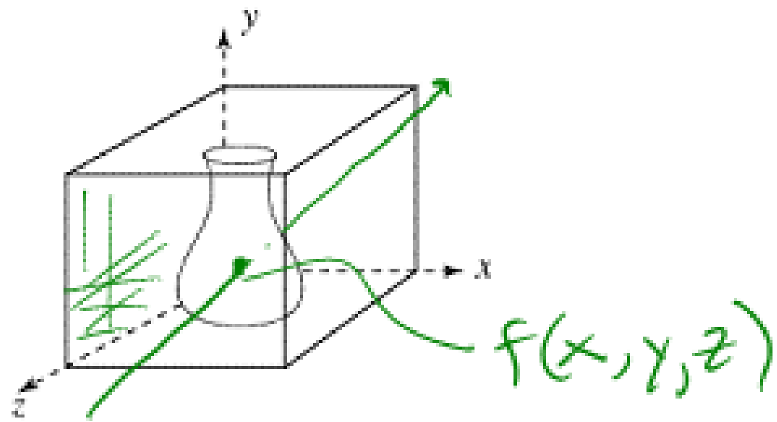


Rendering with bump map wrapped around a cylinder

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

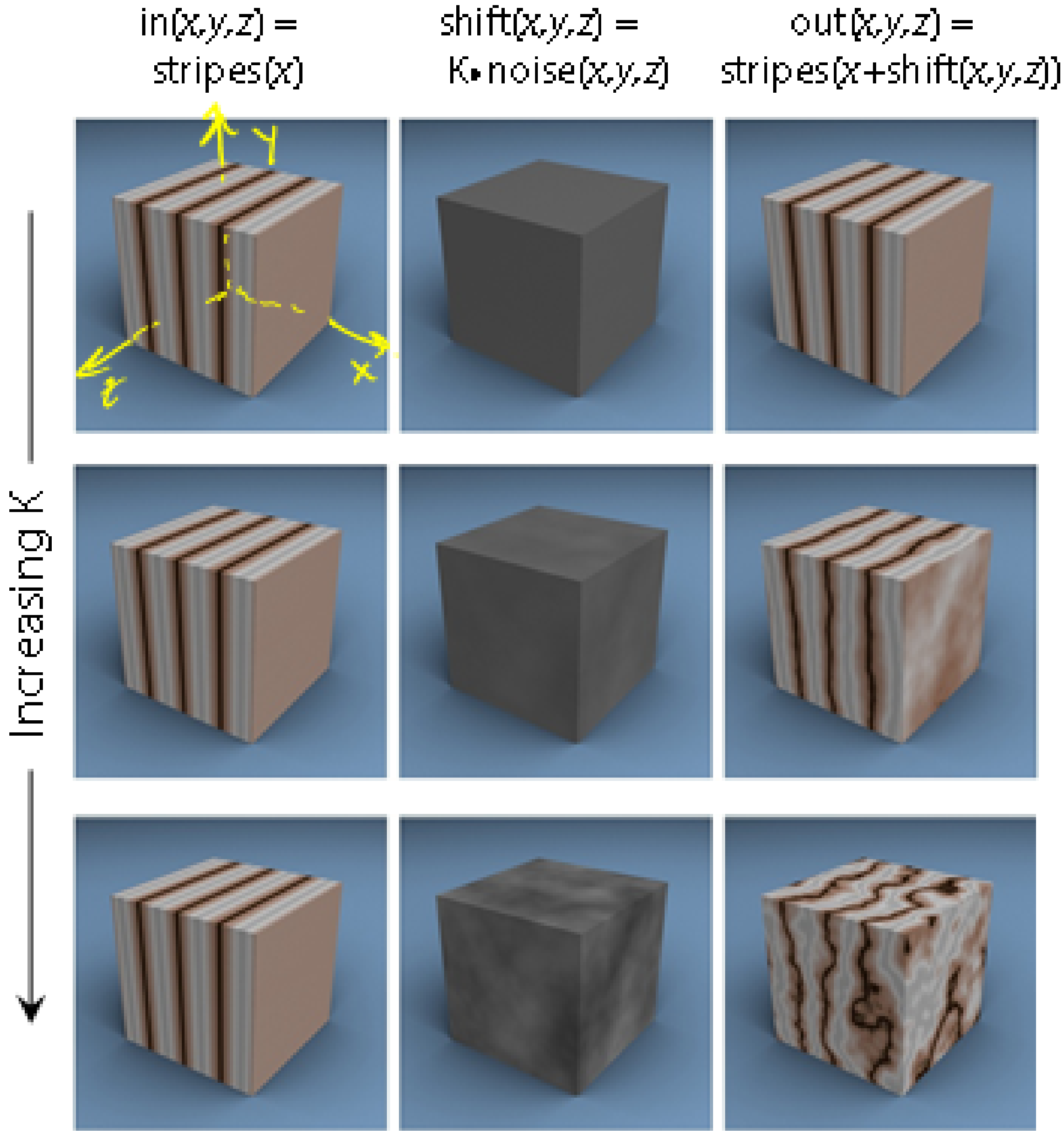
One difficulty of solid texturing is coming up with the textures.

Solid textures (cont'd)

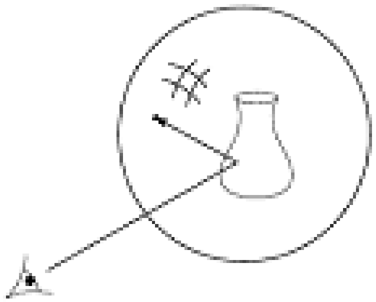
Here's an *example* for a vase cut from a solid marble texture:

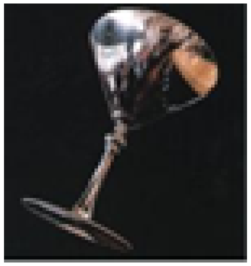
Solid marble texture by Ken Perlin, (Foley, IV-21)

Solid textures (cont'd)



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.