Texture Mapping

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CSE 457

Spring 2015

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)

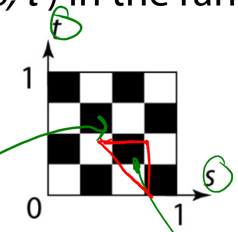
Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

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

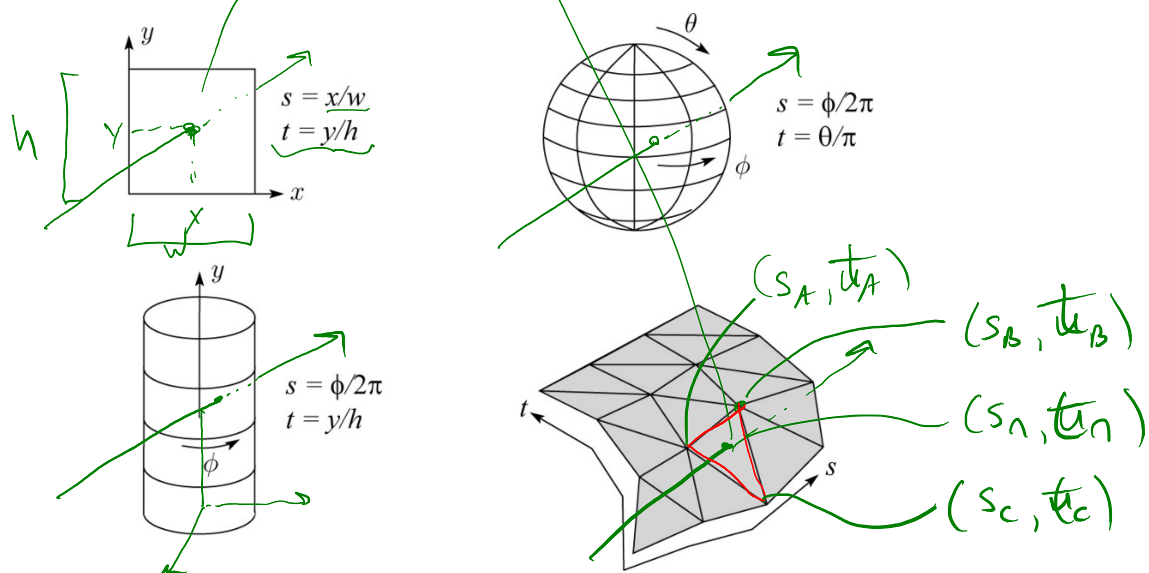
A texture can modulate just about any parameter – diffuse color, specular color, specular exponent, …

Implementing texture mapping

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



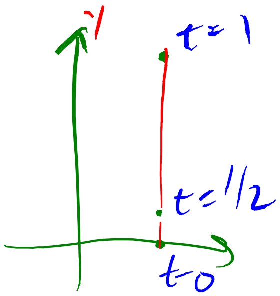
It can be wrapped around many different surfaces:

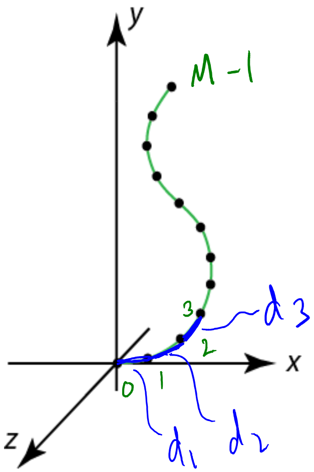


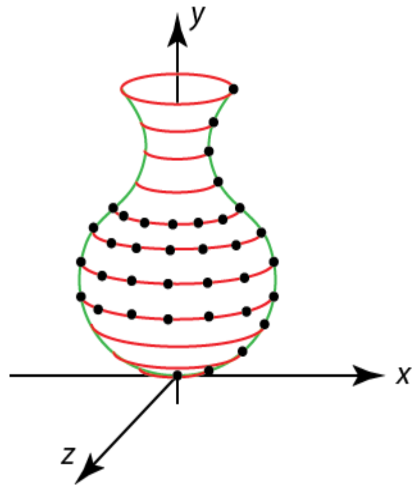
With a ray caster, we can do the sphere and cylinder mappings directly (as we will see later). For z-buffers, everything gets converted to a triangle mesh with associated (*s, t*) coordinates.

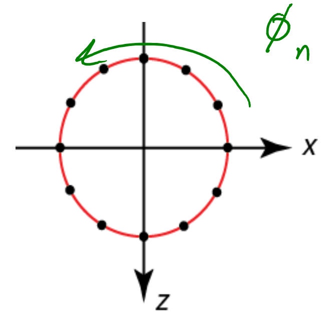
Note: if the surface moves/deforms, the texture goes with it.

Texture coordinates on a surface of revolution









$$\phi_n = \frac{2\pi n}{N}$$

$$s[n] = \frac{\phi_n}{2\pi} = \frac{n}{N}$$

$$\cancel{t = \frac{m}{M-1}}$$

$$t[m] = \frac{\sum_{i=1}^{m} d_i}{\sum_{i=1}^{M-1} d_i}$$

$$(t[0] = 0)$$

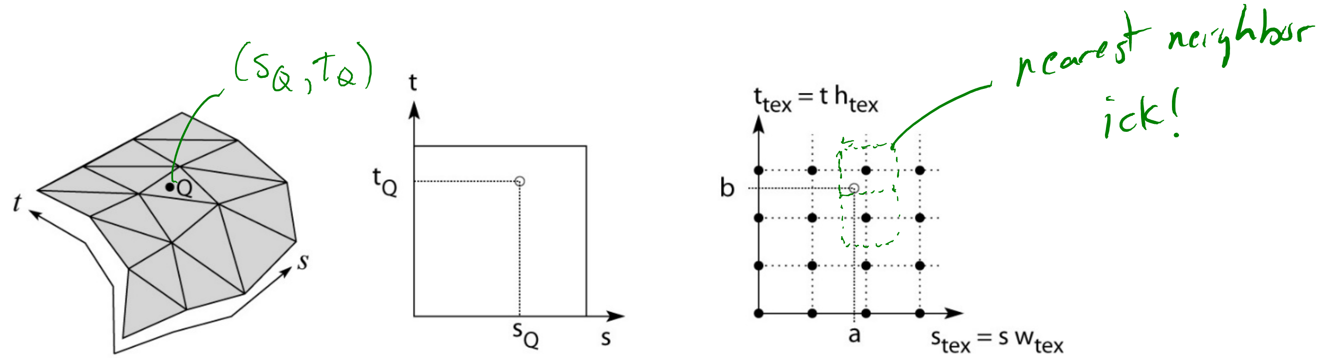
Mapping to texture image coords

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

$$(s, t) \text{ in the range } ([0..1], [0..1])$$

to texture image coordinates:

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



Point on triangle mesh

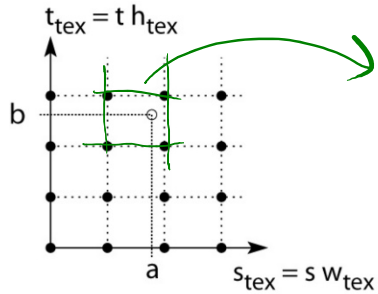
Mapping to abstract texture coords

Mapping to texture pixel coords

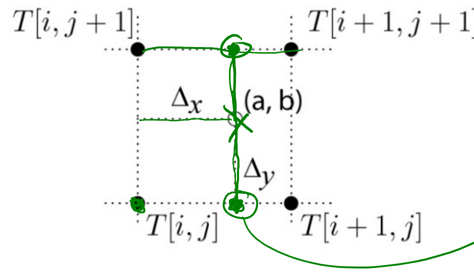
Q: What do you do when the texture sample you need lands between texture pixels?

Texture resampling

We need to resample the texture:



Mapping to
texture pixel coords



Close-up

$\Delta_x, \Delta_y \in [0,1]$

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

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

A common choice is **bilinear interpolation**:

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

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

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

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

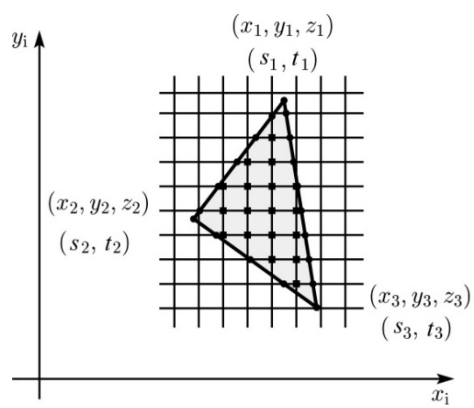
$$\underline{(1-\Delta_x)\,\Delta_y}\,\mathrm{T}[i,j+1] + \underline{\Delta_x\,\Delta_y}\,\mathrm{T}[i+1,j+1]$$

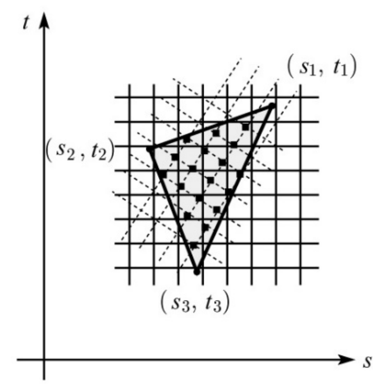
Texture mapping and the z-buffer

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

<u>Method</u>:

- 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



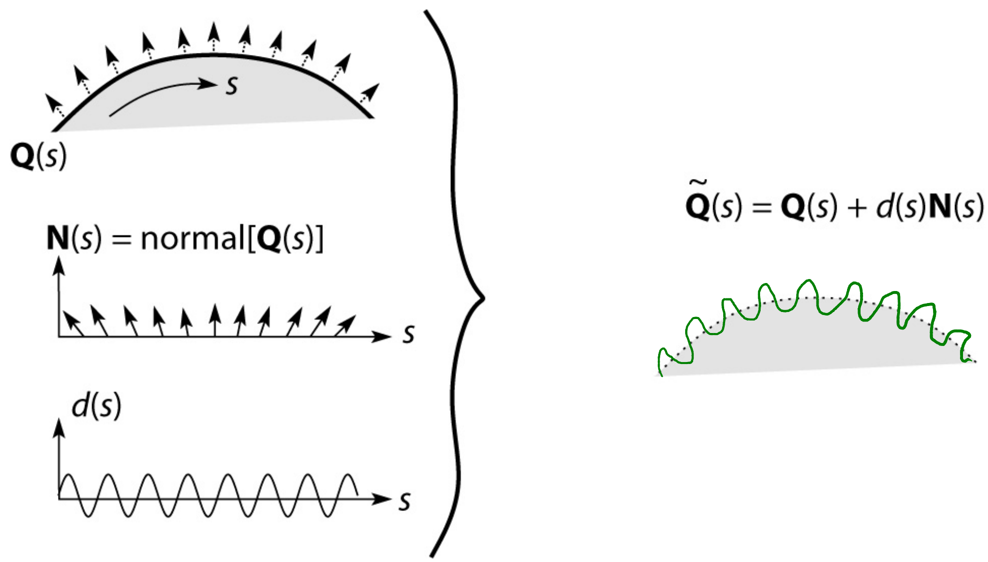


<u>Note</u>: Mapping is more complicated to handle perspective correctly!

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.

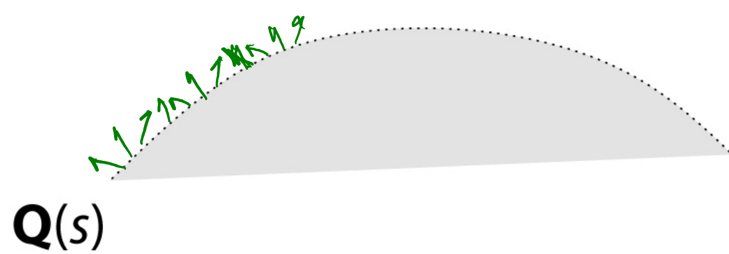
Suppose $\mathbf{Q}$ is a simple surface, like a cube. Will it take more work to render the modified surface $\tilde{\mathbf{Q}}$?   Yes

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:

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

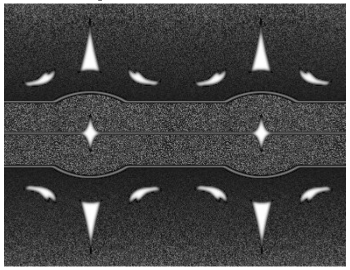


What artifacts in the images would reveal that bump mapping is fake?

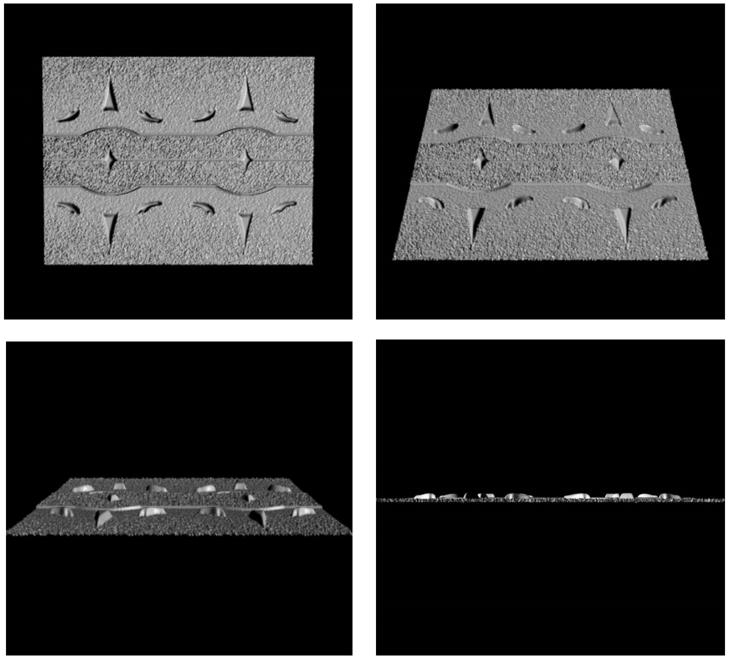
silhouettes, perspective, cast shadows

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

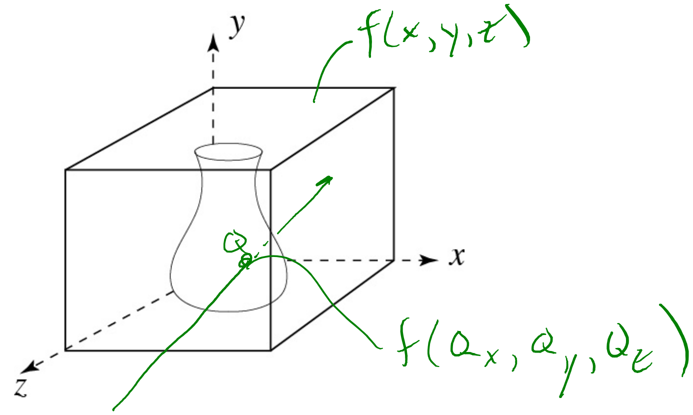
Bump map and rendering by Wyvern Aldinger

Solid textures

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

Edges won't agree where they wrap and meet

Stretch + compression due to different radii



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)

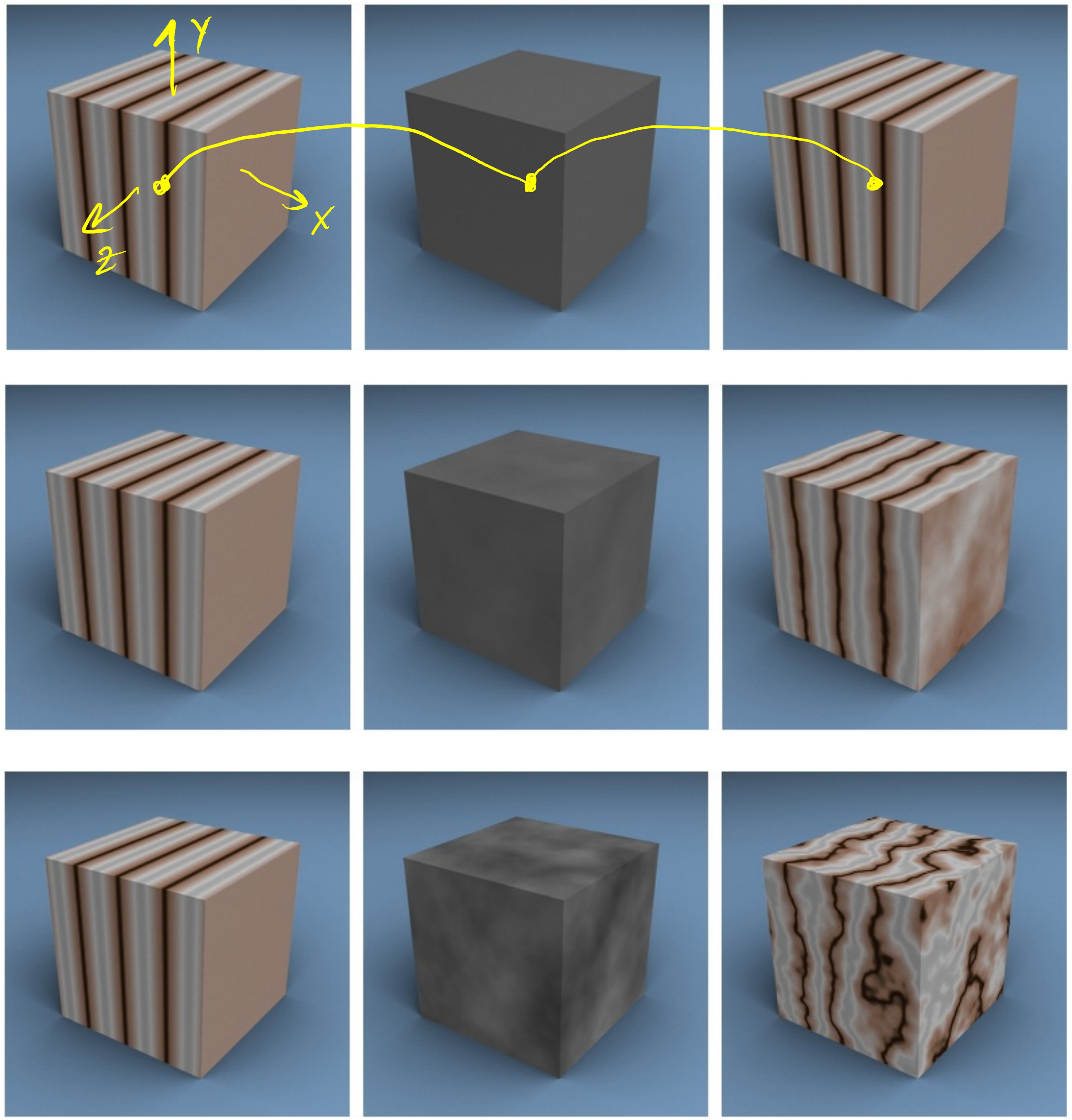
Solid textures (cont'd)

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

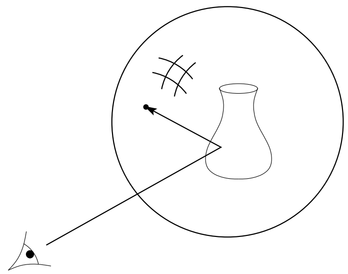
shift(x, y, z) = K•noise(x, y, z)

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

Increasing K



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.