

Texture Mapping

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CSE 457
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Reading

Required

- Angel, 8.6, 8.7, 8.9, 8.10, 9.13-9.13.2

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)

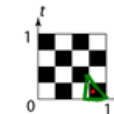
Texture mapping allows you to take a simple polygon and give it the appearance of something much more complex.

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

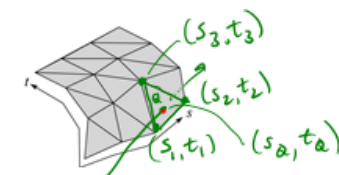
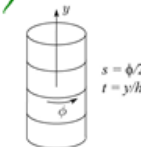
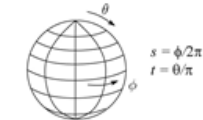
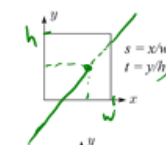
A texture can modulate just about any parameter – diffuse color, specular color, specular exponent, ...

Implementing texture mapping

A texture lives in its own abstract image coordinates parameterized 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.

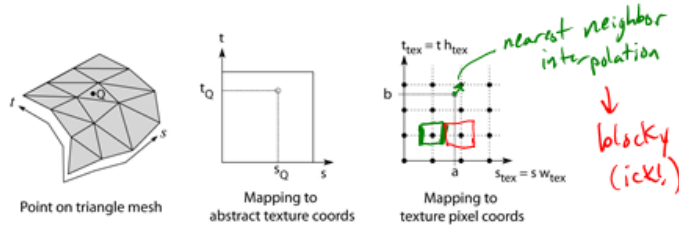
Mapping to texture image coords

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 $([0..w_{tex}], [0..h_{tex}])$

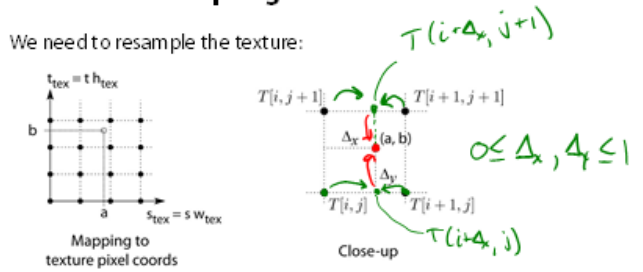


Q: What do you do when the texture sample you need lands between texture pixels?

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Texture resampling

We need to resample the texture:



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

A common choice is **bilinear interpolation**:

$$T(i + \Delta_x, j) = \frac{(1 - \Delta_x)}{1} T(i, j) + \frac{\Delta_x}{1} T(i + 1, j)$$

$$T(i + \Delta_x, j + 1) = \frac{(1 - \Delta_x)}{1} T(i, j + 1) + \frac{\Delta_x}{1} T(i + 1, j + 1)$$

$$\begin{aligned} T(i + \Delta_x, j + \Delta_y) &= \frac{(1 - \Delta_y)}{1} T(i + \Delta_x, j) + \frac{\Delta_y}{1} T(i + \Delta_x, j + 1) \\ &= \frac{(1 - \Delta_x)(1 - \Delta_y)}{1} T(i, j) + \frac{\Delta_x(1 - \Delta_y)}{1} T(i + 1, j) + \\ &\quad \frac{(1 - \Delta_x)\Delta_y}{1} T(i, j + 1) + \frac{\Delta_x\Delta_y}{1} T(i + 1, j + 1) \end{aligned}$$

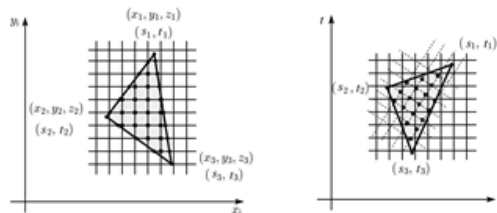
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Texture mapping and the z-buffer

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



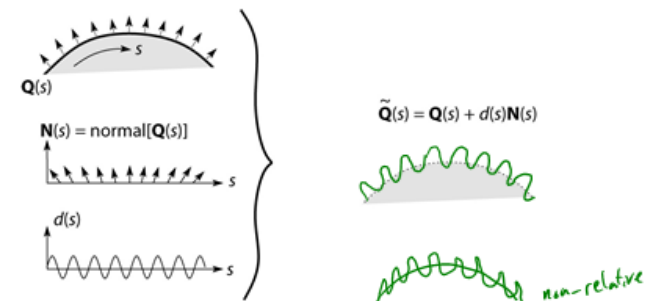
Note: Mapping is more complicated to handle perspective correctly!

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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 ~~plane~~ sphere. Will it take more work to render the modified surface \tilde{Q} ?

Yes, surface is geometrically more complex

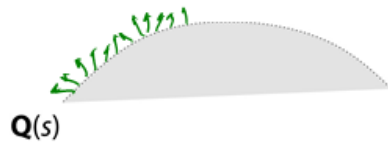
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Bump mapping

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

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

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



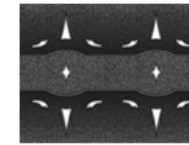
What artifacts in the images would reveal that bump mapping is a fake?

silhouettes self-occlusion
shadows perspective

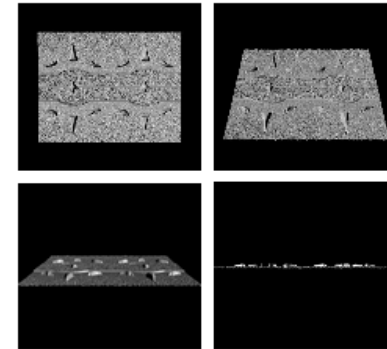
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Displacement vs. bump mapping

Input texture



Rendered as displacement map over a rectangular surface



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Displacement vs. bump mapping (cont'd)



Original rendering

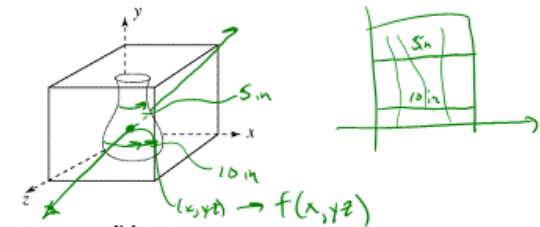
Rendering with bump map wrapped around a cylinder

Bump map and rendering by Wyvem Aldinger

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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.

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Solid textures (cont'd)

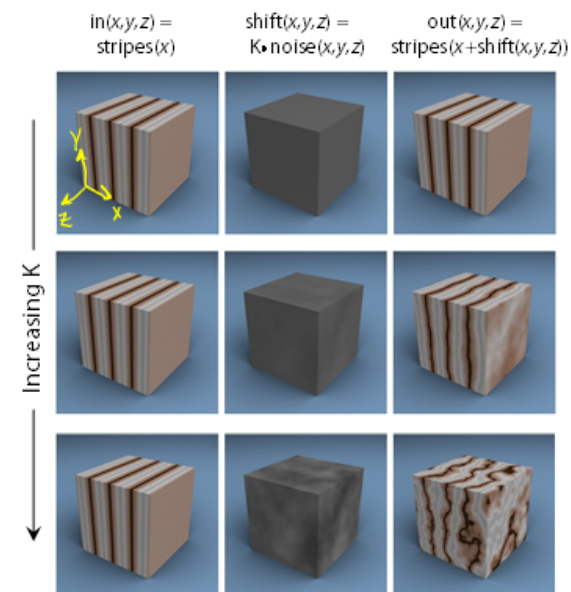
Here's an example for a vase cut from a solid marble texture:



Solid marble texture by Ken Perlin, (Foley, IV-2.1)

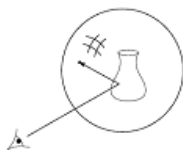
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Solid textures (cont'd)



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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).

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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.

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