Texture Mapping

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Reading

Required

• Angel. 7A-7.10

Recommended

• Paul S. Heckbert. Survey of texture mapping. 
  *IEEE Computer Graphics and Applications*

Optional

• Woo, Neider, & Davis. Chapter 9
• James F. Blinn and Martin E. Newell. Texture 
  and reflection in computer generated images. 
Texture mapping

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 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

\[ s(\phi) = \frac{\phi}{2\pi} \]

\[ d_n = ||C[n+1] - C[n]|| \]

\[ d_0 = 0 \]

\[ t(n) = \sum_{i=1}^{n} d_i \]

\[ t(n) = \frac{n}{N} \]

"native" parameterization
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:

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

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

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

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

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

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

$\Delta_x, \Delta_y \in [0, 1]$
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 \(\tilde{Q}\)?
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:

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

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)

\[ \text{in}(x,y,z) = \text{stripes}(x) \]
\[ \text{shift}(x,y,z) = K \cdot \text{noise}(x,y,z) \]
\[ \text{out}(x,y,z) = \text{stripes}(x + \text{shift}(x,y,z)) \]
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.