Texture Mapping

CSE 457
Reading

Required

• Angel, 7.4-7.10

Recommended


Optional

• Woo, Neider, & Davis, Chapter 9
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 \([0..1], [0..1]\):

\[
\begin{align*}
s &= \frac{x}{w} \\
t &= \frac{y}{h}
\end{align*}
\]

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

\[ \phi_i = \frac{2\pi n}{N} \]

\[ s(h) = \frac{\phi_n}{2\pi} = \frac{2\pi n}{N \cdot 2\pi} = \frac{n}{N} \]

Instead

\[ t(m) = \frac{M}{M} \]

\[ t^+(m) = \sum_{i=0}^{\infty} d_i \]

\[ \sum_{i=0}^{\infty} \]
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:

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

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 $f_o(a, b) = T(i + \Delta x, j + \Delta y)$

A common choice is **bilinear interpolation**:

$$T(i + \Delta x, j) = \frac{1 - \Delta y}{\Delta y} T(i, j) + \frac{\Delta y}{\Delta y} T[i + 1, j]$$

$$T(i + \Delta x, j + 1) = \frac{1 - \Delta y}{\Delta y} T[i, j + 1] + \frac{\Delta y}{\Delta y} T[i + 1, j + 1]$$

$$T(i + \Delta x, j + \Delta y) = \frac{1 - \Delta y}{\Delta y} T(i + \Delta x, j) + \frac{\Delta y}{\Delta y} T(i + \Delta x, j + 1)$$

$$= \frac{(1 - \Delta y)(1 - \Delta x)}{\Delta y} T[i, j] + \frac{(1 - \Delta y) \Delta x}{\Delta y} T[i + 1, j] + \frac{(1 - \Delta x) \Delta y}{\Delta y} T[i, j + 1] + \frac{\Delta x \Delta y}{\Delta y} T[i + 1, j + 1]$$
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 \(\tilde{Q}\)?

\[
\tilde{Q}(s) = Q(s) + d(s)N(s)
\]
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:

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

What artifacts in the images would reveal that bump mapping is a fake?
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
Black mirror, “Be right back”
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)

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