Texture Mapping

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Reading

Required

- Shirley, 11.1-11.2, 11.4-11.6

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 \([0..1], [0..1]\):

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:

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

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:

\[ T[i, j + 1] = T[i + \Delta_x, j + \Delta_y] \]

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

A common choice is **bilinear interpolation**:

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

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

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

\[
= \frac{1 - \Delta_y}{\Delta_x} T[i, j] + \frac{\Delta_y}{\Delta_x} \left( 1 - \Delta_y \right) T[i + 1, j] + \frac{\Delta_x \Delta_y}{\Delta_x} T[i + 1, j + 1]
\]
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:

\[ Q(s) = Q(s) + d(s)N(s) \]

- 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 \(\tilde{Q}\)?

Yes! More geometry to render.
**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:

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

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

- Cast shadows incorrect
- Silhouette incorrect
- Self-shadows missing (bumps shading bumps)
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)

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