Texture Mapping

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CSE 557
Fall 2014

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, ...

Reading

Required
- Shirley, 11.1-11.2, 11.4-11.6

Recommended

Optional
- Woo, Neider, & Davis, Chapter 9

Implementing texture mapping

A texture lives in its own abstract image coordinates parameterized by \((s,t)\) in the range \([0..1],[0..1]\):

![Texture mapping (Woo et al., fig. 9-1)](image)

It can be wrapped around many different surfaces:

- Sphere: \( s = \phi / 2 \pi \), \( t = \theta / \pi \)
- Cylinder: \( s = \theta / \pi \), \( t = z / h \)
- Plane: \( s = x / w \), \( t = y / h \)

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?

Texture resampling

We need to resample the texture:

Thus, we seek to solve for:

A common choice is bilinear interpolation:

\[ T(i + \Delta_i, j + \Delta_j) = \frac{1}{4} (T(i, j) + T(i + 1, j) + T(i, j + 1) + T(i + 1, j + 1)) \]

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:

- 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, \(Q(s)\), 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?

bumps don't occlude each other, cast shadows, self-shadows will be wrong
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).