11. 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, Ph.D. thesis, 1974
- Refined by Blinn & Newell, 1976

Texture mapping must ensure that all the right things happen as a textured polygon is transformed and rendered.

Reading

- Angel, sections 10.2 - 10.4
- Hearn & Baker, 14.8 - 14.9
- Woo, Neider, & Davis, chapter 9


Non-parametric texture mapping

With *non-parametric texture mapping*:

- texture size and orientation are fixed
- unrelated to size and orientation of polygon
- gives cookie-cutter effect
Parametric texture mapping

With parametric texture mapping, texture size and orientation are tied to the polygon:
- separate texture space and screen space
- texture the polygon as before, but in texture space
- deform (render) the textured polygon into screen space

Implementing texture mapping

Textures can be wrapped around many different surfaces:

Implementing, cont.

Texture mapping can also be handled in z-buffer algorithms.
- 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

Antialiasing

If you point-sample the texture-map, you get aliasing:

Proper antialiasing requires area averaging in the texture:
Computing the average color

The computationally difficult part is summing over the covered pixels:

Several methods have been used:

1. Brute force
   ◦ just sum

2. Mip maps
   ◦ Lance Williams, 1983
   ◦ stands for “multum in parvo” — “many things in a small place”
   ◦ keep textures prefiltered at multiple resolutions
   ◦ figure out two closest levels
   ◦ linear interpolate between the two

3. Summed area tables
   ◦ Frank Crow, 1984
   ◦ keep sum of everything below and to the left
   ◦ use four table lookups
   ◦ requires more memory
   ◦ gives less blurry textures

Comparison of techniques
**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...

---

**Procedural texture mapping**

Instead of using texture coordinates to index into an image, use them to compute a function that defines the texture.

---

**Solid textures, cont.**

Here’s an example for a vase cut from a solid marble texture.

---

**Bump mapping**

Textures can be used for more than just color.

\[
l = k_a l_a + \sum_i f(d_i) l_i \left[ k_d (N \cdot L)_i + k_t (V \cdot R)_i \right]
\]

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

- the normal is perturbed in each parametric direction according to the partial derivatives of the texture.

  - these bumps “animate” with the surface

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

In displacement mapping, a texture is used to perturb the surface geometry itself:

- silhouettes are correct
- requires doing additional hidden surface calculations

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
- really, a simplified form of ray tracing
- environment mapping works well when there is just a single object — or in conjunction with ray tracing

Under simplifying assumptions, environment mapping can be implemented in hardware.

With a ray tracer, the concept is easily extended to handle refraction as well as reflection.

Combining texture maps

Using texture maps in combination gives even better effects, as Young Sherlock Holmes demonstrated...
Summary

What to take home from this lecture:

- What texture mapping is, and what it’s good for.
- Understanding of the various approaches to antialiased texture mapping:
  - brute force
  - mip maps
  - summed area tables