Texture Mapping

Objectives
- Introduce Mapping Methods
  - Texture Mapping
  - Environmental Mapping
  - Bump Mapping
- Consider basic strategies
  - Forward vs backward mapping
  - Point sampling vs area averaging

The Limits of Geometric Modeling
- Although graphics cards can render over 10 million polygons per second, that number is insufficient for many phenomena
  - Clouds
  - Grass
  - Terrain
  - Skin

Modeling an Orange
- Consider the problem of modeling an orange (the fruit)
- Start with an orange-colored sphere
  - Too simple
- Replace sphere with a more complex shape
  - Does not capture surface characteristics (small dimples)
  - Takes too many polygons to model all the dimples

Modeling an Orange (2)
- Take a picture of a real orange, scan it, and "paste" onto simple geometric model
  - This process is texture mapping
- Still might not be sufficient because resulting surface will be smooth
  - Need to change local shape
  - Bump mapping
Three Types of Mapping

• Texture Mapping
  - Uses images to fill inside of polygons

• Environmental (reflection mapping)
  - Uses a picture of the environment for texture maps
  - Allows simulation of highly specular surfaces

• Bump mapping
  - Emulates altering normal vectors during the rendering process

Texture Mapping

geometric model  texture mapped

Environment Mapping

Bump Mapping
Where does mapping take place?

• Mapping techniques are implemented at the end of the rendering pipeline
  - Very efficient because few polygons pass down the geometric pipeline

Is it simple?

• Although the idea is simple---map an image to a surface---there are 3 or 4 coordinate systems involved

Coordinate Systems

• Parametric coordinates
  - May be used to model curved surfaces
• Texture coordinates
  - Used to identify points in the image to be mapped
• World Coordinates
  - Conceptually, where the mapping takes place
• Screen Coordinates
  - Where the final image is really produced

Texture Mapping
Mapping Functions

- Basic problem is how to find the maps
- Consider mapping from texture coordinates to a point on a surface
- Appear to need three functions
  \[ x = x(s, t) \]
  \[ y = y(s, t) \]
  \[ z = z(s, t) \]
- But we really want to go the other way

Backward Mapping

- We really want to go backwards
  - Given a pixel, we want to know to which point on an object it corresponds
  - Given a point on an object, we want to know to which point in the texture it corresponds
- Need a map of the form
  \[ s = s(x, y, z) \]
  \[ t = t(x, y, z) \]
- Such functions are difficult to find in general

Two-part mapping

- One solution to the mapping problem is to first map the texture to a simple intermediate surface
- Example: map to cylinder

Cylindrical Mapping

parametric cylinder

\[ x = r \cos 2\pi u \]
\[ y = r \sin 2\pi u \]
\[ z = v/h \]

maps rectangle in \( u, v \) space to cylinder of radius \( r \) and height \( h \) in world coordinates

\[ s = u \]
\[ t = v \]

maps from texture space
**Spherical Map**

We can use a parametric sphere

\[
\begin{align*}
    x &= r \cos 2\pi u \\
    y &= r \sin 2\pi u \cos 2\pi v \\
    z &= r \sin 2\pi u \sin 2\pi v
\end{align*}
\]

in a similar manner to the cylinder but have to decide where to put the distortion

Ex: Mercator projection puts it at the poles

Spheres are used in environmental maps

**Box Mapping**

- Easy to use with simple orthographic projection
- Also used in environmental maps

**Second Mapping**

- Map from intermediate object to actual object
- Three possible strategies
  - Normals from intermediate to actual
  - Normals from actual to intermediate
  - Vectors from center of intermediate

**Aliasing**

- Point sampling of the texture can lead to aliasing errors
  - Miss blue stripes
  - Point samples in texture space
  - Point samples in u,v (or x,y,z) space
Area Averaging

A better but slower option is to use area averaging

Note that preimage of pixel is curved