Texture Mapping

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Limits of geometric modeling

Although modern GPUs can render millions of triangles/sec, that’s not enough sometimes...
Texture mapping for detail

This image contains 8 polygons!
Texture mapping comparison

no texture

with texture
Pixar - Toy Story
Other uses of textures...

- Light maps
- Shadow maps
- Environment maps
- Bump maps
- Opacity maps
- Animation
Lookup reflectance in image

Image source: [1, 2]
Texture mapping in the pipeline

- Geometry and pixels have separate paths through pipeline
- Textures applied in fragment shader
  - End of pipeline
  - Efficient since relatively few polygons get past clipper
uv Mapping

- 2D texture is parameterized by \((u, v)\)
- Assign polygon vertices texture coordinates
- Interpolate within polygon
Texturing triangles

- Store \((u, v)\) at each vertex
- Interpolate inside triangles using barycentric coordinates

\[
\begin{align*}
(a, b, c) & \rightarrow (0.2, 0.8) \\
(A, B, C) & \rightarrow (0.4, 0.2) \\
(A, B, C) & \rightarrow (0.8, 0.4)
\end{align*}
\]
Texturing triangles

- Store \((u, v)\) at each vertex
- Interpolate inside triangles using barycentric coordinates

\[
\begin{align*}
\mathbf{p}(\beta, \gamma) &= \mathbf{p}_a + \beta(\mathbf{p}_b - \mathbf{p}_a) + \gamma(\mathbf{p}_c - \mathbf{p}_a) \\
u(\beta, \gamma) &= u_a + \beta(u_b - u_a) + \gamma(u_c - u_a) \\
v(\beta, \gamma) &= v_a + \beta(v_b - v_a) + \gamma(v_c - v_a)
\end{align*}
\]
Texture mapping
Point sampling

Map back to texture image and use the **nearest texel**
Aliasing

Point sampling textures can lead to aliasing artifacts
Magnification and minification

Minification

Magnification
We apply filtering to reduce aliasing artifacts.
Area averaging

A better but slower option is to use area averaging.
Use bilinear filtering

mitigate magnification artifacts
Mipmapping

Reduce minification artifacts
Prefilter the texture to obtain reduced resolutions
Requires $\frac{1}{3}$ more space
Get a texture hierarchy indexed by level
point sampling  
linear filtering  
mipmapped point sampling  
mipmapped linear filtering
Environment mapping
Environment mapping

Use a texture for the distant environment to simulate the effect of ray tracing more cheaply.
Sphere mapping

- Project objects in the environment onto sphere centered at eye
- Unwrap and store as texture
- Use reflection direction to look up texture value
Cube mapping

- Compute six projections, one for each wall
- Store as texture
- Use reflection direction to lookup texture value
Different environment maps

Blinn/Newell latitude mapping  spherical mapping  cube mapping
Create the effect of a mirror with two-pass rendering

**First pass:** render the scene from the perspective of the mirror

**Second pass:** render from original pov; use the first image as a texture for the mirror
Bump mapping
Normal mapping

- Original mesh: 4M triangles
- Simplified mesh: 500 triangles
- Simplified mesh and normal mapping: 500 triangles
Attribution
