Game Programming

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Game Texturing

- Texture Mapping
- Environment Mapping
- Bump Mapping
- Shadow Maps
The Quest for Visual Realism

Model

Model with Shading

Model with Shading and Textures
Previously, we assume that reflection properties such as are constant within each triangle.

However, some objects have complex appearance which arises from variation in reflection properties.

The common technique to handle this kind of variation is to store it as a function or a pixel-based image and “map” it onto a surface.

The function is called texture map and the process is called texture mapping.
Texture Maps

Tom Porter’s Bowling Pin
Texture Mapping

geometric model

texture mapped
Texture Maps

☐ How is texture mapped to the surface?
  ■ Dimensionality: 1D, 2D (image), 3D (solid)
  ■ Procedural v.s. table look-up
  ■ Texture coordinates (s,t)
    ☐ Surface parameters (u,v)
    ☐ Projection: spherical, cylindrical, planar
    ☐ Reparameterization

☐ What does texture control?
  ■ Surface color and transparency
  ■ Illumination: environment maps, shadow maps
  ■ Reflection function: reflectance maps
  ■ Geometry: displacement and bump maps
Texture Mapping

2D mapping

3D 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

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Vertices ➔ Geometric processing ➔ Rasterization ➔ Display

Pixels ➔ Pixel operations ➔ Rasterization
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Simple Texture Mapping

Geometry

Image

Screen
Antialiasing
Aliasing

Point sampling of the texture can lead to aliasing errors

Point samples in texture space

Point samples in u,v (or x,y,z) space

miss blue stripes
Magnification and Minification

Example:

Texture  Polygon  Magnification
Texture  Polygon  Minification
Changing Resolution

![Diagram showing changing resolution from left to right with a question mark in the middle.

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Nearest Neighbor

☑ a.k.a.
  zero order interpolation
☑ use 1 nearest neighbor
Bilinear

- a.k.a.
  first order interpolation
- use 4 nearest neighbors
Bicubic

- a.k.a.
  second order interpolation
- use 16 nearest neighbors
MIP Mapping

- MIP Mapping is one popular technique for precomputing and performing this prefiltering.

- Computing this series of filtered images requires only a small fraction of additional storage over the original texture.
Storing MIP Maps
Example

- Point sampling
- Mipmapped point sampling
- Linear filtering
- Mipmapped linear filtering
Environment Mapping
Sphere Mapping
Box Maps

St. Peter’s Light Probe
©1999 Paul Debevec
http://www.debevec.org/Probe

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Spherical Mapping
Box Mapping

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

- Map from intermediate object to actual object
  - Normals from intermediate to actual
  - Normals from actual to intermediate
  - Vectors from center of intermediate
Environment Maps

ray traced  environment map
Bump Mapping

Textures can be used for more than just color

\[ I = k_a I_a + \sum f_{att_i} I_{p_i} [k_d (\vec{N} \cdot \vec{L}_i) + k_s (\vec{R}_i \cdot \vec{V})^n] \]

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.
Bump Mapping
Bump Mapping
Illumination Maps
Texture Mapping in Quake

Texture Only

Texture & Light Maps

Light Map
Shadow Maps
Basic Steps of Shadow Maps

- Render the scene from the light’s point of view,
- Use the light’s depth buffer as a texture (shadow map),
- Projectively texture the shadow map onto the scene,
- Use “texture color” (comparison result) in fragment shading.
Shadow Buffer

\[ I = k_e + k_a I_a + \sum_i S_i f_{att_i} I_{p_i} \left[ k_d (\vec{N} \cdot \vec{L}_i) + k_s (\vec{R}_i \cdot \vec{V})^n \right] \]