Texture

Texture maps
- Surface color and transparency
- Environment and irradiance maps
- Reflectance maps
- Shadow maps
- Displacement and bump maps

Level of detail hierarchy
Procedural shading and texturing
Texture synthesis and noise

Texture Maps

How is texture mapped to the surface?
- Dimensionality: 1D, 2D, 3D
- Texture coordinates (s,t)
  - Surface coordinates (u,v)
  - Direction vectors: reflection R, normal N, halfway H
  - Projection: cylinder
  - Developable surface: polyhedral net
  - Reparameterize a surface: old-fashioned model decal

What does texture control?
- Surface color and opacity
- Illumination functions: environment maps, shadow maps
- Reflection functions: reflectance maps
- Perturb geometry: bump and displacement maps
History

Catmull/Williams 1974 - basic idea
Blinn and Newell 1976 - basic idea, reflection maps
Blinn 1978 - bump mapping
Williams 1978, Reeves et al. 1987 - shadow maps
Smith 1980, Heckbert 1983 - texture mapped polygons
Williams 1983 - mipmaps
Miller and Hoffman 1984 - illumination and reflectance
Perlin 1985, Peachey 1985 - solid textures
Greene 1986 - environment maps/world projections
Akeley 1993 - Reality Engine

Texture Mapping

3D Mesh + 2D Texture = 2D Image
Surface Color and Transparency

Tom Porter’s Bowling Pin

Source: RenderMan Companion, Pls. 12 & 13

Reflection Maps

Blinn and Newell, 1976
Gazing Ball

Miller and Hoffman, 1984

- Photograph of mirror ball
- Maps all directions to a circle
- Resolution function of orientation
- Reflection indexed by normal

Environment Maps

*Interface, Chou and Williams (ca. 1985)*
Environment Map Approximation

Ray Traced  Environment Map
Self reflections are missing in the environment map

Cylindrical Panoramas

QuickTime VR
Mars Pathfinder

Memorial Church (Ken Turkowski)
Fisheye Lens

Pair of 180 degree fisheye
Photo by K. Turkowski

Cubical Environment Map

- Easy to produce with rendering system
- Possible to produce from photographs
- “Uniform” resolution
- Simple texture coordinates calculation
Direction Maps

Many ways to map directions to images...

Methods:
- Lattitude-Longitude (Map Projections) [Newell and Blinn]
  Create by painting
- Gazing Ball (N) [Miller and Hoffman]
  Create by photographing a reflective sphere
- Fisheye Lens
  Standard camera lens
- Cubical Environment Map (R)
  Create with a rendering program, photography...

Issues:
- Non-linear mapping - expensive, curved lines
- Area distortion - spatially varying resolution
- Convert between maps using image warp

Combining Reflectance & Illumination

Photographs of 5 spheres in 3 environments (Adelson and Dror)
Material Recognition

People recognize materials more easily under natural illumination than simplified illumination.

Illusion due to Ted Adelson

Reflectance Maps

For a given viewing direction
For each normal direction
For each incoming direction (hemispherical integral)
Evaluate reflection equation
Example: Phong Model

Rough surfaces blur highlight

Reflectance Space Shading

Cabral, Olano, Nemic
1999

12 directions
**Example: Lambertian Reflectance**

\[
B(\mathbf{N}) = \rho E(\mathbf{N})
\]

Radiosity or Irradiance Map

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**Illumination Maps**

\[
\rho(x) \ast E(x) = B(x)
\]
Quake Light Maps

May incorporate shadow maps into lighting calculations
Correct Shadow Maps

Step 1:
Create z-buffer of scene as seen from light source

Step 2.
Render scene as seen from the eye
   For each light
   Transform point into light coordinates
   return (zl < zbuffer[xl][yl]) ? 1 : 0

Barzel’s UberLight.sl

Example of a complex shader
UberLight()
{
    Clip to near/far planes
    Clip to shape boundary
    foreach superelliptical blocker
        atten *= ...
    foreach cookie texture
        atten *= ...
    foreach slide texture
        color *= ...
    foreach noise texture
        atten, color *= ...
    foreach shadow map
        atten, color *= ...
    Calculate intensity fall-off
    Calculate beam distribution
}
Displacement/Bump Mapping

Displacement

\[ P'(u, v) = P(u, v) + h(u, v)N(u, v) \]

Perturbed normal

\[ N'(u, v) = P'_u \times P'_v = N + h_u(T_v \times N) + h_v(T_u \times N) \]

From Blinn 1976

Bidirectional Texture Function (BTF)

Plaster
BTF Mapping

Complex interplay between texture and reflection

Hierarchy

Physics

- Geometrical optics
  - Macro-structures
  - Transport
- Micro-structures
- Physical optics
- Kirchoff approx.
- Quantum optics

Computer Graphics

- Geometry
- Displacement (P) maps
- Bump (N) maps
- Reflection
- Texture