Hierarchy

Physics

Geometrical optics

- Macro-structures
  - Transport
- Micro-structures
  - Microfacets

Physical optics

- Kirchoff approx.

Quantum optics

Computer Graphics

Geometry

Displacement (P) maps

Bump (N) maps

Texels (BRDF)

Texture

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 Maps

Q. What does texture control?

A. Everything!

- Surface color and opacity
- Reflection functions
  - Contributions of ambient, diffuse, specular
  - Roughness or shininess
  - Reflectance maps (reflection integrated with illumination)
- Illumination functions
  - Environment or reflection map
  - Shadow mattes, depth-buffers
- Perturb geometry
  - position - displacement mapping
  - normal - bump mapping
  - tangent - frame mapping
- "Mixing" materials

Texture Mapping

Q. How is texture mapped to the surface?

- Dimensionality
  - 1D table: e.g. rings of saturn, sky color, chrome maps
  - 2D image: e.g. wallpaper
  - 3D solid: e.g. wood, marble, clouds
- 2D Texture coordinates (s,t)
  - Surface parameters (u,v)
  - Direction
    - Normal: e.g. reflectance map
    - Reflection: e.g. environment map
  - Projection: e.g. decal map, two-step map (unfolding)

  Issues:
    - Non-parametric (implicit surfaces)
    - Continuity across surfaces
    - Distortion and singularities

Direction Maps

Many ways to map directions to images...

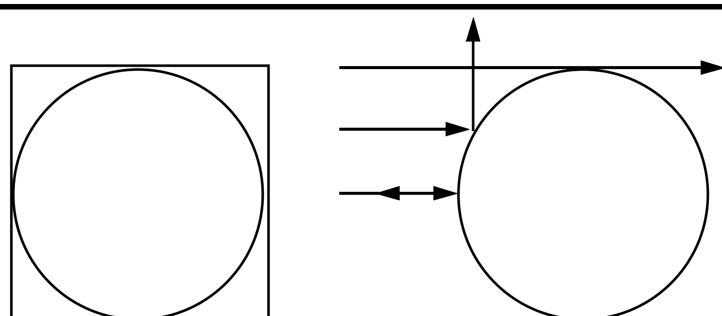
Methods:

- **Gazing Ball (N)**
  Create by photographing a reflective sphere
- **Fisheye Lens**
  Standard camera lens
- **Cubical Environment Map (R)**
  Create with a rendering program, photography...
- **Lattitude-Longitude (Map Projections)**
  Create by painting

Issues:

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

Gazing Ball



Note:

- **Photograph of reflective ball**
- **Reflection indexed by normal**
- **Maps entire field of view to circle**
- **Resolution function of orientation; maximum head-on**
- **Fish eye camera lens similar**

Cubical Environment Map

Note:

- Easy to produce with rendering system
- Possible to produce from photographs
- Resolution roughly the same in all directions
- Texture coordinates simple function of direction
- Lines map to lines

Reflectance Maps

- **Reflectance map**
  For a given viewing direction
    For each normal direction
      For each incoming direction (hemispherical integral)
        Evaluate reflection equation
- **Reflection functions**
  - Diffuse: Irradiance map
  - Glossy: Radiance map
  - Anisotropic: for each tangent direction
  - Mirror: *Reflection map* related to environment map
- **Illumination functions**
  - Environment maps
  - Procedural light sources

Bump Mapping

Shadow Maps

- Shadow mattes
- Shadow meshes - Haeberli
- Light depth buffers

  Step 1: Render z-buffer as seen from light source

  Step 2: Render from eye, using z-buffer for shadow

  Williams 1978
  - Shadow matte as post process
  - Bias and dither to prevent artifacts

  Reeves, Salesin, Cook 1987
  - Incorporate depth map during lighting
  - Percentage-closer filtering

Shading and Texturing Language

Flexibility

- **Create procedural texture models**
- **Modulate multiple parameters**
- **Control over mapping**

Texture access

```
float/color texture( "image", s, t, ...)
point bump("heights", N, Ps, Pt, s, t, ...)
float/color environment("cubefaces", D, ...)
float shadow("depths", P, ...)
```