Overview

Level of detail hierarchy

Texture maps

Procedural shading and texturing

Texture synthesis and noise

Hierarchy

Physics	Computer Graphics
Geometrical optics	Geometry
■ Macro-structures	Displacement (P) maps
Transport	Bump (N) maps
■ Micro-structures	Texels (BRDF)
Microfacets	Texture
Physical optics	
Kirchoff approx.	
Quantum optics	

Texture Maps

How is texture mapped to the surface?

- Dimensionality: 1D, 2D, 3D
- Texture coordinates (s,t)
  - Surface parameters (u,v)
  - Direction vectors: reflection R, normal N, halfway H
  - Projection: cylinder
  - Developable surface: polyhedral net
  - Reparameterize a surface: old-fashion 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

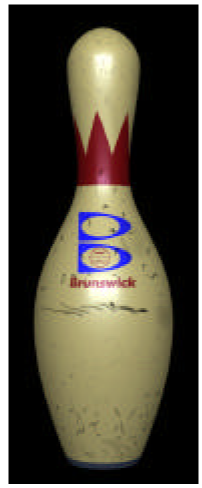
Miller and Hoffman 1984 - illumination and reflectance

Perlin 1985, Peachey 1985 - solid textures

Greene 1986 - environment maps/world projections

Akeley 1993 - Reality Engine

Tom Porter's Bowling Pin



RenderMan Companion, Pls. 12 & 13

Direction Maps

Many ways to map directions to images...

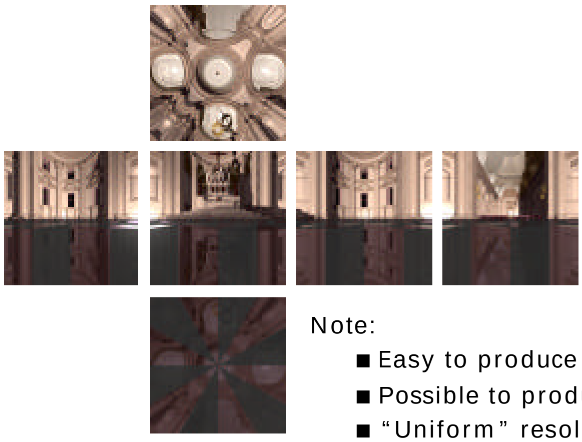
Methods:

- 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

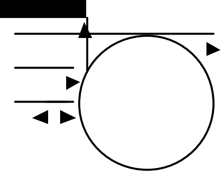
Cubical Environment Map



Note:

- Easy to produce with rendering system
- Possible to produce from photographs
- "Uniform" resolution
- Simple texture coordinates calculation

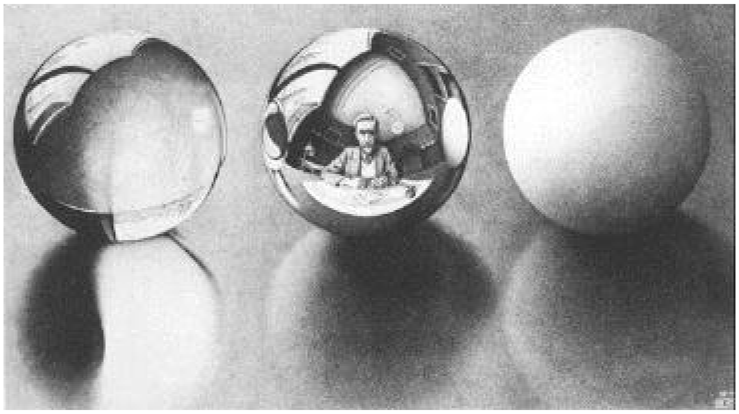
Gazing Ball



Note:

- Photograph of reflective ball
- Reflection indexed by normal
- Maps entire field of view to circle
- Resolution function of orientation; maximum head-on
- Alternatives: Fish eye, map projections

Reflectance Maps



Integrate over a hemisphere: BRDF * L

Very low resolution often sufficient: At NYIT 49x49

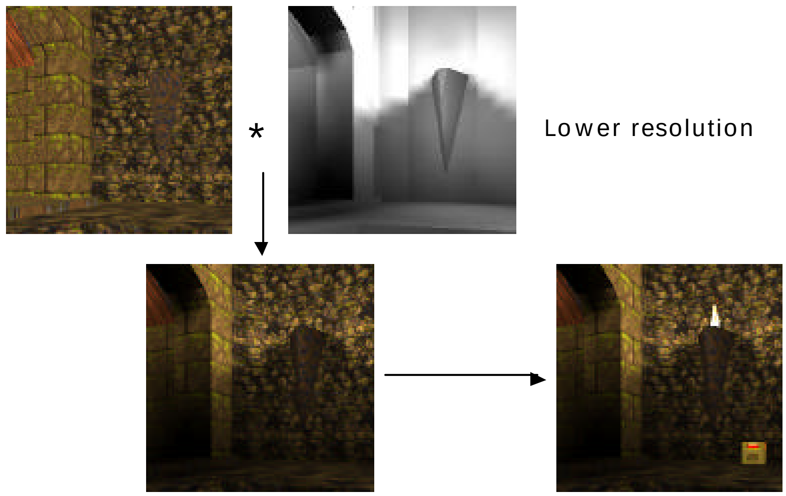
Reflectance Maps

Reflectance map
- For a given viewing direction
  - For each normal direction
    - For each incoming direction (hemispherical integral)
      - Evaluate reflection equation

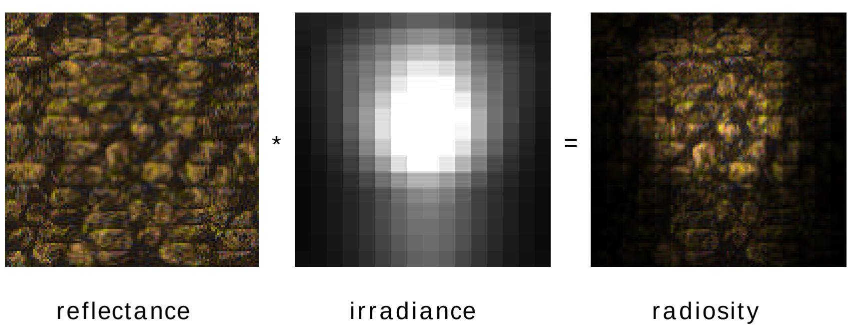
Reflection functions
- Diffuse: Irradiance map
- Glossy: Radiance map
- Anisotropic: for each tangent direction
- Mirror: Reflection map related to environment map

Illumination functions
- Environment maps
- Procedural light sources

Quake Light Maps

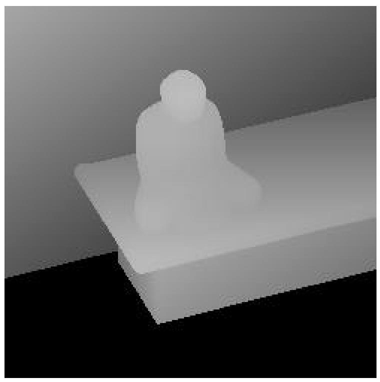


Illumination Maps



Shadow Maps

May incorporate shadow maps into lighting calculations



Correct Shadow Maps

Step 1:

Create z-buffer of scene as seen from light source

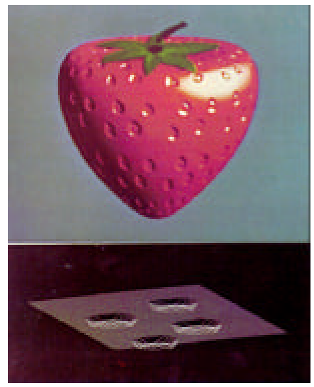
Step 2.

Render scene as seen from the eye

```
For each light
    Transform point into light coordinates
        return (zl < zbuffer[xl][yl] ) ? 1 : 0
```

Displacement/Bump Mapping

[redacted]



From Blinn 1976

Offset surface position

- Displacement

$$\mathbf{P}'(u,v) = \mathbf{P}(u,v) + h(u,v)\mathbf{N}(u,v)$$

- Perturb normal

$$\mathbf{N}(u,v) = \frac{\partial \mathbf{P}(u,v)}{\partial u} \times \frac{\partial \mathbf{P}(u,v)}{\partial v}$$

Shading and Texturing Language

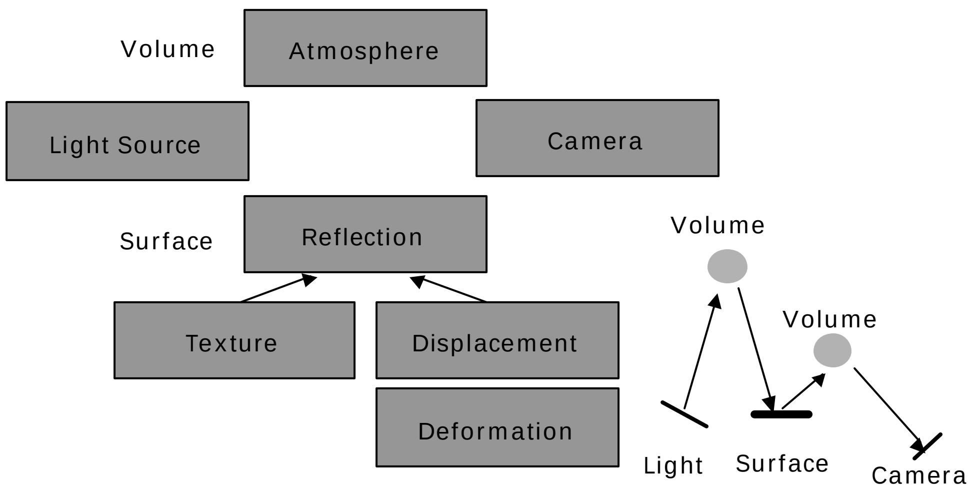
Flexibility

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

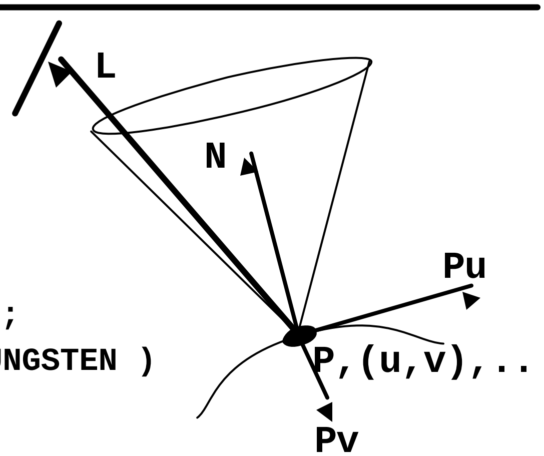
Texture access

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

Abstract Shading Model

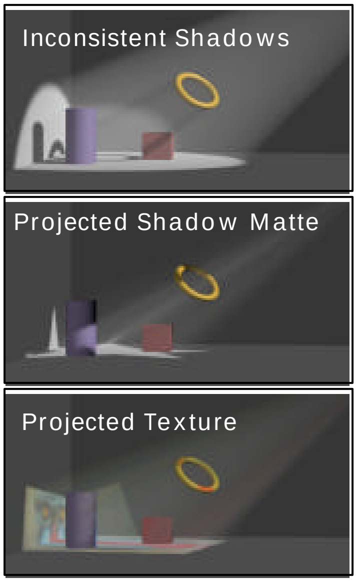


Light Shader State




```
light bulb(
  float intensity = 1;
  color filament = TUNGSTEN )
{
  illuminate( P )
    Cl = intensity * filament / (L.L);
}
```

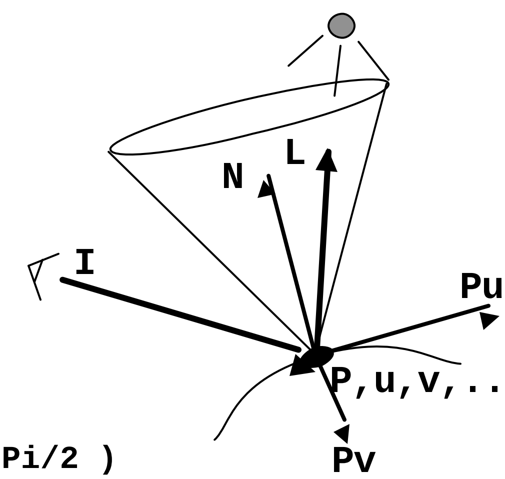
Barzel's *UberLight.sl*



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
}
```


Surface Shader




```
surface diffuse()
{
  color Ci = 0;
  illuminance( P, N, Pi/2 )
    Ci += Cs * Cl * N.L;
}
```

RenderMan Surface Shader

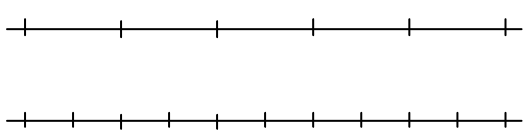
```
surface corrode(float Ks=0.4, Ka=0.1, rough=0.25)
{
  float i, freq=1, turb=0;

  // compute fractal texture
  for( i=0; i<6; i++ ) {
   turb += 1/freq*noise(freq*P);
   freq *= 2;
  }
  // perturb surface
  P -= turb * normalize(N);
  N = faceforward(normalize(calculatenormal(P)));

  // compute reflection and final color
  Ci = Cs*(Ka*ambient()+Ks*specular(N,I,rough));
}
```

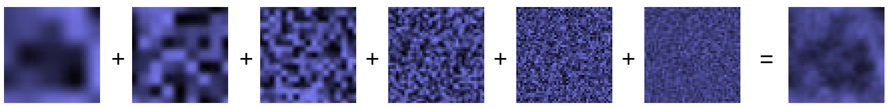
Perlin's Noise Function

1. Generate a table of random numbers
2. Hash a 3D lattice into a table entry
3. Use random values as the gradient
4. Perform cubic interpolation



Turbulence

```
fBm
  // compute fractal texture
  for( i=0; i<6; i++ ) {
   turb += 1/freq*noise(freq*P);
   freq *= 2;
  }
```



Images from http://freespace.virgin.net/hugo.elias/models/m_perlin.htm

Examples

Wood and Stone – RenderMan Companion

Marble – Ken Perlin

Examples (continued)

Cloud –
David Ebert