Texture / Image-Based Rendering

Texture maps

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

Level of detail hierarchy

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
- Geometry: bump and displacement maps

Classic 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

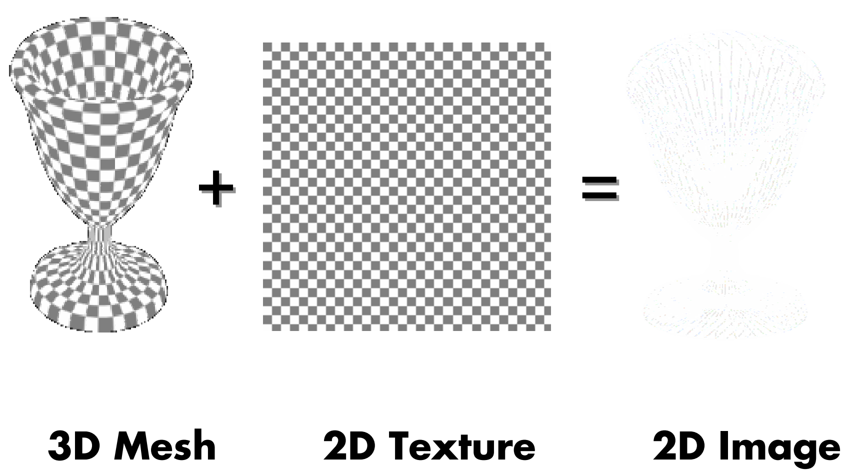
Greene 1986 - environment maps/world projections

Akeley 1993 - Reality Engine

Light Field

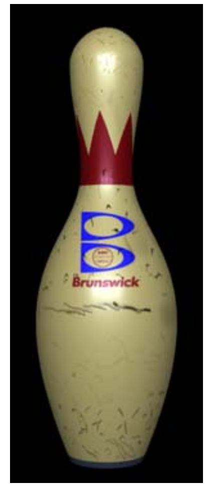
BTF

Texture Mapping



Surface Color and Transparency

Tom Porter's Bowling Pin



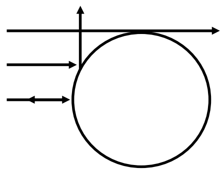
Source: RenderMan Companion, Pls. 12 & 13

Reflection Maps

Blinn and Newell, 1976

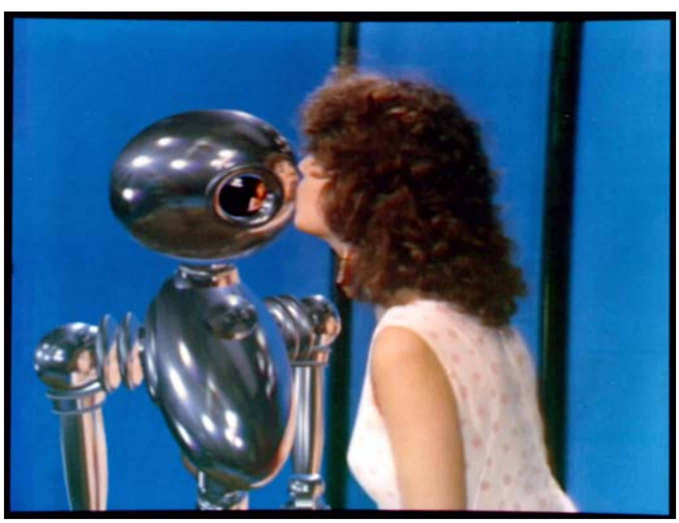
Gazing Ball

Miller and Hoffman, 1984



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

Environment Maps



***Interface,* Chou and Williams (ca. 1985)**

Environment Map Approximation

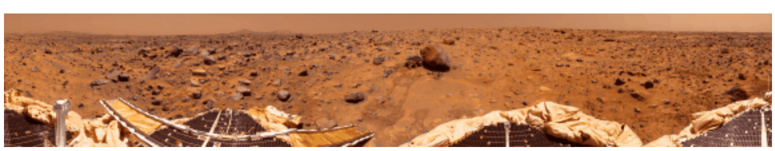
Ray Traced

Environment Map

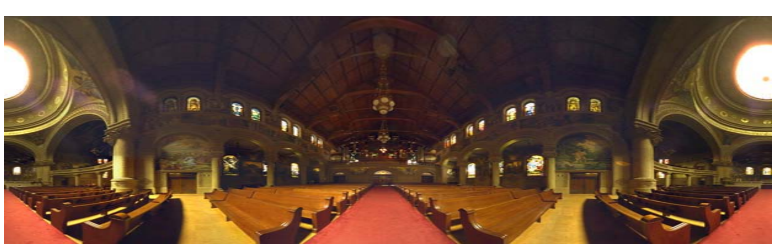
Self reflections are missing in the environment map

Cylindrical Panoramas

QuickTime VR



Mars Pathfinder

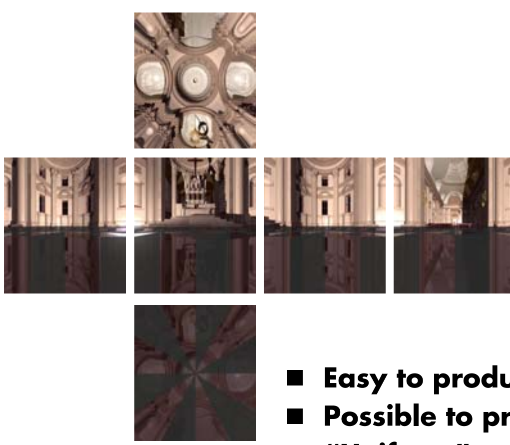


Memorial Church (Ken Turkowski)

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**

Shadow Mattes


```
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
}
```

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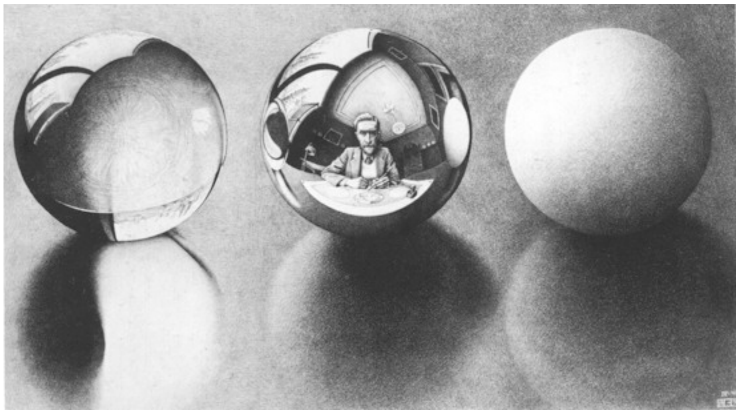
Reflectance Maps



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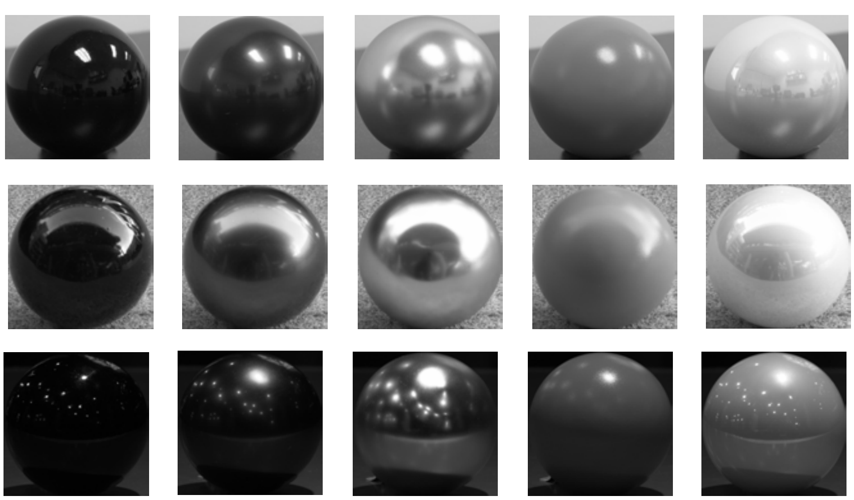
Capturing Reflectance Maps

Photographs of 5 spheres in 3 environments



[Adelson and Dror]

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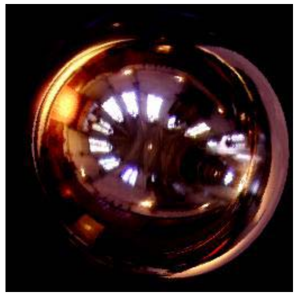
Creating Lambertian Reflectance Map

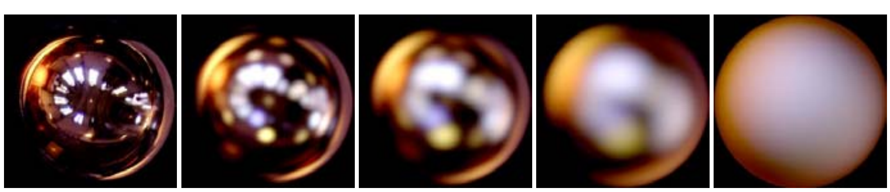


Incident Lighting **Reflected Light**

$$B(\hat{\mathbf{N}}) = \rho E(\hat{\mathbf{N}})$$

Irradiance Map

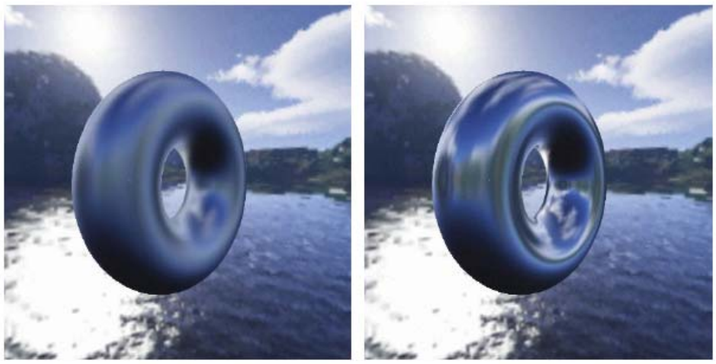
Creating Phong Reflectance Map



$$\longrightarrow$$
$$\sigma$$

For each normal direction
- For each incoming direction (hemispherical integral)
  - Evaluate reflection equation

Filtered Environment Maps



From W. Heidrich

Reflectance Space Shading

Cabral, Olano, Nemic 1999

12 directions

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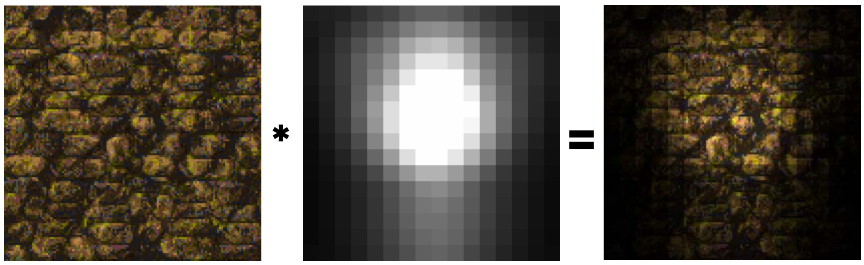
Illumination Maps

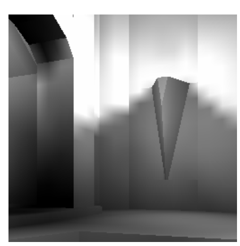


Reflectance $\rho(x)$

Irradiance $E(x)$

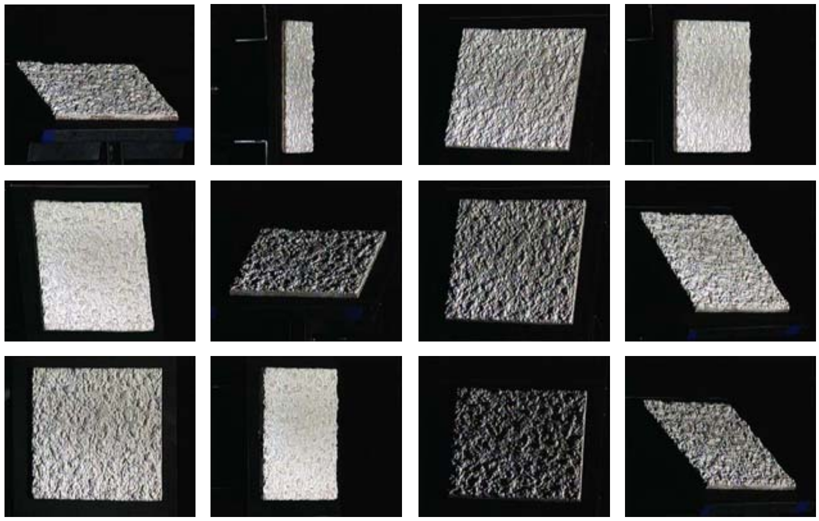
Radiosity $B(x)$

Quake Light Maps



Lower resolution

Bidirectional Texture Function (BTF)



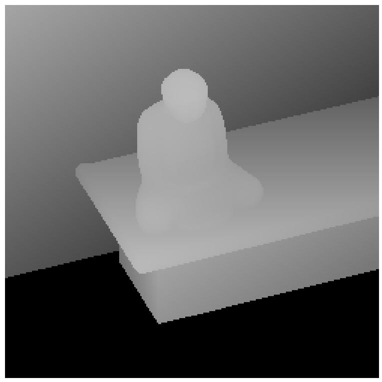
Plaster

BTF Mapping

Complex interplay between texture and reflection

Shadow Maps

Shadow maps = depth maps from light source



Correct Shadow Maps

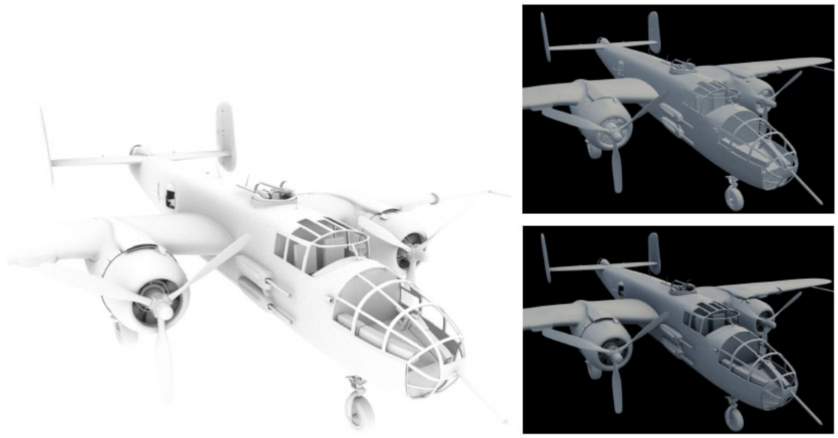
Step 1:

- **Create z-buffer of scene as seen from light source**

Step 2.

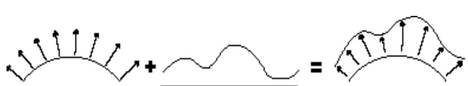
- **Render scene as seen from the eye**
  - **For each light**
    - **Transform point into light coordinates**
      - **return (zl < zbuffer[xl][yl]) ? 1 : 0**

Ambient Occlusion Maps



From Production ready global illumination, Hayden Landis, ILM

Displacement/Bump Mapping



$$\mathbf{P}(u,v)$$

$$\mathbf{S}(u,v)=\frac{\partial \mathbf{P}(u,v)}{\partial u} \qquad \mathbf{T}(u,v)=\frac{\partial \mathbf{P}(u,v)}{\partial v}$$

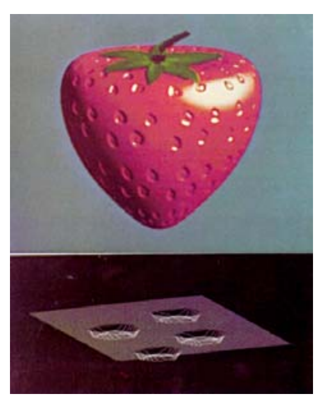
$$\mathbf{N}(u,v)=\mathbf{S}\times\mathbf{T}$$

- **Displacement**

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

- **Perturbed normal**

$$\mathbf{N}'(u,v)=\mathbf{P}'_u\times\mathbf{P}'_v$$
$$=\mathbf{N}+h_u(\mathbf{T}\times\mathbf{N})+h_v(\mathbf{S}\times\mathbf{N})$$



From Blinn 1976

Normal Maps

(nx,ny,nz) = (r,g,b)

http://members.shaw.ca/jimht03/normal.html

Hierarchy

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