Image-Based Lighting

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…with a lot of slides donated by Paul Debevec

15-463: Computational Photography
Alexei Efros, CMU, Fall 2007

Inserting Synthetic Objects

Why does this look so bad?

- Wrong camera orientation
- Wrong lighting
- No shadows

Solutions

Wrong Camera Orientation

- Estimate correct camera orientation and renender object
  - Requires camera calibration to do it right

Lighting & Shadows

- Estimate (eyeball) all the light sources in the scene and simulate it in your virtual rendering

But what happens if lighting is complex?

- Extended light sources, mutual illumination, etc.

Environment Maps

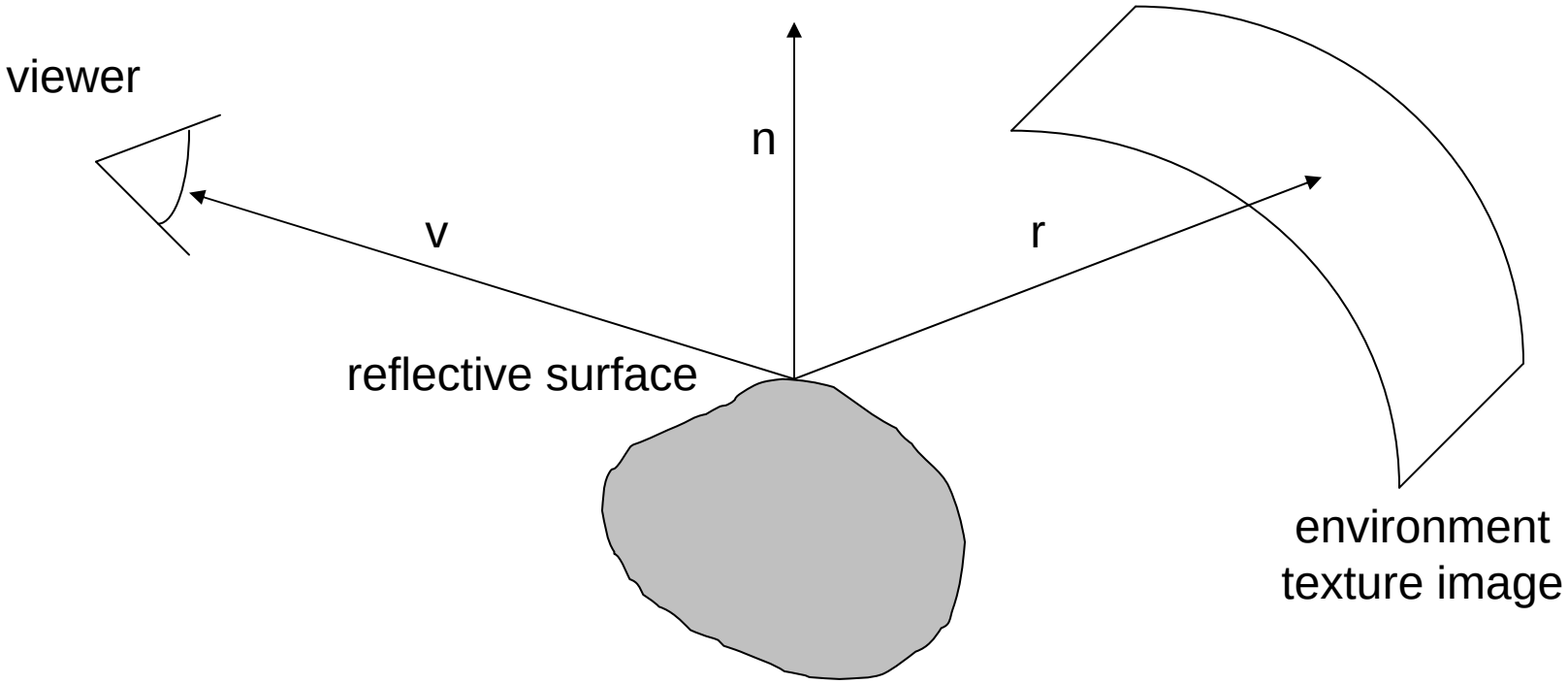
Simple solution for shiny objects

- Models complex lighting as a panoramic image
- i.e. amount of radiance coming in from each direction
- A plenoptic function!!!

Environment Mapping

projector function converts reflection vector (x, y, z) to texture image (u, v)

Reflected ray: $\boldsymbol{r}=2(\boldsymbol{n}\cdot\boldsymbol{v})\boldsymbol{n}-\boldsymbol{v}$



Texture is transferred in the direction of the reflected ray from the environment map onto the object

What is in the map?

What approximations are made?

The map should contain a view of the world with the point of interest on the object as the Center of Projection

- We can’t store a separate map for each point, so one map is used with the COP at the center of the object
- Introduces distortions in the reflection, but we usually don’t notice
- Distortions are minimized for a small object in a large room

The object will not reflect itself!

Environment Maps

The environment map may take various forms:

- Cubic mapping
- Spherical mapping
- other

Describes the shape of the surface on which the map “resides”

Determines how the map is generated and how it is indexed

Cubic Mapping

The map resides on the surfaces of a cube around the object

- Typically, align the faces of the cube with the coordinate axes

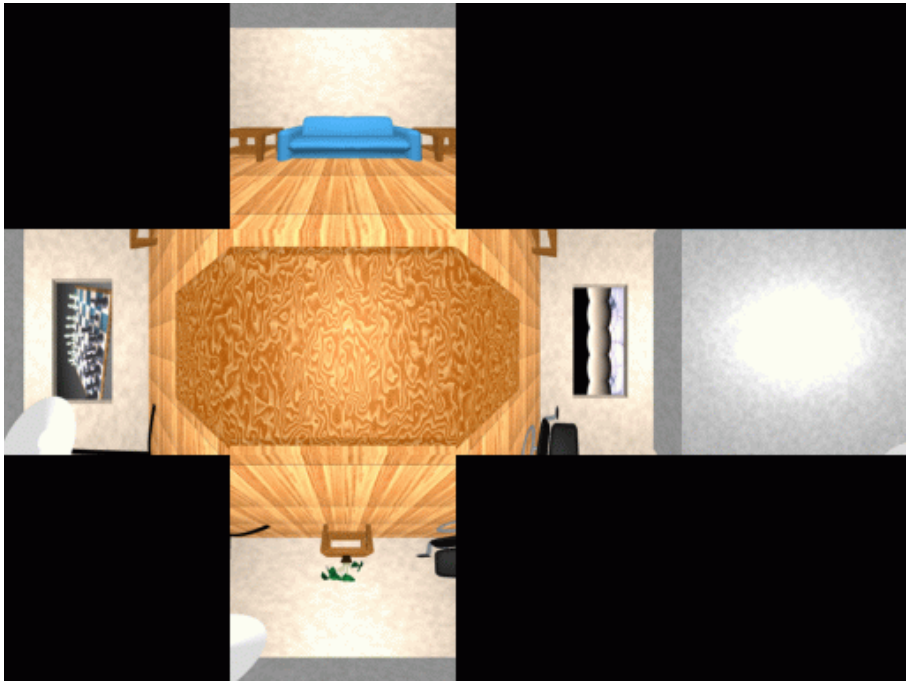
To generate the map:

- For each face of the cube, render the world from the center of the object with the cube face as the image plane
  - Rendering can be arbitrarily complex (it's off-line)

To use the map:

- Index the R ray into the correct cube face
- Compute texture coordinates

Cubic Map Example



Sphere Mapping

Map lives on a sphere

To generate the map:

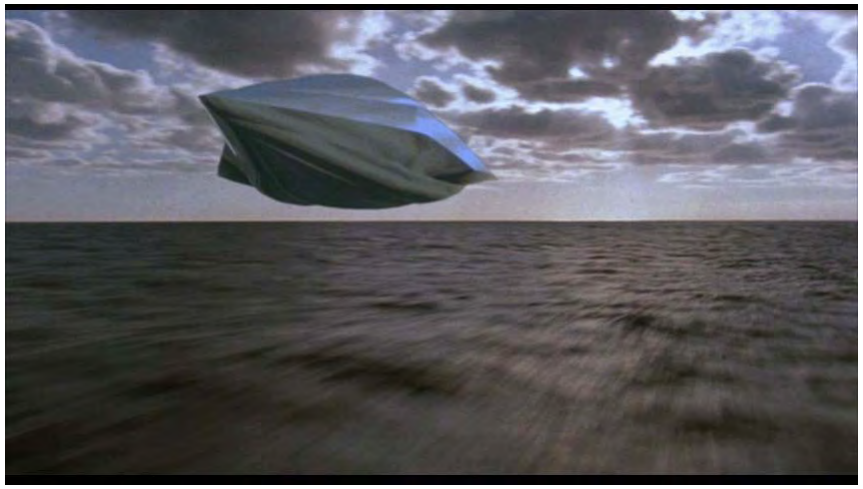
- Render a spherical panorama from the designed center point

To use the map:

- Use the orientation of the R ray to index directly into the sphere

Example

What about real scenes?



From *Flight of the Navigator*

What about real scenes?

from Terminator 2

It’s not that hard!

http://www.nickbertke.com/

Real environment maps

We can use photographs to capture environment maps

- The first use of panoramic mosaics

How do we deal with light sources? Sun, lights, etc?

- They are much much brighter than the rest of the enviarnment

User High Dynamic Range photography, of course!

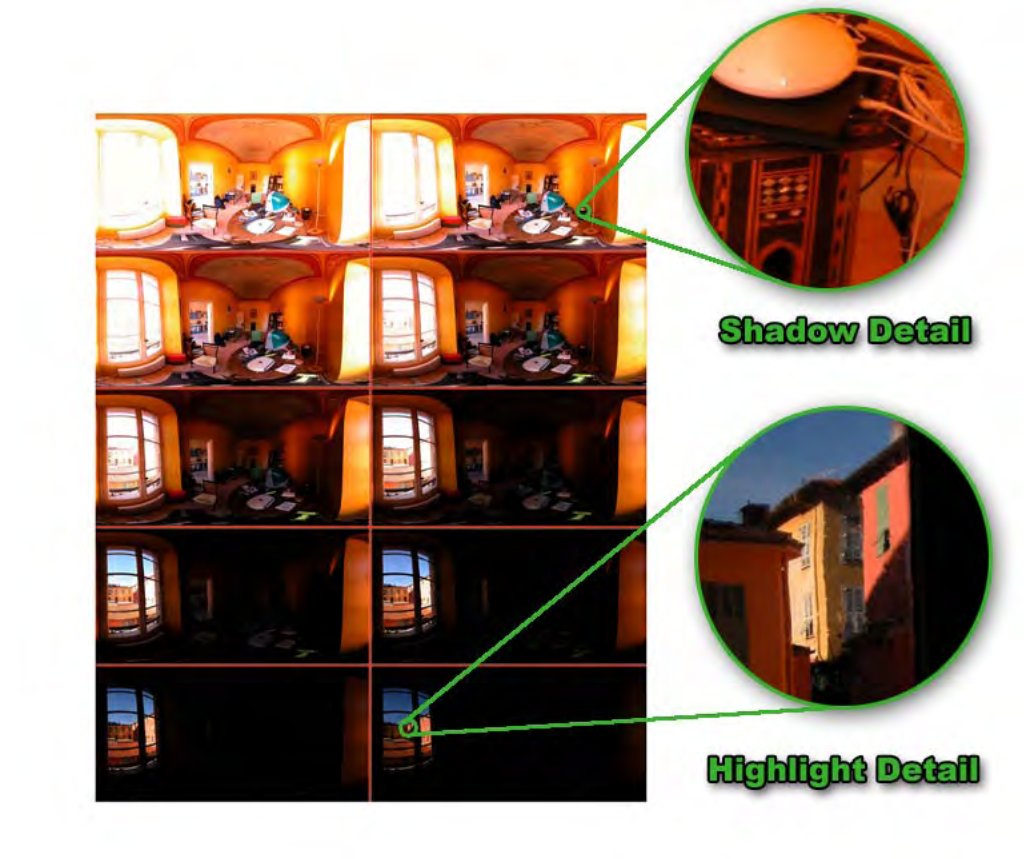
Several ways to acquire environment maps:

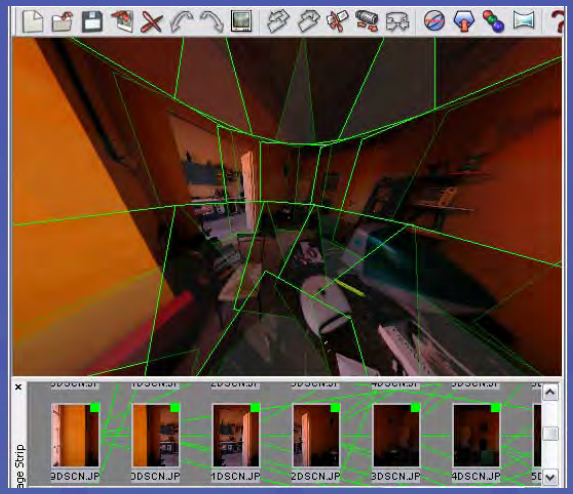
- Stitching mosaics
- Fisheye lens
- Mirrored Balls

Stitching HDR mosaics

SIGGRAPH2004

http://www.gregdowning.com/HDRI/stitched/





Scanning Panoramic Cameras

Pros:

- *very* high res (10K x 7K+)
- Full sphere in one scan – no stitching
- Good dynamic range, some are HDR

Issues:

- More expensive
- Scans take a while

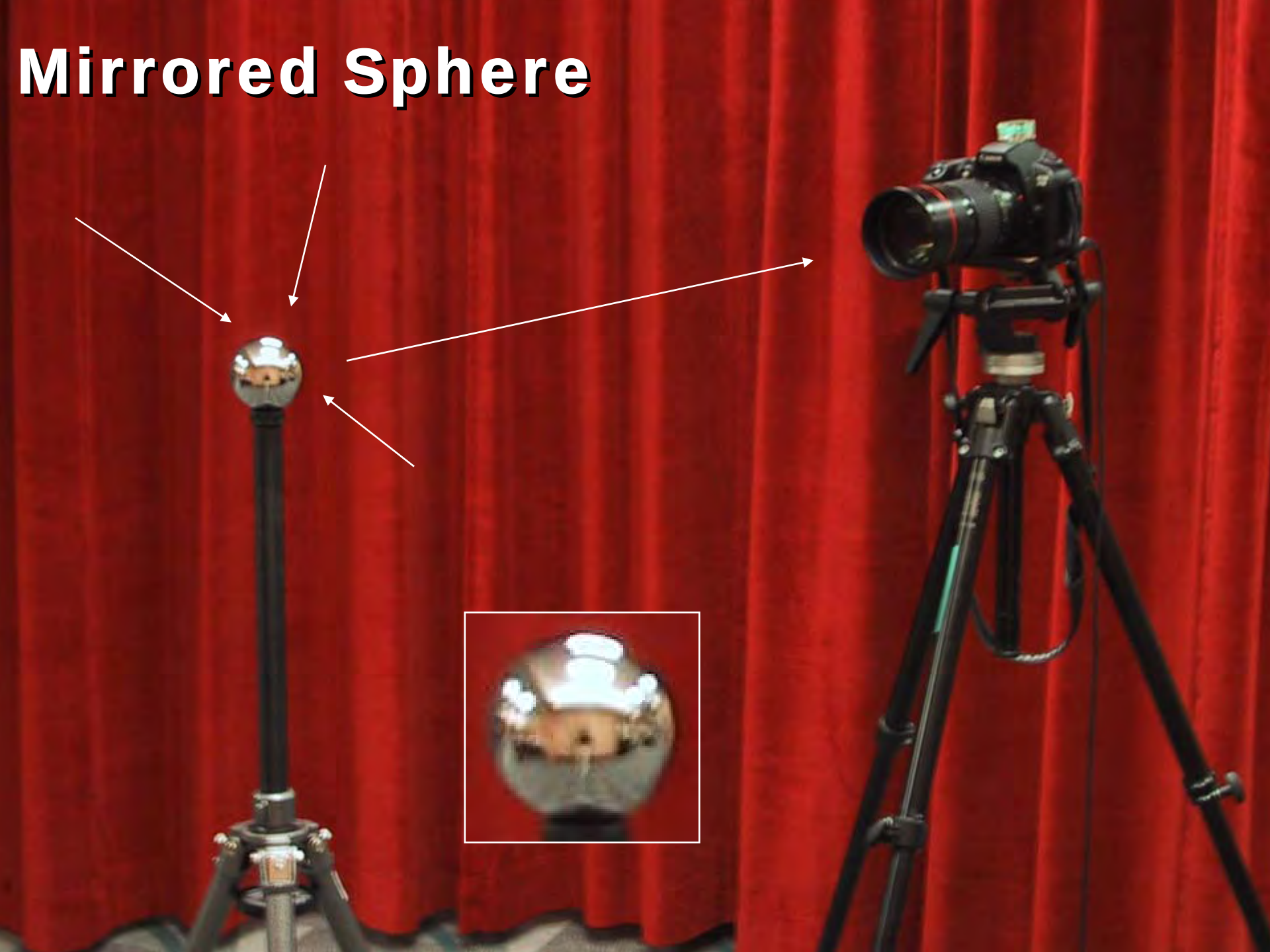
Companies: Panoscan, Sphereon

SIGGRAPH2004

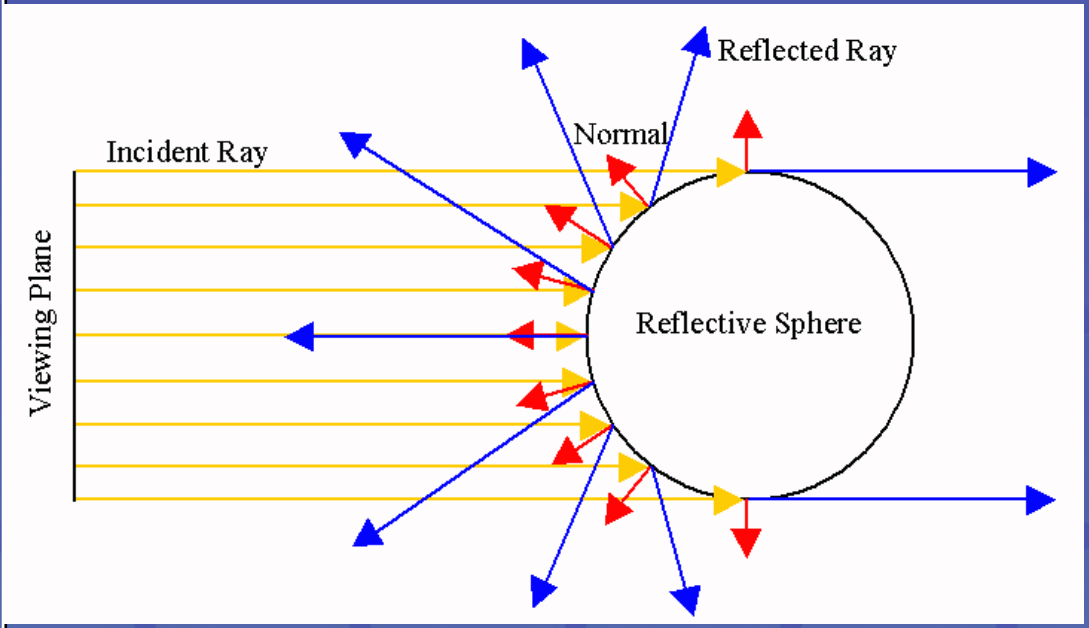
See also www.kaidan.com

Fisheye Images

Mirrored Sphere

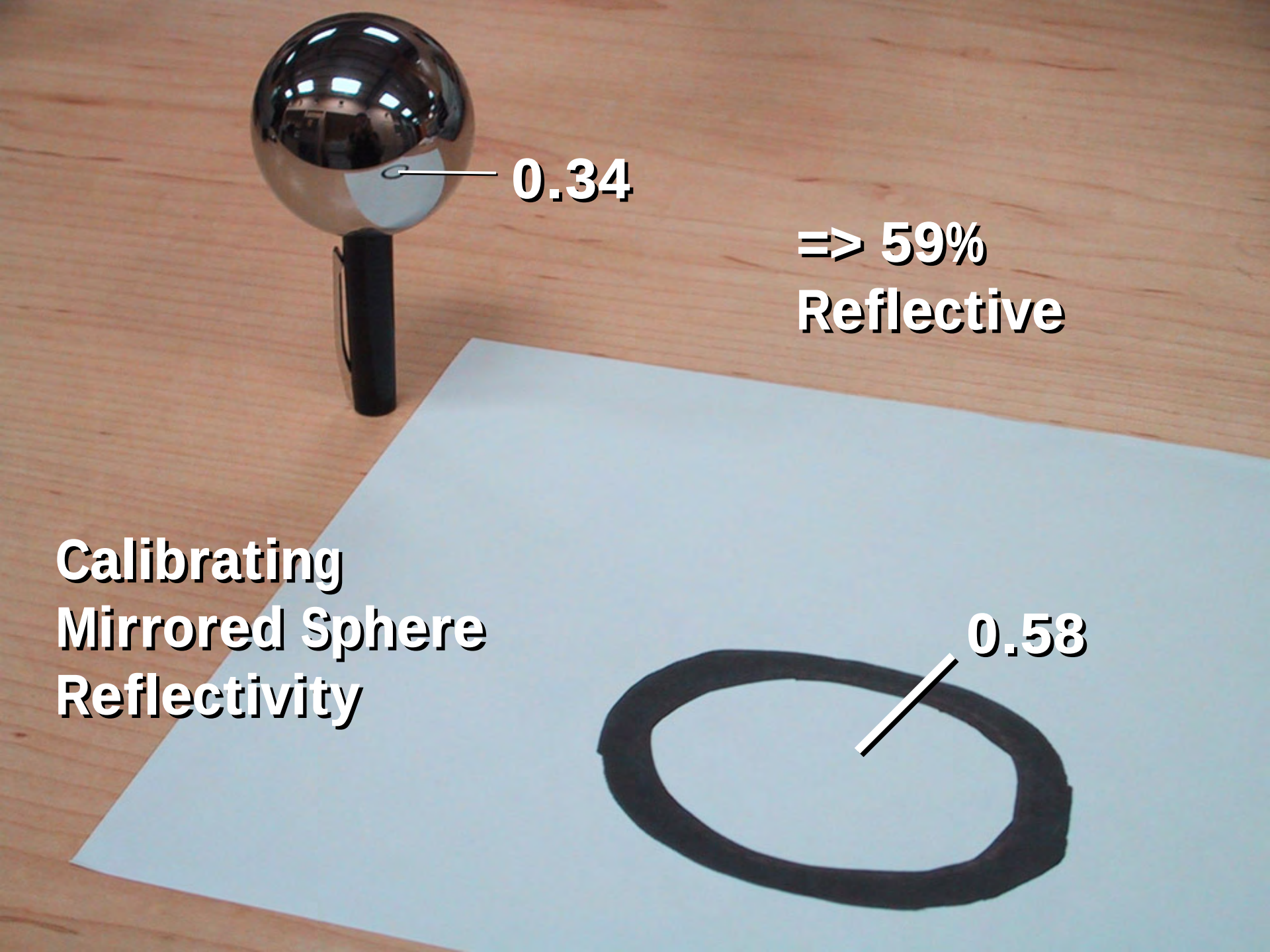



Canon
Canon


Reflected Ray
Normal
Incident Ray
Viewing Plane
Reflective Sphere

Sources of Mirrored Balls

- 2-inch chrome balls ~ $20 ea.
  - McMaster-Carr Supply Company www.mcmaster.com
- 6-12 inch large gazing balls
  - Baker's Lawn Ornaments www.bakerslawnorn.com
- Hollow Spheres, 2in – 4in
  - Dube Juggling Equipment www.dube.com
- FAQ on www.debevec.org/HDRShop/


0.34
=> 59%
Reflective
Calibrating
Mirrored Sphere
Reflectivity
0.58

Real-World HDR Lighting Environments

Funston Beach

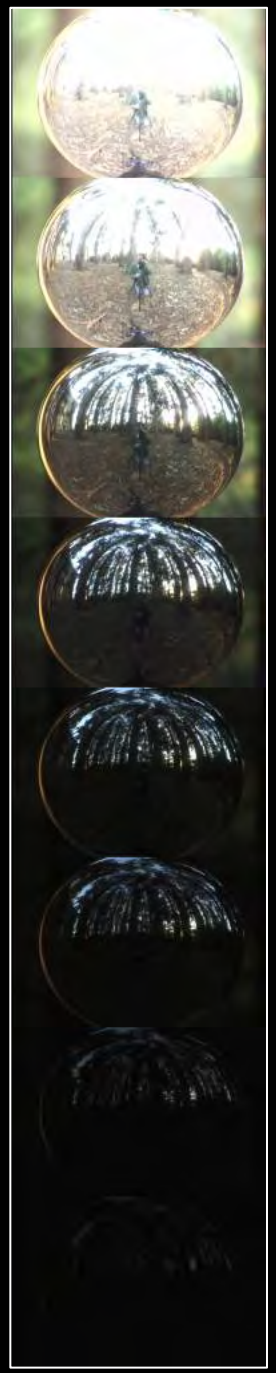
Eucalyptus Grove

Uffizi Gallery

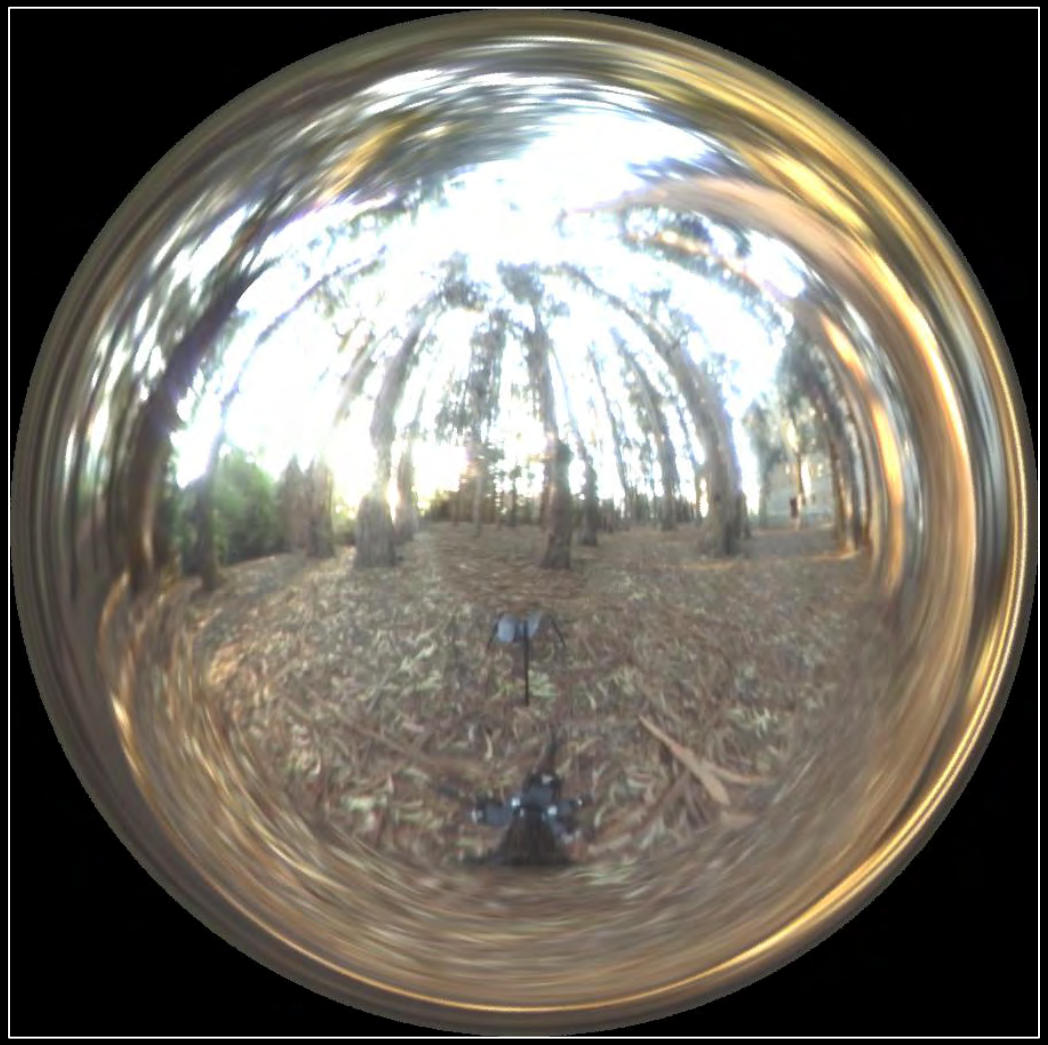
Grace Cathedral

Lighting Environments from the Light Probe Image Gallery:
http://www.debevec.org/Probes/

Acquiring the Light Probe



Assembling the Light Probe



Not just shiny…

We have captured a true radiance map

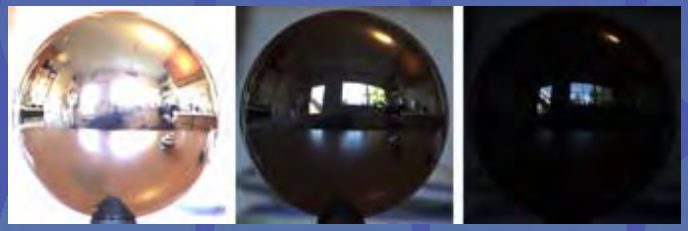
We can treat it as an extended (e.g spherical) light source

Can use Global Illumination to simulate light transport in the scene

- So, all objects (not just shiny) can be lighted
- What's the limitation?

Illumination Results

Comparison: Radiance map versus single image

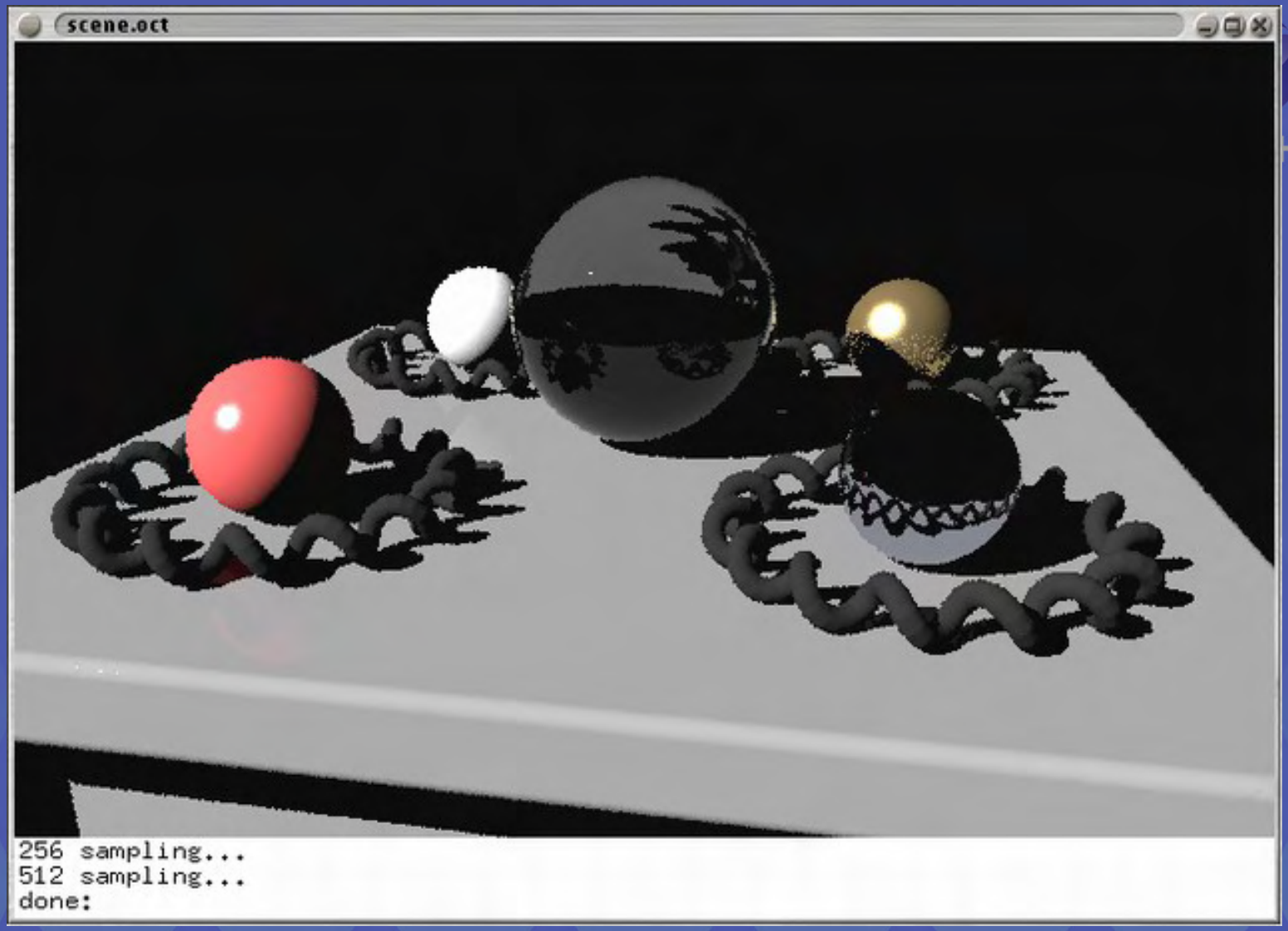


Putting it all together

Synthetic Objects

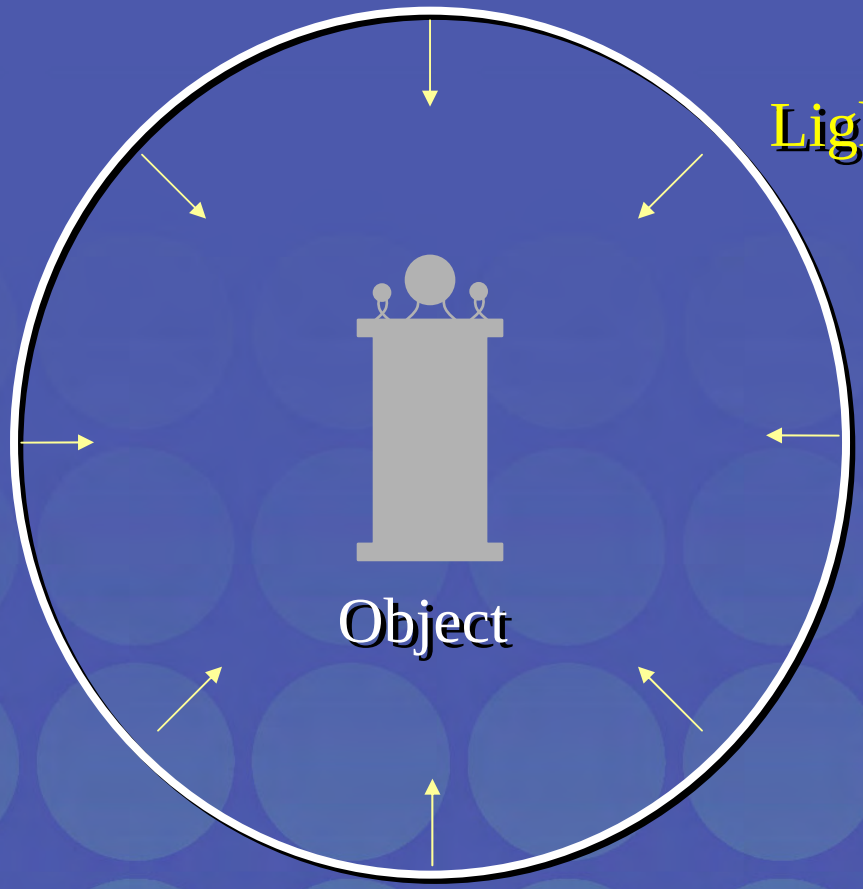
+

Real light!



CG Objects Illuminated by a Traditional CG Light Source

Illuminating Objects using Measurements of Real Light



Environment assigned “glow” material property in Greg Ward’s RADIANCE system.

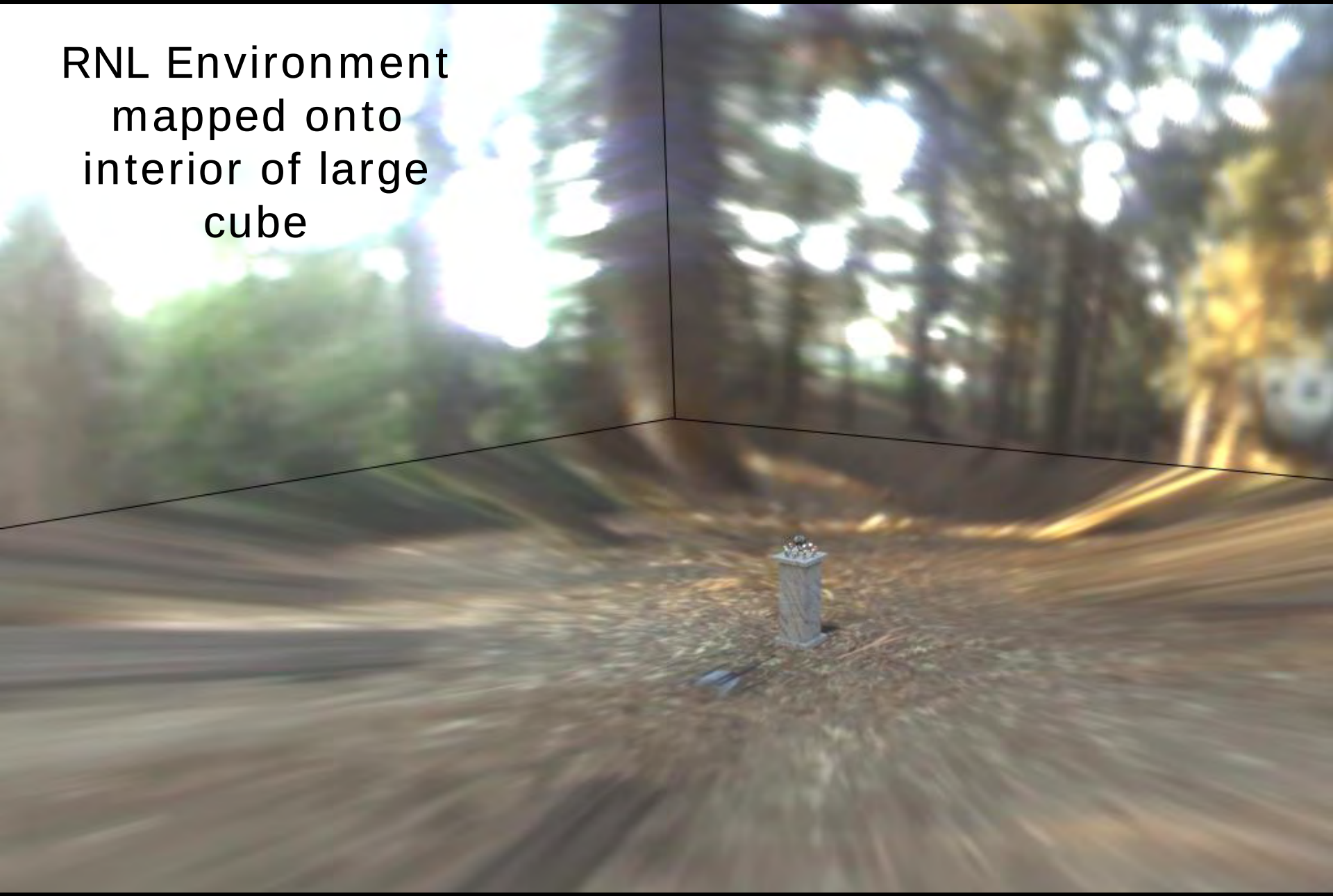
http://radsite.lbl.gov/radiance/



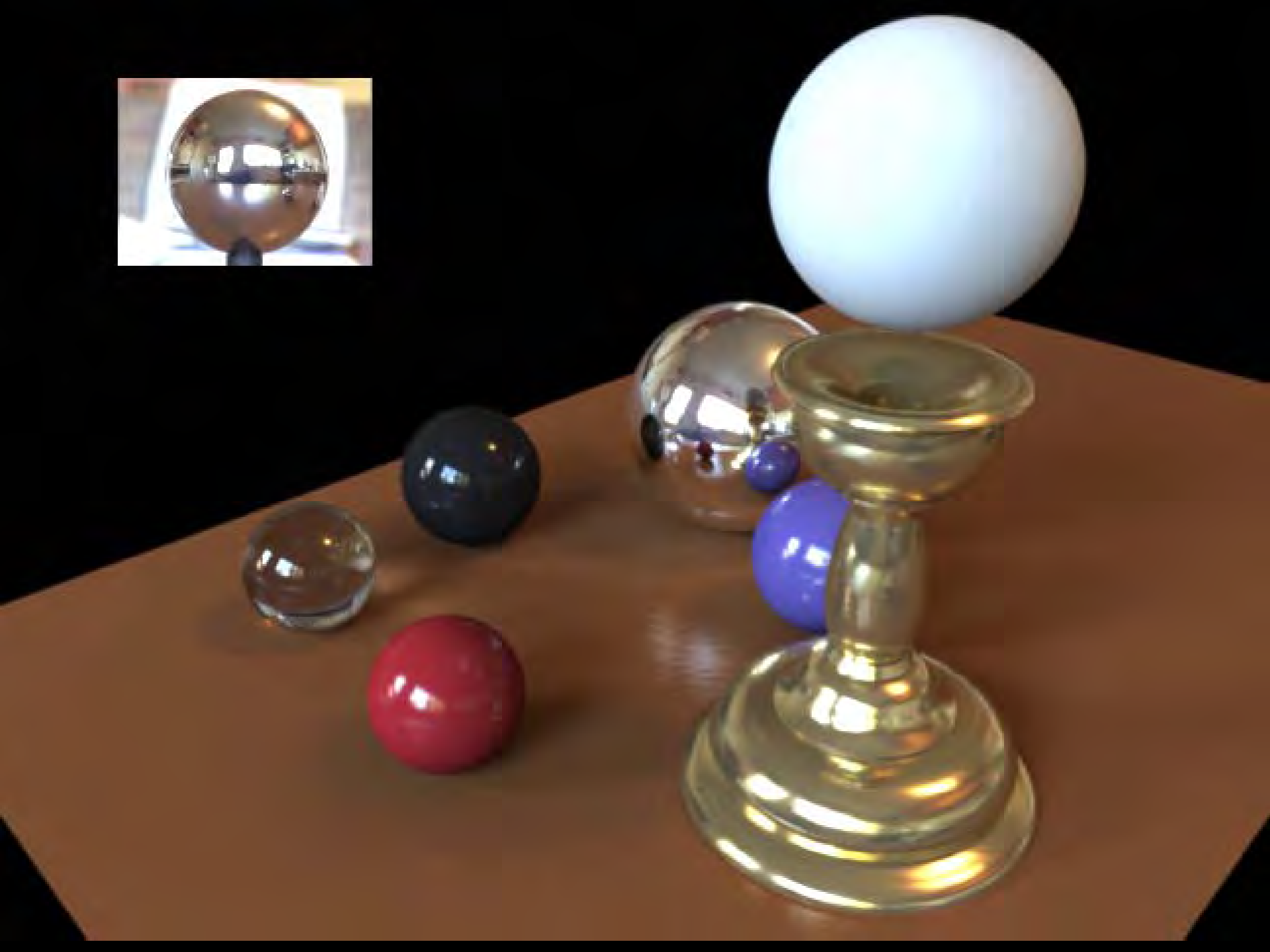

Paul Debevec. A Tutorial on Image-Based Lighting. IEEE Computer Graphics and Applications, Jan/Feb 2002.

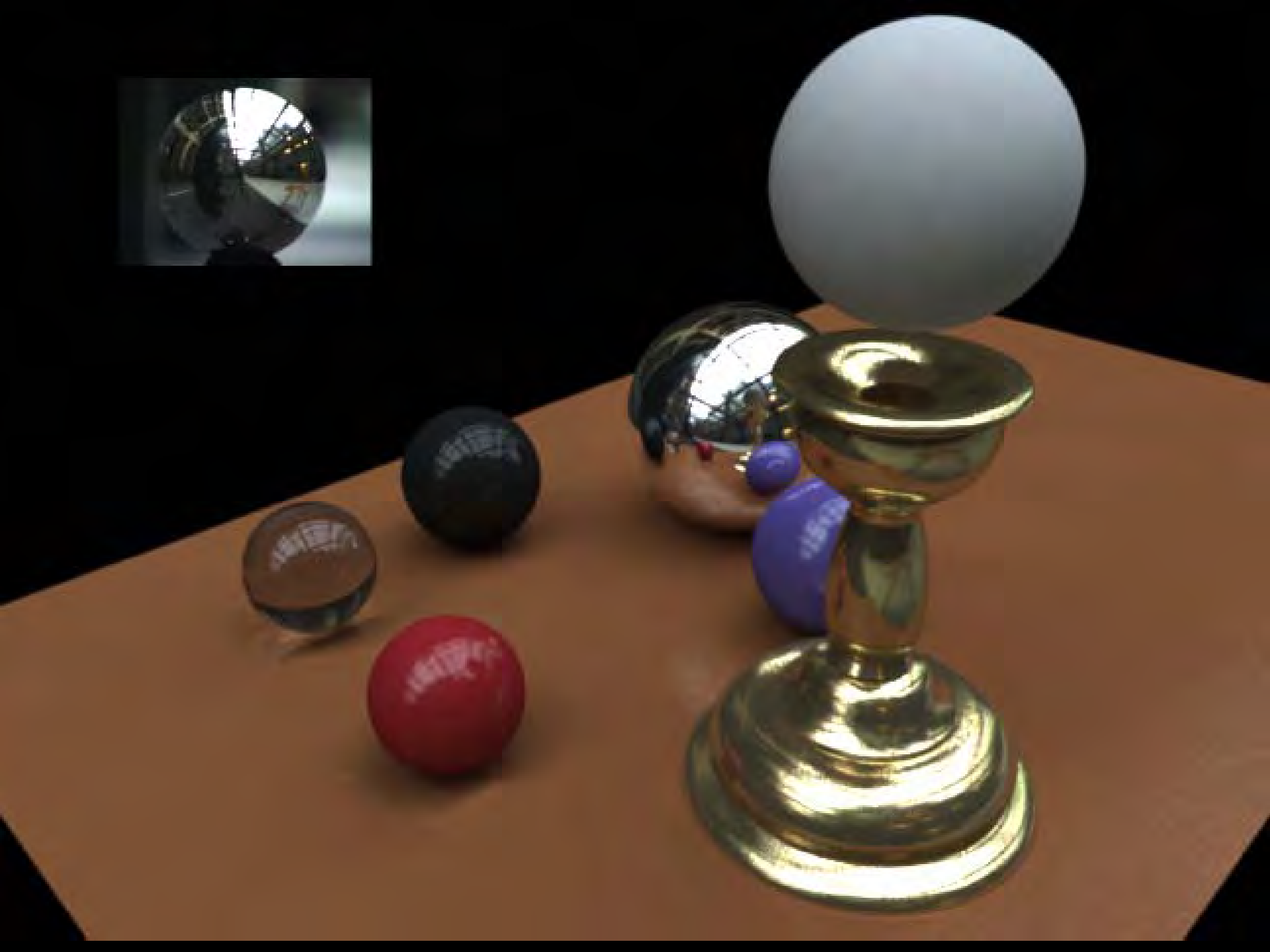
Rendering with Natural Light

SIGGRAPH 98 Electronic Theater


RNL Environment
mapped onto
interior of large
cube

MOVIE!





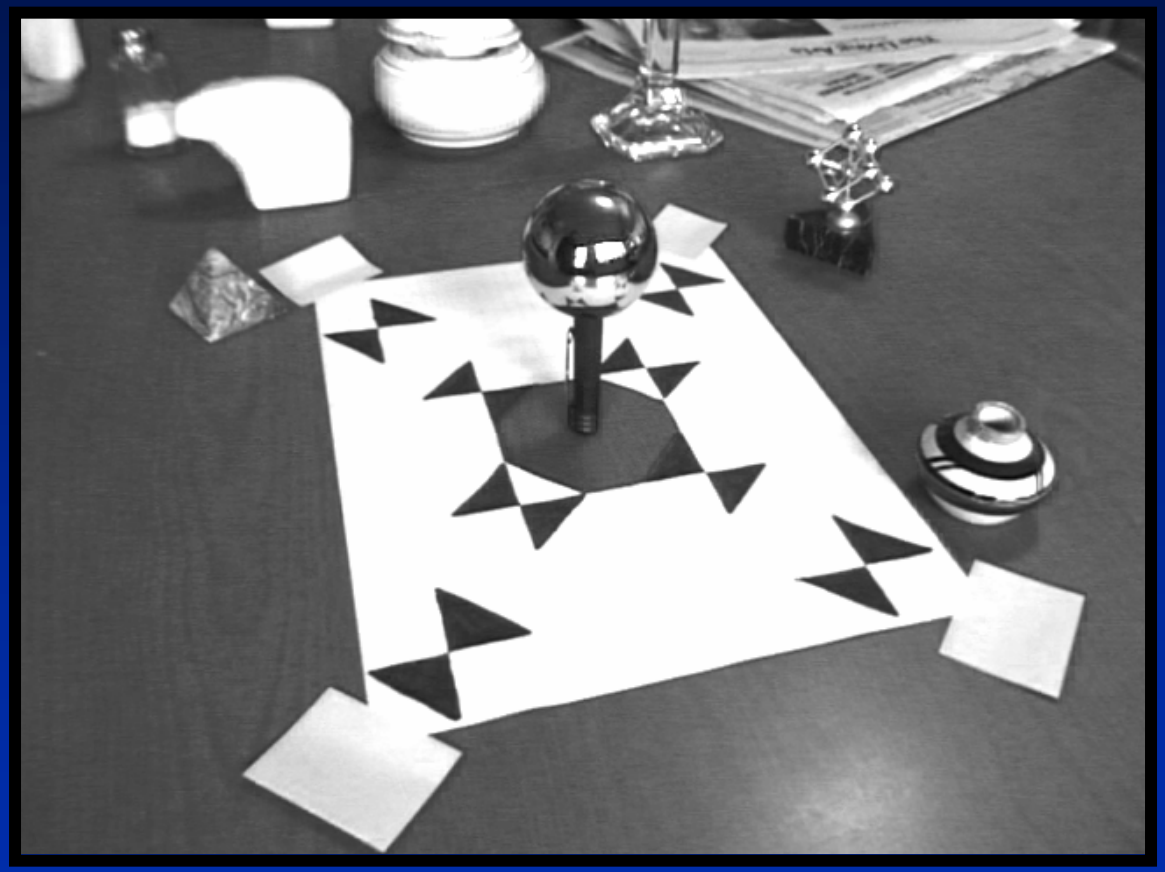
We can now illuminate synthetic objects with real light.

How do we add synthetic objects to a real scene?

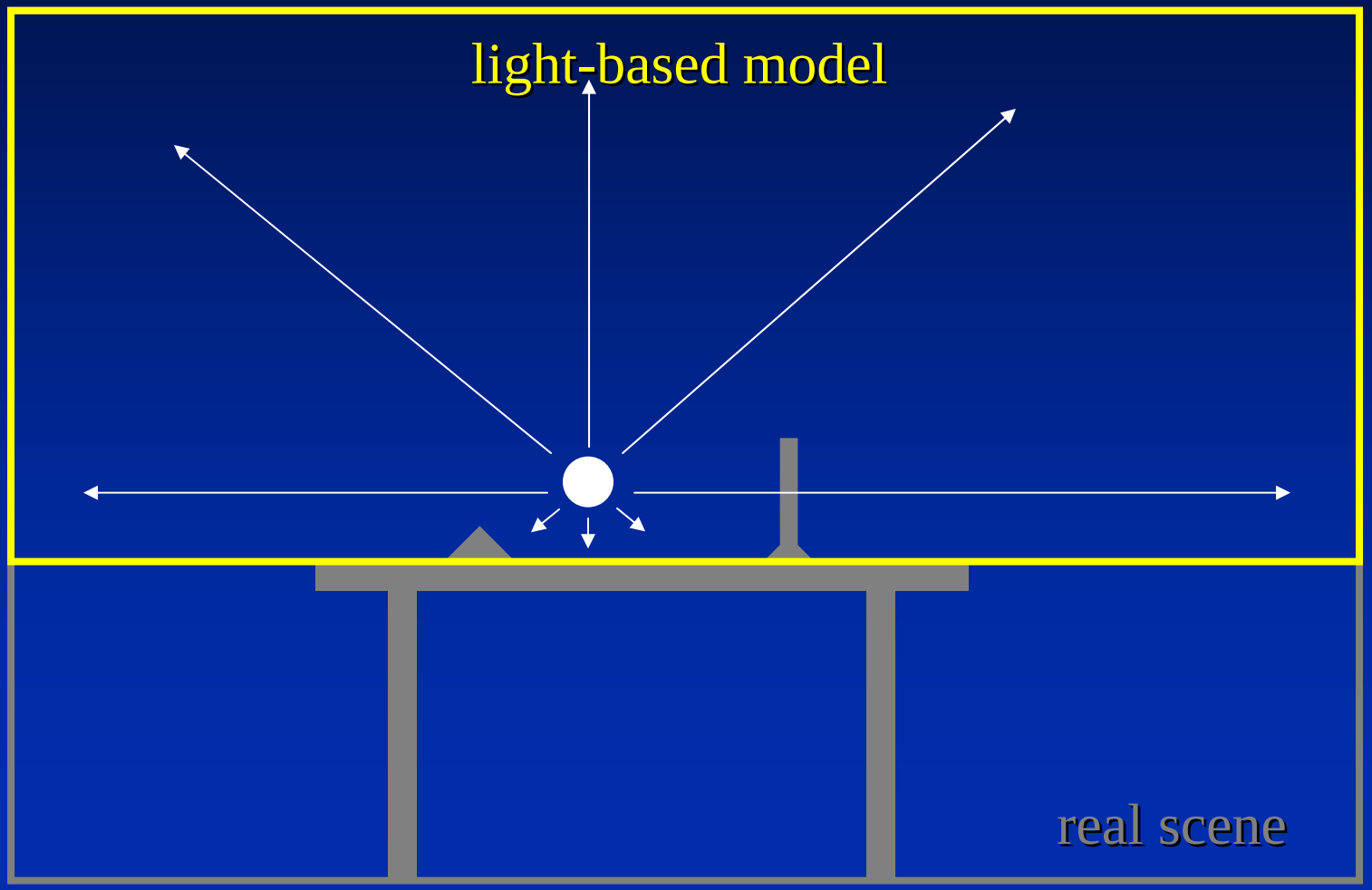
Real Scene Example

Goal: place synthetic objects on table

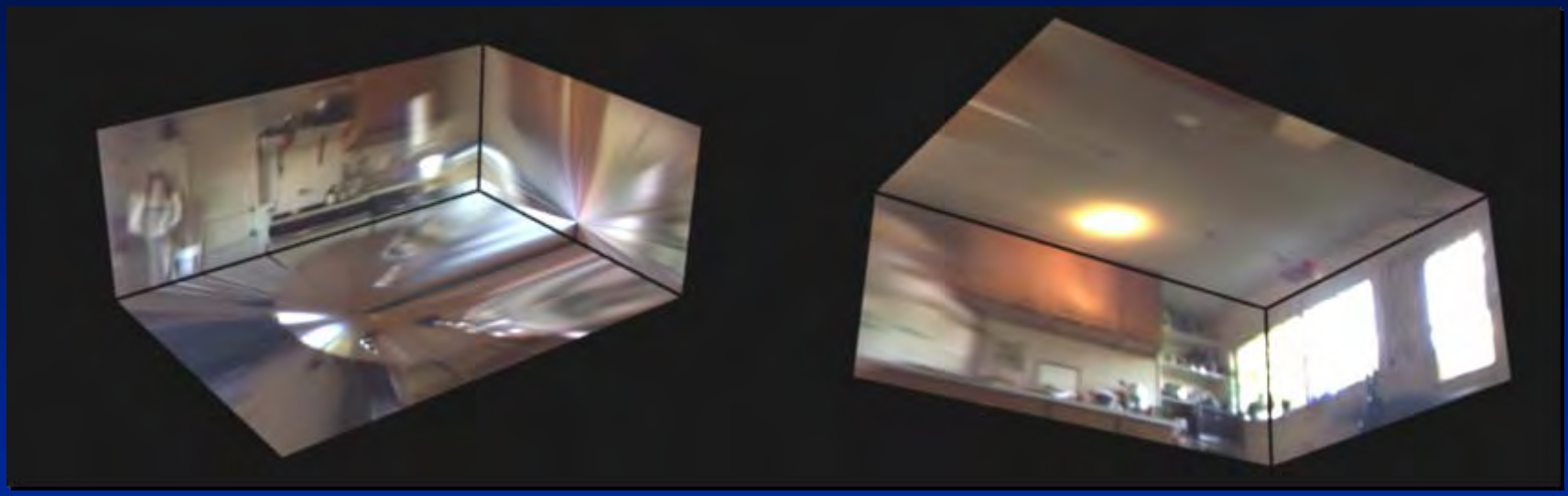
Light Probe / Calibration Grid

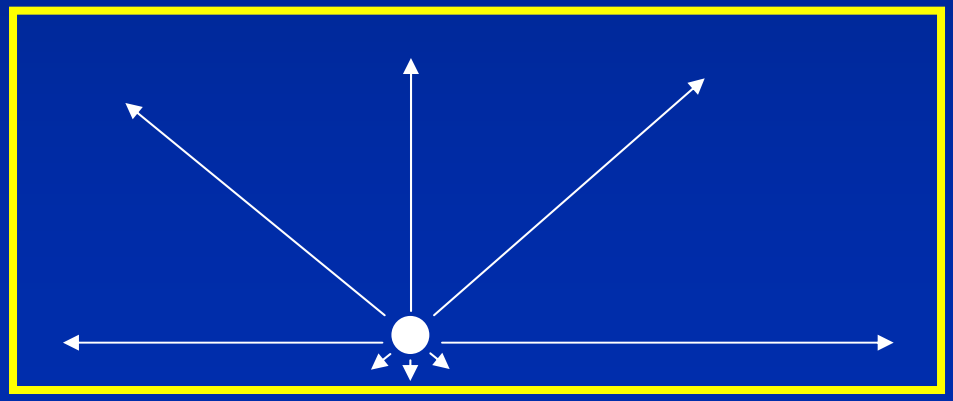


Modeling the Scene

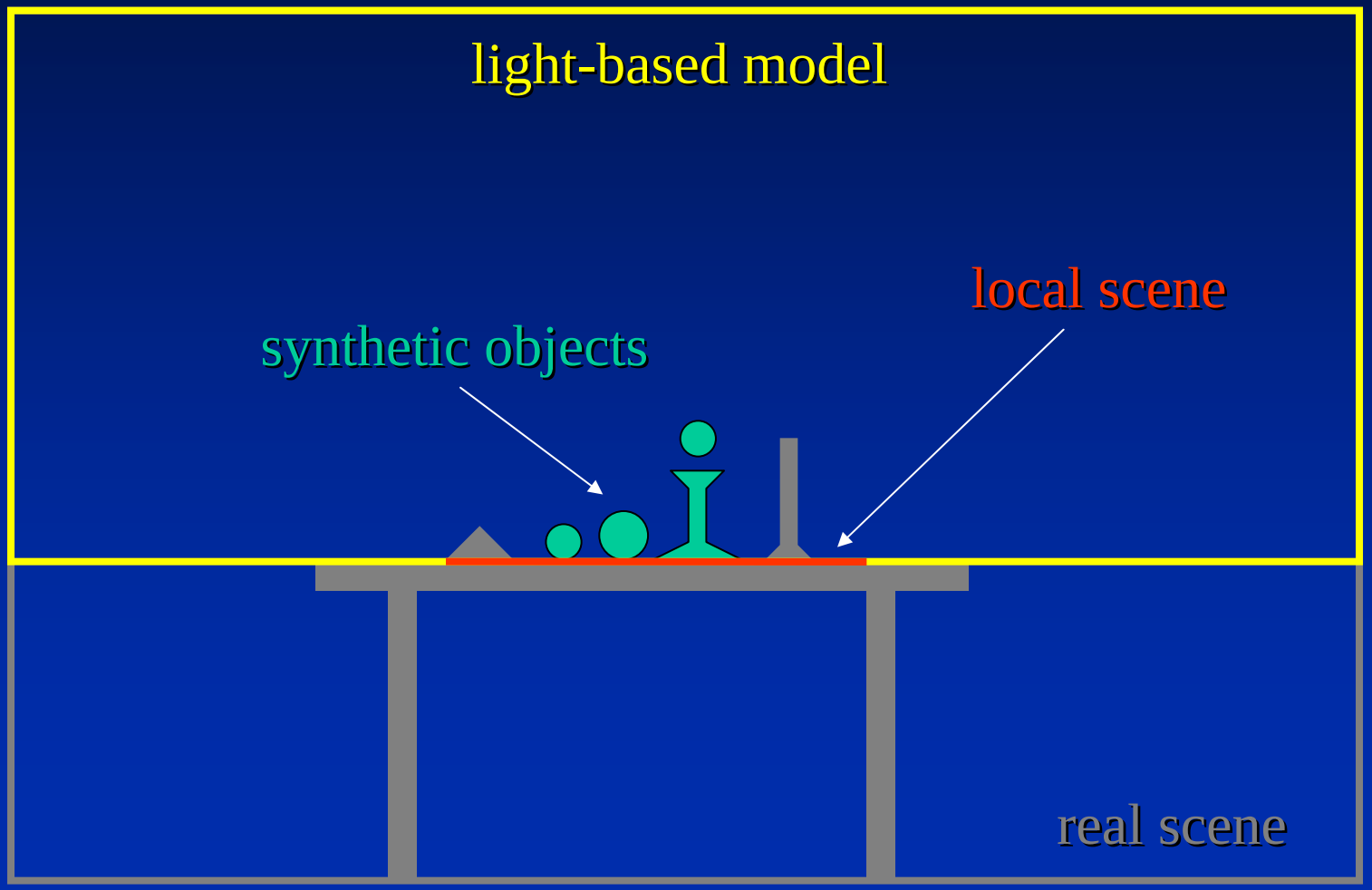


The *Light-Based* Room Model

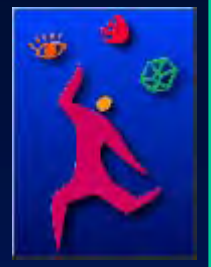


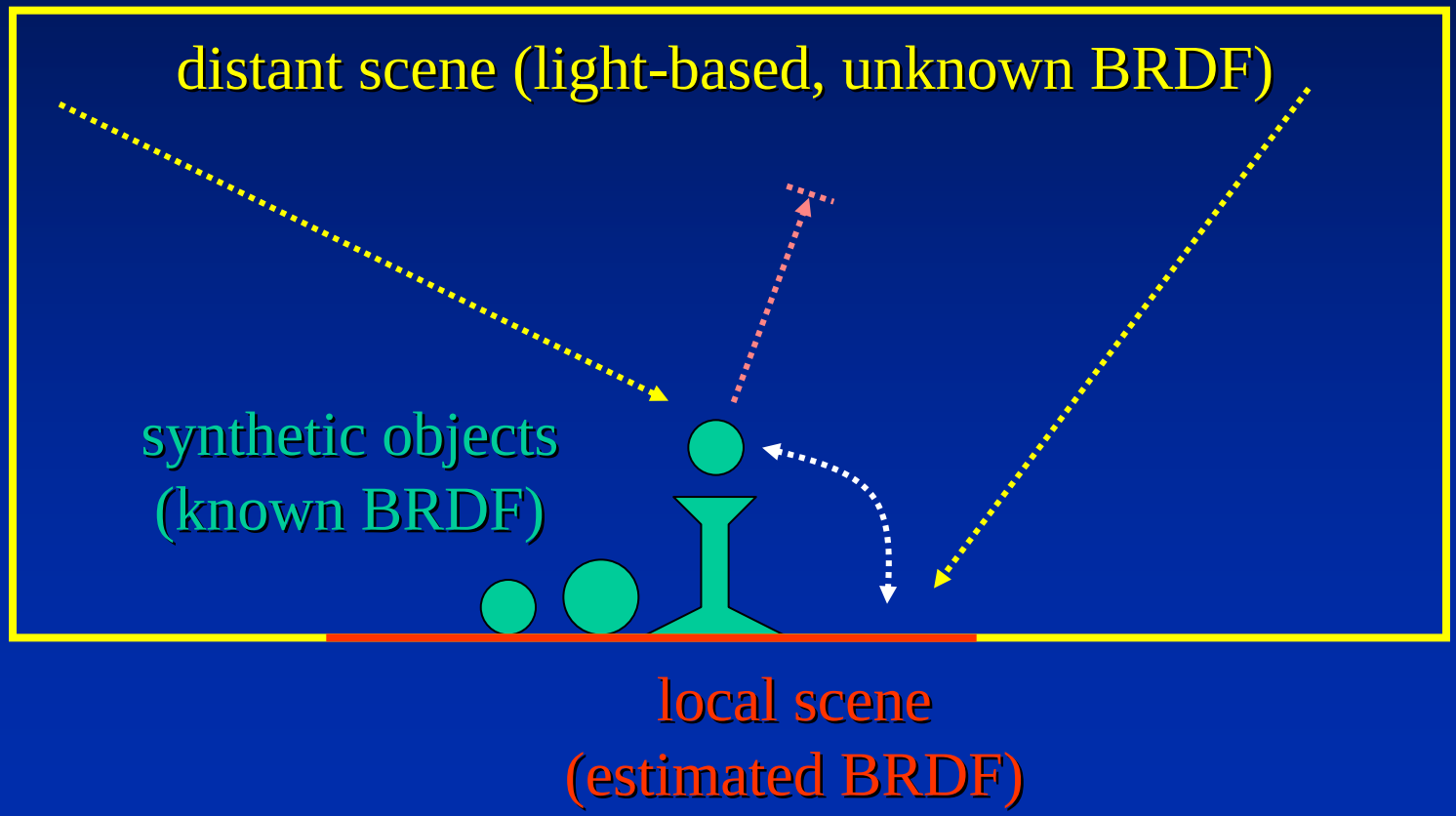


Modeling the Scene



The Lighting Computation





Rendering into the Scene

Background Plate

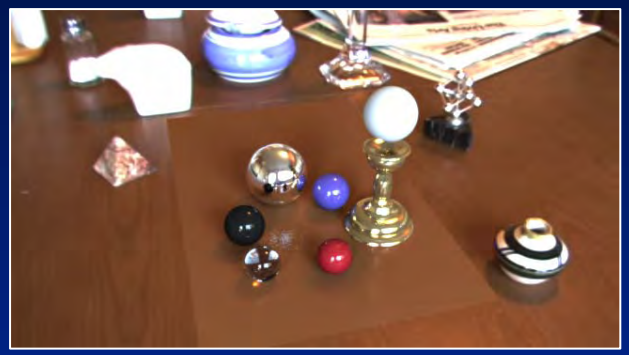
Rendering into the Scene

Objects and Local Scene matched to Scene

Differential Rendering

Local scene w/o objects, illuminated by model

Differential Rendering (2)
Difference in local scene



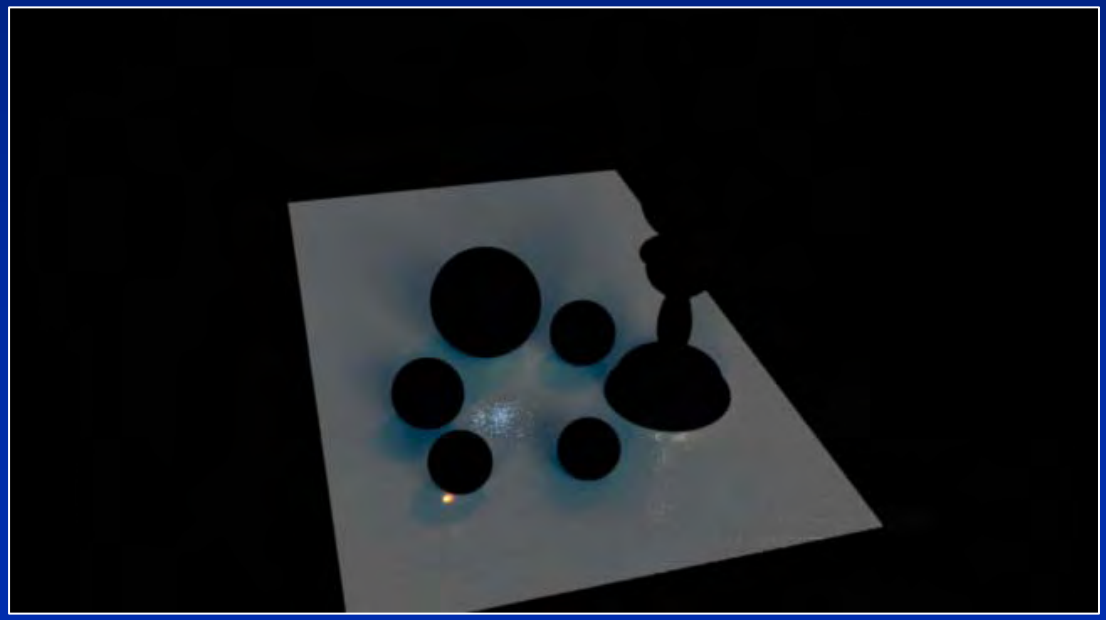


IMAGE-BASED LIGHTING IN *FIAT LUX*

Paul Debevec, Tim Hawkins, Westley Sarokin, H. P. Duiker, Christine Cheng, Tal Garfinkel, Jenny Huang

SIGGRAPH 99 Electronic Theater

HDR Image Series

2 sec

1/4 sec

1/30 sec

1/250 sec

1/2000 sec

1/8000 sec

Stp1
Panorama







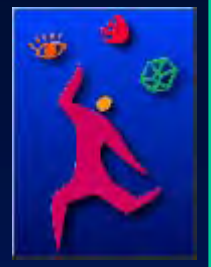



Assembled Panorama

Light Probe Images

Capturing a Spatially-Varying Lighting Environment

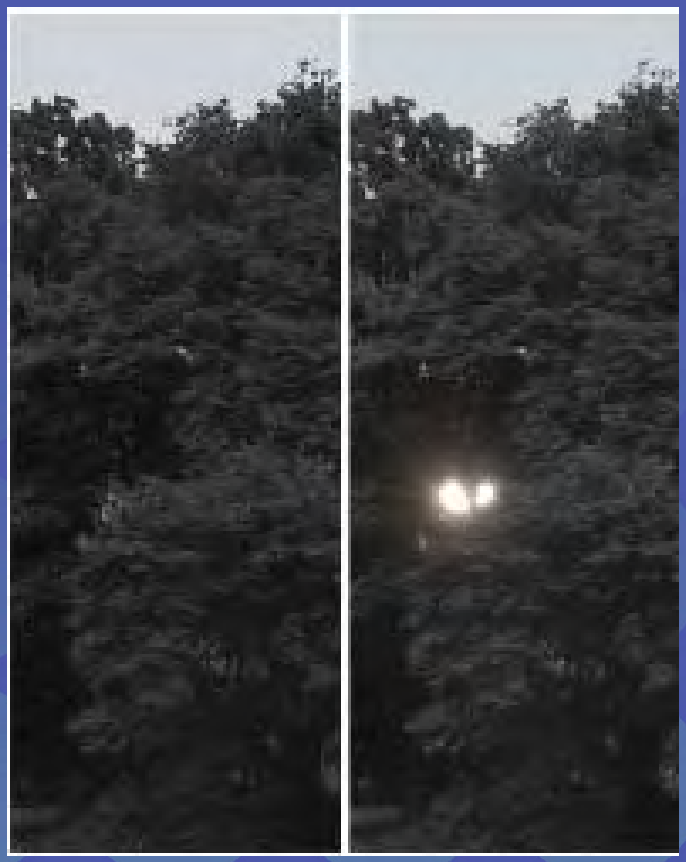
The Movie

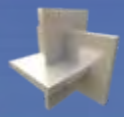


Simulating the Glare in the Human Eye

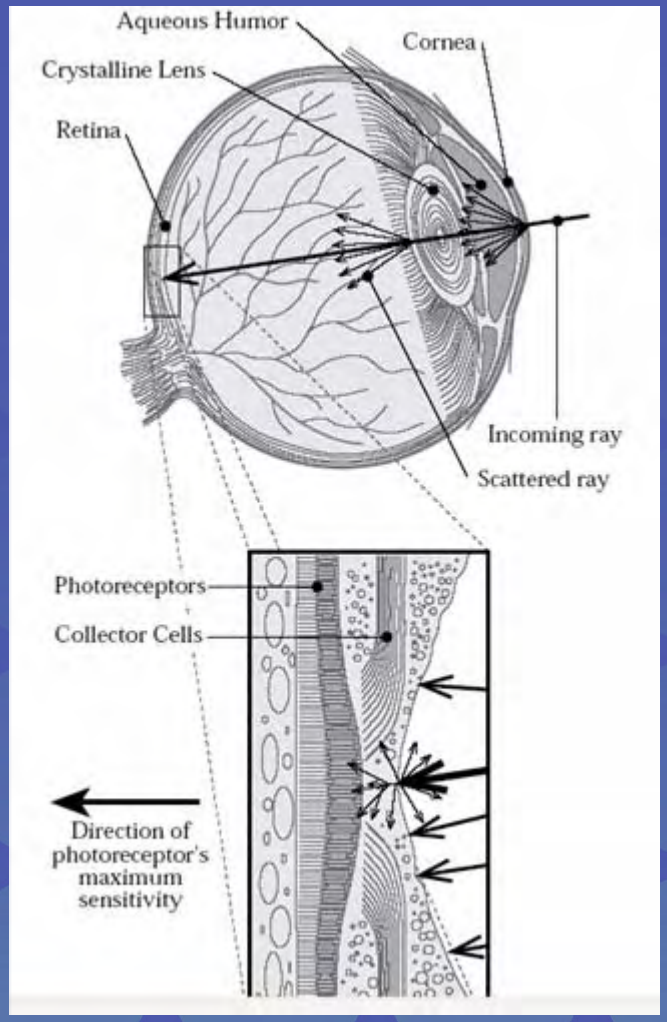
SIGGRAPH2004

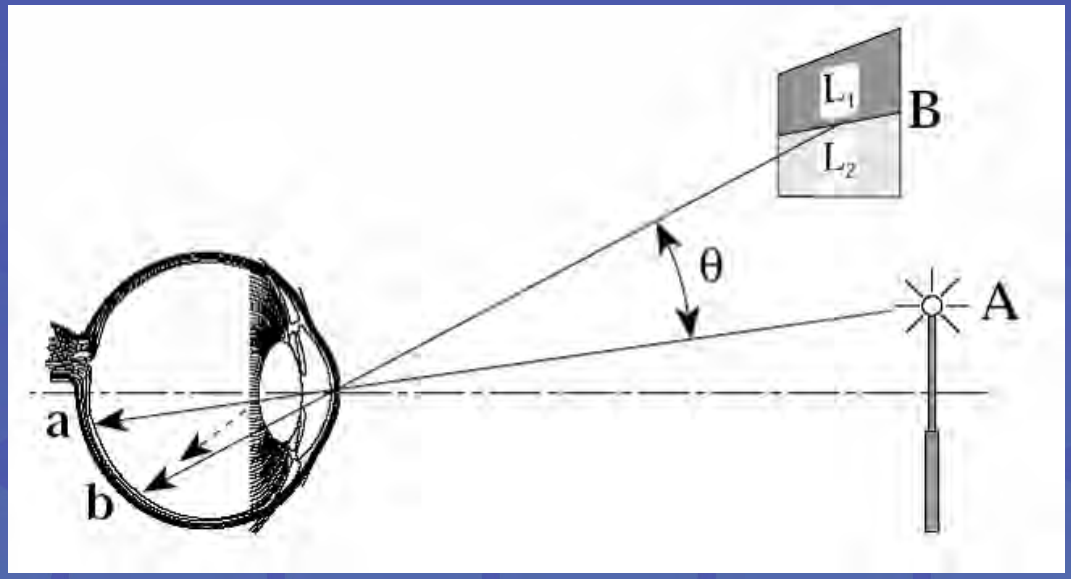
- Greg Spencer, Peter Shirley, Kurt Zimmerman, and Donald Greenberg. Physically-based glare effects for digital images. SIGGRAPH 95.





Scattering in the eye





What's the scattering model?

HDR Image

Gaussian Blur, LDR information Only

Gaussian Blur, Full HDR Information

Full HDR Disc Blur




Frame Postprocessing in Rendering with Natural Light