HDRI and Image-Based Lighting

SIGGRAPH 2003 Course #19

Greg Ward
Anyhere Software

Rod Bogart
Industrial Light and Magic

Paul Debevec
USC ICT

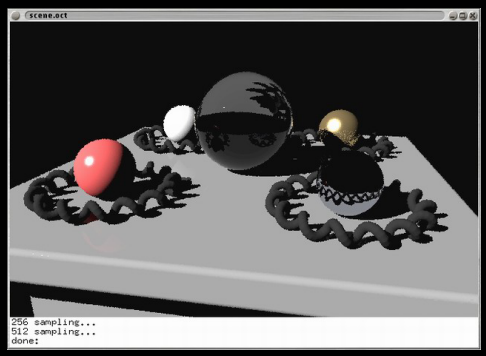
Frank Vitz
Independent VFX Supervisor

SIGGRAPH 2003 SAN DIEGO

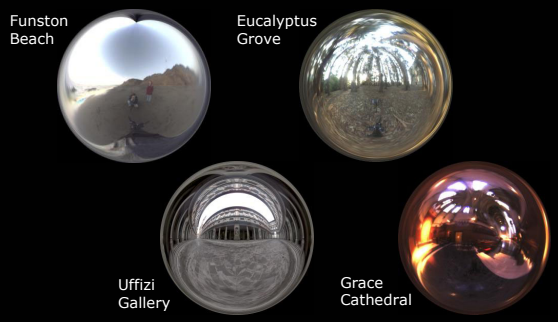
Monday, July 28, 2003
10:30-12:15 and 6:00-8:00

www.debevec.org/IBL2003

What is Image-Based Lighting?

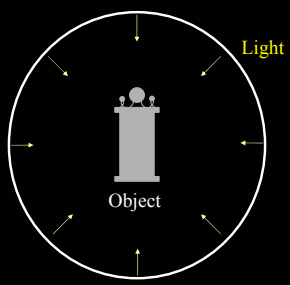


Real-World HDR Lighting Environments



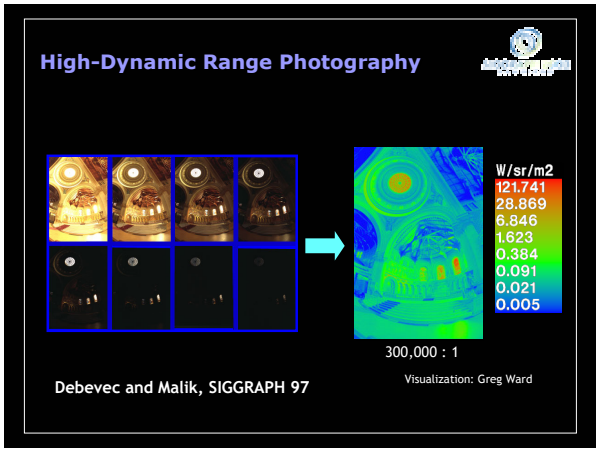
Lighting Environments from the Light Probe Image Gallery:
http://www.debevec.org/Probes/

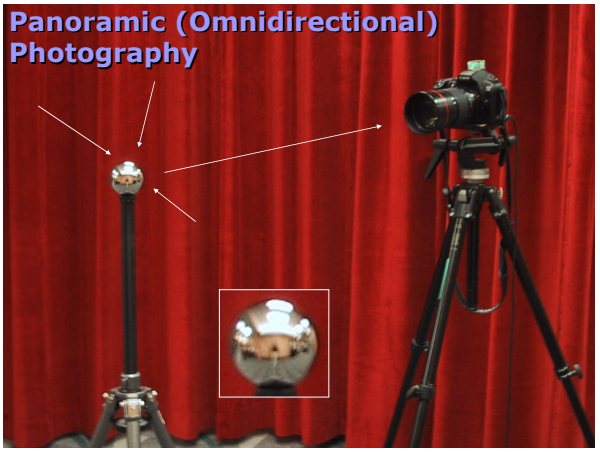
Illuminating Objects using Measurements of Real Light



Environment assigned "glow" material property in Greg Larson's RADIANCE system.

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





Course Schedule
Part I: Fundamentals of HDR and IBL

10:30 Introduction
10:40 Ward
- Global illumination overview
- HDR Image Formats
- HDR Image Display

11:20 Paul Debevec
- Capturing real-world illumination
- Illuminating synthetic objects with real light
- Rendering synthetic objects into real scenes
- Making "RNL" and "Fiat Lux"

12:15 Lunch

Resume at 6pm – same room

Part II: HDR & IBL in Production and Advanced Techniques

6:05 Bogart
- HDR and IBL at Industrial Light + Magic

6:35 Debevec
- Capturing Light Probes in the Sun
- HDRI and IBL at WETA (from Dan Lemmon)

6:55 Vitz
- HDRI and IBL for X-Men 2

7:25 Debevec
- Image Based Lighting Real-World Subjects
  Light Stage 1, 2, and 3

7:45 Q&A
- Bogart, Ward, Debevec, and Vitz

8:00 End

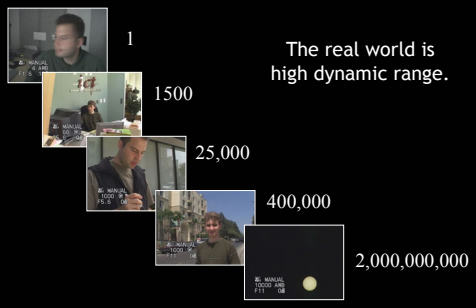
Global Illumination and High Dynamic Range Image File Formats

Greg Ward
Anyhere Software

Capturing Real-World Illumination

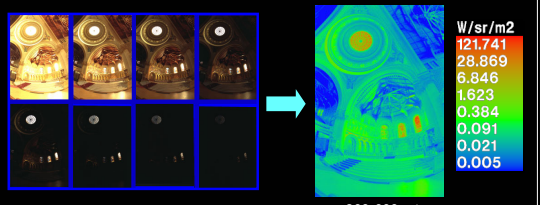
Paul Debevec
USC ICT

Dynamic Range in the Real World



The real world is high dynamic range.

High-Dynamic Range Photography



300,000 : 1

Visualization: Greg Ward

Debevec and Malik, "Recovering High Dynamic Range Radiance Maps from Photographs", SIGGRAPH 97

HDR Shop

High Dynamic Range Image Processing and Manipulation

www.debevec.org/HDRShop

Introduction | Tutorials | Reference | Plugins | FAQ | Download/Licensing | WWW Links | Mailing List

Chris Tchou et al. *HDR Shop*. S2001 Technical Sketch

Ways to vary exposure

- Shutter Speed (*)
- F/stop (aperture, iris)

- Neutral Density (ND) Filters

Methods for taking omnidirectional HDR images

- Mirrored ball + camera
- Fisheye lens images
- Panoramic camera
- Stitching images together

Reflection Mapping - 1982

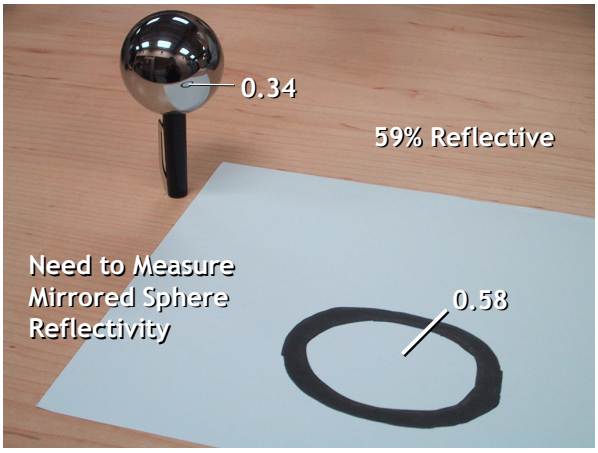
Mike Chou and Lance Williams Gene Miller and Ken Perlin

Today: can perform in real time with graphics hardware

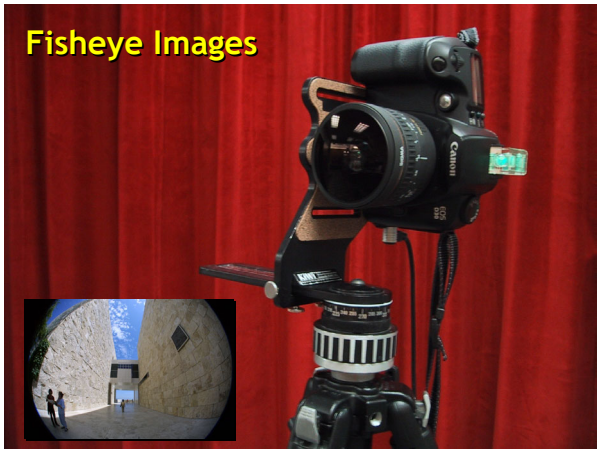
http://www.debevec.org/ReflectionMapping/

Sources of Mirrored Balls

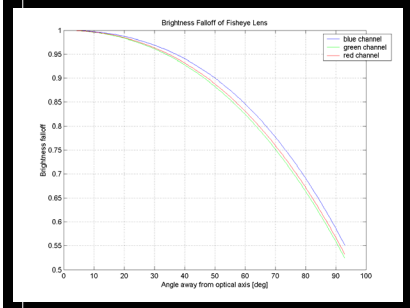
- 2-inch chrome balls ~ $20 ea.
  - McMaster-Carr Supply Company
    www.mcmaster.com
- 6-12 inch large gazing balls
  - Baker's Lawn Ornaments
    www.bakerslawnorn.com
- Hollow Spheres, 2in – 4in
  - Dube Juggling Equipment
    www.dube.com
- FAQ on www.debevec.org/HDRShop



Fisheye Images



Fisheye Lens Radial Falloff



Scanning Panoramic Cameras

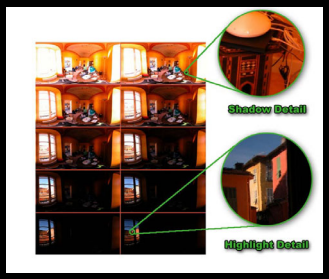
Pros:
- *very* high res (10K x 7K+)
- Full sphere in one scan – no stitching
- Good dynamic range, some are HDR

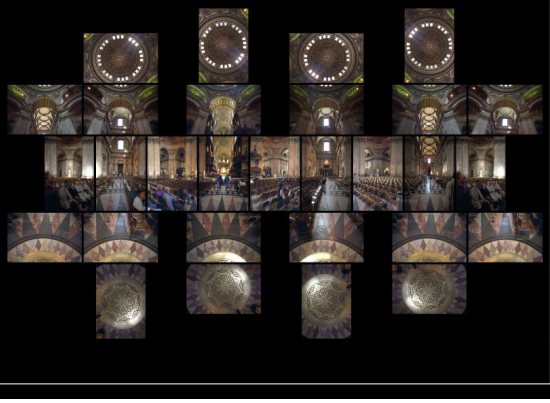
Issues:
- More expensive
- Scans take a while

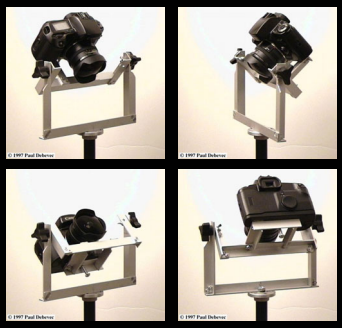
Companies: Panoscan, Sphereon (SIGGRAPH 2003 booth #3340)

Stitching HDRI with Realviz Stitcher

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



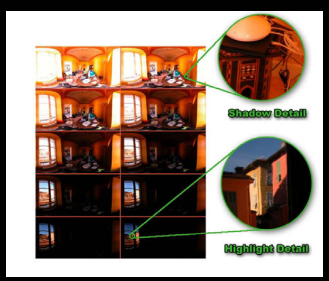


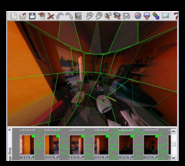


See also www.kaidan.com

Stitching HDRI with Realviz Stitcher

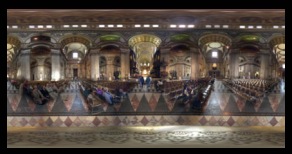
http://www.gregdowning.com/HDRI/stitched/





Types of Omnidirectional Images

Cube Map



Latitude/Longitude

Types of Omnidirectional Images

Mirrored Ball Angular Map

Illuminating Synthetic Objects with Real Light

IBL in Radiance Tutorial

In Jan/Feb 2002 Computer Graphics and Applications and the SIGGRAPH 2003 IBL Course Notes

and

www.debevec.org
under "Publications"

Tutorial

Image-Based Lighting

Paul Debevec
USC Institute for Creative Technologies

This tutorial shows how image-based lighting can illuminate synthetic objects with measurements of real light, making objects appear as if they're actually in a real-world scene.

The basic steps in IBL are:

1. capturing real-world illumination to an omnidirectional, high-dynamic-range image
2. mapping the illumination onto a representation of the environment
3. placing the 3D object inside the environment, and
4. simulating the light from the environment illuminating the computer graphics object.

March/April 2002

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

Putting the probe onto the sphere

```
# Lighting Environment
# specify the probe image and how it is mapped onto
# geometry

void colorpict hdr_env
7 red green blue rnl_probe.hdr angmap.cal u v
0
0

# specify a "glow" material that will use this image hdr_env glow
env_glow 0 0 4 1 1 1 0

# specify a large inward-pointing box for the HDR envir.
!genbox env_glow box 500 500 500 -i | xform -t -250 -18 -250
```

Light Probe Coordinate Mapping

{angmap.cal Convert from directions in the world to coordinates on the angular sphere image

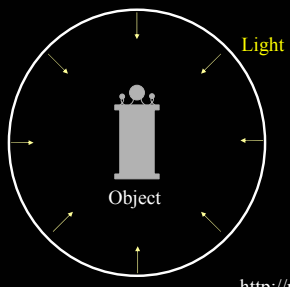
-z is forward (outer edge of sphere)
+z is backward (center of sphere)
+y is up (toward top of sphere)}

```
norm = 1/sqrt(Py*Py + Px*Px + Pz*Pz);
DDy = Py*norm;
DDx = Px*norm;
DDz = Pz*norm;

r = 0.159154943*acos(DDz)/sqrt(DDx*DDx + DDy*DDy);

u = 0.5 + DDx * r;
v = 0.5 + DDy * r;
```

Illuminating Objects using Measurements of Real Light



Environment assigned "glow" material property in Greg Larson's RADIANCE system.

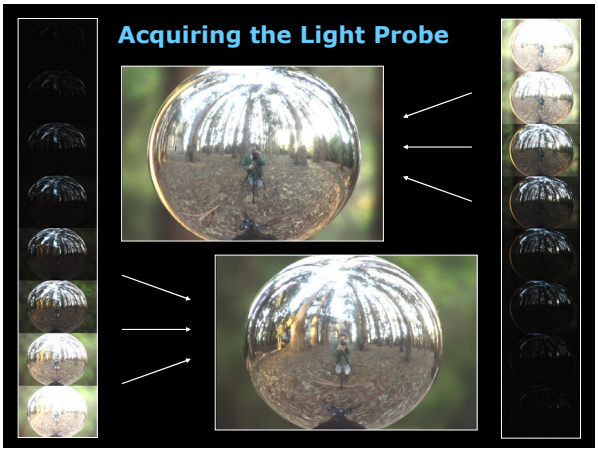
http://radsite.lbl.gov/radiance/

See also: Larson and Shakespeare, "Rendering with Radiance", 1998

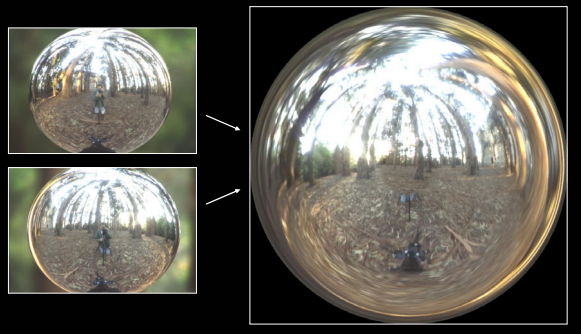
Making *Rendering with Natural Light*

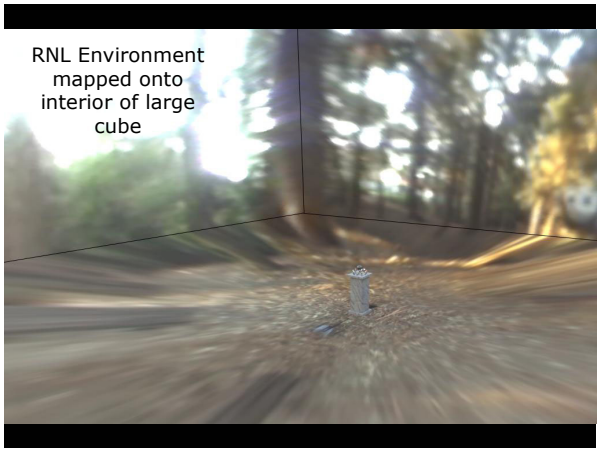
SIGGRAPH 98 Electronic Theater

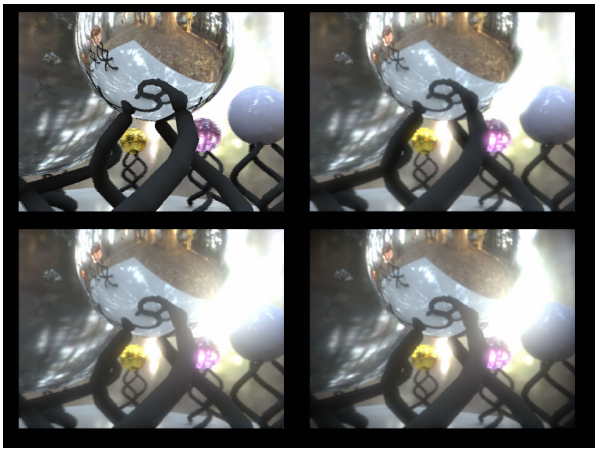
Acquiring the Light Probe



Assembling the Light Probe







Windows Media

Rendering with Natural Light - Movie

Rendering with Natural Light Source Files

This directory contains the original scene files for Paul Debevec's animation 'Rendering with Natural Light' shown at the SIGGRAPH 1998 Electronic Theater in Orlando, Florida.

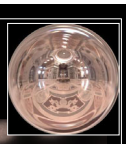
angmap.cal	Angular map equation for mapping light probe to the environment
anim.vf	Animation camera path viewfile
credits.tif	RNL credits card TIF image
genrnpl.sh	Sphere support stand generator script
genrnpls.sh	Central sphere support stand generator script
marble.hdr	Texture map for the pedestal
options	RADIANCE options for rendering the animation
pflare.c	C program for pflare, the HDR image blurring program
pflare	Intel Linux binary for pflare, the HDR image blurring program
rnl_probe.hdr	UC Berkeley Eucalyptus Grove light probe image
rnl_scene.rad	Main scene file for the spheres on the pedestal
texmap0.cal	Texture map equation for mapping marble.hdr onto pedestal
rnl_source.tgz	gzip'ped tar archive of all these files (2,721,019 bytes)

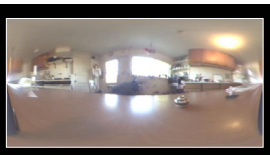
"Rendering with Natural Light" was rendered entirely with Image-Based Lighting captured through High-Dynamic Range Photography in the UC Berkeley Eucalyptus Grove.

To render the animation yourself, follow the following procedure:

www.debevec.org/RNL

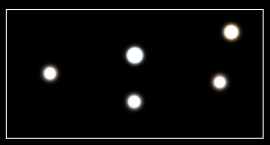
Rendering Light Probes as Light Sources

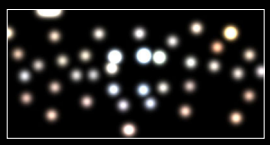


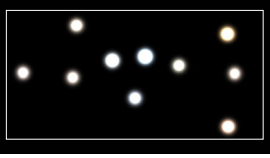


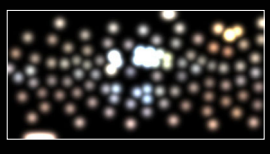
"LightGen" by Jon Cohen et al. at www.debevec.org/HDRShop

Supports Maya, RADIANCE, Mental Ray, Lightwave





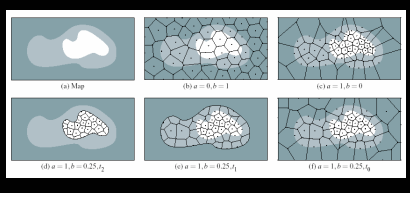


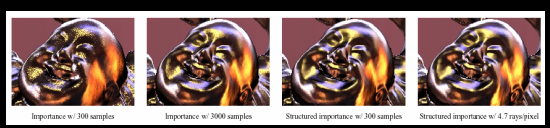


"Structured Importance Sampling of Environment Maps"

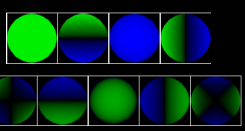
Sameer Agarwal, Ravi Ramamoorthi, Serge Belongie, and Henrik Wann Jensen

Proceedings of SIGGRAPH 2003



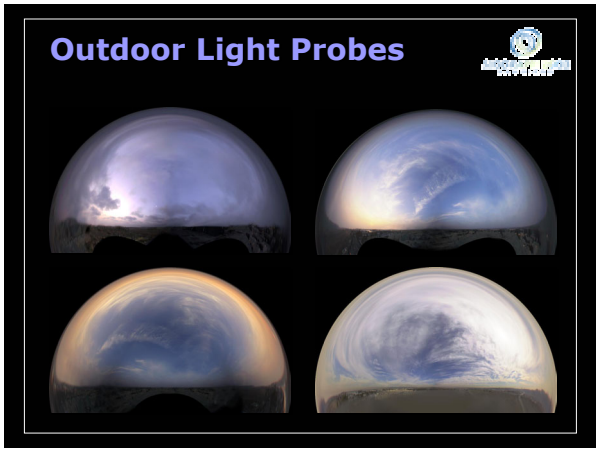


Real-Time IBL with Spherical Harmonics



Frequency Space Environment Map Rendering
Ravi Ramamoorthi, Pat Hanrahan, SIGGRAPH2002

Precomputed Radiance Transfer for Real-Time Rendering in Dynamic, Low-Frequency Lighting Environments
Peter-Pike Sloan, Jan Kautz, John Snyder, SIGGRAPH2002

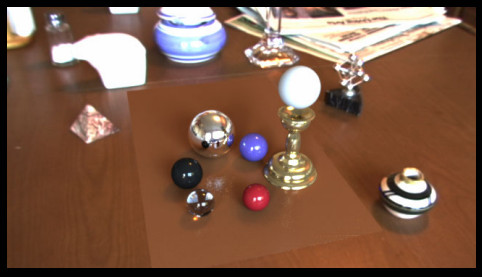

Outdoor Light Probes

Rendering Synthetic Objects into
Real Scenes

Compositing Objects into a Scene

Paul Debevec. *Rendering Synthetic Objects into Real Scenes: Bridging Traditional and Image-Based Graphics with Global Illumination and High Dynamic Range Photography. SIGGRAPH 98.*

Rendering into the Scene

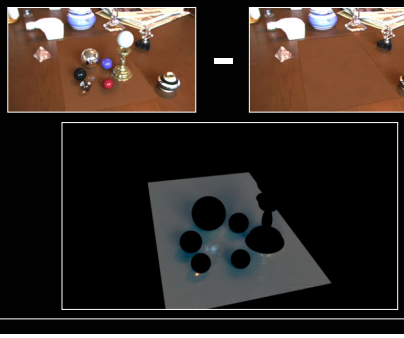


Objects and Local Scene matched to Scene

Differential Rendering

Local scene w/o objects, illuminated by model

Differential Rendering 2



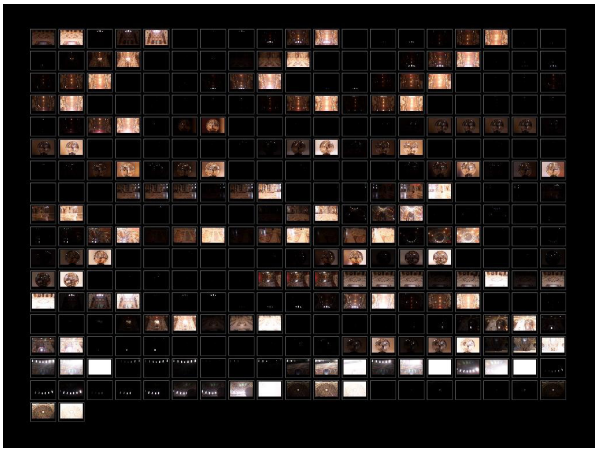
Differential Rendering 3

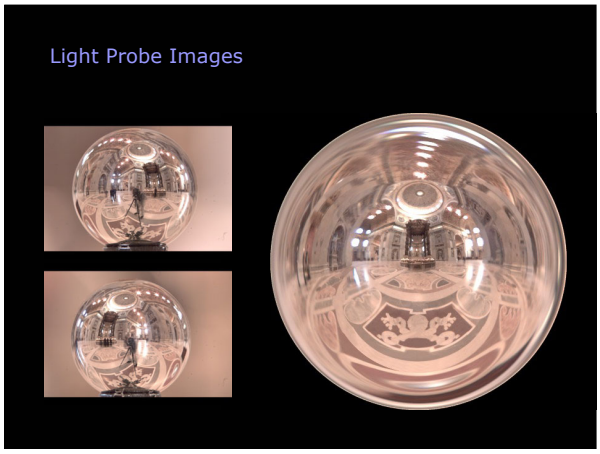
Final Result

Windows Media

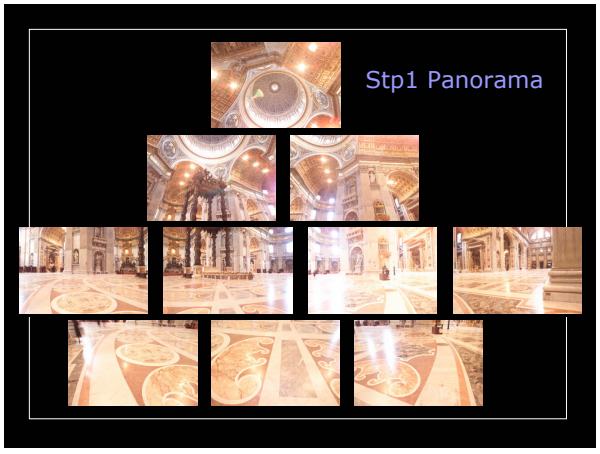
Table Domino Animation

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




Light Probe Images

HDR Image Series
2 sec
1/4 sec
1/30 sec
1/250 sec
1/2000 sec
1/8000 sec


Stp1 Panorama

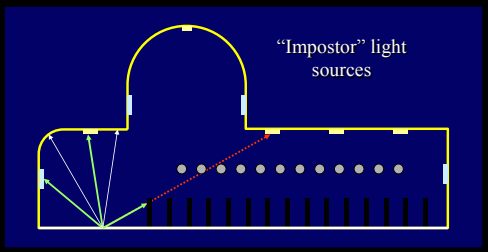
Assembled Panorama

Fiat Lux - Shot Breakdown

Assembled Panorama

Identified Light Sources

Lighting Calculation

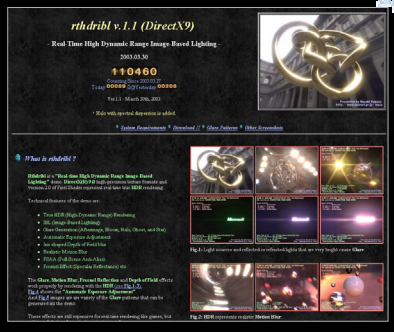


Renderings made with Radiance: http://radsite.lbl.gov/radiance/

Fiat Lux - Movie

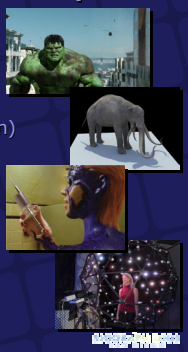
RNL in Real Time!

Masaki Kawase RT HDR/IBL Demo



http://www.daionet.gr.jp/~masa/

Part II: HDR & IBL in Production and Advanced Techniques 6 – 8pm



Rod Bogart
HDR and IBL at ILM

Paul Debevec
Capturing Light Probes in the Sun
HDRI and IBL at WETA (Dan Lemmon)

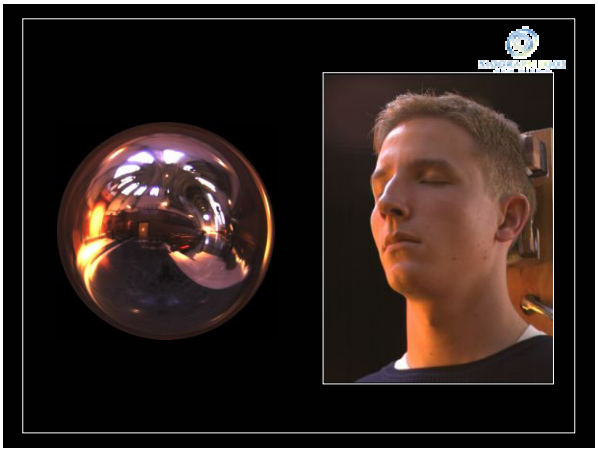
Frank Vitz
HDRI and IBL for X-Men 2

Paul Debevec
IBL for Real-World Subjects
Light Stage 1, 2, and 3

Q&A

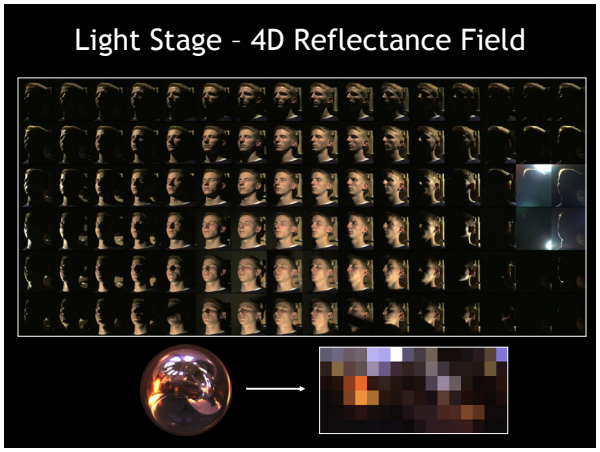
www.debevec.org/IBL2003

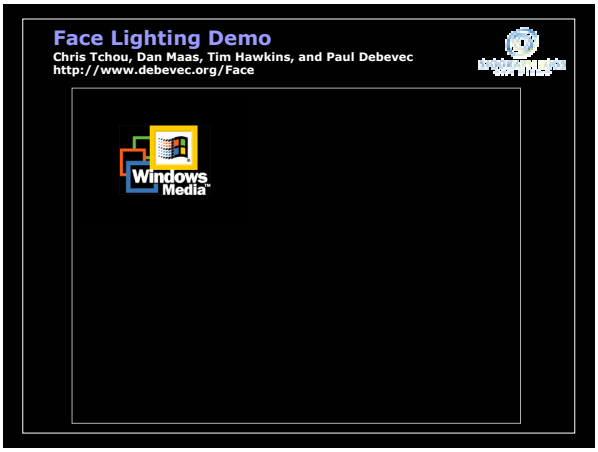
Image-Based Lighting Real Objects and Actors

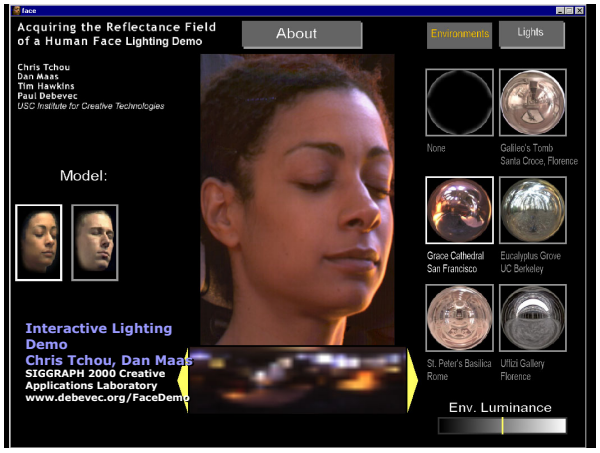


Light Stage 1.0

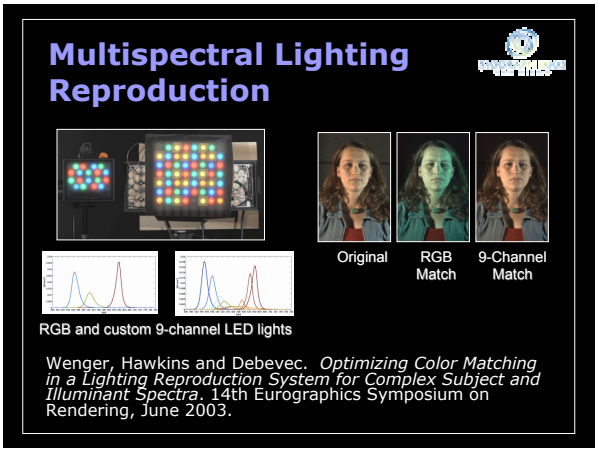
Debevec, Hawkins, Tchou, Duiker, Sarokin, and Sagar. *Acquiring the Reflectance Field of a Human Face*. SIGGRAPH 2000.


Light Stage - 4D Reflectance Field


Face Lighting Demo
Chris Tchou, Dan Maas, Tim Hawkins, and Paul Debevec
http://www.debevec.org/Face
Windows Media


face
Acquiring the Reflectance Field of a Human Face Lighting Demo
About
Environments
Lights
Chris Tchou
Dan Maas
Tim Hawkins
Paul Debevec
USC Institute for Creative Technologies
Model:
None
Galileo's Tomb Santa Croce, Florence
Grace Cathedral San Francisco
Eucalyptus Grove UC Berkeley
St. Peter's Basilica Rome
Uffizi Gallery Florence
Interactive Lighting Demo
Chris Tchou, Dan Maas
SIGGRAPH 2000 Creative Applications Laboratory
www.debevec.org/FaceDemo
Env. Luminance

A Lighting Reproduction Approach to Live-Action Compositing
Paul Debevec Andreas Wenger Chris Tchou
Andrew Gardner Jamie Waese Tim Hawkins
USC Institute for Creative Technologies


Multispectral Lighting Reproduction
Original
RGB Match
9-Channel Match
RGB and custom 9-channel LED lights
Wenger, Hawkins and Debevec. Optimizing Color Matching in a Lighting Reproduction System for Complex Subject and Illuminant Spectra. 14th Eurographics Symposium on Rendering, June 2003.

Thanks!
Light Stage 1
Chris Tchou
Tim Hawkins
Westley Sarokin
HP Duiker
Mark Sagar
Light Stage 2
Tim Hawkins
Andrew Gardner
John Biondo
Jonathan Cohen
George Randal
Light Stage 3
Andreas Wenger
Andrew Gardner
Chris Tchou
Tim Hawkins
Maya Martinez
ILF / LLS
Jonas Unger
Andrew Gardner
Chris Tchou
Tim Hawkins
Modeling and Animation
Brian Emerson
Mark Brownlow
Westley Sarokin
HP Duiker
"Arnold" Rendering Software: Marcos Fajardo
RADIANCE Rendering Software: Greg Ward
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