Image-Based Lighting

A Photometric Approach to Rendering and Compositing

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August 1999

http://www.cs.berkeley.edu/~debevec

Reflection Mapping - 1982

Mike Chou and Lance Williams
Gene Miller and Ken Perlin

http://www.CS.Berkeley.EDU/~debevec/ReflectionMapping/

http://www.cs.berkeley.edu/~debevec/IBMR

99
Motivations

Image-Based Modeling and Rendering
- IBMR allows us to model and render real scenes
- We want to add new objects
  - buildings, furniture, people
- We want the lighting to be correct

CGI / Background Plate Compositing
- Want to add synthetic actors, creatures, props to film and video
- Must be photorealistic
- Current techniques are challenging

CGI / Background Plate Compositing

Need to match:
- Camera Parameters
  - Pose, Focal length, Distortion, Focus
- Film Response
  - Contrast, Toe & Shoulder, Color Balance
- MTF / Film Grain
  - Modulation Transfer Function, Ag Particles
- Illumination
  - Highlights, Reflections, and Shadows
Photometric Approach:

Illuminate Synthetic Objects with Measurements of Real Light

How can we measure the light?

Light is difficult to measure

Concentrated Light Sources => High Dynamic Range

10’ x 15’ x 9’ room, 9” by 9” light, 50% reflective walls

10,000

50,000

100
Mirrored Ball -
Records light in all directions

Brightest regions are saturated
Intensity and color information lost

kitchen scene

High Dynamic Range Photography
Debevec and Malik, SIGGRAPH 97

Image series

\[ \Delta t = \frac{1}{64} \text{ sec} \]
\[ \Delta t = \frac{1}{16} \text{ sec} \]
\[ \Delta t = \frac{1}{4} \text{ sec} \]
\[ \Delta t = 1 \text{ sec} \]
\[ \Delta t = 4 \text{ sec} \]

Exposure = Radiance \times \Delta t
\[
\log \text{Exposure} = \log \text{Radiance} + \log \Delta t
\]
Recovering the Response Curve

"mkdhr" beta package available at:
http://www.cs.berkeley.edu/Research/HDR

Assuming unit radiance for each pixel

After adjusting radiances to obtain a smooth curve

High-Dynamic Range Photography

"mkdhr" beta package available at:
http://www.cs.berkeley.edu/Research/HDR

300,000 : 1
Representing High Dynamic Range Radiance Images

\[ (145, 215, 87, 149) = (145, 215, 87) \times 2^{(149 - 128)} = (1190000, 1760000, 713000). \]

\[ (145, 215, 87, 103) = (145, 215, 87) \times 2^{(103 - 128)} = (0.00000432, 0.00000641, 0.00000259). \]

Radiance Map from the Mirrored Ball

Assembled from ten digital images,
\[ \Delta t = 1/4 \text{ to } 1/10000 \text{ sec} \]
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

Illumination Results
Comparison: Radiance map versus single image
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

light-based model

real scene

The *Light-Based* Room Model
Modeling the Scene

- **light-based model**
- **synthetic objects**
- **local scene**
- **real scene**

The Lighting Computation

- **distant scene (light-based, unknown BRDF)**
- **synthetic objects (known BRDF)**
- **local scene (estimated BRDF)**
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

http://www.cs.berkeley.edu/~debevec/IBMR
Differential Rendering (3)

Final Result

http://www.cs.berkeley.edu/~debevec/IBMR
Estimating the local scene material properties

- Necessary for correct shadows and reflections
- For each part of the local scene, we know its irradiance from the light-based model
- If the material is diffuse, its albedo is its radiance divided by its irradiance
- Non-diffuse properties can be estimated by iterative methods or specified by hand
- See: Ward92, Karner20, Dana97, Sato97, Yu98, Debevec98, Yu99

Video

Domino animation rendered by Son Chang and Christine Waggoner
Reflectance Properties for a Whole Scene: Inverse Global Illumination

Yizhou Yu, Paul Debevec, Jitendra Malik, Tim Hawkins
SIGGRAPH 99, Thursday, 11:50-12:15pm, West Hall A

40 radiance maps of a room

Recovered Geometry and Viewpoints

http://www.cs.berkeley.edu/~Debevec/IBMR
Real/Synthetic Comparison
Same viewpoints, Same lighting, Same objects

Real/Synthetic Comparison
New viewpoint, New lighting, New object
Communicating the sense of Brightness

- **Fade In / Fade Out**
  - Bright areas appear first / fade last

- **Motion Blur**
  - Bright areas leave streaks

- **Blur / Glare / Soft Focus**
  - Bright areas blossom

- **Radial Light Falloff (Vignetting)**
  - Bright areas sear through corners

- **Color tinting**
  - Bright areas still ramp to white

RNL Example

Renderer Output
RNL Example

Defocus & Glare Added

RNL Example

Soft Focus Added
RNL Example

Light Falloff (Vignetting) Added

Motion Blur

Normal digitized photo  Synthetic blur added
Motion Blur

Blurred radiance map, virtually rephotographed

Actual blurred photograph

Color Tinting Example

Input Intensity
Output Color

http://www.cs.berkeley.edu/~debevec/IBMR
Video

Interior Illumination Model
St. Peter’s Basilica for “Fiat Lux”

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

http://fiatlux.berkeley.edu/

http://www.cs.berkeley.edu/~debevec/IBMR
Interior of St. Peter’s from one Viewpoint

http://fiatlux.berkeley.edu/

Related Sketches

The Making of “Fiat Lux”
Wednesday 11 August, 5:25pm - 6:00pm, Room 151 / 152

Image-Based Modeling, Rendering, and Lighting in “Fiat Lux”
Friday 13 August, 11:40am - 12:15pm, Room 408AB