Deep Shadows in a Shallow Box

Xiang Huang,
Ankit Mohan and Jack Tumblin
Northwestern University

(a) Captured Image
(b) Computed Image
(c) Weighting Coefficients
Image Based Relighting (IBR) - Video

Acquisition Basis Images for IBR

object

Basis Images

Capturing of Basis Images

[Debevec et al. 2000]

[Debevec et al. 2002]

[Matusik et al. 2002]

[Malzbender et al. 2002]

[Winnemöller et al. 2005]

[Debevec et al. 2006]
Our Light Stage: Card-board
Our Light Rig: Outside
Our Light Rig: Outside

Camera
Our Light Rig: Inside
Our Light Rig: Inside

Object

Disco Light
Our Light Rig: Inside
Replace Object with a Mirror Ball
Mirror Ball Image 1
Mirror Ball Image 2
Voronoi Partition
Captured Image is a Weighted Sums of Deep Shadow Images: \( Ax = b \)

\[
\begin{bmatrix}
1 & 0.009 & \ldots & 0.008 \\
0.011 & 1 & \ldots & 0.010 \\
\vdots & \vdots & \ddots & \vdots \\
0.012 & 0.011 & \ldots & 1
\end{bmatrix}
\begin{bmatrix}
? \\
? \\
? \\
? \\
\end{bmatrix}
= 
\begin{bmatrix}
\vdots \\
\vdots \\
\vdots \\
\vdots \\
\end{bmatrix}
\]

Lighting Matrix

Deep Shadow Images

Captured Images
Remove Ambient Light: \( x = A^{-1}b \)

\[
\begin{bmatrix}
1 & 0.009 & \cdots & 0.008 \\
0.011 & 1 & \cdots & 0.010 \\
\vdots & \vdots & \ddots & \vdots \\
0.012 & 0.011 & \cdots & 1
\end{bmatrix}
\begin{bmatrix}
\begin{align*}
\text{Deep Shadow} \\
\vdots \\
\text{Captured}
\end{align*}
\end{bmatrix}
= \begin{bmatrix}
\begin{align*}
\text{Lighting Matrix}
\end{align*}
\end{bmatrix}
\]
HDR for High Contrasts

(a) Long exposure 1 second
(b) Short exposure 0.05 second
Deep Shadow Image
Histogram Equalized Image
Field Museum Moche Pots (100-800AD, Peru...)

Courtesy Mary Weismantel, Northwestern University, Field Museum
Open Questions and Future Work

- Direct Physical Verification?
- Area vs. Point light?
- Light Shapes?
Thank you!

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Compute Light Direction $(\theta, \phi)$

(a) Compute $\theta$

\[
\begin{align*}
u &= d \cos \theta \\
v &= d \sin \theta
\end{align*}
\]

(b) Compute $\Phi$

\[
\phi = 2\alpha = 2 \arcsin \left(\frac{d}{R}\right)
\]
Inverse L to Remove Ambient Light

- Linear Additive Principle

\[ I = \sum_{i=1}^{N} R^{(i)} L^{(i)} \ldots \ldots (1) \]

- Total energy received on a sensor pixel
- Light energy from direction i
- Reflectance field on direction i
- \( R^{(i)} \) the image lit ONLY from direction i
**Our Solution**

- **Matrix Inverse to compute R**

\[ I = \sum_{i=1}^{N} R^{(i)} L^{(i)} \ldots \ldots (1) \]

\[
\begin{bmatrix}
L_1^{(1)} & L_1^{(2)} & \cdots & L_1^{(N)} \\
L_2^{(1)} & L_2^{(2)} & \cdots & L_2^{(N)} \\
\vdots & \vdots & \ddots & \vdots \\
L_N^{(1)} & L_N^{(2)} & \cdots & L_N^{(N)}
\end{bmatrix}
\begin{bmatrix}
R^{(N)} \\
R^{(N)} \\
\vdots \\
R^{(N)}
\end{bmatrix} =
\begin{bmatrix}
I_1 \\
I_2 \\
\vdots \\
I_N
\end{bmatrix}
\]

- \( L_j^{(i)} \) light from direction i in image j

- **Compute each pixel, each color channel separately**