Data-intensive Image based Relighting

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Outline

1. Motivation
2. Data-intensive IBRL
   - Introduction
   - Our Approach
   - Results
   - Conclusion

Overview

1 Motivation

2 Data-intensive IBRL
- Introduction
- Our Approach
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- **PHOTOREALISM**
- Traditional CG techniques :
  1. Build a detailed 3D model (geometry)
     - Very time-consuming to specify the *realistic* 3D model
  2. Specify the reflectance characteristics
     - Accurate specification of reflectance properties is difficult
  3. Specify lighting configurations
     - Difficult to specify lighting and reflection conditions
  4. Global Illumination (GI) techniques like Radiosity, Ray Tracing are computationally intensive
- So... **Image Based Rendering !**

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Motivation(contd.)

- Photorealism: Images capture all effects
- Image Synthesis - independent of scene complexity
- Collection of samples easy and cheap

Limitations

Inherent rigidity of images being static !

- Dynamics in CG has been of keen interest to scientists
- Lighting changes is *one* way
  - Relit real/artificial scenes from novel illumination captured in natural/synthetic environments
- Traditional CG techniques apply computationally-intensive GI techniques for recomputing the scene
- Image Based Relighting ?

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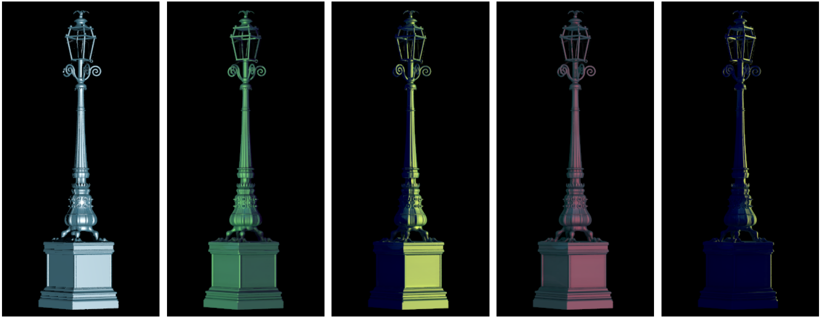
Image-based Relighting



Advantages ?

- Controlling illumination improves recognition and satisfaction
- Saves artist/animator's enormous time and effort to achieve realistic environments and animations
- Applications range from movies and interactive computer games to augmented reality
- Step closer to realizing image-based entities as **rendering primitives** !

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Problem Statement

Image-based Relighting:

Given images of a scene captured under a certain set of illumination conditions, how to render the scene under a novel illumination configuration ?

Overview

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Introduction

- Pre-rendering (synthetic scenes) or pre-acquisition (real scenes) of a collection of images in which the lighting direction is systematically varied.
- Due to linearity of scene radiance, images of the scene under novel illumination can be computed by superposition of synthesized/captured images.
- Issue: Collection of images is typically too large both to store in memory and to synthesize novel images fast.

Contribution

A two-stage image-based algorithm for fast relighting.

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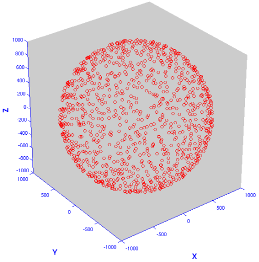
Input/Output

Input

A set of reference images with the same viewpoint, but under different lighting directions sampled uniformly on a sphere.



Output

Given a new lighting configuration, compute a novel relit image.

Related Work

- **Two-Stage Singular Value Decomposition [NBB04]**
  - Uses first level SVD to factorize the original image data into two factors. Then apply SVD again to factorize one of the factors (compute in previous SVD) into another two factors. These three factors are used for relighting.
  - Advantages: Harness both inter and intra pixel correlations. Optimal solution, so good results.
  - Issues: Store too much data (two sets of basis functions and a set of coefficients).
- **Illumination Adjustable Images (IAI) [WL03]**
  - Uses Spherical Harmonics (SH) to model each pixel along the lighting domain. Given a new lighting direction, uses the computed SH coefficients for relighting.
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Overview

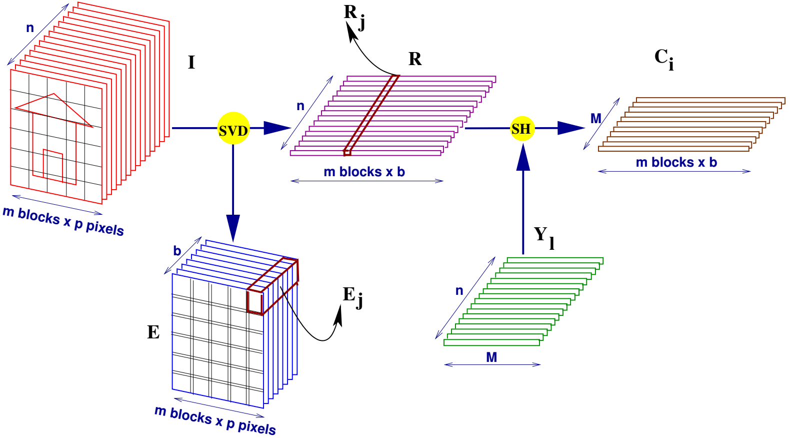
Our Approach

1. First, exploiting the correlation among pixels of an image, compute a set of image bases and their corresponding relighting coefficients using SVD.
2. Second, exploiting the coherence among the computed relighting coefficient, compute a reduced set of SH relighting coefficients.

Stage 1

- Using **SVD**, factorize the set of images ($\mathbf{I}$) i.e., $\mathbf{I} = U * W * V$.
- Compute a rank b approximation.
- Split the singular values into two halves (taking square roots) and multiply them to U and V. So,
- $\mathbf{I} \approx \mathbf{R} * \mathbf{E}$.
- $\mathbf{R}$ and $\mathbf{E}$ are termed the **SVD relighting coefficients** and **eigen image bases** respectively.

Modeling


n
I
m blocks x p pixels
SVD
R_j
R
n
m blocks x b
b
E
E_j
m blocks x p pixels
SH
C_i
M
m blocks x b
Y_l
n
M

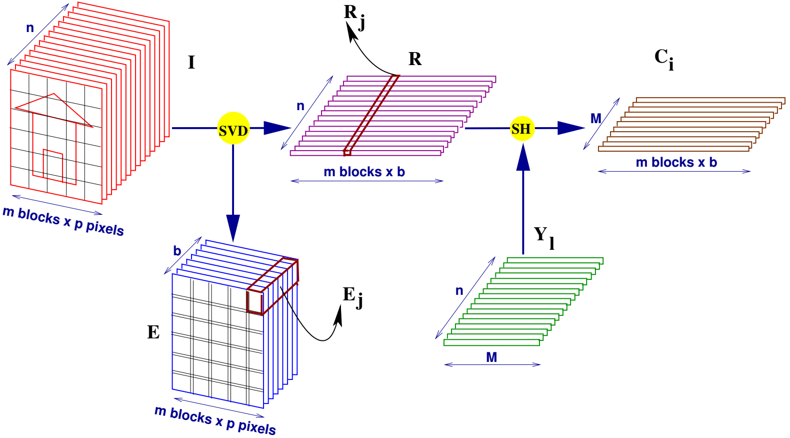
Stage 2

- Model the SVD relighting coefficients ($\mathbf{R}$) using **SH**.

$$\mathbf{C}_{l,m} = \int_0^{2\pi}\int_0^{\pi} \mathbf{R} * Y_{l,m}(\theta,\phi) * \sin\theta * d\theta * d\phi$$

  where $\mathbf{C}_{l,m}$ are the **SH relighting coefficients**, n is the number of lighting directions in the illumination space (θ, ϕ) and $Y_{l,m}$ is the SH function.
- Compute a degree l approximation.

Modeling

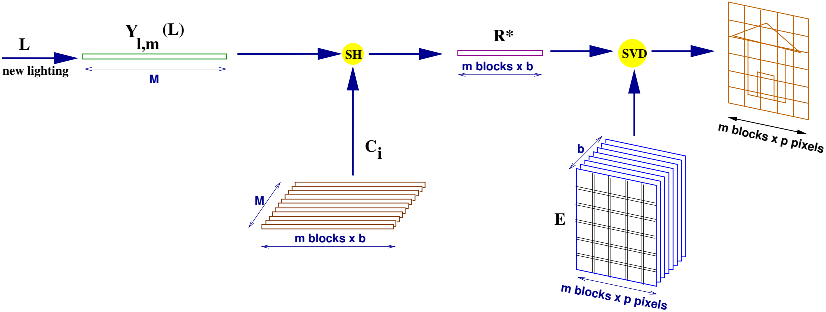

n
I
m blocks x p pixels
SVD
R
j
R
n
m blocks x b
SH
C
i
M
m blocks x b
b
E
m blocks x p pixels
E
j
Y
l
n
M

Relighting

Given a new light source $L(\theta', \phi')$, calculate

- Compute the SH functions $Y_{l,m}(\theta', \phi')$.
- Compute the product $\mathbf{C}_{l,m} Y_{l,m}(\theta', \phi')$, the **reconstructed relighting coefficients** $(\mathbf{R}^*)$.
- Compute the product of the **reconstructed relighting coefficients** and the **eigen image bases** $(\mathbf{R}^* * \mathbf{E})$, which is the novel relit image.

Relighting


L
new lighting
Y l,m (L)
M
SH
Ci
M
m blocks x b
R*
m blocks x b
SVD
b
E
m blocks x p pixels
m blocks x p pixels

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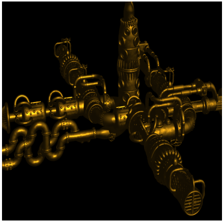
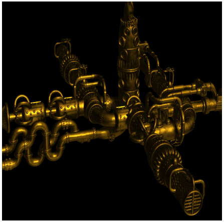
Results

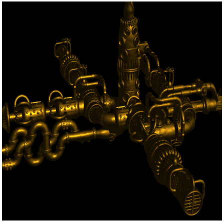
Relighting *PipeSet* under a novel illumination.

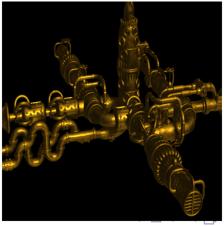


Original



Our Algorithm



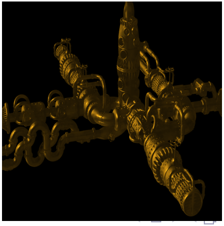


Results

Relighting *PipeSet* under a different novel illumination.

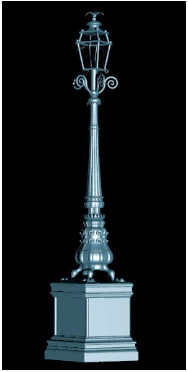
Original

Our Algorithm

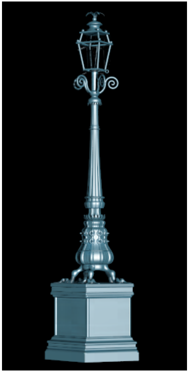


Results

Relighting *LampPost* under novel illumination.



Original



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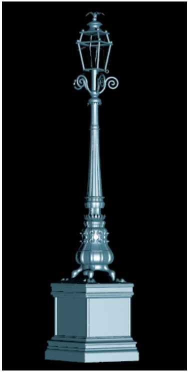
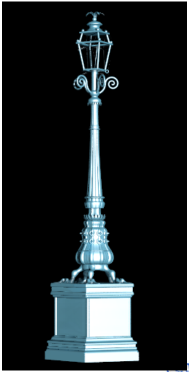


Two-Stage SVD



IAI

Results

Relighting *LampPost* under a different novel illumination.

Original

Our Algorithm

Two-Stage SVD

IAI

Results

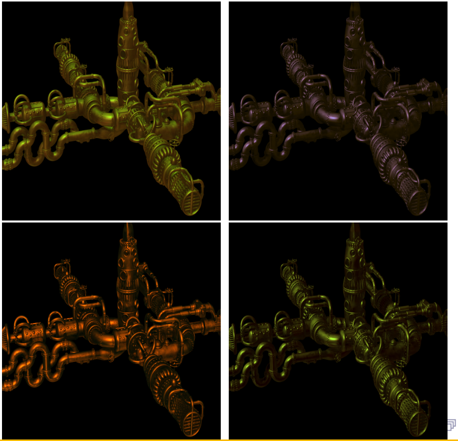
Relighting *Knight-kneeling* under a different novel illumination.

Original

Our Algorithm

Results

Relighting using one or more novel light sources, with different intensity and color.



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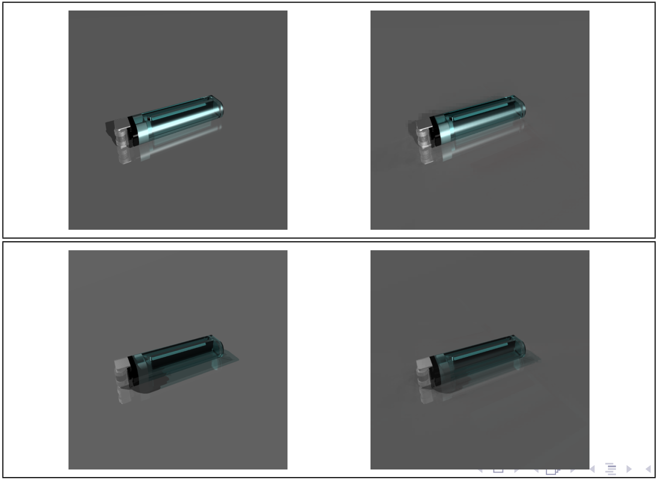
Results

Relighting *Lighter* under novel illuminations.



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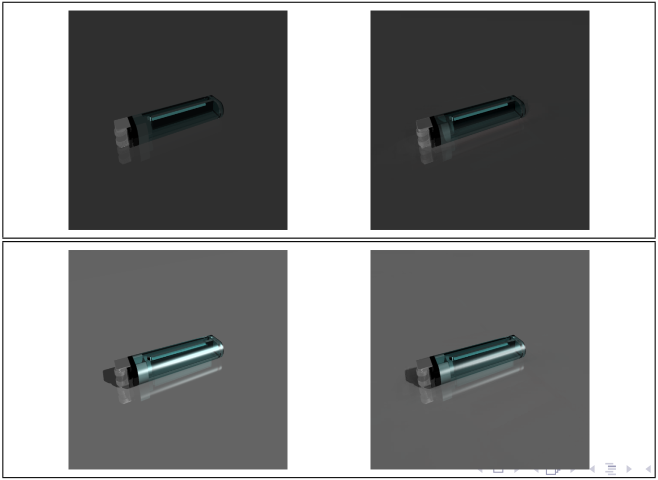
Relighting *Lighter* under novel illuminations.



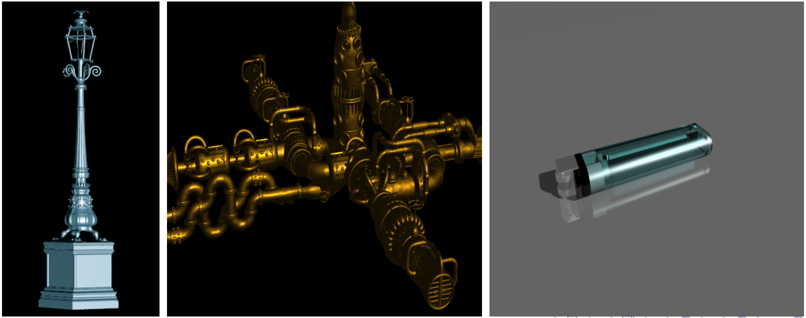
Results

	Our Algorithm			Two-Stage SVD			IAI		
	Size	Pre-P.	Relight	Size	Pre-P.	Relight	Size	Pre-P.	Relight
LampPost 1	130	4206.3	7.2	477	3736.3	29.0	513	34069	28.38
LampPost 2	419	5883.3	15.8	477	3871.4	28.8	513	55873	38.52
LampPost 3	144	2448.5	5.3	477	2195.4	19.4	513	56850	40.52
PipeSet 1	127	649.9	17.4	336	630.5	25.2	347	4566	42.31
PipeSet 2	142	745.5	18.5	336	645.4	25.86	661	11328	60.9
PipeSet 3	129	445.9	10.6	336	466.2	18.0	402	3546	31.74
Knight 1	617	1095.6	41.6	633	839.4	38.5	868	12077	100
Knight 2	588	946.6	26.5	633	604.2	28.0	790	10523	87.6
Knight 3	617	1044.5	32.7	633	618.5	27.7	639	7546	39.2

Overview

Conclusion

- We propose a novel two-stage image based relighting algorithm
- We created three IBRL datasets (*PipeSet*, *LampPost* and *Lighter*) and have made them publicly available at `http://www.cse.iitb.ac.in/biswarup/web/data/`.



Thank you for your time !

Questions ?

http://www.cse.iitb.ac.in/~biswarup/

Debevec's Light Stage 6.0