Illumination from Images

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CS7670: October 4, 2011
Scene Illumination

What is it?

- Environment map
- A sphere *approximate* incident light from long distance
- A 2D radiance function in sphere coordinates

Assumptions

- Far-field lighting
- Independent to position

Grace Cathedral, San Francisco
Angular map format
http://ict.debevec.org/~debevec/Probes/
Applications

- Realistic 3D rendering/relighting

http://gl.ict.usc.edu/Research/RHL/
Applications (cont.)

- Insert 3D objects into photos

Applications (cont.)

- Help scene understanding
  - Illumination vastly changes scene appearance
  - Solution 1: use illumination invariant features (e.g., SIFT)
  - Solution 2: utilize information about scene illumination
Example: Blind Reflectometry

- Ambiguity between illumination and reflectance
- Find material properties by
  - Choosing an appropriate BRDF representation
  - Find the statistics of outdoor environment maps
  - Select most likely BRDF parameters under that distribution of environment maps

[Romeiro and Zickler, 2010]

(a) Back-left  (b) Back-right  (c) Front-left  (d) Front-right
Estimating Scene Illumination

- Light Probe [Debevec et al., 1998]
Outdoor Illumination from Image Sequence

- Webcam time lapsed video

“What do color changes reveal about an outdoor scene?” [Sunkavalli et al., 2008]

“What Do the Sun and the Sky Tell Us About the Camera?” [Lalonde et al., 2008, 2010]

”Webcam Clip Art” [Lalonde et al., 2009]
Outdoor Illumination from Single Image

- Estimating Natural Illumination from a Single Outdoor Image [Lalonde et al., 2009]
  - Estimating sun position and sky color
  - Using image cues:
    - Sky color
    - Shadow lines
    - Shading of vertical surfaces
Geometric Context [Hoiem et al., 2005]

- Pixel location
- Color
- Texture
- Perspective

Classification/Labeling:

- Vertical
- Vertical facing right
- Ground
- Sky
Sun probability distribution map

[Lalonde et al., ICCV 2009]
Sky Model

\[ l_p = f(\theta_p, \gamma_p) = \left[ 1 + a \exp\left(\frac{b}{\cos\theta_p}\right) \right] \times \left[ 1 + c \exp(d\gamma_p) + e \cos^2\gamma_p \right] \]

- [Perez et al., 1993] and [Preetham et al., 1999]
- a,b,c,d,e can be approximated with a linear function of a single parameter, \( t \) (turbidity)
- In this work, sky is assumed to be clear (\( t = 2.17 \))
- Cloud is segmented by clustering based on color
Predicted sky at current sun position

Original sky

[Lalonde et al., ICCV 2009]
Sun behind camera

Sky not visible

[Lalonde et al., ICCV 2009]
Shadow detection

Non-vertical objects

[Lalonde et al., ICCV 2009]
Surfaces shading

Vertical facing left

[Lalonde et al., ICCV 2009]
No flat surface

[Lalonde et al., ICCV 2009]
Cue Combination

\[ P(I \mid S, G, V) \propto P(I \mid S) P(I \mid G) P(I \mid V) P(I) \]

Bayes rule

Sun position

Sky pixels

Ground pixels

Vertical surface pixels

Sky color

Vertical surface

Ground shadow

Sun position prior
Quantitative evaluation

[Lalonde et al., ICCV 2009]
Quantitative evaluation

Data-driven prior + Scene cues + data

[Lalonde et al., ICCV 2009]
• Code and Dataset
  • [Link](http://www.jflalonde.org/projects/outdoorIllumination/)
  • Currently only the code for the Sky model is available
• Extension in Lalonde’s PhD thesis [2011]
  • Find sun direction by person appearance
Shadow Detection

- Application
  - Estimating outdoor illumination
  - Shadow removal
  - Detecting Ground Shadows in Outdoor Consumer Photographs [Lalonde et al., ECCV 2010]
Detecting Ground Shadows in Outdoor Consumer Photographs

- [Lalonde et al., ECCV 2010]
- **Observation:** photometric methods do not work well on consumer images (not linear, lossy compression)
- **Hypothesis:** appearances of shadows on the ground are less varied than shadows in general, and can be learned from labeled images.
Learning shadow appearance

Input

Oversegmentation (watershed)

Strong boundaries (Canny)

CRF

P(shadow)

Feature extraction

Local classifier (boosted decision trees)
Incorporating scene layout

Input

Shadows

P(ground)

Ground shadows

[Hoiem et al., '07]
Single-Image Shadow Detection and Removal using Paired Regions

[Guo et al., CVPR 2011]
Shadow removal
Segmentation
Single/Pairwise region classification
Shadow Labeling
Soft shadow matting
Shadow removal

Shadow mask
Practical Issues

- Applying to outdoor illumination estimation
  - Segmentation (region based)
    => does not work well on thin shadows
Lalonde’s method
Guo’s method
Thank you

- Questions?
Question

I: illumination (sun direction)
S: sky pixels
G: ground pixels
V: vertical surface pixels
S, G, V: input image

\[ P(I \mid S, G, V) = \frac{P(S, G, V \mid I) P(I)}{P(S, G, V)} \]

\[ \Rightarrow P(I \mid S, G, V) \propto P(S, G, V \mid I) P(I) \]

\[ \Rightarrow P(I \mid S, G, V) \propto P(S \mid I) P(G \mid I) P(V \mid I) P(I) \]

Assuming conditional independence

\[ \Rightarrow P(S \mid I) = \frac{P(I \mid S) P(S)}{P(I)} \]

Bayes rule

\[ \Rightarrow P(S \mid I) \propto P(I \mid S) P(S) \]

Can we ignore this?

\[ \Rightarrow P(S \mid I) \propto P(I \mid S) \]

\[ \Rightarrow P(I \mid S, G, V) \propto P(I \mid S) P(I \mid G) P(I \mid V) P(I) \]