Flash Photography Enhancement via Intrinsic Relighting

Elmar Eisemann
MIT/Artis-INRIA

Frédo Durand
MIT

Introduction

Satisfactory photos in dark environments are challenging!

Introduction

Available light:

+ nice lighting

- noise/blurriness
- color

Introduction

Flash:

+ details
+ color

- flat/artificial
- flash shadows
- red eyes

Introduction

Our approach:

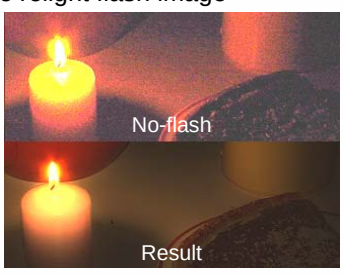
Use no-flash image relight flash image

Introduction

Our approach:

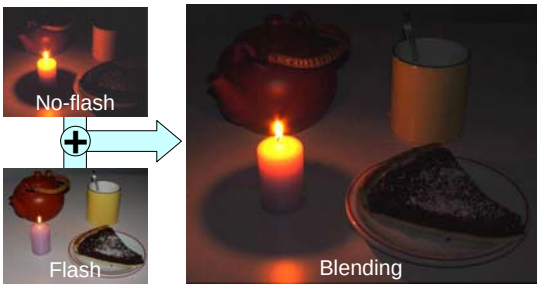
Use no-flash image relight flash image

+ original lighting
+ details/sharpness
+ color



Introduction

One approach: Blend the two photos

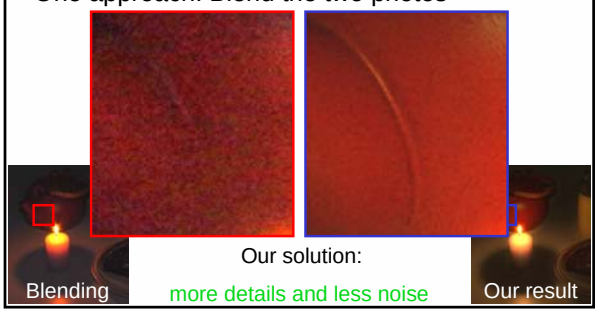


Introduction

One approach: Blend the two photos

Introduction

One approach: Blend the two photos



Overview

- Related Work
- Our Approach
- Results
- Conclusion and Future Work

Overview

- **Related Work**
- Our Approach
- Results
- Conclusion and Future Work

Related Work

Relighting:

Decouple luminance and texture

- Barrow and Tennenbaum [1978]
- Weiss [2001] – using image sequences
- Tappen et al. [2003] – from a single image

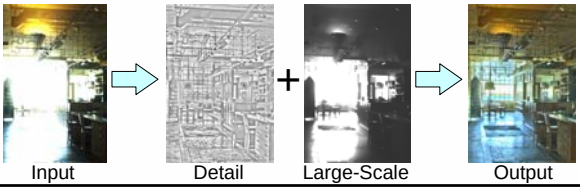
- Oh et al. [2001]

Images courtesy of Oh et al.

Related Work

Tone Mapping of High Dynamic Range Images
Decouple detail / large-scale information

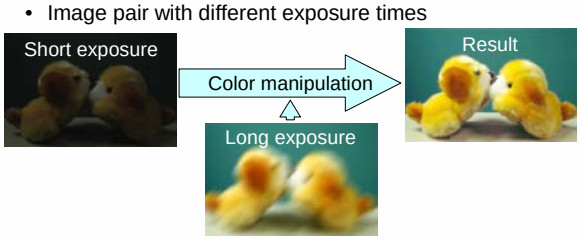
- Tumblin et al. [1999]
- Durand et al. [2002]
- Choudhury et al. [2003]



Related Work

Jia et al. [2004]:

- Solve problem of blur in long exposures
- Image pair with different exposure times



➢ Details from short exposure

Images courtesy of Jia et al.

Related Work

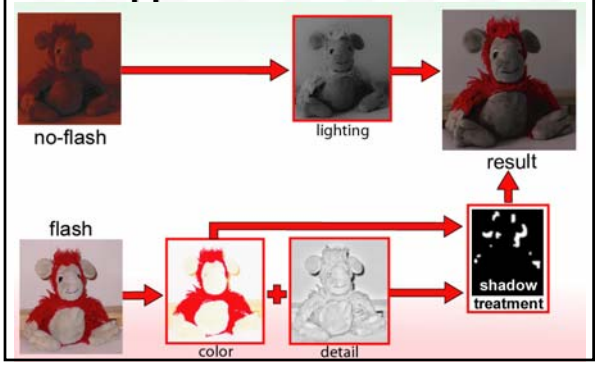
Petschnigg et al.[2004]:

- many similarities
- previous talk
- discussion at the end

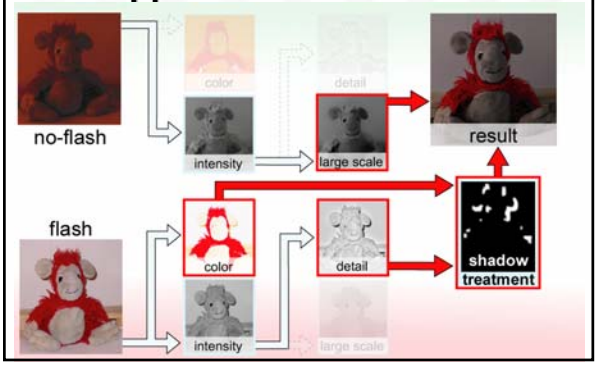
Overview

- Related Work
- **Our Approach**
- Results
- Conclusion and Future Work

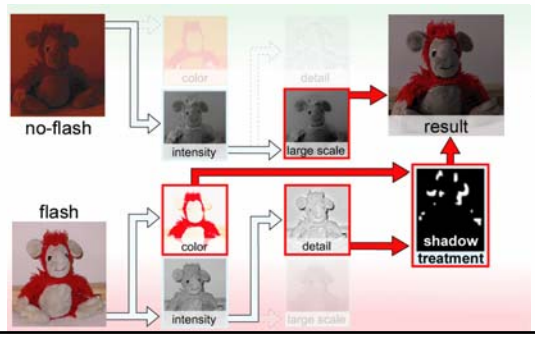
Our Approach - Main Idea



Our Approach

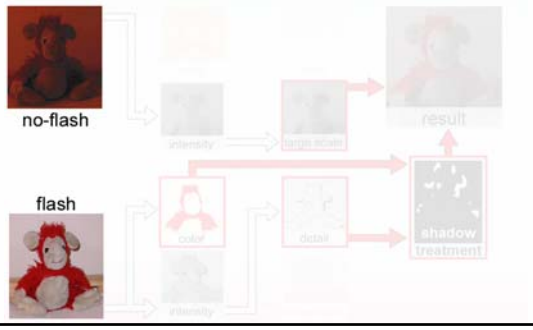


Our Approach



Our Approach

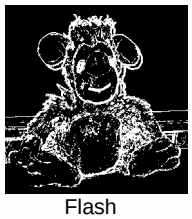
Registration



Registration

- Compensate for camera motion (image translation)
- Difficult because lighting changes
- Edge detection

No-flash

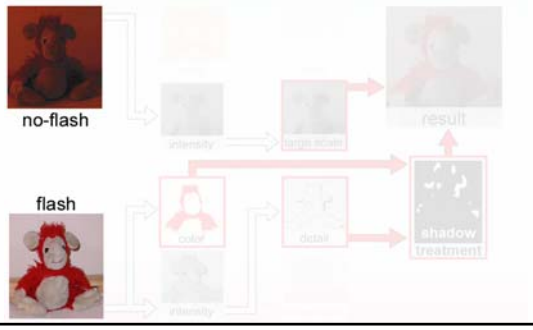


Flash

- See also Ward[2004], Kang[2003]

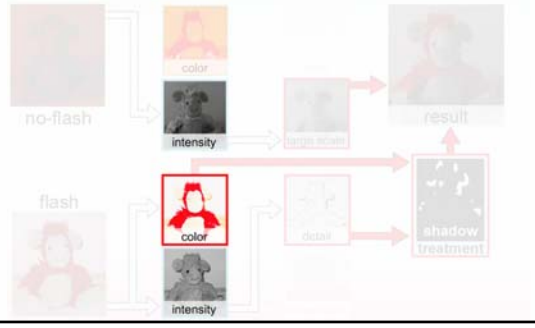
Our Approach

Registration



Our Approach

Decomposition



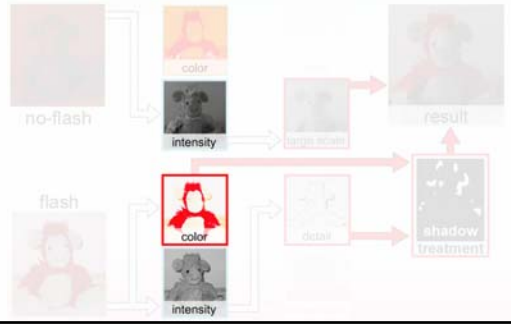
Decomposition

Color / Intensity:

original = intensity * color

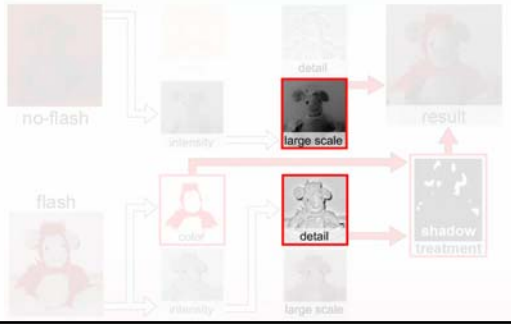
Our Approach

Decomposition



Our Approach

Decoupling



Decoupling

- Lighting : Large-scale variation
- Texture : Small-scale variation

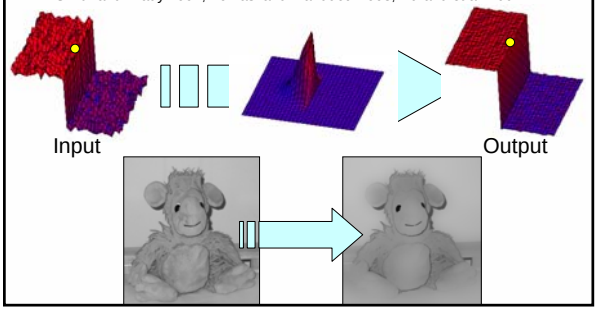
Lighting

Texture

Large-scale Layer

- Bilateral filter – edge preserving filter

Smith and Brady 1997; Tomasi and Manduccí 1998; Durand et al. 2002

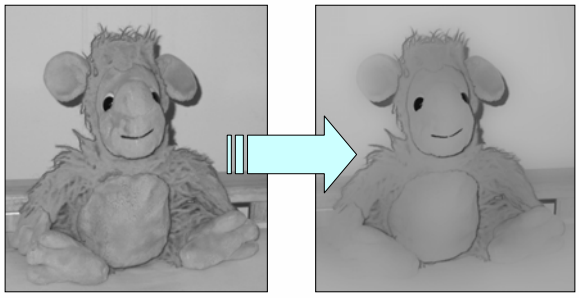


Input

Output

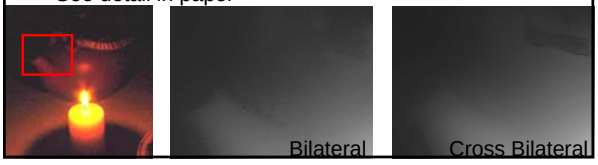
Large-scale Layer

- Bilateral filter



Cross Bilateral Filter

- Similar to joint bilateral filter by Petschnigg et al.
- When no-flash image is too noisy
- Borrow similarity from flash image
  - ➢ edge stopping from flash image
- See detail in paper



Bilateral

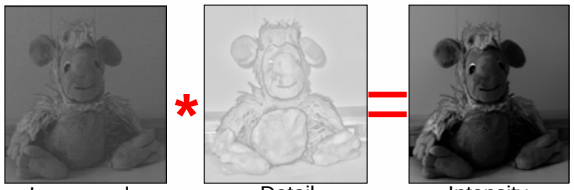
Cross Bilateral

Detail Layer

Intensity | Large-scale | Detail

Recombination: Large scale * Detail = Intensity

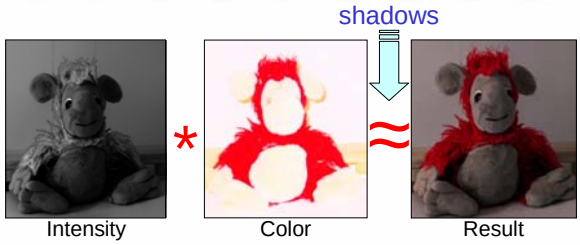
Recombination



Large-scale No-flash | Detail Flash | Intensity Result

Recombination: Large scale * Detail = Intensity

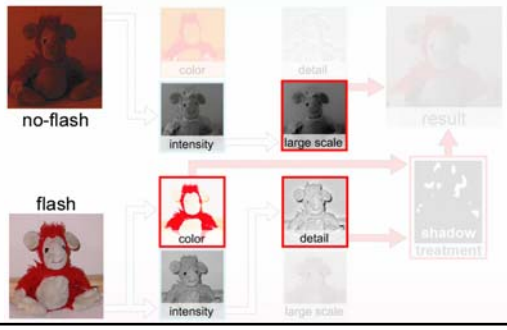
Recombination



Intensity Result | Color Flash | Result

Recombination: Intensity * Color = Original

Our Approach

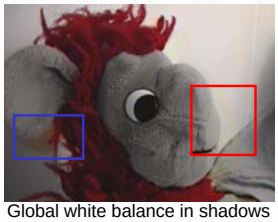


Our Approach

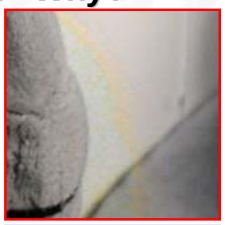
Shadow Detection/Treatment

Shadow Correction – Why?

Shadow Correction – Why?



Global white balance in shadows



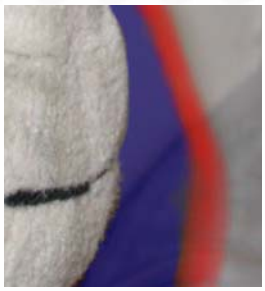
Several artifacts:

- at shadow boundary
- inside shadows (color bleeding)

➢ shadows need to be corrected !

... and detected

Shadow Detection



- Umbra
- Penumbra

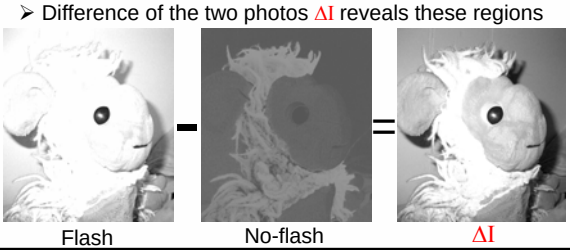
➢ Detection in two steps

Shadow Detection

Umbra detection

- No direct light from flash

➢ Difference of the two photos ΔI reveals these regions

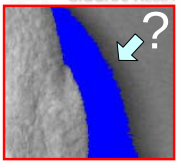


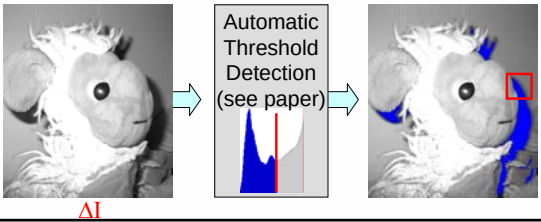
Flash No-flash ΔI

Shadow Detection

Umbra detection

- Difference ΔI = light from the flash
- Goal: Find a threshold for ΔI





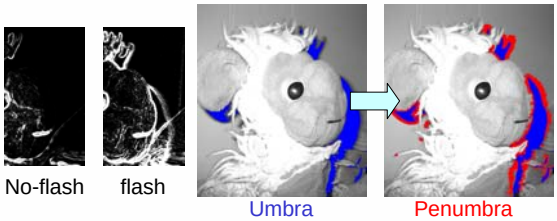
ΔI

Shadow Detection

Penumbra detection

➢ strong gradient at boundary

- no strong gradient in no-flash image
- connected to umbra



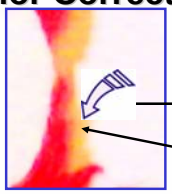
No-flash flash Umbra Penumbra

Shadow Correction

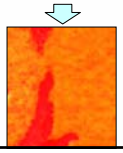
- Correct color and detail

Shadow mask

Shadow Color Correction



Fill in shadow from similar surrounding

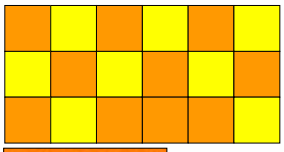


No-flash colors

Shadow Color Correction

No-flash

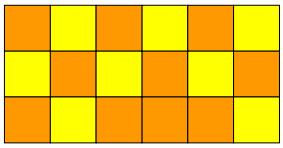
Flash

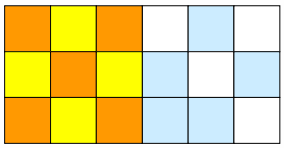


Shadow Color Correction

No-flash

Flash

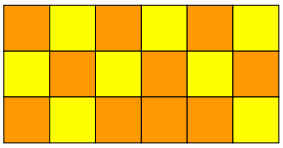


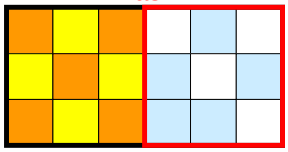


Shadow Color Correction

No-flash

Flash



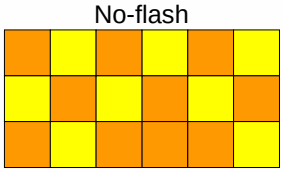


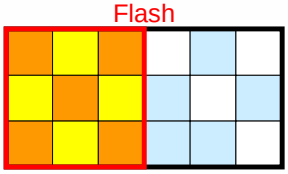
Outside shadow

Shadow Color Correction

No-flash

Flash



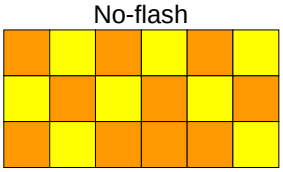


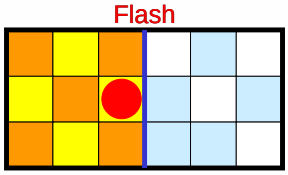
Inside shadow Outside shadow

Shadow Color Correction

No-flash

Flash

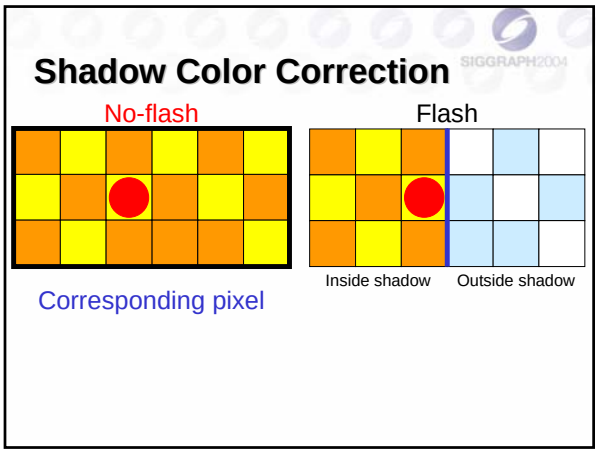




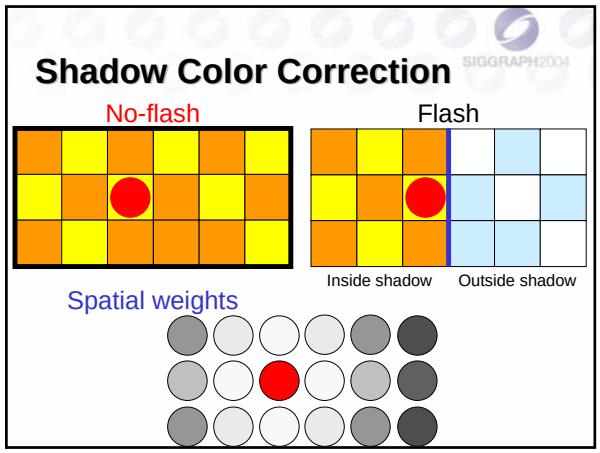
Inside shadow Outside shadow

Select pixel in shadow

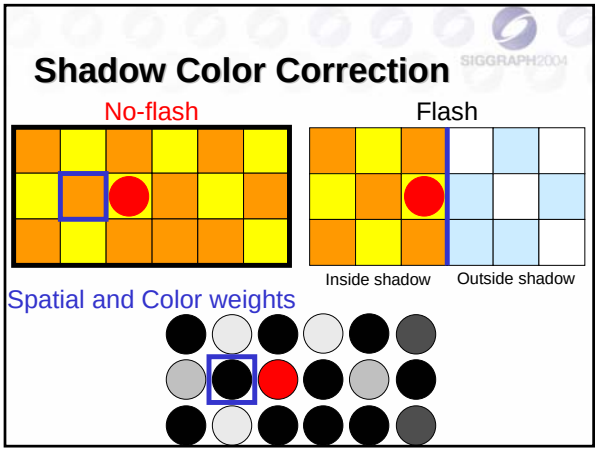
Shadow Color Correction



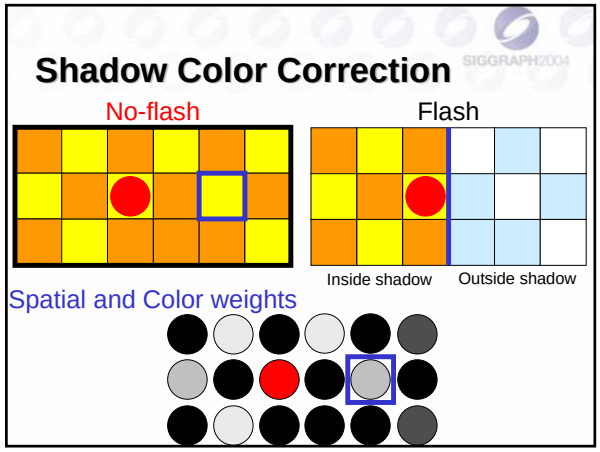
Shadow Color Correction



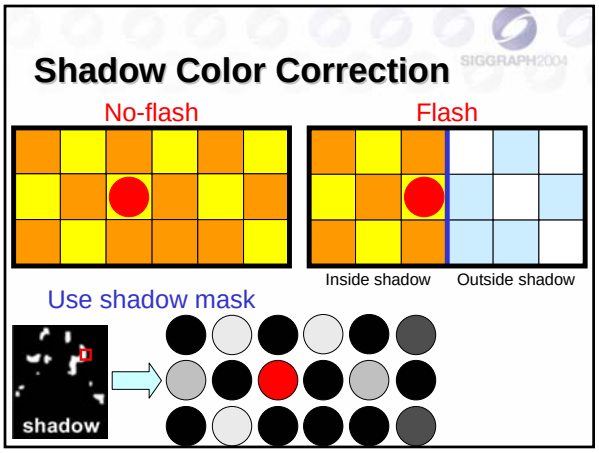
Shadow Color Correction



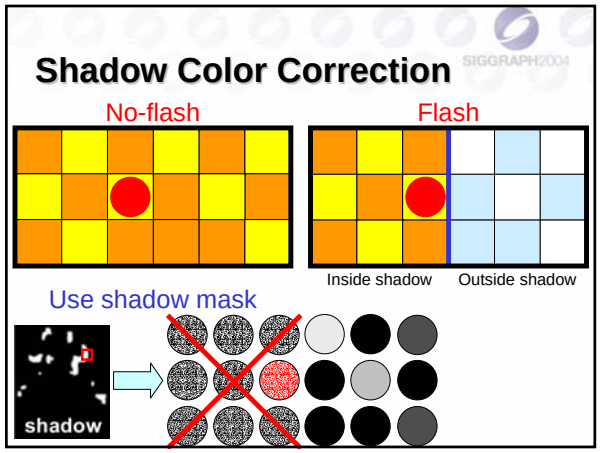
Shadow Color Correction

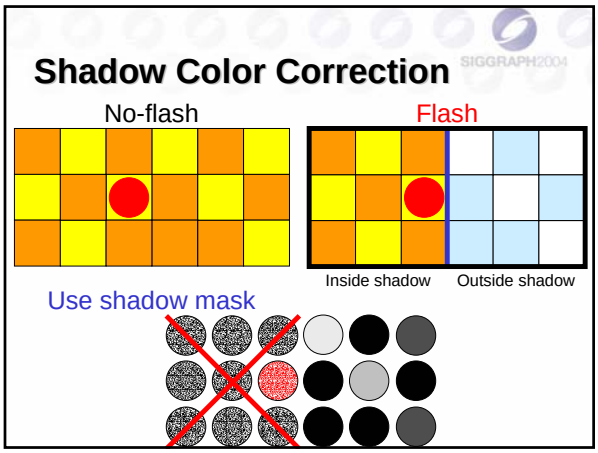


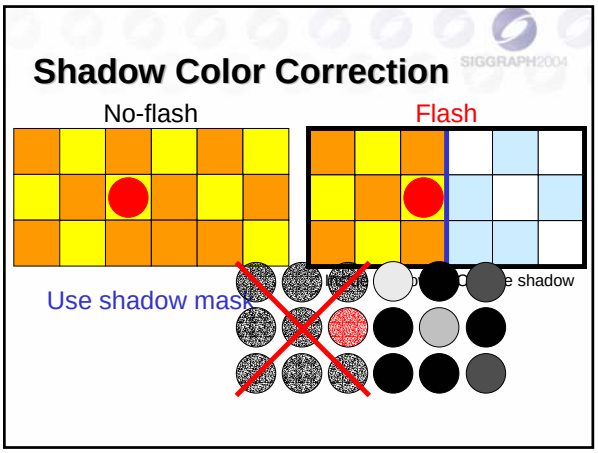
Shadow Color Correction

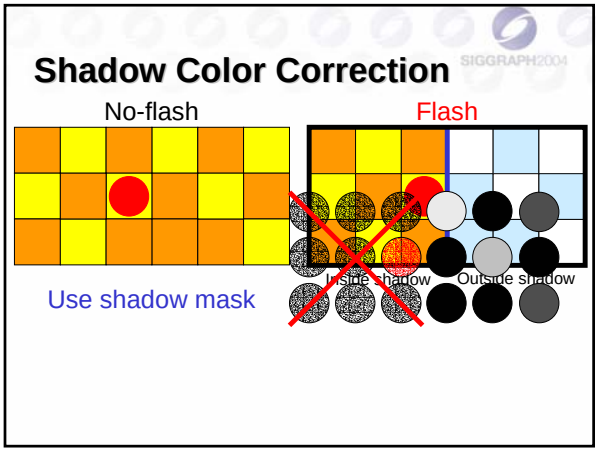


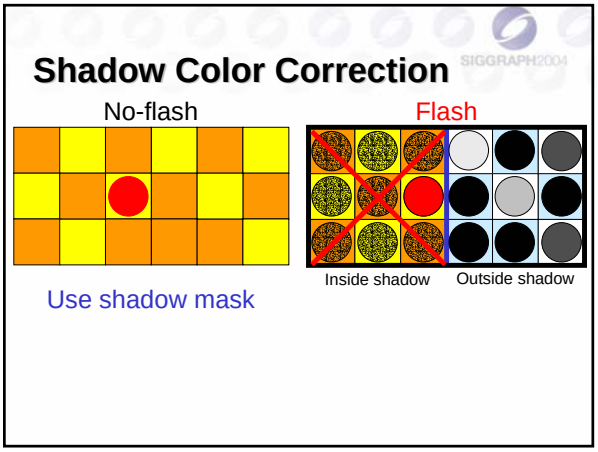
Shadow Color Correction

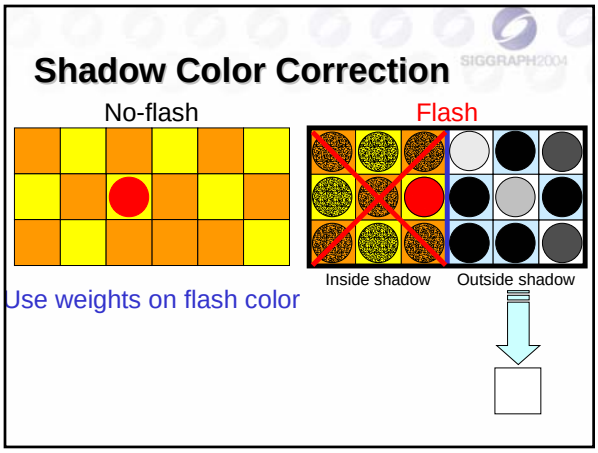


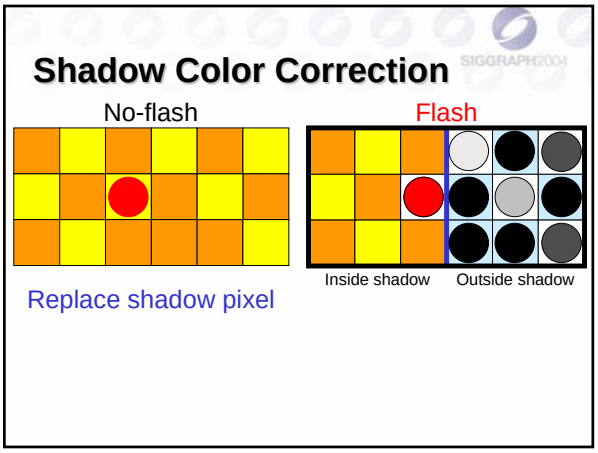

Shadow Color Correction
No-flash
Flash
Inside shadow
Outside shadow
Use shadow mask


Shadow Color Correction
No-flash
Flash
Use shadow mask

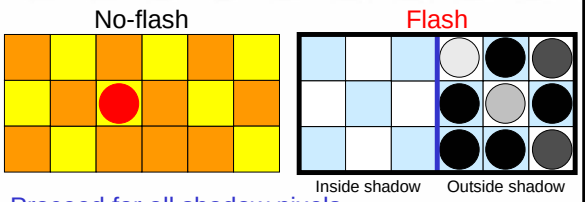

Shadow Color Correction
No-flash
Flash
Inside shadow
Outside shadow
Use shadow mask


Shadow Color Correction
No-flash
Flash
Inside shadow
Outside shadow
Use shadow mask


Shadow Color Correction
No-flash
Flash
Inside shadow
Outside shadow
Use weights on flash color

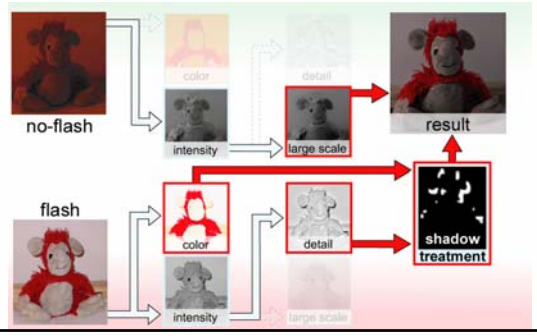

Shadow Color Correction
No-flash
Flash
Inside shadow
Outside shadow
Replace shadow pixel

Shadow Color Correction

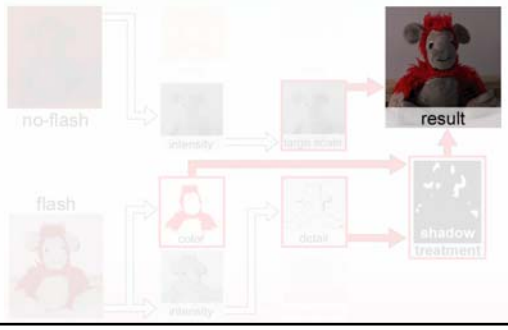


Proceed for all shadow pixels

Our Approach



Our Approach



Overview

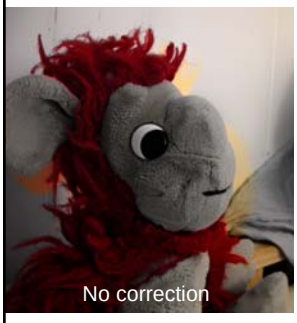
- Related Work
- Our Approach
- **Results**
- Conclusion and Future Work

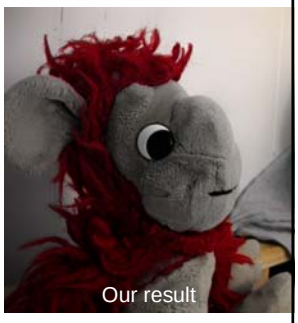
Results

No-flash

Flash

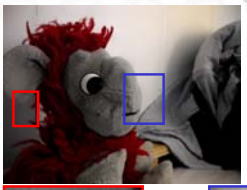
Results



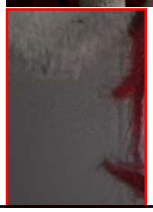


Results

No-flash



Flash



Results

No-flash

Flash

Results

No-flash

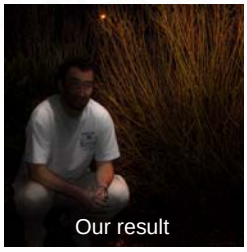
Flash

Our result

Results

Our result

Results



Our result

Emphasize Foreground

Our result

Deduce “distance“ to camera

Exploit $1/r^2$ flash intensity falloff

(see paper)

Emphasized foreground

(Inverse) White Balance

Retain warm tones from available lighting (see paper)

Results

No-flash

Flash

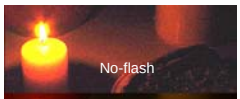
Overview

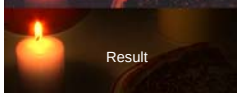
- Related Work
- Our Approach
- Results
- Conclusion and Future Work

Conclusion

Improving photography in dim environments

- Capture original lighting
- Add sharpness/details
- Cross bilateral filter
- Correct flash shadows
- Pseudo distance (emphasize foreground)
- (Inverse) white balance





Future Work

- Local coherence for shadow detection
- Different recombinations
- Bilateral filter parameters
- Infra-red flash

Aknowledgements

- École Normale Supérieure - Paris
- Deshpande Center
- MIT-France
- NSF CISE

Thank you very much for your attention!

Comparison: Similarities

Petschnigg et al.

Eisemann et al.

- Detail transfer or relighting
- Use bilateral filter
- Joint or cross bilateral filter

Comparison: Color

Petschnigg et al.

Eisemann et al.

- Color from no-flash
  - More noisy
  - Less need for shadow correction
  - White balance no-flash image
- Color from flash
  - Less noisy
  - Need correction in shadow
  - Inverse white balance flash image

Comparison: Differences

Petschnigg et al.

Eisemann et al.

Algorithmic differences

- Color from no-flash
- Semi-manual shadows/highlights
- Color from flash
- Automatic shadows

Additional tools

- Continuous flash
- Red-eye removal
- Pseudo distance, emphasize foreground

Thank you again for your attention!