

# Flash Photography Enhancement via Intrinsic Relighting



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# **Introduction**

**Satisfactory photos in dark environments are challenging!**

# Introduction

## Available light:

+ nice lighting

- noise/blurriness
- color



No-flash

# Introduction

## Flash:

+ details  
+ color

- flat/artificial
- flash shadows
- red eyes

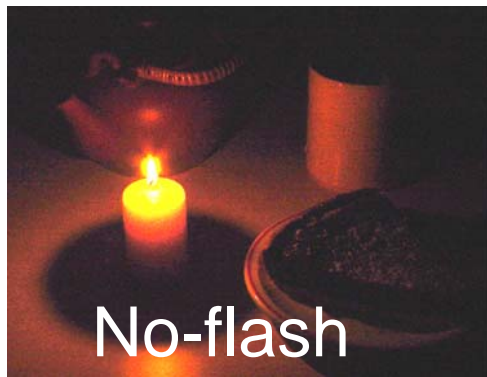




# Introduction

## Our approach:

Use no-flash image relight flash image

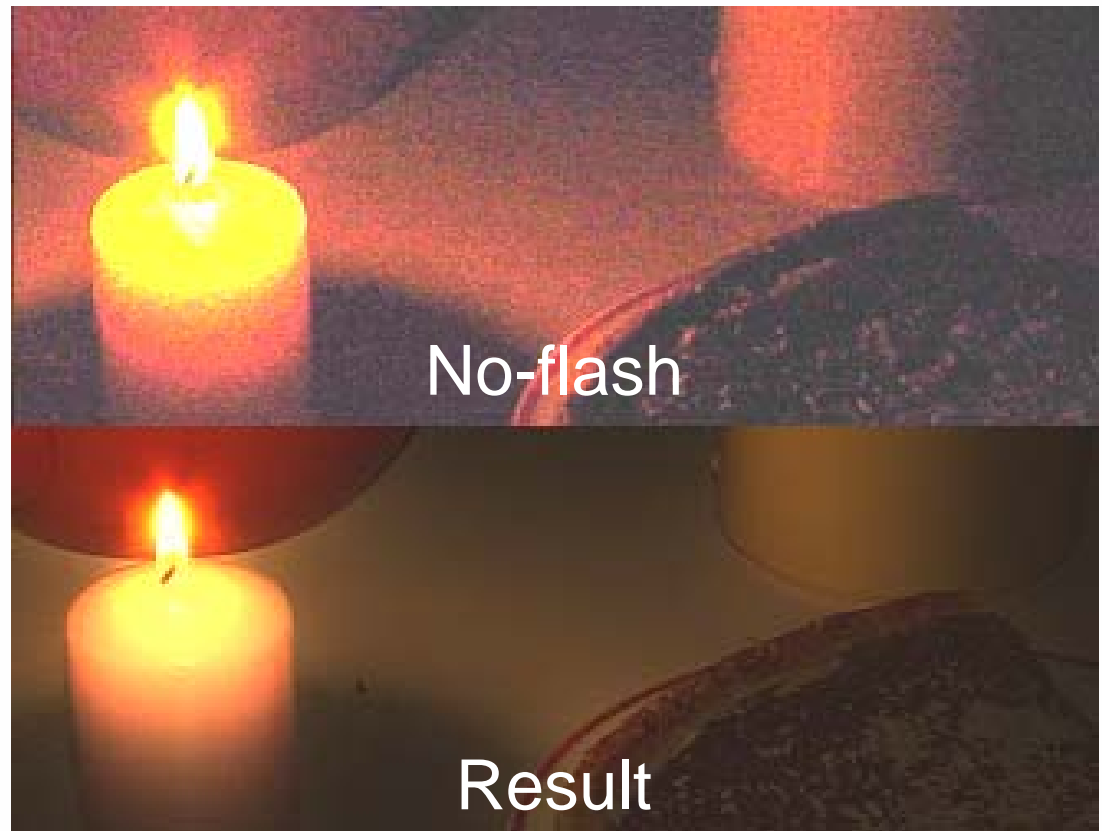


# Introduction

## Our approach:

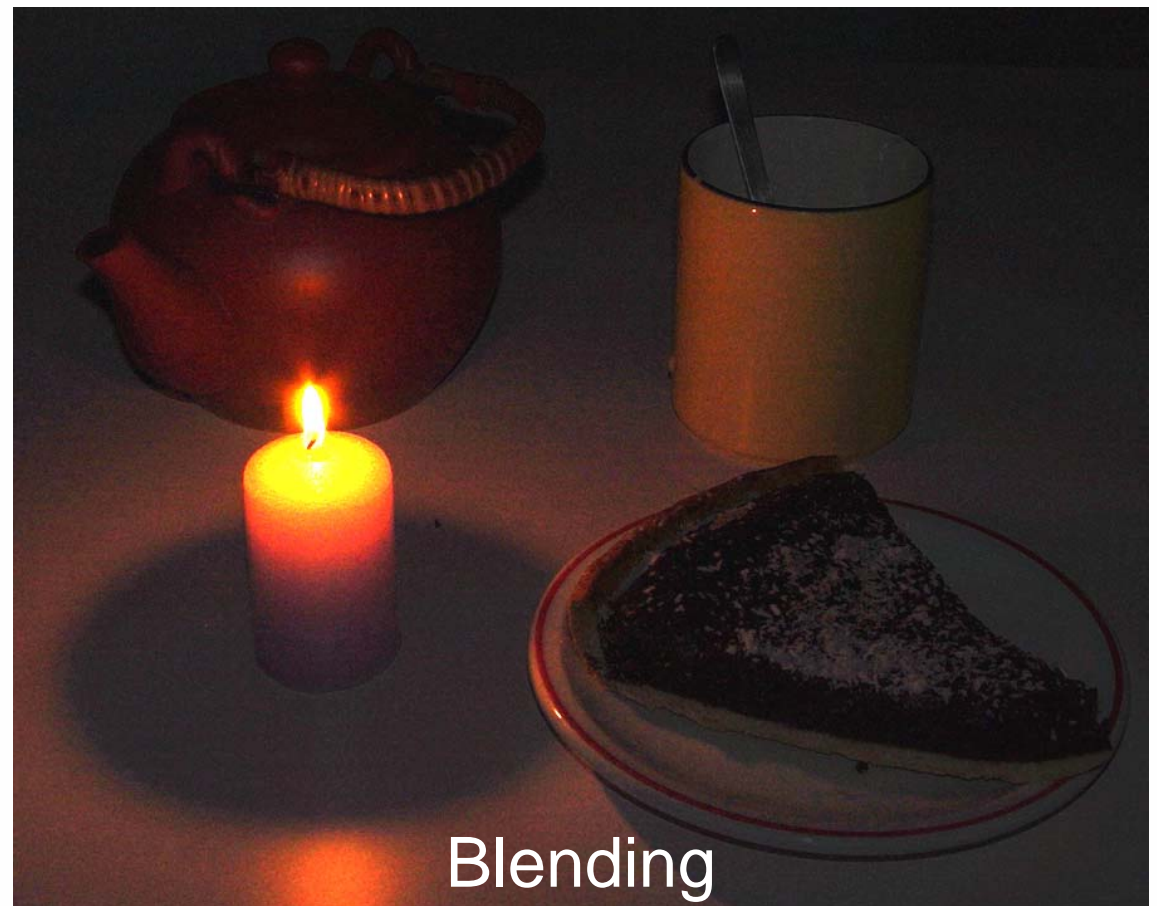
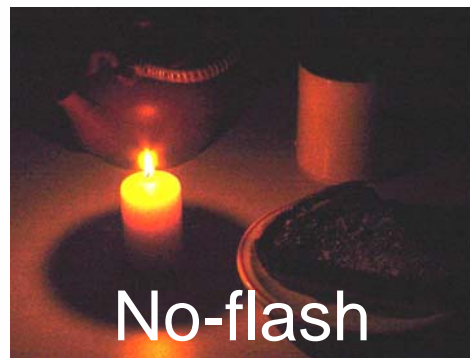
Use no-flash image relight flash image

- + original lighting
- + details/sharpness
- + color



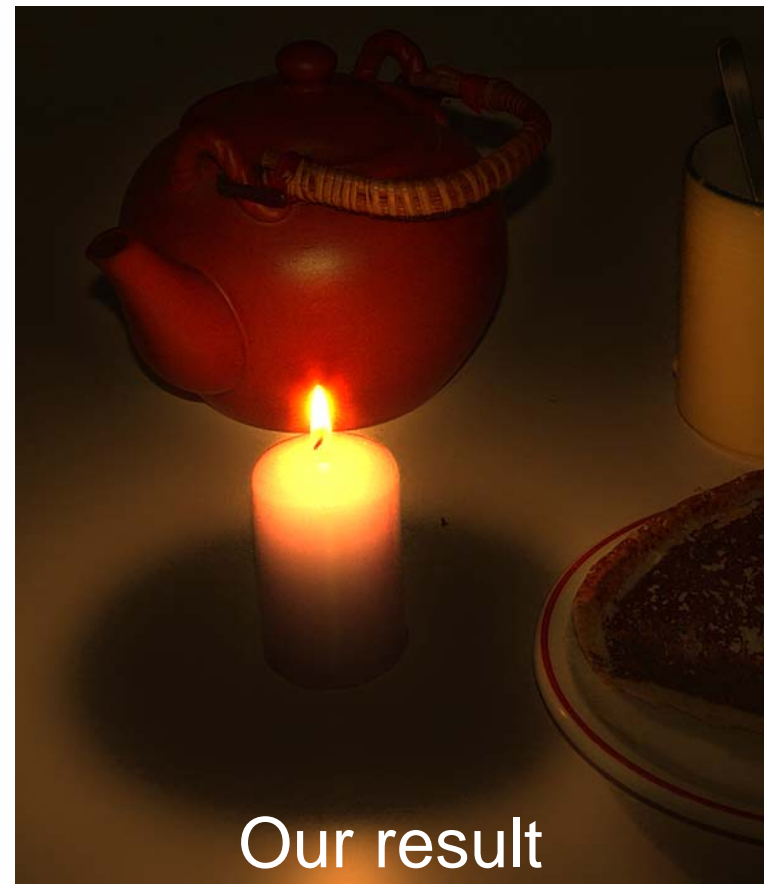
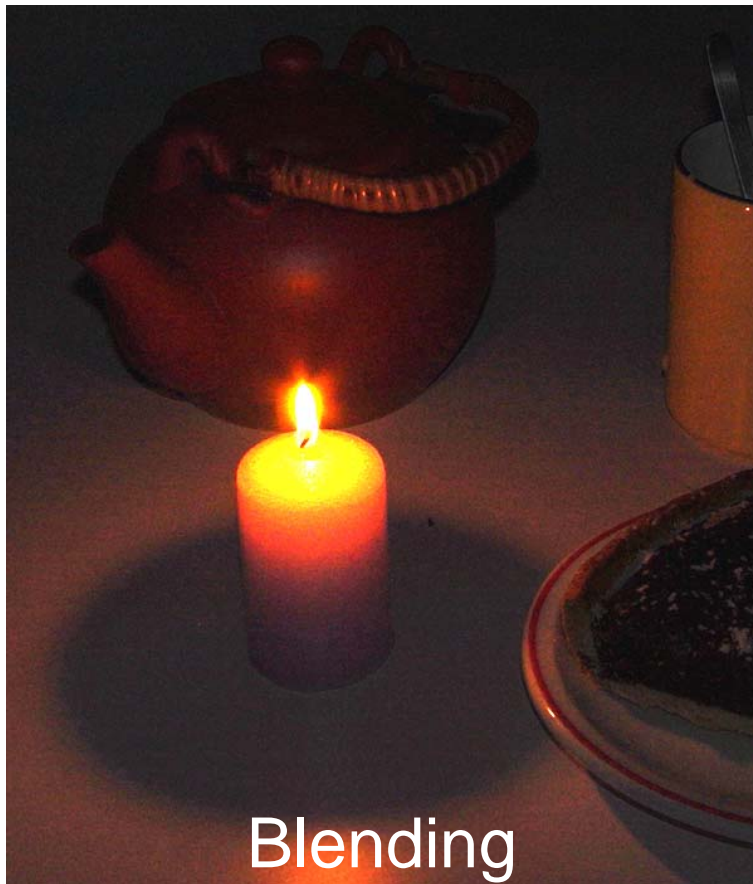
# Introduction

One approach: Blend the two photos



# Introduction

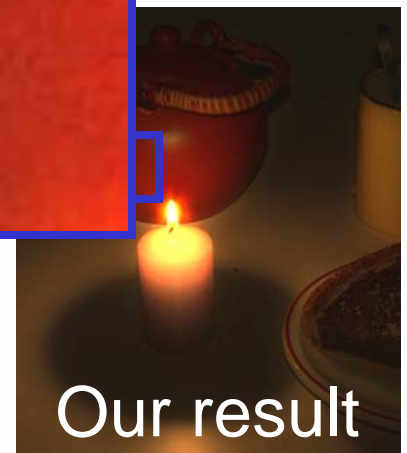
One approach: Blend the two photos





# Introduction

One approach: Blend the two photos



Our solution:

more details and less noise

# Overview

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

# Overview

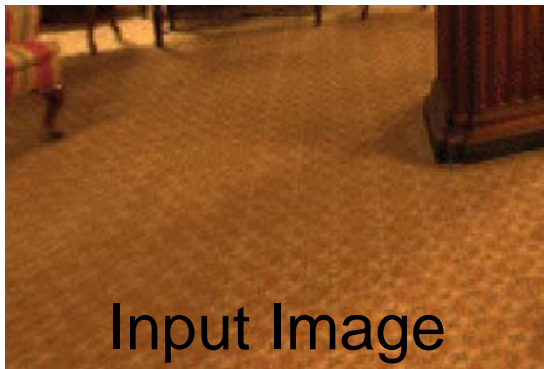
- **Related Work**
- Our Approach
- Results
- Conclusion and Future Work

# 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]



Input Image



Luminance



Texture

Images courtesy of Oh et al.



# Related Work

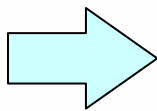
## Tone Mapping of High Dynamic Range Images

Decouple detail / large-scale information

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



Input

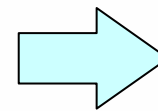


Detail

+



Large-Scale

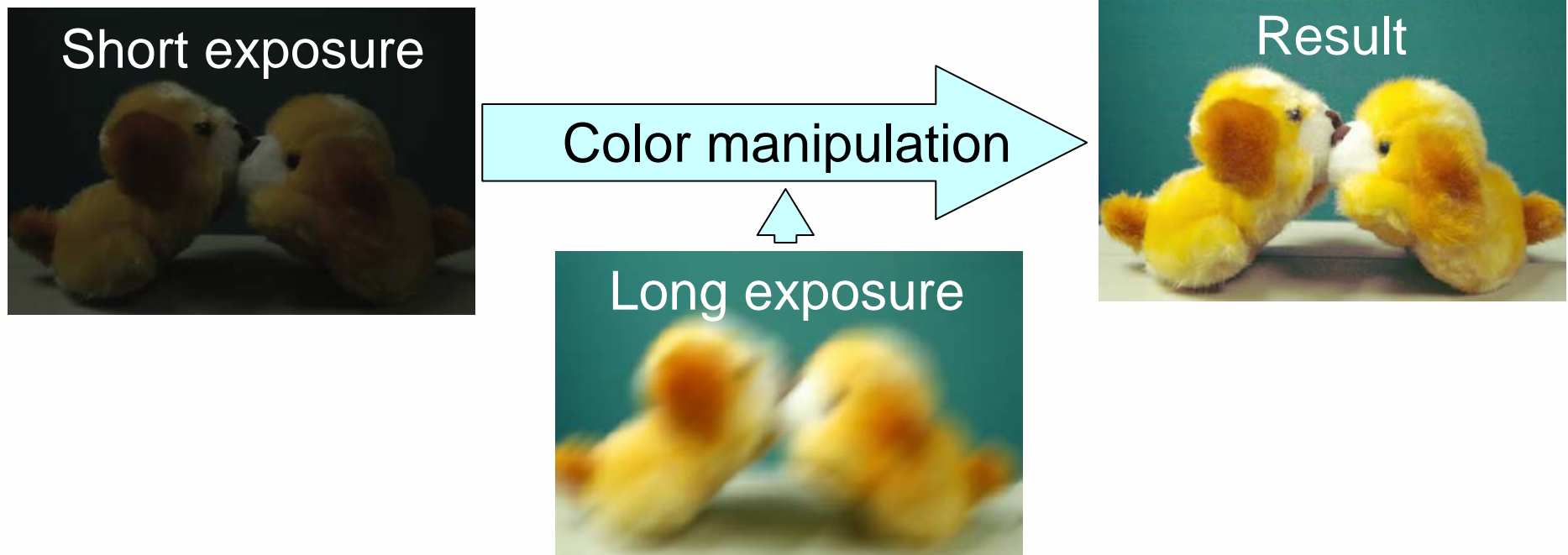


Output

# 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]:

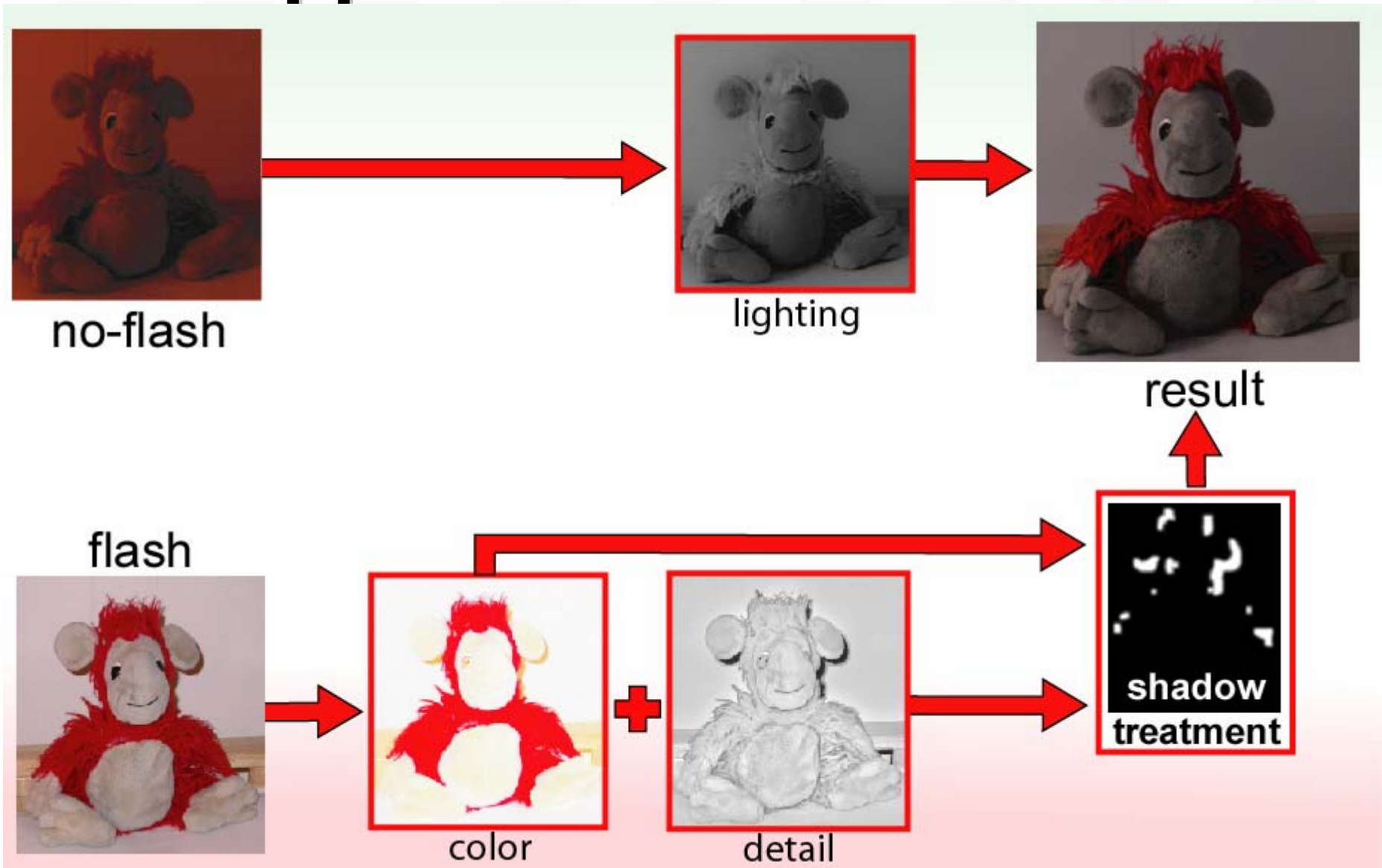
- many similarities
- previous talk
- discussion at the end

# Overview

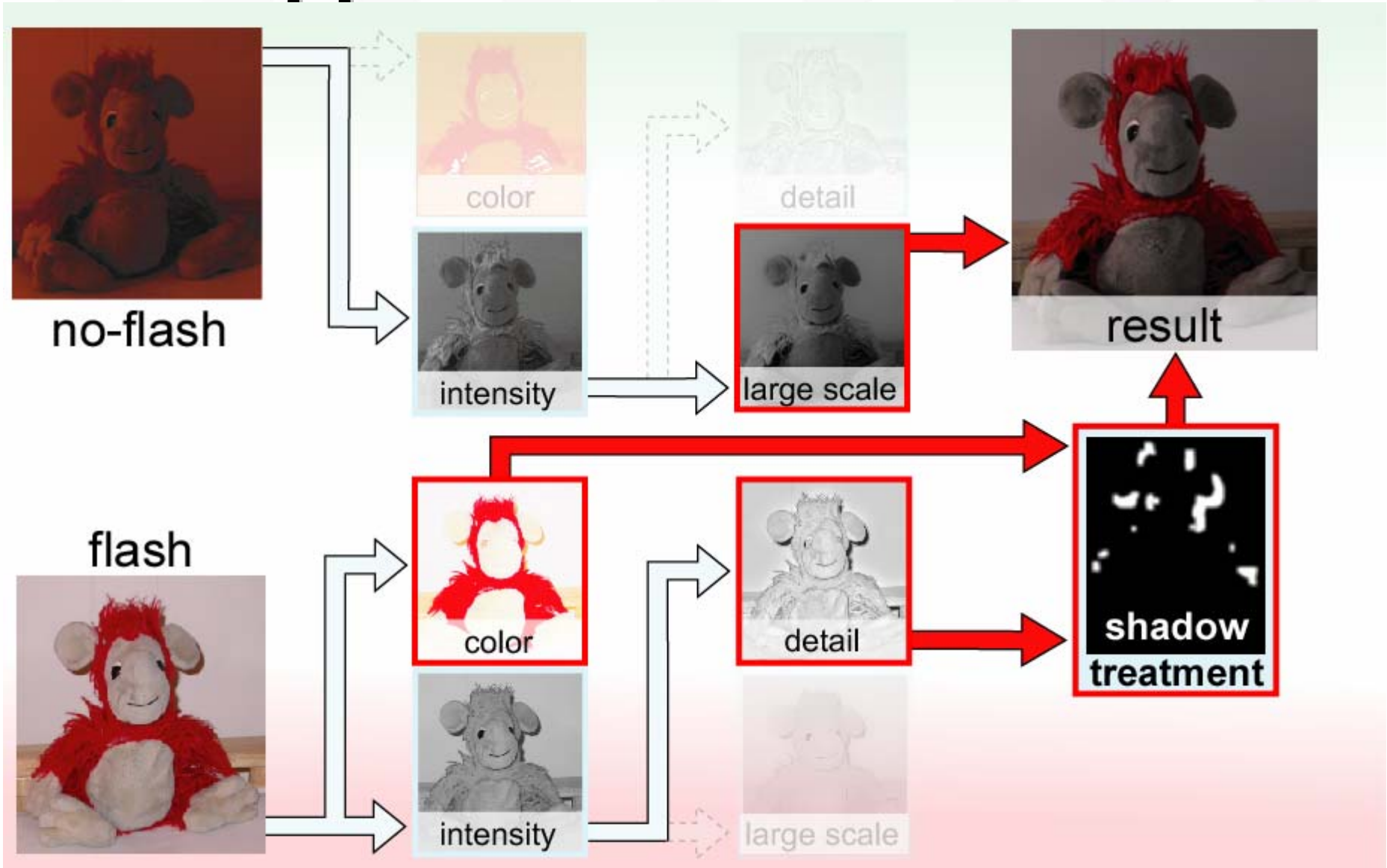
- Related Work
- **Our Approach**
- Results
- Conclusion and Future Work



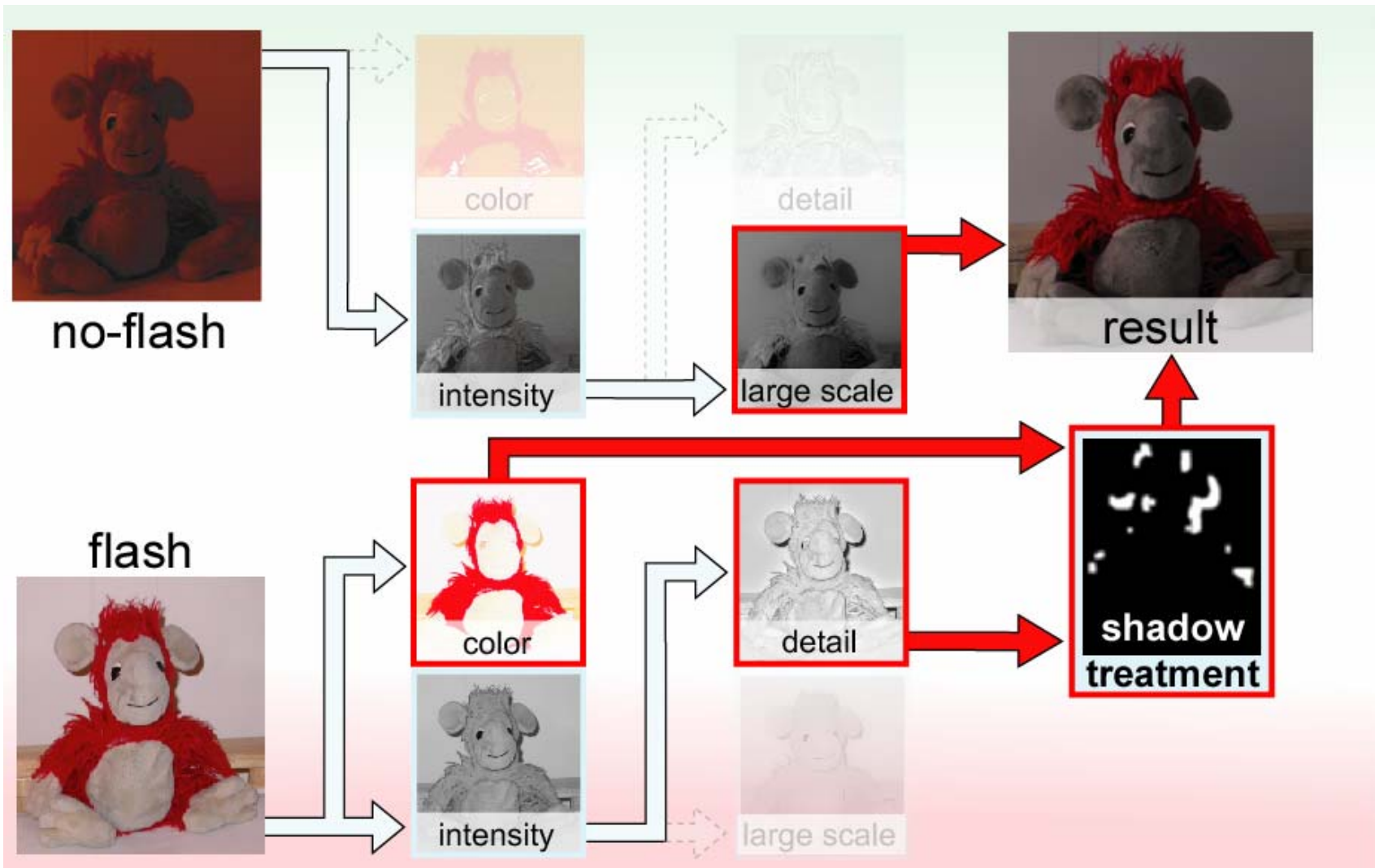
# Our Approach - Main Idea



# Our Approach

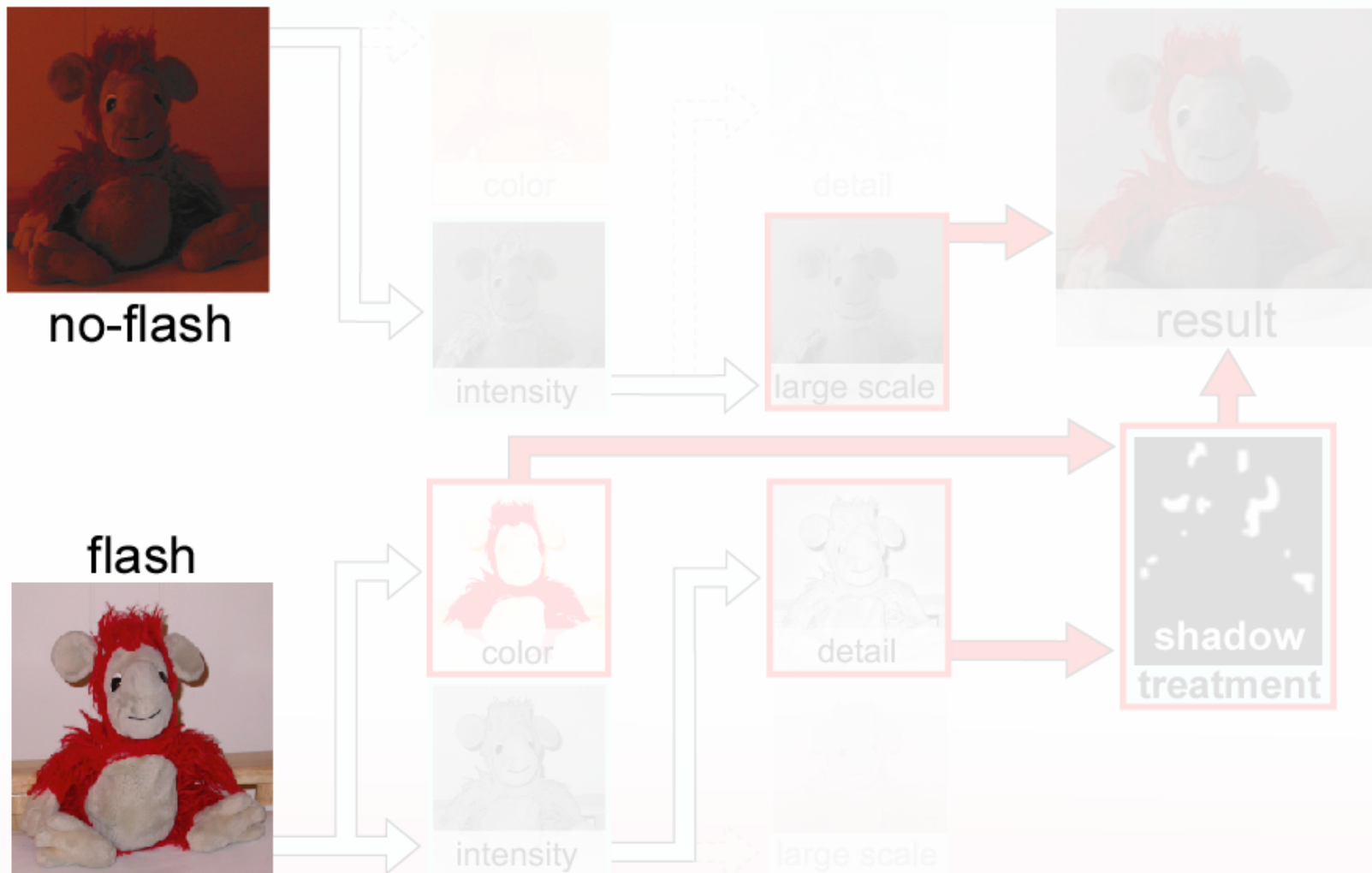


# Our Approach



# Our Approach

## Registration



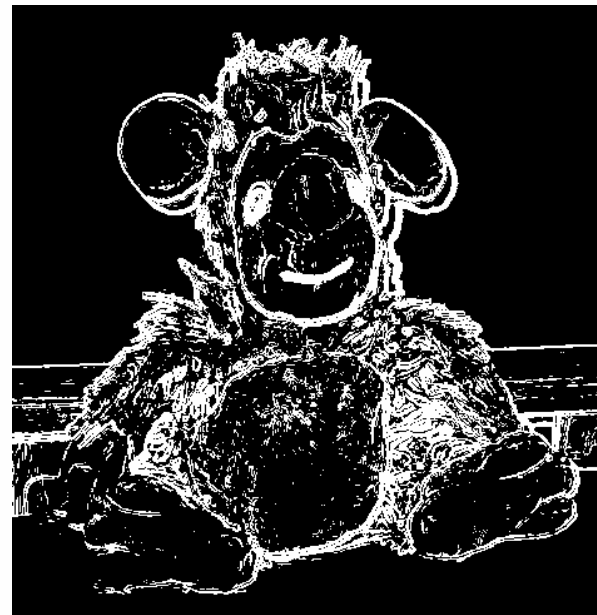


# Registration

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



No-flash

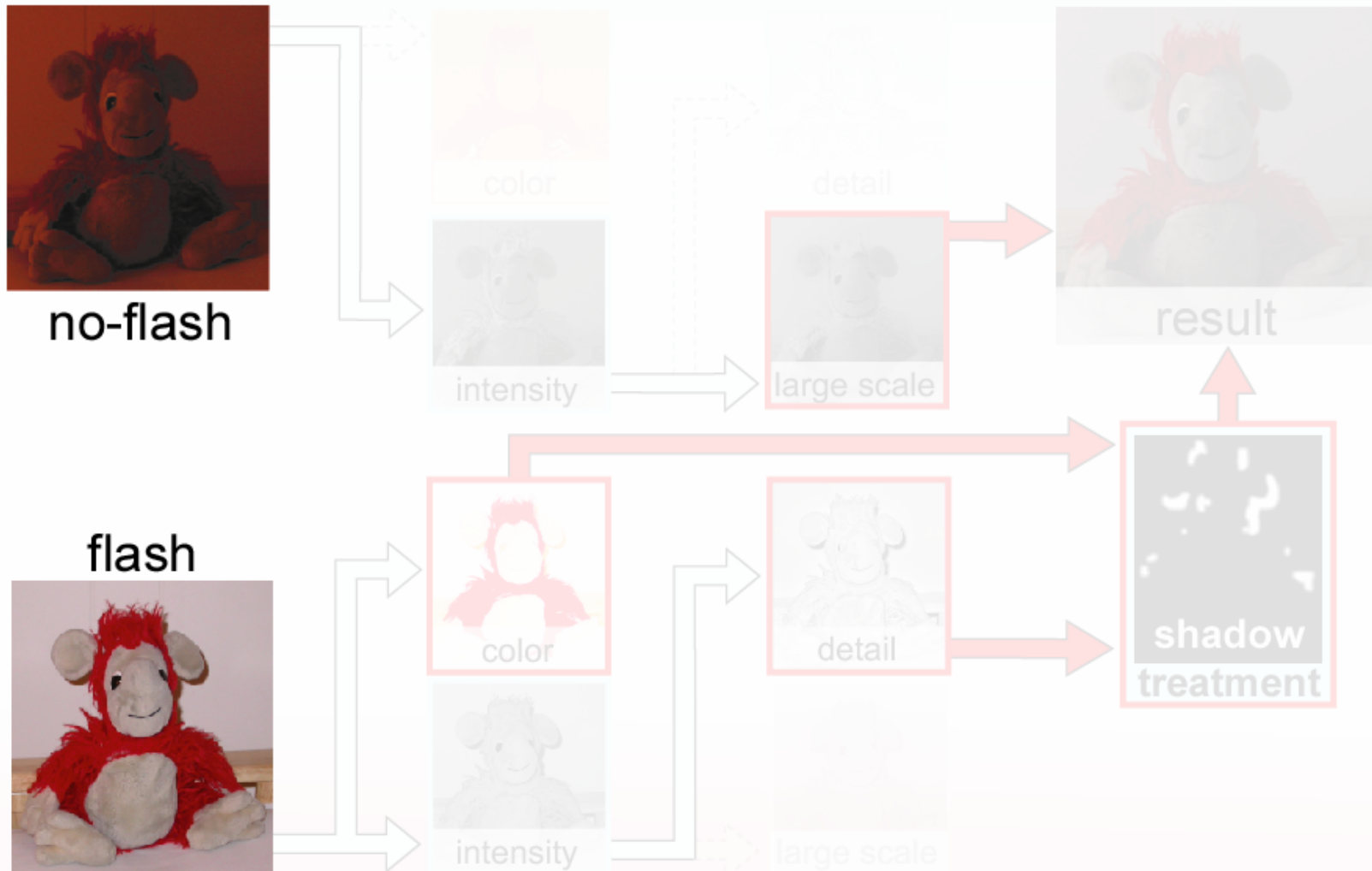


Flash

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

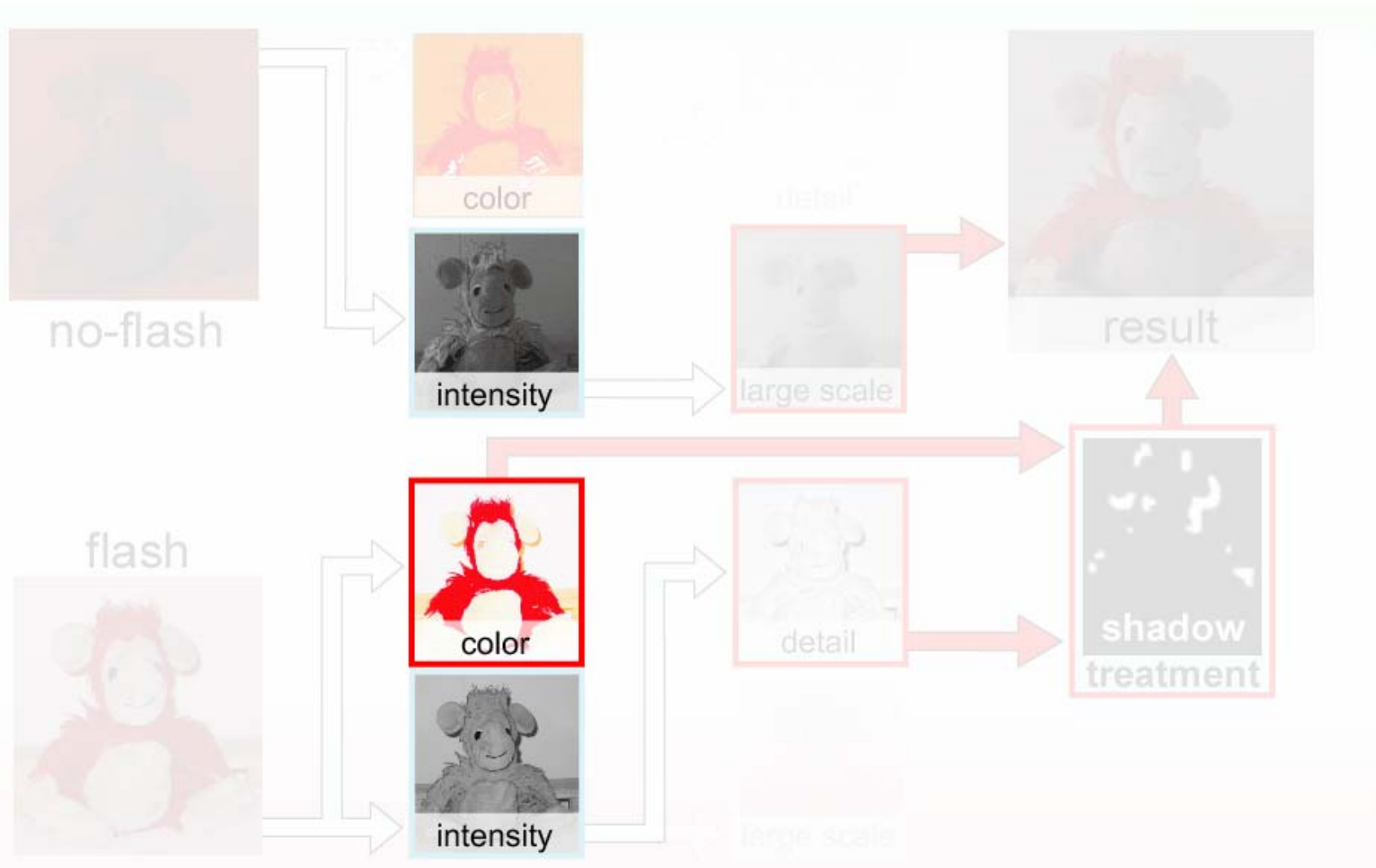
# Our Approach

## Registration



# Our Approach

## Decomposition



# Decomposition

Color / Intensity:



original

=



intensity

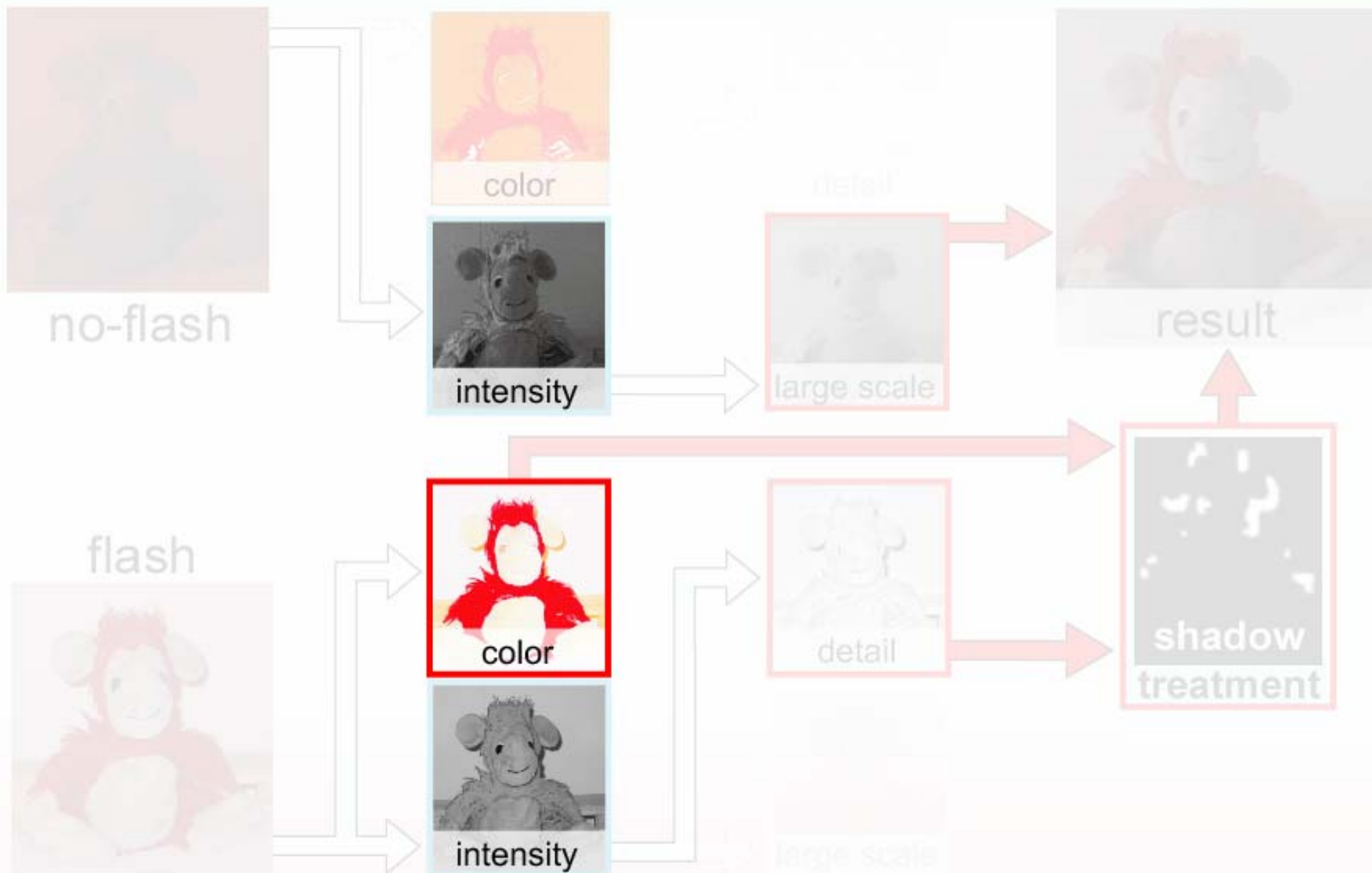
\*



color

# Our Approach

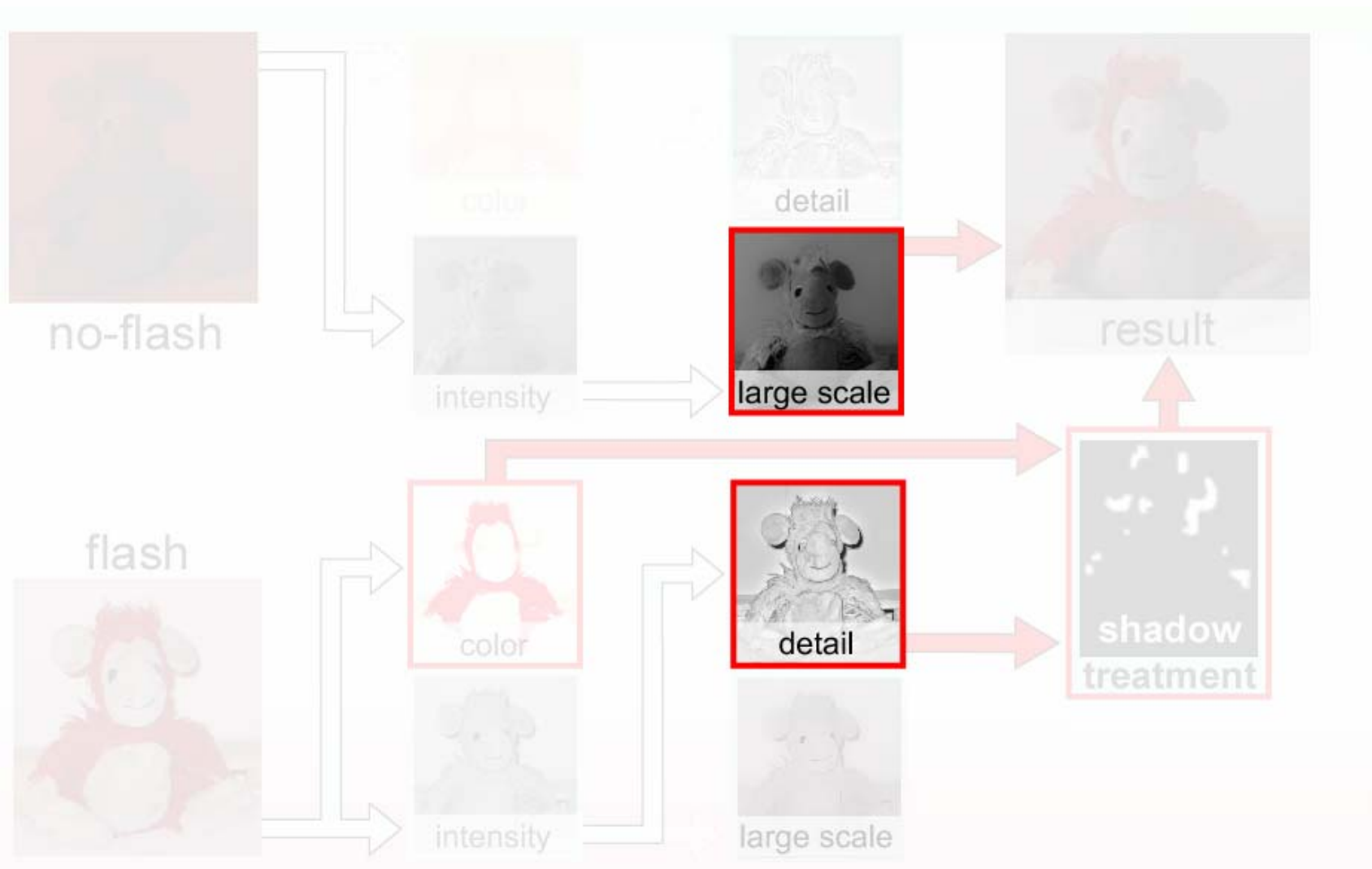
## Decomposition





# Our Approach

## Decoupling



# Decoupling

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



Lighting

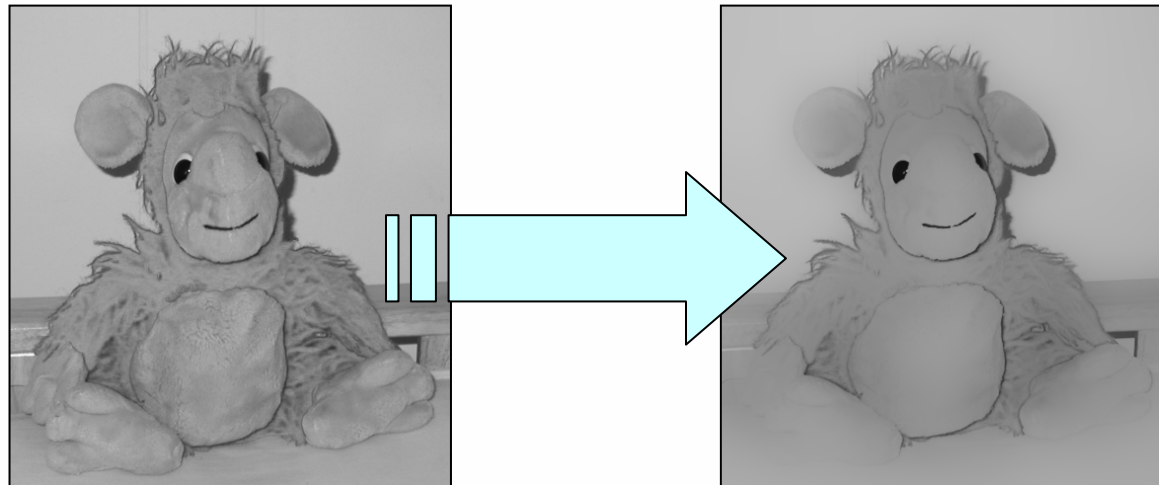
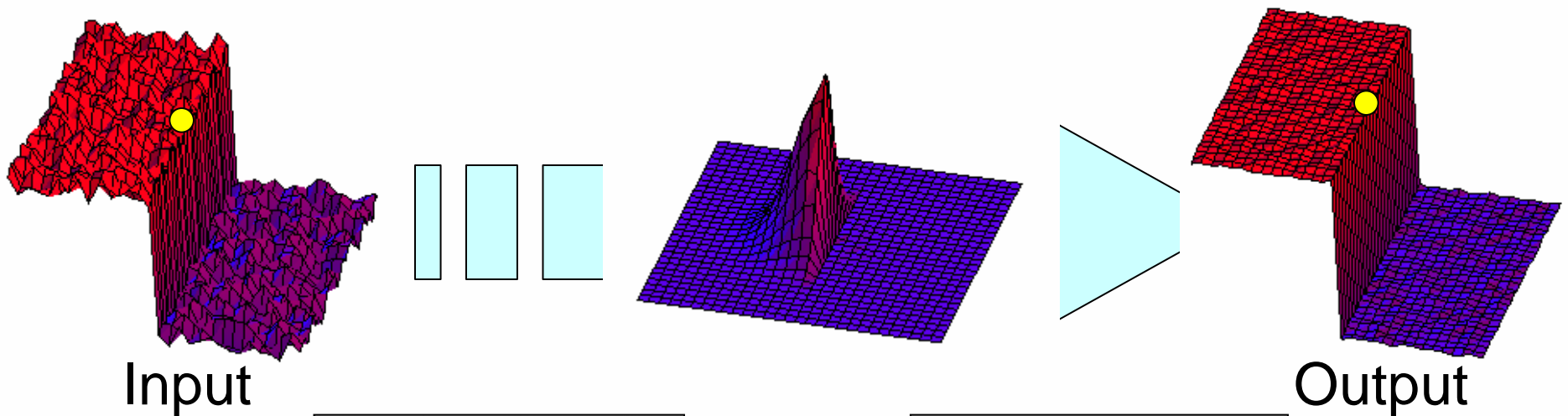


Texture

# Large-scale Layer

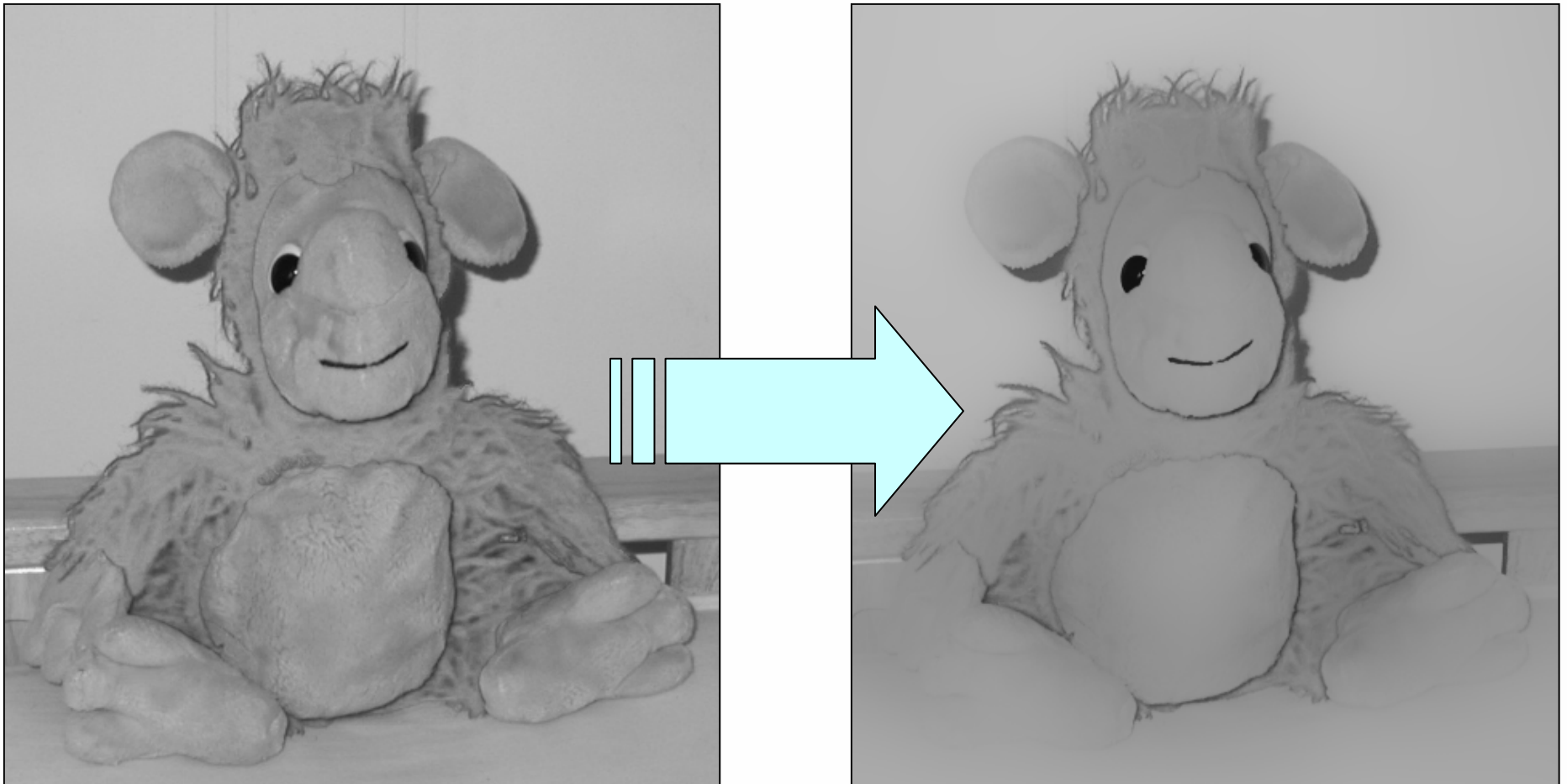
- **Bilateral filter** – edge preserving filter

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



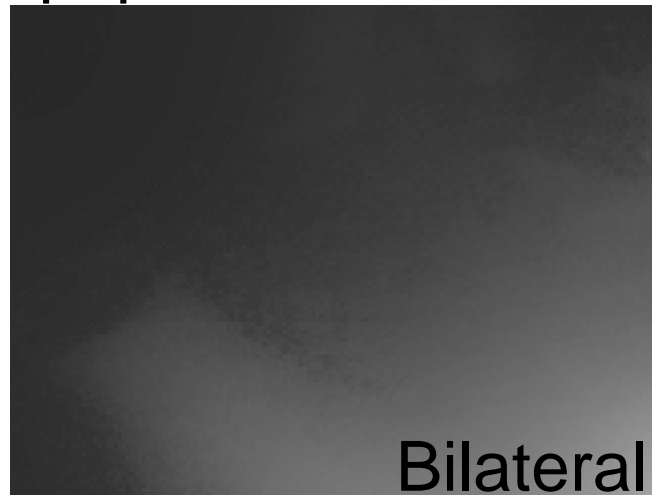
# Large-scale Layer

- 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

shadows

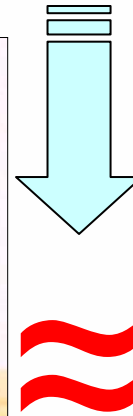


Intensity  
Result

\*



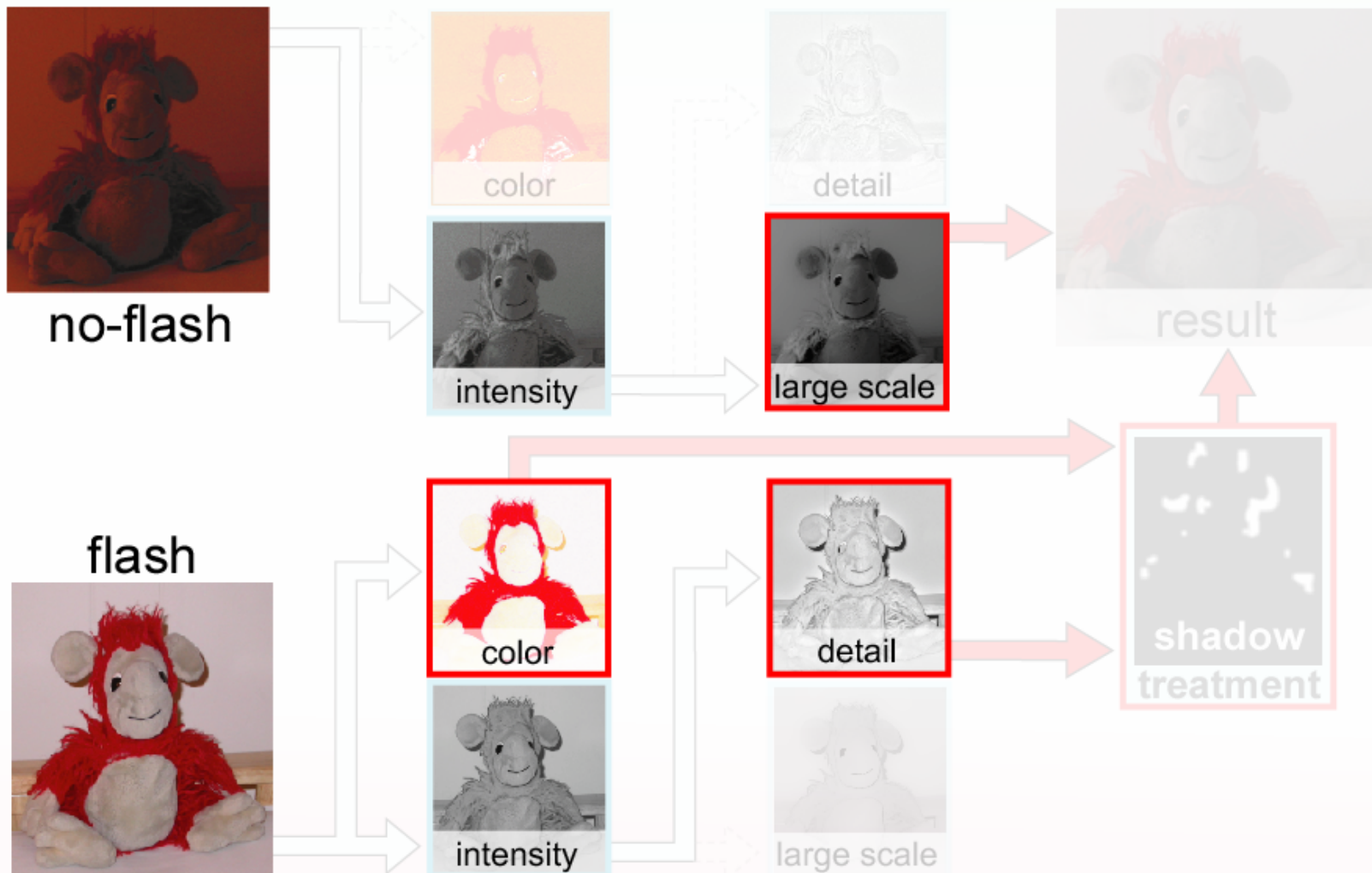
Color  
Flash



Result

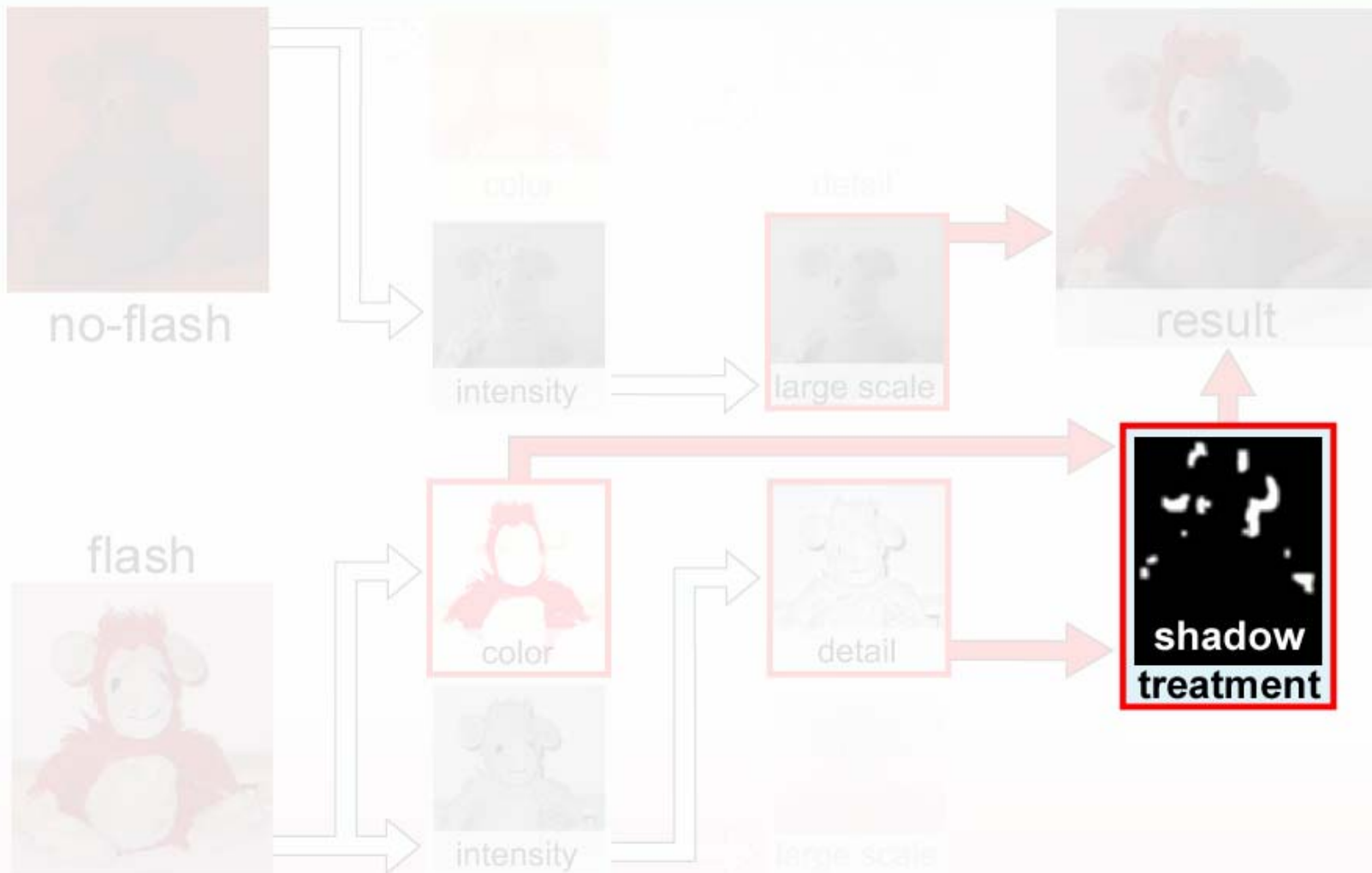
Recombination: Intensity \* Color = Original

# Our Approach



# Our Approach

## Shadow Detection/Treatment



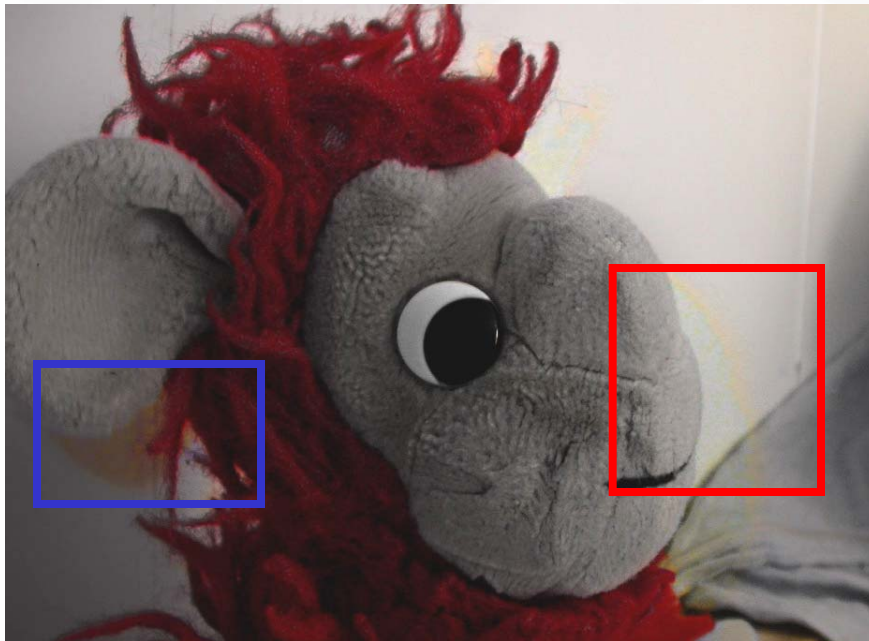


# Shadow Correction – Why?

PIGGGRAPH2004



# Shadow Correction – Why?



Global white balance in shadows

Several artifacts:

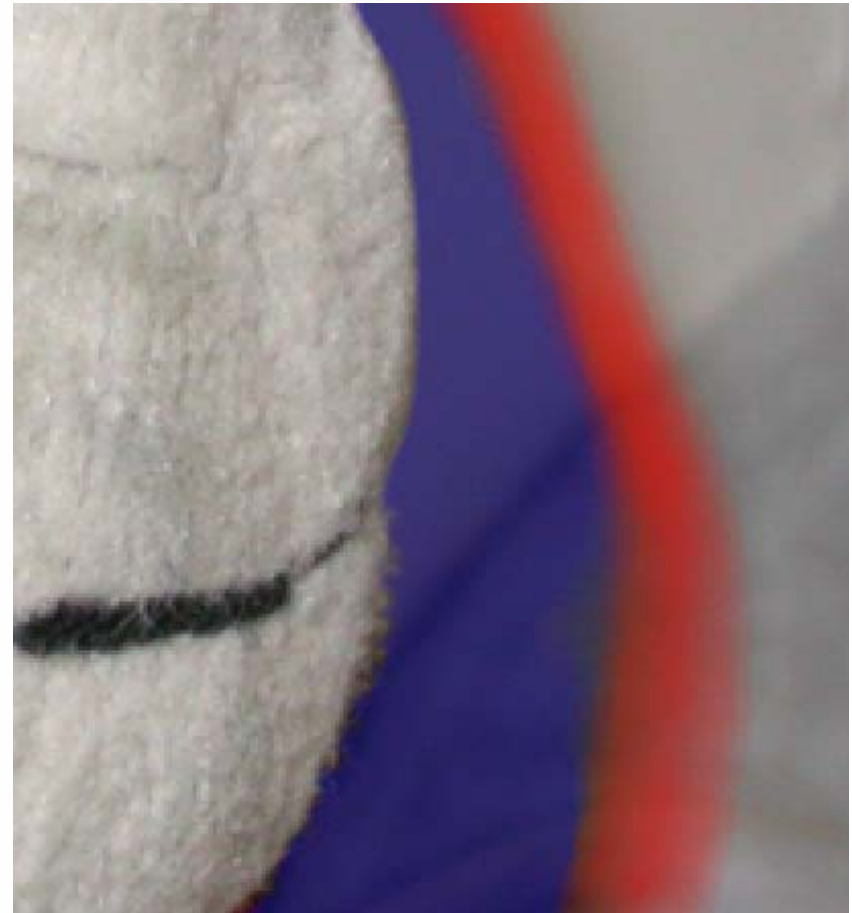
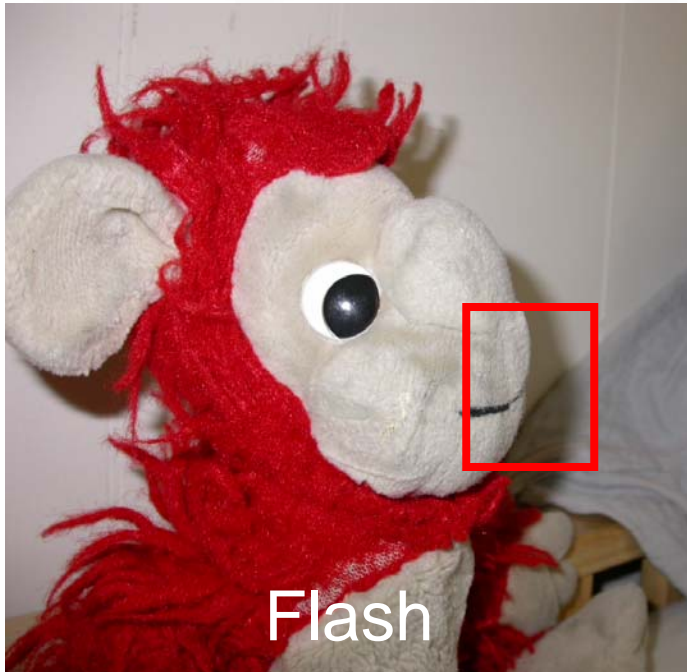
- at shadow boundary
- inside shadows (color bleeding)

➤ shadows need to be corrected !

... and detected



# Shadow Detection



- Umbra
- Penumbra

➤ Detection in two steps



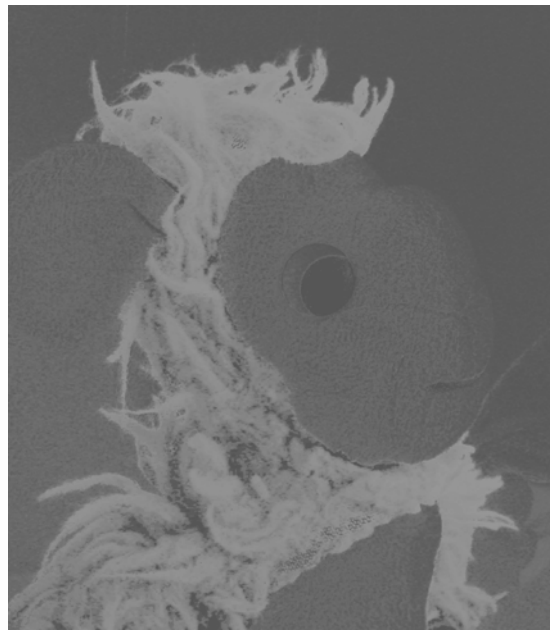
# Shadow Detection

## Umbra detection

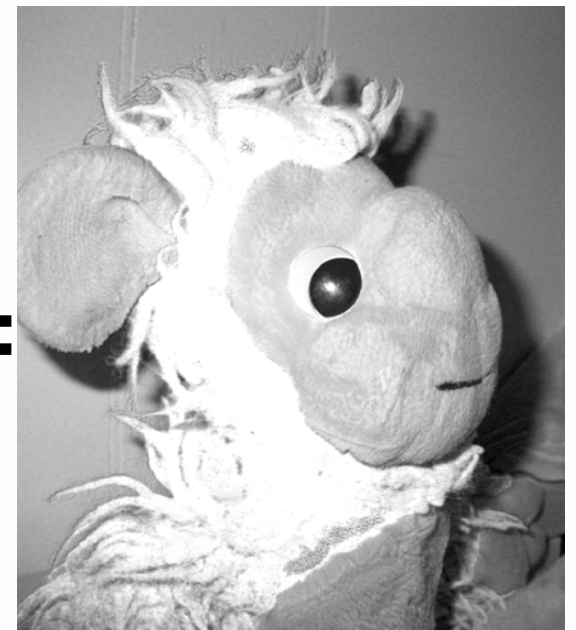
- No direct light from flash
- Difference of the two photos  $\Delta I$  reveals these regions



Flash



No-flash

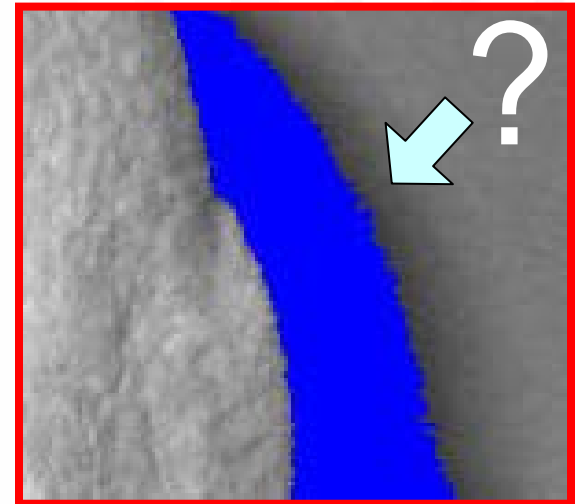


$\Delta I$

# Shadow Detection

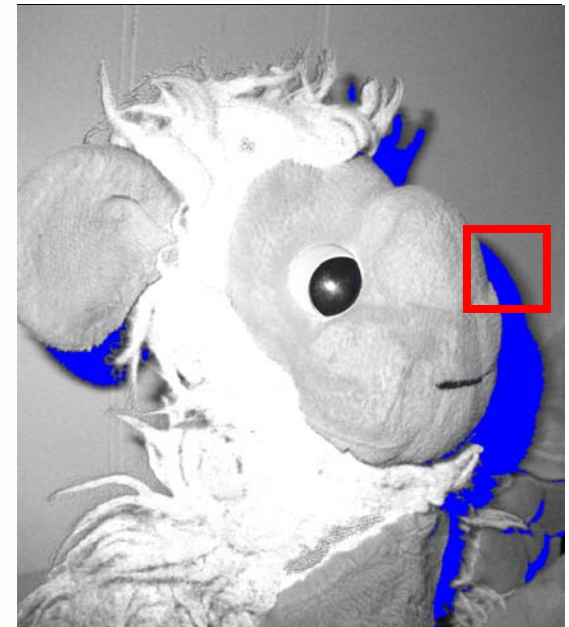
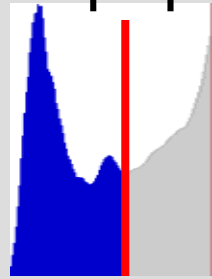
## Umbra detection

- Difference  $\Delta I$  = light from the flash
- Goal: Find a threshold for  $\Delta I$



$\Delta I$

Automatic  
Threshold  
Detection  
(see paper)

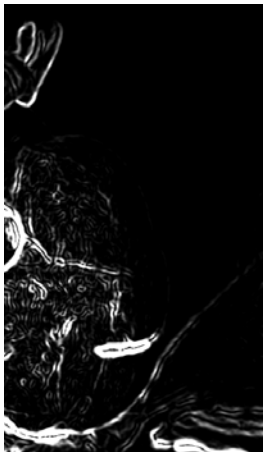




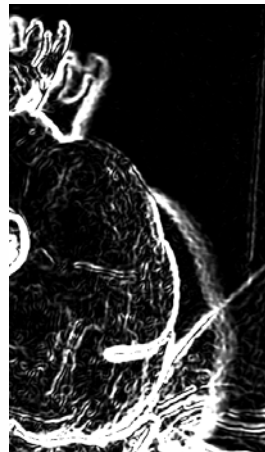
# Shadow Detection

## Penumbra detection

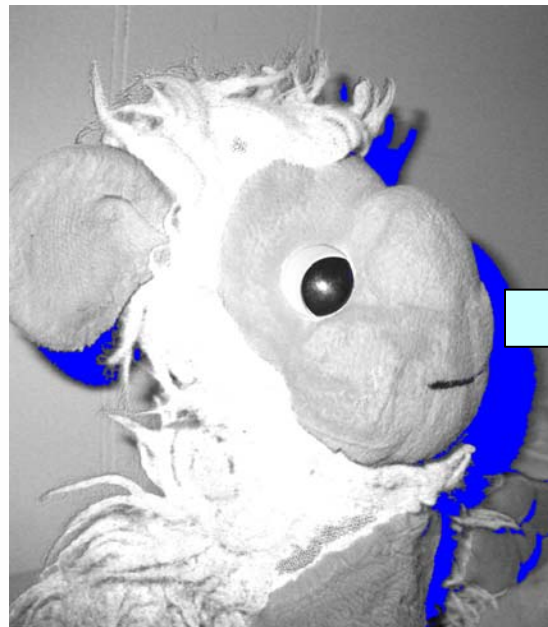
- strong gradient at boundary
- no strong gradient in no-flash image
- connected to umbra



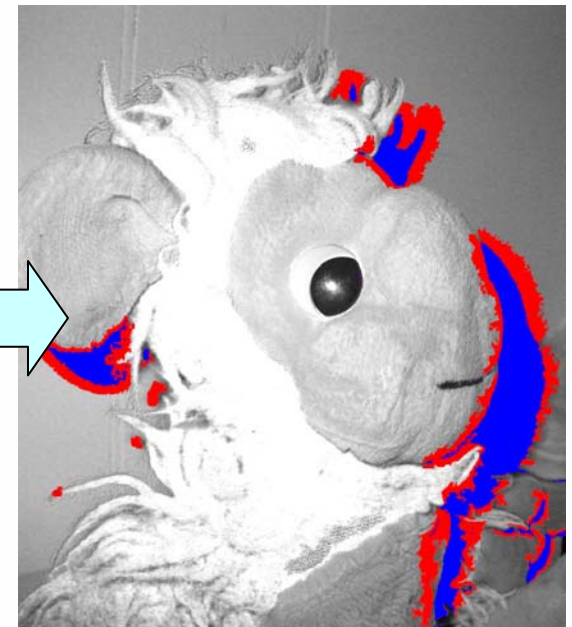
No-flash



flash



Umbra



Penumbra

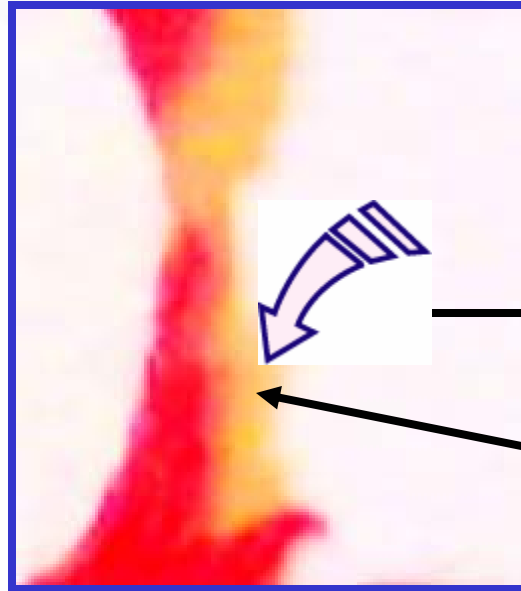
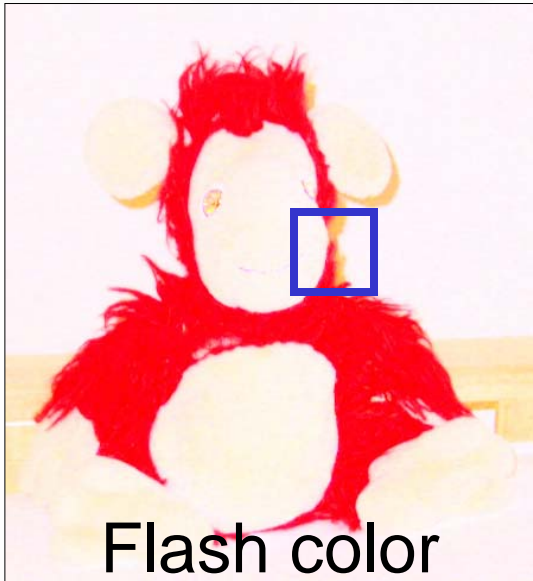
# Shadow Correction

- Correct **color** and **detail**

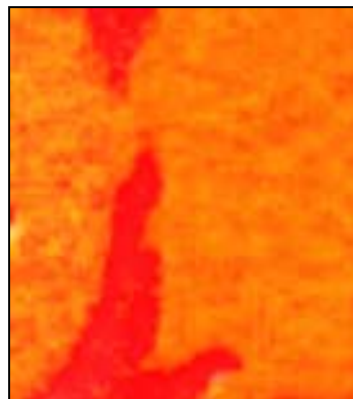


Shadow mask

# Shadow Color Correction



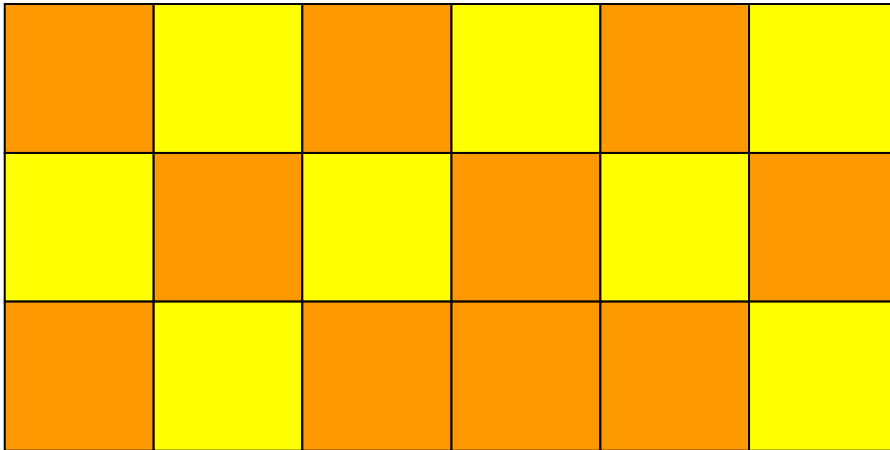
Fill in shadow from **similar** surrounding



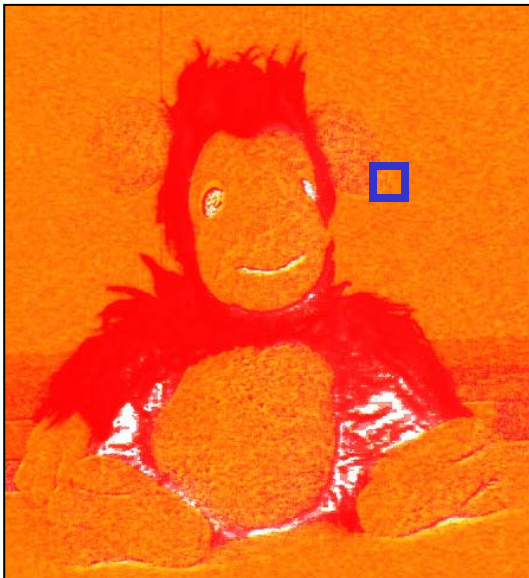
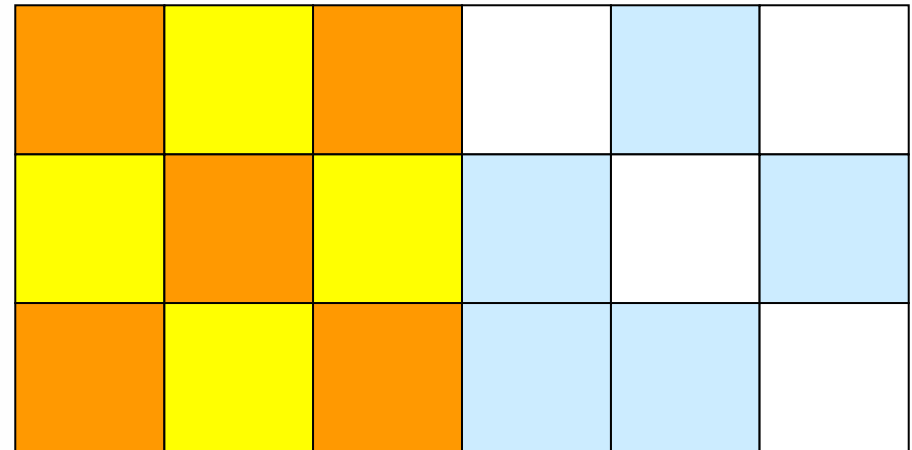
No-flash colors

# Shadow Color Correction

No-flash

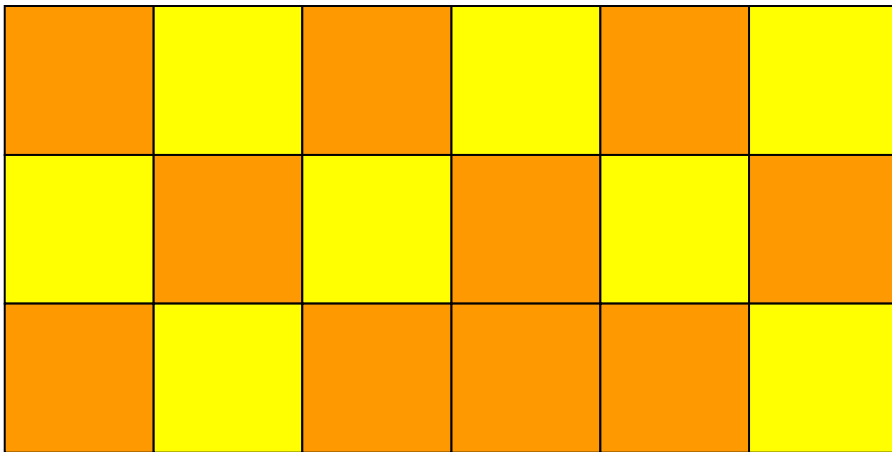


Flash

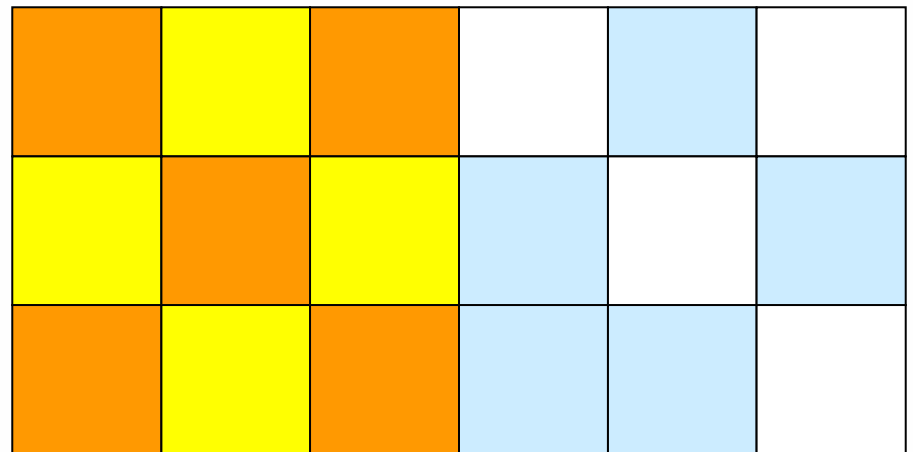


# Shadow Color Correction

No-flash

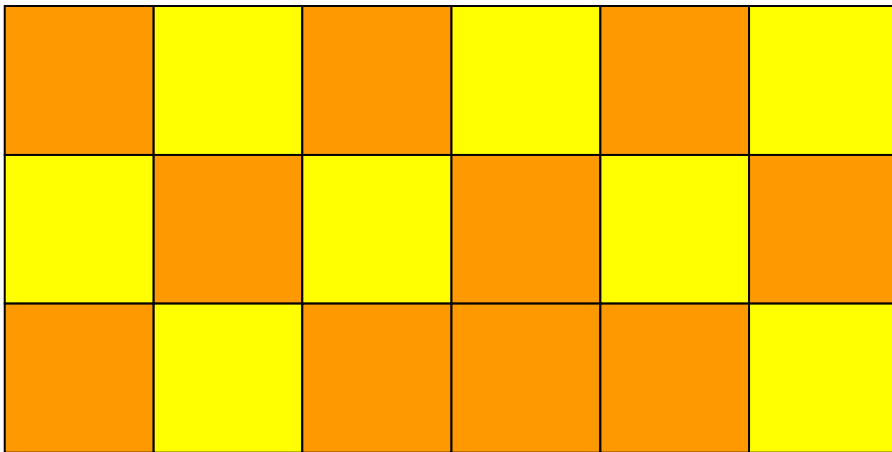


Flash

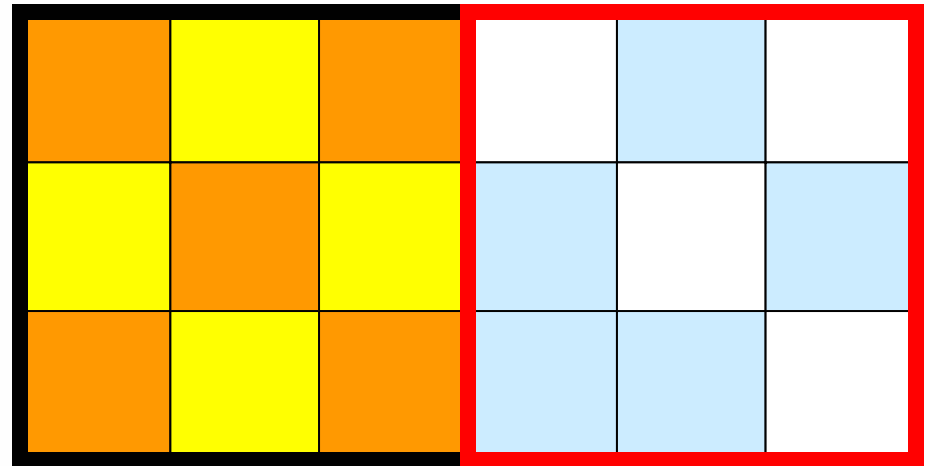


# Shadow Color Correction

No-flash



Flash



Outside shadow

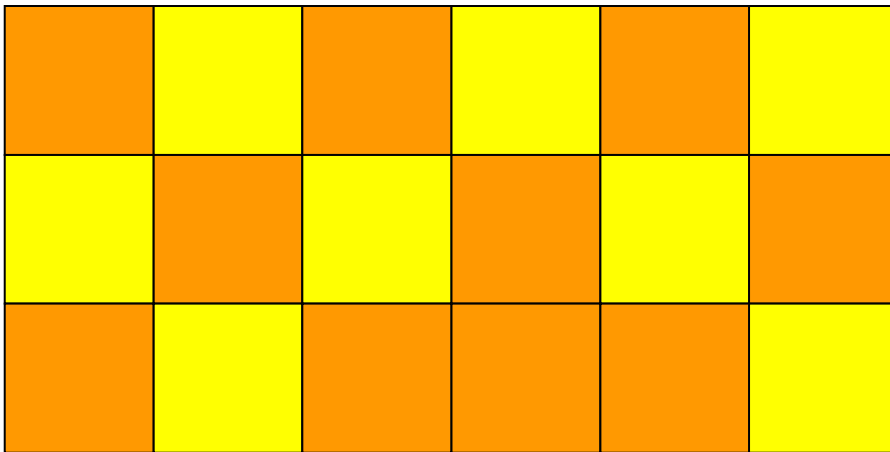


shadow

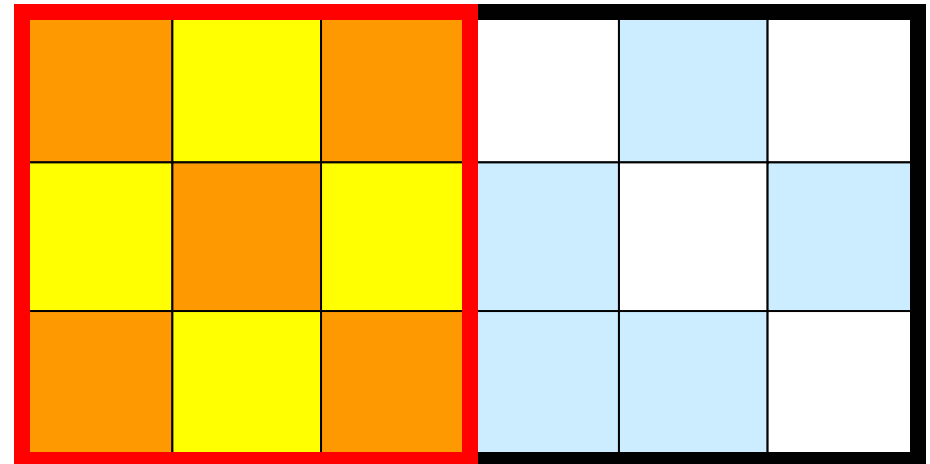


# Shadow Color Correction

No-flash



Flash



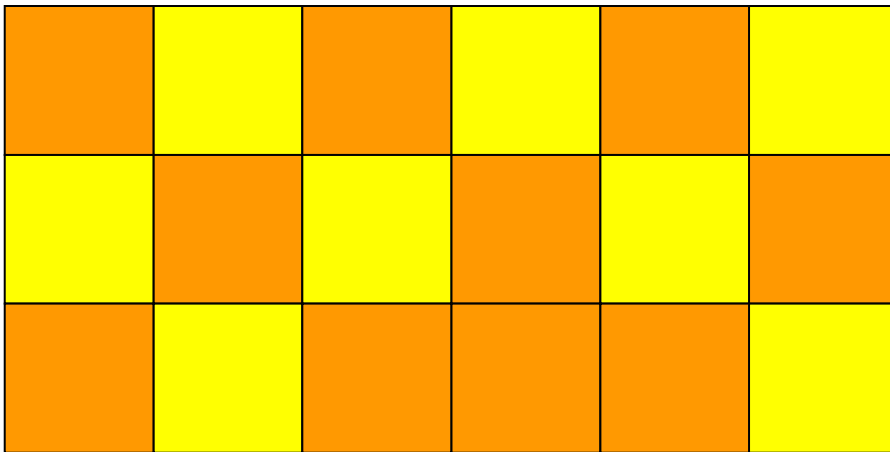
Inside shadow

Outside shadow

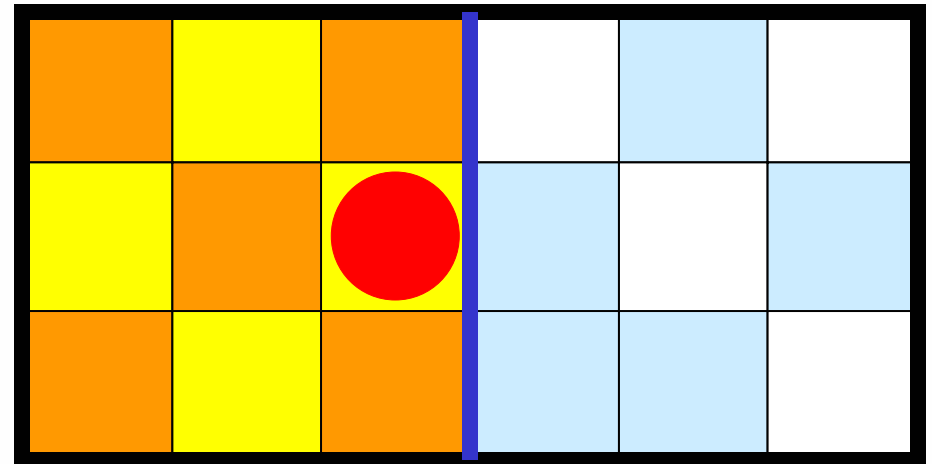


# Shadow Color Correction

No-flash



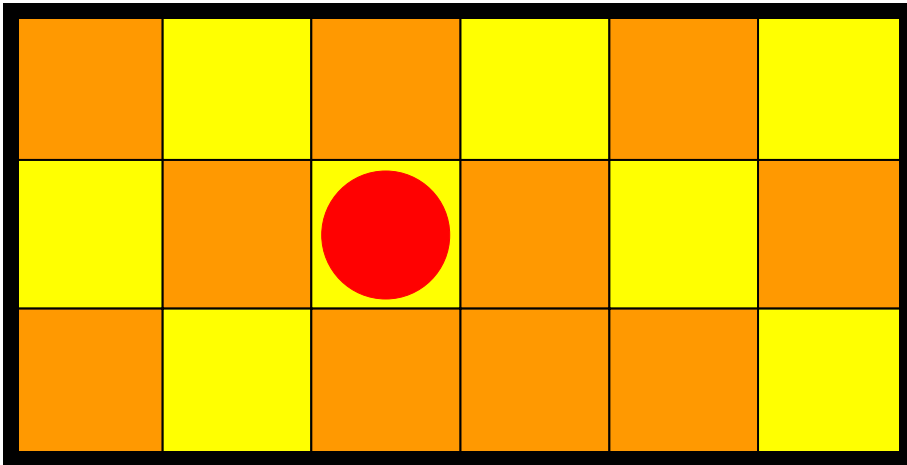
Flash



Inside shadow      Outside shadow  
Select pixel in shadow

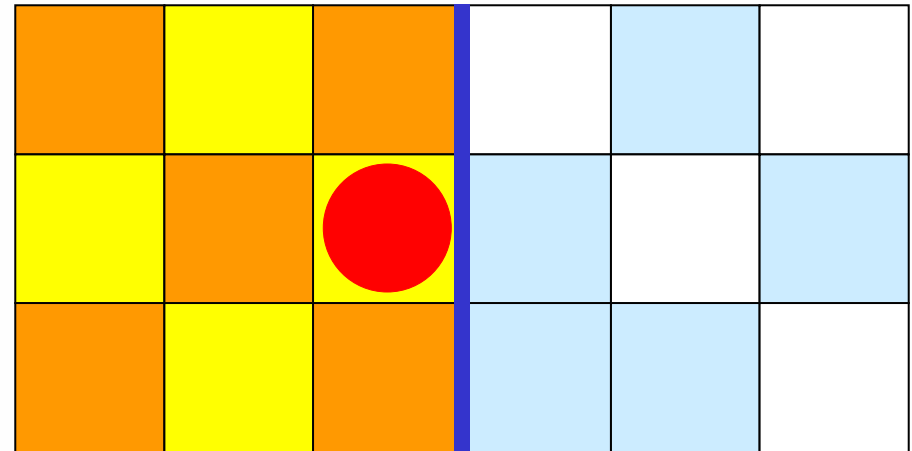
# Shadow Color Correction

No-flash



Corresponding pixel

Flash

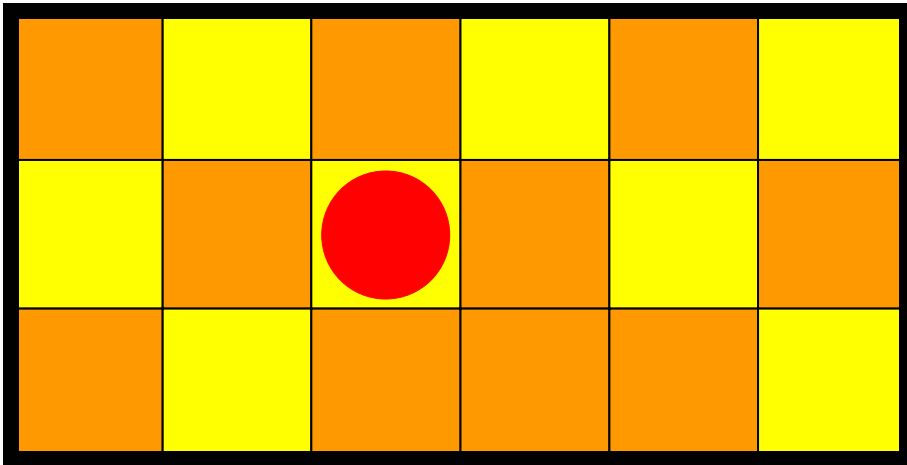


Inside shadow

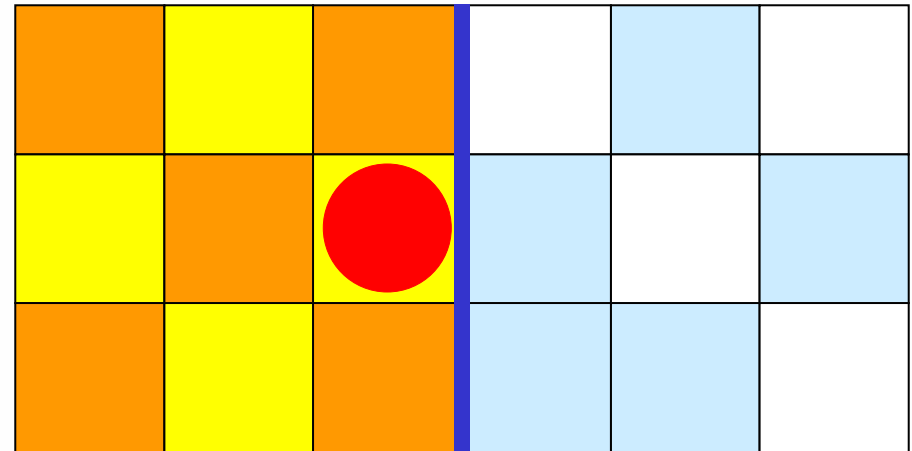
Outside shadow

# Shadow Color Correction

No-flash



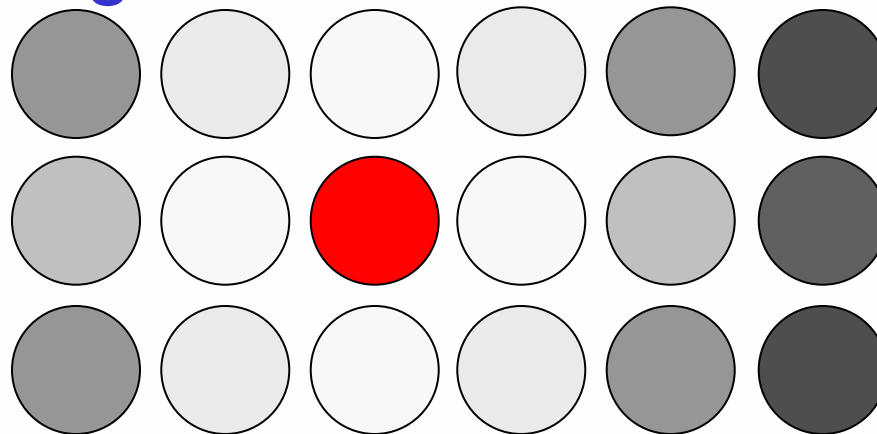
Flash



Inside shadow

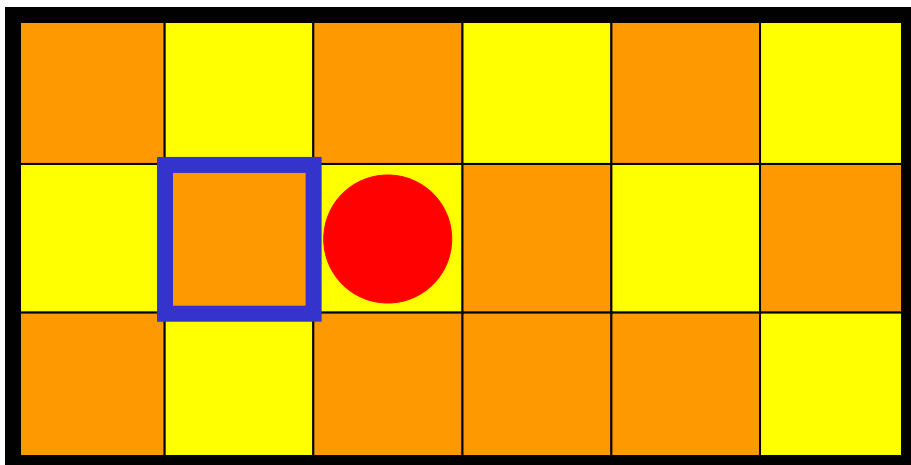
Outside shadow

Spatial weights

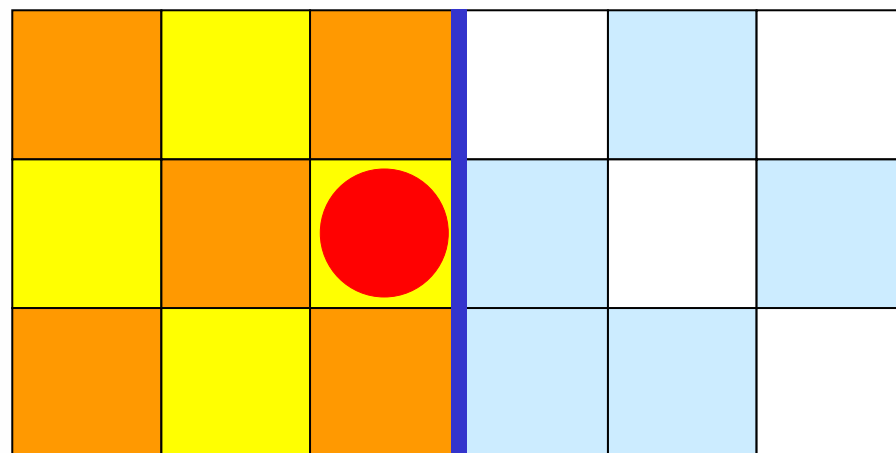


# Shadow Color Correction

No-flash



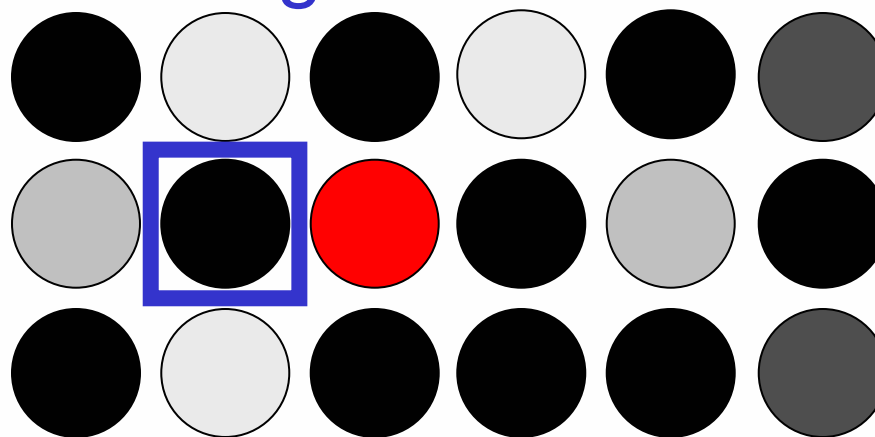
Flash



Inside shadow

Outside shadow

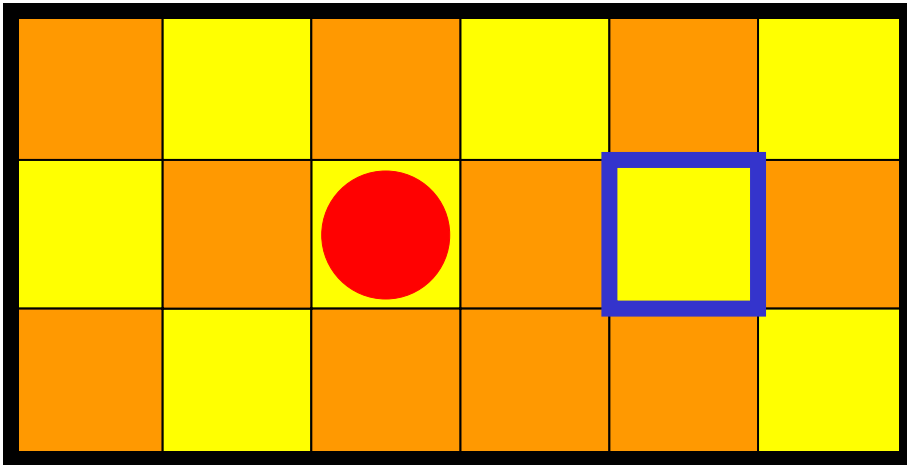
Spatial and Color weights



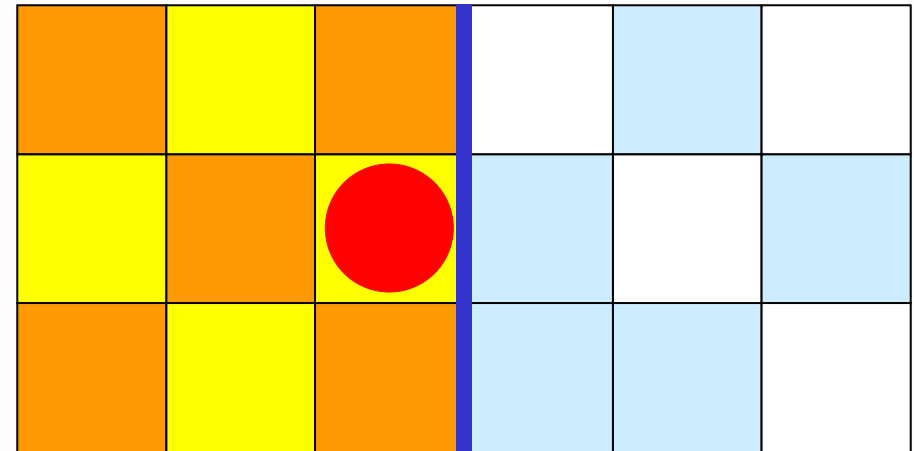


# Shadow Color Correction

No-flash



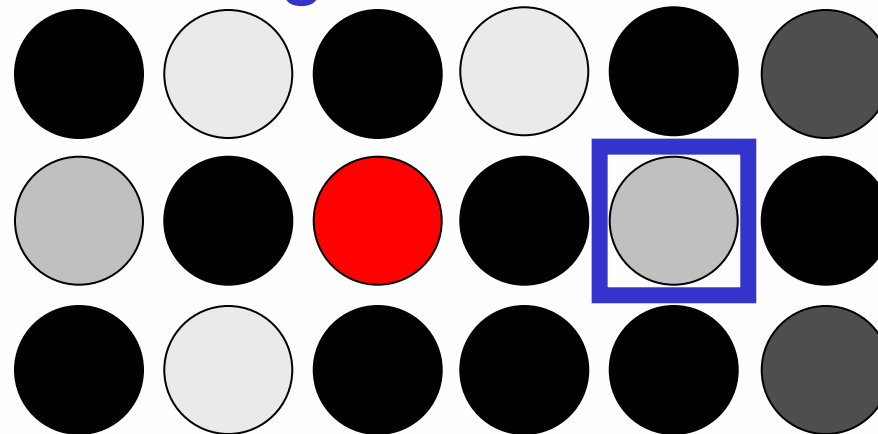
Flash



Inside shadow

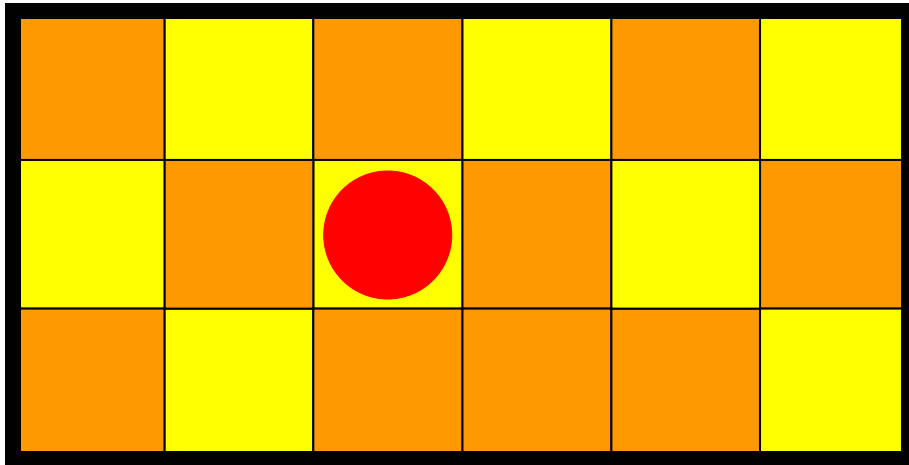
Outside shadow

Spatial and Color weights

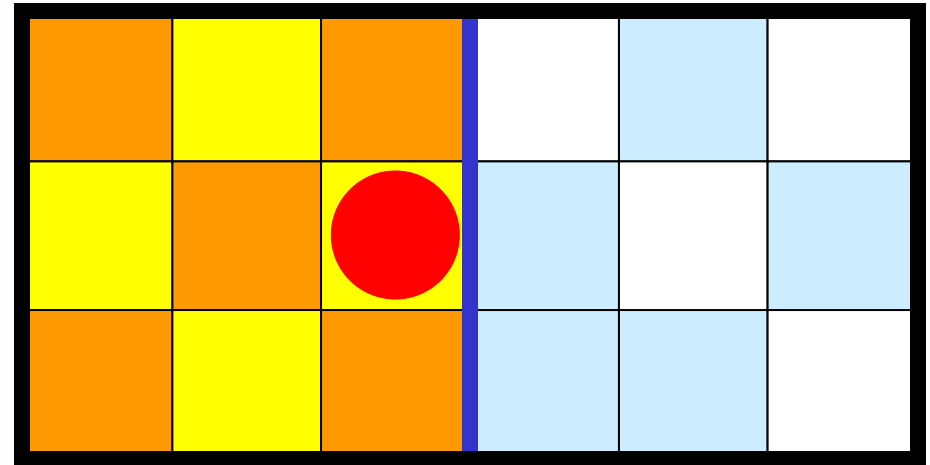


# Shadow Color Correction

No-flash



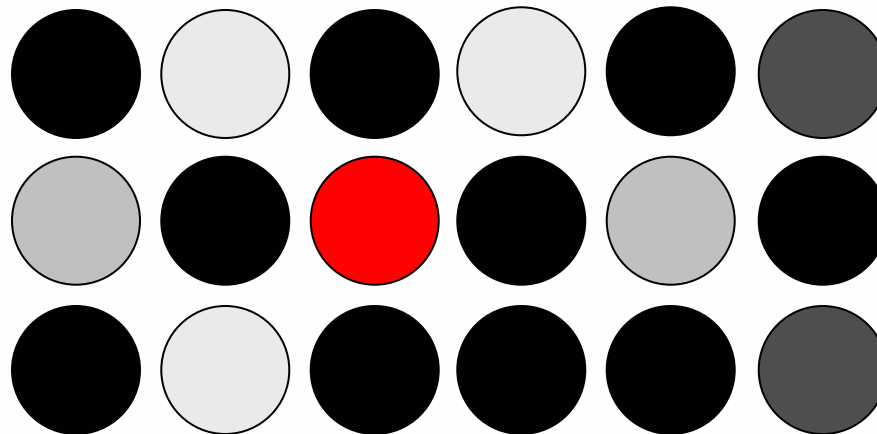
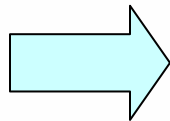
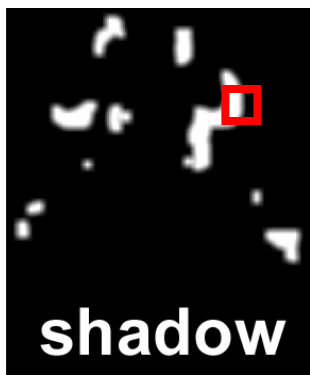
Flash



Inside shadow

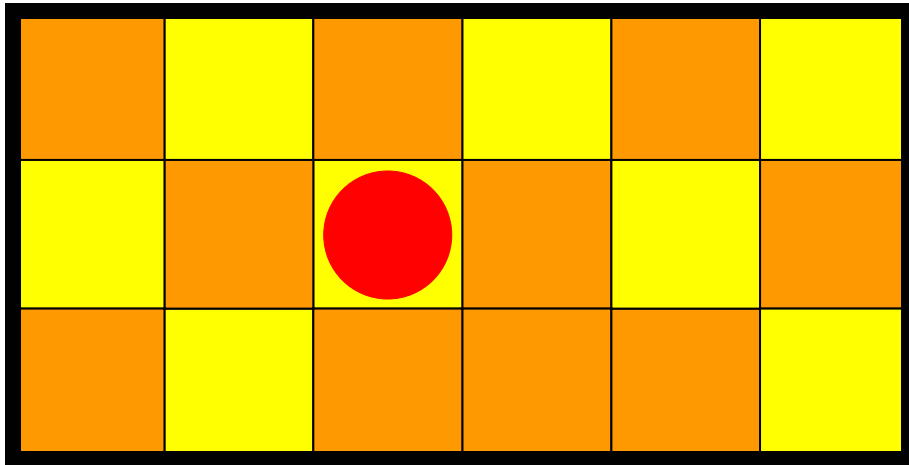
Outside shadow

Use shadow mask

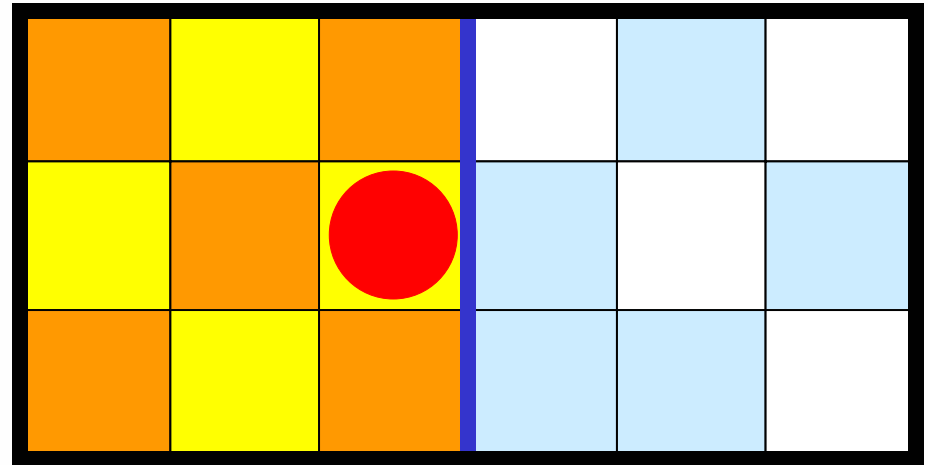


# Shadow Color Correction

No-flash



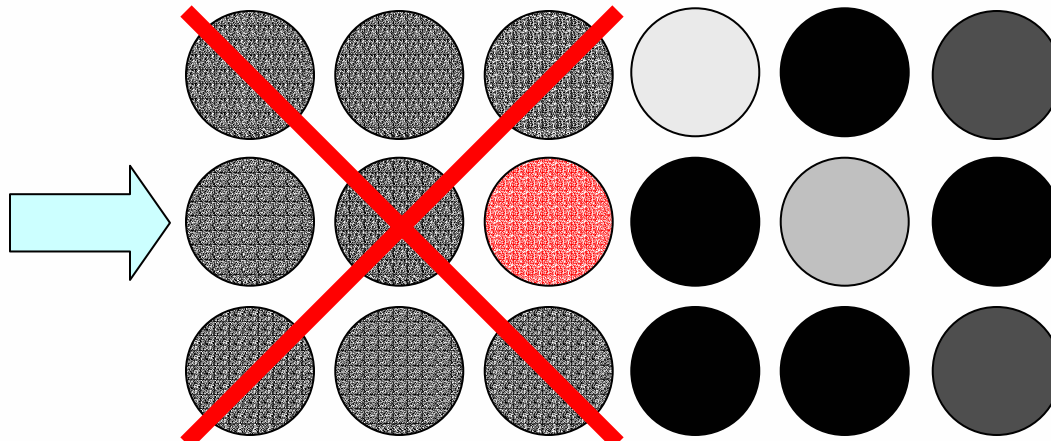
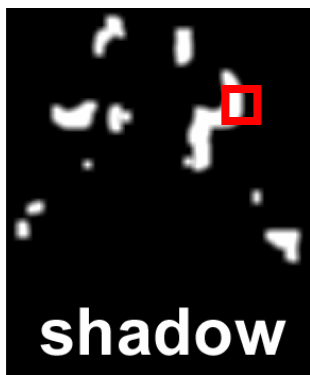
Flash



Inside shadow

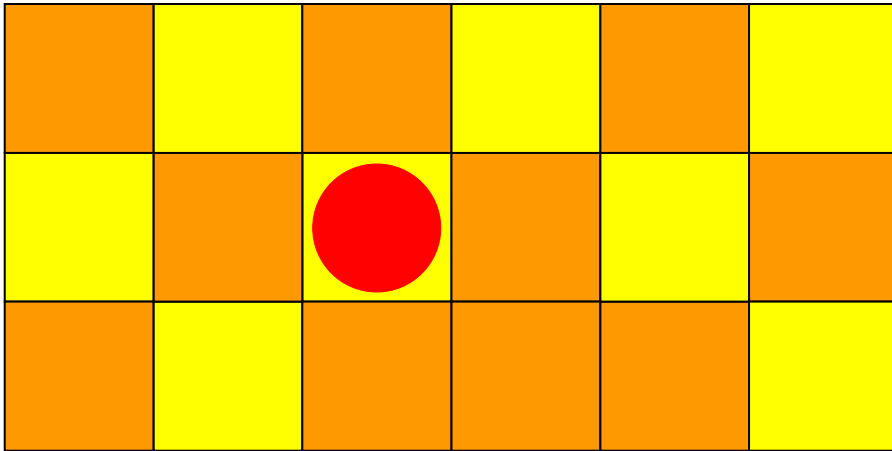
Outside shadow

Use shadow mask

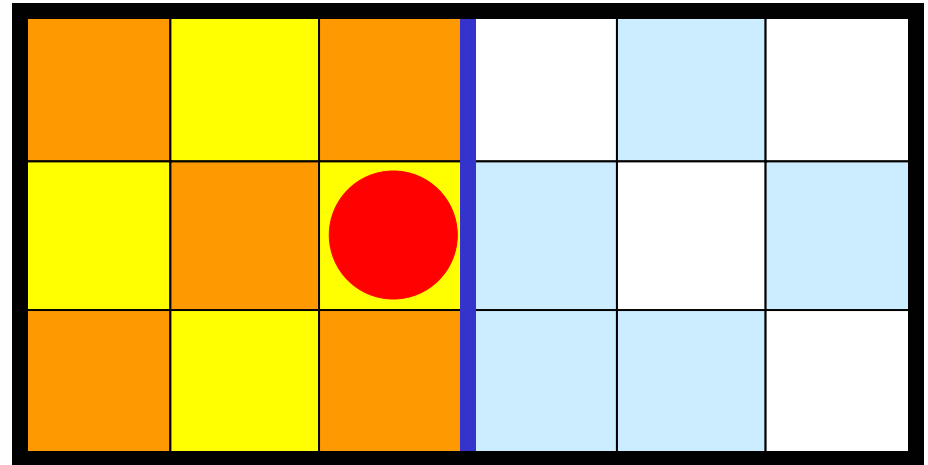


# Shadow Color Correction

No-flash



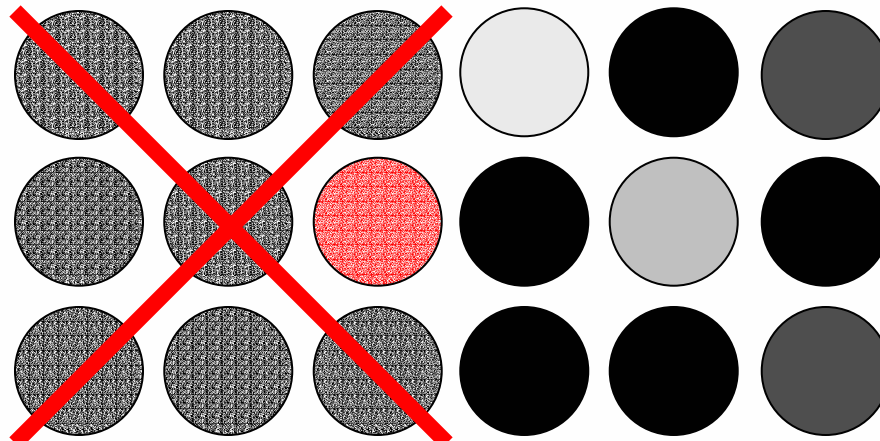
Flash



Inside shadow

Outside shadow

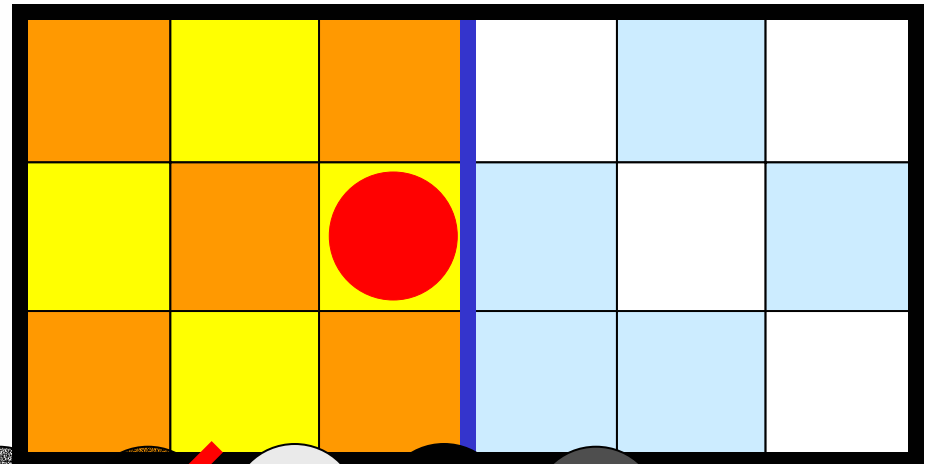
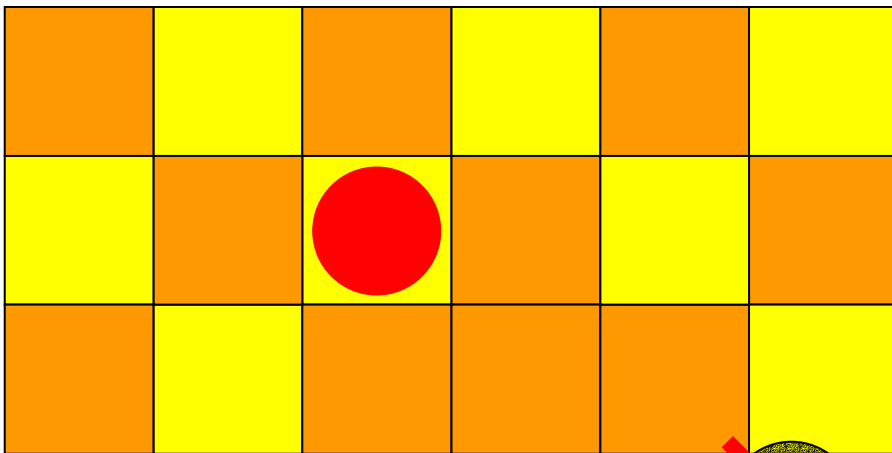
Use shadow mask



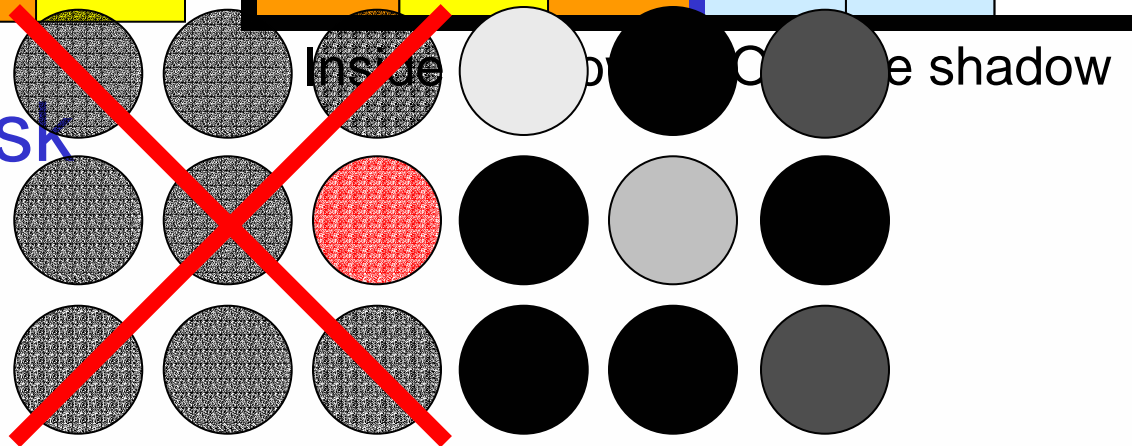
# Shadow Color Correction

No-flash

Flash



Use shadow mask

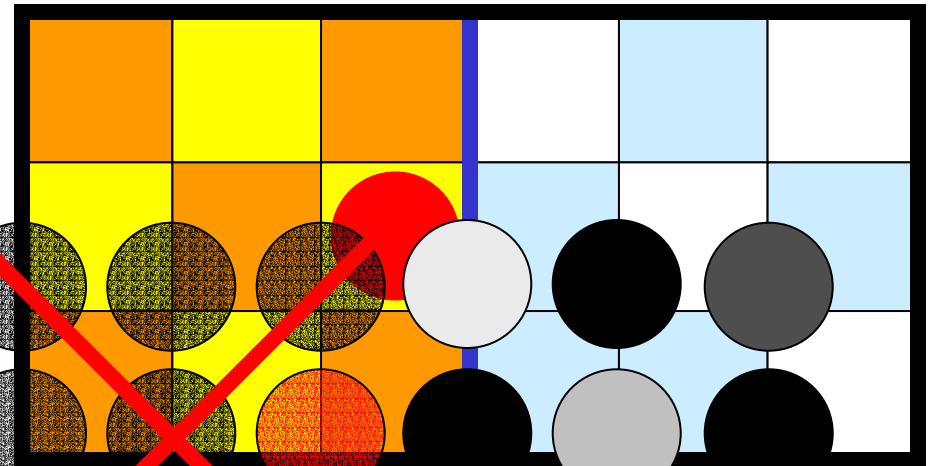
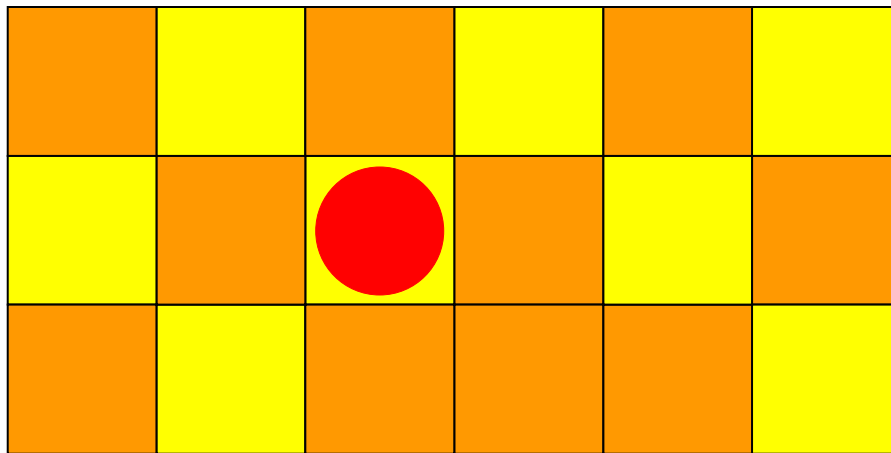




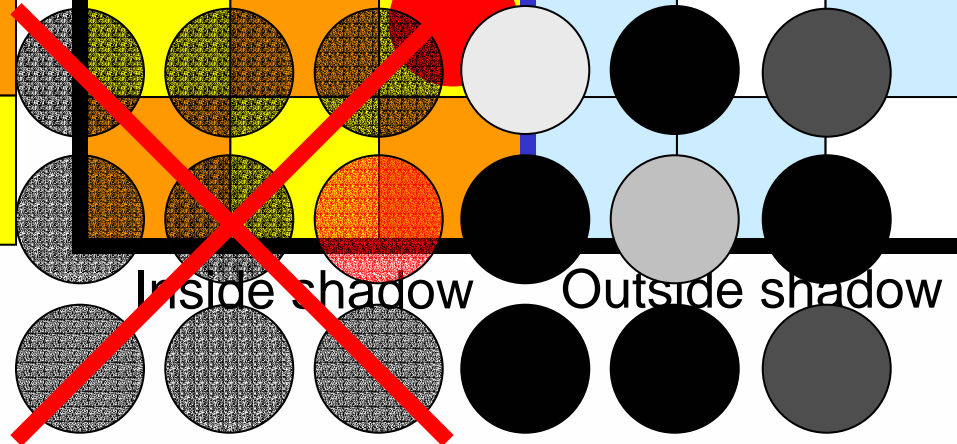
# Shadow Color Correction

No-flash

Flash

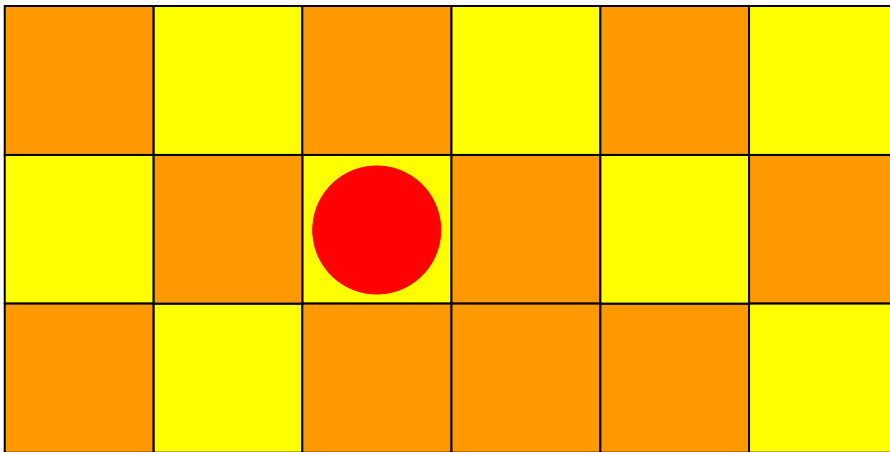


Use shadow mask



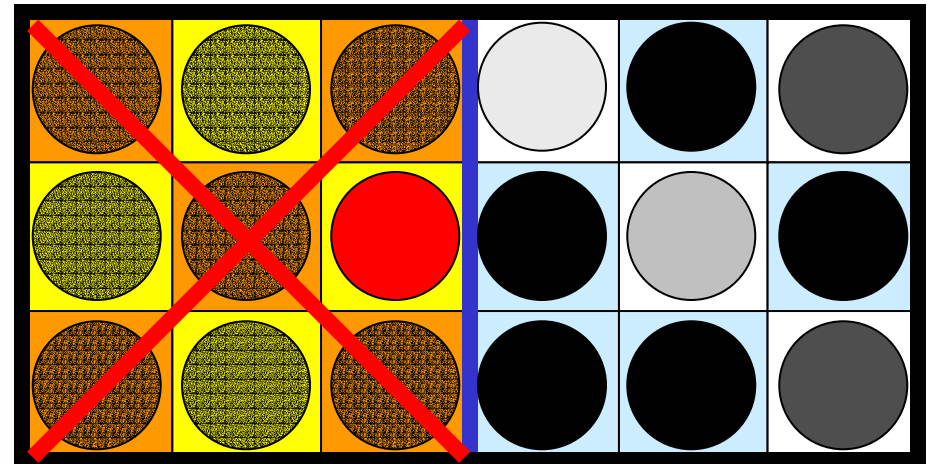
# Shadow Color Correction

No-flash



Use shadow mask

Flash

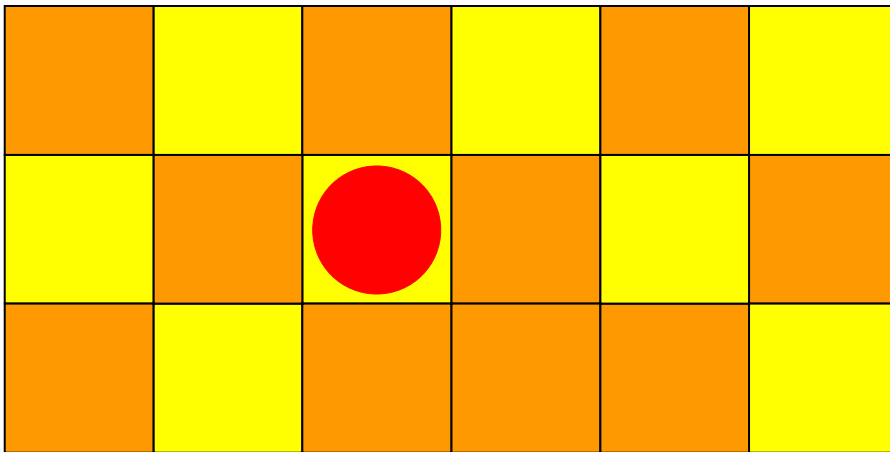


Inside shadow

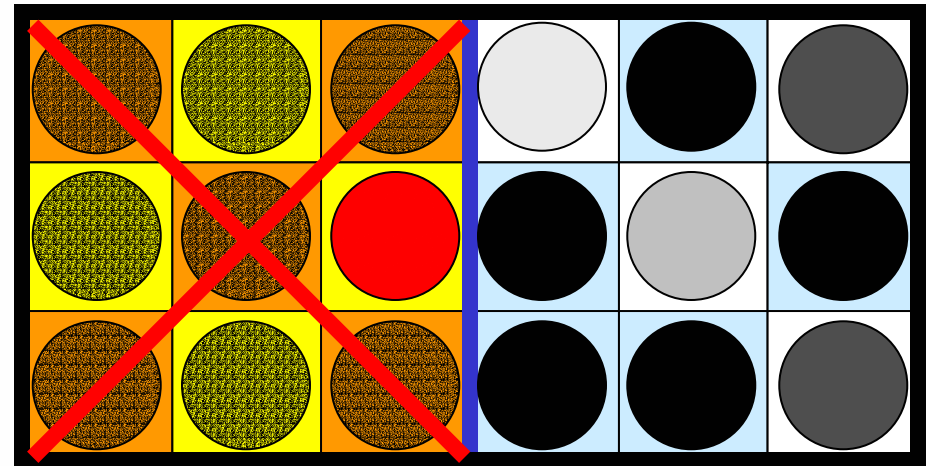
Outside shadow

# Shadow Color Correction

No-flash



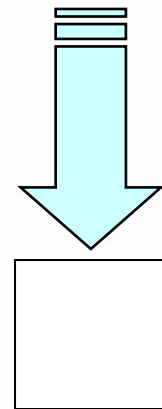
Flash



Inside shadow

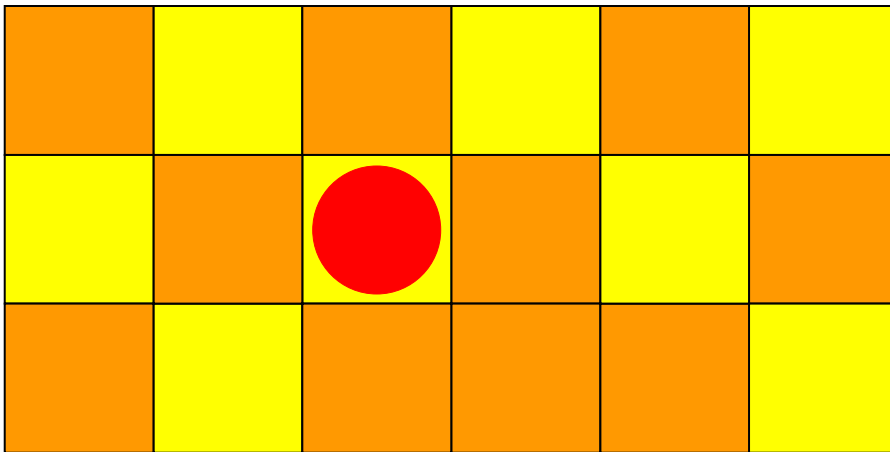
Outside shadow

Use weights on flash color

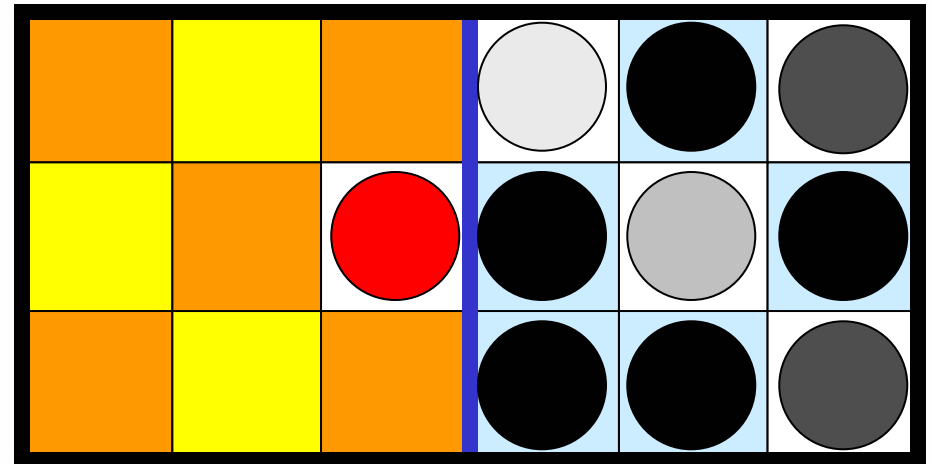


# Shadow Color Correction

No-flash



Flash



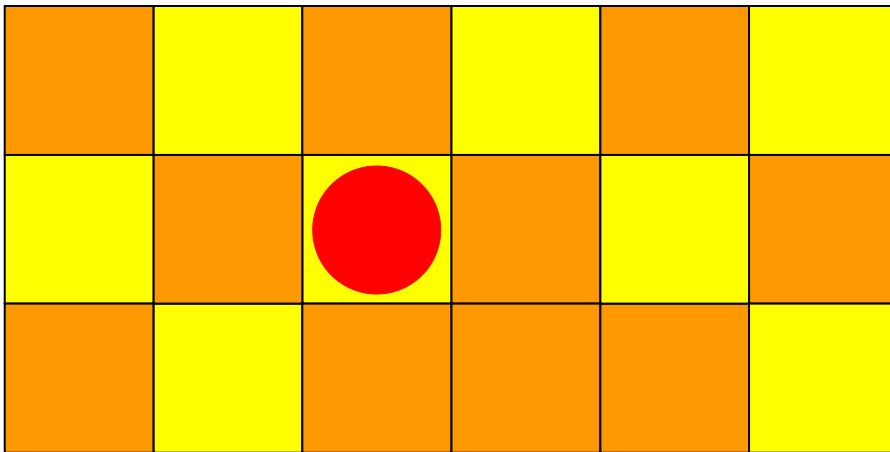
Inside shadow

Outside shadow

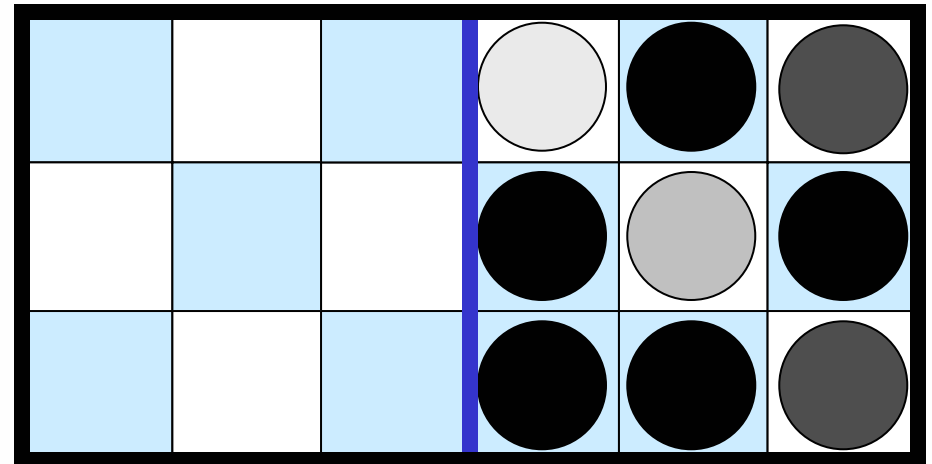
Replace shadow pixel

# Shadow Color Correction

No-flash



Flash

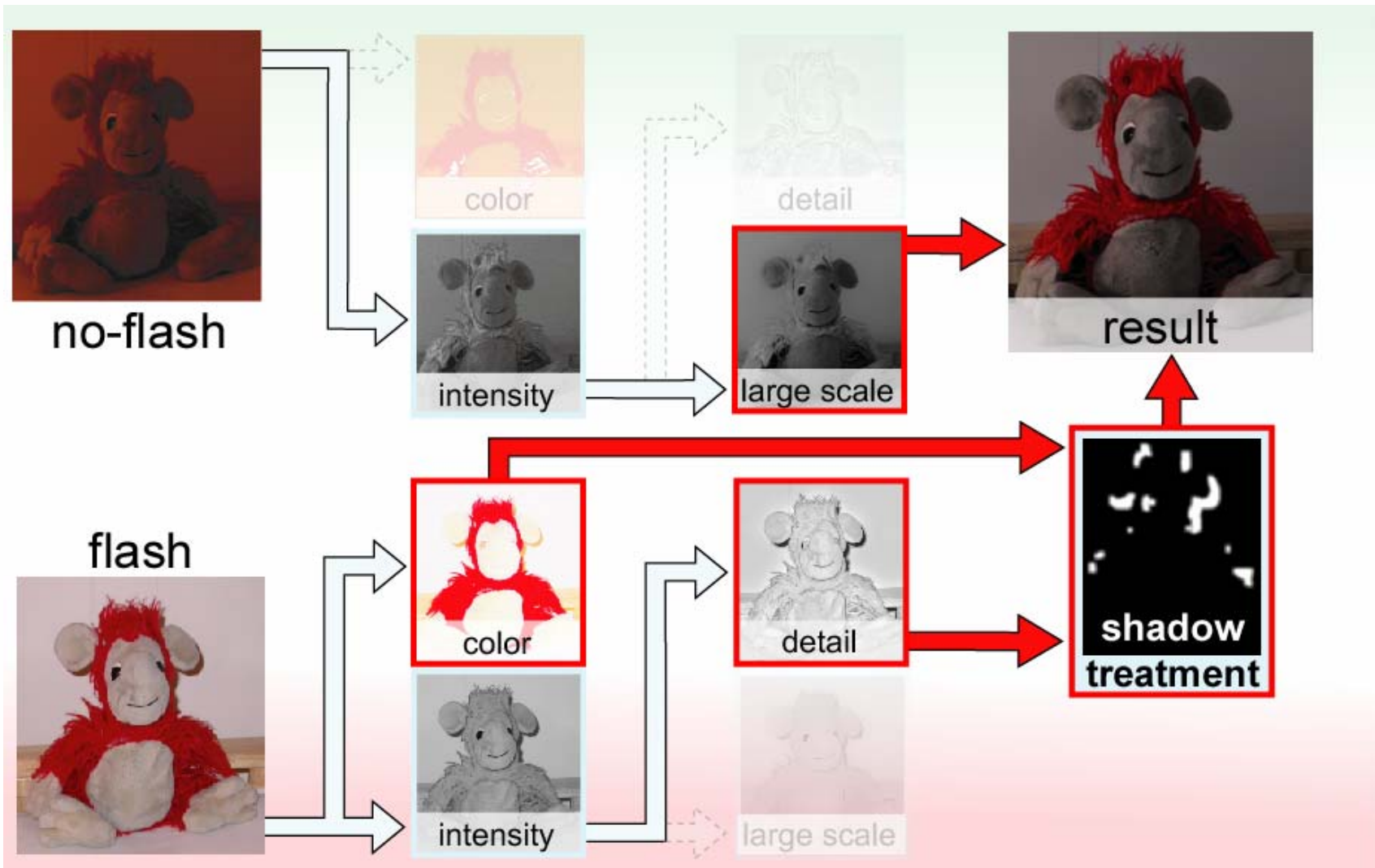


Inside shadow

Outside shadow

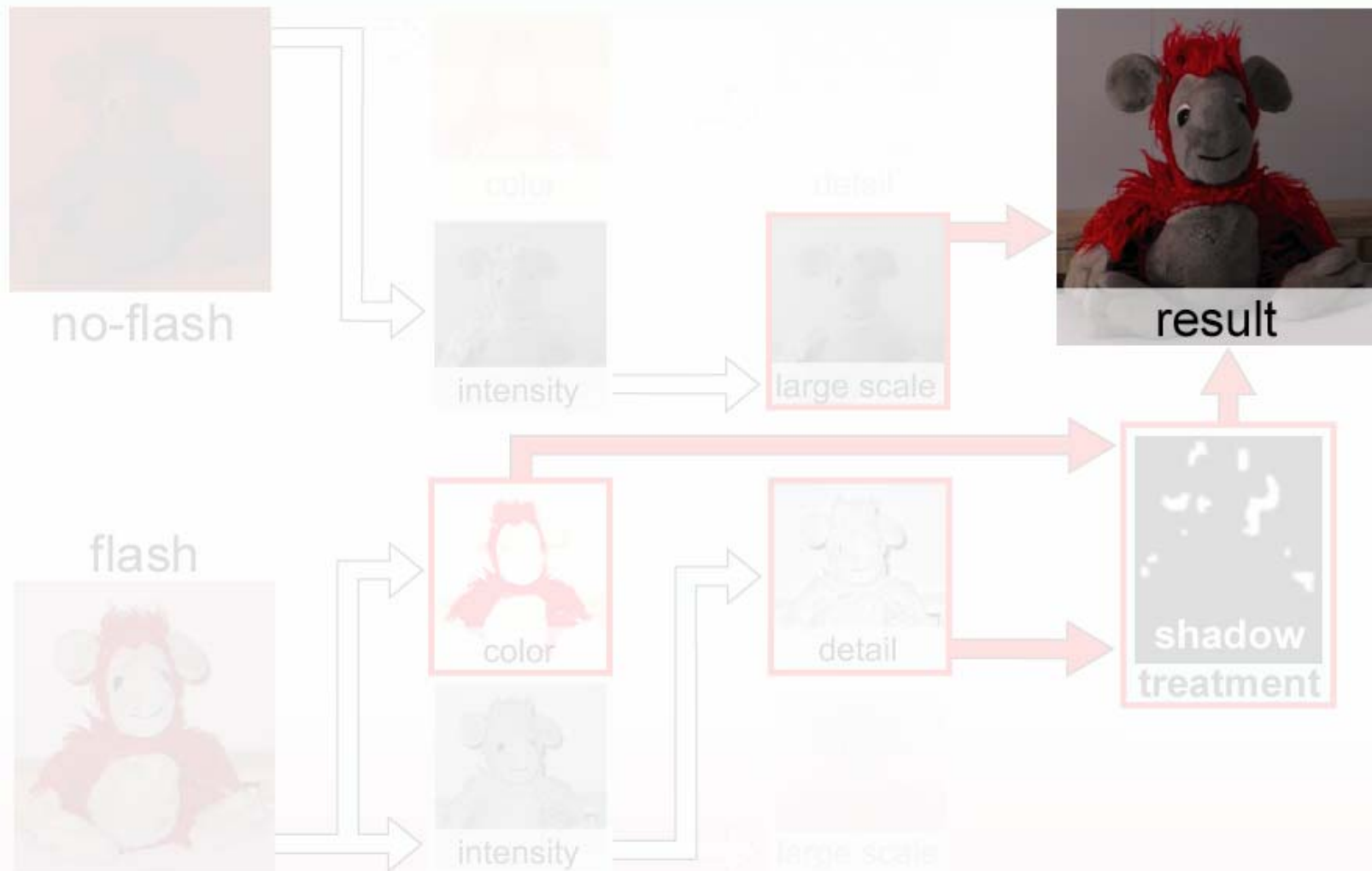
Proceed for all shadow pixels

# Our Approach





# Our Approach



# Overview

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

# Results

SIGGRAPH2004



No-flash

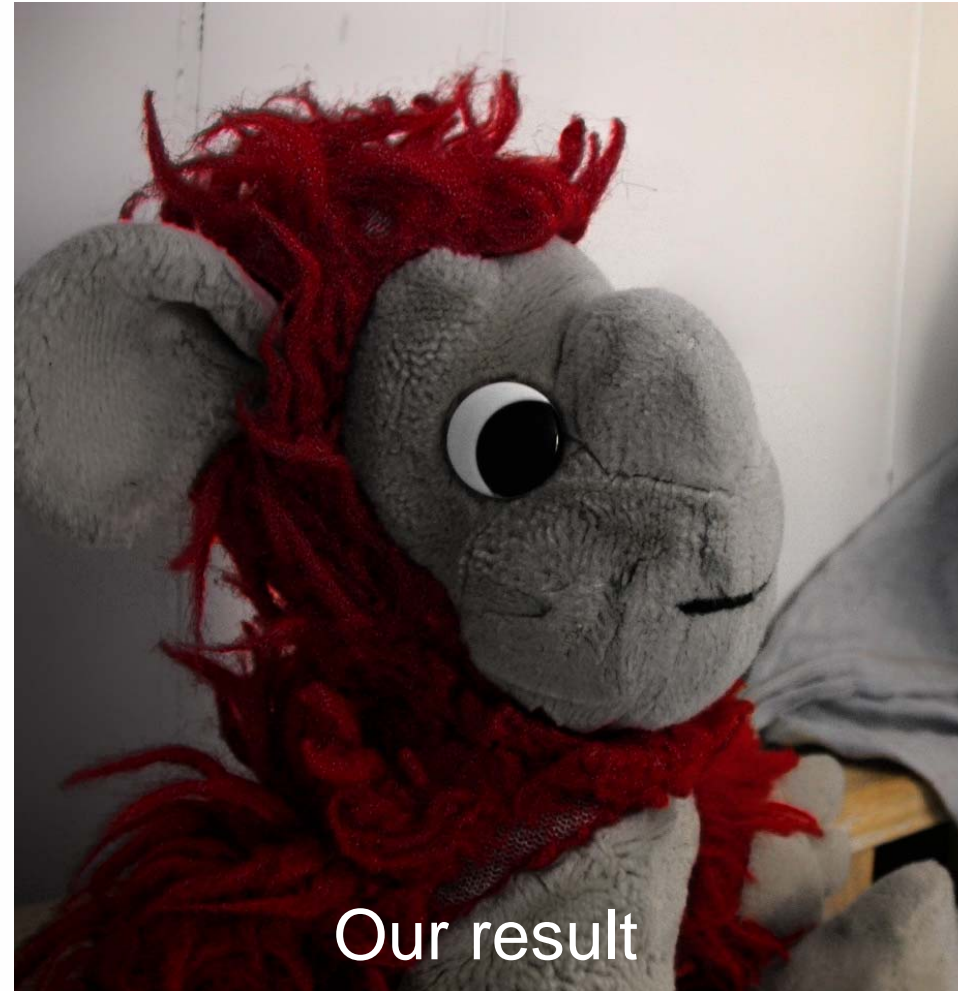


Flash



# Results

SIGGRAPH2004



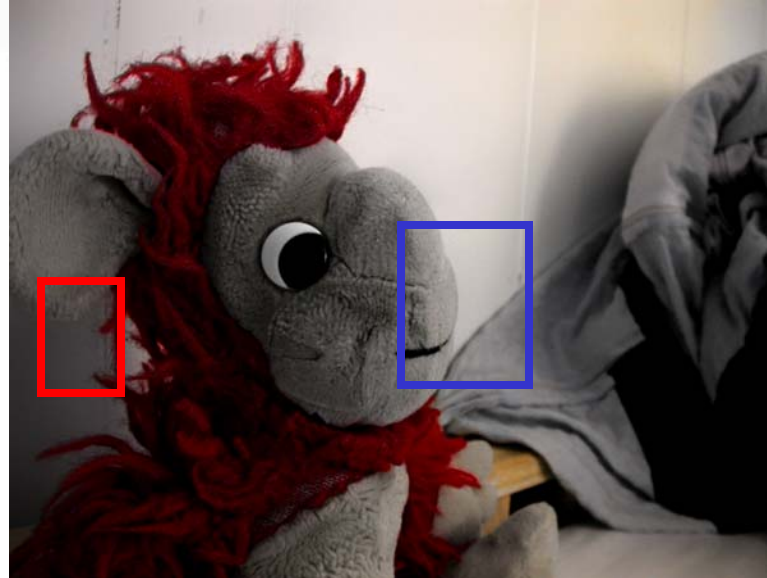


# Results

SIGGRAPH2004



No-flash



Flash



# Results

SIGGRAPH2004



No-flash



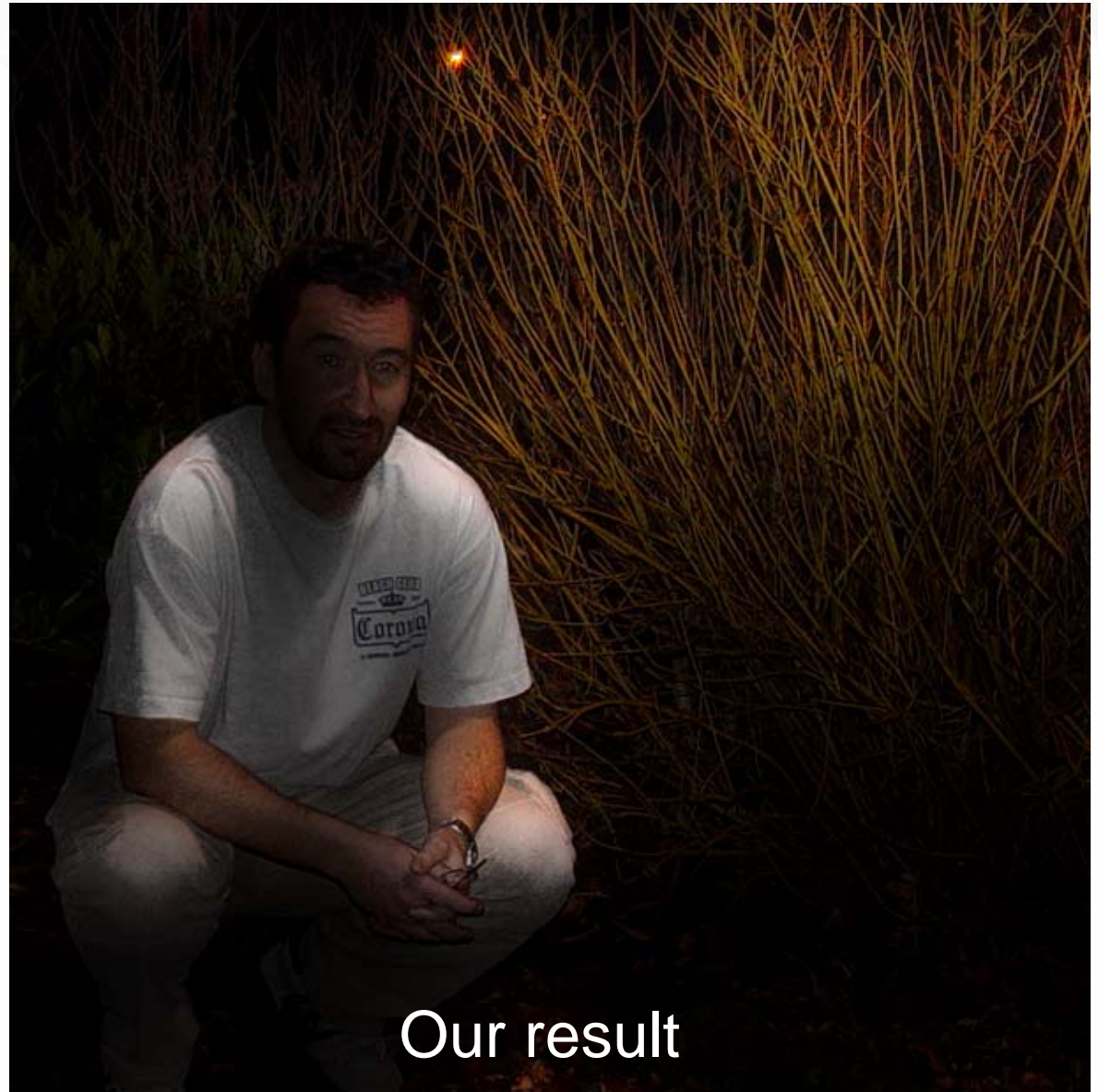
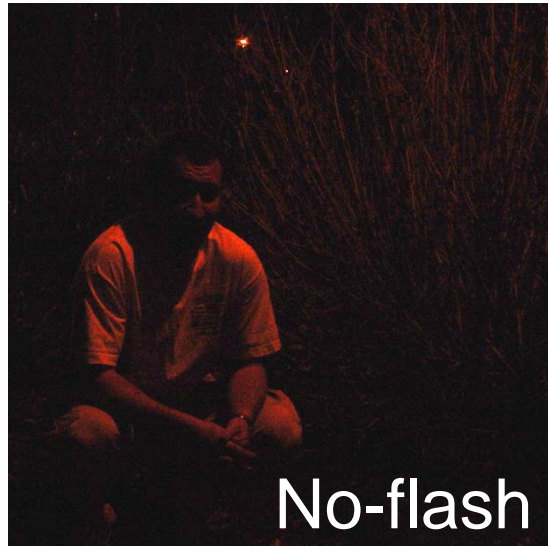
Flash





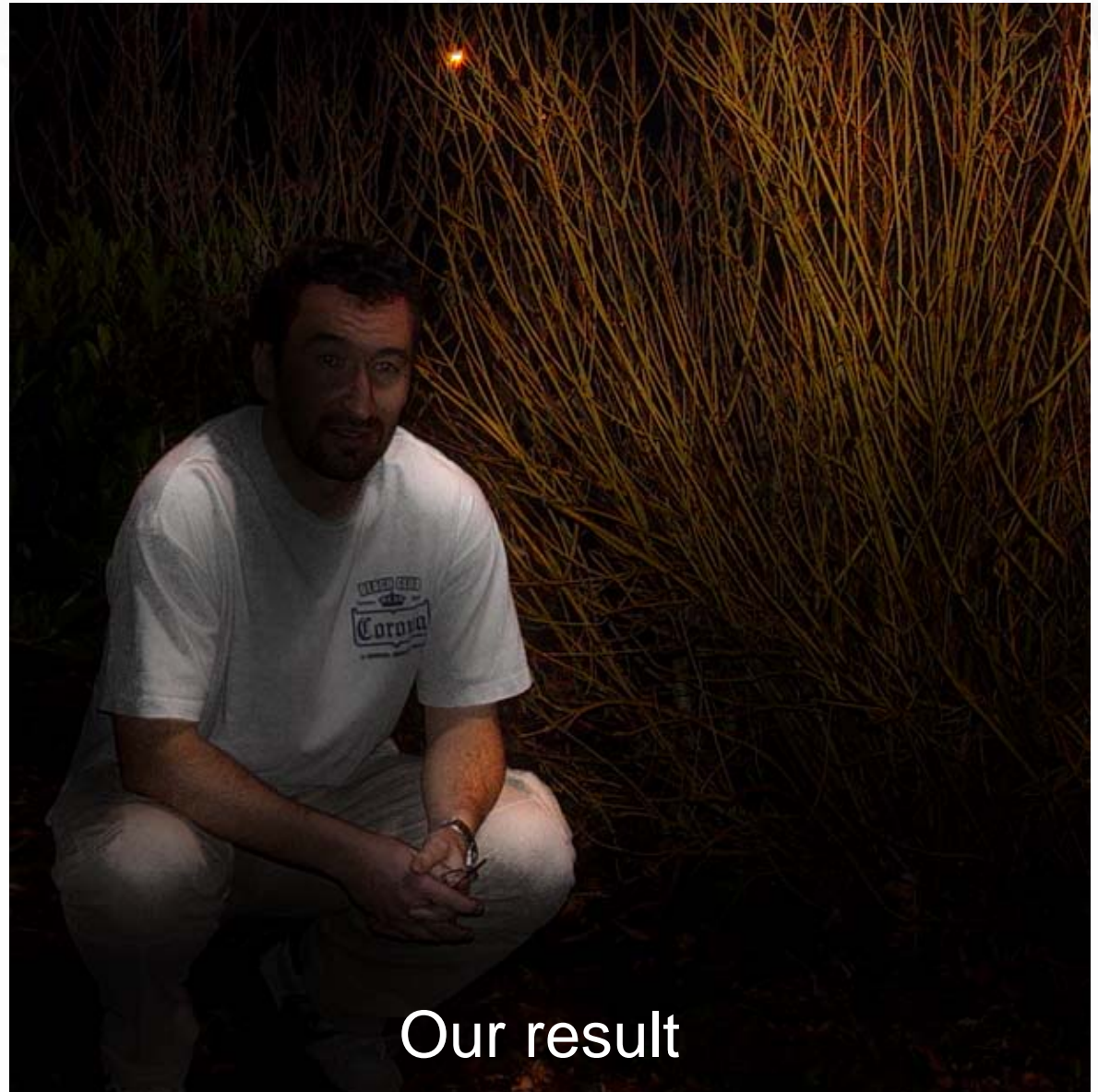
# Results

SIGGRAPH2004



# Results

SIGGRAPH2004

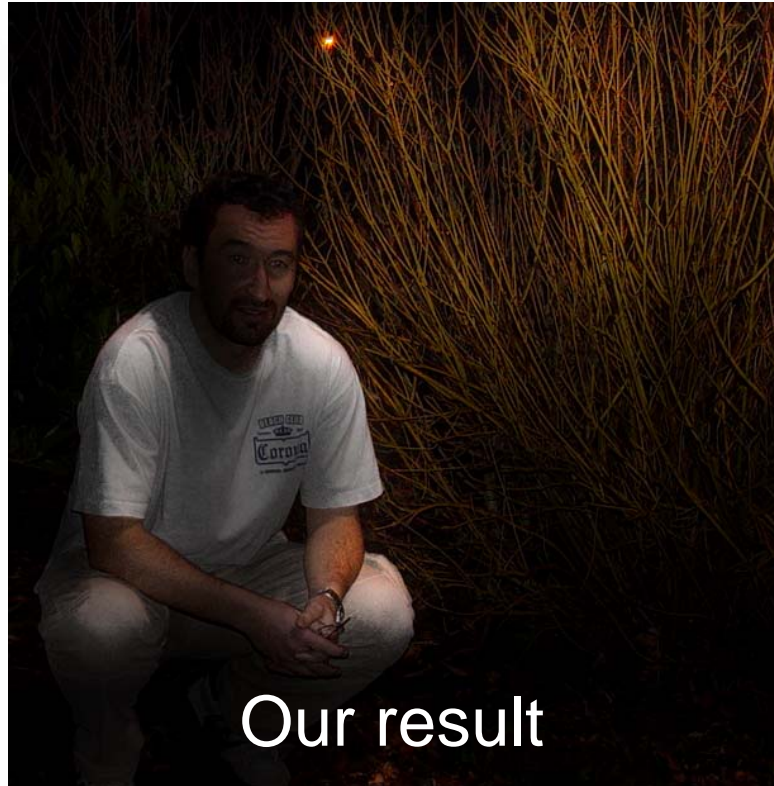


Our result



# Results

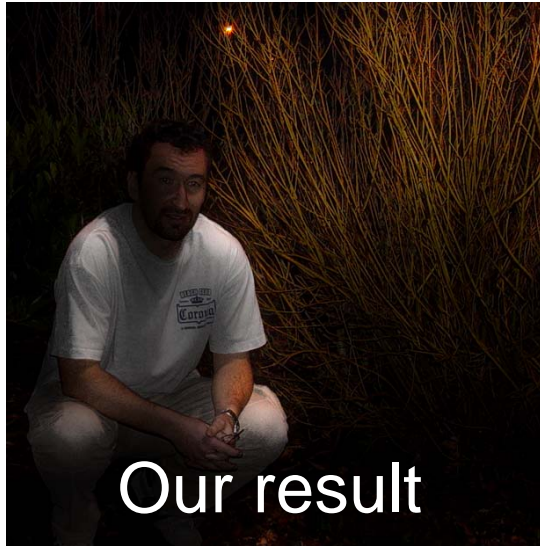
SIGGRAPH2004



Our result

# Emphasize Foreground

SIGGRAPH2004



Deduce “distance”  
to camera

Exploit  $1/r^2$  flash  
intensity falloff

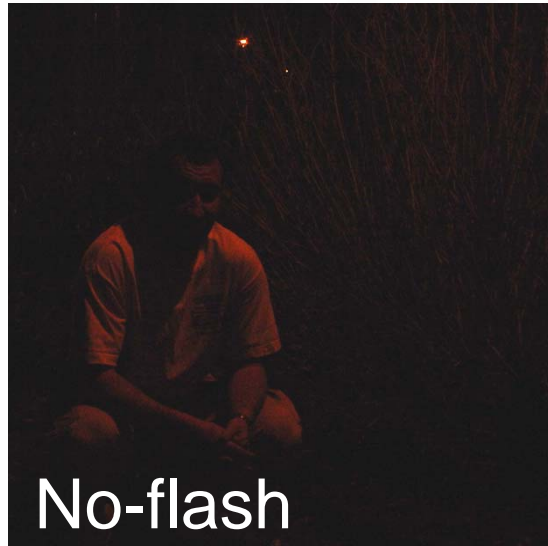
(see paper)





# (Inverse) White Balance

SIGGRAPH2004



Retain warm tones from available lighting (see paper)



# Results

SIGGRAPH2004



No-flash



Flash





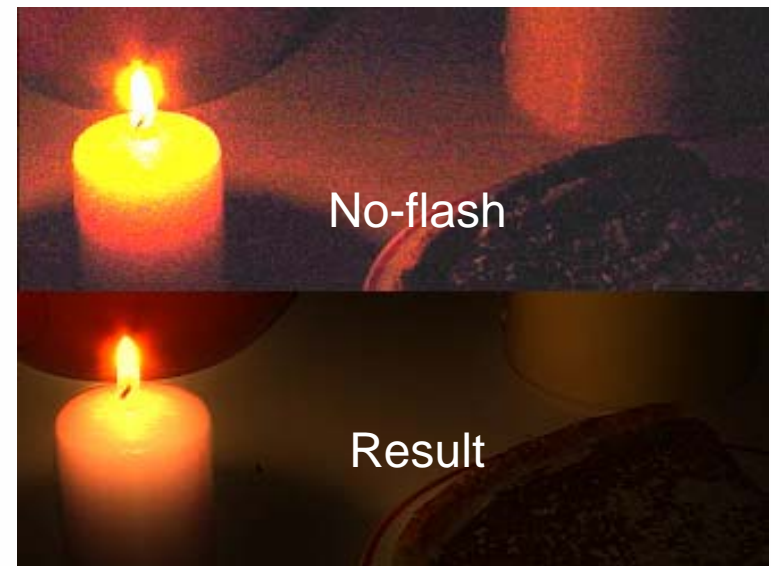
# Overview

- 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

SIGGRAPH2004

- 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

SIGGRAPH2004

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!**