

# Image Processing Prog#3 HDR Imaging

## Meeting 11/29

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# Presentation Overview

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# Environment

- Windows 10 22H2
- Python 3.12.0
  - OpenCV 4.8.1
  - Pillow 10.0.1

# Motivation

- exposure  $X$  vs. pixel value  $Z$
- unknown, nonlinear mapping  $Z = f(X)$
- objective: recover  $E$  from  $Z$
- how: using multiple photo with different exposure

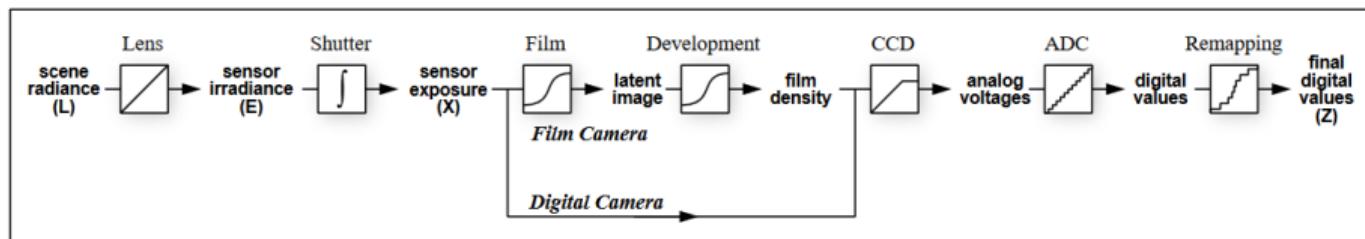


Figure 1: Image Acquisition Pipeline

# Debevec's Method

## Algorithm

- recovering the radiance map  $E_i$  from the pixel values  $Z_{ij}$ 
  - $X = E_i \Delta t_j$
  - $f(X) = f(E_i \Delta t_j) = Z_{ij}$
  - $g = \ln f^{-1}$
  - $g(Z_{ij}) = \ln E_i + \ln \Delta t_j$
- solving  $g$  and  $E_i$  with SVD

$$O = \sum_{i=1}^N \sum_{j=1}^P [g(Z_{ij}) - \ln E_i - \ln \Delta t_j]^2 + \lambda \sum_{z=Z_{min}+1}^{Z_{max}-1} g''(z)^2$$

Figure 2: Objective Function

# Debevec's Method

## Additional Settings

- $g(Z_{mid}) = 0$ 
  - fix the curve
  - set pixel value  $Z_{mid}$  to the unit exposure
- weighted function  $w(Z)$ 
  - emphasize the smoothness
  - fitting terms toward the middle of curve
- pixel value selection
  - ① even distribution
  - ② sampled from low intensity variance region

# Debevec's Method

## Constructing & Display HDR Radiance Map

- reconstruct  $E$  with  $g$ 
  - by using all available exposures
- display
  - take logarithm
  - linearly map to device range

# Experiment

## Image

- 14 images handheld-shot by Xiaomi 12T Pro
- ISO: 800
- Aperture: f/1.69
- Exposure Time: 1/1000, 1/800, 1/400, 1/250, 1/200, 1/125, 1/80, 1/30, 1/15, 1/8, 1/4, 1/2, 1, 2, 4

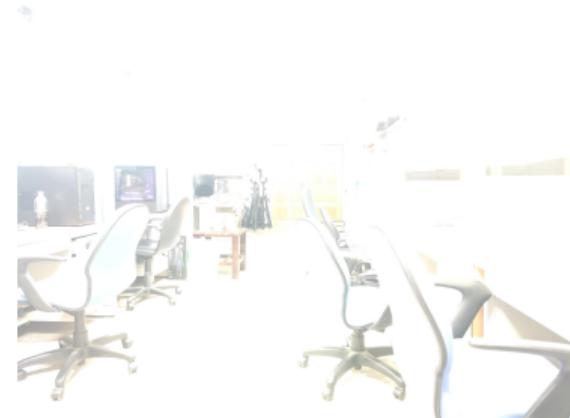


Figure 3: Test Image (Exposure Time: 1/1000, 1/30, 1/2)

# Experiment

## Experiment Settings

- pixel sampling
  - 100 pixels per exposure time
- parameter
  - $\lambda = 10$
  - $Z_{min} = 0, Z_{max} = 255$
- display HDR image
  - linear mapping
  - tone mapping (with OpenCV)

# Experiment

## Response Curve

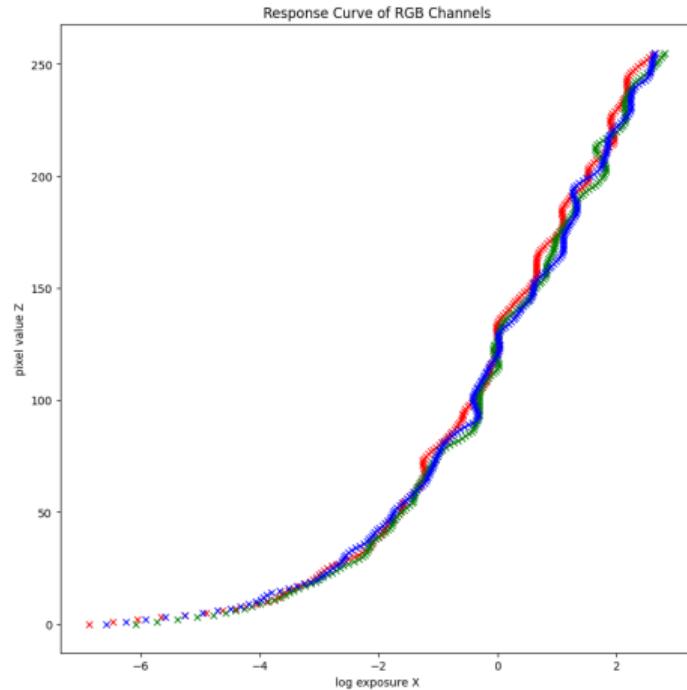


Figure 4: Response Curve

# Experiment

## HDR Radiance Map

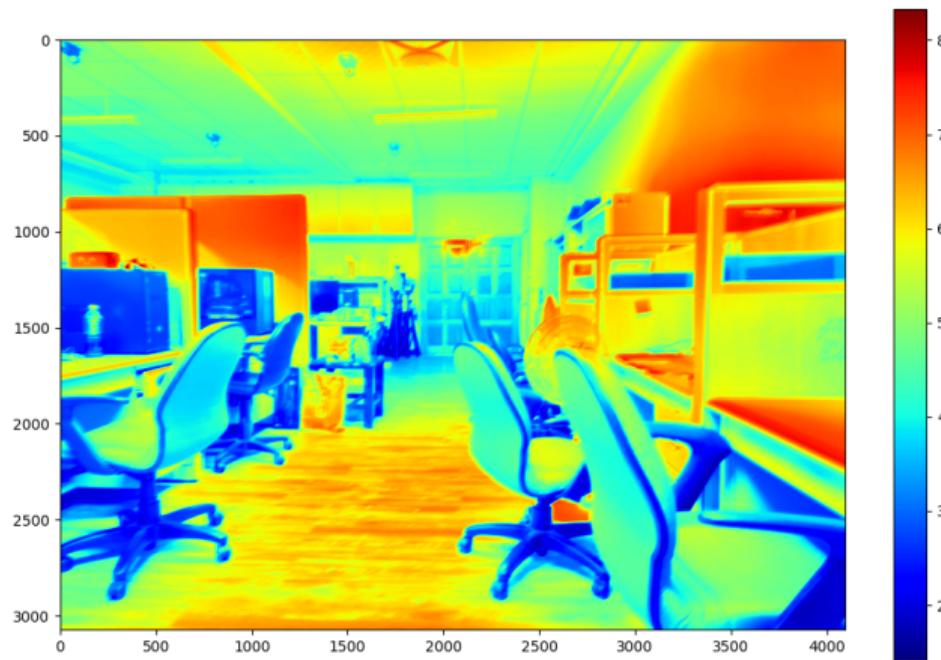


Figure 5: HDR Radiance Map

# Experiment

## HDR Image



Figure 6: HDR Image

# MTB Alignment

## Motivation

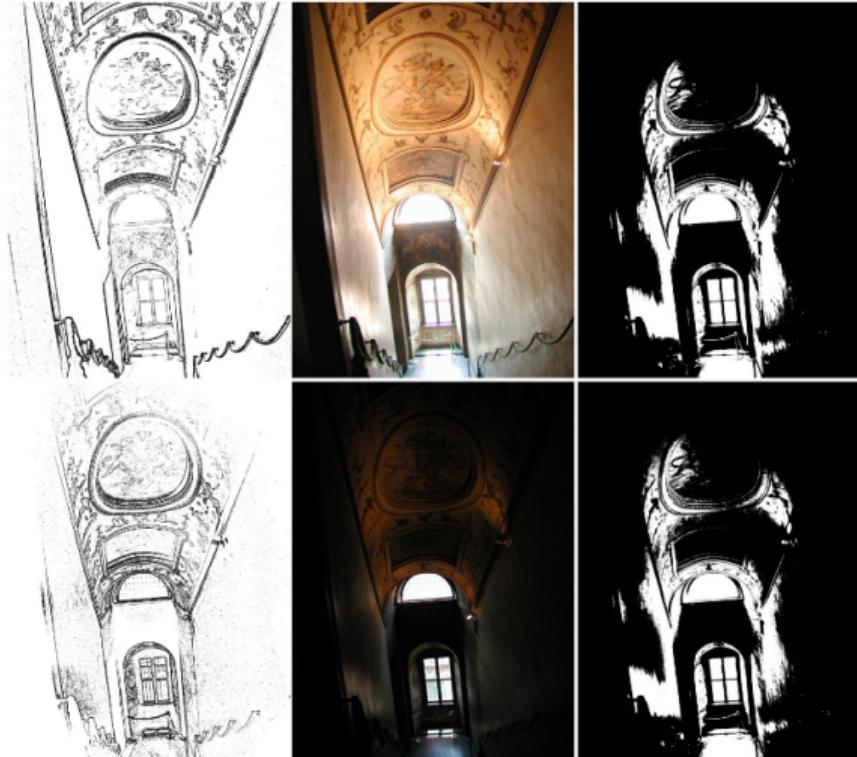
- slight camera movement during exposure
- blurred images



# MTB Alignment

## Approaches

- offset relative to the reference image
- edge-detection
  - dependent on exposure



# MTB Alignment

## Median Threshold Bitmap

- advantages
  - insensitive to exposure
  - bit-manipulation routines
- for extreme cases
  - choosing either 17th or 83th percentile
  - limit the maximum offset

# MTB Alignment

## Image Pyramid

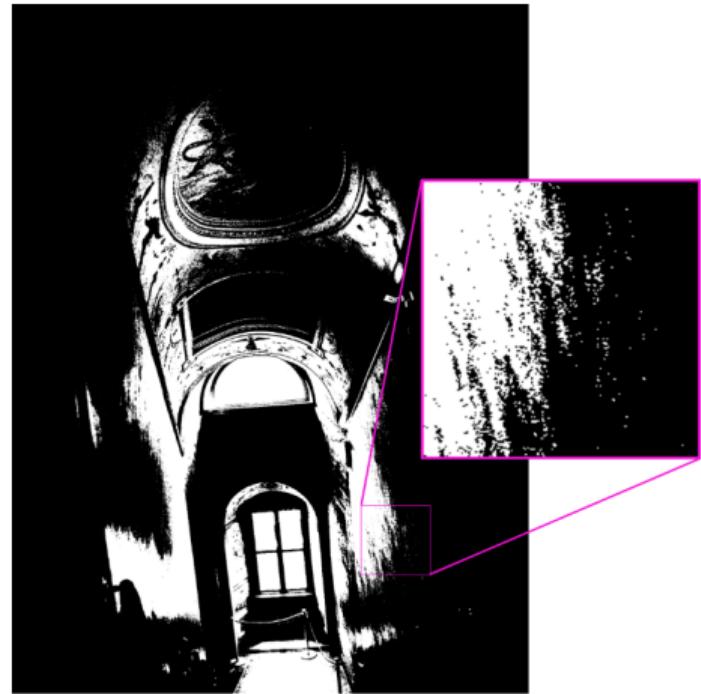
- compare to the reference image
- for each dimension ( $x, y$ ) and resolution
  - $\Delta x_1 = \pm(1, 0)$
  - $\Delta x_2 = 2\Delta x_1 \pm (1, 0)$
  - ...



# MTB Alignment

## Threshold Noise

- too many pixel value near the median cause noise in MTB
- makes XOR difference unstable
- solution
  - exclude pixels from specified distances of the threshold
  - AND with both exclusion map



# Experiment

## Experiment Settings

- same image set
- parameter
  - grayscale traslation:  $\frac{54 \cdot R + 183 \cdot G + 19 \cdot B}{256}$
  - maximum offset: 4
  - noise exclusion distance:  $\pm 4$

# Experiment

Grayscale & MTB



Figure 7: Original, Grayscale & MTB

# Experiment

Noise Threshold



Figure 8: Exclusion Map

# Experiment

## XOR Operation



Figure 9: MTB of Ref Image and Unaligned Image

# Experiment

## XOR Operation



Figure 10: XOR Difference (with & without noise exclusion)

# Discussion & Future Work

- Debevec's Method
  - parameter tuning
  - issues with color image
  - limitation related to pixel and exposure value distribution
- MTB Alignment
  - selection of reference image
- improving image selection
- deep learning-based method



## References

- Debevec, Paul E., and Jitendra Malik. "Recovering high dynamic range radiance maps from photographs."
- Ward, Greg. "Fast, robust image registration for compositing high dynamic range photographs from hand-held exposures."

# Thanks for Listening

Q & A