Image Processing Prog#3 HDR Imaging Meeting 11/29

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Presentation Overview

Environment

- Windows 10 22H2
- Python 3.12.0
  - OpenCV 4.8.1

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

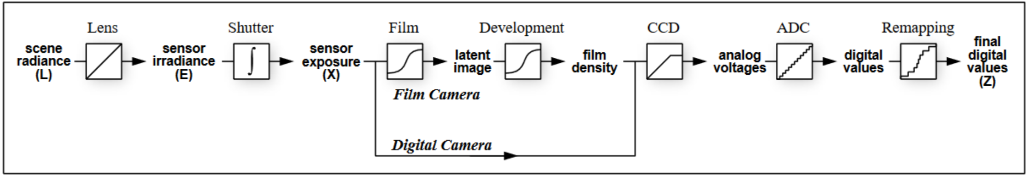


Figure 1: Image Acquisition Pipeline

Debevec's Method

Algorithm

- recovering the radiance map E_i from the pixel values Z_{ij}
  - $X = E_i \Delta t_j$
  - $f(X) = f(E_i \Delta_j) = Z_{ij}$
  - $g = \ln f^{-1}$
  - $g(Z_{ij}) = \ln E_i + \ln \Delta t_j$
- 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
  - even distribution
  - sampled from low intensity variance region
  - how many sample value we need?

Debevec's Method

- 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)

- 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

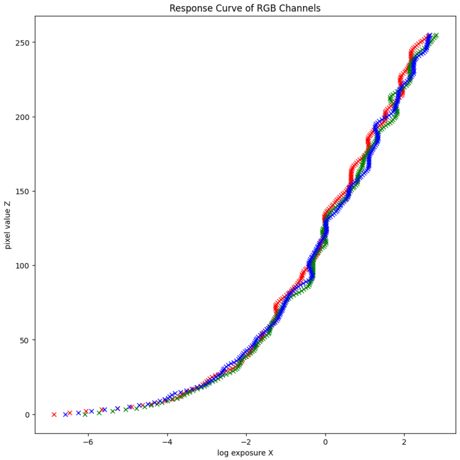


Figure 4: Response Curve

Experiment
HDR Radiance Map

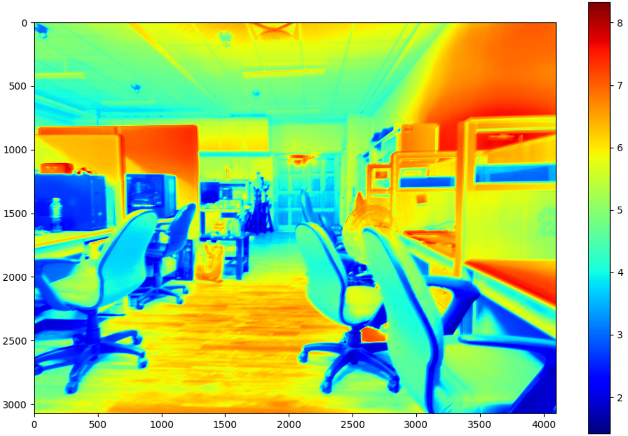
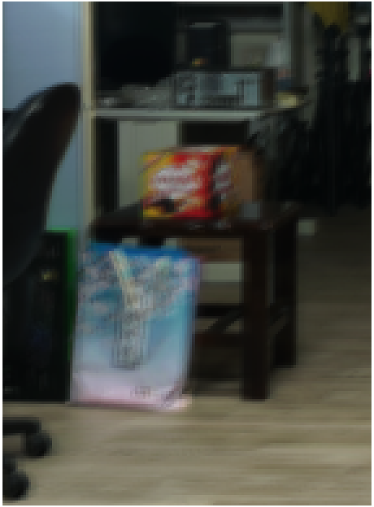


Figure 5: HDR Radiance Map

Figure 6: HDR Image

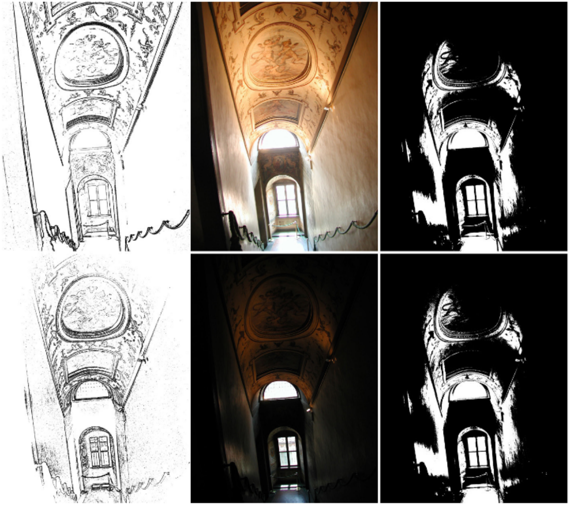
- slight camera movement during exposure
- blurred images



MTB Alignment

Approaches

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



MTB Alignment

Median Threshold Bitmap

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

MTB Alignment

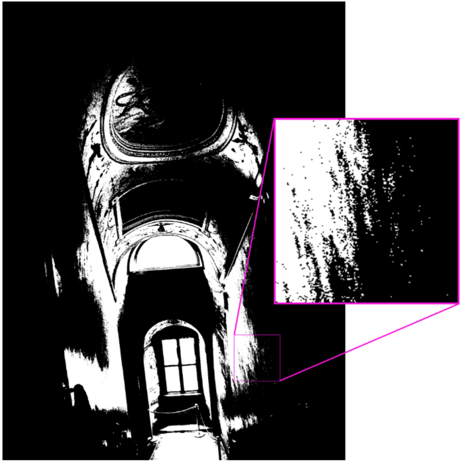
Image Pyramid

- 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



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

Experiment
Grayscale & MTB

Figure 7: Original, Grayscale & MTB

Experiment

Noise Threshold

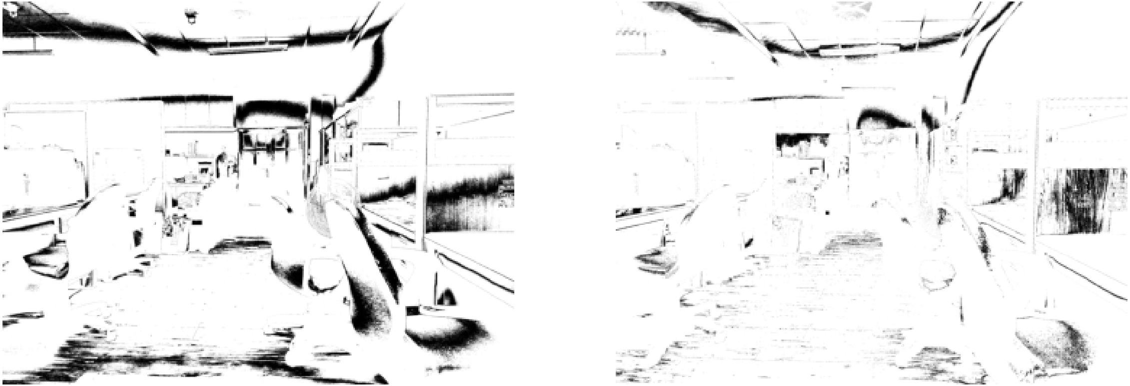


Figure 8: Exclusion Map

Experiment
XOR Operation

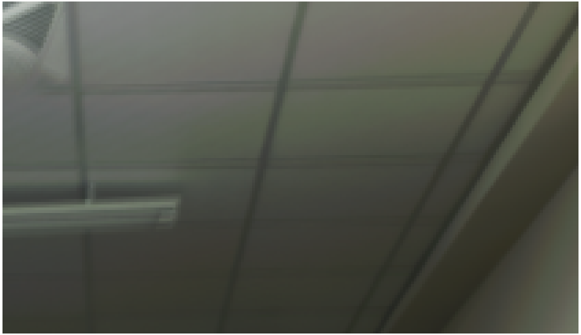
Figure 9: MTB of Ref Image and Unaligned Image

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
- compare with 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