Exposure Time Estimation for High Dynamic Range Imaging with Hand Held Camera

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INTRODUCTION

- Image sensor cannot record details in all parts of a high contrast scene.
- Differently exposed images of the same scene can be captured.

- Every image represents a different portion of the dynamic range.
- Multiple images can be fused to one HDR image.

CAMERA SYSTEM

- Lens
- Electronic Sensor
- ADC
- In Camera Processing
- Pixel Values
- Raw Values

- Shutter attenuates irradiance $E$, $I = E \cdot \Delta t$.
- A nonlinear mapping $M = f(I)$ transforms light intensity $I$ to pixel value $M$.
- Let $g = f^{-1}$ then $I = g(M)$.

COMPOSING HDR IMAGE

Denote a value of the pixel $i$ observed in the image $j$ by $M_{ij}$. Knowing $g(M)$ and the exposure times $\Delta t_j$, the irradiance values $E_i$ can be computed using

$$E_i = \sum_j \omega(M_{ij}) \frac{v(M_{ij})}{\sum_j \omega(M_{ij})}.$$ 

Where $\omega(M_{ij})$ is a weighting criterion, it may be

- derivative of $g(M)$,
- a hat function, $\omega(M) = \begin{cases} M & \text{for } M \leq \frac{1}{2} \\ 1 - M & \text{for } M > \frac{1}{2} \end{cases}$
- SNR function, $\text{SNR} = \frac{\Delta t_i}{\sigma_i}$

EXPOSURE TIMES RECOVERY

- The knowledge of $\Delta t$ affects the quality of composed HDR image.
- Cameras do not report $\Delta t$ properly.
- We proposed a method estimating exposure ratio $k_j = \Delta t_{j+1}/\Delta t_j$ of two images captured using a linear response camera.

- Linear fit to the brightness transfer function $T$ of the two images.

- $k_j \cdot M_A = T_j(M_A)$

Equations are weighted by $\sqrt{h_j(M_A)} \cdot \sqrt{h_{j+1}(M_B)}$.

- The outliers are removed by an iterative scheme.
- The proposed method does not require image registration.

CAMERA CALIBRATION

- Recovering $g(M)$ from the differently exposed images is a difficult task.
- We recommend to use linear RAW images as offered by modern cameras.

IMAGE REGISTRATION

We proposed a method for spatial registration of two differently exposed images. The proposed method enables to capture HDR images with a hand held camera.

- Compensate exposure difference using $g$ and $\Delta t$.
- Initial estimate using correlation in Fourier space $(\Delta \theta_0, \Delta \phi_0) = \max(F^{-1}(F(I_1) \cdot F(I_2)))$.
- Find $\Delta x, \Delta y, \varphi$ by minimizing

$$\epsilon_{ij} = \frac{\sum (I(x, y) - W_2(x, y))^2}{n(x, y)}.$$ 

$$n(x, y) = \begin{cases} t & \text{for } \frac{h(x,y) + W_2(x,y)}{2} < t \\ t^2 & \text{for } \frac{h(x,y) + W_2(x,y)}{2} > t \end{cases}.$$ 

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