CS 484, Fall 2018
Stephen Dueck SADUECK 20561751

Final Project - High Dynamic Range Imaging

Introduction

The goal of this paper is to observe high dynamic range image reconstruction using the Debevec-Malic method[1]. To achieve this I've followed the procedure outlined by Oliver Cossairt[2]. As a sample of the procedure I've selected a set of 11 images of the Agia Sofia cave[3] (3 shown below) as they display a distinct seperation between image content visible in the high and low exposure images.

Exposure time 1/8 sec.

Exposure time 1/250 sec.

Exposure time 1/4000 sec.

Method

To construct the HDR (High Dynamic Range) image we will first model the "camera response curve", the relation between the amount of incoming light and pixel intensit values. We will use this to estimate the full radiance map over the entire dynamic range. Finally we will tone map the full radiance image into a viewable HDR image.

The process is implemented in *20561751_DWM.py*.

Finding the camera response curve: Let $Z_{i,j}$ be the intensity of pixel i for exposure j, let E_i be the true irradiance incident on pixel i, and let B_j be the exposure time of exposure j. We will model $Z_{i,j}$ as:

$$Z_{i,j} = f(E_i B_j)$$

Meaning the intensity of pixel i in exposure j is some unknown function of the true irradiance and the exposure.

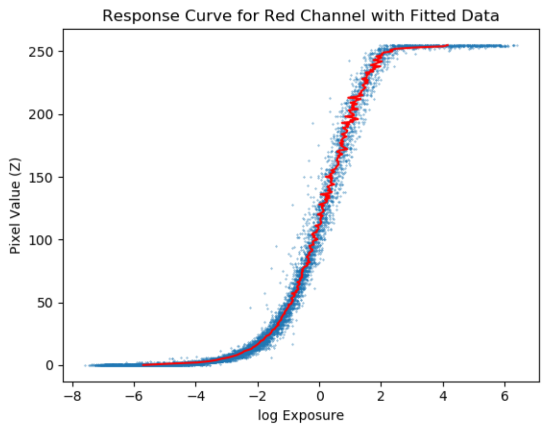
Let $g(x) = ln(f^{-1}(x)$, then we can model the camera response curve as:

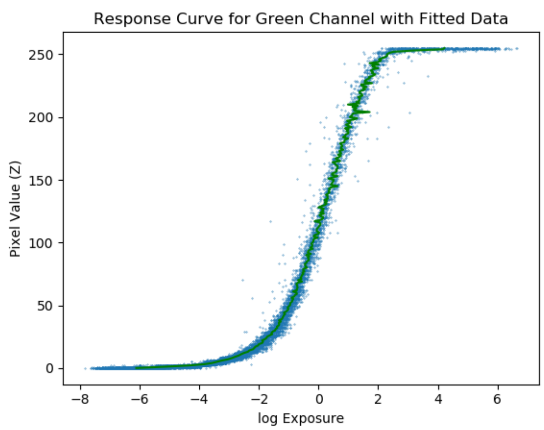
$$g(Z_{i,j}) = ln(E_i) + ln(B_j)$$

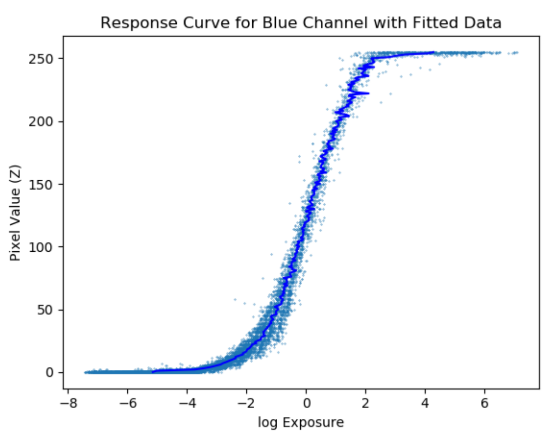
Which is obtained by minimizing the objective function over the domain of $Z \in [0, 255]$:

$$O = \sum_{i=1}^{N} \sum_{j=1}^{P} |g(Z_{i,j} - lnE_i - ln\delta t_j|^2 + \lambda \sum_{z=Z_{min}+1}^{Z_{max}-1} g''(z)^2$$

Using the sample code provided by Debevec and Malik (gsolve.m) to solve this optimization problem, we can sample pixels from our images to find the response curve (one for each RGB channel) and the log exposure of the points on that channel:



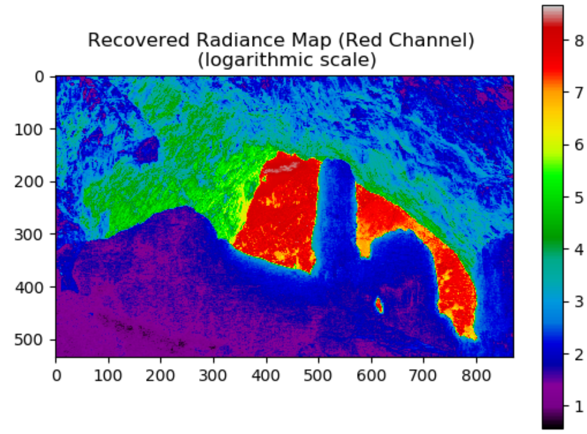


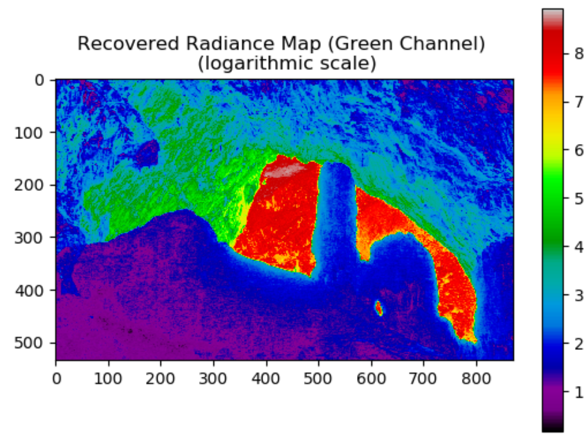


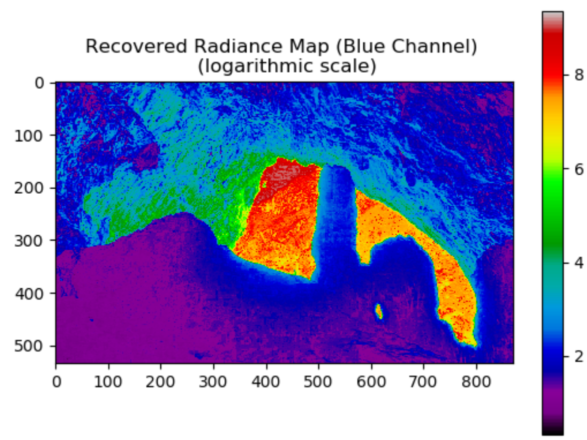
Recovering the HDR radiance map of the scene: We can estimate the true radiance map (one for each channel) as:

$$ln(E_i) = \frac{1}{P}\sum_{j=1}^{P}(g(Z_{i,j}) - ln(B_j))$$

The radiance maps for our example are the following: (dynamic range of almost $10^9 : 1$)







Tone mapping to display the HDR image: To reduce the dynamic range to a viewable range we normalize the values to between $[0, 1]$.

Most of the display range is used by high dynamic range intensities. We can apply gamma correction to get a better result:

Discussion

Results: The HDR image obtained (above) improves the viewable area of the scene noticeably, mid-range and far-range details are clearly distinquishable. The closest foreground section of rock is still obscured by exposure unlike the sample result (below)[3]

The dynamic range of the image is so large compared to the range of values for this dark foreground section. Additional contrast boosting, gamma, or other corection if needed to produce an optinal HDR image.

Problems: The most notable obstacle was producing a smooth camera response curve. Too few sample points or too large of difference in image exposures produced undefined values in the function (g) which would cause patches of undefined intensity in the radiance map.

Extention to multi-exposure homography-based registration. *N/A*

Can you drop the assumption that exposure is known? It is clear that the exposure values are crutial to the HDR reconstruction. The exposure values allow seperation of similar pixel intensities along the entire dynamic range. In other words they map the limited $[0, 255]$ range of each image to the greater HDR $[0, 10^8+]$. If you could artificially estimate the relative exposures of an image sequence, then you could use this estimate to build the HDR image. Cerman and Hlavac[4] outline a method for estimating unknown exposure ratios by recovering a brightness transfer function (which only needs image pair histograms), and fitting it to a linear camera response function. The derivative of this function is proportional to the unknown exposure ratio. So, we need not assume that exposure is known, but if not, we must be able to recover it.

Resources

[1] Recovering High Dynamic Range Radiance Maps from Photogrphs, Paul E. Debevec, Jitendra Malic, http://www.pauldebevec.com/Research/HDR/debevec-siggraph97.pdf

[2] High Dynamic Range Imaging and Tone-mapping, Oliver Cossairt, http://users.eecs.northwestern.edu/ ollie/eecs395/HW4/HW4.htm

[3] Sample HDR photo (Agia Sofia cave), https://www.easyhdr.com/examples/

[4] Exposure time estimation for high dynamic range imaging with hand held camera, Lukas Cerman and Vaclac Hlavac, http://cmp.felk.cvut.cz/ cermal1/files/cvww-2006-01-24-final.pdf