Project Report

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Abstract

Linearize an image, Create a HDR image stack by using different composition algorithm methods and finally Tonemapping to revert to the non-linearity

1 Introduction

HDR images are a useful tool in cameras to create a well saturated image. There are different methods of creating a stack. For our project, we take three pictures with one that is well saturated, one over exposed and one that is under exposed. The three images are then stacked together following different algorithms which will be explained in detail.

2 Report Layout

There are four parts to our report-

1. Part 1 will talk about radiometric calibration where we estimate the approximate brightness for different exposure times.
2. For this part, a image stack with different exposure times were taken and the pictures are linearized as done in (1)
3. The image stack is then composed together using different algorithms to create the HDR stack.
4. A composite image is produced by tonemapping.

3 (Part 1) Camera Radiometric Calibration

A smartphone camera is used to capture a white surface under even light to create an image stack with different exposure times. This calibration is necessary as the camera produces a non-linear response of the images and thus would not give us $B = cETG$ where, c is an unknown proportionality factor, B is pixel brightness, E is ?? , T is exposure time and G is the ISO gain of the camera. For this experiment, the ISO is set to 100.

Thus, the non-linear response must be linearized to get a true (linear) brightness of the image. This is done by taking 8 images with different exposure times. A center portion of [pixel num] were cropped in all eight images and then the pixel brightness for each color channel was averaged.

Figure 1: The different exposure times in order are $T = \frac{1}{30}$, $T = \frac{1}{45}$, $T = \frac{1}{60}$, $T = \frac{1}{90}$, $T = \frac{1}{125}$, $T = \frac{1}{180}$, $T = \frac{1}{250}$. All units in seconds.

The assumptions that are made is $B' = B^{1/g} = K.T^{1/g}$ for some unknown value g.

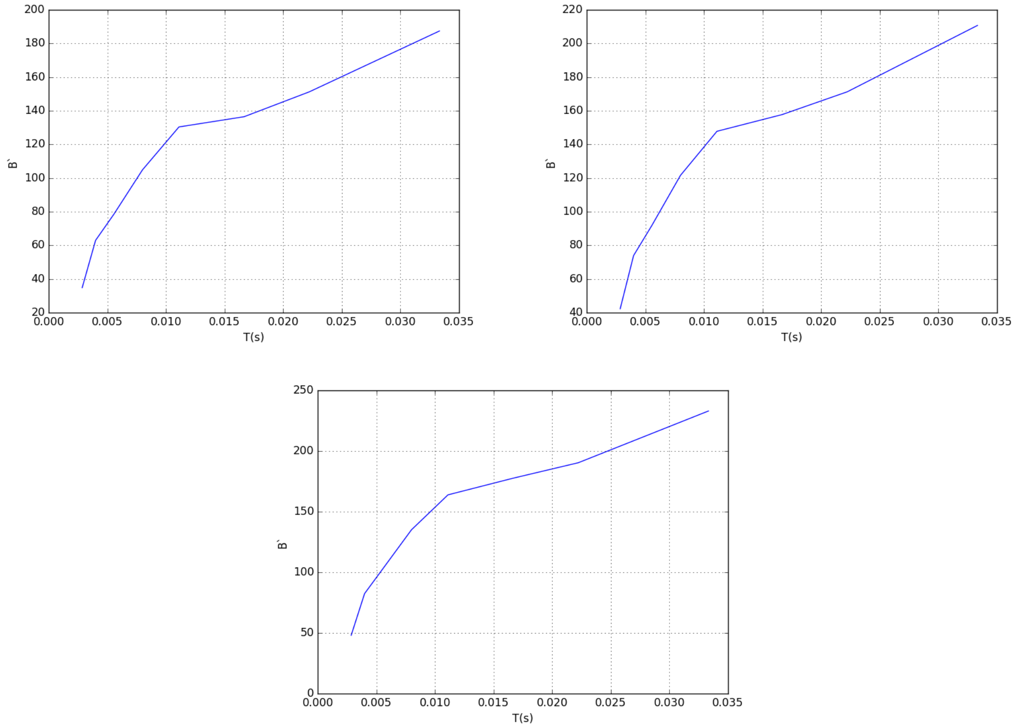

Figure 2: The plot of the non-linearized B with different exposure times. The first image is for blue, followed by green and bottom is for red.

We needed to estimate the parameter g. The method we followed was to create a logarthmic affine function of the equation $B' = KT^{1/g}$ to $log(B') = log(K) + (1/g)log(T)$. Then a linear regression algorithm is applied to linearize this function.

For the linear regression the slope m and intercept r were calculated using the formulas-

$$r = \frac{\Sigma(x - \bar{x})(y - \bar{y})}{\sqrt{\Sigma(x - \bar{x})^2 \Sigma(y - \bar{y})^2}}$$

where,
y is B or the brightness at the pixel.
x is T or the exposure time.
$\bar{x}$ and $\bar{y}$ are mean of each respectively.

$$b = r\frac{S_y}{S_x}$$

where,
b is the intercept.
$S_y = \sqrt{\frac{\Sigma(y-\bar{y})^2}{n-1}}$ is the standard deviation of y.
$S_x = \sqrt{\frac{\Sigma(x-\bar{x})^2}{n-1}}$ is the standard deviation of x.

Thus, the value for g for blue is 1.635, for green is 1.709 and for red is 1.7288.

Now, using the brightness at every individual pixel can be raised to the power of $(1/g)$.
Plot for different color channels.

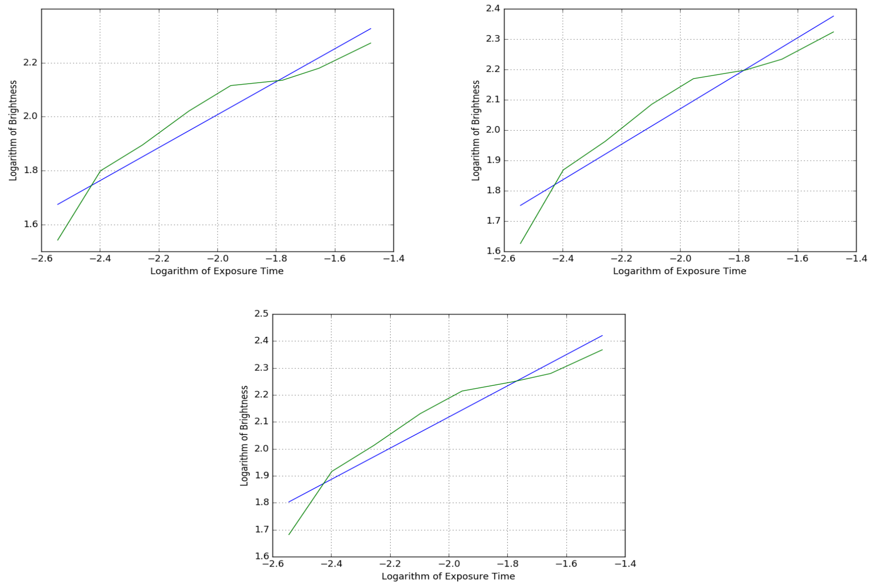

Figure 3: The plot of logarithmic of B and T are shown in green. The linear regressed line for each color channel is shown in blue. The order of plots is for blue, green and red.

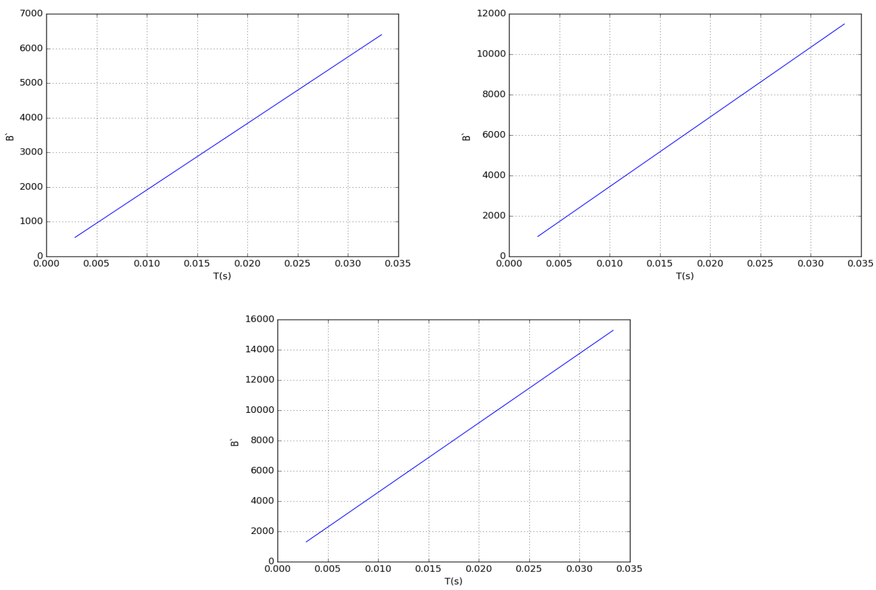

Figure 4: The plot of the linearized B that is $B^{1/g}$ with different exposure times. The first image is for blue, followed by green and bottom is for red.

4 (Part 2) Linearizing the images

In this part there were a stack of images taken with different exposure times. There were 3 images chosen from these for the HDR stack. The selection procedure was:-

- The image with optimal exposure time (the largest exposure time for which none of the pixels were saturated) was chosen as image 1.($\frac{1}{1000}$)
- Defining a_1 to be 2, the second image was chosen to be with an exposure time of $\frac{1}{500}$s
- Defining a_2 to be 4, the third image was chosen to be with an exposure time of $\frac{1}{250}$s

- The optimal exposure time was decided based on their histogram.

The final three images chosen were:- The images were first converted to the 32 bit floating point

Figure 5: From left to right exposure times:- 1/1000s, 1/500s, 1/250s

data-type.

The three images were chosen and and then linearized by raising the pixel values to the powers of g (the regressed parameter for that color channel). The images were then normalized by dividing each pixel value by 255^g

Finally after linearizing the images containing saturated pixels were converted to equivalent exposure time by dividing it by $a_1(2)$ and $a_2(4)$ respectively.

5 (Part 3) Combining the image using composition algorithms

5.1 Composition algorithm-1

There were 2 sets of images, one with the original uint data type images and the second with the floating point linearized images. The first set is used to check for saturated pixels and the manipulations are done on the second set.

- If the pixels in the third image of the first set were not saturated, then the corresponding pixels in the second set for which it was not saturated was used in the final image.
- If the pixels in the second image of the first set were not saturated, then the corresponding pixels in the second set for which it was not saturated were used in the final image.
- If the pixels in the first image of the first set were not saturated (by default), then the corresponding pixels in the second set for which it was not saturated were used in the final image.

5.2 Composition algorithm-2

The conditions were checked as in the algorithm 1. But instead of using the pixels from one image. The pixels were averaged for all the images in which the pixels were not saturated.

5.3 Composition algorithm-3

- If the third image pixels were not saturated, then the average of the three images form the second set were used for that pixel.
- If third saturates and second image is not saturated, the average of the first and second image was used.
- If the second saturates and only the first image is left, then the first image pixels are used as such.

This algorithm was similar to the second algorithm but weighted average was used. The weights were different for different stages.

5.3.1 First stage

$$\eta(T + \frac{T}{a_1^2} + \frac{T}{a_2^2}) = 1$$

$$\eta = \frac{1}{(T + \frac{T}{a_1^2} + \frac{T}{a_2^2})}$$

The weights are:-

$$\eta.T, \eta.\frac{T}{a_1^2}, \eta.\frac{T}{a_2^2}$$

5.3.2 Second Stage

$$\eta(T + \frac{T}{a_1^2}) = 1$$

$$\eta = \frac{1}{(T + \frac{T}{a_1^2})}$$

The weights are:-

$$\eta.T, \eta.\frac{T}{a_1^2}, \text{The third image was not used}$$

And if the second and third image pixels were saturated, the pixels were simply taken from the first image.

6 (Part 4) Reproduce Composite Image

For this part, we used a tone mapping method which is used to approximate HDR images with limited dynamic range. The tone map that we used is Drago which is a fast global tonemapping algorithm that scales the images in the logarithmic domain. The gamma value chosen was 2.2.
The key concept of this tone mapping method (Lightness Perception in Tone Reproduction) is a decomposition of an HDR image into areas (frameworks) of consistent illumination and the local calculation of the lightness values. The net lightness of an image is calculated by merging of the frameworks proportionally to their strength. Particularly important is the anchoring—relating of the luminance to a known luminance, namely estimating which luminance value is perceived as white in the scene. This approach to tone mapping does not affect the local contrast and preserves the natural colors of an HDR image due to the linear handling of luminance.

Figure 6: Image after undergoing tone-mapping for simple HDR algorithm

Figure 7: Image after undergoing tone-mapping for averaging HDR algorithm

Figure 8: Image after undergoing tone-mapping weighted averaging HDR algorithm

6.1 Result

The different composition algorithms were used to produce a HDR stack after the image is linearized. It is observed that the averaging and weighted-averaging work better than first algorithm. The images are brighter after undergoing tone-mapping.