Assignment 4 - High Dynamic Range

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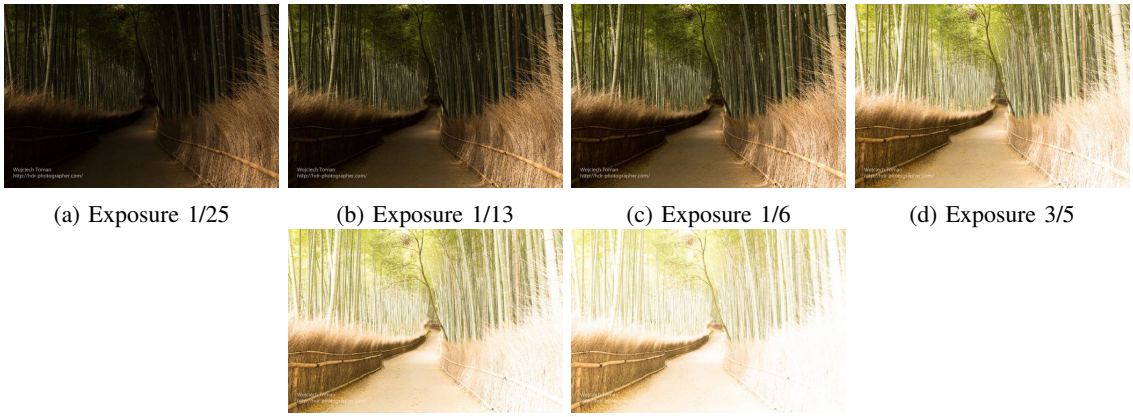
I. Result HDR Images

Fig. 1: Basic

Fig. 2: Histogram Equalized

Fig. 3: Best

II. Input Images



(a) Exposure 1/25 (b) Exposure 1/13 (c) Exposure 1/6 (d) Exposure 3/5

(e) Exposure 1.3 (f) Exposure 2.5

Img	Exposure	Aperture	ISO
01	1/25	f8	100
02	1/13	f8	100
03	1/6	f8	100
04	3/5	f8	100
05	1.3	f8	100
06	2.5	f8	100

The source of my images is hdr-photographer.com

III. Camera Setting Requirements

- **Discuss the camera setting requirements for exposure, aperture, and ISO in an HDR image set as used in this assignment. Identify whether each must be maintained constant or not, and why.**
  For an HDR image set the aperture, and ISO should both be kept constant throughout the different shots. The only setting that must be changed is the exposure time. The exposure is physically controlled by varying the shutter speed while keeping the device in manual mode. One of our goals with HDR composition is to retrieve the response curve, which as discussed in [1] is dependent only on $Z_ij = f(E_i\Delta t_j)$. We wish to keep the irradiance, E value a constant. Changing the aperture or the ISO will both change the level of irradiance on the sensor, as aperture changes depth of field and ISO changes light sensitivity.

IV. HDR Scene Requirements

- **What scene elements must be controlled for a successful HDR image set?**
  Identify and discuss at least 3 distinct required elements.
  As mentioned above, it is crucial to keep the irraidance on the sensor the same across all images captured, therefore lighting of the scene should be consistent. If taken outdoors the images should be taken close to each other in time so as to not have differences due to changes in ambient lighting from sunlight.
  The scene should also be static. If there are moving elements the random pixels we select for comparisons may not be of the identical spot on the all subsequent images. For this reason, using a stable tripod is required.
  Lastly the scene itself must have enough lighting contrast that changing the exposure will enhance certain features while saturating others.

V. Discussion Questions

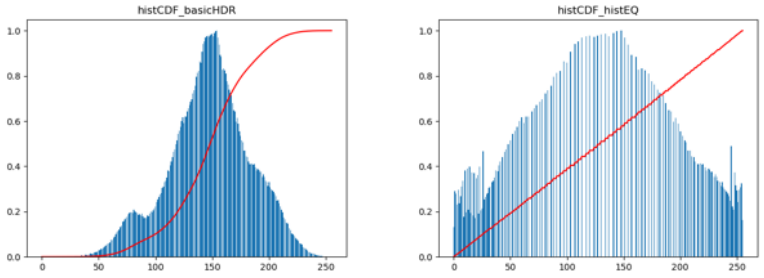
1) Basic HDR

a) **How well does your HDR output represent the input image set? If you used images from online, compare with the online HDR result.**
The BasicHDR image is a fairly good composition in terms of brightness range. As we can see in image 5b, areas of the image that were dark in the lower exposure and areas that were over saturated in the higher exposure images are both well lit in this image. The color however is pretty washed out and there is a strong undertone of blue in the result.

b) **Does your HDR output have artifacts such as motion, color-spots, ghosting, or other artifacts? Consider including close-ups (small crops) to aid in your discussion.**
There are no discernible artifacts in the result. The only visible issue are the washed out colors.

c) **Were your images already in alignment or did you have to align them? If so, what did you do?**
The image set was already aligned so no post-processing was needed. The original images were pretty large so I scaled them to be under the allowed size limit.

(a) Original HDR image (b) Basic HDR (c) Histogram Equalized



(d) Basic HDR CDF (e) Histogram Equalized CDF

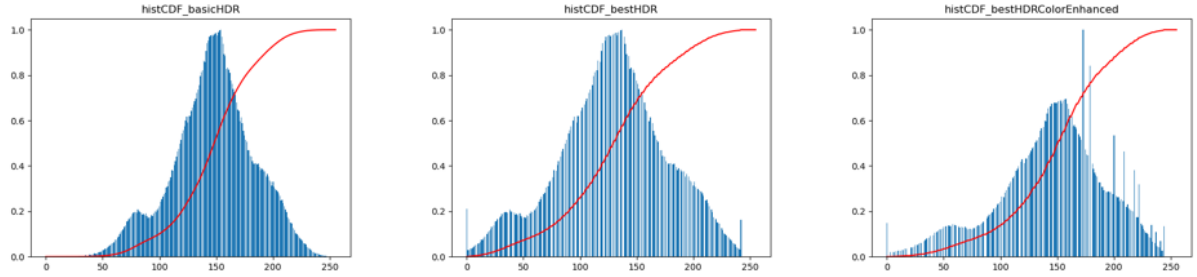
2) Histogram Equalized HDR
Review B. Cromwell's Contrast Enhancement through Localized Histogram Equalization web page.

a) **Compare the two plots and images. What was the effect of equalization on your image set?**
From plots 5d and 5e we can see that the equalization made the overall histogram CDF linear. The equalization technique aims at distributing image brightness values, which is seen as the broader bell shape in 5e. The resulting image shown in 5c has more contrast and the colors are less muted.

b) **Where was the effect of histogram equalization an enhancement, and where was it problematic?**
The color of the trees in the foreground were enhanced, along with section of the pathway farther away. However, the shadow along the left wall of the pathway got much darker. The overall image also looks like it got a bit darker, and bluer. I wasn't expecting this to be the case.

3) Best HDR

(a) Basic HDR (b) Best HDR (c) Color Enchanced



(a) Historgram Basic HDR (b) Histogram Best HDR (c) Histogram Color Enchanced

a) **Describe your general flow path to produce this image, beginning with your basic HDR image. This is a high level discussion, include what you tried, what worked, what didn't.**
For the implementation of $bestHDR$ I used the suggested paper by Wang et al. [2]. The algorithm focuses on using an weighted probability density function (PDF) in place of the standard one. It uses a lower and upper threshold to clamp the PDF values. I directly used this approach. The paper suggests some values for r and v which are used in the calculation of weighted PDF, so I swept across r and v values from 0 to 1.3 and 0 to 1.0 respectively, and storing intermediate image results to disk. During this parameter sweep I also noticed that increasing the r value from 0.1 to 1.3 has the effect of darkening the images. Visually picking the best output image, I chose the associated values to hard-code into my algorithm. Using this I was also created a new cumulative density array that was then used to augment the value layer of the image in HSV space. The image was converted back to BGR prior to being returned..
For the color enchantment, I used a two step approach. Converting the image back into HSV I first increased the saturation layer hoping too enhance the muted colors. Second I applied a gamma correction to increase the overall brightness of the image as I had noticed going from BasicHDR to BestHDR, the image had become noticeably darker. This was my final color enhanced image.

b) **Explain how your chosen method altered the histogram plot, and how that is an improvement.**
Applying the weighted histogram equalization on the Basic HDR image increased the width of the histogram but did not make the CDF linear as seen previously in 5e. The peak of the histogram also shifted to the left which explains why the overall images seems a little darker. The color enchamcent operation seems to have reduced the mean height of the histogram. Also, as my operation was just a simple scaling of all values in the saturation layer of the image arbitrary pixel values got scaled up and are not peaking as seem by the spikes in 7c. This may not be called an improvement per say.

c) **If artifacts were present in the basicHDR image, were you able to reduce or eliminate them here?**
There weren't any discernible artifacts in basicHDR.

VI. Retrospective

- **Reflect on the project: Knowing what you do now (at the end), if you were to start over, what would you do differently and how would you go about doing it?**
  Do NOT say there is nothing you could do differently. There is always a way to improve.
  This time around I felt I could have budgeted my time better. I was short on time to dive deeper into alternative approaches for color enhancement and tome-mapping. I ended up just doing a quick gamma correction and saturation boost in the HSV space. I would certainly spend more time reading about the various methods of implementing tone mapping.
  Additionally, I would have liked to experiment more with different color spaces while developing a solution for the bestHDR. I hadn't used the HSV color space before, and it has some interesting properties, however some posts on ED did discuss the YUV color space, so that would be another area of exploration.
  Lastly, I would pay closer attention to the input and output image types. My code got stuck on trying to resolve the various image dtypes and I ended up spending a lot of time getting past that hurdle. I think an earlier submission to Gradescope would have helped to identify the issues sooner.

References

[1] P. Debevec and J Malik, Recovering High Dynamic Range Radiance Maps from Photographs, 2002
[2] Q. Wang and R. Ward, "Fast Image/Video Contrast Enhancement Based on WTHE," 2006 IEEE Workshop on Multimedia Signal Processing, 2006
[3] Toman , W. "HDR Tutorial Sample HDR photos to play with", (http://hdr-photographer.com/hdr-photos-to-play-with/) Oct 15 2022)
[4] Ed Discussions, Robert Kerner, ED Discussion, Accessed Oct 18, 2022
[5] Numpy Docs, numpy.unique, Numy Docs, Accessed Oct 16, 2022
[6] Numpy Docs, numpy.linalg.pinv, Numpy Docs, Accessed Oct 16, 2022
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[8] Bob Cromwell, , Contrast Enhancement through Localized Histogram Equalization, cromwell-intl.com, Accessed Oct 16, 2022