Project #1: High Dynamic Range Imaging

Github: https://github.com/ntene/VFX/tree/master/hw1_VFX

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Description

Cameras are unable to capture the full dynamic range of commonly encountered real-world scenes. We will combine multiple exposures into a single high dynamic range radiance map, and then convert this radiance map to an image suitable for display through tone mapping in this project.

What you have learned

Camera has its limitations, this limitation can be overcome by combining information from multiple exposures of the same scene. We have learned different algorithms that can be used to combine those photos together. Nevertheless, we need to align those photos as misalignment of images used in composing the HDR image can result in different response functions.

Implementation details and Algorithms

First, we select a scene that has high dynamic range in order to create results which are clearly better than single exposure. Then, we proceed to align the photos and find the response function with different exposures. After computing our radiance map, we need to do tone mapping to show our results clearly.

Alignment

Here are the procedures of Median Threshold Bitmap algorithm that we had implemented.

1. Take the green channel from each image.
2. Convert each image into binary bitmap $binary\_img_n$ using the median of each image as threshold.
3. Repeat procedure 2 by shrinking the image by the ratio of 2 each time down until the layer we set.
4. Compute a binary mask for each image $mask\_img_n$ to avoid the noise in near-median pixels.
5. Shift *binary_img* and *mask_img* to nine direction [(1,1), (1,0), (1,-1), (0,1), (0,0), (0,-1), (-1,1), (-1,0), (-1,-1)] into *shift_binary* and *shift_mask* respectively.
6. Compute the error, which is:
    a. XORing $shift\_binary_i$ and $mask\_img_0$
    b. ANDing it with both $mask\_img_0$ and $shift\_mask_i$

7. Find the direction that brings smallest error.
8. We start from the smallest level, therefore the shift from last layer have to multiply 2 once we head to next layer. Keeping this recursion until reach the largest level, and we can get final shift in x and y direction.

HDR

We use Debevec's algorithm to recover the response function of the imaging process with several photos of different exposures time. In the paper, sampling of the pixels that will be use to compute the response curve function were performed by hand. We decided to pick sample pixels that are spaced apart in the photos evenly. After that, we use the response function to fuse multiple photos into a single, high dynamic range radiance map.

Tone Mapping

We implement Durand's algorithm to do tone mapping. It is based on the decomposition of the image into a base image and a detail image. Since applying gamma compression on intensity can keep the color but detail are blurred, Durand and Dorsey use non-linear filtering to preserve edge. Thus, we can reduce the contrast, but still keep the detail. To be noticed, if we apply large parameter(*sigma*) for bilateral filter, we will get cartoon-like image.
The steps are as follow.

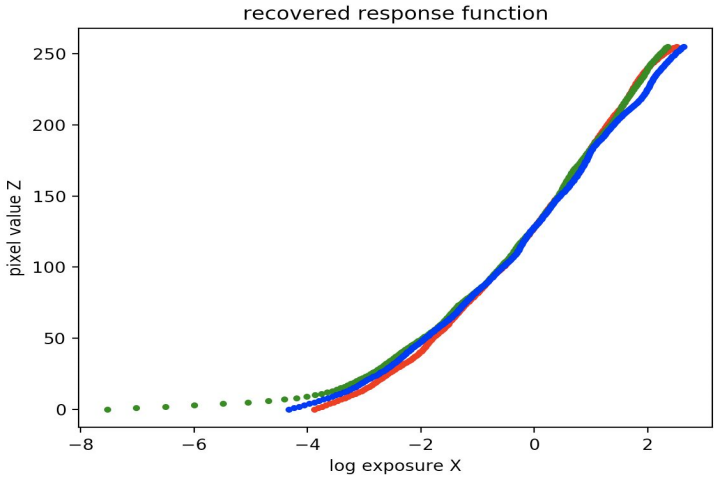
1. Compute the Intensity *I*, in log form: L = log(I).
2. Apply bilateral function: base = bf(L, sigma).
3. Compute detail layer: detail = L - base.
4. Apply an offset and scale to base in order to normalize the image: b' = (base - offset) * scale.
5. Reconstruct the intensity and put back the color: $RGB' = 2^{(b' + detail)} * (RGB/I)$.

Results

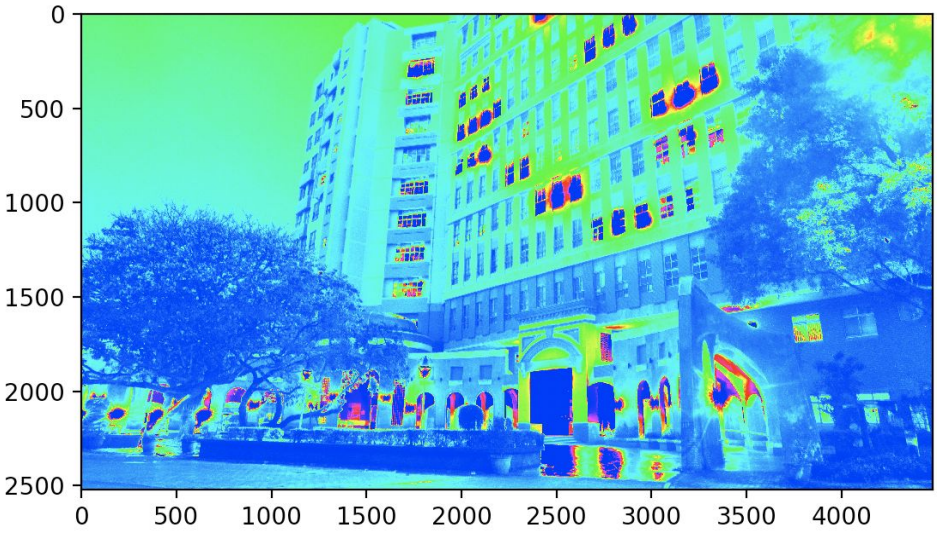
1. Building

Original images in different exposures:

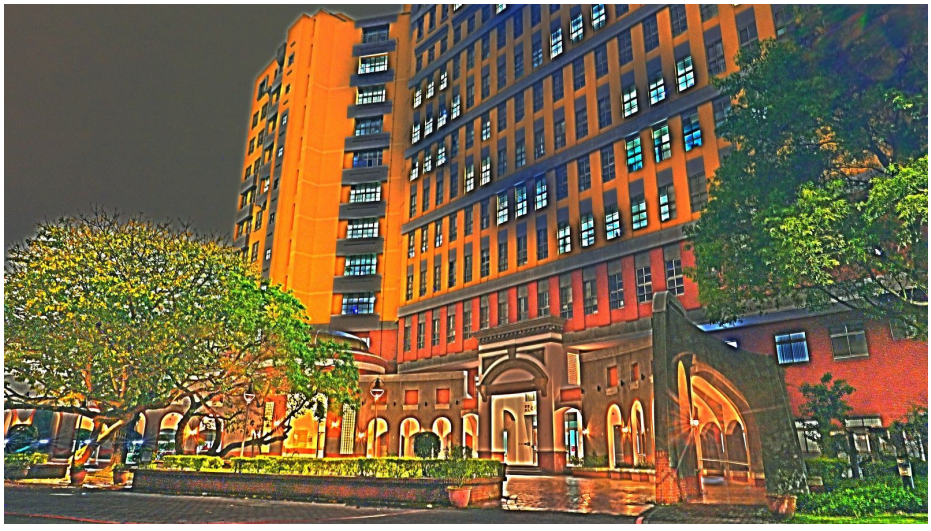
Response curve:



Radiance map:



Result (Durand):



Result (Drago):

2. Tree

Original images in different exposures:

Result:

What extensions you have implemented

Besides the program to assemble an HDR image, we also implement **image alignment** with Ward's algorithm and **tone mapping** with Durand and Dorsey's Fast Bilateral Filtering.

Reference:
[1] Fast, Robust Image Registration for Compositing High Dynamic Range Photographs from Handheld Exposures, G. Ward, JGT 2003
[2] Fast Bilateral Filtering for the Display of High-Dynamic-Range Images http://people.csail.mit.edu/fredo/PUBLI/Siggraph2002/
[3] Recovering High Dynamic Range Radiance Maps from Photographs, Paul E. Debevec, Jitendra Malik, SIGGRAPH 1997