High Dynamic Range Images Using Exposure Metering

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Dynamic Range

The dynamic range is a ratio between the maximum and minimum physical measures. Its definition depends on what the dynamic range refers to. For a scene, dynamic range is the ratio between the brightest and darkest parts of the scene. For a camera, dynamic range is the ratio of saturation to noise. More specifically, ratio of the intensity that just saturates the camera to the intensity that just lifts the camera response one standard deviation above camera noise. For a display, dynamic range is the ratio between the maximum and minimum intensities emitted from the screen.

In photography and imaging, the dynamic range represents the ratio of two luminance values and the luminance is expressed in candelas per square meter.
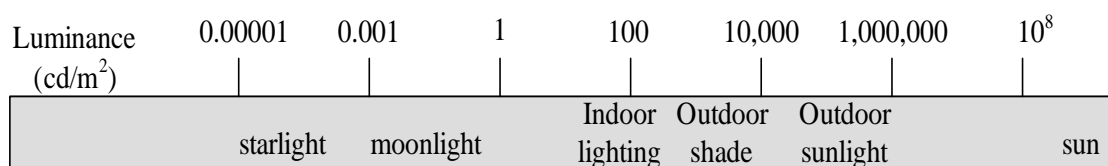
Luminance (cd/m^2)	0.00001	0.001	1	100	10,000	1,000,000	10^8
		starlight	moonlight	Indoor lighting	Outdoor shade	Outdoor sunlight	sun

Figure 1.1 Range of luminance in the natural environment.

As Figure 1.1 shows, real world scenes encompass several orders of magnitudes of luminance. Human vision system is capable of perceiving scenes over five orders of magnitude and can gradually adapt to scenes with dynamic ranges of over nine orders of magnitudes. When we are in the room, we can both see the indoor decoration and outdoor beautiful scenery through the window, the indoor lighting is around 100 cd/m2 and the outdoor sunlight is around 100,000 cd/m2. Moreover, human vision system is capable of distinguishing about 10,000 colors at any given brightness.

High Dynamic Range (HDR)

Real-world scenes contain light ranges that exceed 50,000:1 dynamic range. Assume that an indoor room and sunlight falls through the window. Human vision can both see the indoor scene and outdoor scene through the window, shown in Figure 1.2. The reason is that human vision can accommodate high dynamic range. However, the digital still camera is different from human vision system. If we use digital still camera to take a photo with scene described above, either indoor is clear

and outdoor is over-exposed or outdoor is clear and indoor is under-exposed, as shown in Figure 1.3. Therefore, human vision has higher dynamic range, but digital still camera does not. However, people prefer what we see is what we get. Consequently, high dynamic range imaging technique develops due to this reason.

Figure 1.2 The high dynamic range of human vision system.

(a) Outdoor is over-exposed, and indoor is clear.	*(b) Indoor is under-exposed, and outdoor is clear.*

Figure 1.3 The dynamic range of the digital camera.

Motivation

When we capture an image, we want to acquire high dynamic range images. However, if we use the old method, we may have to take series of images to construct a high dynamic range image. It must take some time to acquire different exposure images. Therefore, we try to decrease time to capture images to construct high dynamic range image. In other words, we do not capture all exposure images, instead of choosing some images to construct an HDR image. The difficulty is how to choose image that can construct an HDR image.

Consequently, we bring up a method here to choose images to construct an HDR image. Moreover, we want it also to preserve enough saturation. First, we analyze the relation between saturation and exposure.
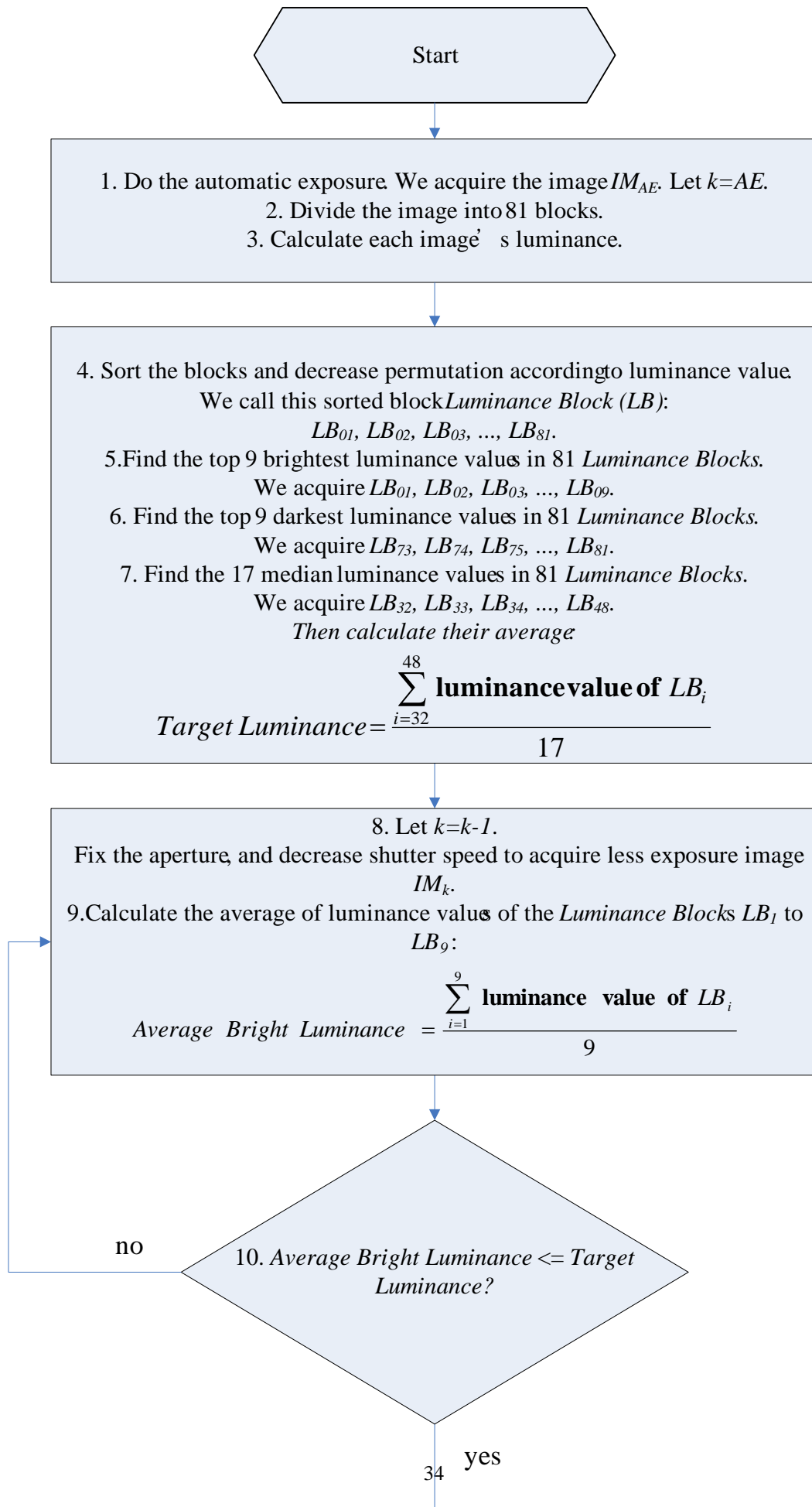
Analyze Saturation

Saturation refers to the relative purity or the amount of white light mixed with a hue. The pure spectrum colors are fully saturated. The white, black, and grey colors have zero saturation.
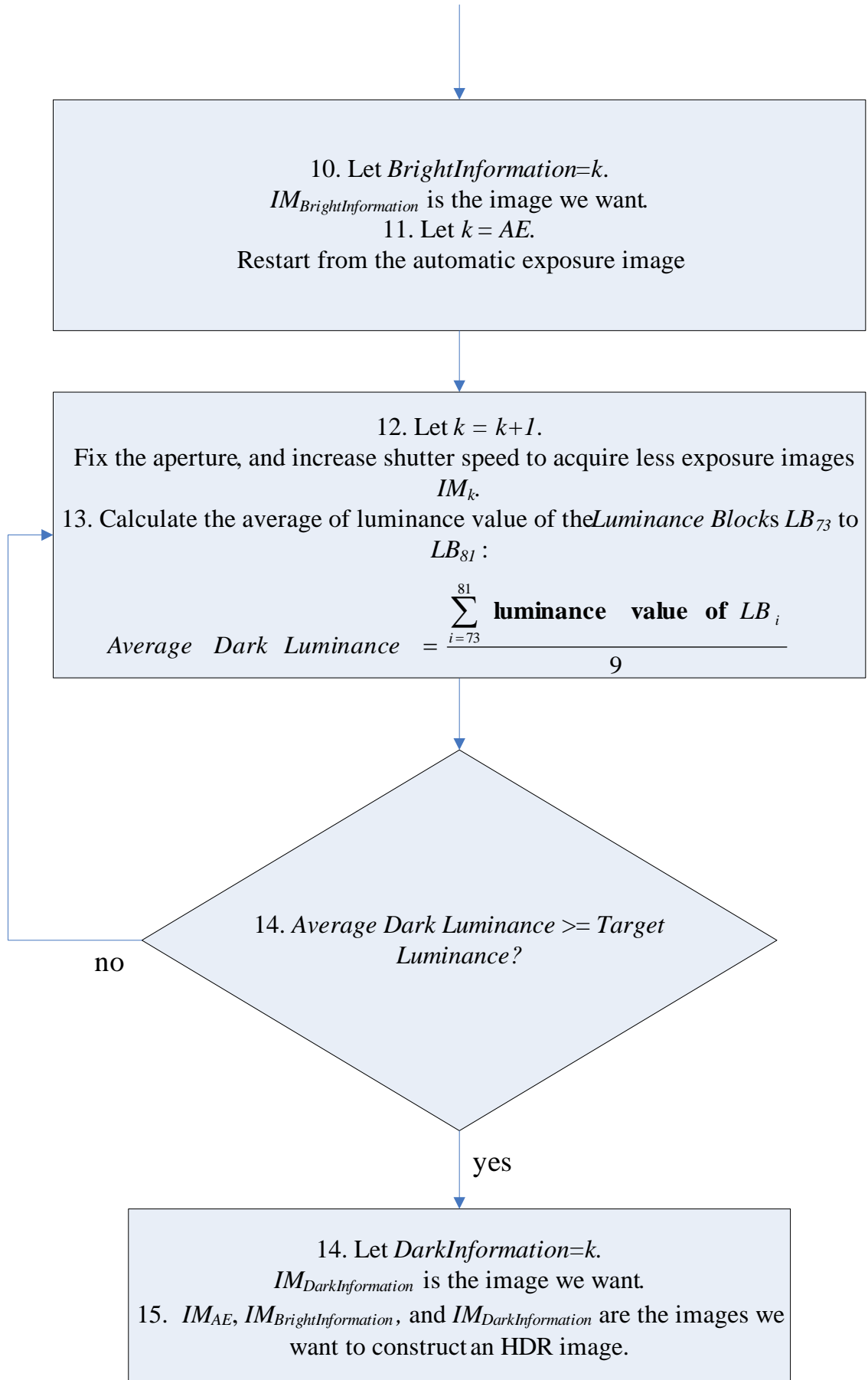
We take a series of images with GretagMacbeth ColorChecker in different exposures. By fixing the aperture diameter, and controlling exposure time to acquire different exposures. After that, we calculate each patch's saturation of ColorChecker in different exposure images. If we want to preserve the saturation of the images, we must use the "good exposure" images to construct a high dynamic range image. The "good exposure" images are close to automatic exposure images.

Choose Better Exposure Images

Therefore we can start from automatic images to increase or decrease exposure to find the appropriate images to construct an HDR image. However, what are appropriate images for high dynamic range images?

The essence of the high dynamic range is that we can both acquire the information in the darker area and the information in the brighter area rather than only get the information in the darker area or brighter area, but not both. On the other hand, we do not prefer the information in the over-exposure (saturated) or in the under-exposure. Therefore, we propose our method to resolve the above concern. Here is the flowchart of our method.
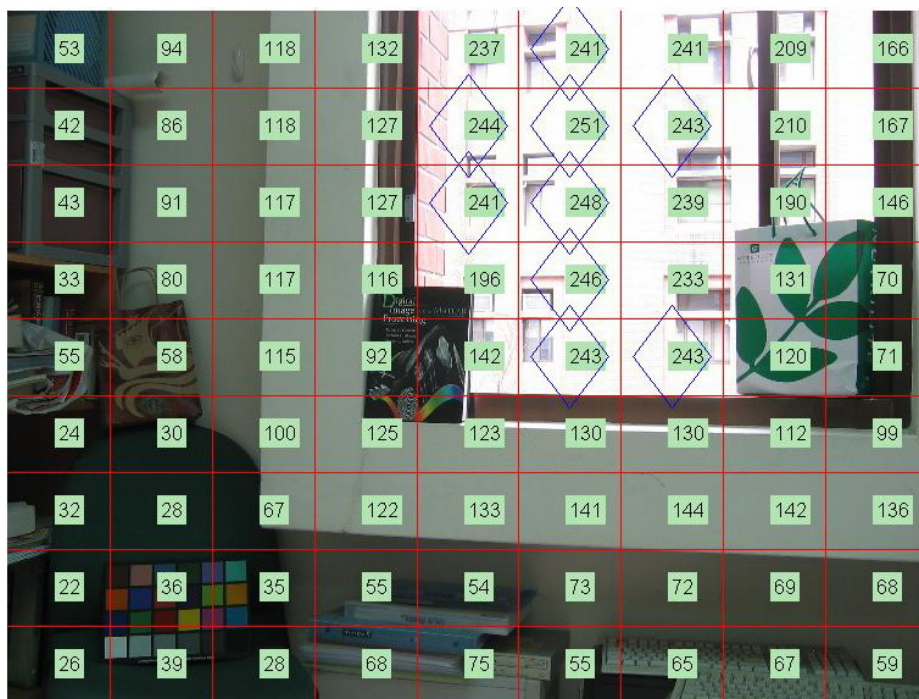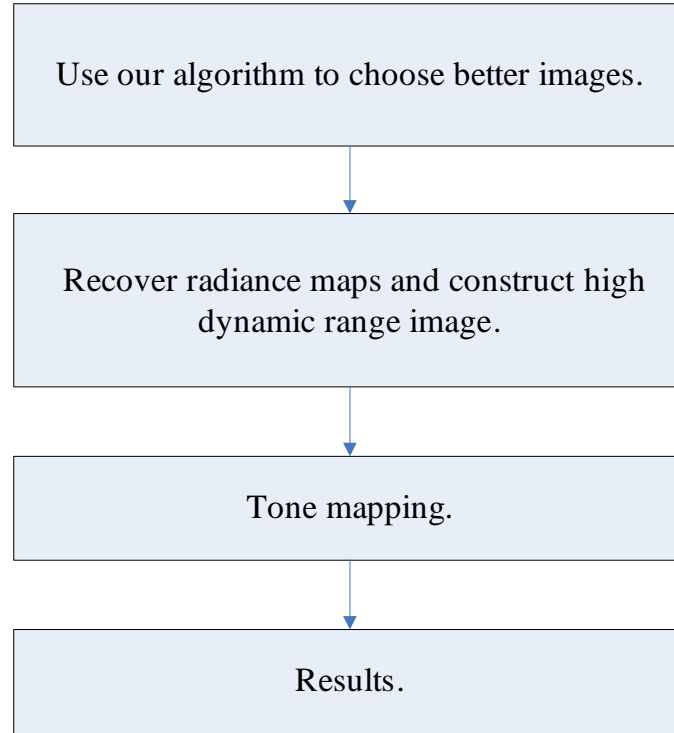
Start

1. Do the automatic exposure. We acquire the image IM_{AE}. Let $k=AE$.
2. Divide the image into 81 blocks.
3. Calculate each image's luminance.

4. Sort the blocks and decrease permutation according to luminance value.
We call this sorted block *Luminance Block (LB)*:
LB_{01}, LB_{02}, LB_{03}, ..., LB_{81}.
5. Find the top 9 brightest luminance values in 81 *Luminance Blocks*.
We acquire LB_{01}, LB_{02}, LB_{03}, ..., LB_{09}.
6. Find the top 9 darkest luminance values in 81 *Luminance Blocks*.
We acquire LB_{73}, LB_{74}, LB_{75}, ..., LB_{81}.
7. Find the 17 median luminance values in 81 *Luminance Blocks*.
We acquire LB_{32}, LB_{33}, LB_{34}, ..., LB_{48}.
Then calculate their average:

$$Target\ Luminance = \frac{\sum_{i=32}^{48} \textbf{luminance value of } LB_i}{17}$$

8. Let $k=k-1$.
Fix the aperture, and decrease shutter speed to acquire less exposure image IM_k.
9. Calculate the average of luminance values of the *Luminance Blocks* LB_1 to LB_9:

$$Average\ Bright\ Luminance = \frac{\sum_{i=1}^{9} \textbf{luminance value of } LB_i}{9}$$

no

10. *Average Bright Luminance <= Target Luminance?*

yes

10. Let $BrightInformation=k$.
$IM_{BrightInformation}$ is the image we want.
11. Let $k = AE$.
Restart from the automatic exposure image

12. Let $k = k+1$.
Fix the aperture, and increase shutter speed to acquire less exposure images IM_k.
13. Calculate the average of luminance value of the $Luminance Blocks$ LB_{73} to LB_{81} :

$$Average \ \ Dark \ \ Luminance \ \ = \frac{\displaystyle\sum_{i=73}^{81} \textbf{luminance} \ \ \textbf{value} \ \ \textbf{of} \ LB_i}{9}$$

14. *Average Dark Luminance >= Target Luminance?*

no

yes

14. Let $DarkInformation=k$.
$IM_{DarkInformation}$ is the image we want.
15. IM_{AE}, $IM_{BrightInformation}$, and $IM_{DarkInformation}$ are the images we want to construct an HDR image.

Figure 1.4 Our algorithm to choose better exposure images: Divide the image into 81 blocks then calculate each block's luminance. Find the top9 brightest luminance values and so on.

Experiment

In order to simulate exposure control of the camera, we need to take a series of photo in advance. First, we need to fix a scene by using tripod, and then we take a shot with automatic exposure mode of camera. We must write down this automatic exposure image's aperture diameter and exposure. Afterwards, we base on the acquired aperture diameter, fix it and set up different exposure time to take different exposure images.

This is a tedious work. Therefore, we can use software to help us to easily finish this work. AHDRIA is software developed for Automatic High Dynamic Range Image Acquisition. It can help us to take a series of images automatically. However, AHDRIA was written with v7.3 of the Canon SDK, so only some version of Canon camera can use this software to take a series of images automatically.

The flow of constructing high dynamic range image:

Use our algorithm to choose better images.

Recover radiance maps and construct high dynamic range image.

Tone mapping.

Results.

Results

We list all of different exposure images and mark their exposure time. We also indicate the image to be IM_{AE}, $IM_{BrightInformation}$ (IM_{BI}), or $IM_{DarkInformation}$ (IM_{DI}). Finally, we show the HDR image which uses IM_{AE}, $IM_{BrightInformation}$, and $IM_{DarkInformation}$ to reconstruct and the other HDR image which uses all of images to reconstruct. To evaluate the result, we calculate the saturation of image to be objective evaluation $(OE) = \sum S$ and ask for a group of people to vote as subjective evaluation (SE). The greater OE means colors are more saturated, vivid, and visually pleasant. Thus, the greater SE and OE one will be the better.

(a) The result using our algorithm.

OE: 0.1009498　　　SE: 14

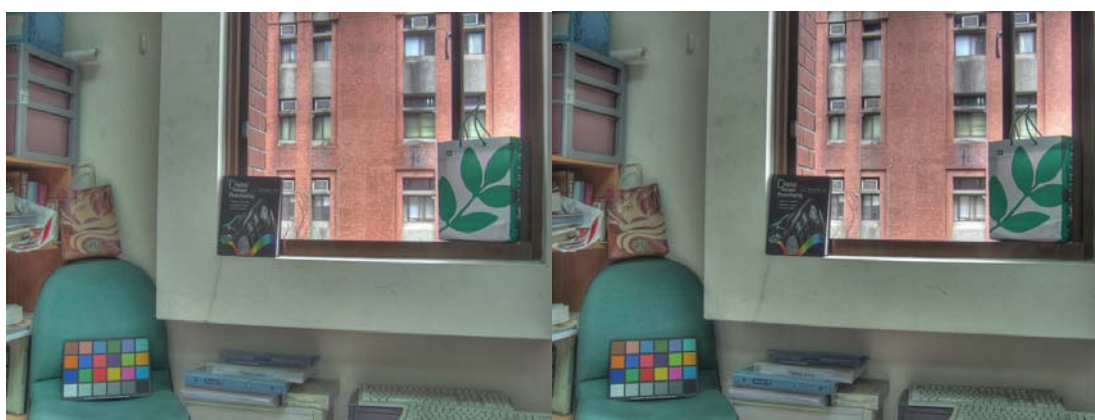*(b) The result using all images.*

OE: 0.0749975　　　SE: 3

(a) The result using our algorithm.　　　　　　*(b) The result using all images.*

　OE: 0.1098769　　SE: 12　　　　　　　OE: 0.0790367　　SE: 5

(a) The result using our algorithm.　　　　　　*(b) The result using all images.*

　OE: 0.0335832　　SE: 12　　　　　　　OE: 0.0340251　　SE: 5

Conclusion

The scene information is derived from images. However, there is a tradeoff between the number of the images which can improve image's information and the long capture time. We want to acquire the dynamic range that resembles the scene we capture.

Our method focuses on both preserving saturation and enough dynamic range of the scene. Though the fewer images to construct an HDR image using Debevec and Malik's method may increase noise due to lost information. However, in most situations, our method constructs better result image. Moreover, we use fewer images, so we can save much storage to record variant exposure images.

In conclusion, when implementing our method, we can use less time to acquire images to construct a higher dynamic image. Our choosing better exposure images method is a suitable assistant to cooperate with generating an HDR image, if we want to save the capture time.

Acknowledgment