Fusion Tone Mapping for HDR images

Areerat Pathomchaiwal
Department of Printing Engineering, Faculty of Engineering, Siam University
38 Petchkasem Road, Phasi Chareon District, Bangkok 10160, Thailand
E-mail: areerat.pathom@gmail.com

Abstract

In this study, we propose tone mapping (TM) method for compressing high dynamic range (HDR) images to low dynamic range (LDR) displays by fusion tone mapping (FTM) method. Firstly, HDR images was produced from multiple LDR images of the same scene with different exposures, through an image alignment method. Next, the HDR images converged LDR images are rendered with a FTM method and displayed on LDR display device. Our approach is subsequently combined with luminance map and bilateral filter, adjust the color saturation and brightness of an image. Finally, the experiment results showed that FTM outperforms and comparison that than other TM methods in the subjective psychophysical evaluation.

Keywords: high dynamic range, low dynamic range, tone mapping

1. Introduction

Nowadays, High dynamic range (HDR) image is defined as an image that contains a wide range of intensities. In general, the method of capturing the full radiance of a static scene is to take multiple exposures of the same scene with varying exposure times and then combine them in HDRI [1].

The camera response curve is constructed by the physical properties of the imaging system. The computation of the response curve is formalized as a least square minimization of an ill-posed problem and the detailed steps for computing the response curve [1-3]. This response curve is then used to convert pixel values into relative radiance maps assuming a known exposure time. The number of photographs needed to recover the full dynamic range of the scene should rationalize to the dynamic range covered by the camera.

The HDRI is usually represented by HDR encodings, that is, a 32-bit floating point RGBE [3], where R, G and B represent the intensity of red, green and blue color components, respectively, and E is the common exponent. HDRIs have the capability to record the full details in shadows and highlights of scene.

However, the display devices are LDR display devices and use sRGB (24 bit).

Tone mapping can be used to display HDR images on LDR display devices. TM can be classified into the two broad categories of global and local operators. Global operators use a single appropriately designed spatially invariant mapping function for each pixel of the image, whilst local operators adapt the mapping functions to local pixel statistics and local pixel contexts. The three TM methods selected for comparison in this paper are as follows. Firstly, the histogram adjustment technique proposed by Ward et al. [4], which uses models of glare, acuity and color sensitivity. This method is based on the population of local adaptation luminance in a scene, and incorporates models of human contrast sensitivity. The second TM method is the photographic technique of dodging and burning, as proposed by Reinhard et al. [5]. This method finds the local contrast and applies different exposures to the areas with a low local contrast. The third TM method is the bilateral filter method proposed by Durand et al. [6] that considers the image as the two different spatial frequency layers of the base and detail layers. The base layer preserves high contrast edges and removes high spatial frequency details of lower contrast. The detail layer is created as the difference between the original image and the derived base layer in a logarithmic scale. After contrast compression in the base layer, both layers are summed up to obtain the tone mapped image. Therefore, this method can keep details in both the dark and the bright areas.

2. Proposed method

In this paper, we proposed Fusion tone mapping (FTM) based on the global and local TM, here a method that can compress HDR scenes to display LDR devices. The FTM method involves a scaled luminance and bilateral filter. The pixel luminance (*L*) of the image is computed from the RGB values, as shown in Eq. (1) [5] :

$$L(x,y) = 0.2126R(x,y) + 0.7152G(x,y) + 0.0722B(x,y) \qquad (1)$$

where R, G and B are the red, green and blue channels.

First, the global TM, the log average of luminance $\overline{L}$ is computed by Eq. (2):

$$\overline{L} = \frac{1}{N}\exp\left(\sum_{x,y}\log\left(\delta + L(x,y)\right)\right) \qquad (2)$$

where *N* is the total number of pixels and δ is a constant with a value of 10^{-4}. Then, the entire image is scaled to pixel luminance *Lp(x,y)* according to Eq. (3):

$$Lp\left(x,y\right) = \frac{a}{\overline{L}}L(x,y) \qquad (3)$$

where a is the key value and is given by Eq. (4) [7] :

$$a = 0.18 \times 4^{\left(\frac{2\bar{L} - Lmin - Lmax}{Lmax - Lmin}\right)} \quad (4)$$

where *Lmax* and *Lmin* are the maximum and minimum luminance.

For this step, FTM can perform LTM based on bilateral filter. The image was decomposed into the base and detail layers [6, 8], which is a non-linear filter that computes the average luminance in the neighborhood of each pixel. The weight of a pixel depends on a Gaussian kernel in both the spatial and intensity domains, which decreases with both the spatial distance and the difference in values, as shown in Eqs. (5) and (6):

$$Lv(s) = \frac{1}{k(s)} \sum_{p \in N(s)} f(p-s) g(Lp - Ls) Lp \quad (5)$$

$$k(s) = \sum_{p \in N(s)} f(p-s) g(Lp - Ls) \quad (6)$$

where *Ls* is the intensity of the pixel at *s, f* is the spatial filter kernel, such as a Gaussian centered over *p*, and *g* is the range filter kernel. *N(s)* is the spatial support of the kernel *f*, and *k(s)* is a normalizing factor.

After this stage is finalized, Eq. (7) was then used to compute the output LDR pixels [9-12] :

$$\begin{aligned} R_{output} &= \left(\frac{R}{L}\right)^s Lv \times Bt \\ G_{output} &= \left(\frac{G}{L}\right)^s Lv \times Bt \\ B_{output} &= \left(\frac{B}{L}\right)^s Lv \times Bt \end{aligned} \quad (7)$$

where R_{output}, G_{output} and B_{output} are the red, green and blue channels of the output LDRI; R, G and B are the red, green and blue channels of the inputs; L and Lv are the pixel luminance before and after TM, and *s* is the controls the color saturation. Bt is the controls the brightness.

3. Experimental, Results and Discussions

HDR image is to capture a sequence of images of the same scene with these exposures (Fig.1) and combine with image alignment that was then transformed through the luminescent intensity using the response curve of the camera as shown in Fig. 2.

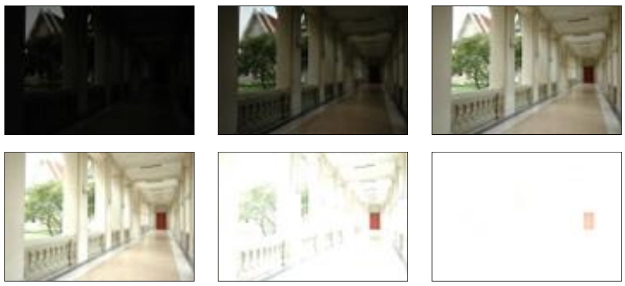

Fig. 1 Multiple exposure images

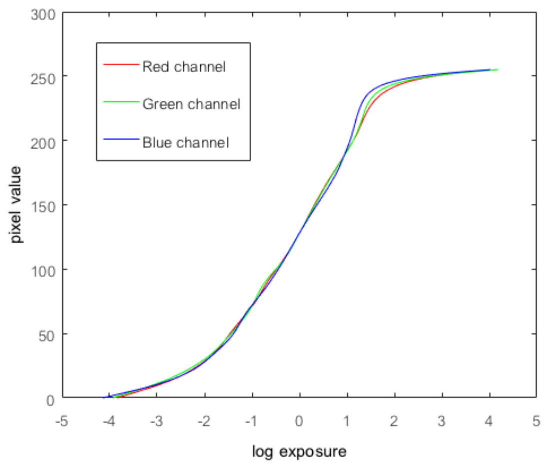

Fig. 2 The camera response curve of DSLR camera

In particular, we select 3 HDR images representing both two indoor ((a) Arts, and (b) Belgium [14]) and one outdoor ((c) Bristolb bridge [15]) scenes, as shown in Fig 3.

(a) (b) (c)

Fig. 3 Scenes used in the psychophysical experiment for the evaluation. (a) Arts. (b) Belgium. (c) Bristolb bridge.

4. Psychophysical Evaluation

In this paper, we present a subjective evaluation of various our method and three method (Ward's method [4], Durand's method [5] and Reinhard's method [6]) using a paired comparison of images and rating scale method, implementing Thurstone's Law of Comparative Judgments (Case V) [13]. This analysis calculates the z-scores from the data.

The images used for subjective evaluation can be seen in Fig. 4. Experiments were performed in a dark surround. The LDR display device responses was measured with the X-rite Eye-One spectrophotometer. The measurement were used to calibrate iMac 21.5-inch diagonal display of 1920 by 1080 pixels resolution. LDR images were presented on a 20% gray background.

A group of 15 observers (12 males and 3 females) between 20 and 35 years old with normal or corrected to normal vision.

The observers were asked to compare and select a better quality image in each of these attributes (colors, details, tonal and overall quality). Then, the observers were invited to use a five-point scale for a particular scene, where the observers estimated the difference between the pair of images. After that, asking an observer to rate it using one of the five categories: 1 (not good), 2 (slightly good), 3 (moderately good), 4 (very good), and 5 (extremely good). Before changing to another scene, the screen was blanked to a grey background with a luminance of 20% of the display for 30 seconds. Then each image of the pair was displayed for 15 seconds.

(a)

(b)

(c)

(d)

Fig. 4 Comparison of the images from different tone mapping methods for HDR images using (a) Ward’s method. (b) Reinhard’s method. (c) Durand’s method method. (d) Our method.

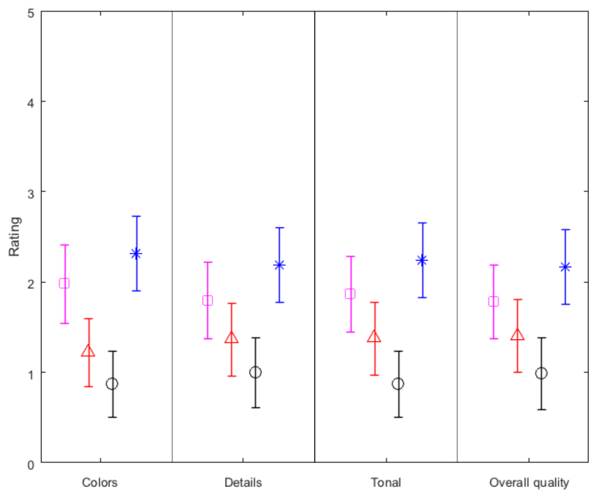

Fig. 5 Rating obtained for tone mapping methods for three scenes (see Fig. 4). Legend: (R) Reinhard's method. (D) Durand's method. (W) Ward's method. (O) Our method

In Fig. 5 shows the subjective rating of selected tone mapping method. The results as interval scales are shown with standard errors. Our method achieved the highest scores in all attributes (color, detail, tonal and overall image quality). Other methods have poor results; Reinhard's method has good details and some bright regions. Durand's method has lost the details of the bright regions. Ward's method has poor quality and low rating.

5. Conclusions

In this paper a FTM method that is based on global and local TM was proposed and compared with three other established TM methods. The result shows that the overall image quality obtained by this proposed FTM method was better than the three other TM methods in terms of color, details and overall image quality. However, the tone reproduction was given a low rating because of the low contrast appearance.

References

[1] P.E. Debevec, and J. Malik, "Recovering High Dynamic Range Radiance Maps from Photographs", Proceedings of SIGGRAPH 97, pp. 369-378(1997).

[2] G. Ward, "Fast, Robust Image Alignment for Compositing High Dynamic Range Photographs from Handheld Exposure", Journal of Graphics Tools, 8(2), pp. 17-30(2004).

[3] G. Ward, "Real Pixels", Graphics Gems II, pp. 80-83(1991).

[4] G. Ward, H. Rushmeier, and C. Piatko, "A Visibility Matching Tone Reproduction Operator for High Dynamic Range Scene", IEEE Transaction on Visualization and Computer Graphics, 3(4), pp. 291-306(1997).

[5] E. Reinhard, M. Stark, P. Shirley, and J. Ferwerda, "Photographic Tone Reproduction for Digital Images", ACM Transactions on Graphics, 21(3), pp. 267-276(2002).

[6] F. Durand, and J. Dorsey, "Fast Bilateral Filtering for the Display of High-dynamic-

range Images," ACM Transactions on Graphics, 21(3), pp. 257-266(2002).

[7] E. Reinhard, "Parameter Estimation for Photographic Tone Reproduction". Journal of Graphics Tools, 7(1), pp. 45-51(2003).

[8] C. Tomasi and R. Manduchi, "Bilateral Filtering for Gray and Color Images", Proceedings of Computer Vision, pp. 839-846(1998).

[9] R. Hall, "Illumination and Color in Computer Generated Imagery", New York; London: Springer-Verlag(1989).

[10] C. Schlick, "Quantization Techniques for the Visualization of High Dynamic Range Pictures", Photorealistic Rendering Techniques, Springer-Verlag, pp. 7–20(1994).

[11] J. Tumblin and G. Turk, "LCIS: A Boundary Hierarchy for Detail-preserving Contrast Reduction", Computer Graphics Proceedings, pp. 83-90(1999).

[12] J.W. Lee, R.H. Park and S.K. Chang, "Tone Mapping Using Color Correction Function and Image Decomposition in High Dynamic Range Imaging", IEEE Transaction on Consumer Electronics, 56(4), pp. 2722-2780(2010).

[13] Thurstone, L.L., "A Law of Comparative Judgment", Psychological Review, 34(4), pp. 273-286(1927).

[14] Belgium.hdr [Online image]. Retrieved September 20, 2015 from http://www.cs.huji.ac.il/~danix/hdr/hdrs/belgium.hdr

[15] Bristolb.hdr [Online image]. Retrieved September 20, 2015 from https://www.cs.utah.edu/~reinhard/cdrom/hdr/bristolb.hdr