A Hybrid Tone Mapping for High Dynamic Range Images

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Abstract

In this study, low dynamic range images were produced from high dynamic range images using hybrid tone mapping. Firstly, high dynamic range images were constructed from the series of images by varying exposure through an image fusion method. Then the high dynamic range images were mapped into 8 bit images using hybrid tone mapping. Our approach is based on combination of luminance map and bilateral filter, and increasing the brightness of an image. We present results of subjective psychophysical tests that we have performed our method by compared to the other tone mapping. The results show that our method better low dynamic range images for detail, tone, and color reproductions, as well as overall quality.

Keywords: high Dynamic Range image, low dynamic range, tone mapping.

Introduction

The high dynamic range image (HDRI) is defined as an image contains a wide range in luminance information and therefore HDR can exhibit more details in both highlight and shadow areas. The method of capture full radiance of a static scene is to take multiple exposures of the same scene with varying exposure times and combine them to a high dynamic range image (HDRI)[1].

In the image registration method, there are vertical and horizontal shifts for a high dynamic range image composition. In fact, the images have been differently exposed; the method needs to be insensitive to the intensity of the image. Ward[2] purposed the median threshold bitmap (MTB) algorithm. This method is based on the median of the pixel values that helps the comparison of images taken under different exposure settings by effectively removing most of the illumination differences between image exposures.

The high dynamic range image is usually represented by an HDR encodings (32-bit floating point RGBE)[3]. Here, R, G, and B represent the intensity of the three color components and E is the common exponent. However, most display devices such as monitors are sRGB encoding (24-bit RGB). In order to reproduce HDRI in the low dynamic range (LDR) devices, HDR values are mapped to LDR values. This method is called the tone mapping. It is used to convert floating-point radiance maps into an 8-bit representation suitable for rendering. Tone mapping can be classified into two broad categories: global and local operators. Global operators use a single appropriately designed spatially invariant mapping function for each pixel of the image; local operators adapt the mapping functions to local pixel statistics and local pixel contexts.

In the literature, Ward et al.[4] proposed the histogram adjustment method technique and models of glare, acuity and color sensitivity. This method is based on the population of local adaptation luminance in a scene, and incorporating models of human contrast sensitivity. Reinhard et al.[5] proposed the photographic technique of dodging (darkening) and burning (brightening) process. The algorithms will find the local contrast and apply different exposures to the areas with low local contrast. Durand et al.[6] proposed the bilateral filter method considering the two different spatial frequency layers: a base layer and a detail layer. The base layer preserves high contrast edges and removes high spatial frequency details of lower contrast. The detail layer is created as the difference of the original image and the base layer in logarithmic scale.

Purposes

In this paper, we proposed hybrid tone mapping (HTM) operator which can effectively and efficiently compress high dynamic range scene to display on the low dynamic range device. The first step was a global tone mapping process using the global portion based on Reinhard proposed technique was used. Then, a local tone mapping process to modify the input luminance based on bilateral filter. The flowchart of the proposed workflow is illustrated as in Fig. 1.

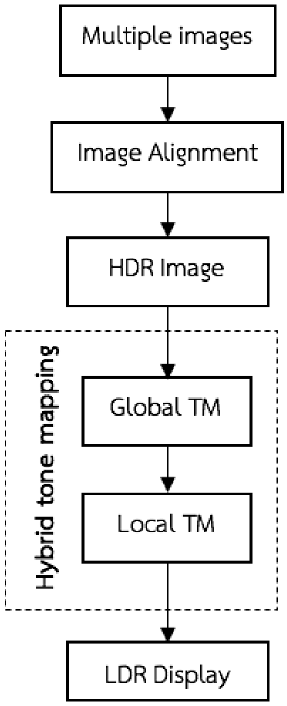

Fig. 1. Framework of the proposed method.
HDR: high dynamic range.
TM: tone mapping.
LDR: low dynamic range.

The luminance values of image can be computed from the RGB values, the pixel luminance (Lv) is computed by

$$\mathrm{Lv} = 0.2126\mathrm{R} + 0.7152\mathrm{G} + 0.0722\mathrm{B} \qquad (1)$$

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

For the first global tone mapping, we compute the average luminance, which control the transfer function that provides a good initial luminance mapping. The log average luminance is given by

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

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

$$\mathrm{L} = \frac{a}{\overline{\mathrm{Lv}}} \mathrm{Lv} \qquad (3)$$

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

$$a = 0.18 \times 4^{\left(\frac{2\overline{Lv} - Lmin - Lmax}{Lmax - Lmin} \right)} \qquad (4)$$

where Lmax and Lmin are the maximum and minimum luminance.

After the Reinhard Global tone mapping, the next tone mapping was to perform the Local mapping.

For the Local tone mapping of the luminance components of the image is done via a modified bilateral filter[6,8]. This is a non-linear filter to compute the average luminance on the neighborhood of each pixel. The weight of a pixel depends both on a Gaussian kernel in the spatial domain *f*, and on a Gaussian kernel in the intensity domain *g*, which decreases both with a spatial distance and with difference in values, as show in Eqs. (5) and (6) :

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

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

where 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 display devices[9-12] :

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

where R_{output}, G_{output} and B_{output} are the trichromatic values 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 HTM, s is the color saturation,.and Bd is the brightness factor.

Experimental, Results and Discussions

The same scene is captured also with the Nikon camera to recover its response. The sequence is captured by using a tripod. The exposure times from darkest to brightest exposure vary from 1/80000 to 2 seconds, with doubling at each exposure.

Fig. 2. LDR images with different exposure time

Fig. 2 show the captured images. These different exposure value images were aligned and combined into one single HDR image, and then it was transformed to a luminescent scale using the response curve of the camera[2] as shown in Fig. 3.

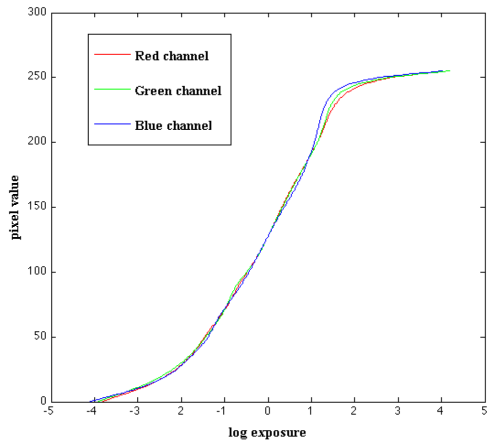

Fig. 3. The response curve of a Nikon D70s camera

Psychophysics Experiment

In order to confirm any improvement in this Our method, a psychophysical assessment was performed. For this purpose, our method was directly compared to three other commonly used TM methods (Ward's histogram adjustment method[4], Durand's bilateral filter method[5] and Reinhard's photographic methods[6]) using a pairwise comparison and five-point category rating system of the obtained LDRIs by a panel of 10 observers, implementing Thurstone's Law of Comparative Judgments, Case V. [13] This analysis calculates the z-scores from the data, resulting in an interval scale of rendering accuracy.

The 10 observers, eight males and two females, were aged between 21 and 28 years. They had normal or corrected to normal vision.

The experiment was conducted in a dark room to avoid ambient light. Observers were allowed to adapt to the dark room for 15 minutes before starting the experiment and were seated throughout at a distance of about 70 cm from the display.

Each observer was presented with 3 different scenes representing both outdoor (a) Synagogue[14] and two indoor ((b) Chamchuri, and (c) Office[16]) scenes, as shown in Fig. 4.

(a) (b) (c)

Fig. 4. The 3 scenes for the data set. (a) Synagogue, (b) Chamchuri, (c) Office.

Each scene had 24 pairs of images from the HTM and three different TM methods. The resulting images (Fig. 6) were displayed on a characterized and calibrated iMac with a 21.5-inch diagonal display of 1920 by 1080 pixels resolution. Calibration was performed using an X-Rite i1 spectrophotometer to D65 and was characterized by measuring the International Color Consortium (ICC) profile.

All the results LDRIs were displayed on a grey background with a luminance of 20% of the display. 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 scoring scale for a particular scene, where the observers estimated the difference between the pair of images and assigned a number to this difference from: 1 (not good), 2 (slightly good), 3 (moderately good), 4 (very good), and 5 (extremely good). The technique is, therefore, a combination of a pair comparison and a five-point category rating scale. 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.

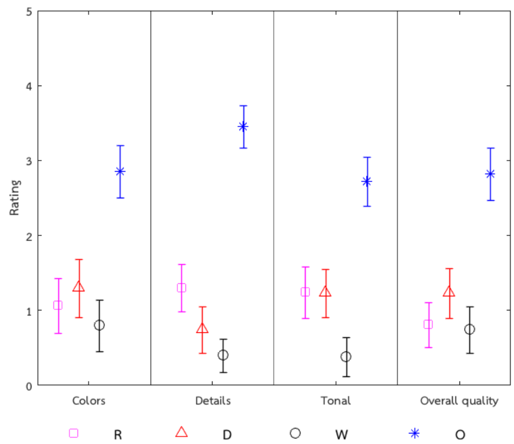

Fig. 5. Rating obtained for tone mapping methods for three scenes (see Fig. 6). Legend: (R) Reinhard's photographic method, (D) Durand's bilateral filter method, (W) Ward's histogram adjustment method, and (O) Our method

Fig. 5 shows the rating of selected tone mapping method on three scenes. The results for one of these images, while interval scales are shown with standard errors in the

Fig. 5. (overall average results) Our method achieved the highest scores in all attributes. Other methods have poor results; Ward's histogram adjustment method has lost the details of the bright and dark regions as it is clear in the other TM method and show very poor quality and they have low rating. In Reinhard's photographic method and Durand's bilateral filter method have color imbalance because the image is very greenish. Reinhard's photographic method has good details and some bright regions. Durand's bilateral filter method has colors balance and good overall quality.

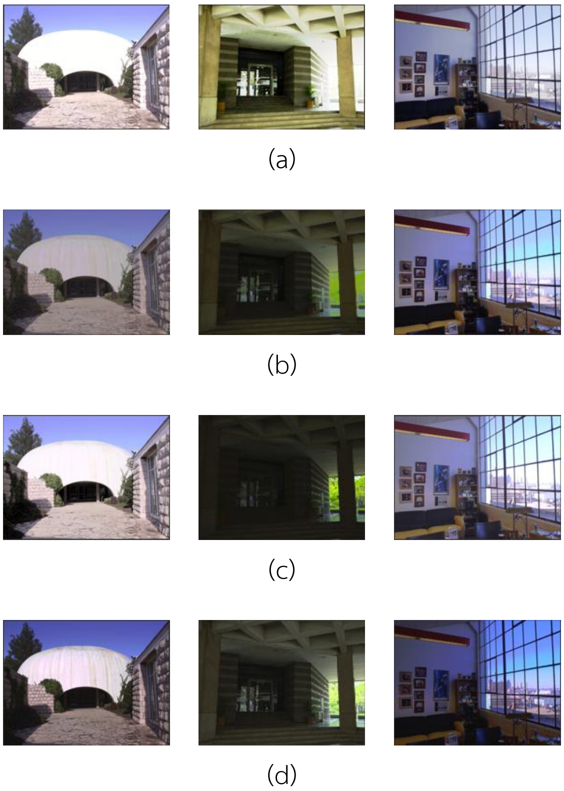

Fig. 6. Comparison of the images from different tone mapping methods for HDR images using (a) Ward's histogram adjustment method, (b) Reinhard's Photographic method, (c) Durand's bilateral filter method, and (d) Our method

Conclusions

In this paper, we have presented a hybrid tone mapping algorithm, which combines luminance map and bilateral filter, and increasing the brightness of an image. The performance of our method was psychophysical experiments using our proposed and compared with three other established TM methods. The result shows that the overall image quality obtained by this proposed HTM method was better than the three other TM methods in terms of color, details, tone of reproduction and overall image quality.

References

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

2) G. Ward, "Fast, Robust Image Registration 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", In Siggraph 1999, 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, pp. 273-286, 1927.

14) http://www.cs.huji.ac.il/~danix/hdr/results.html

15) http://people.csail.mit.edu/fredo/PUBLI/Siggraph2002/index.html#hd