An Integrated Tone Mapping for High Dynamic Range Image Visualization

Lei Liang¹,³, *, Jeng-Shyang Pan¹,² and Yongjun Zhuang³

¹ Department of Computer Science and Technology, Shenzhen Graduate School, Harbin Institute of Technology, Shenzhen, China
² Fujian Provincial Key Lab of Big Data Mining and Applications, Fujian University of Technology, Fujian, China
³ Qihan Research, Qihan Technology Co., LTD, Shenzhen, China

Email: *lianglei8568@163.com

Abstract. There are two type tone mapping operators for high dynamic range (HDR) image visualization. HDR image mapped by perceptual operators have strong sense of reality, but will lose local details. Empirical operators can maximize local detail information of HDR image, but realism is not strong. A common tone mapping operator suitable for all applications is not available. This paper proposes a novel integrated tone mapping framework which can achieve conversion between empirical operators and perceptual operators. In this framework, the empirical operator is rendered based on improved saliency map, which simulates the visual attention mechanism of the human eye to the natural scene. The results of objective evaluation prove the effectiveness of the proposed solution.

1. Introduction

In order to solve the problems of the mismatch between high dynamic range (HDR) image and low dynamic range (LDR) display device, many scholars have proposed a variety of tone mapping operators in recent years. Existing tone mapping operators are mainly divided into two categories: one is perceptual operators and the other is empirical operators. Perceptual operators are based on human visual system (HVS) model, such as photoreceptor adaptation model [1], threshold-versus-intensity (TVI) model [2], and adaptive logarithmic model [3] and so on. Physiological mechanisms of the human eye are generally added to the operator. The advantage is the mapped images are realistic and the disadvantage is the lack of visibility of local details (As shown in Figure 1). Empirical operators are not based on HVS model, but it tries to create aesthetically-pleasing or visual impact images inspired by other fields, such as histogram adjustment [4], bilateral filtering [5] and gradient domain [6] and so on. These operators can maintain the visibility of local details, but the image looks unrealistic (As shown in Figure 2). Nowadays, there is no common tone mapping operators suitable for all applications. Therefore, the suitable tone mapping operators should be selected based on the specific application. To solve this problem, this paper proposes a novel tone mapping framework which can achieve conversion between empirical operators and perceptual operators, called integrated tone mapping. The proposed framework is based on improved saliency map and has a user parameter, by adjusting the parameter, it can be conversion between detail visibility and realism of the result image.
2. Proposed framework

Overall procedure of the proposed framework, depicted in Figure 3. The steps of our framework are summarized as follows:

Step 1: The input HDR image was tone mapped by empirical operators. This paper takes gradient operator as example. Fattal’s gradient operator is the most well-known empirical tone mapping operators. Fattal et al. [6] conduct multi scale attenuation for luminance image in the image gradient domain, and then use compressed gradient distribution to restore the luminance of the image by solving the Poisson equation. This operator is simple, efficient and can almost display all the details. However, the effectiveness of the operator does not match the human visual perception and the realism of the result image is poor.
**Figure 3.** Overall procedure of the proposed framework.

**Step 2:** Calculating improved saliency map. Itti and Koch [7] proposed “Itti model” based on the neurobiological framework. Itti model provides a bottom-up mechanism with each feature map parallel computed. The model combines a variety of features in a multi-scale, and synthesizes into a comprehensive visual saliency map. But itti model is not suitable for calculating HDR image and we
propose an improved saliency map calculation model for HDR image. Firstly the saliency map generation by calculating the itti model, and then it transform according to the Eq. (1-3),

\[ s_1(i) = \log_{10}[s(i)] \] (1)

\[ s_2(i) = a \cdot \frac{s_1(i) - \max[s_1(i)]}{\max[s_1(i)] - \min[s_1(i)]} \] (2)

\[ s_3(i) = b \cdot 10^{s_1(i)} \] (3)

where \( i \) is the position of the pixels in the map, \( s(i) \) is saliency map values, \( s_3 \) is improved saliency map values, \( s_1, s_2 \) are intermediate variables. \( \max(s_1), \min(s_1) \) is the maximum and minimum pixel values in \( s_1 \). \( a \) and \( b \) are user parameters which can adjust the shape of the mapping curve. As shown in Figure 4. Above the black line represents the enhanced and below represents attenuation. Studies have shown that human eye perceive luminance in the form of a logarithmic curve [3]. The above transformation equation is equivalent to a logarithmic compression. It can simulate the human eye's visual sensitivity change in HDR scene.

![Improved saliency map curve](image)

**Figure 4.** Improved saliency map curve.

**Step 3:** The result of step 1 and step 2 synthesis. As shown in Eq. (4).

\[ R(i) = E(i) \cdot s_3(i) \] (4)

Where \( E(i) \) is the tone mapped image by empirical operators, \( R(i) \) is the result image.

3. **Experimental results**

In this paper, Experimental results are evaluated by Dynamic Range Independent (DRI) image quality assessment model [8]. DRI model produces a distortion probability map, and the green pixels represent the pixel value is too small, the blue pixels represent the pixel value is too large, and the red pixels represent gradient reversal. As shown in Figure 5. When user parameters \( a=0 \) and \( b=1 \), the HDR image mapped by empirical operators. There are a large number of green pixels and blue pixels
existing in bright and dark region, and the image is flat. When user parameters \( a=2 \) and \( b=2.5 \), the HDR image mapped by Perceptual operators, both green and blue pixels are reduced and the image looks more layered.

![Figure 5](image)

**Figure 5.** Top row: Experimental results. Bottom row: Evaluate results. From left to right: Empirical operators and its bright, dark region. \((a=0, b=1)\). Perceptual operators and its bright, dark region. \((a=2, b=2.5)\).

4. Conclusion

Based on improved saliency map, a novel framework for integrated tone mapping is introduced. By adjusting the user parameter, it can be conversion between detail visibility and realism of the result image. Evaluate results of DRI model prove the effectiveness of the proposed solution.

References

[1] E. Reinhard and K. Devlin, Dynamic range reduction inspired by photoreceptor physiology, IEEE Trans. Visualization and Computer Graphics, vol. 11, pp. 13-24, 2005.
[2] J. A. Ferwerda, S. N. Pattanaik, P. Shirley, and D. P. Greenberg, A model of visual adaptation for realistic image synthesis, Proc. ACM SIGGRAPH ’96, pp. 249-258, 1996.
[3] F. Drago, K. Myszkowski, T. Annen, and N. Chiba, Adaptive logarithmic mapping for displaying high contrast scenes, Computer Graphics Forum, pp. 419-426, 2003.
[4] J. Duan, M. Bressan, C. Dance, G. Qiu. Tone-mapping high dynamic range images by novel histogram adjustment, Pattern Recognition, vol. 43, pp. 1847-1862, 2010.
[5] F. Durand and J. Dorsey, Fast bilateral filtering for the display of high-dynamic-range images,” ACM Trans. Graphics, vol. 21, pp. 257-266, 2002.
[6] R. Fattal, D. Lischinski, and M. Werman, Gradient domain high dynamic range compression,” ACM Trans. Graphics, vol. 21, pp. 249-256, 2002.
[7] L. Itti, C. Koch, and E. Niebur, A model of saliency-based visual attention for rapid scene analysis, IEEE Trans. Pattern Analysis and Machine Intelligence, vol. 20, pp. 1254-1259, 1998.
[8] T. O. Aydin, R. Mantiuk, K. Myszkowski, S. Hans-Peter, Dynamic range independent image quality assessment, ACM Trans. Graphics, vol. 27, pp. 69-78, 2008.