A METHOD FOR HDR IMAGE RENDERING BASED ON ICAM FRAMEWORK

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ABSTRACT

Image color appearance model (iCAM) can predict how an image would be perceived by human visual system under a wide variety of viewing conditions. One of its applications is for high dynamic range (HDR) image rendering. Published studies have verified that iCAM06, the latest iCAM for HDR image rendering, outperforms other tone mapping algorithms. When iCAM06 is used for HDR image rendering, however, there is a hue shift problem with this model and the workflow of iCAM06 is a little too complicated. In this study, a new method based on iCAM framework for HDR image rendering was proposed, which incorporates three main steps, i.e. color adaptation, tone compression and adjustments. Compared with iCAM06, the proposed method is easier to understand and more efficient to apply, and it has better performance for HDR image rendering as evaluated via a psychophysical experiment.

INTRODUCTION

The dynamic range of the real-world scene can reach 8 orders for the sunlight at noon (10^5 cd/m^2), which may be 100 million times brighter than starlight (10^{-3} cd/m^2) [1]. Natural scenes usually span a range of 5 orders [2]. Human visual system is capable of adapting to 10 orders of luminance magnitude in minutes and functions over a range of about five orders of magnitude simultaneously. Through emerging techniques of HDR Imaging, we can capture HDR images by multiple exposures, and store them in HDR formats with HDR encodings. Although the present imaging technology has made it possible to capture and store the broad dynamic range image, the output limitations of common desktop displays as well as hardcopy prints have not yet followed the same advances [3]. The only available commercial HDR display device is a product of Brightside HDR display, but it is far more expensive than we can afford in general usage. Hereby the HDR image rendering algorithms, also known as tone mapping operators (TMOs), are of great importance for displays.

The HDR image rendering algorithm can be classified in different ways [1]. TMOs can be divided into global and local ones by spatial processing techniques. Global operators apply an identical transformation to each pixel in the image, while local operators modulate each pixel dependently on neighbourhood. TMOs can also be grouped into different categories by its mechanism: ranging from sigmoidal compression to image appearance models to a collection of perception- and engineering-based methods.

Published studies have verified that image color appearance model, especially iCAM06, performs better than others, for the rendering images of iCAM06 are more faithful to the real-world scenes and more preferable to those of other HDR rendering algorithms [3]. However, according to recent papers, iCAM06 causes hue shift and color distortion of the output image [4,5,6]. Lee *et al.* proposed the rotation matrix method for hue correction, and they also proposed color adjustment method to compensate the white shift in low-chromatic region and the color distortion in high-chromatic region [4,5].

In this study, a new method was proposed based on iCAM framework for HDR image rendering to solve the hue shift problem and to be of more efficiency for applications. The white point adaptation, chromatic adaptation, and attributes adjustment were inherited from the iCAM framework, while the convenient and efficient tone compression operator was employed.

PROPOSED METHOD

Our proposed method contains three steps as color adaptation, tone compression, and adjustments, of which the flowchart is illustrated in Fig. 1.

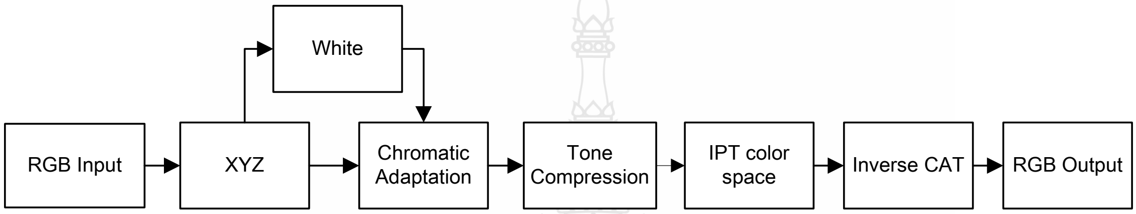

Fig. 1 Flowchart of the proposed method

1. Chromatic adaptation transformation (CAT). The chromatic adaptation transformation embedded in this method is the same as CIECAM02, which is a linear von Kries transformation with an incomplete adaptation factor [7]. The adaptation is processed on the cone response with the equations as follows.

$$\begin{bmatrix} R \\ G \\ B \end{bmatrix} = M_{CAT02}\begin{bmatrix} X \\ Y \\ Z \end{bmatrix}, M_{CAT02} = \begin{bmatrix} 0.7328 & 0.4296 & -0.1624 \\ -0.7036 & 1.6975 & 0.0061 \\ 0.0030 & 0.0136 & 0.9834 \end{bmatrix} \tag{1}$$

$$\mathrm{D} = 0.3\mathrm{F}\left[1 - \left(\frac{1}{3.6}\right) e^{\left(\frac{-(L_A-42)}{92}\right)}\right] \tag{2}$$

$$X_c = \left[\left(X_{D65}\frac{D}{X_W}\right) + (1-D)\right]X, X = R, G, B \tag{3}$$

where D and F are the adaptation factor and surround factor, respectively. L_A is the adaptation luminance, which is 20% of the adaptation white. The adaptation white point (X_W) is obtained by operating Gaussian low-pass filter on the HDR image itself.

2. Tone compression (TC). Since the iCAM compresses RGB cone responses separately, the ratios of RGB channel are imbalanced after compression. In this method, we transform the RGB cone responses to luminance and chromatic channels, then process the luminance channel and hold the chromatic channel unchanged, and at last combine them to form the final compressed cone responses. The photographic tone reproduction operator is chosen to map the luminance channel due to its simplicity and automation [8]. The initial mapping function is expressed as Eq. (4).

$$\mathrm{L_d}(\mathrm{x},\mathrm{y}) = \frac{\mathrm{L}(\mathrm{x},\mathrm{y})\left(1+\frac{\mathrm{L}(\mathrm{x},\mathrm{y})}{\mathrm{L_{white}}}\right)}{1+\mathrm{L}(\mathrm{x},\mathrm{y})} \tag{4}$$

where L(x,y) is the linearly scaled luminance by anchoring the average luminance to 0.18, and L_{white} is the smallest luminance that will be mapped to pure white. To accomplish a better result, the advanced operator with automatic local dodging-and-burning technique is applied instead of this initial one.

3. Adjustments in IPT space. In order to predict the phenomenon of Hunt effect, the stage of image attribute adjustments [3] is retained in this method. The images in XYZ space should be converted to those in IPT uniform opponent color space, and P and T channels are enhanced as the function of the factor F_L and chroma value as follows.

$$P = P\left[(F_L + 1)^{0.2}\left(\frac{1.29C^2-0.27C+0.42}{C^2-0.31C+0.42}\right)\right] \quad (5)$$

$$T = T\left[(F_L + 1)^{0.2}\left(\frac{1.29C^2-0.27C+0.42}{C^2-0.31C+0.42}\right)\right] \quad (6)$$

RESULTS AND DISCUSSION

To evaluate the performance of the proposed method, it was tested and further compared with the iCAM06 algorithm. Firstly, the hue shift performance was estimated. The gradient gray stripe alone was rendered respectively by the individual operators, as shown in Fig. 2. Then, the gradient gray stripe was embedded in the common HDR images to test their performances, of which the results are presented in Fig. 3.

(a) iCAM06 **(b) The proposed method**

Fig. 2 The rendered results of gradient gray stripe alone

(a) iCAM06 **(b) The proposed method**

Fig. 3 The rendered images by embedded gradient gray stripe

As shown in Figs. 2 and 3, the reddish shift of white in iCAM06 could be viewed obviously, while the white point is corrected in the proposed method.

Secondly, a psychophysical experiment was conducted for HDR rendered images. We picked 7 images with various kinds of contents including natural scenery in day or night, people in the picture, indoor and outdoor, resulting in the testing images as shown in Fig. 4.

(a) iCAM06

(b) The proposed method

Fig. 4 The testing images rendered by different algorithms

Two rendering pictures were displayed at the same time, and a panel of 8 observers (4 male and 4 female) participating in the experiment was asked to judge which one of them were more realistic according to their experiences. To analyse the comparative visual data, the Law of Comparative Judgement was applied and their Z-scores were calculated and plotted in Fig. 5.

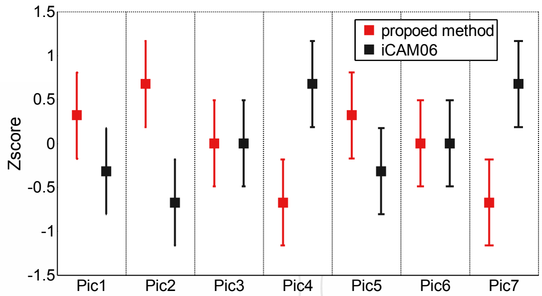

Fig. 5 The Z-scores of the two HDR image rendering methods

It can be seen from Fig. 5 that the proposed method performs better in outdoor pictures of daytime, but produces worse results of indoor or night scenery, in comparison with iCAM06. Then we carried out the additional experiments of contrast and color evaluation, which indicated that the photographic tone operator has some deficiency. Moreover, for the efficiency of the two methods, the time consuming of image processing by iCAM06 is about four times as much as that of this proposed method.

CONCLUSION

In this study, a method for HDR image rendering based on iCAM framework was proposed, of which the main three steps are demonstrated by modifying the iCAM algorithm. The evaluation experiment indicates that this method not only solves the hue shift problem of the iCAM with a preferable results, but also is more efficient. Meanwhile, the deficiency found in the tone compression would be further discussed in the future work.

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