Tone mapping High Dynamic Range Image using Cone Response Function based on CAM16

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***Abstract*— This article presents a tone mapping approach to overcome several problems in the conventional tone mapping methods. The proposed tone mapping method is composed of tone mapping operator and cone response function based on CAM16 using CIE XYZ tristimulus values. In order for the resulting image to represent the detail information and to achieve the one-to-one correspondence without color distortion like color leakage, hue shift, and luminance shift, the proposed tone mapping operator consists of two parameters by using logarithmic function and power function, respectively. In addition, the adaptive gamma correction is used to control the dynamic range in the given image, parameter free. Thereafter, the resulting image is finally processed by using CAM16 to deal with mismatch between real-life scene and displayed image. The experimental results show that the proposed method yields better performance of the tone mapping over the conventional method in subjective and quantitative quality and color reproduction.

Keywords— ***XYZ tristimulus value, color distortion, detail information, tone mapping operator, cone response function***

I. Introduction

The human visual system (HVS) consists of two types of photoreceptors. The retina features cones and rods with different spectral sensitivity; rods are geared towards low luminance level; cones are involved in a case of high luminance level. The function of these photoreceptors supports visual adaptation, which allows human vision to perceive a wide range of luminance in real-life scene. A large luminance change influences the quality of the captured image using an imaging system now that the dynamic range of the imaging systems and current display devices is limited. For this reason, the captured images (or displayed images) are over or under-saturated in daylight conditions and then the saturated images lose color appearance information such as hue, colorfulness, chroma, brightness, and lightness. The objective of HDR imaging is to overcome the limitation of the current imaging techniques and low dynamic range (LDR) display devices as well as to improve these problems. Thus, in recent years, researchers and institution begin to emphasize on generating HDR imaging from low dynamic range images (LDRIs) [1],[2].

HDR imaging is composed of tools and techniques to capture, store, transmit, and display images with considerably higher fidelity than can be achieved with conventional imaging techniques. Thus, an important aspect of HDR imaging involves the reproduction of images on conventional displays. Now that in such cases, the dynamic range of image can be much higher than the display device can accommodate, dynamic range reduction techniques need to be employed [3-6]. So, high dynamic range images (HDRIs) should be reshaped so that output image follows the dynamic range of conventional LDR displays, which is called tone mapping operator (TMO) [7]. In order to do this, many algorithms have been proposed by researcher and institution. However, the conventional methods are of several problems such as color leakage, luminance shift, hue shift and so forth.

Accordingly, this article presents a tone mapping approach for HDRIs, which consists of the TMO and chromatic adaptation transform (CAT) based on CIEXYZ tristimulus values. The contribution of the proposed tone mapping method is to represent the detailed information and to enhance the contrast based on the human visual perception in the given HDRIs without color distortions by using TMO and CAM16 instead of the CIECAT02.

II. Proposed Method

The tone mapping operator is to control the dynamic range and to represent detailed information in the given HDRI. To do this, the input image in the proposed tone mapping operator is presented in CIE XYZ tristimulus value that ideally would be linear and specified in absolute value. It is assuming that the image is given in the CIE XYZ tristimulus values and that the absolute luminance Y channel is expressed in cd/m^2. The proposed tone mapping operator is of two parameters based on logarithmic function and power function to represent detailed information and one-to-one correspondence in the given HDRIs. Based on the absolute luminance Y channel (I_Y), the parameters, $I_{E,Y}(x,y)$ and $I_{M,Y}(x,y)$, are calculated as follows:

$$I_{E,Y}(x,y) = \lceil \log_2 I_Y + 128 \rceil, \tag{1}$$

$$I_{M,Y}(x,y) = \lfloor I_Y 2^{I_{E,Y}} \rfloor, \quad (2)$$

where $\lceil x \rceil$ rounds x to the nearest integer greater than or equal to x, and $\lfloor x \rfloor$ rounds x to the nearest integer less than or equal to x. In Eq. (1), the logarithmic function approximates the transformation performed by the retina of the HVS. Therefore, the detailed information in the given HDRI will be well represented in the resulting image. In Eq. (2), the power function is adopted to achieve the one-to-one correspondence, as mentioned above. From the Eq. (1) and Eq. (2), the tone mapping operator is described as follows:

$$L_{d,i}(x,y) = \frac{L_i}{1+(I_{E,Y}+I_{M,Y})^{\gamma_a}}; i \in \{X,Y,Z\} \quad (3)$$

where $L_{d,i}(x,y);\ i \in \{X,Y,Z\}$ refers to the input luminance based on CIE XYZ tristimulus value. γ_a is defined as the adaptive gamma correction.
The CAM16 model is then adopted to deal with the mismatch between the real-life scene and the displayed image based on HVP.

III. Experimental Results

For feasible experiment, a number of well-known HDRI and the captured images under five different standard illumination (A, D65, TL84, UV, CWF) are presented. These HDRIs are publicly available, and widely used to access performance for the tone mapping method. The resolution of the test images is 1025×769. The resulting images as shown in Figure 1 are obtained after performing the tone mapping method such as iCAM06[8], Reinhard's method[9], Choi's method[10], and proposed method.


(a) (b)


(c) (d)

(e)

Fig. 1. "Montreal_float_o935" image with (a) Original image (b) iCAM06, (c) Reinhard's method, (d) Choi's method, and (e) Proposed method.

(a) is original image which is widely used to access the performance. In addition, now that these images influence over-illumination condition, these images are of high contrast. (b), (c) and (d) show the resulting image based on the conventional methods. As result, the conventional methods are of colour distortion in the entire resulting image. (e) is the resulting image from the proposed method. The colour distortion problem overcomes in the resulting image.

The captured images under five standard illuminations (A, CWF, TL84, UV, and D65 illumination) are used to objectively conduct quantitative measurement of the performance. Figure 2 and Table 1 are the result of the colour difference ($\nabla E_{IPT-EUC}(Euclidean\ IPT)$)[11] based on IPT colour space so as to measure the colour reproduction degree after correcting the colour. The colour space is based on the human visual perception (HVP).

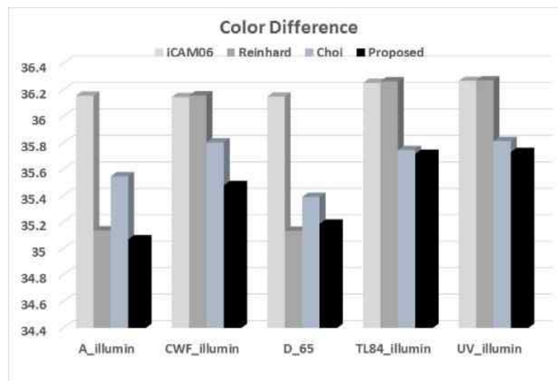

Fig. 2. Color difference ($\nabla E_{IPT-EUC}$) based on uniform color space using IPT color space.

Table 1. Color difference ($\nabla E_{IPT-EUC}$) based on uniform color space using IPT color space

	iCAM06	**Reinhard**	**Choi**	**Proposed**
A_illumin	36.158	35.1391	35.5482	**35.0713**
CWF_illumin	36.1468	36.1597	35.8051	**35.4803**
D_65	36.1512	35.1368	35.3923	**35.1892**
TL84_illumin	36.2546	36.2667	35.7471	**35.7176**
UV_illumin	36.2694	36.2738	35.8144	**35.7314**

The proposed method is of the state of the art performance in that the proposed method is of lower scores in the assessment of the error, compared with conventional method.

IV. CONCLUSIOIN

HDR content can be visualized only on specialized displays with much higher luminance range and contrast ratio. Given that this technology is still in its infancy, the only way to visualize HDR content on conventional display devices is through tone mapping. In addition, tone mapping can also help in HDR content compression. As a result, it is an important and indispensable tool in HDR processing. Unfortunately, even if much work achieved by the researchers and institutions has been done on the tone mapping technique to enhance contrast, brightness, and visibility of LDRIs, the effective method has yet to be developed. That is, local tone mapping and global tone mapping techniques are of several problems such as color shift, luminance changes, and hue shift and so on.

Accordingly, this article presents a tone mapping approach to overcome these problem in the conventional tone mapping technique, which consists of tone mapping operator and cone response function based on CIE XYZ tristimulus values.

In the experimental results, several well-known HDRIs are used to assess the performance. The detailed information in the resulting image is well represented after tone mapping operator by using two parameters. Also, the contrast is well scaled by using adaptive gamma correction. In addition, color difference which is based on the Euclidian IPT color space is adopt to assess the color reproduction degree. The Euclidian IPT color space is adopted to measure the color difference based on HVP. In the results, the proposed method is of lower score than conventional methods except for some illumination images. However, even if the proposed method yields better performance, the proposed method is of somewhat low quality in the case of D 65 illumination image. We will make a study in order to solve this problem, in the timeline of the near future, continuously.

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