A Color Rendering Operator for High Dynamic Range Image using Tone Mapping Method

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Abstract: - The mapping of the potentially high dynamic range of the real world luminance to the low dynamic range of photographic devices is one of the classic photographic tasks. Therefore, the colour rendering or colour reproduction method is proposed and described in many literatures over the past five decades. However, there are well-known problems associated with these methods. This paper presents a colour compression method, which is a combination of tone mapping and chromatic adaptation. The tone mapping resultant image is obtained by using chromatic and achromatic colours. The resulting image, thereafter, is processed through the cone response function, and emphasis is laid on human visual perception (HVP). The experiment results show that the proposed method yields better performance of the colour compression over the conventional method in subjective quality and colour reproduction.

Key-Words: - HDR image, color compression, XYZ tristimulus, tone mapping method, cone response function, HVP

1 Introduction

The human visual system (HVS) is influenced by various viewing conditions such as illumination and surroundings, in addition to several others. The illumination component has a significant effect on visual adaptation and possesses the ability to change visual sensitivity. Visual adaptation can be divided into two parts: luminance adaptation, which is caused by luminance level, and chromatic adaptation, which is caused by illuminant chromaticity. Luminance adaptation changes the overall gain of the cone photoreceptors in accordance with the illuminant color [1]. In addition, there is a difference between the original scene and HVS in the sense of the dynamic range. In other words, from starlight to sunlight, HVS has the dynamic range of approximately 9 orders of magnitude, whereas the original scene has a dynamic range of over 9 orders of magnitude. Moreover, low dynamic range (LDR) display devices have the dynamic range of approximately 2 or 3 orders of magnitude [2, 3]. Therefore, high dynamic range (HDR) image has been developed based on visual adaptation. HDR imaging is an attractive technique that mimics the human eyes, which readily captures a range of light intensities in multi-exposure time, and it has a dynamic range of 6 orders of magnitude. Thus, an HDR technique is used with LDR devices. The HDR image will become generally available for direct capturing of HDR images in the near future. Therefore, the availability of HDR data will become considerably improve than at present. In contrast, the dynamic range of display devices is currently limited and economically sensible HDR devices are not commonly used. However, current display devices have a low dynamic range. Therefore, the mismatch between HDR data acquisition and HDR display technology will persist in one form or another. This leads to the problem of how HDR data can be displayed on low dynamic range display devices, a problem which is generally termed as tone mapping or tone reproduction [4, 5]. Therefore, tone reproduction algorithms attempt to scale HDR data such that the resulting displayable image preserves certain characteristics of the input data, such as brightness, visibility, contrast, or appearance. This paper presents a colour compression method, which is composed of a tone mapping and chromatic adaptation method using a XYZ tristimulus colour space. The tone mapping resultant image is obtained by using chromatic (XYZ tristimulus value) and...
achromatic colours (absolute luminance Y component). The chromatic adaptive transformation (CAT) method is adopted to deal with the perceptual mismatch between the real scene and the displayed images.

2 Proposed Method

The proposed tone mapping method uses the modified tone mapping method from previous work in ref. [2], and the input image is obtained by using the non-linear power function for luminance (Y component) of CIEXYZ tristimulus value. The non-linear power function is adopted to control the dynamic range and remove the halo-artifact. Therefore, for luminance Y \( f_Y(x, y) \), the tone cover of the achromatic component is defined as follows:

\[
L_{out}(x, y) = (f_Y(x, y)^\alpha)
\]

where \( L_{out}(x, y) \) is the output image for absolute luminance Y and \( \alpha \) is the gamma coefficient to control the dynamic range. The result of Eq. (2) is used, by the tone-mapping method, to preserve luminance, which involves linear interpolation between chromatic and corresponding achromatic colours. The proposed tone-mapping method is described by using the input image and is as follows:

\[
C_{out,i}(x, y) = \frac{f_i(x, y)}{1 + L_{out}(x, y)} + \text{STD}; i \in \{X, Y, Z\}
\]

where \( C_{out,i}(x, y), i \in \{X, Y, Z\} \) are the resulting tone-mapped images of X, Y, and Z components and refers to standard deviation, which is used to describe changes in the entire image.

3 Experimental Results

In this section, we compare the performances between the proposed method and some existing methods with respect to visual quality. Results on a number of well-known HDR images are presented and linked: http://www.anyhere.com/gward/hdrenc/pages/originals.html and http://www.cs.utah.edu/~reinhard/cdrom/hdr.html. These over 30 images are used to evaluate performance of the proposed method in this paper. Of these images, “Rend02_oC95” image is typically exhibited as a resulting image after collecting the color.

The image in Figs. 1 shows the result image for HDR images after performing color correction using techniques of iCAM06, the previous work in ref. [2], and the proposed method. (a) is the original image, and (b) show the resulting image after performing iCAM06. The halos appear in the resulting image as the image adapts to the bilateral filter. In addition, it seemed to have added to the red color in the entire result image because of the luminance factor in the chromic adaptation transform. In order to avoid these problems, the tone mapping method is proposed in the [2]. The halo is significantly reduced in the entire result image (c) as compared to (b). The proposed method (d) is a modified method of the previous work, the halo and dominated color is substantially reduced when compared with both (b) and (c), as shown in the resulting images. Fig. 2 shows the result of the other images. The results have similar performance. Table 1 shows the result of the brightness evaluation for Fig. 2. The result of the proposed method is well enhanced compared to conventional methods in that it has higher brightness values compared to conventional methods.

Fig.1. “Rend02_oC95” image with (a) original image, (b) iCAM06, (c) previous work of ref. [2], and (d) proposed method (\( \alpha = 0.2 \)).

Fig. 2. experimental result for other images with (a) original image, (b) iCAM06, (c) previous work, and (d) proposed method.
Table 1. Assessment of Brightness for Fig.2 images.

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<tbody>
<tr>
<td>Orig.</td>
<td>1.36</td>
<td>64.33</td>
<td>101.98</td>
<td>39.75</td>
</tr>
<tr>
<td>iCAM</td>
<td>79.68</td>
<td>87.05</td>
<td>43.35</td>
<td>81.29</td>
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<tr>
<td>Prev.</td>
<td>102.62</td>
<td>82.77</td>
<td>28.57</td>
<td>62.28</td>
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<tr>
<td>Prop.</td>
<td>107.87</td>
<td>131.00</td>
<td>134.46</td>
<td>119.48</td>
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</table>

4 Conclusion
The goal of color rendering is to scale the image contrast, to reproduce the color, and to compress the dynamic range while preserving colors in the resulting image based on HVP. In this paper, a color rendering operator, which is composed of tone mapping and chromatic adaptation method using an XYZ tristimulus color space, is proposed. The results for the proposed method showed that the dominated color was remarkably reduced throughout the image as against the conventional method, regardless of the illumination. In the brightness evaluation, the proposed method has higher brightness values than conventional methods. As a result, the local contrast and image detail were improved without any color distortion of the dominated color.

References: