HDR Image Reproduction based on ICAM06 and Bilateral Filtering

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Abstract

HDR Image could not be reproduced on LDR medium directly. A lot of tone information and detail information can't be perceived when we use the LDR medium, e.g., display and paper, which are the most often medium used. Although there are several progresses in traditional display medium technique including large gamut, adaptive lightness adjustment, etc., a lot of details are compressed in the reproduction of HDR image. In fact, HDR image is always correlated to the surround conditions when it is perceived through human eyes. When we perceive the scene with high dynamic range, e.g., sun rise or sun set, the responses captured by human and processed in our brain always show beautiful aspect. Theoretically, HDR image representation is highly correlated to color appearance. And the image appearance and dynamic range are always satisfied at the same time when we use our eyes as the receptor. To solve the problem that HDR image could not be reproduced in most LDR medium, a novel method based on iCAM06 and bilateral filtering was presented in this paper. Firstly, the HDR image was subjected to bilateral filtering based on the human visual characteristics. Then it was processed adaptively according to the light source information and the edge details retained. As a result, the noises in shadow portion could be reduced by the brightness adaptive function and the HDR image could be reproduced using the digital print output. It showed that the saturation of the image color was enhanced and the image contrast was improved. Additionally, the Halo phenomenon was eliminated more and the details information and edge sharpening were enriched.

Introduction

The range of HDR image is wider and more detailed information can be recorded. HDR image is able to record more color attributes including color appearance and lightness than LDR medium can do[1]. However, HDR image can't be displayed directly using LDR medium, i.e., display or paper medium. In conventional color reproduced process, both color appearances and color information are lost. And HDR image must be processed using decoder technique and tone mapping method to reduce the information lost for reproduction and real visual effect can be perceived. Using color appearance model to process HDR image is one method. Color appearance model is able to predict the complex color appearance in the complicated view condition. So it becomes more and more popular in cross medium color reproduction process. Visual properties of color of single pixel or local pixels, including relative lightness, colorimetric coordinates and hue, even contrast and sharpness, can be described using such appearance model[2]. Perception effect is able to be described in color appearance model because the view condition is taken into consideration. More details of color information can be represented. However, more details would be lost if only one method, i.e., color appearance model, is used to represent HDR image on conventional low dynamic range medium. So several methods were gathered together to reproduce HDR image on LDR medium.

HDR image visualization method was developed based on iCAM in 2004 which satisfied the needs of more tone range retaining, lightness perception and colorimetric perception. Nevertheless special viewing scene had poor perception[3]. Color appearance model and tone mapping method were combined together to process the HDR image and better reproduction on display were perceived and complex appearance were predicted. In the method bilateral filter was used to process the lightness channel[4].

Multi-filter method based on iCAM was developed to process HDR image according to human visual properties in this paper. The HDR images were processed multiple and the colorimetric attributes were replaced by color appearance attributes. And the detail information related to the lightness e.g., saturation and contrast, were enhanced. The processed HDR images were output using inkjet printer in the end. It showed that more color information and lightness were retained and better color appearance was perceived.

iCAM06 and Bilateral Filter

iCAM06

The purpose of iCAM frame is to predict the visual attributes in a large tone range under different viewing conditions. iCAM includes both color appearance model and hierarchical mapping process. Moreover, chromatic attributes and spatial visual model are included too. It can predict the chromatic attributes, color appearance attributes, lightness range and some special visual phenomenon etc. So iCAM was used to connect the connection space for color transferring and tone mapping. In iCAM, bilateral filter was used to take place Gaussian filter and was used three times to get more accurate result. And one frame to reproduce the HDR image was designed as in Fig.1.

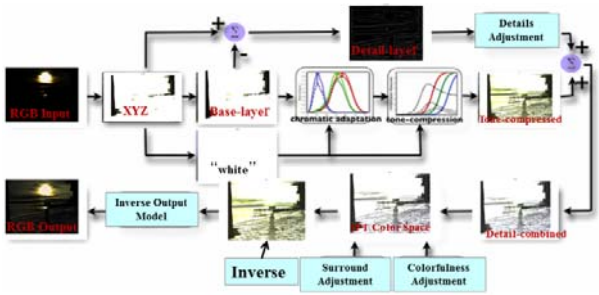

Figure 1. Framework for HDR image reproduction using iCAM06 and Bilateral Filter

HDR image has large dynamic range which can record more than 256 levels for the real scene lightness. And the excessive tone range can't be recorded on the LDR medium. Linear decode method is a good method to reproduce HDR image on LDR medium while it has several disadvantages which would result in too bright or too dark in some areas. So tone gamut mapping method is always used to push away the shortage. It was described in Fig. 2.

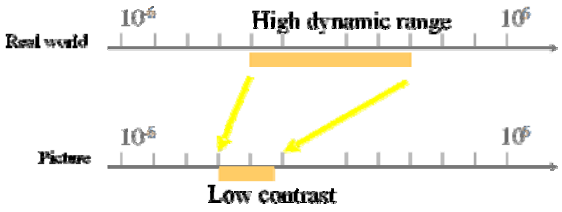

Figure2. Tone range Mapping between Real word and Picture

The whole workflow to reproduce HDR image in graphic communication would include four steps, such as filtering process using bilateral filter, base layer process, detail layer process and image fusion for LDR medium. Such workflow was described in Fig. 1.

2.Bilateral Filter

Image is formed by light being reflected from surface of medium or scenes according to Retinex theory.[5] So it can be decomposed into two layers including lightness layer and detail layer, i.e., base layer and reflectance layer. It can be showed as follows:

$$R=I/L \tag{1}$$

In which, *R* is the reflectance, *I* is image pixel, *L* is the lightness. Logarithmic function is used to describe the relation between visual perception and lightness according the human visual system. It is showed as follows:

$$LogR = \log(I/L) = logI - logL \tag{2}$$

Where, if we set Detail=LogR, Image = LogI, Base = LogL, we would get the following equation as follows:

$$\begin{cases} Detail = Image - Base \\ Image = Detail + Base \end{cases} \tag{3}$$

Spatial filter is often used to get the above two layers. Bilateral filter was used in this paper with its advantageous attributes in processing image. The operator is easier to implement and has higher algorithm efficiency[6]. The process can be described as follows:

$$F(I(i,j)) = \sum W_{BF} * I(i,j) \tag{4}$$

Where,

$$W_{BF} = \frac{d(x_i,x_j)r(p_i,p_j)}{\sum_{j\in I(i,j)} d(x_i,x_j)r(p_i,p_j)},\ (x_i,x_j) = -\frac{1}{2\pi\delta_d}\exp\left(\left(\frac{\|x_i-x_j\|}{\delta_d}\right)^2\right),$$

$$r(p_i,p_j) = -\frac{1}{2\pi\delta_r}\exp\left(\left(\frac{\Delta E_{ab}(p^i,p^j)}{\delta_r}\right)^2\right).$$

BF is to use bilateral filter. *Iin* is original image, $d(x_i,x_j)$ is the Gaussian function of the distance between pixel *i* and pixel *j*, $r(p_i,p_j)$ is the Gaussian function of the color difference between pixel *i* and pixel *j*. δ_d is to represent the spatial position relation between pixel *i* and pixel *j*. δ_r *is* to represent the color difference relation between pixel *i* and pixel *j*.

3 Experiments and Discussion

One digital printing workflow using Cannon iPF8410s inkjet printer was developed to get the tone range of paper medium. And the color management was also used to guarantee the reproduction quality of digital printing process. The original HDR image was processed using iCAM06 model and bilateral filter according to the framework illustrated in Fig. 1.

In the bilateral filter processing for original image, δ_d was set as 2.54 and δ_r was set as 3. The HDR images were outputted on paper medium after processed. The original HDR images were shown in Fig.3. The basic impression of the outputted HDR images was shown in Fig. 4.

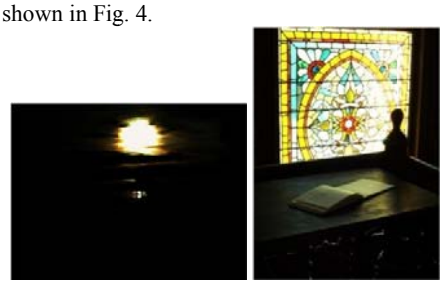

Figure 3 The original HDR images

From Figure 3 and Figure 4, more detail information of the HDR images was perceived. The differences between the original HDR images and the outputted images on paper medium were very obvious.

Figure 4 The outputted images processed according to iCAM06 and bilateral filter

Summary

One digital printing workflow using Cannon iPF8410s inkjet printer was developed to output the processed HDR images. And the color management was also used to guarantee the reproduction quality of digital printing process. The original HDR image was processed using iCAM06 and bilateral filter according to the framework developed in this paper. And the results showed that good reproduction of HDR image could be performed using iCAM06 and bilateral filer together. Saturation and visual perception were better. The detail information and contrast were retained with the viewing condition. And color appearance

correlated with the viewing conditions was also enhanced. The theory and technique foundation will also be promoted in such thesis.

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Author Biography

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