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ADAPTIVE SCIENTIFIC VISUALIZATION OF COLOUR INFORMATION IN HDR IMAGE

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ABSTRACT

While tone mapping operation of high dynamic range (HDR) images for realistic display is commonly researched, scientific visualization for analysing scene luminance within HDR image has much less attention from researches. This paper has presented and implemented an approach for the reproduction and visualization of the colour information in HDR images. We attempt several simple colour visualizing functions, and estimate their effectiveness through the evaluation factors with common HDR images. The experimental result shows that sigmoidal mapping function is better performance in the visualization, compared to other approaches.

Keywords: scientific visualization, high dynamic range image, colour visualization, image analysis.

INTRODUCTION

At the most recent, technologies of digital photography are rapidly advanced. However, in order to achieve a level which is comparable to amazing human visibility, the technology still has a problem to follow the capability of human visual system. For example, our daily-life scenes have a very wide range of radiance values, and HVS can simultaneously perceive real world scenes with dynamic ranges over five or nine orders of magnitude. However, current displaying devices, such as monitor, CRT and print device, most of all have a limitation on display a wide dynamic range. For instance, digital camera can store a colour picture with 24 bit/pixel, and this can only capture a dynamic range onto two orders of magnitude [1].

HDR imaging, where image file records the true radiance dynamic range and colour gamut of the daily-life scene, holds potential in advanced technology of digital photography. HDR imaging technologies have been developed by researchers in both scientific and artistic communities for several years, especially, JPEG backward-compatible coding scheme of HDR image, named JPEG XT [2], ranging from HDR radiance map capturing [3], efficient storage of 96 bit/pixel radiance maps [4], and tone mapping operation of HDR image for displaying in low dynamic range (LDR) media [5]. Despite these efforts, many technological challenges in HDR imaging remain. One of the challenges is a visualization of HDR image for analysis and understanding of the real world scene. Actually, visualizing HDR image is distinguished from contrast-enhancement and dynamic range compression techniques [6]. The key problem of visualization is laid on how to translate from real world scene to digital image, while preserving the relevant information of the scene, producing an image as natural looking, and avoiding common artifacts.

In the field of image research, image visualization technique is an effective way to explore the characteristics of image data at early stage of image analysis [7]. Colour visualization and false colouring enables a user to expand the dynamic range of the usual grey shades, so that they are more easily recognizable by human eye [8]. As well as they are used to enhance certain features such as sea surface temperature patterns or extraction of certain features to use the image in computer vision.

In this paper, we have a main focus on presentation for how to visualize a HDR image for the purpose of scene analysis of the image luminance. The goal of this paper is to attempt to show that colour visualizing method such as false colouring can play an important role in description of the visualization of HDR image. That is, by evaluating the visualization functions, the extracted information of the brightness can be utilized in many applications, which is available to detect features and/or to recognize an object from the images.

This paper is organized as follows: Section 2 reviews related works about HDR imaging analysis and tone mapping operation. Section 3 presents our method that uses two tasks of colour conversion and colour visualizing functions. Section 4 shows the experimental results, and section 5 summarizes the study.

RELATED WORKS

There are already many existing studies on the tone mapping operations. Tumblin *et al.* developed a tone mapping operator using human perception model [9]. The main drawback of the developed algorithm is that they used a global brightness adaptation, dark and bright regions are clipped. Qiu *et al.* proposed a framework for tone mapping to offer a brief and insightful method to control the appearance of the tone mapped image [10]. Li *et al.* proposed a demanded local tone mapping of HDR image using assigning saliency-aware weights and edge-aware weights [11]. Reinhard *et al.* proposed a practical technique of photographic to develop a tone reproducing algorithm, which is simple to implement and produces good results for a wide variety of HDR images [12]. They utilized and extended the technique developed by Adams to deal with digital images.

Visualization is a process of presenting data graphically to obtain and understand the insight information from image [13]. Information visualization is

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a study of interactive visual representations of abstract data to reinforce human cognition [14]. The abstract data should be included both numerical and non-numerical data, such as text and spatial information. In this focus, study of visualizing HDR image is more accessible from the field of image processing. Pattanaik *et al* proposed a multi-scale model for the representation of pattern, luminance and colour in the human visual system [15]. The main problem with their work is that, although interesting for its detailed modelling of the human visual system, it cannot avoid halos. Pardo *et al* proposed a visualizing information scheme to provide a minimal set of image capturing the information over the HDR data [16]. The basic problem of the work is that a region of the focused scene with limited dynamic range is considered. Akyuz presented a framework to generate false coloured representation of HDR image [17]. The main drawback of his work is that evaluation of the results is performed subjectively by participants. Branchitta *et al* proposed an algorithm for enhancing local contrast on HDR image by applying two techniques which are balanced contrast-limited and adaptive histogram equalization [18].

THE PROPOSED METHOD

Main idea of this work is to investigate an effective scheme to visualize all the information of HDR image in a relevant way. First, high-level scheme to generate colour visualization of HDR image is explained. Then we discuss mapping functions that can be used in our method.

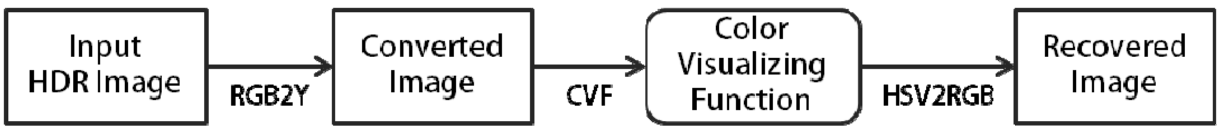

Figure-1. Procedure of the proposed system.

PROCEDURE

As shown in Figure-1, we start with an input HDR image, which has an extension filename as HDR, and is in a linear colour space with sRGB primaries. Since the goal is to assign different colours for different luminance values, our method utilizes HSV colour space. The colour spaces based in polar coordinates (such as HSV, HIS) are widely used in image processing [19]. In addition, HSV has the desired property, which transition of the values from dark to light can be easily presented. There are two advantage of the colour space used. First one is that HSV space is good to compatible with human intuition of colours [7]. Another is that saturated pixels (larger than 255) are clipped in sRGB space, however, those values are avoided in HSV. Thus, we first convert the colour space to HSV to compute luminance information by Equation. (1) [19].

$$Y_h = (0.299 \cdot R_h) + (0.587 \cdot G_h) + (0.114 \cdot B_h) \tag{1}$$

where Y_h is a luminance of the high dynamic range image, R_h, G_h and B_h are pixel values of the HDR image, respectively. Although HSV colour space encompasses a cylindrical volume, we utilize a single hue slice that has the highest possible value and the desired saturation for maximizing human visibility. Hue angles with a luminance are calculated by Equation. (2).

$$H = 240° \cdot \left(1 - CV(Y_h)\right) \tag{2}$$

where CV is a visualizing colour function, and it will be presented in the next subsection. In HSV colour space, the hue angle of 0° corresponds to red and a hue angle of 240° blue. From 240° to 360°, the hue angle transits the colour from blue to violet, and back to red. On the side of colour spectrum, violet has a high frequency and the signal is very weak for blue and red receptor [8]. Thus, we exclude the violet portion of the hue circle, to avoid mapping both high luminance and low luminance to similar hue values. Since the function works variables as floating point numbers between 0.0 and 1.0, the results should be converted back to integers from 0 to 255 to display [19]. Thus, we finally convert the computed HSV values back to RGB to obtain the colour visualized HDR image.

VISUALIZING FUNCTIONS

We estimate that our method with several colour visualizing functions, described in Equation. (2), which are linear scaling, logarithmic scaling, and sigmoidal mapping. Most of mapping methods can be either global or local processing. While local processing algorithms apply different functions for different spatial location of the pixels, global approach algorithms apply same function to all pixels of the image. Global methods generally produce that one input value results in one-by-one and only one output value. They can be a power function, a linear, a logarithm, a sigmoid or a function that is image-dependent [20]. In this paper, we have focuses on linear scaling, logarithmic scaling, and sigmoidal approaches.

The first function of colour visualization is a linear scaling with clipping, defined as following:

$$CV_m(Y) = \frac{[Y]^{m \div (100-m)} - [Y]^m}{[Y]^{100-m} - [Y]^m} \tag{3}$$

where $[Y]^m$ is a value at the m_{th} percentile, and $[\cdot]^{m,n}$ is an operator which is clamped by input with given m_{th} and n_{th} percentile.

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The second one is a logarithmic mapping, defined as:

$$CV_l(Y) = \frac{\log(Y+\delta)-\log(Y_{min}+\delta)}{\log(Y_{max}+\delta)-\log(Y_{min}+\delta)} \quad (4)$$

where δ is a certain small value to avoid singularity in cylindrical coordinates for black pixels.

The third one is a sigmoidal mapping, given by following:

$$CV_s(Y) = \frac{Y_s}{1+Y_s} \text{ where } Y_s = \frac{\mu}{\bar{Y}} \cdot Y \quad (5)$$

where μ is a user-defined small value, and Y is the log-average luminance.

EXPERIMENTAL RESULTS

We have tested our method with several HDR images, which are commonly used in the literature to assess the impact of HDR images. Those are easily downloaded from website [21], which are named as Bottles Small(size 688×912, dynamic range 4.8), Forest Path(1,536×2,048, 4.1), MpiAtrium(676×1,024, 4.4), MpiOffice(676×1,024, 4.1), NancyChurch(2,048×1,536, 5.2), OxfordChurch (1,200×1,013, 5.2), and SeymourPark(2,160×3,840, 4.5).

Two measurements are calculated in experiment, which are relative mean absolute error (RMAE) and signal-to-noise ratio (SNR), described by Equation. (6), to objectively measure how well each visualizing function describes the luminance in the given HDR image. In Equation. (6), R_h, G_h and B_h are HDR image pixels, R'_h, G'_h and B'_h are the recovered HDR image pixels, respectively. First measuring the image quality is a RMAE. Since a RMSE (root mean squared error) is appropriate for scalar quantities, not for vector, a RMAE is used to include error of magnitude and direction in a single statistic. RMAE value of zero implies a perfect match between prediction and observation. However, this will never be achieved, practically, smaller value of RMAE is better [22]. Another one is a SNR, which is used in imaging as a physical measure of the sensitivity of digital imaging system. A larger SNR value means that an encoded image preserves the original image quality better [20].

For each HDR image, we attempt to draw the colour representation using the equations, described in the previous, and the output results for sample HDR image are represented in Figure-2. Then, we calculate the evaluation factors given in Equation. (6). Our experimental results for all images are shown in Figure-3. The experimental results reveal that the sigmoidal function is chosen as the best approach for colour visualization with all images. As shown in Figure-3, the second approach is appeared in logarithmic scaling function, and linear scaling with clipping performs as the worst colour visualizing method. According to the results, it showed a good performance in 5 images from 7 images. In particular, sigmoidal mapping function showed a better performance at high resolution and high dynamic range. Note that SNR analysis reveals the results more briefly. In the measurements of SNR, sigmoidal function obtained the highest SNR value in all the experimental data.

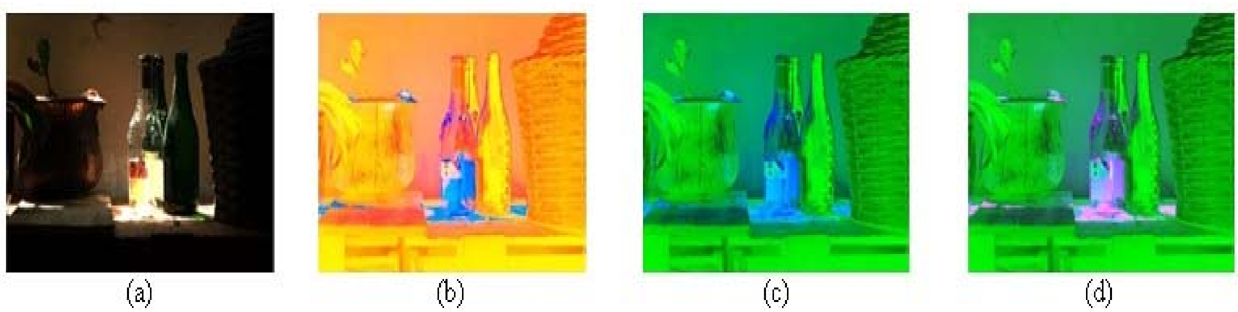

Figure-2. Outputs (b~d) of HDR colour visualizing method with sample HDR image, Bottles Small; From left to right, (a) Original Image, (b) Linear Scaling Function with 5% Clipping, (c) Logarithmic Scaling Function, and (d) Sigmoidal Scaling Function.

$$RMAE = \frac{1}{3N} \cdot \sum_{i=0}^{N-1}\left(\frac{|R_h(i)-R'_h(i)|}{R_h^{max}-R_h^{min}} + \frac{|G_h(i)-G'_h(i)|}{G_h^{max}-G_h^{min}} + \frac{|B_h(i)-B'_h(i)|}{B_h^{max}-B_h^{min}}\right)$$

$$SNR = 10 \cdot \left(\frac{\sum_{i=0}^{N-1}\left(R_h^2(i)+G_h^2(i)+B_h^2(i)\right)}{\sum_{i=0}^{N-1}\left(\left(R_h(i)-R'_h(i)\right)^2+\left(G_h(i)-G'_h(i)\right)^2+\left(B_h(i)-B'_h(i)\right)^2\right)}\right) \quad (6)$$

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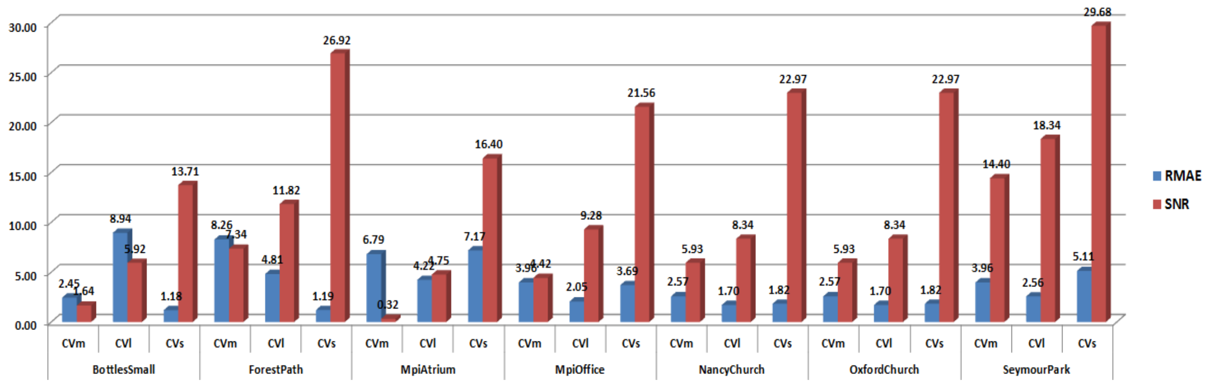

Figure-3. Experimental results with $n = 1, f = 0.15$ and $\rho = 0.10$.

CONCLUSIONS

Tone mapping operation of high dynamic range images for realistic display is a commonly researched, however, scientific visualization for analysis of scene luminance has much less attention in the researches. In fact, many studies in the areas of HDR image are focused on tone mapping and/or compression method. This paper presents and implements a simple approach for reproducing and visualizing HDR information. The experimental results reveal that sigmoidal scaling function shows the better performance in terms of conveying the luminance analysis in all HDR images. This function can be easily and effectively used for false colour and color visualization of image information. This can make you to get better luminance distribution using in the kind of several applications

As for future works, we still have some questions remain after this work. The specific function which is described in this paper for the computation of the image data set is for particular example, and more spatial functions should be estimated. In addition, which is the best algorithm of tone mapping operation for most of all HDR images? We hope that this work will be the first study on answering this question.

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