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Research Article

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Tone Mapping for High Dynamic Range Image using Modified Gamma Correction

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Abstract In this paper, we propose an algorithm to enhance high dynamic range image using modified gamma correction. As modern technology is developed, the modern imaging sensor can acquire high dynamic range image. However, the monitor has limited dynamic range. Dynamic range compression (DRC) process is necessary and it is important to preserve information. Liu et al. proposed a DRC algorithm using gamma correction. However, the algorithm loses the details of bright region. The loss of detail is caused by oversaturation. Proposed algorithm prevents oversaturation and improves visual quality using modified gamma correction. Experiment result shows that proposed algorithm has better performance than conventional algorithm.

Keywords high dynamic range, tone mapping, guided image filter, gamma correction

Introduction

The dynamic range means the ratio of the brightest and darkest values in an image. The human visual system has wide dynamic range. A human can perceive luminance ranging from10^{-6} to 10^8 (cd/m^2). Consumer display device normally presents luminance up to 500 (cd/m^2) [1]. Because it has much smaller dynamic range than the human visual system, it doesn't have the ability to present bright and dark region simultaneously. To overcome this problem, high dynamic range (HDR) imaging technique is developed.

The purpose of HDR imaging technique is to capture all natural luminance range. HDR images are acquired using modern high-quality imaging sensor or exposure fusion technique. HDR image contains luminance up to 10,000 (cd/m^2). Because an HDR image can represent a wide dynamic range, they can express dark and bright region similar to the human eye. Since the dynamic range of the display device and the HDR image are different, the dynamic range must be compressed to display the HDR image on the display device. This process is called tone mapping or dynamic range compression.

Dynamic range compression (DRC) is often a useful method to make the human eye pleasure. The simple way to compress is linear mapping. However, it results in lots of information loss because it is performed using the just linear function. The many DRC methods are proposed to preserve valuable information. For example, Drago *et al*. [1] proposed tone mapping method using the adaptive logarithmic function. They used the property that logarithmic function has very similar property with the human eye. Reinhard *et al*. [2] proposed tone mapping method applied zone system that divides the brightness based on the human visual system. Liu et al. [3] proposed a new HDR image processing method which is based on the Guided filter. The Guided image filter (GIF) is a local linear image filter that is edge preserving filter without gradient reversal artifacts. In this method, GIF is used to separate the input image into base and detail layer. The base layer has low-frequency information and detail layer has high-frequency information. Because base layer contains overall the brightness information of the contents, DRC is performed at base layer and the detail layer is enlarged to enhance the details. They use gamma correction for base layer compression. However, the use of gamma correction in log domain results in loss of detail information at the bright region. To prevent losing details, we proposed an algorithm to enhance HDR image using modified gamma correction.

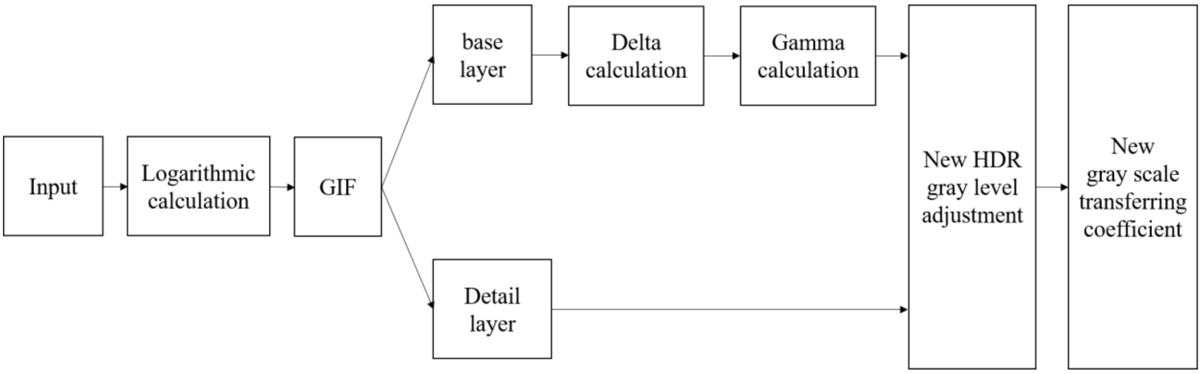

Figure 1: Flow chart of conventional algorithm

The composition of this paper is as follow. Section 2 describes the conventional algorithm. The proposed algorithm is described in Section 3. Section 4 presents and analyzes the experimental results, Section 5 concludes this paper.

Conventional Algorithm

The procedure of conventional algorithm is described as shown Fig. 1. The purpose of logarithmic calculation is to adjust the gray value to easily calculate the following steps. GIF is conducted to separate the input image into base and detail layer. After dividing into two layers, the gamma value is calculated adaptively in the base layer. At the process of new HDR gray level adjustment, gamma correction is performed and acquire output image in gray scale. After all values are computed in gray scale, the gray scale transferring coefficient is calculated to reconstruct the color image.

At GIF process, the base layer is same as the guided image filtering result and the detail layer is the subtract between raw image and base layer. The detail layer is extracted from the input image using following equation.

$$I_D = I_{in} - I_B \tag{1}$$

where I_{in} represents input image and I_B, I_D represents the base layer and detail layer respectively. The base layer contains low-frequency information and detail layer contains high-frequency information. Therefore, the conventional algorithm used DRC to compress base layer while preserving detail layer

In order to compress the dynamic range of base layer, the delta and gamma value should be calculated. The delta value is defined using following equation.

$$\Delta_d = \max(I_B) - \min(I_B) \tag{2}$$

where Δ_d represents the difference between the maximum and minimum gray value of base layer. The delta value means the biggest difference in the luminance value of the HDR image.

The delta value is used to calculate new gamma value. The gamma value is calculated using following equation.

$$\gamma = \frac{log(C_{contrast})}{\Delta_d} \tag{3}$$

where γ represents the gamma value and The parameter $C_{contrast}$ is a pre-set value. γ is used for gamma correction that is mapping function of base layer. $C_{contrast}$ is used to modify the gamma calculation and related to the distribution of output image. The larger $C_{contrast}$ value makes the distribution become spread. Therefore, for widely distributed result, $C_{contrast}$ should be large enough.

At the process of new HDR gray level adjustment, gamma correction is performed. The tone mapping function applies gamma correction to the base layer and combines it with the detail layer (Eq. (4)).

$$I'(i,j) = 10^{[\gamma \cdot I_B + G \cdot I_D]} \quad (4)$$

where G represents the gain coefficient. it controls detail intensity. After I' is computed, the gray scale coefficient can be calculated. The gray scale coefficient which is used to compute color component at each pixel is calculated using following equation (5). And color component is calculated using following equation (6).

$$S = \frac{I'(i,j)}{I(i,j)} \quad (5)$$

$$I_{color}(i,j,x) = S \cdot I_{in}(i,j,x) \quad (6)$$

where the parameter x represents R, G, B color channels of color image.The conventional algorithm uses adaptive gamma value to adjust gray scale effectively. Depending on the image, well- distributed result can be obtained using appropriate gamma value. At conventional algorithm, all processes are conducted in log domain. Gamma value which is logarithmic value is applied to gamma correction that has a linear form at log domain. The positive value at log domain is transformed into oversaturation at the linear domain. Because the positive value cannot be negative using the linear function, the conventional algorithm exhibits the results with oversaturated region.

Proposed Algorithm

The proposed algorithm is a tone mapping algorithm for HDR image using modified gamma correction, which is complemented version of the conventional algorithm. The overall process follows the flow chart of the conventional algorithm (Fig. 1). However, at the conventional algorithm, there is a problem at the bright region as mentioned above. The conventional mapping function is a linear function at log domain. Values of 0 in log domain are transformed into one in linear domain and pixel value larger than 1 is oversaturated at output image. That means the region which has a positive value at log domain is oversaturated. To cope with this problem, we propose the partial linear function to compress base layer. The proposed mapping function is following equation which is modified version of equation (4).

$$I'(i,j) = 10^{[f(I_B) + G \cdot I_D]} \quad (7)$$

$$f(I_B) = \begin{cases} \gamma \cdot I_B, & I_B < 0 \\ 0, & I_B \geq 0 \end{cases} \quad (8)$$

where $f(I_B)$ is mapping function for base layer and has the form of partial linear function. After the base layer is compressed using modified gamma correction, detail layer is added. The detail layer preserves details of the input image. If the base layer is oversaturated, the detail layer loses the ability to preserve details. Although detail layer has all of the details of the input image, the output value becomes larger than 1 because of oversaturated base layer. To preserve the detail layer, the base layer should be adjusted so that it is not oversaturated.

The mapping function of base layer is shown in Fig. 2. Because gamma correction is an exponential term at the linear domain, it is applied linear function at log domain (Fig. 2(a)). A lot of pixels are calculated as positive values using linear mapping function of the conventional algorithm. As mentioned above, positive values make the image oversaturated. At the proposed algorithm, the mapping function is partial linear function as shown in Fig. 2(b).The mapping function of base layer is shown in Fig. 2. Because gamma correction is an exponential term at the linear domain, it is applied linear function at log domain (Fig. 2(a)). A lot of pixels are calculated as positive values using linear mapping function of the conventional algorithm. As mentioned above, positive values make the image oversaturated. At the proposed algorithm, the mapping function is partial linear function as shown in Fig. 2(b).

The tone mapped values are shown on the graph (Fig. 3). The x-axis means base layer values and y-axis means tone mapped results using the summation of base layer and detail layer. The pixels exceeding the yellow line become oversaturated. In the conventional algorithm, there are a lot of oversaturated pixels whereas, in proposed algorithm, the oversaturated pixels decrease. It means the proposed algorithm prevents the oversaturation and preserves more detail in bright region.

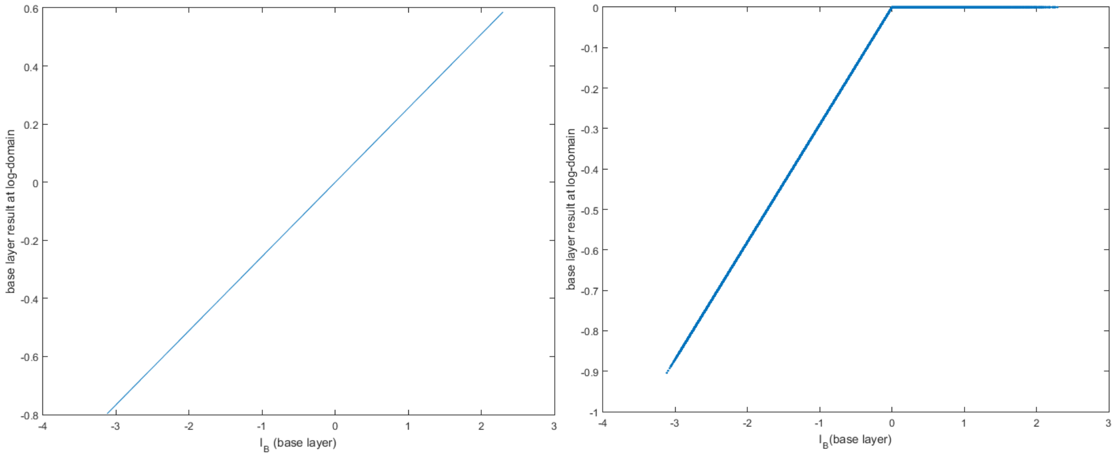

Figure 2: Mapping function at base layer

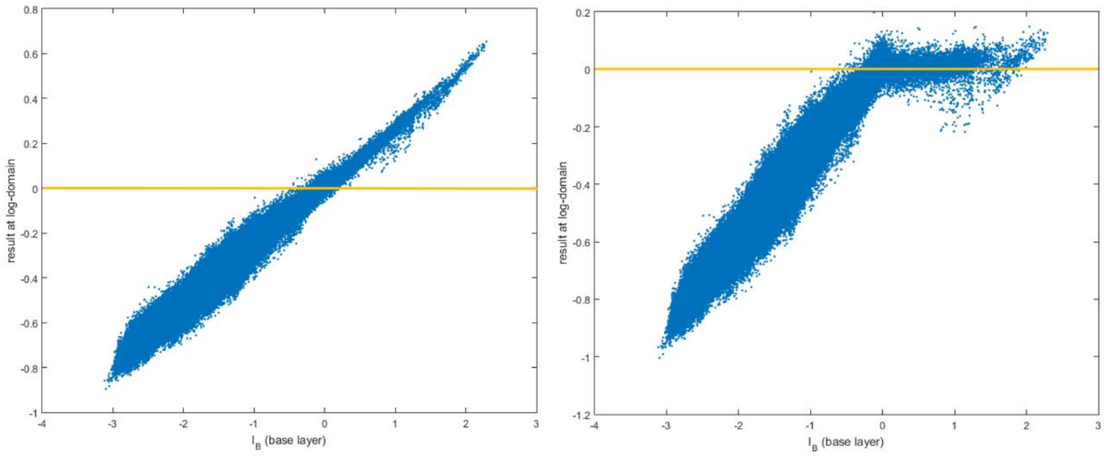

Figure 3: Tone mapping results

Experiment Result

In order to verify that proposed algorithm is improved, we performed the experiment. All image processing is performed via MATLAB 2016a in a PC environment of Windows7 64-bit operating system Intel Core i7-4770K CPU @ 3.50GHz. Experimental results were obtained by extracting the luminance components in the RGB color space of the input image. Because there is no objective quality measure for the HDR image, we only compared subjective quality. For subjective quality comparison, we should focus on the ability to preserve details and edge.

We compared two algorithms using three sequences (memorial, Belgium, and office). Comparing the conventional algorithm and proposed algorithm, both these two algorithms showed similar overall brightness but the proposed algorithm contained more details in the bright region than conventional algorithm.

At first image, Fig. 4(b) contains lots of details on the ceiling and windows. At Fig. 4(a), we cannot recognize the pattern of stained glass because of oversaturation. However, we can recognize the stained glass of Fig. 4(b). At second image, the outdoor yard part represents the bright region. In this region, proposed algorithm preserved more details. Also, it was possible to recognize objects of Fig. 4(d). At third image, the outside windowrepresents the bright region. This case also expressed similar result with before. At the proposed algorithm, we can recognize outside object near the sky and the sky has realistic color. These results made the proposed algorithm get better visual quality.

In order to compare two algorithms specifically, we set region of interest (ROI). Fig. 5 shows ROI at first sequence of Fig. 4. We set ROI which size is 90 pixels by 105 pixels to observe ceiling area at Figs. 5(a), (b) and 100 pixels by 110 pixels to observe stained glass area at Figs. 5(c), (d). Figs. 5(a), (c) are results of conventional algorithm and Figs. 5(b), (d) are results of theproposed algorithm. Comparing Figs. 5(a) and (b), Fig. 5(b) shows the bar at

(a) Conventional algorithm (b) Proposed algorithm

(c) Conventional algorithm (d) Proposed algorithm

(e) Conventional algorithm (f) Proposed algorithm

Figure 4: subjective quality comparison

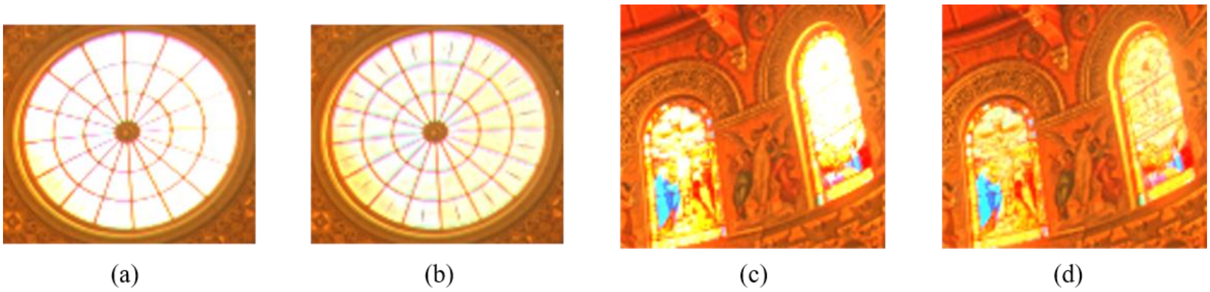

Figure 5: Region of interest at memorial.hdr

outer circle line that is not in Fig. 5(a). Comparing Figs. 5(c) and (d), Fig. 5(c) cannot recognize the patterns but Fig. 5(d) represents that patterns clearly. The patterns and bar must be represented because they actually exist.

Conclusion

In this paper, we proposed tone mapping algorithm using GIF and modified gamma correction. GIF and gamma correction was used to separate the input image into two layers and compress base layer, respectively. To prevent oversaturation, we proposed modifying the conventional gamma correction. Proposed algorithm reduced the oversaturation and preserved more details using modified gamma correction. Experiment results demonstrate that proposed algorithm outperforms the conventional algorithm.

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