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Study on MSBF-based HDR Image Compression

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Abstract

Recently, with the development of technology of hardware and software, high dynamic range (HDR) image is increasingly comprehensive in digital image applications. But at present conventional displays, output equipments and large quantity algorithm only provide to support 8 bit image. In this paper, a kind of method based on imaging model and multi-scale bilateral filtering (MSBF) is presented to deal with HDR image, which not only keeps image's details and colors, but also compresses image's brightness distributions. MSBF is essentially extension of combing bilateral filter and Multi-Scale Retinex (MSR) algorithm. Consequently dynamic range compression based on MSR algorithm may be realized in four scales. Wherein, the Gaussian kernel whose scale is small is used to suppress halo, the Gaussian kernel of middle scale and bigger scale is used to keep natural whole colour tune. But the dynamic range compression based on this algorithm just partly weakens local contrast reversal, and can not effectively control the extent of edge diffusion. By edge-cutoff function, bilateral filter may effectively suppress halo, which is formed by local contrast reversal derived from Gaussian filter. In space domain the scale of Gaussian kernel was not sensitive to filtering result when edge-cutoff function based on Gaussian kernel was used, therefore, constant may be chosen as scale of filter. At last, an experiment was carried out to compare MSBF with HDR shop. A conclusion can be draw that MSBF is more effective than HDR shop in describing image details, colors and Brightness distributions.

Keywords: Image Processing; Image Compression; High Dynamic Range Image; Multi-Scale Bilateral Filtering

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1 Introduction

In recent years, the relative fields of computer vision, Image and Graphics have already obtained and used HDR images [1]. At the same time displays and transmission media that display and transmit HDR images drop behind. HDR images have been simply transformed and mapped to low range displays and transmission media by linear transformation. Many detailed information of high brightness or low brightness in HDR images would be loss [2]. This result is very disappointing. The HDR images should be compressed for application of storage, transmission, processing, displaying and be exported to neighboring low dynamic device to show conceivably the lifelike scene.

Since Oppenheim and Schafer introduced Homomorphic filter for rendering images in 1968 [3], many algorithms derived from it can't avoid the reversion of local contrast near the clear edges on account of Low-pass filter and Band-pass filter. In order to validly solve above-mentioned problems, Tumblin and Turk introduced low curvature image simplifier (LCIS) to process image [4]. But the algorithm can't still completely eliminate noise like "halo" which cause by the reversion of local contrast near the clear edges. Subsequently, Durand and Dorsey put forward an argument that two-scales for decomposition of the image were used in the base layer (encoding large-scale variations) and the detail layer. In base layer contrast reduced, thereby many details may be preserved. In order to realize quickly resolving and denoising, they used a faster and steady edge-keeping filter, which is bilateral filter. Bilateral filter first was introduces by Tomasi, which developed a method to construct and reconstrct Gaussian [5] based on the work of Durand and Dorsey. Later Fattal manipulated multi-scale method on the gradient [6] field, but gradient field need to solve oval partial differential equation by orthogonal projection or iterative algorithm for reconstruction because it is not always integrabel, which generates the questions that solution is knotty.

2 MSBF-based HDR Image Compression

Combining with existing research, a new method was presented. In this method, a simplified multi-scale imaging model was established. By combining the results of multi-scale bilateral filtering, bilateral filter's shortcoming is only decomposed and compressed with two scales. But this shortcoming can be compensated. Meanwhile, the question, where Poisson equation has been solved directly so as to rebuild gradient field and therefore local contrast can not been considered, can be avoided, so the multi-scale dynamic range compression can be realized, its expression is showed as equation (1) and its flow chart is showed as Fig. 1.

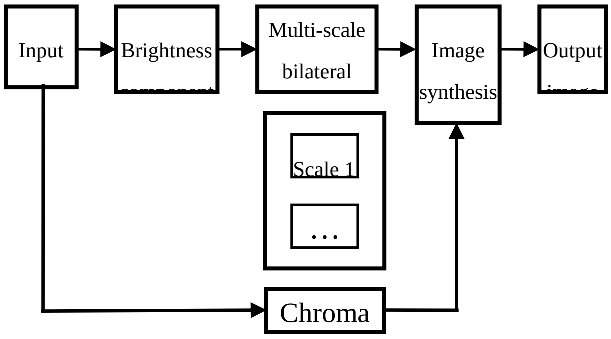

Fig.1 Flow chart of simplified multi-scale imaging model

Brightness L can be summarized by the following equation:

$$L_o(x,y)=\sum_{s=1}^{n}\omega_s\left\{\log\left[L(x,y)\right]-\log\left[J_s\otimes L(x,y)\right]\right\}+\omega_{global}\log\left[L(x,y)\right] \tag{1}$$

Where $L_o(x,y)$ is the luminance at each point (x, y) of a photo, $L(x,y)$ is input luminance from the scene and ω_s is each scale filter, ω_{global} is the weight of the each scale of synthesized image, J_s is the each scale bilateral filter and defined by

$$J_s=\frac{1}{k(s)}\sum_{p\in\Omega}f(p-s)g(I_p-I_s)I_p \tag{2}$$

3 Chroma Restriction and Brightness Component Calculation

Aiming at following two kinds of data format, a new processing technique of HDR image was put forward.

TIFF format: Image brightness of each channel is directly described by means of high integer bit, such as digital image derived from satellite image sampled with high-bit A/D in highly speed. They are usually stored with TIFF format.

HDR format: In scene, absolute or relative irradiation intensity of each channel is directly recorded with float data; this kind of image is usually stored with HDR format.

Because the quantified interval of float-data-recorded image is difficult to be identified and its color information is difficult to be processed with by converting color space, non-linearity Chroma restriction mode is consistently adopted. Where the brightness (L) is given by

$$L=0.299R+0.587G+0.114B \tag{3}$$

At last, color information is synthesized according to following equation:

$$R_d=\left(\frac{R_{in}}{L_{in}}\right)^{\gamma}L_d,G_d=\left(\frac{G_{in}}{L_{in}}\right)^{\gamma}L_d,B_d=\left(\frac{B_{in}}{L_{in}}\right)^{\gamma}L_d \tag{4}$$

Where R_d, G_d, B_d is respectively three channels output value of color image; R_{in}, G_{in}, B_{in} is respectively input value; L_{in} is brightness value of unprocessed HDR image, and L_d is brightness value of processed HDR image already; γ is non-linearity coefficient and here it was set as 0.5, which compensate for the difference of correction between cameras, displays and other output equipments.

4 Parameter Control of the Edge-cutoff Function

While discussing using bilateral filter to obtain reflectivity component of close-range image, bilateral filter and edge-cutoff function respectively are defined by equation (5) and (6).

$$J_s = \frac{1}{k(s)} \sum_{p \in \Omega} f(p-s) g(L_p - L_s) L_p \tag{5}$$

$$g\left(I_p - I_s\right) = e^{-\left[(I_p - I_s)^2 / (2*\sigma_g{}^2)\right]} \tag{6}$$

The threshold of edge-cutoff function was already analyzed and the parameter σ_g was pointed out to control extent of edge diffusion. Smaller is the σ_g, stronger is its suppression effect to Gaussian smooth. Presently, in the discussion on σ_g, absolute Empirical value 0.4 was presented by Durand and Dorsey while relative Empirical value was put forward as follow by Ledda et al (2004)[7].

$$\sigma_g = 0.15 I_s \tag{7}$$

The former quickly attenuates to e^{-7} when the scope of brightness difference is ± 1.5, and the later attenuates to $e^{-5.6}$ under the scope of brightness difference $\pm 0.5 I_s$.

As far as a HDR image is concerned, a large numbers of pixels distribute in brightness interval [0, 1]. Diffusion can be effectively suppressed by using fixed parameter when brightness value is in the interval $[0,1]$, however excessive attenuation will occur when brightness interval is in $[1, \infty)$. Gaussian convolution kernel, which is formed after this function is weighed, can obviously suppress smooth effect and results in different detail loss of brighter field. Likely, when suppression effect of edge diffusion is controlled with relative empirical value, equation (6) may be rewritten as follow:

$$g\left(I_p - I_s\right) = e^{-\left[(I_p - I_s)^2 / (k*I_s^2)\right]} \tag{8}$$

The small k value can strongly suppress edge diffusion derived from Gaussian filtering, but at the same time, part of detail may be lost.

Based on above-mentioned analysis, a conclusion can be draw that the suppression effect of edge-cutoff function is opposite to the smooth effect of Gaussian filter. So when simply HDR image is processed, a smaller σ_g may be adopted so as to reduce edge diffusion in the course of low-pass filtering; while the complex HDR image is processed, a bigger σ_g value should be considered.

5 Scale Choices

MSBF is essentially extension of combing bilateral filter and Multi-Scale Retinex (MSR) algorithm (Jobson et al 1997) [8]. Because MSR algorithm was not used in HDR image, the optimized scale function and Gaussian kernel need be confirmed through experiment. Further study was carried out by Herscovitz (2003) [9]. He put forward replacing bigger scale component by superposing original image and suppressing reversal of local contrast by adding a small scale component, consequently dynamic range compression based on MSR algorithm may be realized in four scales. Wherein, the Gaussian kernel whose scale is small is used to suppress halo, the Gaussian kernel of middle scale and bigger scale is used to keep natural whole colour tune. But the dynamic range compression based on this algorithm just partly weakens local contrast reversal, and can not effectively control the extent of edge diffusion.

However, by edge-cutoff function, bilateral filter may effectively suppress halo, which is formed by local contrast reversal derived from Gaussian filter. Durand and Dorsey suggested that in space domain the scale of Gaussian kernel was not sensitive to filtering result when edge-cutoff function based on Gaussian kernel was used, therefore, constant may be chosen as scale of filter according to 2% of image (2002) [10]. In fact, this conclusion may be draw on the basis of algorithm which realized dynamic range compression. Fig. 2 shows the topology frame of bilateral filter with single scale decomposition.

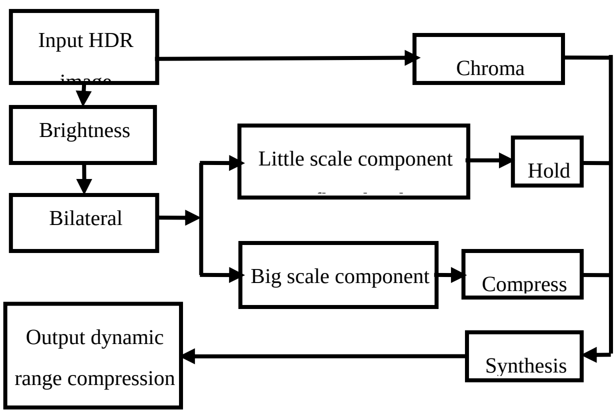

Fig.2 Bilateral filter with single scale decomposition

Many literatures suggested that bilateral filter has not enough theoretical proofs to reflect vision characteristic, therefore, in this paper; edge-cutoff function was rewritten as follow:

$$g\left(I_p - I_s\right) = e^{-\left[(I_p/I_s - 1)^2/k\right]} \tag{9}$$

Thus, this function may reflect local effect of contrast of neighborhood, and the degree of suppression or augment of local contrast can be controlled by adjusting k. It can be regarded as a kind of simulation to local adaptability of vision system.

Combined with MSR theory, in time domain and intensity domain, the contrast characteristic of the vision system and simulated signal can be reflected well. The reason is that mechanism of eye imaging tallies with equation describing image very well. Generally, the resolving power of vision system to detail may be described with reciprocal of visual angle H which is used to distinguish two neighbor points. The reciprocal value of H is correlative with imaging position of the two points in retina. It non-linearly declines from the central yellow spot to circumambience. The relationship between the reciprocal and brightness depends on change of relative brightness, and does not depend on average brightness of the whole area. Obviously, in the imaging model based on Gaussian function, Gaussian function realizes to weigh to convolution window of filter in space domain. In equation (9), Ip/Is describes change of relative brightness between central pixel of filtering window and neighbor pixel, and the weight is added to convolution window of filter by means of Ip/Is, and the local adaptability can be controlled by adjusting k. Exponential function that is served as bottom with e describes the non-linear trend of attenuation of relative change.

The MSDF compression algorithm, which is described as equation (6), can be formed by combing MSR algorithm. In order to keep down more integrated local characteristics of different scale, k value of equation (7) should be properly increased. Under this condition, the 2-D convolution kernel weighed with edge-cutoff function is very sensitive to the change of scale; therefore, by superposing multi-scale filter, the edge characteristics of different scales may be synthetically reflected by scale space derived from filters of different scale, meanwhile, the strongpoint that edge diffusion is effectively suppressed by bilateral filter can be kept down. Consequently, imaging model multi-scale algorithm is presented to replace single scale bilateral filtering algorithm. Firstly, the edge characteristics of different scales are described with some small scale bilateral filters, then, the whole color tune is reflected by superposing original image. Thus, both local contrast reversal and local characteristics of different scales can be reflected; meanwhile, dynamic range compression can be effectively realized.

6 Experiment and Discussion

Two experiments were carried out to testify our ideas. Part of the experimental results is shown as Fig. 3 and Fig. 4.

(a). Result of liner filtering (b). Result of multi-scale bilateral filtering

Fig. 3 Comparison of dynamic range compression of 12-bit aero photo

(a). Result of HDRshop (b). Result of multi-scale bilateral filtering

Fig. 4 Comparison between HDRshop and the method suggested by the dissertation

As far as HDR image compression as concerned, because of the restriction of actual display device and processing method. Subjective appraisement still is mainly used in HDR image appraisement. While mean gradient index is adopted in appraising local characteristic.

The difference of expressive force between linear filtering and bilateral filtering was showed experiment 1 showed in Fig. 3. Comparing to the linear filtering, in bilateral filtering experiment, the details of HDR image can be expressed very well, and the brightness is also kept down. In experiment 2, comparing with HDR shop which is mature business software, in MSDF image, more details was kept down and the chromatogram is rather even in the whole band, meantime a little declination generated in color expression, but the declination may be tolerated.

From Fig. 4, the result indicates that the method of multi-scale bilateral filtering can effectively represents 12-bit Aero Photo more detail in the dark area and make the whole color tune more natural. Meanwhile, Fig. 4 shows that this method also effectively enhances HDR image' details in the dark and bright area and make the whole color tune more natural, whereas HDRshop can't represent this kind of performance.

7 Conclusion

By above-mentioned experiments, some conclusion can be draw:

a) The MSBF can express detail better than the single scale filter in HDR image processing.

b) The method does not realize dynamic scope compression of HDR image, but it can avoid artifacts like "halo" caused by the reversion of local contrast near the clear edges by general local compression method.

c) MSBF is more effective than HDR shop in describing image details, colors and Brightness distributions.

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