A New MSBF-based HDR Image Processing Algorithm

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***Abstract*—High dynamic range (HDR) image is increasingly comprehensive in digital image applications recently. But conventional output equipments and algorithm only provide to support 8 bit image. Here, a new algorithm based on 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. 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, a series of experiments were conducted to test this algorithm. A conclusion can be draw that the MSBF-based algorithm is rather effective in processing HDR image.

***Keywords*—image processing, image compression, high dynamic range image, multi-scale bilateral filtering.**

I. INTRODUCTION

The relative fields of computer vision, Image have already obtained and used HDR images recently [1]. At the same time the corresponding displays and transmission media fall behind. HDR images have always been 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 lossy in this process [2].

In 1968, Oppenheim and Schafer introduced Homomorphic Filter for rendering images [3]. Many algorithms derived from Homomorphic Filter 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) [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 presented an argument which realize HDR image processing in two scales. 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 image [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.

II. MSBF-BASED HDR IMAGE PROCESSING ALGORITHM

Combining with existing research, a new algorithm is presented. In this algorithm, a simplified multi-scale imaging model was established. The shortcoming of bilateral filter is only decomposed and compressed in two scales. But this shortcoming can be compensated now. 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 image processing can be realized, its expression is showed as formula (1) and its flow chart is showed as figure 1.

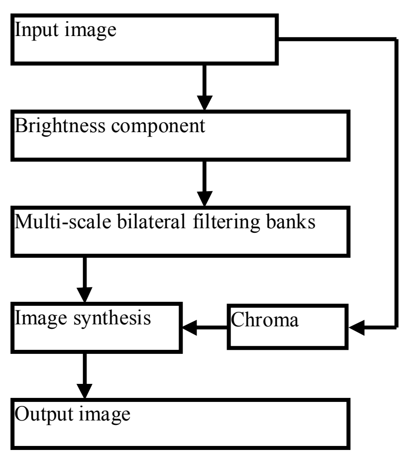


Figure 1. Flow Chart of Simplified Multi-scale Imaging Model

Brightness L can be summarized by the following equation:

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

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

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

III. CHROMA RESTRICTION AND BRIGHTNESS COMPONENT CALCULATION

In this paper, aiming at TIFF and HDR image formats, a new processing algorithm of HDR image was put forward.

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, nonlinear Chroma restriction mode is consistently adopted. Where the brightness (L) is given by

$$L=0.299*R+0.587*G+0.114*B \quad (3)$$

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

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

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.

IV. PARAMETER CONTROL OF THE EDGE-CUTOFF FUNCTION

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

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

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

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., 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].

$$\sigma_g=0.15*I_s \quad (7)$$

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 $\pm0.5I_s$.

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:

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

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

V. 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. Figure 4 shows the topology frame of bilateral filter with single scale decomposition.

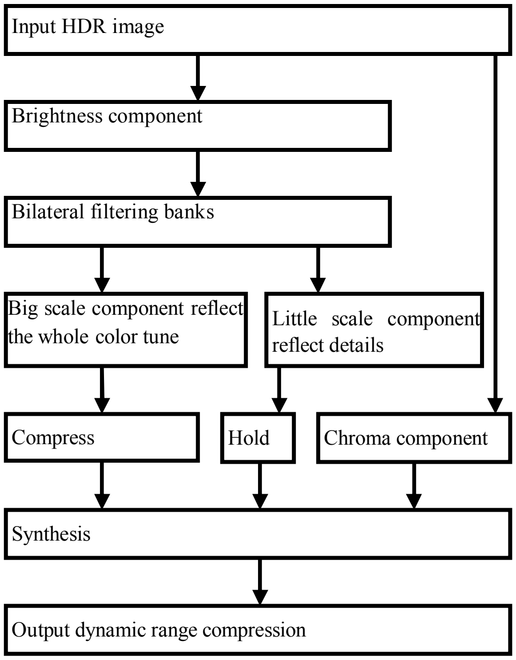


Figure 2. Bilateral Filter with Single Scale Decomposition

Generally, 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.

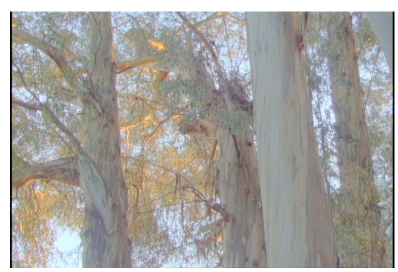
Combined with MSR theory, in time domain and intensity domain, the contrast characteristic of the vision system and simulated signal can be reflected well. The reason is that mechanism of eye imaging tallies with equation describing image very well. Generally, the resolving power of vision system to detail may be described with reciprocal of visual angle H which is used to distinguish two neighbour 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), I_p / I_s describes change of relative brightness between central pixel of filtering window and neighbour pixel, and the weight is added to convolution window of filter by means of I_p / I_s , 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-based processing algorithm, which is described as expression (6), can be formed by combing MSR algorithm. In order to keep down more whole 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.

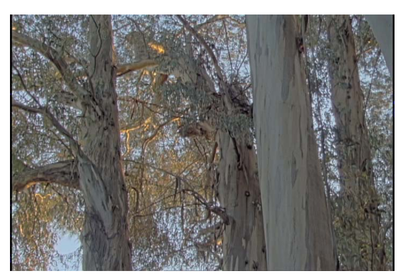
VI. EXPERIMENT

According to the discussions above-mentioned, a series of experiments were carried out to testify our ideas. Part of the experimental results was shown as follows:

(a) σ g=0.4



(b) σ g=0.15Is



(c) σ g=10Is

Figure 3. Dynamic Range Compression with Different σ g

In Figure 3, we show the results of experiment when k of formula (8) was set with different value. On the basis of above-mentioned experiment, 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.

(a)：HDR image compression with MSBF-based algorithm

(b)：HDR image compression with algorithm proposed by Fattal

(c)：HDR image compression with the algorithm proposed by Durand & Dorsey

Figure 4. Comparison of Dynamic Range Compression of HDR Image (Format: HDR)

VII. APPRAISEMENTAL METHODS

It is very important to appraise the quality of processed image. Because this kind of appraisement can directly describe how well the image processing system and the algorithm are. The methods can generally be categorized with subjective and objective appraisement.

A. *Subjective methods for appraising image quality*

Subjective appraisement is that the quality of image is judged by subjective feelings and statistics based on direct observation of human's eyes according to some standards or image samples. At present, the subjective appraisement methods of image mainly include MOS (Mean opinion Score) and CCIR 500 (Comes et al, 1990; CCIR, 1986) [11].

These methods may describe better of image quality, but they need spend many times and cost because some certain quantity of appraiser are required to take part in and these appraisement must be done according to complicated program. Meanwhile, the result is easily influenced by subjective behaviour and perceptive ability of the observers. Furthermore, these methods are hard to give a quantificational description with mathematic model and hard to process automatically.

B. *Objective method for appraising image quality*

The common ground of objective appraisement for image quality is to measure physical characteristics of influence factors. These factors may come from physical or mathematic modeling, image transportation and image processing. Then the measured value is compared with stated standard or reference data to gain quantificational description of image quality. At present, studies on image appraisement mainly focus on objective methods. And these methods have been developed from simple statistic to some characteristics that can inflect human vision system (HVS).

- Classical objective appraisement methods. Among relative methods for image quality appraisement, some classical objective appraisement methods based on simple statistic are always used in related applications because of their advantages in calculation and reliability. These methods include information entropy, variance, average gradient, mean square error and peak signal noise rate etc. wherein, the anterior three indexes are absolute appraisement indexes for single image respectively on information quantity, contrast and particular contrast; and the latter are relative appraisement indexes on processed image in the course of restoration, compression and transportation.
- Quality appraisement method based on HVS. The most objective appraisement methods just simply describe the difference between original image and processed image by statistics methods. Human vision feeling characteristics are not considered. Since 1977, HVS model was attempted to apply in image appraisement （Hall & Hall; 1977; Crranrath, 1981; Marmolin, 1986 ） [12-14]. In recent years, HVS-based image appraisement models continually appear （Daly, 1992; Karunasekera & Kingsburg, 1995; Fuhrman et al, 1996; Kitt et al, 1997; Lai & Jay Kuo, 2000; Naranjan, 2000; Chin & Xydeas; 2002 ） [15-21]. HVS characteristics almost were applied in all these models and the effect is fine.

C. Analysis on experimental results

As far as HDR image compression as concerned, because of the restriction of actual display device and processing method, the effective quantificational appraisement is hard to do. 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 was showed in experiment 1(showed by Figure 3) when k was set with different value. When k=10, HDR image keep more tone information. When k was set with a small value, HDR image lost most tone information. In experiment 2(showed by Figure 4), comparing with some famous compression algorithms, in MSDF-based HDR image processing, 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.

VIII. Conclusion

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

- The MSBF can express detail better than the single scale filter in HDR image processing.
- The MSBF-based algorithm 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.
- This MSBF-based algorithm is very effective in describing image details, colors and Brightness distributions.

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