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Reconstruction of High Dynamic Range Image from Multiple Exposure Images with Integrated Color Reproduction and Ghost Removal System

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Abstract: In this paper, propose a technique for reconstruction of high dynamic range image from multiple exposure images and integrated approach for colour reproduction and ghost removal. In the standard or commonly used multiple exposure fusion HDRI generation methods are suffer from the perceptual reproduction of colour and affects of moving objects ghost artefacts. In this paper presents an integrated approach for ghost removal and perceptual reproduction of colour in the HDR images. The ghost detection in this proposed method is based on the order relation between pixel values in differently exposed images and then applies the weighting function in the HDR generation equation for ghost removal. Finally, the ghost free HDRI apply the integrated colour correction and tone mapping algorithm. The experimental results show that the proposed system produces ghost free super resolution high dynamic range images.

Keywords: High dynamic range, Image Fusion, Ghost detection, Ghost removal, Tone reproduction and contrast enhancement.

I. INTRODUCTION

Conventional digital cameras can only capture a limited luminance dynamic range and most monitors and displaying media also have limited dynamic range due to the limited capacity of digital sensors, to about orders two of degree. As a result, when taking a photograph of a scene, bright areas have a tendency to be overexposed while dark regions have a tendency to be underexposed. It is possible to capture a High Dynamic Range Image (HDRI) using multiple imaging devices, or devices that use special sensors]. The recent years the dynamic range spanned by conventional cameras a very interesting and powerful technique has been developed high dynamic range imaging. The obtained images are known as high dynamic range (HDR) images and characterize the scene more faithfully than conventional low dynamic range (LDR) images [13].

High dynamic range images can be obtained by using either hardware or software methods. In the Hardware methods to capture HDR images include the use of more than one imaging devices..In the case of software method for generating HDR image is based on the fusion of multiple distinct exposures. The inspiration of this technique is that different exposures capture different dynamic range characteristics of the same scene. This simple and easy multiple exposure fusion technique suffers from two main problems: i) Ghosting: moving objects in the scene while capturing images will appear in different locations in the combined HDR image, creating what are called ghost or ghosting artifacts.. ii) Faithful reproduction of color in the real scene.

The ghosting problem is a severe limitation of the multiple exposures technique since motion can hardly be avoided in outdoor environment which contain moving entities such as automobiles, people and motion caused naturally; due to wind for example. Even a very small or limited movement will produce a very noticeable artifact in the combined HDR image. We propose to detect ghost by using pixel order relation method and remove the ghost directly by adjusting the weighting function used in the HDR image generation equation. After the ghost removal and image fusion process a tone reproduction algorithm is introduced. This algorithm gives color depth in the final image. In this paper we propose an integrated technique for removal of ghosting artifacts and faithful reproduction of color.

In the remaining sections, proposed HDR imaging system is described in methodology Section II. In Section III we show some experimental results. Finally, we conclude and give some perspectives in Section IV.

II. METHODOLOGY

The proposed HDRI system concurrently deals with the issues of ghost removal and color reproduction. The basic concepts of this system contains: A. Ghost removal and Image fusion, B. Tone and color reproduction.

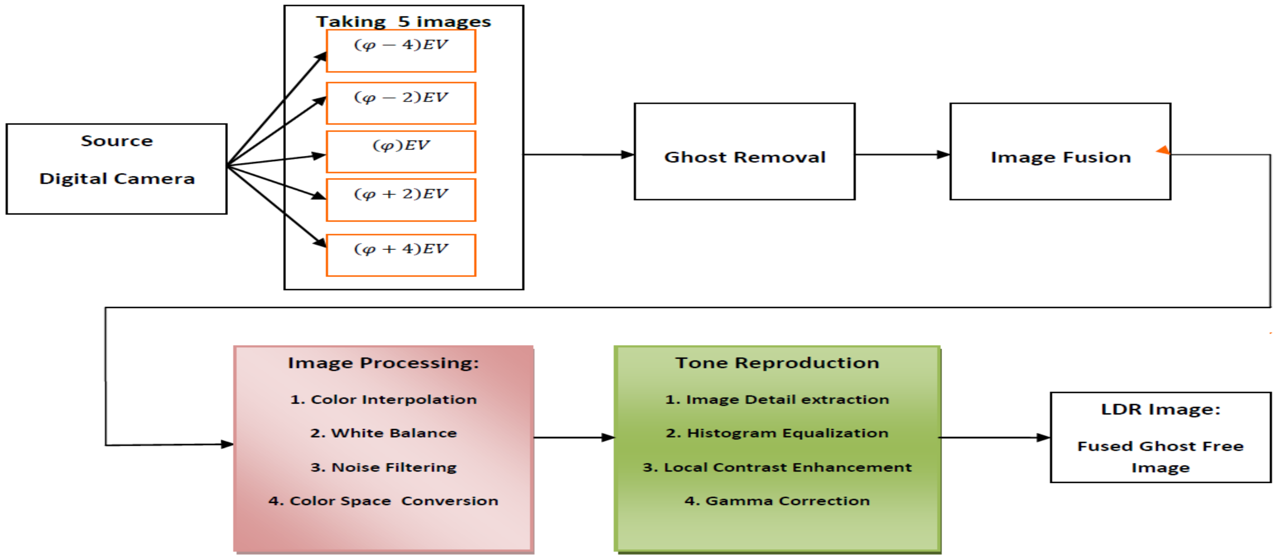

Fig.1. Block Diagram of the proposed System

A. Ghost removal and Image fusion

In the Pixel order relation method deals with the order relation between pixels values in differently exposed images to find ghost area. More precisely, it is possible to related pixel values to radiance values using the camera response function [2]:

$$Z_{uv}^{m} = f(E_{uv}^{m}\, \Delta t_m)$$

Then, assuming that f () is monotonic, which is a reasonable assumption since an increase in radiance values always produces an increased or equal recorded pixel values, it can be shown that for each pixel location(u; v) the intensity values in different exposures must satisfy:

$$Z_{uv}^{m} \le Z_{uv}^{n}\, , if\ \Delta t_m < \Delta t_n$$

Therefore, if the input LDR images [1] are arranged in increasing order of exposure times, the ghost map is generated by the following equation:

$$(GM)_{uv} = \begin{cases} 0 & if\ Z_{uv}^{1} \le Z_{uv}^{2} \le \cdots \le Z_{uv}^{N} \\ 1 & otherwise \end{cases}$$

As the above order relation works only if the pixel is not under- or over-exposed, saturated pixels are excluded from the ghost map computation.

Then calculate the weight of the pixel value and apply in equation.(3). Given the camera response function f (), the HDR image is computed as the weighted average of pixels values across exposures using the following equation:

$$R_{uv} = \frac{\sum_{k=1}^{N} w(Z_{uv}^{m}) f^{-1}(Z_{uv}^{m})/\Delta t_m}{\sum_{k=1}^{N} W(Z_{uv}^{m})}$$

B. Tone and colour reproduction.

The aim of tone reproduction is enhancing the contrast ratio for fine image details/textures while maintaining color constancy. It can be further decomposed into four steps: fine image details extraction, image edges histogram equalization, local contrast calculation, *RGB* gain setting, and gamma correction. Since gamma correction is a standard step of an image pipeline [12].

(i) Fine Image Details Extraction

The proposed tone reproduction algorithm first extracts the image information in different luminance levels. The fused image is scaled up four times and the pixel values are clipped to the saturation value in each iteration. The Sobel operator is applied for detecting all possible image details from the different luminance levels. All false edge points in the merged edge map are further filtered out such that the final edge map only keeps the most important image details/textures that should be visible in the final image[1].

(ii) Image Edges Histogram Equalization

To have better visual quality, the proposed tone production system is operated on *CIELAB* color space which is recommended by Commission International e de l'Eclairage (CIE). *CIELAB* is a relatively uniform color space that has better separation between luminance and chrominance components. It is much easier to evaluate the luminance of the image textures in human perception than other spaces [13].

The design concept is to expand the contrast of more image details by assigning larger dynamic range for highly populated regions [2]. Assuming the entire dynamic range of luminance value *L** with *CIELAB* space is normalized to the range of 0 to100, all extracted edges are first assigned to the *M* histogram bins HBk , $1 \leq k \leq M$, according to their original *L** luminance values. The cumulative frequency distribution function ($t(j)$, $1 \leq j \leq M$) is constructed, where $h(k)$, $1 \leq k \leq M$, denotes the histogram value for the bin *k*.

$$t(j) = \sum_{i<j} h(i) / \sum_{1 \leq i \leq M} h(i)$$

$$L_{x},j \ \ X \ \ (100 /M) \quad L_{x} \quad (j+1) \times (100/M)$$

For a pixel *x* with luminance value assigned in the *j*-th bin. The target luminance value of pixel *x* should be moved to the *p*-th bin, where $p = M \times t(j)$ after histogram equalization. Hence the gain corresponding to global histogram equalization, which is denoted as ω_G , can be expressed as follows :

$$\omega G = p / j = M \times t(j) / j$$

(iii) Local Contrast Enhancement

Incorporating local contrast enhancement is particularly useful for further improving the contrast of the image details in HDR imaging. The major drawback of local contrast enhancement is that it may have brightness reversal problem or generate some undesired artifacts. These problems may not be so important for medical imaging or surveillance systems, but for consumer digital cameras, having a beautiful picture without artifacts would be a basic requirement. If an image taken by a digital camera has some artifacts or the contrast of the image details becomes too harsh, the camera is always unacceptable in consumer market.

In the proposed system, we incorporate the local contrast enhancement into tone reproduction. The weight regarding to local contrast is defined in above equation, where the function f_C is used for data normalization which is defined in equations L* $x_{,AVG}$, L is the average L^* values of the neighboring pixels for the pixel x. Red, Green, Blue values can be combined with exponent to form world coordinate Red, Green, Blue channel pixel values as follows.

$$\omega_L = f_C(\log(L_x) - \log(L_{x,AV\,G}))$$

$$f_C(u) = (u - \Delta_{\min})/\,(\Delta_{max} - \Delta_{min})$$

$$\Delta_{min=}\ \sigma - \log\left(L_{x,AVG}\right))$$

$$\sigma = arg\min_x\ ((\log L_x)$$

$$\Delta_{max} = \varphi - \log(L_{x,AVG})$$

$$\varphi = arg\max_x(\log\,(L_x))$$

The integrated gain ω for a pixel x in L^* component is determined by (12), where $L^T{}_X$ denotes the target L^* value of the pixel x. It simultaneously performs global and local contrast enhancement.

$$\omega_L = L_x^T\ /\ L_x = \omega_G \times \omega_L$$

(iv) RGB gain setting

After the gain in L^* domain for a pixel x has been determined, we can change the luminance of a pixel accordingly. However, directly adjusting the luminance value (L^*) in *CIELAB* color space may not get good color reproduction. This is because the chrominance of a pixel highly depends on the illuminant. An object in a daylight scene appears more colorful, but the same object becomes grayish in the night. Adjusting only the L^* component for pixels may improve the contrast. But it is not helpful for enhancing or recovering the right colors that it should be under a better illuminant condition. Changing the chrominance components (a^* and b^*) may enhance the colors, but it must use different scaling factors for the pixels according to their luminance levels. Systematical methods are not derived yet in the field. Our tone reproduction system aims at recovering colors for the image area whose exposure is not good in original raw images. The system always adjusts the stimulus values by scaling the data in linear *sRGB* color space and the scaled output tends to equal the target luminance value $L^T{}_x$ determined in previous steps. The improvement with the proposed approach comes from the fact that using linear *sRGB* color space to represent the stimulus values of a pixel has better linearity in radiometry point of view. *CIELAB* color space is defined by the human perception which is inherently nonlinear response to original light intensity. Dealing with the data in a nonlinear space to recover the poor exposed pixels is much more difficult than with linear one. Hence using *sRGB* would be a better solution than in *CIELAB* color space, if we want to recover the right intensity values for those objects under poor exposure conditions.[13]

Based on the objective mentioned above, the gain setting problem of tone reproduction can be formulated as follows: Given the original values R_x, G_x, and B_x of a pixel x in linear *sRGB* space and its luminance value (L^*) in *CIELAB* space is Lx, find the scaling factor α such that the luminance value can be mapped to $L_x^T = \omega \times L_x$ if their *RGB* values *Rx*, *Gx*, and *Bx* are scaled to α *Rx*, α*Gx*, and α *Bx*, respectively. As stated in the scaling factor α can be derived as, where Y_x and Y_0 are the Y components of the input pixel x and reference white point, respectively.

$$\alpha = \begin{cases} \omega + (16/116)\sqrt[3]{Y_0/Y_x}(1-\omega)^2)Y_x/Y_0 > 0.008856 \\ \omega \qquad\qquad\qquad\qquad Yx/Yo \qquad \leq 0.008856 \end{cases}$$

After applying the gain α for a pixel in linear *sRGB* color space, the luminance (L^*) of that pixel has been moved to L_x^T. However, the entire image is typically unexposed in global and local contrast enhancement after processed based on the above equation. This is because ω is usually much lower than 1. Most of data are scaled down through such data processing. To have better visual quality for a picture, we apply auto-level stretching before gamma correction [1].

III. RESULTS

We tested our method with various scene types. A tripod was used for capturing the sequences of images, in order to keep the camera stable and avoid misalignment. So, we are interested in detecting motion in the scene being captured. As mentioned before, motion can be caused either by a moving object on a static background or by movements of the background itself. The Fig.2(a) and (b) are the result of static multiple exposure combined scene. Fig.2.(a) shows the ghost affected in the multiple exposure HDR images without ghost removal algorithm. We use only the image fusion algorithm. Fig.2.(b) shows the result of image fusion with ghost removal and color correction algorithm. In static scene the proposed algorithm gives best result.

As we can observe the result of dynamic scenes, both the moving leafs and water ripples are detected by the algorithm. The Fig.4 shows this observation result. The Fig.4(a) shows the leafs and water ripples are affected the ghost artifacts. In the Fig.4(b) remove the ghost artifacts from the multiple exposed HDR image. Only some leaves on the branches are in motion during the time of capture. In the proposed method based on an order relation between pixel values in different exposures, can detect, almost precisely, the small ghosting regions in the image. We therefore, minimize the loss of dynamic range of the final combined HDRI.

Our experiments, with various sequences, show that the order relation-based method and integrated color correction method. It gives more precise results than the previous methods.

HDRI generation by using multiple exposure fusion in the radiance domain and pixel order method used for ghost detection, color correction RGB gain setting in CIELAB color space. As can be seen, the leaves motion ghost has been correctly removed. The static and dynamic ghosts are effectively removed in this proposed method.

Fig.1 multiple exposure Images for Fig.2

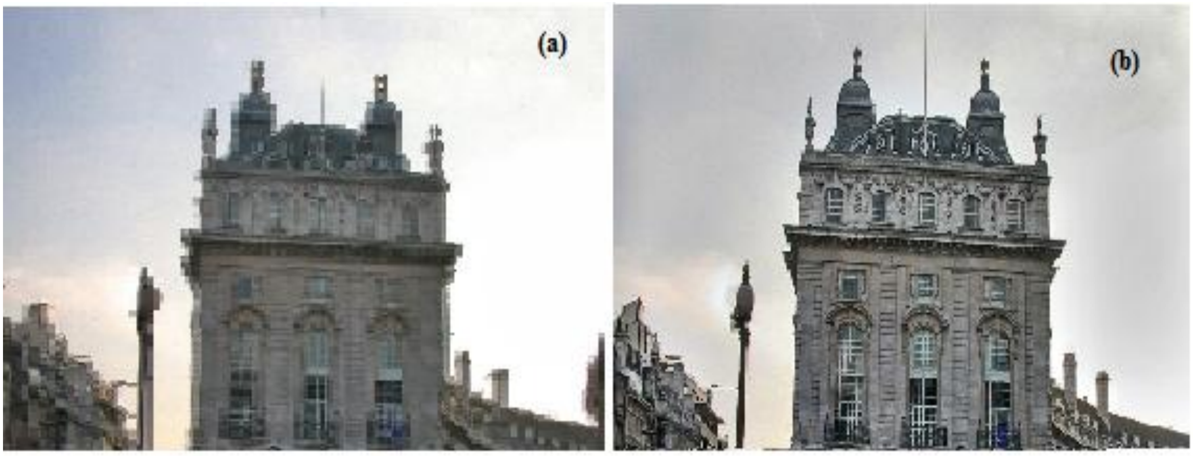

Fig. 2 A Result of a static scene. (a) Multiple exposure fusion HDR result without ghost removal and color correction algorithm (b) Result of our proposed Ghost removal and color correction algorithm

Fig.3 multiple exposure Images for Fig.4

Fig.4 A Result of dynamic scene with moving leaves and water ripples (a) Multiple exposure fusion HDR result without ghost removal and color correction algorithm (b) Result of our proposed Ghost removal and color correction algorithm Result of a static scene.

IV. CONCLUSION

In this paper, a competent method for detecting ghost regions in HDRI is presented. The method is based on an order experimental results show that the method can detect either moving objects and static object or small back grounding motion. In this method do not use the any threshold values compared to other methods. The proposed method can then automatically detected the pixels of ghost affected and ghost not affected pixels on the basis of ghost map. In the algorithm moving and static image pixels are detected this integrated method. Our future work will intend to employs the ghost free super resolution HDRI.

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