

Ghost-Free High Dynamic Range Imaging Using Weighted Histogram Separation and Fuzzy Fusion Method

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ABSTRACT: This paper works on high dynamic range (HDR) image generating process to an single input image. To remove the ghost image in an moving object we use weighted histogram separation method. The Red Green Blue model is appeared as an primary spectral component they must be converted to hue, saturation and vibrance color format. The linear stretching process of algorithm is transformed to 8 bit gray scale, where it is applied to image which has low or high brightness and the pixel value is recorded to histogram. The contrast limited adaptive histogram equalization (CLAHE) is processed which is the greater version of adaptive histogram equalization. In this method the histogram noise is reduced by clipping level and the fuzzy fusion method is used to exposed images. By fusing the different exposed images, the high dynamic range image is obtained as output.

KEYWORDS: High Dynamic Range, Weighted Histogram Separation, Linear Stretching, Contrast Limited Adaptive Histogram Equalization, Fuzzy Fusion Method.

I. INTRODUCTION

The real world scenes have a very wide range of luminance levels. But in the field of photography, the ordinary cameras are not capable of capturing the true dynamic range of a natural scene. To enhance the dynamic range of the captured image, a technique known as High Dynamic Range (HDR) imaging is generally used. HDR imaging is the process of capturing scenes with larger intensity range than what conventional sensors can capture. It can faithfully capture the details in dark and bright part of the scene.

If the bright and dark regions coexist in the same scene, these regions tend to be under- or over-saturated. In order to overcome the limited dynamic range, high dynamic range (HDR) imaging has been introduced, and the capability of taking images in extremely HDR scenes has become necessary for a modern digital still camera (DSC). Since digital imaging sensors, such as charge coupled devices, has lower dynamic range than analog negative films, DSC highly relies on the auto exposure (AE) control function to determine the right exposure value for covering the maximum dynamic range of the scene being taken. High Dynamic Range (HDR) imaging techniques have been utilized in recent years as an alternative approach for digital imaging .

The limitation of digital cameras in capturing real scenes with large lightness dynamic range, a category of image acquisition and processing techniques, collectively named High Dynamic Range Imaging, gained popularity. To acquire HDR scenes, consecutive frames with different exposures are typically acquired and combined into a HDR image that is viewable on regular displays and printers.

Image Enhancement is essentially a simplest and attractive area of digital image processing. Image enhancement is method used to enhance the overall superiority of the corrupted images can be attained by using enhancement mechanisms. So that the human eye can naturally detect the key features of the pictures. It is used to eliminate

the inappropriate artifacts from the pictures like noise or brighten the photograph and it simply to identify main features and then it looks improved. It is an individual area of digital image processing. To create a graphic display further helpful to visualize and examination, it recover the photograph features such as edges or boundaries. It enlarges the dynamic range of collected features. It does not increase the inbuilt content of data.

In this technique an image is captured through a camera of different exposure and they are fused together to form a High Dynamic Range Image [2], [3]. Shen *et al* [4] proposed a novel algorithm based on extended Retinex model to fuse multi-exposure images. Instead of composing the input image intensities, this approach decomposes them into the luminance and reflectance components which are composed independently before being merged together to produce the final result. Gu *et al* [5] proposed an algorithm to fuse multi-exposure images in the gradient field. Fused gradient field was derived from the structure tensor of inputs based on multi-dimensional Riemannian geometry with a Euclidean metric. These proposals does not satisfy dynamic mode of image of moving scenes and suits only the static mode of scenes and various artifacts such as ghosting cannot be avoided due to the sequential capture of differently exposed images. There are various methods in which the camera and local motion are compensated to eliminate ghosting effect.

Jacobs *et al* [6] proposed a ghost detection approach on entropy computation. In this method the local entropy is obtained and it is added to the difference entropy values with that of the weighting factor between the LDR images. Khan *et al* [7] presented an iterative ghost effect removal approach. In this process by weighting the probability of pixels of an moving object we can obtain an HDR image.

Zhang *et al* [11] proposed to use gradient direction changes among the different images for object motion detection. This approach is an drawback because it doesn't consider the local regions of an ghost image and in addition this approach takes that the moving region takes the small portion of an image. Zhang *et al* [12] proposed a new de-ghosting algorithm to overcome these shortcomings of the method presented by Zhang *et al* [11] by taking not only the temporal consistency but also spatial consistency. This approach generalize the previous effort but it fails to produce an perfect HDR images.

Lee *et al* [13] proposed to obtain a ghost-free high dynamic range image based on a low-rank matrix completion. In this approach the low-matrix and sparse matrix method is used represent the moving objects. The ghost region detection is formulated as the low-rank matrix completion problem with multiple physical constraints on the properties of the ghost regions. But this method is consider as complexity for mobile camera application.

Im *et al* [14] proposed to generate high dynamic range (HDR) images using a single image instead of acquiring differently exposed images in order to avoid ghosting effect. This method uses weighted histogram separation which utilizes image for histogram separation. Then the single histogram is divided into sub-histograms which produces different LDR images from an single image and this process is not affected by any ghosting effects. But it has fixed weighted histogram where different characteristics of an image cannot be produced. Im *et al* [15] proposed a similar approach for generating ghost-free HDR images. This method utilizes histogram quantization based spatially adaptive histogram equalization approach and generates two LDR images using single input image by performing two sub-histogram equalizations.

Then it fuses the LDR image with that of the input image to form an fixed weighted HDR image. In this paper, it is proposed to produce HDR image using a single image similar to [14]. However, the proposed approach computes an adaptive weight for each image to improve HDR performance. To increase the appearance of an HDR image in dark and local regions contrast limited adaptive histogram equalization (CLAHE) is used. Then finally fuzzy logic is used in LDR images where the pixels of the image is made into count and thus the proposed single HDR image produces increased dynamic range images.

II. PROPOSED WORK

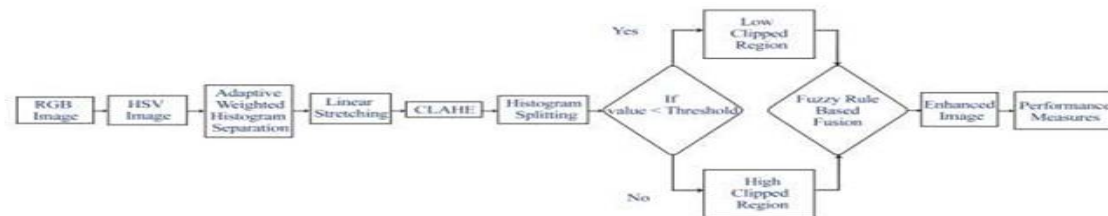


Fig. 1: Flow diagram of proposed method

The Proposed approach based on High Dynamic Range (HDR) it has following three steps. The first step is generating Low Dynamic range (LDR) image from original image following Adaptive Weighted Histogram approach. The second step is to generate LDR image using Linear Stretching (LS) and Contrast Limited Adaptive Histogram Equalization (CLAHE). The third step is to LDR images are fused into the fuzzy based fusion and it obtains the output of HDR image. The fixed weighted at the WHS process is not suitable for wide range of images. The WHS method with the proposed adaptive weight computation is applied to the V channel to obtain initial under and over exposed images. Thus, it is proposed to obtain adaptive weight specific to input images. It is important that only the channel is used along the HDR process. Finally, the HDR image is constructed from these three differently exposed LDR images by making use of a fuzzy based fusion approach which takes pixel visibility into account.

The proposed method utilizes adaptive weighted histogram separation firstly in order to perform single image based HDR. The weighted histogram separation (WHS) is presented by Pei *et al* [16]. However, a fixed weight at the WHS process is not suitable for wide range of images. Thus, it is proposed to obtain adaptive weights specific to input images. It is important to note that only the V (Value) channel is used along the HDR process.

Weighted Histogram Separation (WHS)

The weighted Histogram Separation is based on the Data Separation Unit (DSU) which separates the image dataset into two subsets. The first step is to estimate the threshold τ and it defined as

$$\tau = \arg_{0 \leq t < V} \min \left| w - \frac{1}{n} \sum_{l=0}^t H_V(l) \right|$$

Where HV is used to denote the histogram of V channel of the input image. HV(l) denote number of pixel in gray level ranges from 0 to 255 for an 8 bit image. t denote the gray level value. n is the total number of pixel. w denote the weighted factor. The overall pixel intensity is defined as

$$r = \frac{\sum_{m=0}^b H_V(m)}{\sum_l H_V(l)}$$

The a and b are fixed intensity level and a, b varies from 0 to 64. The small weighted factor result is detail loss of HDR image. The high weighting factor is not able to improve the dynamic range of the input image. The second step is to estimate the adaptive weight factor (w) and compute the threshold (τ) divide the input histogram image into two sub histogram based on the threshold value.

$$H_v(l) = \begin{cases} H_V(l), & \text{if } l < \tau \\ 0, & \text{otherwise} \end{cases}$$

$$H_v(l) = \begin{cases} H_V(l), & \text{if } l > \tau \\ 0, & \text{otherwise} \end{cases}$$

Linear Stretching

Linear Stretching technique can be applied to the images where lack of contrast in result is false identification of object and its spatial relationship and signification. Contrast enhancement by linear stretching is applied to image with very low or very high variation of brightness. Linear stretching algorithm needs to be converted into gray scale 8 bits pixel value recorded into histogram. When the histogram of the image is created maximum and minimum values are identified. The linear stretching can be applied for V_0 and V_1 .

$$V_{0-LS}(x,y) = \frac{V_0(x,y) - \min(V_0(x,y))}{\max(V_0(x,y)) - \min(V_0(x,y))} * 255$$

$V_0(x,y)$ The image obtained by WHS

$V_{0-LS}(x,y)$ Over exposed image obtained after linear stretching

$V_{1-LS}(x,y)$ Under exposed image obtained after linear stretching

Contrast Limited Adaptive Histogram Equalization

Im et al [14] propose to apply only linear stretching to V_0 and V_1 for obtaining differently exposed images. In this paper, it is proposed to apply CLAHE [18] after linear stretching in order to improve appearance of the local details in HDR image. Note that a recently presented approach by Çelebi [19] proposes to utilize CLAHE together with linear stretching specifically for dynamic range improvement on underwater images.

Adaptive histogram equalization (AHE) is a method for local contrast enhancement and it is an extension to the traditional histogram equalization technique. AHE simply partitions the image into non-overlapping regions and applies histogram equalization to each sub-region in order to redefine the pixel values of the image. As a result, contrast of each region is enhanced by improving local details. One of the important problems with the AHE is the over-amplified noise in relatively homogeneous regions. CLAHE is an improved version of AHE which prevents over-amplification of noise in homogeneous regions by limiting the contrast. In CLAHE, each sub-histogram is partially flattened by clipping the values which are larger than a given threshold, and distributing them to other bins in the histogram. By selecting the clipping level of the histogram, undesired noise amplification can be reduced.

Fuzzy Logic Based Fusion

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved. Fuzzy logic has three main stages like image fuzzification, modification of membership values and image defuzzification. The fusion is the process of combining the information from two or more images into a single image. The resulting image will be more informative than any of the input images. The final stage of the proposed method is fusion into the over, under and normal exposed images to generate an HDR image.

The coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make it possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (modification of membership values). After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. The pixels having mid-level values are higher and compared to the low-level values of the difference between the pixel level. The HDR images constructed as

$$I_{HDR}^c(x,y) = \frac{\sum_{k \in \{OE, NE, UE\}} I_k^c(x,y) \text{FuzzyWeight}(V_k(x,y))}{\sum_{k \in \{OE, NE, UE\}} \text{FuzzyWeight}(V_k(x,y))}$$

$c \in \{R, G, B\}$

I_k^c denote under exposed images.

III. EXPERIMENTAL RESULTS

The proposed method is tested using various input images that have different characteristics. As described in previous section, Im *et al* [14] proposed to generate HDR image using histogram separation with a fixed weight for all input images. However, in this paper, the weight is estimated adaptively for each input image. These results show that the fixed weight does not perform well for different type of images. But the proposed method obtains better results thanks to adaptive weight. The adaptive weights of these images are computed as 0.44, 0.16 and 0.18, respectively by the proposed approach. It is seen from these results that there is considerable improvement in the dynamic range and visual quality of the images. In addition, HDR images generated by the proposed method have more details, because the regions are properly selected from the LDR images. When the visual HDR performance of the other compared methods is evaluated, the proposed method has better visualization results compared to the methods presented by Zhang *et al* [11] and Im *et al* [14].

The HDR performance of the proposed method is also examined by making use of some objective blind image quality criteria such as entropy and Cumulative Probability of Blur Detection (CPBD) [20]. The entropy measures the richness of information in HDR image. Hence, the higher entropy simply means better performance. The CPBD is based on the just noticeable blur (JNB) and is able to predict the relative amount of blurriness in images with different content. A higher value of this metric depicts a sharper image. As the blurriness in an image increases the value of this metric is expected to decrease. Table II shows the entropy and CPBD values of the proposed approach and other methods. As seen from this table the proposed approach provides good performance in this objective evaluation as well.

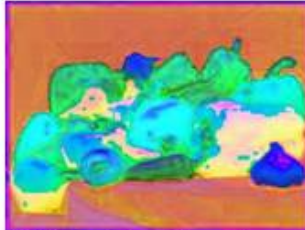
The approach presented by Im *et al* [14] and the proposed approach are implemented on a smart phone with a 1.9GHz CPU using C++ language at the same software optimization level. Table III shows average execution times in milliseconds for full HD (1920×1080 pixel) input images. As seen from this table, the computational complexity before the fusion stage is similar. The additional processing time at this stage for the proposed method originates from the implementation of CLAHE introduced in this paper. At the fusion stage, the approach presented by Im *et al* [14] is implemented by making use of a 1-dimensional Look-Up Table (LUT) based weighting factor computation in addition to color space conversion. However, in the proposed approach, additional local extreme computation and filtering is required to decide contribution level of each pixel in the LDR images to final HDR image.

These extra computations consume around additional 1300ms compared to the method presented by Im *et al* [14]. For the implementation of the fuzzy fusion stage in the proposed method, a 2-dimensional LUT is generated by sampling inputs at 0.001 resolution. Thus, the size of LUT is 1000×1000 which requires an additional 8MB of memory. Compared to the 1-dimensional LUT utilized for the implementation of the method presented by Im *et al* [14], the proposed fuzzy based fusion requires an additional 100ms processing time. Thus, the proposed approach requires approximately two times higher processing time in total for HDR image generation process. However, it is important to note that the proposed approach provides significantly better HDR performance compared to the method presented by Im *et al* [14]. Additionally, it might be possible to improve computation time of the local extreme calculations by making use of some software optimizations.

IMAGE PROCESSING TECHNIQUE



a) Input Image



b) Colour Transformation



c) Low Contrast



d) High Contrast



e) Low Contrast-Linear Stretching



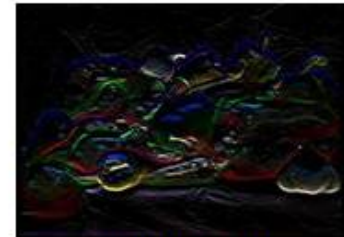
f) High Contrast-Linear Stretching



g) Over Exposed



h) Under Exposed



i) Differential image



j) Output Image

Entropy value	CPBD
1.0362	0.9595

Performance Measure

IV. CONCLUSION

The method that generate the High Dynamic Range Image using an input image is presented. This approach induces an adaptive histogram separation to create an exposed images i.e. over and under exposed images. The contrast limited adaptive histogram equalization enhance the local details of the images. Then at last the fuzzy

logic based fusion does an attractive HDR image. The proposed method produces an ghost free high dynamic range image though it uses single image instead of multi-exposing images. Hence, there is no effect of moving object and movement in camera in this method. In addition this approach is suitable for smart phones and consumer camera because of its low computational complexity.

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