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FUZZY FUSION LOGIC BASED HDR IMAGE USING NOVEL CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALISATION

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ABSTRACT

In this work a high dynamic range (HDR) image generated by a single input image. In this approach over- and under-exposed images generated by make use of a novel adaptive histogram separation scheme. Thus, it become possible to eliminate the ghosting effect which generally occur by object or the camera - image captured the source is in motion. In addition to that the image generation, it uses fuzzy logic at the fusion stage, which accounts the visibility of the every input pixel. This approach is easy, so it is possible to implement it on mobile devices such as smart phones and compact cameras. Finally, the project shows the ghost free and improved HDR performance compared to the existing methods.

Index Terms - HDR, Histogram Separation, Adaptive Novel Histogram Separation, Fuzzy Logic, Fusion Stage, Ghost Free.

I. INTRODUCTION:

In weakly illuminated environments, the quality of images captured by optical imaging devices is often degraded. This can reduce the performance of particular systems, such as those used in intelligent traffic analysis, visual surveillance and consumer electronics. The best examples are:

1. Backlighting, where objects and details cannot be simultaneously captured in both bright regions (background) and dark regions (foreground) because of limitations in the exposure setting of many imaging systems.
2. The low lighting conditions in night time environments can produce images with low contrast, reducing visibility.

The recent approaches have been in the contest of literature to produce HDR images with extended dynamic range using LDR images. In these techniques, generally multiple images of the scene are captured at different exposure times via a single camera and fused to form the HDR image.

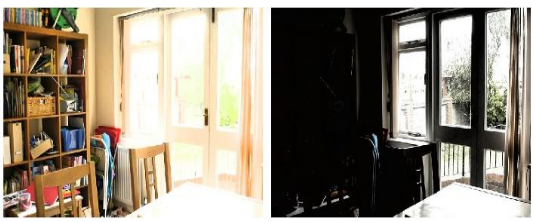

Fig 1 Images for Backlighting and Low lighting conditions

A typical conventional consumer grade camera has 24-bit depth per pixel to 256 discrete intensity levels for each color channel of the image. However, light intensity in the outside has much large dynamic range compared to that digital camera image. In order to overcome dynamic range limitation of the typical low dynamic range (LDR) images, High Dynamic Range (HDR) imaging techniques have been utilized in recent years as an alternative approach for digital imaging. HDR images generally have higher quality and powerful appearance. In HDR imaging, usually a set of differently exposed low dynamic range (LDR) images are fused into a single image to overcome the dynamic range limitation of existing imaging sensors. As a result, the fused image may have higher amount of information and enhanced visual quality because of its extended dynamic range.

The Acquisition of realistic photographs becomes easier for non-experts since high-quality imaging devices are popular in consumer electronics market. Three fundamental factors for realistic acquisition include:

i)High spatial resolution,
ii)Accurate color reproduction, and
iii)High dynamic range (HDR).

The major aim is to image enhancement, there are different techniques have been proposed to improve the quality of degraded images captured in varying circumstances. There are three major approaches that are:

A. Histogram-based methods,
B. Retinex based methods, and
C. Filtering based methods.

These approaches are to improve the visual appearance of an image. These methods focus on emphasizing the global image luminance i.e. color variations to enhance perceptual visibility. However, the proposed approach computes an adaptive weight for each image to improve HDR performance. Additionally, contrast limited adaptive histogram equalization (CLAHE) is utilized to improve overall appearance of the HDR image in local dark and bright regions. As a final contribution, fuzzy logic based fusion of LDR images is presented which takes pixel visibility into account. Thus, the proposed single image based HDR approach produces an image which has increased dynamic range.

II. FUZZY FUSION LOGIC BASED HDR IMAGE USING NOVEL CLAHE:

A. SOME OF THE STANDARAD PROPOSED METHODS:

Zhang *et al* [11] proposed to use gradient direction changes among the different images for object motion detection. The main drawback of this approach is that it estimates the moving

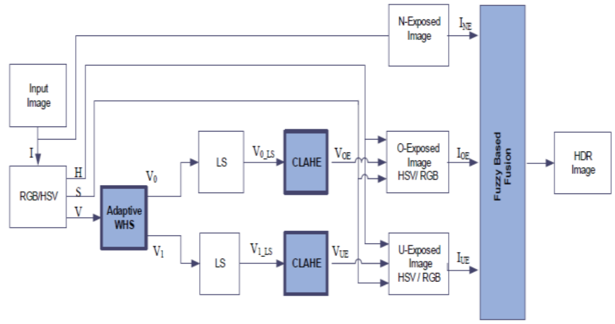

Fig 2 Block diagram-HDR Image generation for input image by the Basic Principal of CLAHE

objects without considering the local properties of ghost regions. In addition, this approach assumes that the moving object occupies only a small portion of the 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. Thus, this approach generalizes the previous assumption and allows higher amount of local motion. However, if an inappropriate exposed image is selected as the reference view, this approach may fail to produce acceptable HDR images.

Lee *et al* [13] proposed to obtain a ghost-free high dynamic range image based on a low-rank matrix completion. The background and moving objects are represented as a low-rank matrix and sparse matrix, respectively. Next, the ghost region detection is formulated as the low-rank matrix completion problem with multiple physical constraints on the properties of the ghost regions. However, these kind of approaches have considerably higher computational complexity which may not be suitable for mobile/consumer level cameras and real-time applications.

Recently, 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 utilizes weighted histogram separation (WHS) to estimate the threshold for histogram separation. Then it divides the histogram into two sub-histograms and generates differently exposed (over and under) LDR images from a single image. This method is not affected by ghosting effect inherently since it generates differently exposed images from a single image. However, this method utilizes a fixed weighting factor for histogram separation which is not suitable for images displaying different characteristics.

B. HDR IMAGE GENERATION BY AN IMAGE USING CLAHE:

The Presented approach based on High Dynamic Range (HDR) 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* [15]. 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.

After getting the V value the image that the system generated may be the normally-exposed image (I_{NE}), over-exposed image (I_{OE}) or under-exposed image (I_{UE}). By using these signals I_{NE}, I_{OE} and I_{UE} with fuzzy based fusion approach HDR image generated.

C. ADAPTIVE WEIGHTED HISTOGRAM SEPARATION (AWHS):

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

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

Where H_V is used to denote the histogram of V channel of the input image. $H_V(l)$ 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 denotes the weighted factor. The overall pixel intensity is defined as

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

The variables 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.

$$H_{V_0}(l) = \begin{cases} H_V(l), & if \quad l < \tau \\ 0, & otherwise \end{cases}$$

$$H_{V_1}(l) = \begin{cases} H_V(l), & if \quad l > \tau \\ 0, & otherwise \end{cases}$$

D. LINEAR STRETCHING (LS):

This type referred a contrast stretching, linearly expands the original digital values of the remotely sensed data into a new distribution. By expanding the original input values of the image, the total range of sensitivity of the display device can be utilized. Linear contrast

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enhancement also makes subtle variations within the data more obvious. These types of enhancements are best applied to remotely sensed images with Gaussian or near-Gaussian histograms, meaning, all the brightness values fall within a narrow range of the histogram and only one mode is apparent.

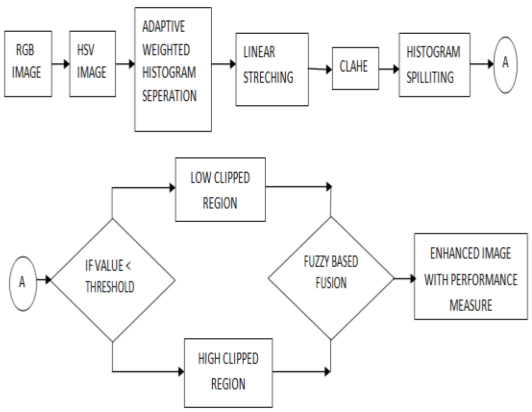

Fig 3: Implemented Method from the Basic Principal of CLAHE

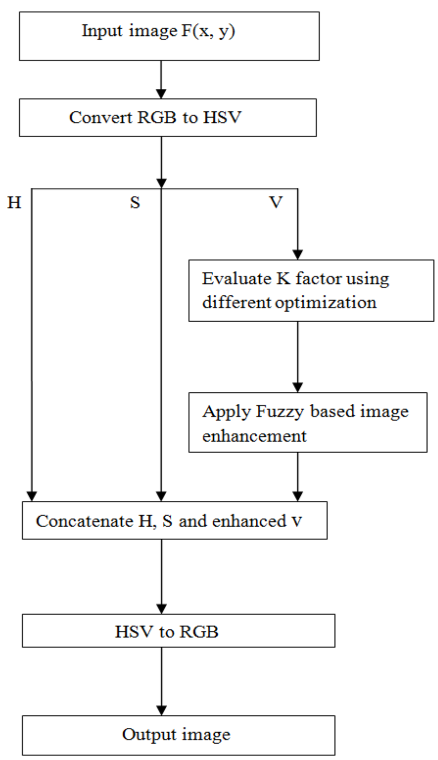

Fig 4: Flow diagram for HDR Image generation for an input image F(x, y).

When using the minimum-maximum linear contrast stretch, the original minimum and maximum values of the data are assigned to a newly specified set of values that utilize the full range of available brightness values. Consider an image with a minimum brightness value of 45 and a Maximum value of 205. When such an image is viewed without enhancements, the values of 0 to 44 and 206 to 255 are not displayed. Important spectral differences can be deselected by stretching the minimum value of 45 to 0 and the maximum value of 120.this method is applying with respect to image application type**.**

$$g(x,y)=(f(x,y)-min)/(max-min))*No.$$ of the intensity level

where g(x,y) represents the images, on the left side it represents the output image, while f(x,y) the represents input image. In this equation the "min" and "max" are the minimum intensity value and the minimum intensity value in the current image. Here "no. of intensity levels" shows the total number of intensity values that can be assigned to a pixel. For example, normally in the gray-level images, the lowest possible intensity is 0 and the highest intensity value is 255. Thus "no. of intensity levels" is equal to 255.

E. CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION:

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 andapplies 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 problem 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 homogenous 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. It is applied to the over exposed linear stretched voltage and upper exposed linear stretched voltage separately to enable enhancement of local details. A higher dynamic range is achieved on local regions by virtue of local pixel statistics.

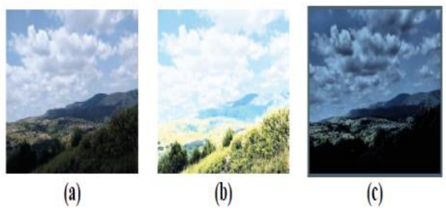

Fig 5: (a) The normally-exposed image (I_{NE}) (b) Over-exposed image (I_{OE}) (c) Under-exposed image (I_{UE})

CLAHE was developed to prevent the over amplification of noise that AHE can rise. It can able to increase contrast more than the other techniques. When it introduces large changes in the pixel gray levels, It may affects the decision making process. This can operates on small data regions (Tiles) rather than the entire image. It is computationally expensive and is quite complex. By comparing, it is time consuming because of recursions are performed sequentially.

F. FUZZY LOGIC BASED EXPOSURE FUSION

The final stage of the proposed method is the fusion of over-, under- and normally-exposed images to generate the HDR image. Firstly, the over-exposed V channel ($OE\ V$) andunder-exposed V channel ($UE\ V$) are combined individually with the unprocessed H and S channels and transformed back into the RGB color space to obtain the over-exposed andUnder-exposed images for fusion process.

The idea of exposure fusion is to exploit the best parts of the differently exposed images and fuse them to generate a high quality image. There are several quality metrics for this purpose, such as well-exposedness, saturation, contrast or variance. The smoothed and normalized difference between the local extremes is assigned as the first input of the fuzzy system whereas the normalized pixel value of the V channel is considered as the second input. The smoothing is required to eliminate unwanted local noise in the fuzzy inputs.

When the difference between local extremes around a pixel is low then the contribution of this pixel on the HDR image will be low even though the pixel intensity is relatively high. These rules eliminate erroneous contribution of the pixels located at the homogenous region. It is important to note that the contributions of the pixels having mid-level values are higher compared to that of relatively low-level and high-level pixel values.

Fuzzy logic is a form of many valued logic in which the truth values of variables may be any real number between 0 and 1. Fuzzy image processing is not a unique theory. It is a collection 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 image into single image. The resulting image will be more information than any of the input image. The final stage of the proposed method is fusion into the over under and normal exposed image into generate of HDR image.

The coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make 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 pixel having midlevel values are higher and compared to the low level value of the difference between the pixel levels.

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The HDR images constructed as

$$I^{c}_{HDR}(x,y)=\frac{\sum_{k\in\{OE,NE,UE\}} I^{c}_{k}(x,y)\,FuzzyWeight(V_{k}(x,y))}{\sum_{k\in\{OE,NE,UE\}} FuzzyWeight(V_{k}(x,y))}$$

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

I^{c}_{k} denote under exposed images.

EXPERIMENTAL RESULTS

- **BY IMAGE PROCESSING TECHNIQUES:**

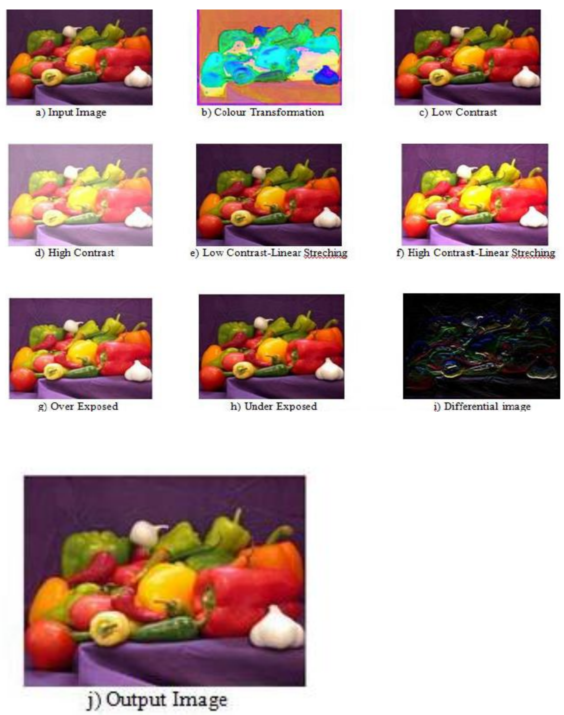

Figure 6: Images after application of image processing techniques a) input image b) Color transformation c) Low Contrast d) High Contrast e) Low Contrast-Linear Stretching f) High Contrast-Linear Stretching g) Over Exposed h) Under Exposed i) Differential image j) Output image

By means of Image Processing Techniques, the input image can be modified by Colortransformation, Low Contrast, High Contrast, Low Contrast-Linear Stretching, High Contrast-Linear Stretching, Over Exposed, Under Exposed, Differential image and Output HDR image as shown in the resultant image. There are several proposed methods for image processing. The below shown images corresponds to the image sequences image1& image 2for different approaches with final result HDR image.

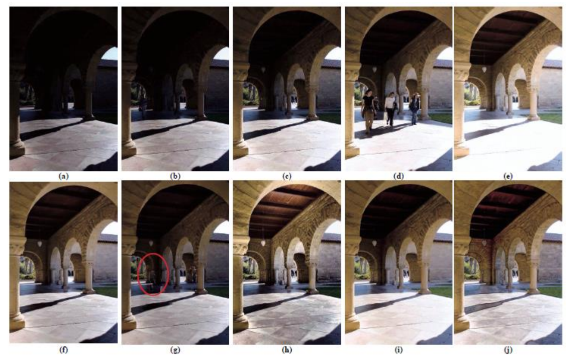

Fig 7: Image1 sequence - collected from different standard methods as description mentioned from (a) to (i), (j) HDR image by the Image1

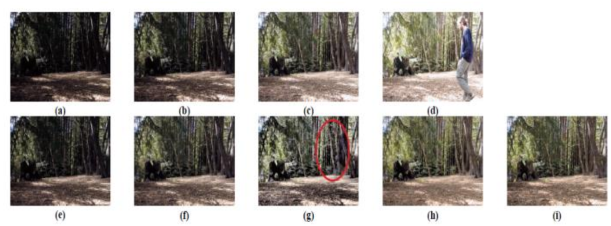

Fig 8: Image2 sequence - collected from different standard methods as description mentioned from (a) to (h), (i) HDR image by the Image2

The method presented by Im *et al* [14], the HDR performance of the proposed approach is compared against to some recent techniques [11]-[13] where multiple input images are required to generate HDR image. In Fig. 7 and Fig. 8, original differently exposed input images and HDR images generated by the methods presented by Zhang *et al* [11], Zhang *et al* [12],Lee *et al* [13], Im *et al* [14] and the proposed method are shown for visual assessment. As seen from these figures,the

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methods presented by Zhang *et al* [12] and Lee *et al* [13] still suffer from ghost effect even though these approaches have anti-ghost schemes. When the visual HDR performance of the other compared methods is evaluated, the present method has better visualization results compared to the methods presented by Zhang *et al* [11] and Im *et al* [14].

- **PERFORMANCE MEASURE OF HDR IMAGES:**

The HDR performance of the present method is also examined by making use of some objective blind image quality criteria such as entropy and Cumulative Probability of Blur Detection (CPBD). 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.

Methods Of Operation	Image 1 Sequence		Image 2 Sequence	
	Entropy	CPBD	Entropy	CPBD
Zhang et al [11]	7.752	0.758	7.171	0.768
Zhang et al [12]	7.385	0.775	7.423	0.764
Lee et al [13]	7.623	0.773	7.629	0.715
Im et al [14]	7.358	0.774	7.637	0.784
Present Method	7.648	0.773	7.644	0.789

Table 1: Image Quality Assessment

In order to evaluate the contribution of fuzzy based fusion of LDR images introduced in this work, appearance based fusion approach presented by Im *et al* [14] is integrated into the proposed method. The visual results are shown in Fig. 9 for comparison. As seen from this figure, the proposed fuzzy logic based fusion approach not only improves the general HDR performance but also enables efficient HDR image generation for extremely dark regions. In general, these experiments show that the proposed method is able to improve visual quality of the images having different characteristics compared to original images and a recently proposed single image based HDR technique proposed by Im *et al* [14].

Fig 9: (a) Original Image (b) HDR Image Obtained after applying Fusion method (c) HDR Image obtained after applying Fuzzy based Fusion method.

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 present 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.

Stage of operation	**Im *et al* [14]**	**Present Method**
Before fusion stage	814 ms	943 ms
Fusion stage	527 ms	1684 ms
Total	1341 ms	2627 ms

Table 2: Average Execution Time on a Smart Phone

Conclusion

In this paper, a novel method to generate HDR image using a single input image is presented. This method utilizes an adaptive histogram separation approach to produce over- and under-exposed images. The CLAHE based image enhancement enables efficient extraction of local details. Finally, the proposed fuzzy logic based fusion approach facilitates to construct an attractive HDR image with the efficient combination of the LDR images obtained in the previous stages.

The proposed method generates ghost-free HDR images inherently because it uses a single image instead of using multiple differently exposed images. Hence, this method is not affected by the moving objects and camera movement. Additionally, the low computational complexity of the proposed approach makes it suitable for smart phones and compact consumer cameras.

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