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# Improving brightness using Dynamic Fuzzy Histogram Equalization

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**Abstract**

*This paper proposed brightness preserving dynamic fuzzy histogram equalization using triangular membership function which is the modified technique of histogram equalization. This modified technique, called Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE), uses fuzzy statistics of digital images for their representation and processing in the fuzzy area which enables the technique to handle the approximation of gray level values in a better way for better presentation. This algorithm enhances image contrast as well as conserves the brightness very well. Some images are not available to excellent quality, so proposed Fuzzy algorithm can be used for image enhancement to improve the quality of the image.*

***Index Terms*** *— Fuzzy sets, image enhancement, image processing, histogram equalization*

## 1. Introduction

Subjective contrast enhancement of an image is an important challenge in the field of digital image processing. Contrast enhancement produces an image that individually looks better than the original image by varying the pixel intensities. These techniques find application in areas ranging from consumer electronics, medical image processing to radar and sonar image processing.

In Digital image processing ,image contrast enhancement using Image histograms is strong technique and very much accepted. Global Histogram Equalization (GHE) [1] is one such commonly used technique which uses image histogram. GHE is employed for its simplicity and good performance over variety of images. However, GHE introduces main changes in the image gray level when the spread of the histogram is not considerable and cannot preserve the mean image-brightness which is Critical to consumer electronics applications. To overcome this limitation, several brightness preserving histogram modification approaches, such as bi-histogram equalization (BBHE [2], MMBEBHE [3]), multi-histogram equalization (DHE [4], BPDHE [5,8]) and histogram specification (BPHEME [6]) have been proposed by various researchers in their literature.

Abdullah-Al-Wadud, proposed dynamic histogram equalization (DHE) , this technique claims of preserving the mean image brightness by this approach. However, this method has the restriction of remapping the peaks which leads to perceivable changes in mean image brightness. To avoid peak remapping, Ibrahim

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and Kong, proposed Brightness Preserving Dynamic Histogram Equalization (BPDHE) technique, these techniques process the crisp histograms of images to enhance contrast. The crisp statistics of digital images suffers from the normal limitation that it does not take into account the approximation of gray-values. Additionally, crisp histograms need smoothing to achieve useful partitioning for equalization. Here we introduce a modification to BPDHE technique with the use of fuzzy statistics of digital images (fuzzy histogram) [7]. Besides, the imprecision in gray levels is handled well by fuzzy statistics, fuzzy histogram, when computed with appropriate fuzzy membership function, does not have random fluctuations or missing intensity levels and is essentially smooth. This helps in obtaining its meaningful partitioning required for brightness preserving equalization. Experiments expose that the use of fuzzy information has indeed better performance of the algorithm. Henceforth this customized technique is referred to as Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE) technique.

## 2. Brightness Preserving Dynamic Fuzzy Histogram Equalization

The BPDFHE this technique manipulates the image histogram in such a way that only redistribution of gray-level values in valley portion between two consecutive peaks takes place and no remapping of the histogram takes place. The BPDFHE technique consists of following operational stages:

2.1. Fuzzy Histogram Computation.
2.2. Partitioning of the Histogram.
2.3. Dynamic Histogram Equalization of the Partitions.
2.4. Normalization of the image brightness.

The following sub-sections contain the details of the steps involved.

### 2.1. Fuzzy Histogram Computation

Fuzzy statistics is able to handle the inexactness of gray value and produces a smooth histogram. Fuzzy histogram[10] is a series of real numbers h(i), i Є {0,1,…,l-1} where h(i) is the frequency of rate of gray levels that are around i. By considering the gray values I(x, y) as a fuzzy number the fuzzy histogram $\tilde{I}(x,y)$ can be computed as

$$h(i) \leftarrow h(i) + \sum_{x}\sum_{y} \mu_{\tilde{I}(x,y)i}\ ,\ k \in [a,b]$$

Where $\mu_{\tilde{I}(x,y)i}$ a triangular fuzzy membership function Triangular fuzzy membership function is can be defined as

$$\mu_{\tilde{I}(x,y)i} = \max\left(0, 1 - \frac{|I(x,y) - i|}{4}\right)$$

[a,b] is the support of triangular membership function.

### 2.2. Partitioning of the Histogram

Partitioning of histogram is done to get sub-histograms[11] based on local maxima. The partition is every Valley region between two consecutive local maxima. Then dynamic equalization of these partitions is performed which not only preserves the image brightness without the remapping of histogram peaks but also image contrast is increased. To partition the image histogram first we have to detect local maxima.

#### 2.2.1. Detection of Local Maxima

To find the discrete derivative as the fuzzy histogram [9] is a discrete data sequence the central differential operator is used

$$h'(i) = \frac{dh(i)}{di} \triangleq \frac{h(i+1)-h(i-1)}{2}$$

Where $h'(i)$ is first order derivative of fuzzy Histogram h (i) corresponding to $i^{th}$ intensity level.

#### 2.2.2. Fuzzy histogram with marked local maxima

To minimize the approximation errors which occurs if computed from first order derivative, second order derivative is computed directly from fuzzy histogram using second order central difference operator

$$h''(i) = \frac{d^2h(i)}{di^2} \triangleq h(i+1) - 2h(i) + h(i-1)$$

Where $h''(i)$ is the second order derivative of fuzzy histogram h(I) corresponding to $i^{th}$ intensity level.

$$i_{max} = i \quad \forall \ \{h'(i+1)h'(i-1) < 0, \ \ h''(i) < 0\}$$

As perfect zero crossings do not at occur at integral values of intensity levels, points of ambiguity arise .In such cases to neighboring pairs are detected as points of maxima. To solve the problem of ambiguity the point with highest count among the neighboring pair of maxima is preserved.

#### 2.2.3. Creating partitions

Detected local maxima points are used to form partitions in the fuzzy histogram. Suppose (n+1) intensity levels corresponds to local maxima are denoted by { $m_0$, $m_1$, … , $m_n$ }. If the fuzzy histogram is defined in the range of [$I_{min}$, $I_{max}$], then after partitioning (n+1) sub-histograms [11] are obtained. They will spread in the range given {[$I_{min}$ , $m_0$], [$m_0$+ 1, $m_1$], ….. [$m_n$+ 1, $I_{max}$].

### 2.3. Dynamic histogram equalization of sub-histogram

Each sub-histogram is equalized by using a spanning based on total number of pixels in the partition. DHE of each sub-histogram involves two operations-mapping partitions to a dynamic range and histogram equalization.

#### 2.3.1. Mapping Partition to a Dynamic Range

The parameters that are useful in dynamic equalization [12] process can be given by the equations

$$span_i = high_i - low_i$$

Where $high_i$ and $low_i$ are highest and lowest intensity values contained in $i^{th}$ input sub histogram

$$factor_i = span_i \times \log_{10} M_i$$

$M_i$ is the total number of pixels contained in sub-histogram. $span_i$ Is the dynamic range of input sub histogram

If $range_i$. Is the dynamic range of output sub histogram, it can be given as

$$range_i = \frac{(L-1) \times factor_i}{\sum_{k=1}^{n+1} factor_i}$$

Then the dynamic range for $i^{th}$ output sub-histogram is obtained as

$$start_i = \sum_{k=1}^{i-1} range_k + 1$$

$$stop_i = \sum_{k=1}^{i} range_k$$

The exceptions are nearby at the two extremities where

$$[start_1, stop_1] = [0, range_1] \text{ and}$$

$$[start_{n+1}, stop_{n+1}] = [\sum_{k=1}^{n+1} range_k ,\ \ L-1]$$

#### 2.3.2. Equalizing Each Sub-histogram

Global HE method is used to equalize each sub-histogram . The remapped values are obtained for the $i^{th}$ sub histogram as

$$y(j) = start_i + range_i \sum_{k=start_i}^{i} \frac{h(k)}{M_i}$$

Where y (j) is the new intensity level corresponding to $j^{th}$ intensity level on the original image.h (k) is the histogram value at $k^{th}$ intensity level on the fuzzy histogram

$M_i = \sum_{k=start_i}^{stop_i} h(k)$ Is the total population count in the $i^{th}$ sub-histogram of fuzzy histogram.

### 2.4. Normalization of image brightness

After DHE of each sub-histogram the image obtained has the mean brightness slightly different than input image. To overcome this normalization of output image is done. If g is output image of BPDFHE technique then the grey level value at pixel location (x, y) for image g is given by

$$g(x, y) = \frac{m_i}{m_0} f(x, y)$$

Where $m_i$ and $m_0$ are mean brightness levels of the input image (f) obtained after DHE. This ensures that the mean intensity of the output image of BPDFHE is same as the input image.

## 3. Result

In this paper, we present some experimental results of our proposed method, simultaneously with uniformly histogram equalization (UHE), generalized histogram equalization (GHE), adaptive histogram equalization (CLAHE), Brightness preserving dynamic fuzzy histogram equalization (BPDHE) . The algorithm performance evaluated and compared on three parameters. Here we use error in mean brightness, comparison of mean brightness and the PSNR value, computed from Fuzzy Gray Level .Testing of our image enhancement method is performed on 3 different images. We are used triangular membership function and parameter used 5 in BPDHE. Here we compared original image and its histograms. The quantative analysis is performed by calculating the mean brightness of images before and after enhancement, difference in mean brightness and the PSNR of enhanced and original images. We have used 3 different histogram equalization techniques to demonstrate the performance of our brightness preserving enhancement algorithm. The methods we have used are written below: Generalized histogram equalization (GHE) Uniform histogram equalization (UHE) Adaptive histogram equalization (CLAHE).

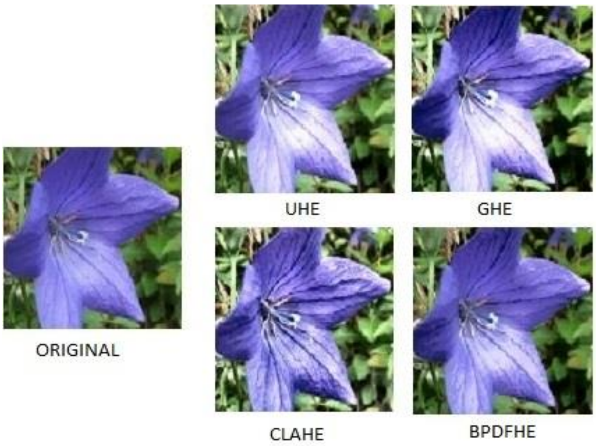



**Figure 1. Enhanced Image**

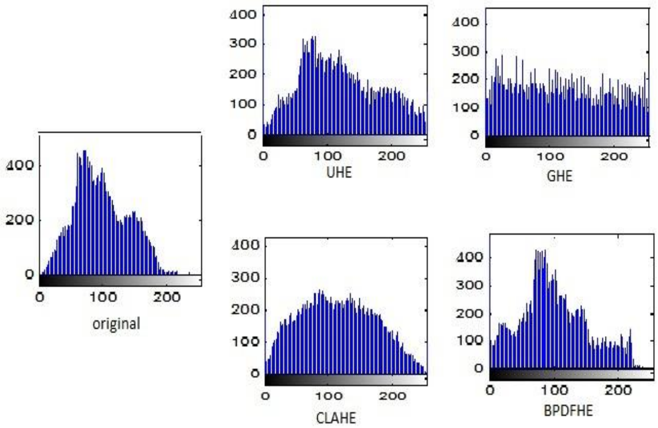
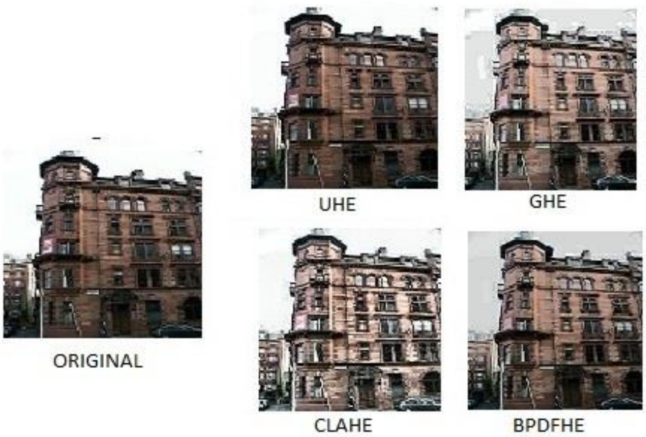



**Figure 2. Histograms of Image**

Fig.1 and fig.2- ORIGINAL IMAGE (I1), UHE (Uniform histogram equalization), GHE (Generalized histogram equalization ), CLAHE (adaptive histogram equalization), BPDFHE (brightness preserving dynamic fuzzy histogram equalization)



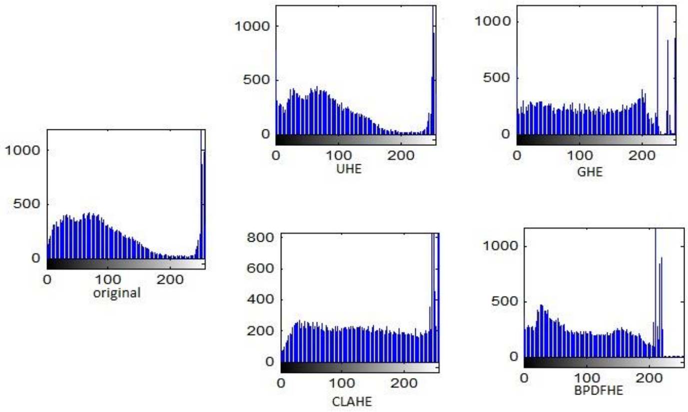



**Figure 4. Histograms of Image**

Fig.3 and Fig.4- ORIGINAL IMAGE (I2), UHE (Uniform histogram equalization) GHE (Generalized histogram equalization), CLAHE (adaptive histogram equalization), BPDFHE (brightness preserving dynamic Fuzzy histogram equalization)

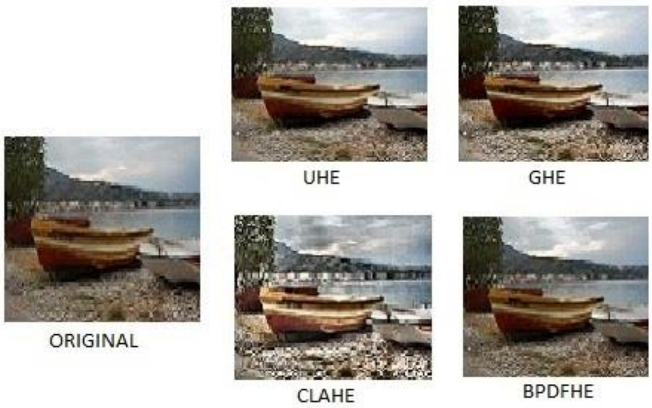



**Figure 5. Enhanced Image**

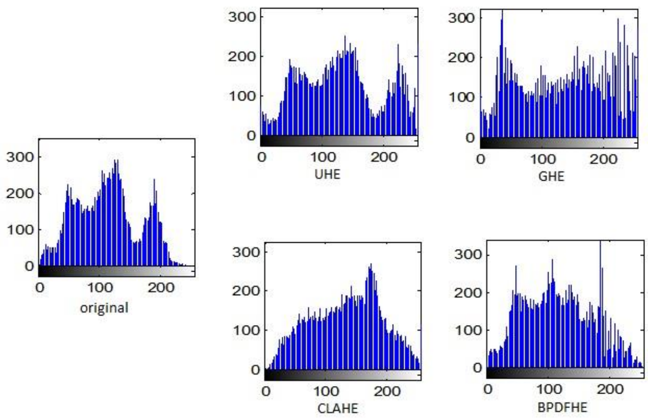



**Figure 6. Histograms of Image**

Fig.5 and Fig.6- ORIGINAL IMAGE (I3), UHE (Uniform histogram equalization) GHE (Generalized histogram equalization), CLAHE (adaptive histogram equalization), BPDFHE (brigh tness preserving dynamic Fuzzy histogram equalization)

## 4. Quantitative Analysis

We have performed calculations to justify our results in terms of parameters value. The measures that we have used are mean brightness, change in mean brightness and PSNR in between enhanced and original images.

| original | | GHE | UHE | CLAHE | BPDFHE |
|---|---|---|---|---|---|
| I1 | 112.54 | 126.43 | 131.67 | 128.74 | 112.83 |
| I2 | 104.17 | 122.29 | 102.01 | 137.32 | 103.31 |
| I3 | 104.69 | 120.51 | 120.79 | 125.26 | 104.93 |

**Table 1. Comparison of Mean Brightness**

Table 1 shows the mean brightness obtained before and after enhancing the images. First column shows original image mean brightness and there after it shows mean brightness obtained by using UHE, GHE, CLAHE and BPDFHE using TMF. Rows indicate the images names on which we have tested our enhancement results. For first image I1.jpg the original image brightness on average was 112 (approx.) but in case of UHE, GHE and CLAHE it has increased and reached to 131, 126 and 128 hence none of them were able to preserve the brightness. However, in case of FHT mean brightness is 112 and 113 hence it shows that our FHE algorithm is capable of maintaining the mean image brightness. Similar results for justifying the brightness preserving quality can be seen from other images.

| original | | GHE | UHE | CLAHE | BPDFHE |
|---|---|---|---|---|---|
| I1 | 0 | 13.89 | 19.13 | 16.20 | 0.29 |
| I2 | 0 | 18.11 | 2.16 | 33.15 | 0.56 |
| I3 | 0 | 15.81 | 16.09 | 20.56 | 0.23 |

**Table 2. Error in Mean Brightness**

The error in mean brightness is shown in Table 2. It shows that error in brightness using FHE is not more than 0.5 but in other cases it is very large. We can even say that CLACHE is showing highest error in mean image brightness after enhancement.

| original | GHE | UHE | CLAHE | BPDFHE |
|---|---|---|---|---|
| I1 | 16.44 | 18.67 | 16.09 | 25.60 |
| I2 | 16.75 | 38.75 | 13.28 | 20.10 |
| I3 | 18.99 | 20.92 | 15.51 | 31.61 |

**Table 3. PSNR Comparison of all HE Techniques**

PSNR measure indicates the error in between content of our image obtained by enhancement method to the original contents. Higher the SNR indicates the minimum differences or error in enhanced and original image. In brief, we can say that a technique will be considered good if it has high SNR. Hence, Table 3 is given and highest PSNR is obtained for FHE technique which is compared to other histogram equalization methods. If we compare HE using TMF then TMF based FHE is giving better PSNR.

## 5. Conclusion

In this paper we propose a brightness preserving dynamic fuzzy histogram equalization (BPDFHE) technique having contrast enhancement capabilities with reduced computational complexity by representing an image values in fuzzy domain helps the histogram equalization technique in handling the inexactness of gray level in a better way that give improved performance. As shown in Table 3 , higher PSNR is obtained for FHE technique compared to the other histogram equalization methods. If we compare FHE using triangular membership function (TMF) then FHE is giving better PSNR. From the results it is seen that BPDFHE can very efficiently preserve the mean image-brightness and PSNR than other histogram techniques as UHE, GHE, and CLAHE.

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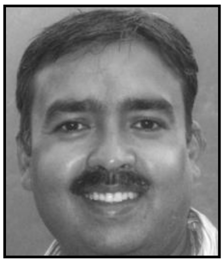

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