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An Analysis of Image Enhancement Based On Histogram Equalization Methods

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Abstract: - **Histogram Equalization is the most familiar method used in the analysis of contrast and brightness in images. The objective of image enhancement techniques is to process images based on Histogram Equalization so that the result is more suitable than the original image for a specific application. The choice of the technique depends upon the requirement. Histogram equalization method is powerful compared to other methods as it increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through histogram equalization, the intensities can be better spread on the histogram and this allows for areas of lower local contrast to improvement a higher contrast. Various methods have been proposed for limiting the levels of enhancement and most of the enhancement algorithms are based on Histogram Equalization. A comparative study is done on Brightness Preserving System with histogram equalization (BBHE) and Recursive Method of BBHE. Recursive Mean-Separate Histogram Equalization (RMSHE) is another improvement of BBHE. These algorithms clearly state that the Image enhancement using Histogram equalization significantly improve the visual appearance of the image.**

Keywords: **Brightness Preserving Bi-Histogram Equalization(BBHE), Contrast Enhancement, Dualistic Sub Image Histogram Equalization (DSIHE), Recursive Mean-Separate Histogram Equalization(RMSHE), Sub Image Histogram Equalization(SIHE), Recursive Sub Image Histogram Equalization(RSIHE), Minimum Mean Brightness Error Bi-Histogram Equalization(MMBEBHE).**

I. INTRODUCTION

Digital Image Processing means transforming images into new images treating every pixel independently. It actually refers to the graphical representation of the brightness /color distribution in an image. The most important task in pre-processing an image is enhancing the contrast and brightness of images. Histogram equalization is one of the most popular methods used for improving the contrast in images. A histogram is an estimate of the probability distribution of a continuous variable and was first introduced by Karl Pearson. Histogram is a graph that shows frequency of anything. It has two axes. X axis contains the event whose frequency is to be counted and Y axis contains the frequency. A histogram is a discrete function that is typically plotted as a bar chart where the horizontal axis corresponds to the dynamic range of the image and the height of each bar corresponds to the sample count or the probability. Histogram only plots the frequency at which each gray-levels of an image occurs from 0 (black) to 255 (white). The histogram of a digital image is therefore a distribution of its discrete intensity levels in the range [0, L-1]. Histogram is a graphical representation of data distribution. Fig 1 represents the image of Lena and its corresponding histogram.

Histogram Equalization

Histogram equalization is a method to process images in order to adjust the contrast of an image by modifying the intensity distribution of the histogram. The prime benefit of the method is that it is a fairly straightforward technique and an invertible operator. Hence if the histogram equalization function is known, then the original histogram can be recovered.

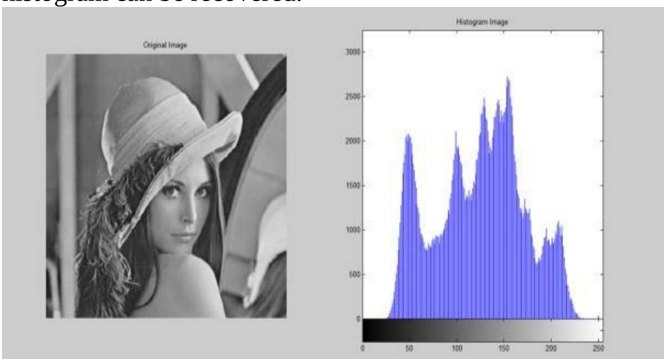

Fig 1 a) Lena Image b) Histogram of Lena image

Histogram Equalization is used in many image processing applications such as object recognition, medical image processing and as a preprocessing step in video processing applications. It has the effect of transforming the data distributions such that the most frequent values are distributed more uniformly than the least frequent data values.

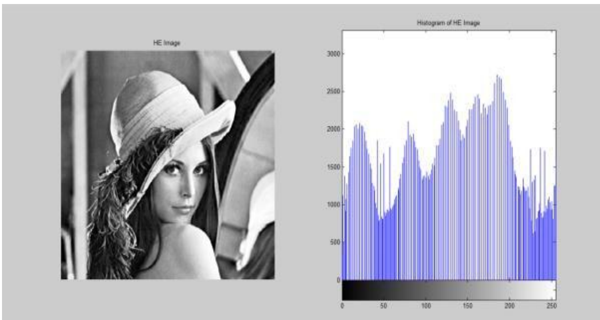

Fig 2 Histogram Equalization of Lena Image

Histogram equalization adjusts the contrast of an image by modifying the intensity distribution of the histogram. The objective of this technique is to give a linear trend to the cumulative probability function associated to the image. But HE has "mean-shift" problem, it shifts the mean intensity value to the middle gray level of the intensity range. This method is especially useful in images having large regions of similar tone such as an image with a very light background and dark foreground. Histogram equalization can expose hidden details in an image by stretching out the contrast of local regions and hence making the differences in the region more pronounced and visible. Fig 2 represents the Histogram Equalization of Lena image.

III. PERFORMANCE METRICS

Probability Density Function (PDF) The approximations of the PDF individual pixel in an image are distributed is defined as:

$$P(R_k) = n_k / N \qquad \text{..... (1)}$$

Where R_k and N_k are intensity level and number of pixels in an image with intensity respectively.

Probability Mass Function (PMF)

First we have to calculate the PMF of all the pixels in this image. The probability of each number in the frequency of each element.

$$P(X = x) \qquad \text{..... (2)}$$

Cumulative Distribution Function (CDF)

Cumulative sum of values calculated by PMF will be calculated using the histogram. CDF makes the PDF grow monotonically is necessary for histogram equalization.

$$cdf(X_i) = \sum_{i=0}^{k} P(X_i) \qquad \text{..... (3)}$$

Transformation Function

Histogram equalization involves finding a grey scale transformation function that creates an output image with a uniform histogram. Assuming that grey levels are continuous and have been normalized to lie between 0 and 1,

$$s = T(r) \qquad \text{..... (4)}$$

This T(r) is single valued and monotonically increasing also the integration of a PDF is a PDF in the same range.c

Absolute Mean Brightness Error (AMBE)

It is the difference between original and enhanced image and is given as

$$AMBE = E(X) - E(Y) \qquad \text{..... (5)}$$

Where E(X) is average intensity of input image and E(Y) is average intensity of enhanced image

Peak signal to noise ratio (PSNR)

For peak signal to noise ratio (PSNR) assume an input image is X (i, j) which contains M × N pixels and the processed image Y (I, j). First compute the Mean Squared Error (MSE),

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N} |X(i,j) - Y(i,j)|^2}{M \times N} \qquad \text{..... (6)}$$

Now peak signal to noise ratio (PSNR),

$$PSNR = 10\log_{10}\frac{(L-1)^2}{MSE} \qquad \text{..... (7)}$$

Entropy (E)

The entropy is a valuable tool to measure the richness of the details in the output image.

$$E = -\sum_{j=0}^{i-1} p(X_k)\log_2 p(X_k) \qquad \text{..... (8)}$$

IV. HISTOGRAM EQUALIZATION TECHNIQUES

There are numerous methods by which Histogram of an image can be equalized. Depending upon the area of application, the user can choose different histogram equalization techniques. The following types of Histogram Equalization methods are analyzed in detail:

. Brightness Preserving Bi-Histogram Equalization

. Recursive Mean-Separated Histogram Equalization
. Sub Image Histogram Equalization
. Recursive Sub Image Histogram Equalization
. Dualistic Sub Image Histogram Equalization
. Minimum Mean Brightness Error Histogram Equalization.

A. Brightness Preserving Bi-Histogram Equalization

The BBHE decomposes an input image histogram into two sub-images initially based on the mean of the input image. After separation these two sub images are equalized independently by using histogram equalization and the resultant image contains the mean brightness between input mean and middle gray level. The drawback is that it cannot preserve the natural appearance of the image. Fig 3 represents the BBHE of Lena Image.

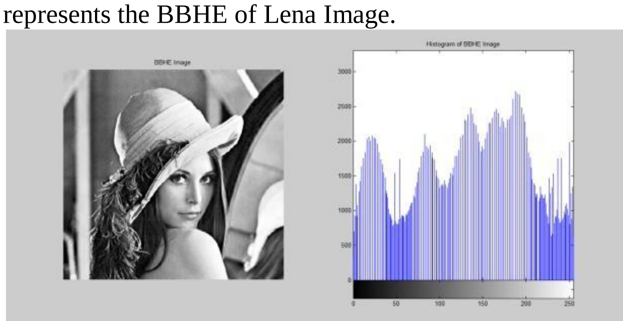

Fig 3 BBHE of Lena Image

B. Recursive Mean-Separated Histogram Equalization

This method is the generalization image enhancement of the BBHE to overcome its limitation and for scalable brightness preservation. BBHE separates the input histogram into two based on its mean before equalizing then independently while the separation is done only once in BBHE. The RMSHE performs the separation recursively, separates each new histogram further based on their respective means. Its recursive nature implies scalable preservation which is very useful in consumer electronic products. Fig 4 represents the RMSHE of Lena Image. In RMSHE, the brightness of the equalized image is nearly analogous to that of the input image but the contrast of the image is improved.

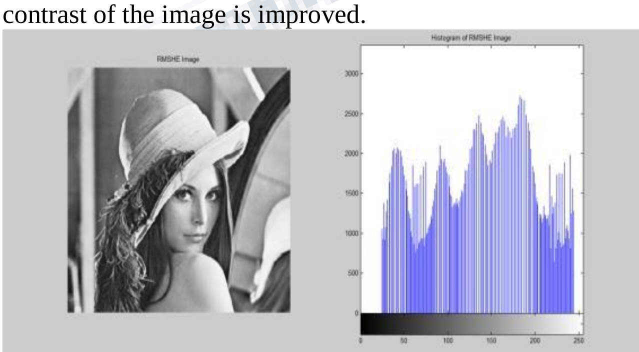

Fig 4 RMSHE of Lena Image

C. Sub Image Histogram Equalization

The method based SIHE consists of Histogram calculation, Histogram Clipping Process, Exposure Threshold and Histogram Sub division & Equalization. It provides to be very effective for contrast enhancement. The histogram clipping process is combined with Histogram Equalization to be very effective for enhancing under-exposed images. The entropy measures of the SIHE method outperform other HE based methods.

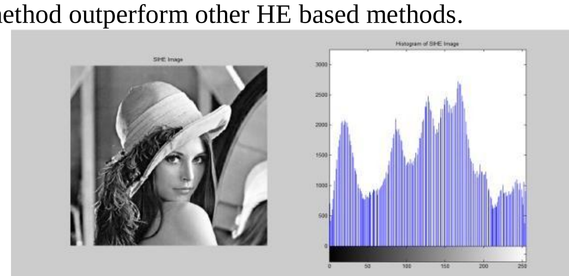

Fig 5 SIHE of Lena Image

D. Recursive Sub Image Histogram Equalization

The RSIHE is a contrast enhancement method based on the histogram equalization. The RSIHE method uses cumulative probability density equal to 0.5 for separating the input histogram into sub-histograms. This process can be applied recursively for a specified number of recursion levels to divide the image equally into sub-images. Each sub image will contain the same number of pixels. The recursive nature based scalable brightness is preserved in this method.

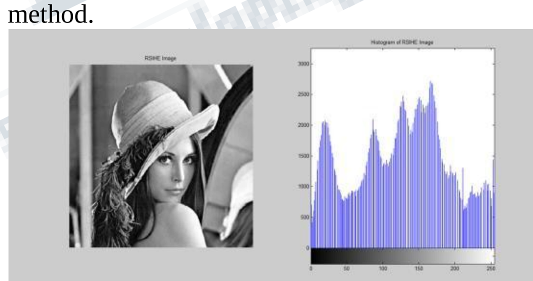

Fig 6 represents the RSIHE of Lena Image.

E. Dualistic Sub Image Histogram Equalization (DSIHE)

DSIHE [5] divides the image into sub images on the basis of median value. DSIHE is a term of preserving an image's brightness and entropy. It does not present a significant change in the brightness of the input image, especially for the large area of the image with the same gray-levels. As it preserves the original image luminance it is used in video systems but some noise may be present in output enhanced image. Fig 7 represents the DSIHE of Lena Image.

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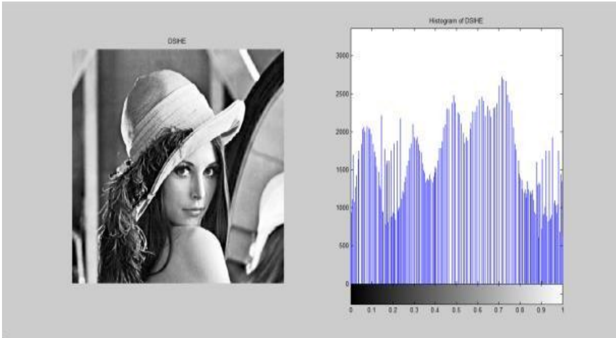

Fig 7 DSIHE of Lena Image

F. Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE)

MMBEBHE [10] divides the image into sub images on the basis of threshold level and is equalized by histogram equalization to produce output image that returns return minimum absolute mean brightness error (AMBE) [10]. It preserves the mean brightness of the image & suitable for real time applications. Fig 8 represents the MMBEBHE of Lena Image

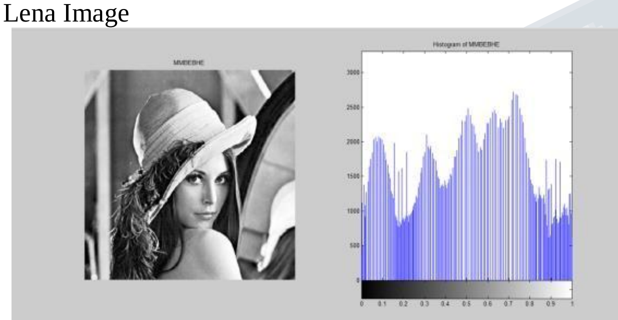

Fig 8 MMBEBHE of Lena Image

IV. EXPERIMENTAL RESULTS

To analyze the various HE techniques, experiments were performed on different images of varied sizes using MATLAB 2013a on HCL notebook under Windows 7 environment.

Assessment of Brightness Preservation

Absolute Mean Brightness Error, AMBE is used to assess the degree of brightness preservation. The lesser the AMBE value, the better is the brightness preservation. The results shown in Table I present the performance of brightness preservation of various methods discussed in this paper. It is clear from the graph shown in Fig 9 that MMBEBHE offers the best brightness preservation.

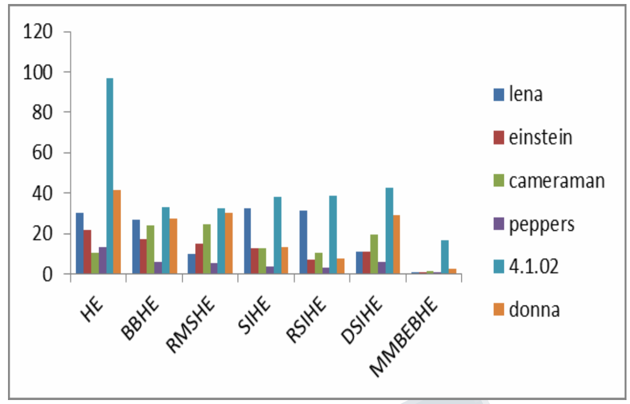

Fig 9 AMBE

AMBE							
Images	HE	BBHE	RMSHE	SIHE	RSIHE	DSIHE	MMBEBHE
Lena	30.06	26.68	9.94	32.35	31.08	11.28	0.70
Einstein	21.50	17.46	14.99	12.51	7.09	10.80	1.08
Cameraman	10.59	24.02	24.32	12.43	10.21	19.56	1.20
Peppers	13.20	6.05	5.56	3.88	3.21	6.11	0.67
4.1.02	97.01	33.13	32.21	38.18	38.70	42.82	16.40
Donna	41.68	27.28	30.14	13.21	7.74	29.01	2.26

Table I for AMBE

Assessment of contrast enhancement

Peak Signal to Noise Ratio, PSNR is a metric for image quality assessment. The greater the PSNR, the better is the image quality (contrast enhancement). The results shown in the Table II presents the PSNR values for various methods applied to some standard images It is clear from the graph shown in Fig 10 that Sub Image Histogram Equalization SIHE offers the best contrast enhancement

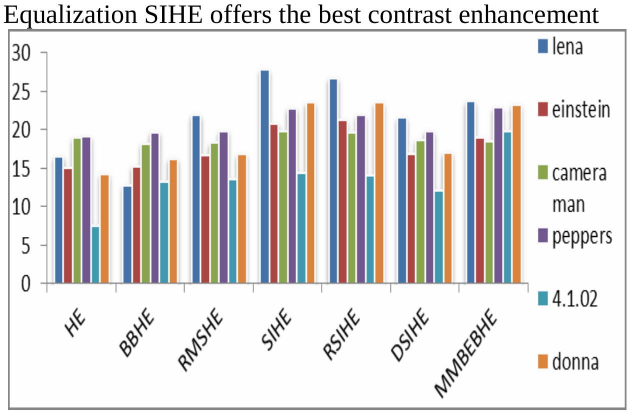

Fig 11 Entropy

Entropy							
Images	HE	BBHE	RMSHE	SIHE	RSIHE	DSIHE	MMBEBHE
Lena	7.44	7.44	7.39	7.54	7.53	7.39	7.47
Einstein	6.74	6.74	6.74	6.85	6.81	6.73	6.72
Cameraman	6.76	6.74	6.79	6.89	6.80	6.77	6.77
Peppers	7.37	7.34	7.34	7.45	7.40	7.33	7.32
4.1.02	7.37	6.18	6.16	6.34	6.33	6.18	6.13
Donna	6.51	6.48	6.38	6.67	6.61	6.39	6.49

Table III for Entropy

V. CONCLUSION

In this paper, several techniques of histogram equalization for Image Contrast and Brightness preserving Enhancement were analyzed. An analysis of the various histogram equalization techniques was performed using the quantitative measures AMBE, PSNR and Entropy. From the experimental results, it is observed that all of these techniques yield improvement in different aspects. To conclude, it is obviously seen that MMBEBHE method has the least AMBE value, thereby offering the best brightness preservation and contrast enhancement is offered by SIHE is the best as it has the highest PSNR and entropy values.

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