Histogram specification: A Review

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***Abstract -** Image preprocessing, Gaussian smoothing, Contrast stretching is concerned with producing and re-arrange an actual array of pixels for object representation to enhance the noisy and low contrast images. In the suggested method after noise smoothing & contrast stretching, image is equalized for better contrast using Histogram Equalization (HE), however, it tends to change the mean brightness of the image, and hence not suitable for consumer electronics products, where preserving the original brightness is essential to avoid annoying artifacts and unnatural enhancement. So this paper reviewed a novel extension of histogram specification to overcome such drawback as HE, named (BBHE) Bi-Histogram Equalization,(DSIHE) Dualistic sub-image Histogram Equalization and (BPHEME) Brightness Preserving Histogram Equalization with Maximum Entropy, Experimental results show that BPHEME can not only enhance the image effectively, but also preserve the original brightness in the form of mean and provide maximum entropy.*

Key words: HE, BBHE, DSIHE, BPHEME.

1. INTRODUCTION

One of the most widely used technique for image enhancement is Histogram equalization (HE).The main disadvantage of Histogram equalization (HE) is that it tends to change the mean brightness of the input image. In theory, the mean brightness of its output image is always the middle gray level regardless of the input mean, because the desired histogram is flat. This is not a desirable property in some applications where brightness preservation is necessary. Brightness preserving Bi-Histogram Equalization (BBHE) has been proposed to overcome that problem [3]. BBHE first separates the input image's histogram into two by its mean, and thus two non-overlapped ranges of the histogram are obtained. Next, it equalizes the two sub-histograms independently. It has been analyzed that BBHE can preserve the original brightness to a certain extent when the input histogram has a quasi-symmetrical distribution around its mean [7]. Later, equal area Dualistic Sub-Image Histogram Equalization (DSIHE) has been proposed, it claims that if the separating level of histogram is the median of the input image's brightness, it will yield the maximum entropy after two independent sub-equalizations [8]. DSIHE will change the brightness to the middle level between the median level and the middle one of the input image. Nevertheless, neither BBHE nor DSIHE could preserve the mean brightness. In the consumer electronics such as TV, medical imaging and Astronomical imaging the preservation of brightness is highly demanded. The aforementioned algorithms (HE, BBHE, DSIHE) preserve the brightness to some extent; however, they do not meet that desirable property quite well. In this paper, a novel enhancement method is proposed which can yield the optimal equalization in the sense of entropy maximization, under the constraint of the mean brightness, called Brightness Preserving Histogram Equalization with Maximum Entropy (BPHEME). BPHEME, together with the aforementioned algorithms, is essentially a kind of histogram specification [1] in general, except that different "ideal" histograms are employed in different algorithms. In the next section, histogram specification will be reviewed, and HE, BBHE, DSIHE, will be quickly introduced as special cases of histogram specification. The proposed algorithm, BPHEME, will be presented, which is "ideal" in the sense of maximum entropy with an invariant mean brightness. Some noise occurs during image acquired by modern sensors consist of thermal noise, amplifier noise, photon noise, quantization noise, distortions or shading. A linear filter is used for slowly varying noise; and. a nonlinear filter (Gaussian filter) is used for rapidly varying noise. Histogram equalization (HE) flattens and stretches the dynamic range of the image's histogram and results in overall contrast improvement. However, it may significantly change the brightness of an input image and cause problem in some applications where brightness preservation is necessary. In this paper, a novel enhancement method is proposed which can yield the optimal equalization in the sense of entropy maximization and contrast enhancement by using Brightness Preserving Histogram Equalization with Maximum Entropy (BPHEME) and Piecewise linear transform (PLT) respectively.

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Why do we use histogram of an image?

Histogram of image gives information about image contrast.

- Dark image, Histogram will be clustered towards the lower gray level.
- Lighter image, Histogram will be clustered towards the higher gray level.
- Low contrast image, Histogram will not be spread equally.
- High contrast image, Histogram will be spread equally.

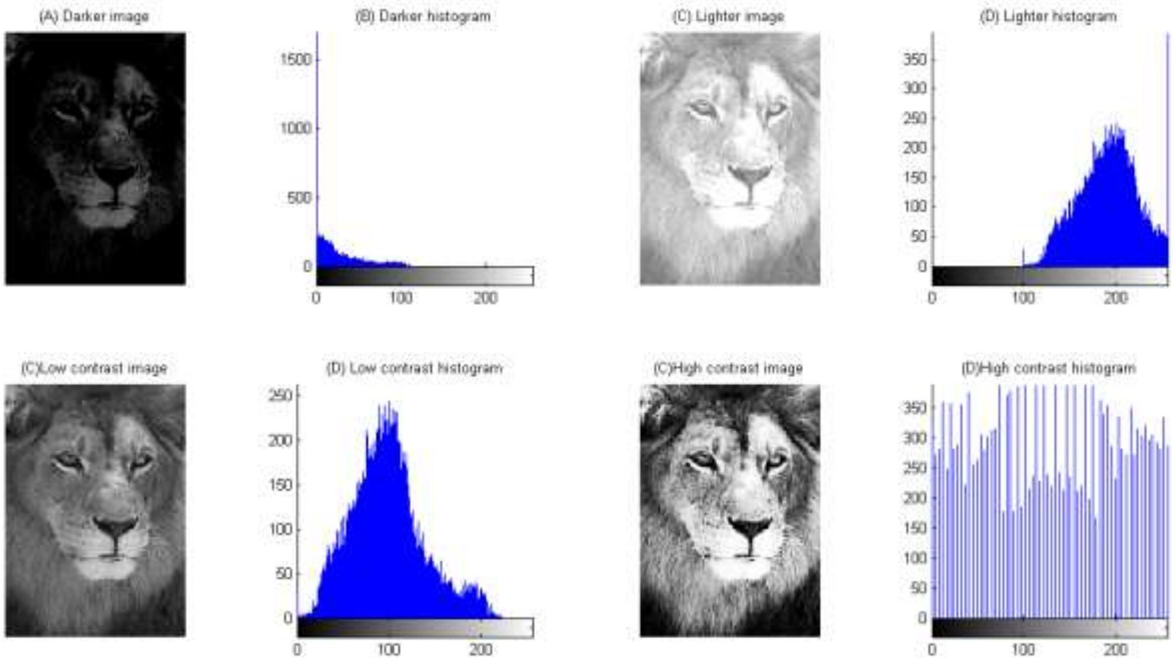

Fig.1Shows nature of Histograms

2. Histogram equalization:

The histogram equalization is an approach to enhance a given image. The approach is to design a transformation **T (.)** such that the gray values in the output is uniformly distributed in [0, 1].We need to design a gray value transformation s = T(r), based on the histogram of the input image, which will enhance the image. Histogram equalization yields an image whose pixels are (in theory) uniformly distributed among all gray levels.

(i) T(r) is a monotonically increasing function for $0 < r < 1$ (preserves order from black to white).

(ii) T(r) maps [0,1] into [0,1] (preserves the range of allowed Gray values). So the grey levels for continuous variables can be characterized by their probability density functions p(r) and p(s). The probability density of the transformed grey level is $P(s) = P(r)\frac{dr}{ds}$ (1)

To find a transformation, Let us consider the Cumulative Density Function (CDF), which is obtained by simply adding up all the Probability density functions (PDF) $S = T(r) = \int_0^r P(r)dr;$; $1 \geq r \geq 0$; (2)

$P(s) = [1] = 1$; $1 \geq s \geq 0$;

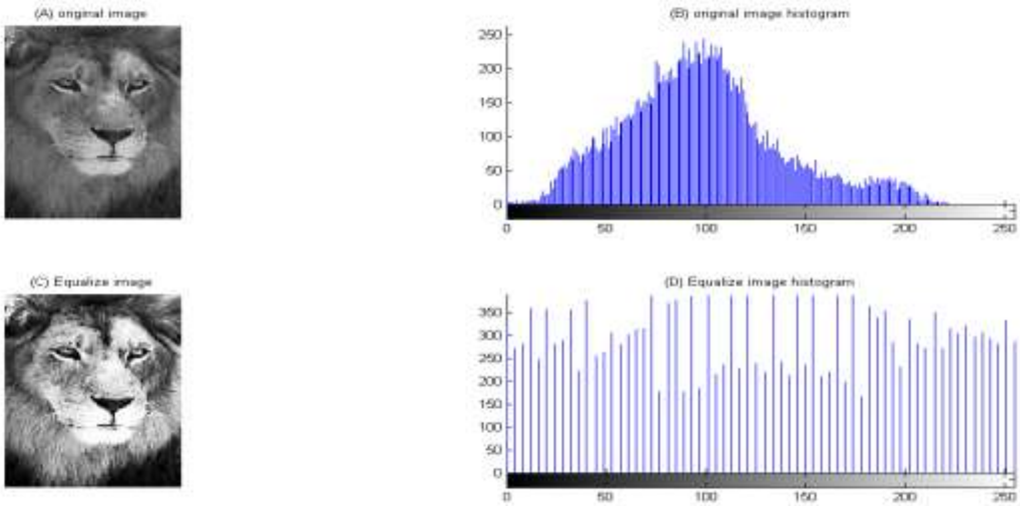

Fig.2 Histogram equalization for High contrast image

Drawback of Histogram Equalization:

- Change the mean brightness of the image.
- Natural look of image may be lost.
- Original image color change's from white to black.

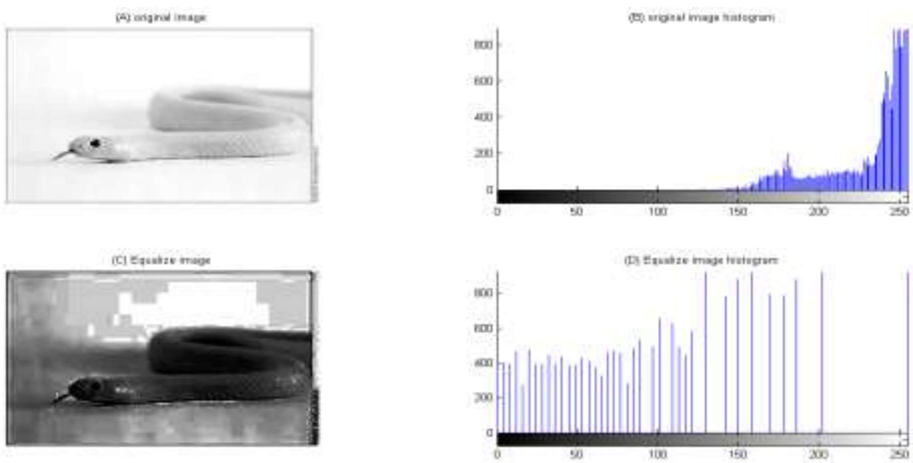

Fig.3 Snake color changes from white to black after histogram equalization.

3. Histogram specification (Histogram Matching):

Histogram equalization yields an image whose pixels are (in theory) uniformly distributed among all gray levels. Sometimes, this may not be desirable. Instead, we may want a transformation that yields an output image with a pre-specified histogram. This technique is called **histogram specificatio**n. Given information are, Input image from which we can compute its histogram and desired histogram. With the help given information derive a point operation, that maps the input image into an output image that has the user-specified histogram.

4. Bi-Histogram Equalization (BBHE):

Let X_m is the mean of image X and the input image is decomposed into two sub-images X_L and X_U by its mean. Where, $X=(X_L \cup X_U)$ $X_L=\{X(i , j) < X_m\}$; $X_U=\{X(I , j)>X_m\}$;while X_L is composed of $\{X_0 , X_1 ,....X_m\}$ and X_U is composed of $\{X_{m+1} , X_{m+2} ,....X_{L-1}\}$ hence the Transform functions are $f_L(X)=X_0+(X_m-X_0)\, C_L(x)$; (3)

$f_U(x)=X_{m+1}+(X_{L-1}-X_{m-1})\, C_U(x)$; (4)

Where $C_L(x)$ and $C_U(x)$ are cumulative density functions for X_L and X_U respectively.

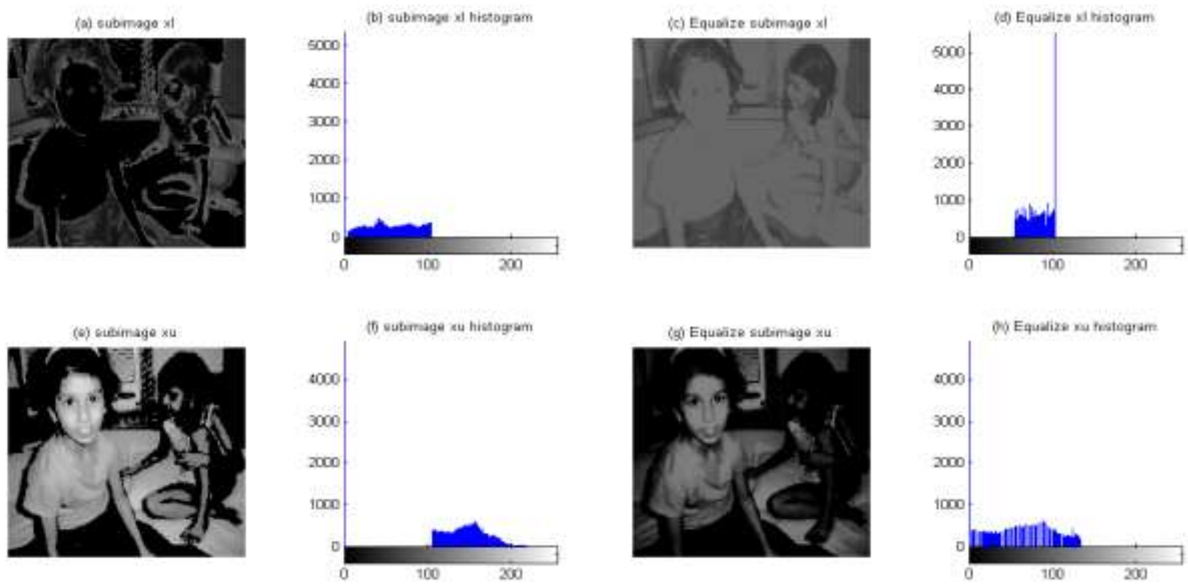

Fig.4 Mean-based separated images and their equalize histogram

5. DSIHE (Dualistic sub-image histogram equalization):

In this method separating level of histogram is the median of the input image. Which provide maximum entropy after two independent sub-equalization? Both BBHE and DSIHE is similar except that DSIHE choose to separate the histogram based on gray level with cumulative probability density equal to 0.5 instead of the mean as in BBHE.

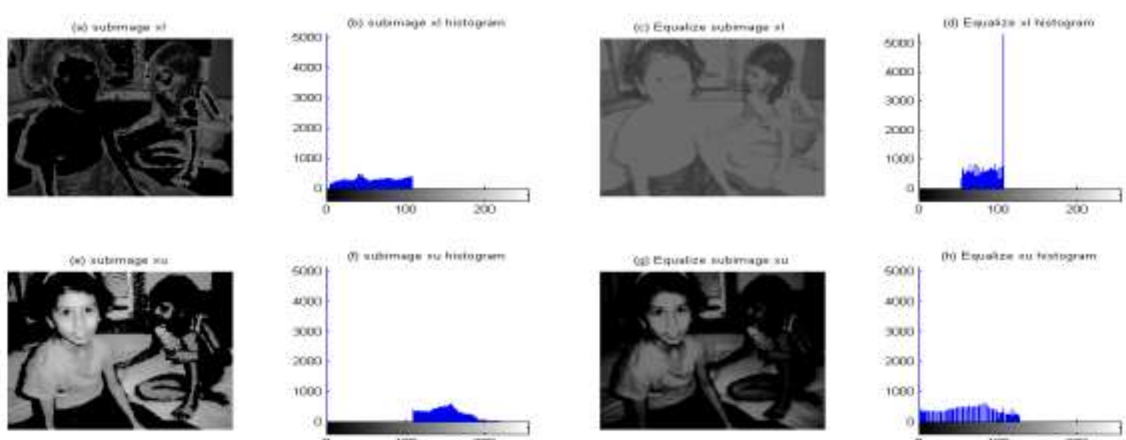

Fig.5 Median-based separated images and their equalize histogram.

6. Entropy (Information)

The differential entropy h(X) of a continuous random variable X with a density f(x) is defined as

$$h(x) = -\int_{S} f(x) \log f(x) dx \quad (5)$$

Here S is the support set of the random variable. *h(x)* is also named as the continuous variable's entropy [4].

7. Gaussian smoothening Filter:

Gaussian filters are a class of linear smoothing filter with the weight chosen according to the shape of a Gaussian function. The Gaussian kernel is widely used for smoothing purpose. The Gaussian filter in the continuous space is

$$h(m, n)=\left[\frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-m2}{2\sigma^2}}\right] * \left[\frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-n^2}{2\sigma^2}}\right] \quad (6)$$

This shows that Gaussian filter is separable, rotationally symmetric in two dimensions and Fourier transform of a Gaussian function is itself a Gaussian function. Fourier transform of a Gaussian has a single lobe in the frequency spectrum. Images are corrupted by high –frequency noise, and the desirable feature of the image will be distributed both in the low-and-high frequency spectrum. The single lobe in the F.T of a Gaussian means that the smoothened image will not be corrupted by contributions from unwanted high-frequency signals, while most of the desirable signal properties will be retained. The degree of smoothing is governed by variance (σ). A larger variance implies a wider Gaussian filter and greater smoothening. Here a spatial image processing is used to blur image and to remove noise from a image. Blurring is used in the pre-processing stage.

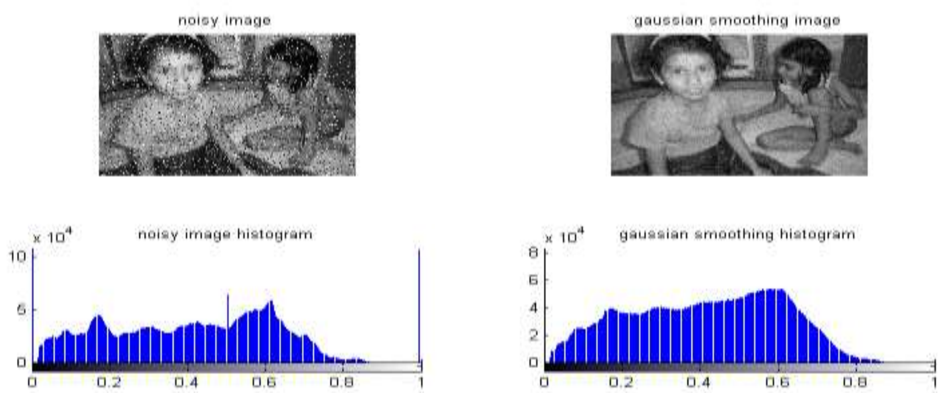

Fig.6 Gaussian smoothing image and its Histogram.

8. BPHEME: Brightness Preserving Histogram Equalization with Maximum Entropy based Histogram specification:

HE is to make the output histogram as flat as possible. A superficial reason for HE relies on that a flat histogram makes all the gray levels uniform, and thus will cause a more comfortable perception. A further comprehension is that a uniform distribution limited to a given range gives the maximum information, measured by entropy, so we would like to find an "ideal" histogram (PDF) as a target one to perform the histogram specification. That ideal histogram preserves the mean brightness of the input image, and has the maximum entropy [4]. Thus an optimal brightness preserving enhancement method using histogram transformation may be to maximize the target histogram's entropy under the constraints of brightness. Mathematically speaking, we want to maximize *h*(*f*) over all probability densities *f* subject to some constraints:

$$\max\ f\{-\int_s f(s)\log f(s)ds\} \text{ such that } \begin{cases} f(s) \geq 0; \\ \int_s f(s) = 1; \\ \int_s sf(s)ds = \mu r \end{cases}$$

Now using Lagrange multiplier expression

$$J(f) = [-\int_s f(s)\log f(s)ds] + \lambda 1[\int_0^1 f(s)ds - 1] + \lambda 2[\int_0^1 sf(s)ds - \mu r] \quad (7)$$

$$\text{Now } \frac{\partial j(f)}{\partial f(s)} = 0; \quad f(s) = e^{(\lambda 1-1)}.e^{(s*\lambda 2)} \quad (8)$$

Now from constraint (2) and eq.(8) ;

$$f(s) = \frac{\lambda 2}{(e^{(\lambda 2)}-1)}.e^{(s.\lambda 2)} \quad (9)$$

$$\mu r = \frac{(\lambda 2.e^{(\lambda 2)}-e^{(\lambda 2)}+1)}{\lambda 2.(e^{(\lambda 2)}-1)} \quad (10)$$

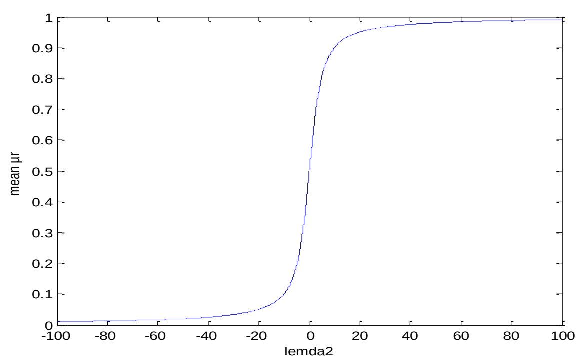

Fig.7 Plot between mean (μr) and lemda2 ($\lambda 2$)

$$\lim_{\lambda 2\to 0} f(s) = \lim_{\lambda 2\to 0}\left[\frac{\lambda 2}{(e^{(\lambda 2)}-1)}.e^{(s.\lambda 2)}\right]$$

$$= \lim_{\lambda 2\to 0}\left[\frac{(s.\lambda 2.e^{(s.\lambda 2)}+e^{(s.\lambda 2)})}{e^{(\lambda 2)}}\right] = 1; \quad (11)$$

$$\lim_{\lambda 2\to 0} \mu r = \lim_{\lambda 2\to 0}\left[\frac{(\lambda 2.e^{(\lambda 2)}+e^{(\lambda 2)})}{(\lambda 2.e^{(\lambda 2)}+e^{(\lambda 2)}+e^{(\lambda 2)})}\right] = 0.5;$$

$$\text{Hence } f(s) = \begin{cases} 1, & \mu r = 0.5 \\ \frac{\lambda 2}{(e^{(\lambda 2)}-1)}.e^{(s.\lambda 2)}, & \mu r \in (0, 0.5)U(0.5, 1) \end{cases} \quad (12)$$

Thus we have cumulative histogram, or cumulative distribution ,

$$C(s) = \int_0^s \frac{\lambda 2}{(e^{(\lambda 2)}-1)}.e^{(t.\lambda 2)}\ d(t) \quad (13)$$

$$C(s) = [\frac{e^{(s.\lambda 2)}-1}{(e^{(\lambda 2)}-1)}] \quad (14)$$

Thus we have the cumulative histogram, or cumulative distribution function, c(s) as following.

$$C(s) = \begin{cases} s, & \mu r = 0.5 \\ \frac{e^{(s.\lambda 2)}-1}{(e^{(\lambda 2)}-1)}, & \mu r \in (0, 0.5)U(0.5, 1) \end{cases} \quad (15)$$

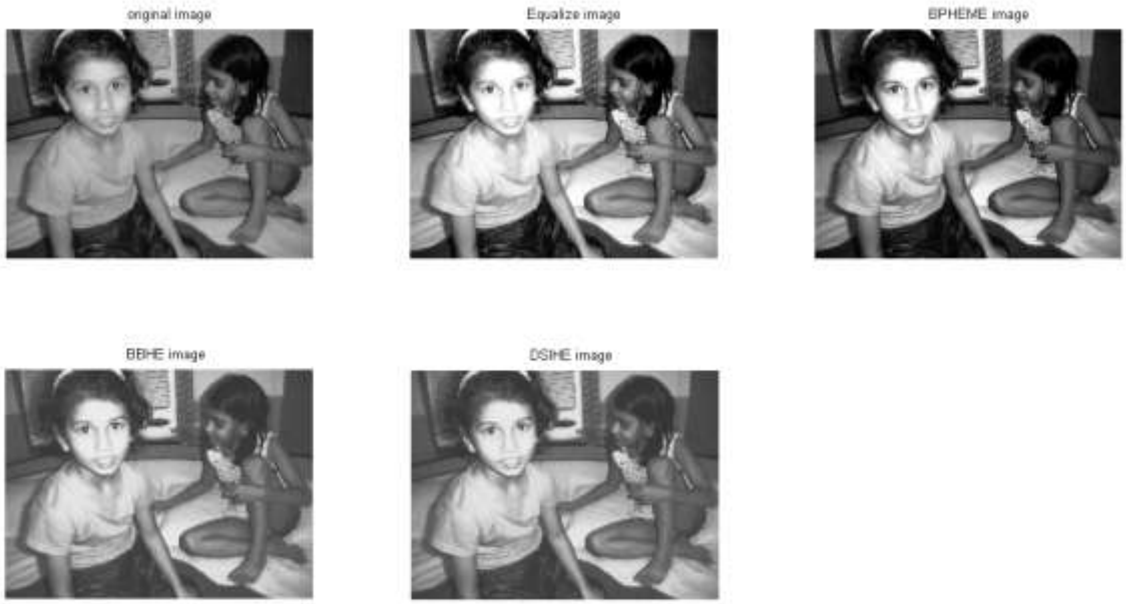

Fig.8 Image (DS03987) by using HE, BPHEME, BBHE , DSIHE method.

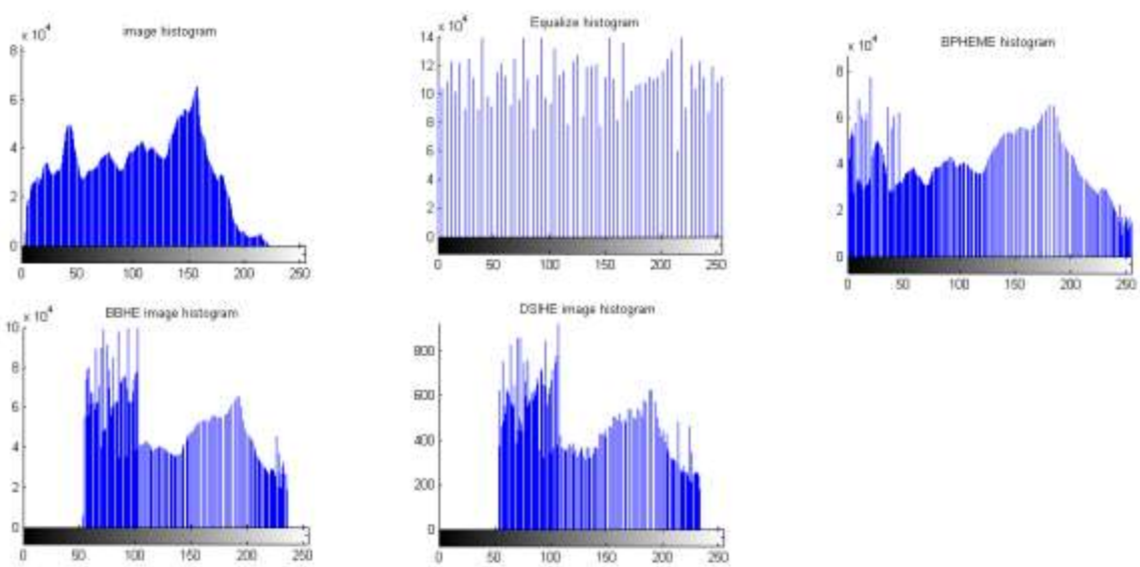

Fig.9 Histogram of image (DS03987) by using HE, BPHEME, BBHE, DSIHE method

9. Mean (Image Brightness):

The mean of a discrete random variable x is given by taking the product of each possible value of x and its probability *P(x)*, and then adding all these products together, giving $\mu = \sum x * P(x)$

10. Entropy (Information):

$H = -\sum_{i=0}^{256} P(i) * \log 2(P(i))$. Where *p(i)* is the probability of occurrence of gray level (i).

11. Peak-signal-to-noise-ratio (PSNR):

PSNR is the evaluation standard of the reconstructed image quality, and is important measurement feature. PSNR is measured in decibels (dB) and is given by: PSNR= 10 log (255^2 /MSE).where the value 255 is maximum possible value that can be attained by the image signal. Mean square error (MSE) is defined as Where (m*n) is the size of the original image. Higher the PSNR value is, better the reconstructed image is.

12. Visual Quality:

By looking at the enhanced image, one can easily determine the difference between the input image and the enhanced image and hence, performance of the enhancement technique is evaluated.

Results of test image:

Table.1 Mean

Images	ORIGINAL (MEAN)	HE (MEAN)	BBHE (MEAN)	DSIHE (MEAN)	BPHEME (MEAN)
DS03987	104.0286	127.5565	126.9356	126.1309	103.2234

Table.2 Entropy (bits/pixel)

IMAGES	**ORIGINAL IMAGE (ENTROPY)**	**HE (ENTROPY)**	**BBHE (ENTROPY)**	**DSIHE (ENTROPY)**	**BPHEME (ENTROPY)**
DS03987	7.5872	5.9832	7.0231	7.0238	7.4172

Table.3 Peak signal to noise ratio

IMAGE	**HE/PSNR(db)**	**BBHE/PSNR(db)**	**DSIHE/PSNR(db)**	**BPHEME/PSNR(db)**
DS03987	17.7970	19.5378	19.8126	20.9872

CONCLUSION:

BPHEME technique was proposed that specifies a histogram automatically. The method runs in 2.796 by using a 1.19 GHz PC computer and produce satisfactorily enhance images.

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