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Histogram Equalization Based Image Enhancement Techniques For Brightness Preservation And Contrast Enhancement

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Abstract
Histogram Equalization is a contrast enhancement technique in the image processing which uses the histogram of image. However histogram equalization is not the best method for contrast enhancement because the mean brightness of the output image is significantly different from the input image. There are several extensions of histogram equalization has been proposed to overcome the brightness preservation challenge. Contrast enhancement using brightness preserving bi-histogram equalization (BBHE) and Dualistic sub image histogram equalization (DSIHE) which divides the image histogram into two parts based on the input mean and median respectively then equalizes each sub histogram independently. This paper provides review of different popular histogram equalization techniques and experimental study based on the absolute mean brightness error (AMBE), peak signal to noise ratio (PSNR), and contrast.

Keywords
Histogram Equalization, Contrast Enhancement, Brightness Preservation, Absolute Mean Brightness Error, Peak Signal to Noise Ratio

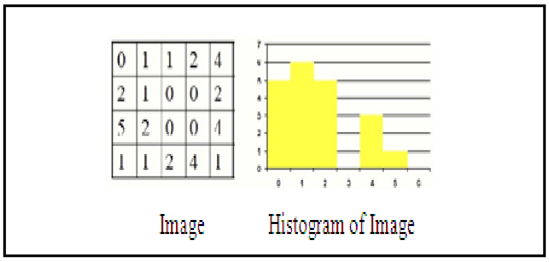
I. Introduction

Image enhancement is aprocess of changing the pixels intensity of the input image;to make the output image subjectively look better. Contrast enhancement is an important area in image processing for both human and computer vision. It is widely used for medical image processing and as a pre-processing step in speech recognition, texture synthesis, and many other image/video processing applications. Contrast enhancement plays a crucial role in image processing applications, such as digital photography, medical image analysis, remote sensing, LCD display processing, and scientific visualization. There are several reasons for an image/ video to have poor contrast: the poor quality of the used imaging device, lack of expertise of the operator and the adverse external conditions at the time of acquisition. These effects result in under-utilization of the offered dynamic range. As a result, such images and videos may not reveal all the details in the captured scene and may have a washed out and unnatural look. Contrast enhancement targets to eliminate these problems, thereby to obtain a mor visually-pleasing or informative image or both. Histogram equalization is a well-known contrast enhancement technique due to its performance on almost all types of image. Contrast is created by the difference in luminance reflectance from two adjacent surfaces. In our visual perception, contrast is determined by the difference in the color and brightness of an object with other objects. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to enhance the contrast of an image in order to represent all the information in the input image.Brightness preserving methods are in very high demand to the consumer electronic products. Numerous histogram equalization (HE) based brightness preserving methods tend to produce unwanted artefacts.

In spite of fundamental advantage in histogram equalization, it has a significant drawback of changing the brightness globally, which results in either under-saturation or over-saturation of important regions. Due to this reason, for the implementation of contrast enhancement in consumer electronic products it is advised that the loss of intensity values by the histogram processing should be minimized in the output image. The first challenge of modified histogram has been proposed by Kim, in 1997 using bi-histogram equalization (BHE) technique. In this paper, histogram equalization based bi-histogram equalization, multi-histogram equalization.

II. Histogram Equalization

The histogram is a graph showing the number of pixels in an image for each intensity level in the image. For an 8 bit greyscale image there are 0-255 intensity levels so the histogram will graphically display 0-255 numbers on X-axis and number of occurrences of an intensity level in image correspondingly.



The horizontal axis of the histogram represents the tonal variations, while the vertical axis represents the number of pixels in that particular tone. The left side of the horizontal axis represents the black and dark areas, the middle represents medium grey and the right hand side represents light and pure white areas.

Definition :

Suppose X =(,) denotes a given image composed of L intensity levels denoted as $\{X_0, X_{1,\ldots,} X_{L-1}\}$, where X (i, j) represents an intensity of the image at the spatial location (i, j) and X (i, j) $\{Xo, X_i, \ldots, X_{L-1}\}$, for a given image X, the probability density function p (X_k) is defined as: -

$$p(X_K) = \frac{n^k}{n}$$

For k= 0,1,…, L-I, where n_k represents the number of times that the level X_k appears in the input images X and n is the total number of

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pixels in the input image. Where $p(X_k)$ is associated with the histogram of the input image which represents the number of pixels that specifics intensity X_k. In fact, a plot of n_k vs. X_k is known as the histogram of X. based on the probability density function, we can define the cumulative density function as

$$c(x) = \sum_{j=0}^{k} p(X_j)$$

where k= 0, 1,...., L-I. Note that $c(X_{L-I})= 1$ by definition. Histogram equalization is a scheme that maps the input image into the entire dynamic range, (X_o, X_{L-I}), by using the cumulative density function as a transform function. A transform function f(x) is based on the cumulative density function as

$$f(x)= X_o + (X_{L-I} - X_o) \times c(x)$$

Then the output image of the histogram equalization, Y= {Y(i,j) }, can be expressed as

Y= f(X)

={f(X(i,j)) | for all X(i,j) ϵ X}

HE can introduce a significant change in brightness of an image, and therefore, the direct application of HE scheme in consumer electronics is not suitable, for instance, show original image and the resultant equalized image of warplaneplane that are composed of 256 gray levels. If we observe the equalized image then we find that unnatural enhancement has occurred in most part of the images is much darker than the input image.This is a direct consequence of the excessive changes in brightness by HE.

III. Proposed Methodology

A. Bi-histogram equalization (BBHE METHOD)

The BBHE firstly decomposes an input image into two sub image based on the mean of the input images. One of the sub images is the set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub images independently based on their respective histograms with the constraint that the samples in the formal set are mapped into the ranges from the minimum gray level to the input mean and the samples in the latter set are mapped into the ranges from the mean to the maximum gray level. In other words, one of the sub images is equalized over the range up to the mean, based on the respective histogram. Thus, the resulting equalized sub images are bounded by each other around the input mean, which has an effect of preserving mean brightness.

Definition

Let X= {X (i, j)} denote a given image composed of L intensity levels denoted as

{ Xo, X1, ……, X L-I }, where X(i, j) represents an intensity of the image at the spatial location

(i, j) and X (i, j) ϵ {X0,X1,…..XL-I} and Xm denote the mean gray level of the image X. Based

on the mean, the input image is decomposed into two sub images XLand XU as –

X= XL ∪ XU

where

XL= {X(i, j) |X(i,j) ≤ Xm ,∀ X(i,j) ϵ X}

and

XU= {X(i,j) |X(i,j) > Xm , ∀ X (i,j) ϵ X}

where sub image XL is a set of {XO, X1, X2,……Xm} gray levels and the other sub image XU is

a set of {Xm+1, Xm+2, ……, X L-1}gray levels. Probability density functions of the sub image XL

and XU is-

$$p_L(X_k) = \frac{n_L(k)}{n_L} \qquad \text{where K= 0,1.......,m.}$$

And

$$p_U(X_k) = \frac{n_U(k)}{n_U} \qquad \text{where k= m+1, m+2......,L-1}$$

where nL(k) and nU(k) represent the respective numbers of XK gray level in sub image XL, and

sub image XU, and nU represent the total numbers of pixels in sub images XL and XU

respectively. Here

$$n_L = \sum_{k=0}^{m} n_L(k)$$

and

$$n_U = \sum_{k=m+1}^{L-1} n_U(k)$$

The respective cumulative density functions for sub image XL and sub image XU are defined

As-

$$c_L(X_k) = \sum_{j=0}^{k} p_L(X_j)$$

$$c_U(X_k) = \sum_{j=0}^{k} p_U(X_j)$$

where cL(Xm) = 1 and cU (X L-I) = 1 by definition

The transfer function of each sub images is defined by cumulative density function

i.e.-

fL(x) = X0 + (Xm- Xo) cL(x)

fU(x) = Xm+1 + (X L-1 – X m+1) cU(x)

Based on these transformation functions, the decomposed sub images are equalized

independently and both equalized sub images on combining together gives output of the

BBHE. That is finally expressed as

Y = {Y (i, j)} = fL(XL) ∪ fU(XU)fL(XL)

equalizes the sub images XL over the range (X0,XU) whereas fU(XU) equalizes the sub images XU over the range (Xm+1, XL-I) whereas fU(XU) equalizes the sub images XU over the range (Xm+1, XL-1). As a consequence, the input image X is equalizes over the entire dynamic range (X0, XL-1) with the constraint that the samples less than the input mean are mapped to (X0, Xm) and the samples greater than the mean are mapped to (Xm+1, X L-I)

B. Dual Subimage He (DSIHE)

In this method the original image is decomposed into two equal area sub-images based on its gray level cumulative density function. Then the two sub- images are equalized respectively. At last, we get the result after the processed sub-images are composed into one image.

Algorithm of Dualistic sub-image Histogram Equalization:

Suppose image X is separated with gray level of X= Xe, and the two sub-images are XL andXU, so we have X= XL ∪ XU, Here-

XL= {X (i, j) | X (i, j) < Xe, ∀ X (i, j) ϵ X}

XU= {X (i, j) | X (i, j) ≥ Xe, ∀ X (i, j) ϵ X}

where Xe has cdf 0.5

Here sub-image XL is composed of gray level {X0, X1, ………, X e-1}, while sub-image XU is composed of gray level {Xe, Xe+1, ….., XL-1}.The original probability distribution is decomposed into PL(Xk) where k =0, 1….e-1 and PU(Xk) where k = Xe, Xe+1…..L-I correspondingly. Probability density functions, cumulative distribution functions and the transform function are obtained.The result of the dualistic sub-image histogram equalization is obtained after the two equalized sub images are combined into one image. Suppose Y is the output image, then-

Y = {Y (i, j)} = fL(XL) ∪ fU(XU)

fL (XL) = {fL(X (i,j)) | ∀ X (i,j) ϵ XL}

fU(XU) = {fU(X (i,j)) | ∀ X (i,j) ϵ XU}

Namely Y (i,j) = { Xo + (Xe-1 - Xo) cL(X)}, if X< Xe

{Xe+ (XL-I- Xe) CU (X), otherwise

C. Weighted Threshold Histogram Equalization

The WTHE performs histogram equalization based on a modified histogram which is modified by using weighted threshold pwt(k) instead of original pdf

$$p(k)=\frac{nk}{n}$$

where nk is the number of pixels having intensity level k and n is the total number of pixels in the image. The weighted pdf is given as

$$P_{wt}(k) = \begin{cases} p_u & if\ p(k) > p_u \\ \left(\frac{p(k) - p_l}{p_u - p_l}\right)^r \times p_u & if\ p_l \le p(k) \le p_u \\ 0 & if\ p(k) < p_l \end{cases}$$

where pu = 0.5 × pmax and pl = 0.0001× pmax This pwt(k) is used in calculating cdf using equation.Then this cdf is used intransformation function given in equation.The weighted pdf limits the original pdf at an upper threshold pu and a lower threshold pl and transform all values between pl and pu The power index r controls the level of enhancement. When r < 1, more dynamic range is allocated to the less probable levels and when r >1, the levels with high probabilities (e.g.background) are enhanced.

Bi- Histogram Equalization with a Plateau Limit (BHEPL)

Histogram equalization (HE) stretches the contrast of high histogram regions and compresses the contrast of low histogram regions. so, when the object of interest in image occupies a small portion of image , then this object (region) will not be properly enhanced by histogram equalization and also the high histogram regions saturates the image. So, to remove this problem high histogram regions are clipped to a threshold value (plateau limit) to limit the enhancement rate. We know that enhancement in histogram equalization is dependent on cdf c(x). the rate of enhancement is proportional to rate of cdf c(x).

$$cdf = \int pdf$$

$$\frac{d}{dx}(cdf) = pdf = p(x)$$

We know that,

Therefore, rate of enhancement is dependent on p(x) or number of intensity occurrence. So, enhancement rate can be controlled by limiting the value of p(x) or histogram.

BHEPL method

The first step is same as BBHE i.e. decomposing the image X in two sub-images XL and XU on the basis of mean of image Xm .

So, X = XL ∪ XU

where XL = _X (i,j) |X(i,j) ≤Xm, ∀ X(i,j) ∈ X

and XU = _X(i,j) |X(i,j) >Xm, ∀ X(i,j) ∈ X

which means XL is composed of intensities X0,X1,X2………,Xm and XU is composed of intensities Xm+1,Xm+2,…………,XL-1

The histogram created from XL is denoted as hl and the histogram created from XU is denoted as hU.

The two plateau limits TL and TU for XL and XU respectively are calculated as

$$T_L = \frac{1}{X_{m+1}} \sum_{k=0}^{Xm} hl(k)$$

And

$$T_U = \frac{1}{(L-1) - X_m} \sum_{k=X_{m+1}}^{X_{L-1}} hu(k)$$

The plateau limits are average of number of intensity occurrence in respective subhistogram.

The sub-histograms are clipped using TL and TU and denoted as hCL and hCU such as

hCL(x) = hL(x) if hL(x) ≤ TL

TL otherwise

And

hCU(x) = hU(x) if hU(x) ≤ TU

TU otherwise

Probability density function (pdf) is calculated for each intensity level in both clipped sub-histograms.

PCL(XK)= hCL(XK)/M1 for k= 0,1,2,……….,m

PCU(XK) = hCU(XK)/M2 for k= m+1,m+2…………, L-1

where, M1 is number of pixels in XL and M2 is number of pixels in XU.

Then respective cdf for XL and XU are calculated as

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$$C_L(x) = \sum_{j=0}^{m} P_{CL}(X_j)$$

$$C_U(x) = \sum_{j=m+1}^{L-1} P_{CU}(X_j)$$

These cdf are used in transformation function for histogram equalization
fL(x) = X0 + (Xm-X0)[CL(x)-0.5PCL(x)]
fU(x) = Xm+1 + (XL-1 -Xm+1)[CU(x)-0.5PCU(x)]

Gamma Correction

Using the transformation function $s = cr^{\Upsilon}$
which is also called as Gamma Correction,
for various values of $^{\Upsilon}$ different levels of enhancements can be obtained. Gamma correction
technique can be employed using a gamma correction function T (l) for intensity of each
pixel in image X,

$$T(l) = l_{max}(l/l_{max})^{\Upsilon}$$

Lmax is maximum intensity of input image and l is the intensity level of a pixel which is being transformed and ϒ is a parameter. Now when the contrast is modified by gamma correction with fixed parameter than the all the images will exhibit the same changes. Therefore, we must have to include some constraint from input image into parameter so that the output image depend on input image and this way the parameter which we get is called as Adaptive parameter.

Adaptive Gamma Correction with Weighting Distribution (AGCWD)

To remove the above mentioned problem AGCWD is introduced which uses pdf of
input image in calculating adaptive parameter ϒ but it does not use pdf as it is, it makes some
changes in pdf and calls it weighted pdf. This weighted pdf modifies the original histogram
and lessen the generation of aderse effects. The weighted pdf is calculated as

$$pdf_w(l) = pdf_{max}\left(\frac{pdf(l) - pdf_{min}}{pdf_{max} - pdf_{min}}\right)^{\alpha}$$

where α is the adjusted parameter, we have taken it as 1, pdfmax is the maximum pdf of original histogram and pdfmin is the minimum pdf . The modified cdf is calculated by using weighted pdf

$$cdf_w(l) = \sum_{l=0}^{l_{max}} \frac{pdf_{w(l)}}{\Sigma pdf_w}$$

where the sum of pdfw is calculated as

$$\Sigma pdf_w = \sum_{l=0}^{l_{max}} pdf_{w(l)}$$

Finally, the adaptive gamma parameter is calculated on the basis of equation

ϒ = 1 - cdfw(l)

Then this ϒ is used in transformation function

$$T(l) = l_{max}(l/l_{max})^{\Upsilon}$$

(a) Original image of warplane

(b) AGCWD image of warplane

Absolute Mean Brightness Error (AMBE)

An objective measurement is proposed to rate the performance in preserving the original brightness. It is stated as Absolute Mean Brightness Error (AMBE). It is defined as the absolute difference between the mean of the input and the output images and is proposed to rate the performance in preserving the original brightness.

$$AMBE=|E(\boldsymbol{X})-E(\boldsymbol{Y})|$$

X and Y denotes the input and output image, respectively, and E (.) denotes the expected value, *i.e.*, the statistical mean. Lower AMBE indicates the better brightness preservation of the image. Equation (1) clearly shows that AMBE is designed to detect one of the distortions–excessive brightness changes.

Peak Signal-to-Noise Ratio (PSNR)

Let, X(i,j) is a source image that contains M by N pixels and a reconstructed image Y(i,j), where Y is reconstructed by decoding the encoded version of X(i,j). In this method, errors are computed only on the luminance signal; so, the pixel values X(i,j) range between black (0) and white .First, the mean squared error (MSE) of the reconstructed image is calculated as;

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[X(i,j)-Y(i,j)]^2}{M \times N}$$

The root mean square error is computed from root of MSE. Then the PSNR in decibels (dB) is computed as;

$$PSNR = 20log_{10}(\frac{Max(Y(i,j))}{RMSE})$$

Greater the value of PSNRbetter the contrast enhancement of the image.

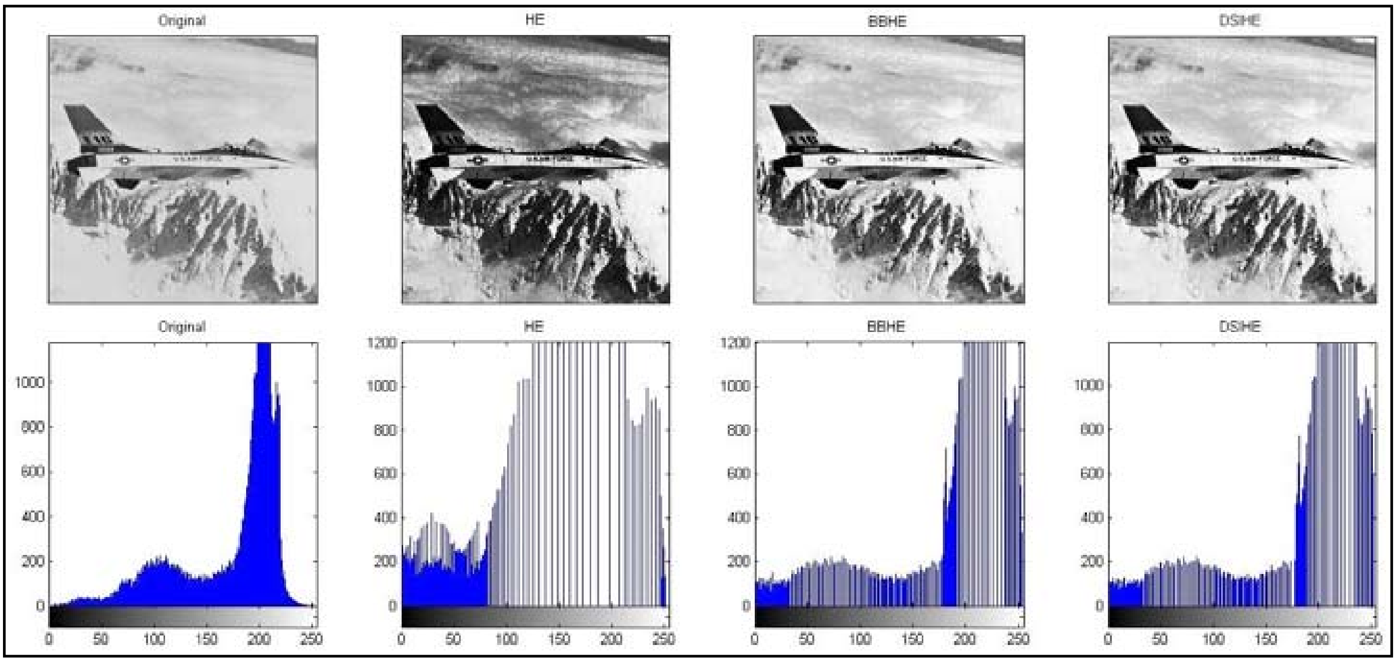

Fig. A: (a)original image, (b)Image using HE method, (c)Image using BBHE method, (d)Image using DSIHE method, (e)original image Histogram, (f)HE method histogram, (g)BBHE method histogram, (h)DSIHE method histogram

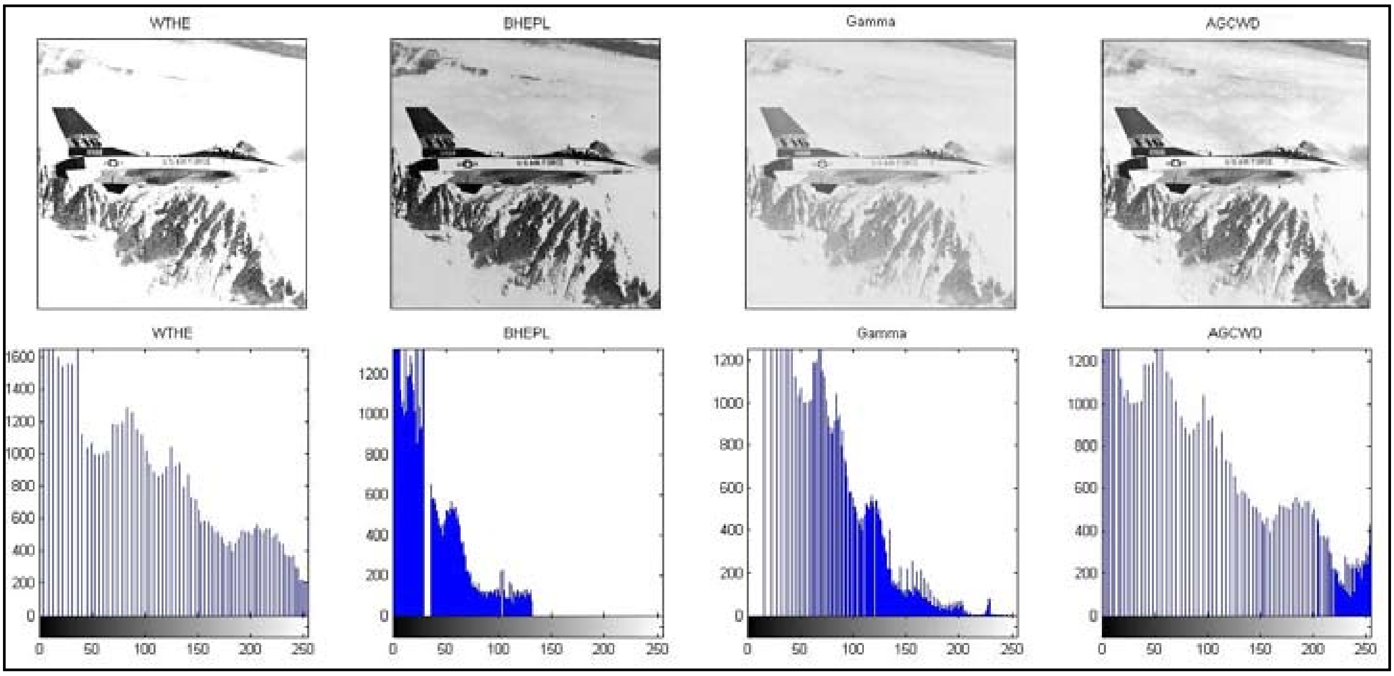

Fig. B: (a)Image using WTHE method (b)Image using BHEPL method (c) Image using Gamma method(d) Image using AGCWD method(e) WTHE method histogram (f) BHEPL method histogram (g) Gamma method histogram (h) AGCWD method histogram.

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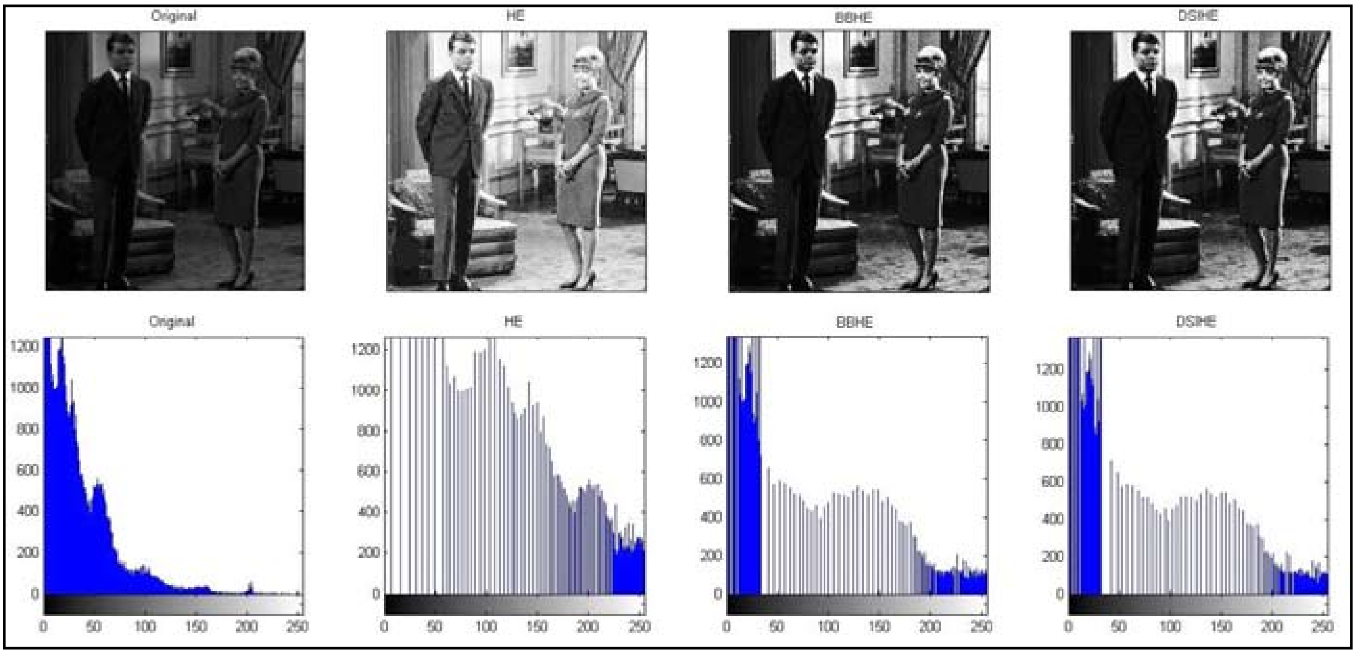

Fig. C: (a)original image, (b)Image using HE method, (c)Image using BBHE method, (d)Image using DSIHE method, (e)original image Histogram, (f)HE method histogram, (g)BBHE method histogram, (h)DSIHE method histogram

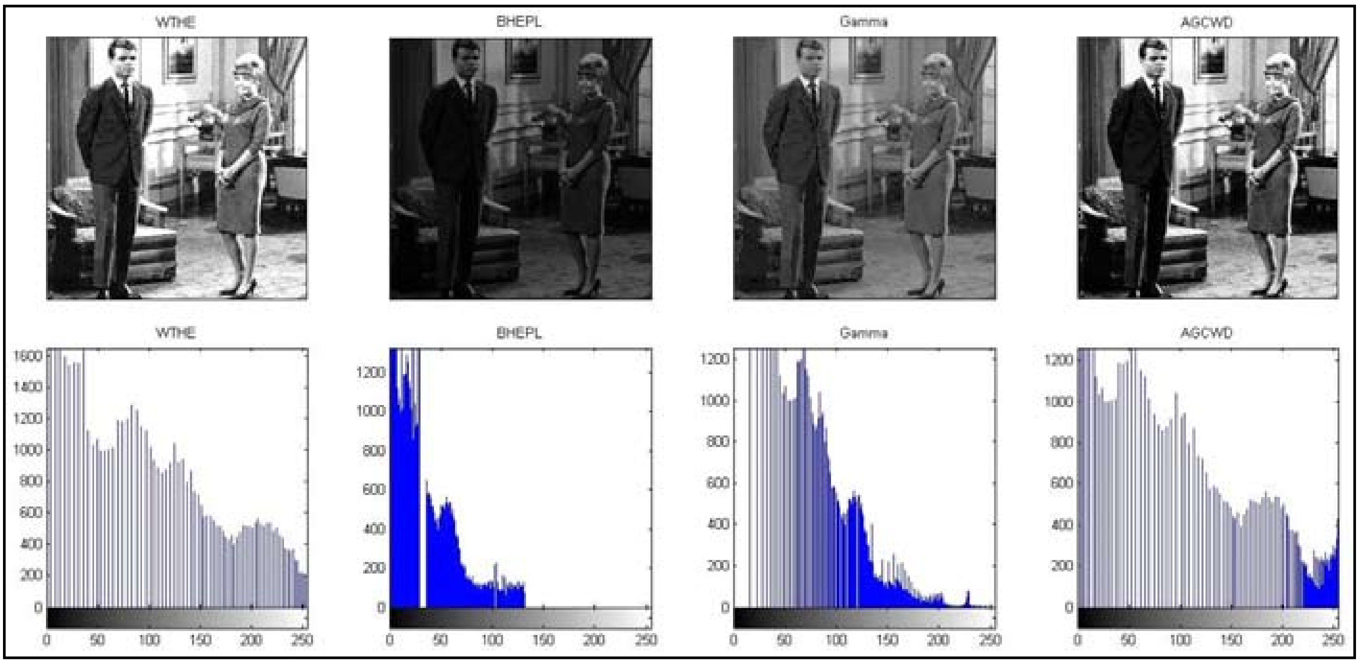

Fig. D: (a)Image using WTHE method (b)Image using BHEPL method (c) Image using Gamma method(d) Image using AGCWD method(e) WTHE method histogram (f) BHEPL method histogram (g) Gamma method histogram (h) AGCWD method histogram.

Table1: Parameters For Cople Image:

METHOD	AMBE	PSNR	CONTRAST
ORIGINAL	0	Inf.	27.291
HE	92.743	15.764	63.825
BHHE	31.144	27.306	59.281
WTHE	90.734	15.157	72.816
DSIHE	33.096	26.269	61.206
BHEPL	1.6368	63.235	25.195
GAMMA	47.414	28.375	39.872
AGCWD	63.47	19.767	68.837

Table 2: Parameters For Warplane Image:

METHOD	AMBE	PSNR	CONTRAST
ORIGINAL	0	Inf.	40.671
HE	55.415	23.336	70.699
BHHE	3.0537	44.738	58.777
WTHE	37.793	30.299	51.82
DSIHE	3.3541	44.755	58.572
BHEPL	20.396	37.92	51.407
GAMMA	26.488	36.738	26.851
AGCWD	18.191	45.06	44.879

IV. Conclusion

The present paper gives the review of existing histogram-based contrast enhancement techniques for brightness preserving and contrast enhancement. Bi-histogram equalization methods such as BBHE, DSIHE.Clipped Histogram equalization methods such as GC-HE and BHEPL techniques are compared with Image Quality Measurement (IQM) tools such as absolute mean brightness error (AMBE) and peak signal-to-noise ratio (PSNR) and contrast. All the techniques have overcome the drawbacks of histogram equalization and have shown a better brightness preserving and contrast enhancement than HE. For BBHE, DSIHE methods, the contrast of the images is improved, but the problem of the intensity saturation occurs in some regions of the image as well and also presented stimulated amplification of noise in the output image. All these techniques show brightness preserving DHE methods have shown good brightness preserving as well as a controlled over-enhancement, but introduced annoying noise in the output image. BHEPL technique has also shown good brightness preserving except bright images. GC-HE techniques are more suitable for consumer electronic products where preserving the original brightness is essential.

References

[1] *Chao Zuo, Qian Chen, Xiubao Sui, and Jianle Re., "Brightness Preserving Image Contrast Enhancement using Spatially Weighted Histogram Equalization", The International Arab Journal of Information Technology, Vol. 11, No. 1, January 2014*

[2] *S.S. Bedi,Rati Khandelwal., "Various Image Enhancement Techniques- A Critical Review", International Journal of Advanced Research in Computer and Communication Engineering, Vol. 2, Issue 3, March 2013.*

[3] *Miss. Ankita sharma ,Prof. Rekha sharma., "IMAGE ENHANCEMENT OF GRAY AND COLOR IMAGES USING IMAGE FUSION METHOD", International Journal of Advanced Research in Electronics and Communication Engineering (IJARECE) ,Volume 3, Issue 9, September 2014.*

[4] *S.Gayathri,N.Mohanapriya,Dr.B.Kalaavathi., "Survey on Contrast Enhancement Techniques", International Journal of Advanced Research in Computer and Communication Engineering,Vol. 2, Issue 11, November 2013.*

[5] *Manvi,Rajdeep Singh Chauhan. Manpreet singh," IMAGE CONTRAST ENHANCEMENT Using HISTOGRAM EQUALIZATION", International Journal of Computing & Business Research ,2012.*

[6] *Seema Rajput, Prof.S.R.Suralkar., "Comparative Study of Image Enhancement Techniques", International Journal of Computer Science and Mobile Computing, Vol. 2,Issue.1, pg.11 – 21January 2013.*

[7] *Er. Mandeep Kaur, Er. Kiran Jain, Er Virender Lather., "Study of Image Enhancement Techniques: A Review", International Journal of Advanced Research in Computer Science and Software Engineering, Volume 3, Issue 4, April 2013.*

[8] *Dinesh Sonker, M. P. Parsai., "Comparison of Histogram Equalization Techniques for Image Enhancement of Grayscale images of Dawn and Dusk", International Journal of Modern Engineering Research (IJMER),Vol. 3, Issue. 4, Jul - Aug. 2013.*

[9] *Komal Vij, Yaduvir Singh., "Enhancement of Images Using Histogram Processing Techniques", Int. J. Comp. Tech. Appl., Vol 2 (2),JULY 2011.*

[10] *Pooja Kaushik and YuvrajSharma., "Comparison Of Different Image Enhancement Techniques Based Upon Psnr & Mse", International Journal of Applied Engineering Research, ISSN 0973-4562 Vol.7 No.11, 2012.*

[11] *Raman Maini and Himanshu Aggarwal., "A Comprehensive Review of Image Enhancement Techniques",Journal Of Computing ,VOLUME 2, ISSUE 3, MARCH 2010.*

[12] *https://en.wikipedia.org/wiki/Image_processing.*

[13] *https://en.wikipedia.org/wiki/Enhancement*

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