Enhanced Dynamic Quadrant Histogram Equalization Plateau Limit for Image Contrast Enhancement

Rizwan Khalid, Muhammad Rizwan Ali Kamran
GC University Faisalabad, Layyah Campus, Pakistan

***Abstract*:**
Consumer electronic devices require brightness preservation while image enhancement. Many of the histogram equalization techniques that have been introduced tend to strike out the mean image brightness while the process of enhancement is carried out. Hence, we suggest a method that enhances the image while keeping its brightness in a better form as compared to the former methods applied. Firstly, based on median value, the input image histogram is divided into sub-histogram and this process reprises until we have derived 8 sub-histograms. Further, the clipping of the histogram is implemented based on the average pixels in each sub-histogram. Then, each sub-histogram is assigned with a new dynamic range and finally customary histogram equalization is done independently on each sub-histogram. Proposed method is tested against conventional methods and results indicate that image mean brightness is preserved better than other methods while enhancing the image. The proposed method keep the brightness save of the original image while during the enhancement of the images. Many images has been taken from the SIPI database and applied the proposed method for the contrast enhancement of the low contrast images and results are improved. The major problem is to keep the brightness of the low contrast image preserve. The proposed technique has dealt with brightness preservation of the images.
Keywords- Clipped Histogram Equalization, Sub-histogram Equalization, EDQHEPL, Plateau Limit Equalization, Dynamic Histogram Equalization, Brightness Perserving Image Enhancement

INTRODUCTION :

Histogram Equalization [1] is a famous technique to convert low contrast images into high contrast images. This involves calculating input image probability density function (pdf). This is followed by calculating the cumulative density function (cdf) of the original image. Finally, this cdf acts as a mapping function to transform input image to occupy full gray level scale available. However, this technique tends to deviate input mean brightness as well as introduce unwanted effects like over-enhancement and saturation. Thus this technique is not very effective [2].

Brightness preserving bi-histogram equalization (BBHE) is introduced in [3] where input image is divided into two sub-histograms based on mean brightness. Then histogram equalization is applied to these sub-histograms independently that leads to brightness preservation to some extent. Mostly, images still suffers from intensity saturation.

Alternately, the input histogram can be divided based on median pixel value such that each sub-histogram has equal number of pixels. In dualistic sub-image histogram equalization (DSIHE) [4], we then apply sub-histogram equalization which produces results with better brightness mean preservation and increases entropy as well.

Brightness error bi-histogram equalization (MMBEBHE) [5] suggested an alternative method to select separating point for sub-histogram equalization in minimum mean where minimum mean brightness error between the input and the enhanced image was calculated. This value is then used as a separating point for sub-histogram segmentation.

Further improvements were made [6] where multiple sub-histogram segmentation technique was implemented. In recursive mean-separate histogram equalization (RMSHE) original histogram is divided into 2r sub-histograms, where r is an integer value. Conventional HE is applied to each sub-histogram independently.

Recursive sub-image histogram equalization (RSIHE) [7] Suggested where median was used as a separating point for segmenting each histogram instead of mean. However, both RMSHE and RSIHE fail in enhancement when r increases beyond a certain value.

In Dynamic Histogram Equalization (DHE) [8] where segmentation takes place based on local minima and each sub-histogram is assigned a new range for sub-histogram equalization. But this technique fails to preserve brightness of image.

Improvement to DHE was Suggested in [9] where brightness preserving dynamic histogram equalization method (BPDHE) technique segments input histogram based on local maxima. It is claimed that local maxima tends to preserve image brightness better than local minima. Then DHE is applied to this segmented histogram to enhance contrast of the image.

Clipped histogram equalization (CHE) [2] where a clip level is determined to avoid over-enhancement. Clipped portion is re-distributed back to dynamic range followed by HE to enhance contrast. However, clipping levels needs to be input manually.

Bi-histogram equalization plateau limit (BHEPL) in [10] which is a combination of CHE and BBHE. Here the sub-histograms are clipped first then HE applied to preserve brightness as well as avoid over-enhancement.

In [11] Bi-histogram equalization plateau limit, the acceptable and natural enhanced images were produced where some intensity levels are squeezed to the right tail of the histogram but this method produced some intensity saturation problem.

An extension to BHEPL was implemented in [12] named Dynamic Quadrants Histogram Equalization Plateau Limit (DQHEPL) where input histogram was segmented to 4 sub-histograms based on median and clipping level was also automated by selecting mean value in each sub-histogram as clipping level. Resultant preserved brightness however was open to improvements.

Technique we propose is EDQHEPL that is an advanced form of previously proposed method DQHEPL where number of histograms is increased to8 sub-histograms named as y1,y2,y3,y4,y5,y6,y7,y8 and y8 in order to apply sub-histogram equalization to each sub-histogram independently. This technique (EDQHEPL) was intended to further reduce the mean brightness error in DQHEPL while retaining the enhancement level, if no improving it. Further, technique is quite simple to implement and does not require complex computations. Algorithm was tested and results showed that considerable fairer results are achieved when compared to DQHEPL in particular and other methods in general.

HISTOGRAM EQUALIZATION:

Global Histogram Equalization:

A Technique, where input histogram of low contrast images, is mapped to entire dynamic range which tends to enhance the contrast of these images. Firstly, probability of each gray level is calculated (1).

$$h(j)=nj \quad \text{for } j=0,1....L-1 \tag{1}$$

Where nj is pixel count against gray level j.

Next, pdf of these images is calculates by dividing nj by total pixel count in image as given in (2).

p(j)=h(j)/T for j=0,1.....L-1 (2)

Where h(j) gives probability of each gray level value j. and T is total number of pixels in image.

Then, cdf of image is calculated using (3). Note that cdf and pdf should both be normalized.

$$c(j) = \sum_{c=0}^{L-1} p(c) \qquad (3)$$

Lastly, transformation done to map the input pixel values to the entire dynamic range using cdf calculated.

g(j)=j.*c(j) j=0,1......L-1 (4)

Sub-Histogram Equalization

In this technique, the input histogram is divided into r sub-histograms by using mean or median value as the segmentation point. Assuming r=4, we show that median can be used to segment histogram into four sub-histograms.

x1= 0.25 x T (5)

x2= 0.5 x T (6)

x3= 0.75 x T (7)

Where x1 is grey level at 25 % pixels, x2 for 50% pixel and x3 for 75% pixels. x0 and x4 give the maximum and minimum intensity levels.

Once these sub-histograms have been segmented, we apply histogram equalization given in section A to each of these sub-histograms independently.

Dynamic Histogram Equalization

In this technique, the sub-histograms are mapped to a new range. This range is calculated using the segmentation points x0-x4 calculated in previous section. Following will be the new ranges for each sub-histogram.

$$y0 = 0 \qquad (8)$$

$$y1 \cong \frac{(x1 - x0)}{(x2 - x0)} \times x2 \qquad (9)$$

$$y2 = x2 \qquad (10)$$

$$y3 \cong (L - 1 - x2) \times \frac{x3 - x2}{x4 - x2} + x2 \qquad (11)$$

And y4 is given by maximum value (L-1). Once, new ranges have been computed, sub-histogram equalization is done to enhance the image.

$$g(j) = y_{i-1} + (y_i - y_{i-1}) \times \frac{\sum_{j=x_{i-1}}^{x_i} h(j)}{U_i} \qquad (12)$$

Where g(j) is the equalized output sub-histogram, h(j) is the input sub-histogram and i is the sub-histogram number. Ui is the total pixel count in sub-histogram i and is given by.

$$U_i = \sum_{j=x_{i-1}}^{x_i} h(j) \quad (13)$$

Clipping Histogram Equalization:

A technique where enhancement rate is controlled by clipping pixels excessive of the clipping limit. It has been observed that enhancement technique tend to fail if enhancement rates are not controlled leading to over saturation on intensity levels. Since output image heavily depends on c(j) (4), enhancement depends on cdf too. We can control the enhancement rate by controlling the change in c(j). Change of c(j) is given by following equation which shows that it depends on pdf of the image, given by p(j).

$$\frac{d}{d(j)} c(j) = p(j) \quad (14)$$

$$\alpha + \beta = \chi. \quad (1)$$

Therefore, if we limit the pdf of the image, we can control the enhancement rate of the image and avoid oversaturation.

Thus, in this technique, the clipping level is determined by calculating mean gray level in each histogram and using that as clipping level to clip off excess pixels. This helps to modify the cdf of the input image and the output image will be enhancement controlled. Following equation gives technique to calculate the clipping level in each sub-histogram.

$$C_i = \frac{1}{x_i - x_{i-1}} \times \sum_{j=x_{i-1}}^{x_i} h(j) \quad (15)$$

Where i denotes the sub-histogram number (1, 2, 3, 4) and h(j) is the pixel count at intensity level j. Once clipping limits have been calculates, we clip off all the pixels in histogram that are above this limit. This is given by following equation.

$$h_{Ci}(j) = \begin{cases} h(j) & h(j) \leq C_i \\ P_i & h(j) > C_i \end{cases} \quad (16)$$

Once clipped sub-histogram has been computed, we calculate the cdf corresponding to each sub-histogram and equalization done as per following equation.

$$g(j) = x_{i-1} + (x_i - x_{i-1}) \times \frac{\sum_{j=x_{i-1}}^{x_i} h_{Ci}(j)}{V_i} \quad (17)$$

Where yi is by (8)-(11) and Vi is pixel count in clipped sub-histogram equalized image given by

$$V_i = \sum_{j=x_{i-1}}^{x_i} h_{Ci}(j) \quad (18)$$

Methodology

Our implemented methodology uses all four of the above describe sub-sections. First, image histogram h(j) is computed, given by (1).

Next, we compute sub0histogram equalization using r=8. Thus, we divide input histogram into 8 sub-histograms, whether segmentation done by median. Thus, we have

x1=0.125 x T (19)
x2=0.250 x T (20)
x3=0.375 x T (21)
x4=0.500 x T (22)
x5=0.625 x T (23)
x6=0.750 x T (24)
x7=0.875 x T (25)

where T is total pixel count in the image and x1 is the grey level with 12.5% pixel and x7 is grey level at pixel count 87.5%. Rest of values indicate the in between values. x0 and x8 contain the minimum and maximum grey level values of input histogram.

Once this segregation is done, we use the DHE technique to calculate new dynamic ranges for each of 8 sub-histograms. New values are given by following equations.

$$y0 = 0 \tag{26}$$

$$y1 \cong x4 \times \frac{(x1 - x0)}{(x4 - x0)} \tag{27}$$

$$y2 \cong x4 \times \frac{(x2 - x1)}{(x4 - x0)} + x1 \tag{28}$$

$$y3 \cong x4 \times \frac{(x3 - x2)}{(x4 - x0)} + x2 \tag{29}$$

$$y4 = x4 \tag{30}$$

$$y5 \cong (L - 1 - x4) \times \frac{(x5 - x4)}{(x8 - x4)} + x4 \tag{31}$$

$$y6 \cong (L - 1 - x4) \times \frac{(x6 - x5)}{(x8 - x4)} + x5 \tag{32}$$

$$y7 \cong (L - 1 - x4) \times \frac{(x7 - x6)}{(x8 - x4)} + x6 \tag{33}$$

And y8 gives Maximum intensity level (L-1).

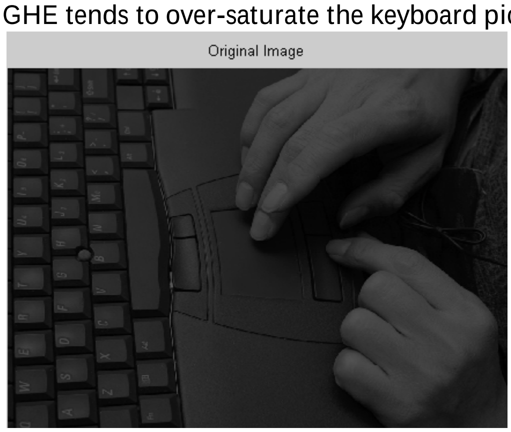
Next, we apply histogram clipping given in section D where mean value in each sub-histogram is calculated using equation (15).

Once we have the clipping limits, we use equation (16) to get the clipped histogram values hci where i= (1-8). Modified version of equation (17) can be used to map the clipped histogram to new ranges in each sub-histogram.

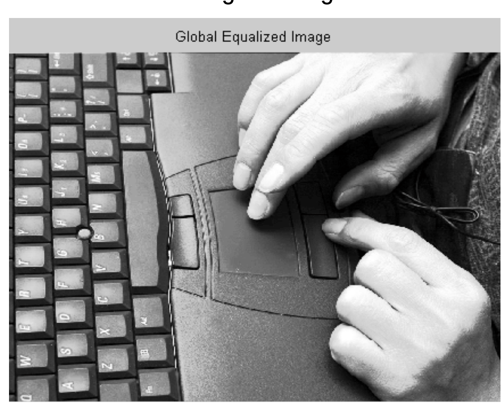
We call this technique Enhanced Dynamic Quadrants Histogram Equalization Plateau Limit (EDQHEPL).

RESULTS:

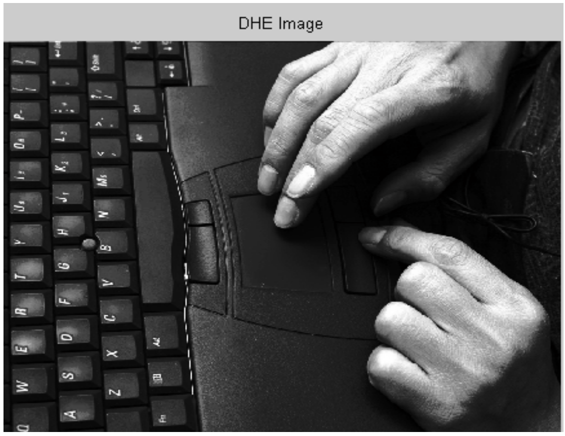
The technique discussed was applied on different image and results were observed in the form of image improvement as well as calculated in the form of two statistical parameters. We tested the applied technique on two different images shown in Figure 1 and 2. Technique of GHE, DHE, BPDHE and DQHEPL were applied along with proposed technique on all of these images. Figure 1 is a low contrast image where GHE tends to over-saturate the keyboard picture whereas BPDHE tends to give a slighter darker output.



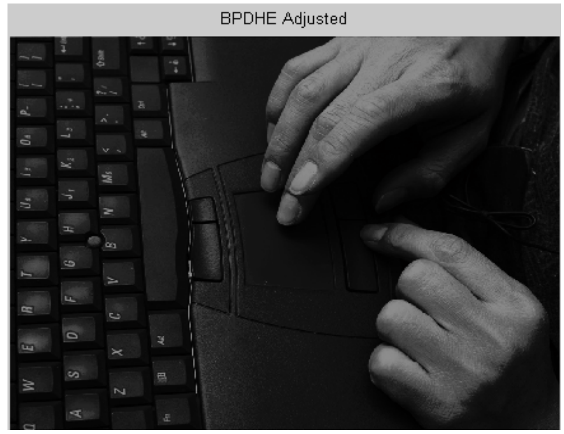
(a)



(b)

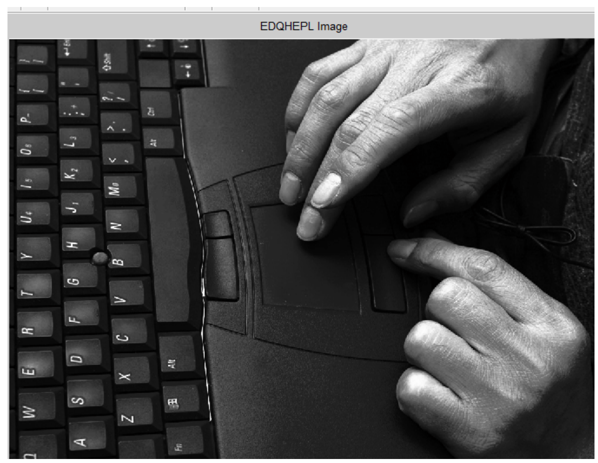


(c)



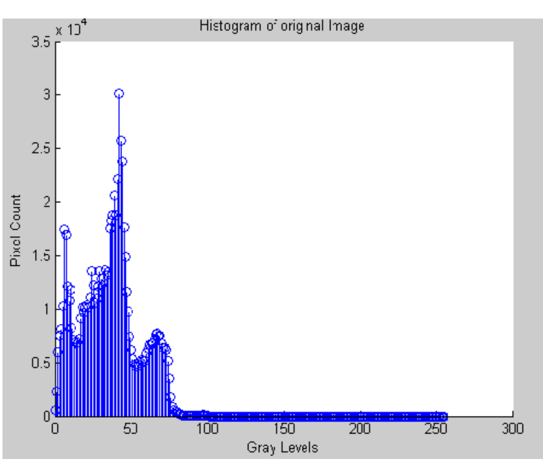
(d)

(e)

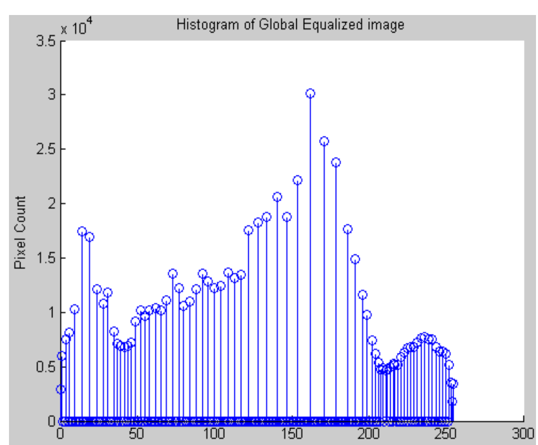


(f)

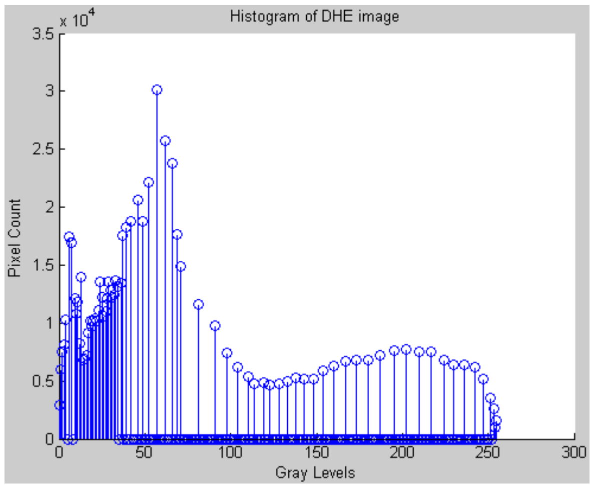
Figure 1: Comparison of GHE (b), DHE (c), BPDHE (d), DQHEPL (e) and EDQHEPL (f) with low contrast original image (a).



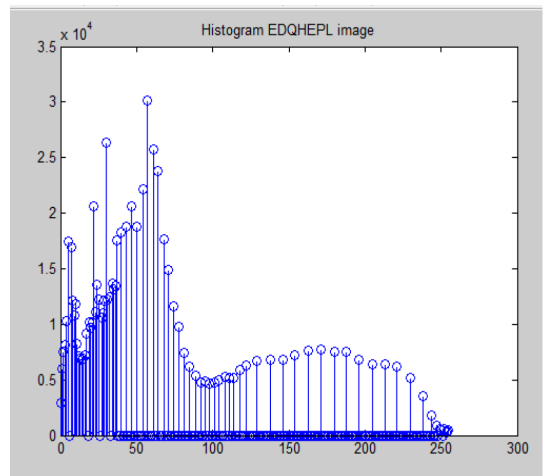
(a)



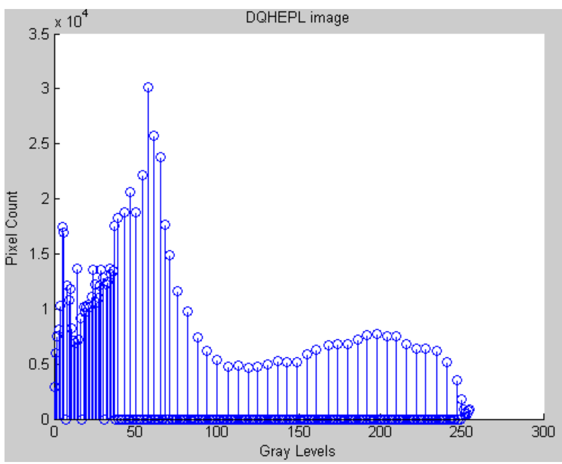
(b)



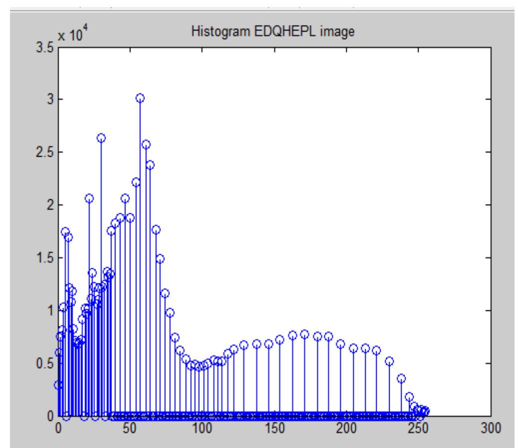
(c)



(d)



(e)



(f)

Figure 2: Comparison of Histograms of GHE (b), DHE (c), BPDHE (d), DQHEPL (e) and EDQHEPL (f) images with low contrast original image histogram (a).

DHE and DQHEPL tend to give slightly brighter picture than proposed technique EDQHEPL which retains the image mean brightness error. Figure 2 shows the histograms of images in Figure 1. Histogram of BPDHE clearly shows darker image with pixels not occupying whole dynamic range. EDQHEPL and DQHEPL both occupy whole dynamic range however upon close inspection; we can see wrinkles on fingers which is not at all visible in DQPEPL enhanced image. Similarly, the histogram is shifted slightly to the left meaning thereby that our method preserves brightness better than DQHEPL. For statistical testing, we selected two parameters to check our results. Average Absolute Mean Brightness Error (AAMBE) is calculated as below and it calculates average of difference in mean brightness error between input and output image.

$$AAMBE = \frac{1}{T}\sum \left|M(f) - M(g)\right| \quad (34)$$

A lower value of AAMBE means that image is closer to original image and retains image attributes. However, we can only refer to this parameter AFTER looking at the enhancement done on output image. Similarly, we calculate Mean Square Error (MSE) between the input and output images. This is given by

$$MSE = \frac{1}{T}\sum \sum_{i=0}^{M-1}\sum_{j=0}^{N-1}\frac{[f(i,j)-g(i,j)]2}{M\times N} \qquad (35)$$

Where MXN gives total pixel count in each image, f(i,j) is input image value at (i,j) and g(i,j) is output image. T is the total number of samples. A lower value of MSE will also indicate that lower difference between input and output image given the image is enhanced visually.

Results have been tabulated in Table 1. It indicates that for AAMBE, GHE gives very high values which indicate that mean brightness has deviated significantly from input image. BODHE gives a very low value but that is expected since we mean adjust the image once DHE has been applied however, its histogram in Figure 2 clearly shows that image does not occupy full range of grey levels available. So this technique will not enhance image contrast. Similarly DQHEPL gives higher value as compared to our proposed technique,. Thus as proposed, EDQHEPL is effective in retaining image attribute and at the same time provide image enhancement with no degrading effects.

TABLE I. STATISTICAL COMPARISON OF AVERAGE OF 50 DIFFERENT IMAGES FROM USC – SIPI IMAGE DATABASE

Method	AAMBE (50 Images)	MSE (50 images)	APSNR(db) (50 images)
GHE	30.35	50.2	10.54
DHE	11.9	38.7	14.23
BPDHE	0.26	50.85	17.57
DQHEPL	5.6	36.55	19.22
EDQHEPL	**4.032**	**34.27**	**21.50**

CONCLUSION:

We have proposed an image enhancement technique Enhanced Dynamic Quadrant Histogram Equalization Plateau Limit (EDQHEPL) which is an improvement to DQHEPL. Input histogram is divided into 8 sub-histograms recursively based on Median values. Mean value in each sub-histogram is selected as Clipping value and over-enhancement avoided by clipping excess pixels. Next DHE is applied to enhance range of the sub-histograms to cover full range of available gray levels. Testing done on numerous images show that our proposed technique enhances images better than conventional method avoids over-saturation and maintains mean brightness of images which is a fundamental requirement for electronic consumer products like TV and Monitors. Figure 1 & 3 give visual enhancement in the images whereas Figure 2 shows the difference in Histograms of all the conventional techniques where our technique enhances dynamic range and preserves image brightness too(indicated by shift of values to left).

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