Duo-Histogram Equalization method for Contrast Enhancement for Images using Power-Law Transformation of Mean based on Kurtosis

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Abstract—**An amalgamation of a new and old method is presented in this paper for the purpose of better contrast enhancement and elegant brightness preservation of images. The core idea of this close approximation is to incorporate the concept of power-law and kurtosis into account. When kurtosis is greater than or equal to three (kurtosis of Gaussian distribution) then the different values of exponent λ in the formula of power-law generates different average points termed as modified mean and whenever kurtosis value is less than three then the modified mean becomes square-root of the sum of the mean and kurtosis. The histogram of the input image is then divided into two divisions based on the concept of modified mean. Thereafter the basic histogram equalization process is applied onto both the sections separately. Finally, the union of those two histogram equalized segments generates a far better contrast enhanced output image with preserved brightness. The verification, tests and impressive results of our proposed method is shown in this paper.**

Keywords-Brightness preservation; histogram equalization; kurtosis; power-law transformation; skewness.

I. INTRODUCTION

Image enhancement is the method in which the pixel intensity of the input image is processed for a better output image [1] [12]. Contrast enhancement method, a wider dynamic range in image processing, is widely in use. Due to the simplicity and effectiveness of Histogram Equalization (HE) technique, contrast enhancement is performed based on HE's algorithm [2]. The functionality of HE is done by remapping the gray level of the input image based on the Probability Mass Function (PMF) [2]. The dynamic range of the image's histogram is stretched and flattened and thus the overall contrast enhancement is achieved [3]. In HE method, instead of measuring the input mean value, the emphasis is solely given on the middle gray level to calculate the mean brightness of a histogram equalized image. This is a limitation in some cases where brightness preservation concept comes into reality [8] [9] [10] [11].

The histogram gives us a general idea of the shape, but two statistical measures of shape give a more precise evaluation. They are skewness and kurtosis. Skewness gives us the idea about the amount and direction of skew [14] and kurtosis tells us how tall and sharp the central peak is, relative to a standard bell curve. If the value of the kurtosis is more than three, the images can be considered as low contrast, as most of the pixels of the image will concentrate towards the mean. The fourth standardized moment (kurtosis = β_2) is defined as:

$$\beta_2 = \frac{E\left[(X-\mu)^4\right]}{\left(E\left[(X-\mu)^2\right]\right)^2} \qquad (1)$$

Where, E is the expectation, μ is the mean of the distribution and σ is the standard deviation of the distribution.

Our proposed method of DUO-Histogram Equalization (DUO-HE) method comes into the scenario to solve the limitations of HE method. At first using kurtosis, it is checked whether the input image's histogram is in approximately normal distribution or not. For kurtosis < 3, the modified mean (MM) is taken as the square-root of the sum of the mean and kurtosis [14] and when kurtosis is ≥ 3, different values of λ in the formula of power-law generate different MM. From its various values obtained by putting different values of λ in the range (0 to 1), a proper and suitable value of MM is taken where the resulting output is good. After obtaining the MM point, the input image's histogram is divided into two parts based on it. The range of the first division is from the minimum gray level to MM and the range of the second division is from the MM to maximum gray level [7]. Then these two histogram

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divisions are equalized independently. Finally the union of these two equalized outputs generates the final result. The DUO-HE effectively preserves the original brightness to a certain level [6] and also produces a good contrast enhanced output image.

II. Related Work and Proposed Method

A. Histogram Equalization (HE)

A digital gray level image is taken with gray level in the range $\left[0, L-1\right]$, Probability Mass Function $\left(PMF\right)$ of the image can be sited as:

$$PMF(R_t) = \left(\frac{N_t}{N}\right) \tag{2}$$

Where, $t = 0, ..., \left(L-1\right)$

Where R_t is the t^{th} gray level and N_t is the number of pixel in the image with gray level R_t and N is the total number of pixels [1].

Cumulative Distribution Function $\left(CDF\right)$ calculated is as follows:

$$CDF\left(R_t\right) = \sum_{n=0}^{n=t} PMF\left(R_n\right) \tag{3}$$

Where, $t = 0, ..., \left(L-1\right);\ 0 \le CDF\left(R_t\right) \le 1$

Histogram Equalization (HE) remaps the gray level M_t to gray level R_t of the input image using (3). So we get:

$$M_t = \left(L-1\right) \times \left(CDF\left(R_t\right)\right) \tag{4}$$

Gray level M_t's change is calculated in normal Histogram Equalization technique:

$$\Delta M_t = \left(L-1\right) \times \left(PMF\left(R_t\right)\right) \tag{5}$$

Equation (5) indicates the distance between M_t and $\left(M_t + 1\right)$ having direct relation with the PMF of input image at gray level R_t.

This method of HE holds good in those images where the background and foreground are both bright or both dark. Thus this leads to the better understanding of bone structure in x-ray images and also allows better views of underexposed photographs [2] [4].

B. Proposed DUO-Histogram Equalization (DUO-HE)

1) Obtaining Modified Mean for kurtosis ≥ 3

In this case the image of the distribution is low contrast in nature as pixels are considered to be concentrating near the mean, for kurtosis ≥ 3. So, the method applied here is, Power-Law Transformation of mean.

The formula of Power-Law Transformation is:

$$\text{MM} = \left(mean\right)^{\lambda} \tag{6}$$

Where, $0 \le \lambda \le 1$

Different values of λ in the mentioned range give us different MM point. Based on this MM, the histogram of input image is separated. A favorable MM is chosen while experimentation.

2) Obtaining Modified Mean for kurtosis < 3

In this case the method applied for getting the modified mean (MM) is based on simple statistics.

$$\text{MM} = \sqrt{mean \pm kurtosis} \tag{7}$$

Where, 'mean' is the average pixel value of an image. Positive sign when kurtosis is negative and negative sign otherwise.

3) Equalization or Transformation technique

DUO-HE is an advanced HE technique for contrast enhancement. After calculating the MM value from the histogram of the input image using power-law formula or using simple statistics it then divides the histogram of input image into two parts based on this MM. Thereafter HE operation is applied on each segment separately. CDF of two segments are then generated from it. Gray levels R_t below the kurtosis value are pointed to the new gray level M_t as shown in (8).

$$M_t = L_1 \times \left(CDF_1\left(R_t\right)\right)$$

$$CDF_1\left(R_t\right) = \frac{\sum_{n=0}^{t} N_n}{\sum_{p=0}^{L_1} N_p} \tag{8}$$

Where, $t = 0, 1, ..., L_1$ and L_1 is the MM point obtained. This is shown in (9).

$$L_1 = \sum_{t=0}^{L-1} PMF\left(R_t\right) \times \left(R_t\right) \tag{9}$$

Gray levels R_t above the MM are pointed to the new gray levels M_t. This is shown in (10).

$$M_t = \left(L - 1 - L_1\right) \times \left(CDF_2\left(R_t\right)\right) + L_1$$

$$CDF_2\left(R_t\right) = \frac{\sum_{n=L_1+1}^{t} N_n}{\sum_{p=L_1+1}^{L-1} N_p} \tag{10}$$

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Where, $t = (L_1 + 1), ..., (L - 1)$

The result of DUO-HE with HE is shown in the results and discussion section later.

III. Image Quality Measurement

The output image quality measurement is calculated based on two parameters. They are: Peak Signal to Noise Ratio (PSNR) and Absolute Modified Mean Brightness Error (AMMBE) [13].

A. *Peak Signal to Noise Ratio(PSNR)*

To calculate the PSNR, the input image $X(i, j)$ is so chosen that it contain $M \times N$ pixels (i.e. $i = 1, ..., M$ and $j = 1, ..., N$). The output image $Y(i, j)$ has also the same structure. The error is calculated in the luminance region of the signal so that the pixel values of $X(i, j)$ ranges from gray level 0 (black) to 255 (white).

PSNR value in decibels (dB) is given by:

$$PSNR = 20 \log_{10} \left(\frac{\max(Y(i,j))}{RMSE} \right) \quad (11)$$

Where the Root Mean Square Error (RMSE) is given by:

$$RMSE = \left(\frac{\sum_{i=1}^{M} \sum_{j=1}^{N} \left(X(i,j) - Y(i,j) \right)^2}{M \times N} \right)^{\frac{1}{2}} \quad (12)$$

A high PSNR value, says that it has an improved contrast.

B. *Absolute Modified Mean Brightness Error (AMMBE)*

If the absolute difference of the modified mean X_{MM} of the input image X and the modified mean Y_{MM} of the output image Y is very low, then the brightness of the input image is preserved in the output image [5].

$$AMMBE(X, Y) = |X_{MM} - Y_{MM}| \quad (13)$$

IV. Results And Discussions

A. *Results of Bi-Histogram Equalization (BHE) and DUO-Histogram Equalization (DUO-HE)*

The comparative performance of the proposed method of DUO-HE with BHE [6] [7] is observed with some test images.

Test images taken are cell-1, leena, cell-2 and tyre.

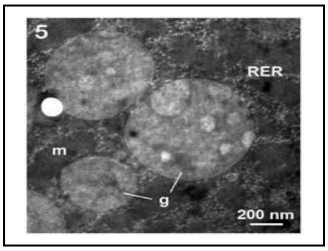

Figure 1. Original (cell-1)

Figure 2. Original (leena)

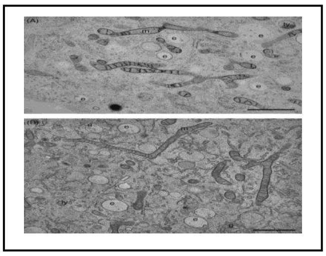

Figure 3. Original (cell-2)

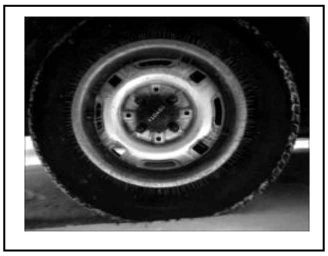

Figure 4. Original (tyre)

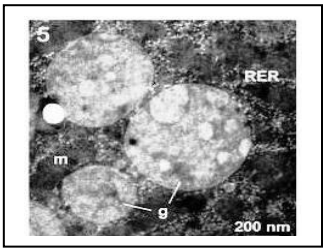

Figure 5. DUO-HE (cell-1)

Figure 6. DUO-HE (leena)

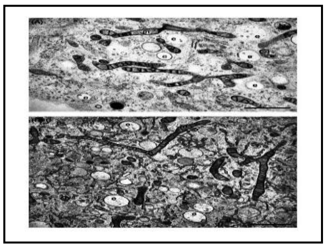

Figure 7. DUO-HE (cell-2)

Figure 8. DUO-HE (tyre)

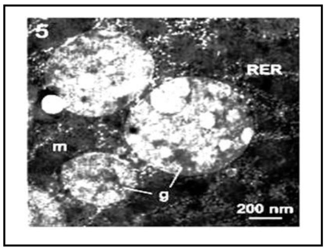

Figure 9. BHE (cell-1)

Figure 10. BHE (leena)

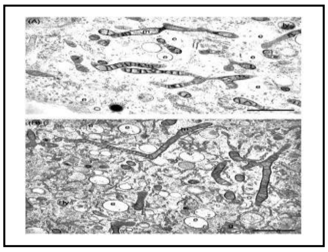

Figure 11. BHE (cell-2)

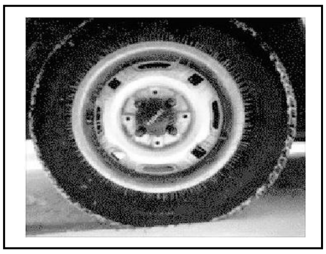

Figure 12. BHE (tyre)

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B. Table comparing the PSNR values and AMMBE values of BHE images and DUO-HE images

We have not only concentrated on images, instead we also emphasized on calculating mathematical values to prove our method.

TABLE I. TABLE COMPARING PSNR VALUES

Name of Image	BHE	DUO-BHE
cell-1	14.1980	15.4605
leena	13.0274	15.4045
cell-2	11.9645	14.0982
tyre	11.0939	10.2469

TABLE II. TABLE COMPARING AMMBE VALUES

Name of Image	BHE	DUO-BHE
cell-1	29.3435	1.1392
leena	18.8025	0.7676
cell-2	45.0501	0.0111
tyre	46.6756	0.1302

The above value clearly shows us that the DUO-HE image is better than the BHE image in every respect. The brightness of the input image is properly preserved as the AMMBE values are very small and contrast enhancement is also better as the PSNR values are higher.

C. Results Comparing the Histogram of Original image and DUO-HE image

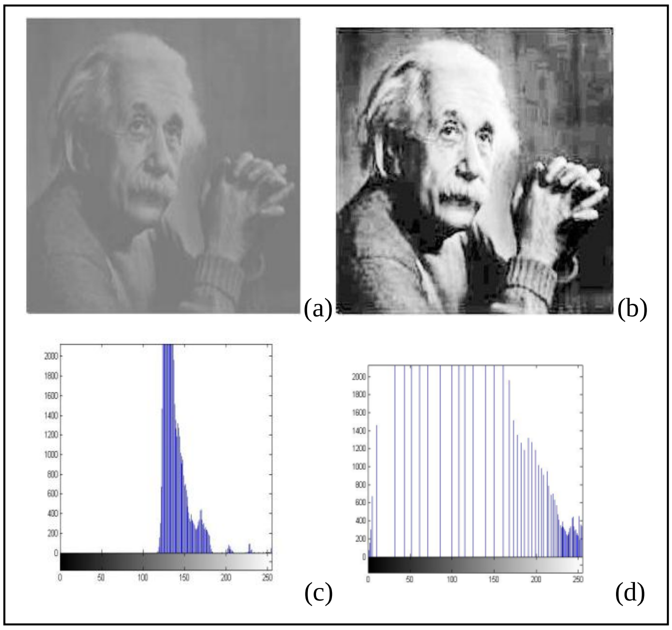

Figure 13. (a) Sir A. Einstein (Original-low contrast), (b) Sir A. Einstein (DUO-HE), (c) Original Histogram, (d) DUO-HE

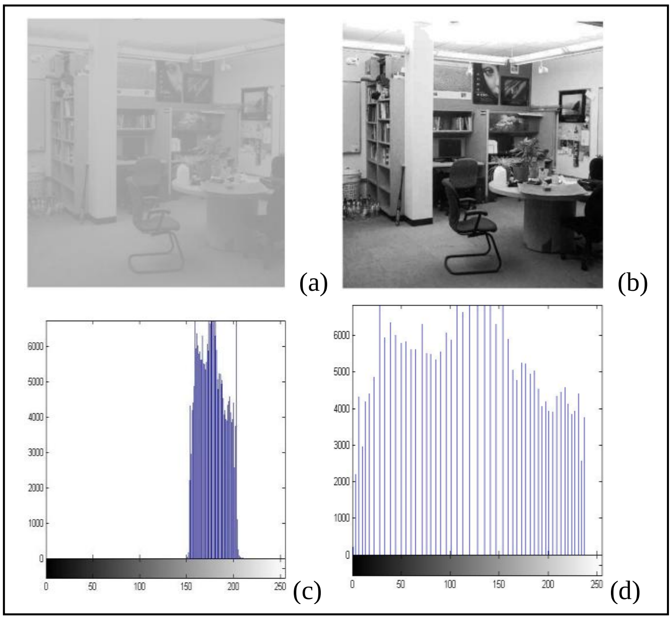

Figure 14. (a) Room (Original-low contrast), (b) Room (DUO-HE), (c) Original Histogram, (d) DUO-HE

It is very clear from the above histograms that the contrast enhancement is quite brilliant in DUO-HE as the pixels are evenly distributed everywhere.

V. CONCLUSION

Our proposed method of DUO-Histogram Equalization (DUO-HE) is far better and promising than the existing method of Bi-Histogram Equalization (BHE). This is not because that our output image came perfect and better than the BHE but the mathematically calculated values of DUO-HE came proper. The smaller value of AMMBE shows that the brightness is preserved elegantly and the higher value of PSNR shows that the contrast enhancement is done properly. Moreover DUO-HE has an existing feature to modify images, having different λ values between 0 and 1.

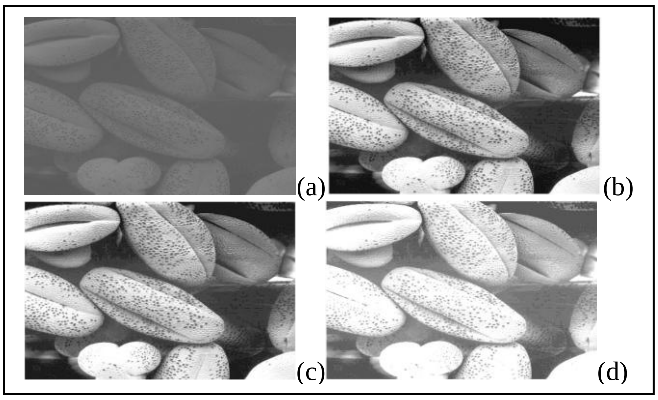

Figure 15. (a) Original (seeds), (b) DUO-HE (for lambda=0.1), (c) DUO-HE (for lambda=0.5), (d) DUO-HE (for lambda=0.9)

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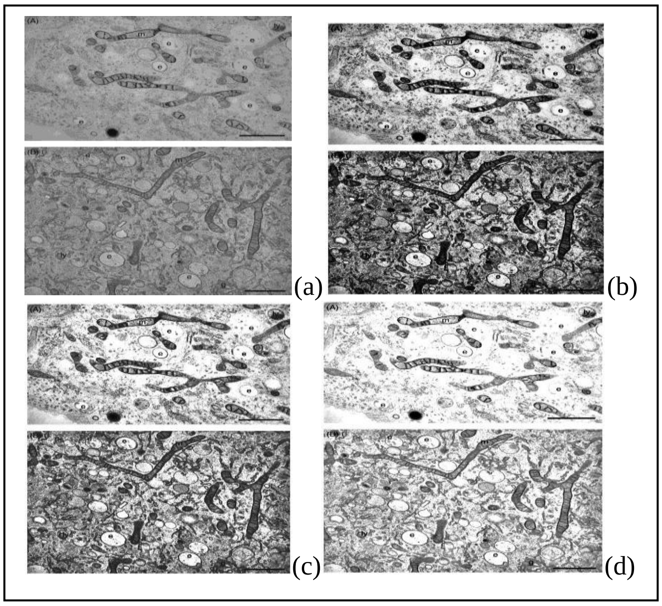

Figure 16. (a) Original (cell-2), (b) DUO-HE (for lambda=0.1), (c) DUO-HE (for lambda=0.5), (d) DUO-HE (for lambda=0.9)

Thus, using the algorithm of DUO-HE, the desired contrast and brightness can be achieved just by changing values of lambda (λ) from 0 to 1. The DUO-HE method using λ =0.1, λ =0.5 and λ =0.9 is shown in Fig. 15 and Fig. 16 respectively. All experimental results are obtained by performing tests in Matlab (R2010b).

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