IJARCCE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 12, December 2015

Simulative Analysis of Histogram Equalization Techniques for Gray Scale Images

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Abstract: Histogram equalization techniques are used for enhancing images. The aim of an image enhancement is to improve the quality of the image for better visualization. This paper presents implementation of three methods of histogram equalization namely BHE, DHE and BPDFHE taking a common dataset using MATLAB platform. Moreover the performance of above mentioned techniques has been evaluated on the basis of visual results and objective image quality parameters namely PSNR, RMSE, AD, SC and MD. A comparative analysis has been carried out and it has been observed that for gray level images, BHE and DHE introduce impractical and improbable effects in the enhanced images. However the BPDFHE technique overcomes this limitation by fuzzifying the weight of histogram region to avoid contouring.

Keywords: Histogram Equalization, Image Enhancement, MD, PSNR, SC, RMSE and Visual Quality.

I. INTRODUCTION

The fundamental objective of an image enhancement is to enhance the quality of the image, so that the resultant image is better when contrasted with original image. Image enhancement is the process used for changing the pixels intensity of input image, so that the resultant image is of better quality.

The most significant use of image enhancement is contrast enhancement. Contrast enhancement enhances the perceivability of an object in the image by improving brightness in the object and their background. The enhancement methods can be divided into two main categories namely spatial domain methods and frequency domain methods. Spatial domain methods directly operate on pixels whereas frequency domain methods operate on fourier transform of an image.

Various image contrast enhancement algorithms are proposed in literature, which includes gray scale manipulation, filtering and histogram equalization. The main purpose of these techniques is to bring out the hidden details in an image or to increase contrast in low contrast image. The contrast enhancement adjusts the brightness and darkness in the image to improve its visibility. In this paper, three histogram equalization techniques namely BHE, DHE and BPDFHE have been implemented for contrast enhancement taking a common dataset using MATLAB platform.

The rest of the paper is organized as follows: Section II describes histogram equalization techniques and in section III, experimental step-up has been discussed. Section IV describes objective image quality measures used in this work and experimental results and discussion are presented in section V. Conclusion of this work is presented in section VI.

II. HISTOGRAM EQUALIZATION TECHNIQUES

Histogram Equalization (HE) is a popular technique for contrast enhancement of an image. Contrast of an image may be defined by its dynamic range, which is ratio of brightest and darkest pixel of the image. This method increases the global contrast of an image and allows areas of lower contrast to gain higher contrast of an image. Fig. 1 shows the spreading of intensity values in histogram equalization technique.

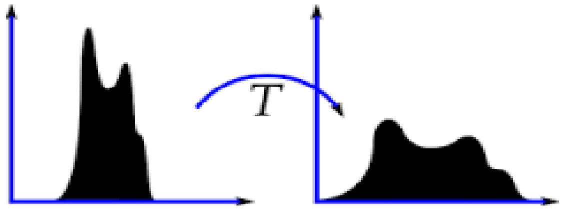

Fig. 1: Spreading the Intensity Values of Image

Various HE techniques implemented in this work have been briefly discussed below:

A. Bi-Histogram Equalization (BHE)

BHE is the improved version of HE method. In this method, the histogram of an image is divided into two parts by calculating the average point of histogram. After the separation, histograms are independently equalized. The mean brightness of the resultant image lies between the input mean and middle of gray level.

Step 1: Load the original gray scale test image.

Step 2: Make histogram of the original image.

Step 3: Divide the histogram into two sub histograms.

Step 4: Apply histogram equalization technique on each histogram independently.

Results of applying BHE technique and comparison with other methods are depicted in results section.

 DOI 10.17148/IJARCCE.2015.41220

IJARCCE
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Vol. 4, Issue 12, December 2015

Fig. 2 depicts the flow chart of Bi-Histogram Equalization technique.

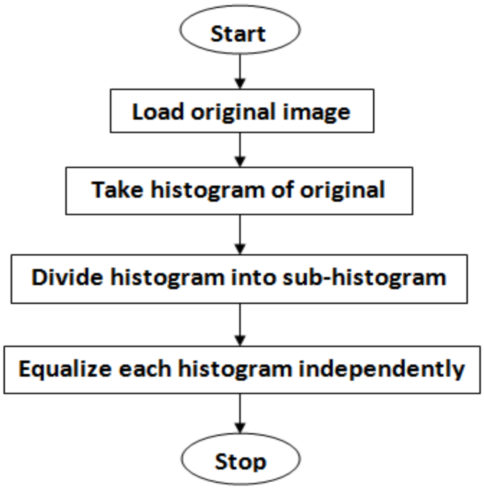

Fig. 2: Flow Chart of BHE

B. Dynamic Histogram Equalization (DHE)

DHE partitions the histogram of an image into multiple segments based on the positions of local minima and then equalizes each segment independently. Generally, DHE does not consider the mean brightness preservation. The DHE may cause saturation and it is not enough to smooth a noisy histogram. The limitation of this method is that the peaks are not remapped properly which leads to perceivable changes in mean image brightness.

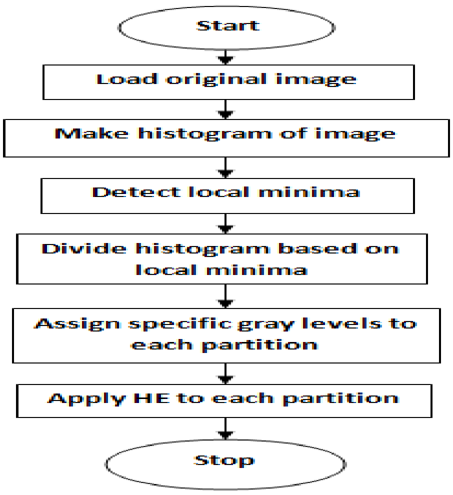

Fig. 3: Flow Chart of DHE

Fig. 3 shows the flow chart of Dynamic Histogram Equalization.

Step 1: Load the original gray scale test image.
Step 2: Make histogram of the original image.
Step 3: Detect local minima in the histogram of original image.
Step 4: Divide the histogram into mutiple segments based on the position of local minima.
Step 5: Assign the specific value to the gray levels of each portions.
Step 6: Apply HE technique to enhance the contrast of the resultant image and generate histogram of enhanced image.

C. Brightness Preserving Dynamic Fuzzy Histogram Equalization (BPDFHE)

BPDFHE is fuzzy version of Brightness Persevering Dynamic Histogram Equalization (BPDHE). BPDHE is similar to DHE but it uses local maxima as a separating point instead of local minima. The results of BPDHE produce false contouring in the connected regions and ignore details. To overcome this problem fuzzy approach for BPDHE is used. Fig. 4 shows the flow chart of BPDFHE

Step 1: Load the original gray scale test image.
Step 2: Make histogram of the original image.
Step 3: Detect local maxima in the histogram of original image.
Step 4: Divide the histogram into mutiple segments based on the position of local maxima.

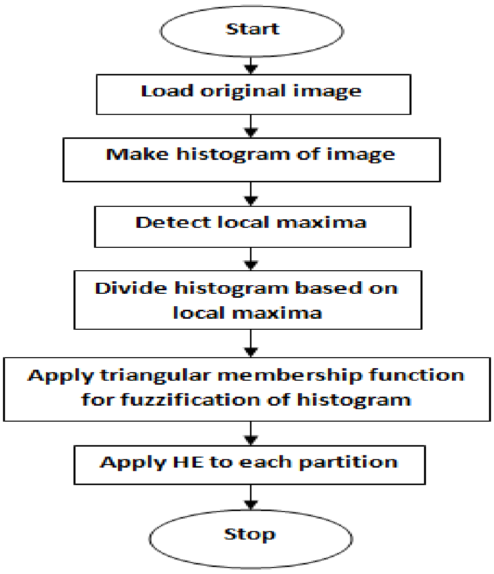

Fig. 4: Flow Chart of BPDFHE

Step 5: Apply triangular membership function for fuzzification of the regions of histogram. Step 6: Apply HE technique to enhance the contrast of the resultant image and generate histogram of enhanced image.

III. Experimental Setup

In this paper, three histogram equalization techniques namely BHE, DHE and BPDFHE have been implemented taking a common data set using MATLAB platform. Histograms of test images before and after applying HE techniques are observed for comparison purpose. Steps of experimental setup for this work are depicted in figure 5.

Step 1: Load the original gray scale test image.

Step 2: Make histogram of the original image.

Step 3: Apply HE namely BHE, DHE and BPDFHE technique to enhance the contrast of the resultant image.

Step 4: Generate histogram of enhanced image.

Step 5: Calculate Objective image quality parameters.

Moreover, for performance analysis of various HE techniques, objective image quality measures are calculated and compared.

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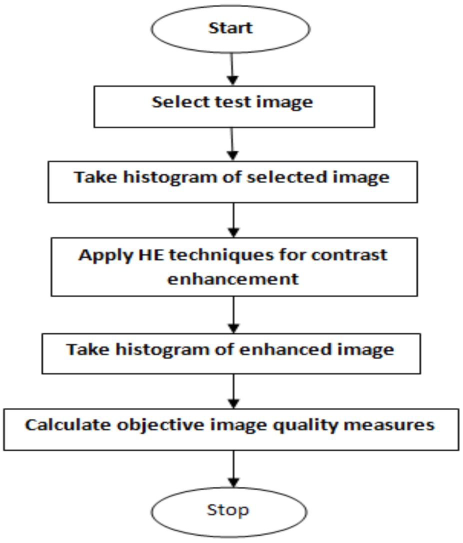


Fig. 5: Flow Chart of Methodology for Experiment

IV. QUALITY MEASURES

Image quality measures are important in the development of image processing algorithms such as enhancement, deblurring and denoising etc. as these measures are used to evaluate the performance of these algorithms in terms of quality.

Objective Image Quality Measures:

1. Peak Signal to Noise Ratio (PSNR): PSNR is the evaluation standard of the reconstructed image quality. The small value of PSNR means that the image is poor. Practically it should be as high as possible and mathematically can be expressed as:

$$PSNR = 10\log_{10}\left(\frac{R^2}{MSE}\right) \qquad (6)$$

Where
R= Maximum value of pixel present in an image.
MSE= Mean Square Error between original and de-noised image with size M*N.
MSE can be calculated as

$$MSE = \frac{1}{M*N}\sum_{i=1}^{M}\sum_{j=1}^{N}[I(i,j) - \hat{I}(i,j)]^2 \qquad (7)$$

Where
I (i, j) = Original image.
Î (I, j) = De-noised image.
M and N are number pixels in row and column directions, respectively.

2. Root Mean Square Error (RMSE): It is defined as the square root value of MSE and can be represented as:

$$RMSE = sqrt\ (MSE) \qquad (8)$$

3. Average Difference (AD): It is the average sum of pixel wise error between two images. The large the value of AD means image of poor quality.

$$AD = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|I(i,j) - \hat{I}(i,j)|}{MN} \qquad (9)$$

Ideally it should be zero.

4. Structural Content (SC): SC is defined as the sum of square of original image to the sum of square of enhanced image.

Mathematically,

$$SC = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}|I(i,j)|^2}{\sum_{i=1}^{M}\sum_{j=1}^{N}|\hat{I}(i,j)|^2} \qquad (10)$$

The large value of SC means the image is poor quality. Its value range is 0 to 1.

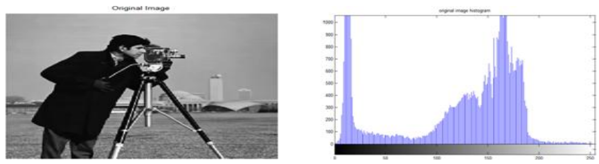
5. Maximum Difference (MD): It measures maximum of the difference between original and enhanced image and is defined as follows:

$$MD = \max[|I(i,j) - \hat{I}(i,j)|] \qquad (11)$$

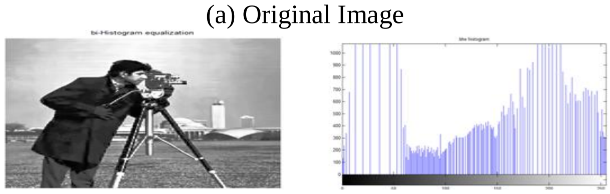
Its value range is of 0 to ∞. The large value of MD means the image is of poor quality.

V. RESULTS AND DISCUSSION

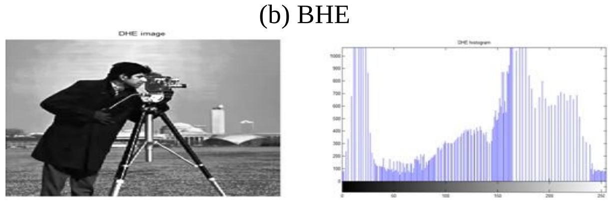
Various HE techniques namely BHE, DHE and BPDFHE have been implemented taking common set of 5 test images using MATLAB platform. The performance of the same has been analyzed on the basis of various image quality measures such as PSNR, RMSE, AD, SC and MD. Results have been represented as follows:
Test image 1:



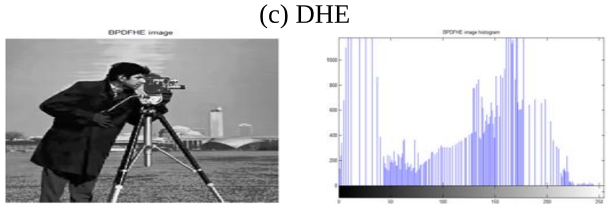
(a) Original Image



(b) BHE



(c) DHE



(d) BPDFHE

Fig. 6: Before and After Applying HE Techniques with Corresponding Histograms

Experimental results of image 1 in terms of PSNR, RMSE, AD, SC and MD are summarized in table 1.

Table 1: Objective IQM for Test Image 1

Metrics	BHE	DHE	BPDFHE
PSNR	24.1877	30.0363	**34.2044**
RMSE	995.5627	258.9464	**99.1751**
AD	**-24.0778**	-5.9381	0.0118
SC	**0.7046**	0.8878	1.0121
MD	63.0000	51.0000	**25.0000**

IJARCCE

ISSN (Online) 2278-1021
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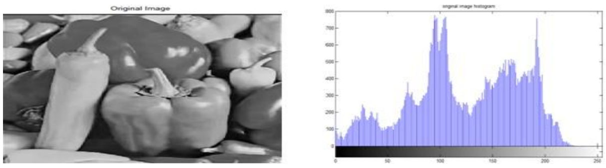
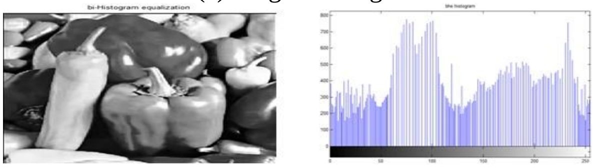
It is seen that BPDFHE gives the high PSNR, low RMSE and MD which shows that BPDFHE resultant image is of good quality. On the other hand BHE gives low AD and SC.

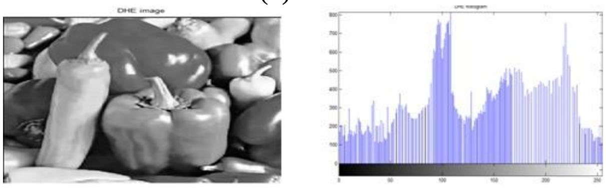
Test image 2:



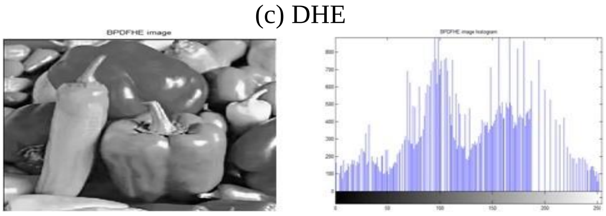
(a) Original Image



(b)BHE



(c) DHE



(d) BPDFHE

Fig. 7: Before and After Applying HE Techniques with Corresponding Histograms

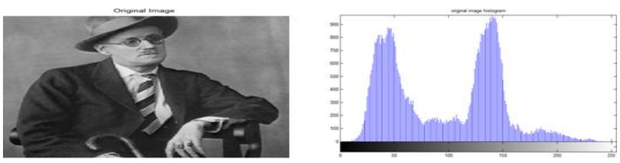
Performance analysis in terms of PSNR, RMSE, AD, SC and MD are summarized in table 2 for comparison purpose.

Table 2: Objective IQM for Test Image 2

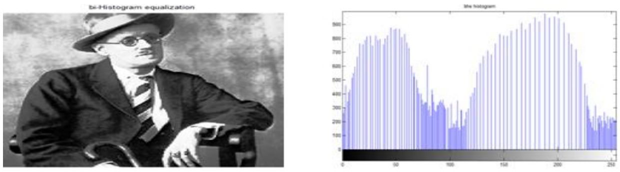
Metrics	BHE	DHE	BPDFHE
PSNR	26.8520	32.0436	**36.5215**
RMSE	539.0624	163.1097	**58.1686**
AD	-2.0608	**-3.9540**	0.0066
SC	**0.8496**	0.8933	0.9804
MD	45.0000	39.0000	**34.0000**

BPDFHE gave high value of PSNR, low values of RMSE and MD that indicates the resultant image is less noisy and has better quality. DHE have low value of AD that indicates good quality of image. BHE enhanced image has lowest value of SC.

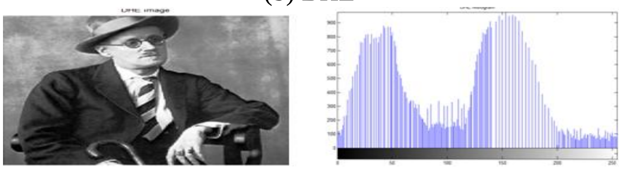
Test image 3:



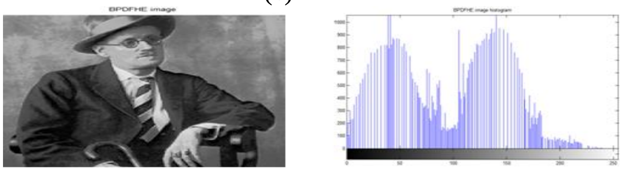
(a) Original Image



(b) BHE



(c) DHE



(d) BPDFHE

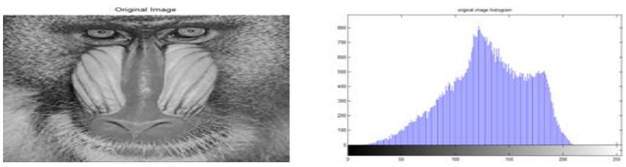
Fig. 8: Before and After Applying HE Techniques with Corresponding Histograms

BPDFHE enhanced image has highest value of PSNR that shows the resultant image is of better quality. Also the same conclusion is drawn from the lowest value of RMSE and MD. Moreover, BHE has lowest PSNR which shows that enhanced image is noisy but it has low AD and SC, which improves image quality.

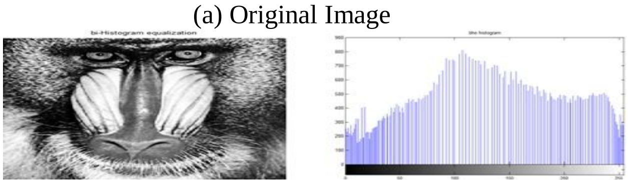
Table 3: Objective IQM for Test Image 3

Metrics	BHE	DHE	BPDFHE
PSNR	23.6451	29.7928	**35.5943**
RMSE	1.1281e+003	273.8821	**72.0130**
AD	**-18.7399**	-6.6873	-0.0111
SC	**0.6269**	0.8079	0.9820
MD	76.0000	47.0000	**19.0000**

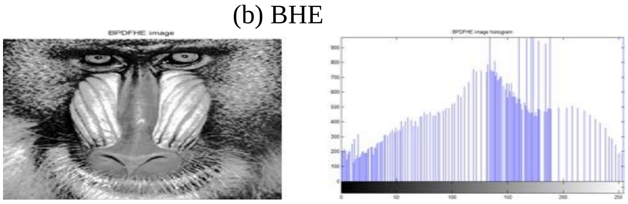
Test image 4:



(a) Original Image



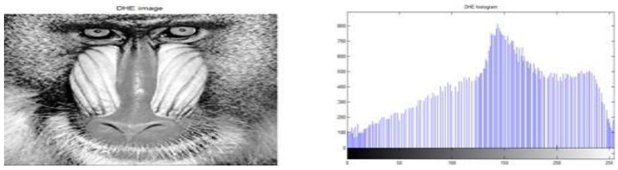
(b) BHE



(c) DHE

ISSN (Online) 2278-1021
ISSN (Print) 2319 5940

International Journal of Advanced Research in Computer and Communication Engineering
Vol. 4, Issue 12, December 2015



(d) BPDFHE

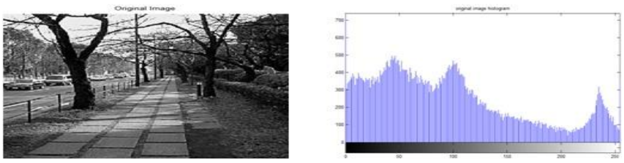
Fig. 9: Before and After Applying HE Techniques with Corresponding Histograms

BPDFHE have highest value of PSNR, low value of RMSE. DHE has low PSNR that indicates the resultant image is noisy but it has low value of AD, MD and SC which shows that the enhanced image has better quality
Performance analysis of test image 4 in terms of PSNR, RMSE, AD, SC, MD are given in table 4.

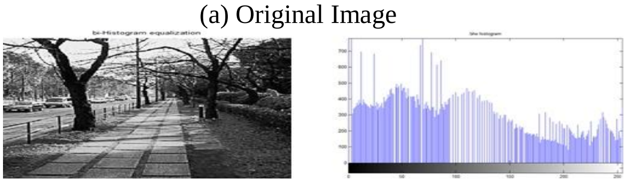
Table 4: Objective IQM for Test Image 4

Metrics	BHE	DHE	BPDFHE
PSNR	22.6900	24.4796	**26.0904**
RMSE	1.4055e+033	930.8491	**642.3904**
AD	0.2029	**-20.3586**	0.0689
SC	0.8197	**0.6987**	0.8866
MD	58.0000	**56.0000**	61.0000

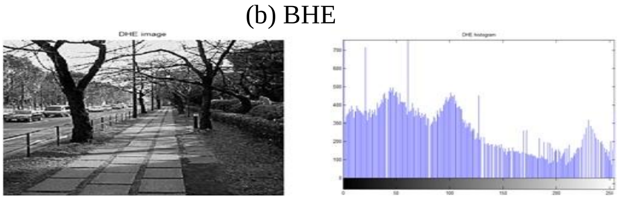
Test image 5:



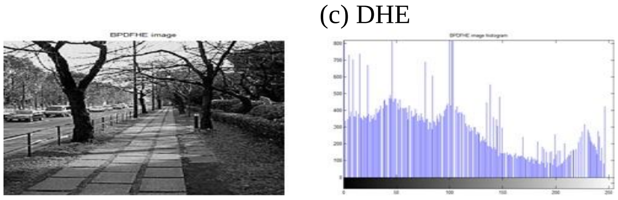
(a) Original Image



(b) BHE



(c) DHE



(d) BPDFHE

Fig. 10: Before and After Applying HE Techniques with Corresponding Histograms

Objective image quality parameters of test image 5 are shown in table 5.
For this test image DHE has highest value of PSNR which shows the resultant image is less noisy. Moreover, DHE has low value of RMSE. BPDFHE has low value of PSNR as compared to DHE but it has low value of MD which indicates the enhanced image has better quality. BHE have low value of AD and SC.

Table 5: Objective IQM for Test Image 5

Metrics	BHE	DHE	BPDFHE
PSNR	31.0486	**44.3018**	42.0968
RMSE	205.1057	**9.6975**	16.1124
AD	**-8.9365**	-0.9441	-0.0100
SC	**0.8465**	0.9885	1.0220
MD	33.0000	**9.0000**	15.0000

VI. CONCLUSION

In this paper, histogram equalization techniques like BHE, DHE and BPDFHE are implemented and compared. Visual and qualitative measure performance of these methods have been analyzed and it is found that all three techniques yields different grey scale images for different parameters such as PSNR, RMSE, AD, SC and MD. The images in which brightness preservation is required are not handled well by both BHE and DHE. The improved results can be better attained when they are enhanced by BPDFHE technique which provides brightness preservation and contrast enhancement. It is found that BPDFHE is the most suitable technique in terms of PSNR, RMSE and MD. In terms of AD and SC, BHE ensures good enhancement of image. BHE is better technique with low values of AD and SC but its performance is not satisfactory in terms of PSNR, RMSE and MD. DHE is simple method which provides enhanced results by preserving an image details in terms of PSNR, RMSE, AD, SC and MD. In future, for the enhancement purpose more images can be taken from the different sectors like medical, forensic etc. New parameters and new color model can also be chosen for better comparison.

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