A Modified BPDHE Enhancement Algorithm for Low Resolution Images

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Abstract. Image enhancement is an important image processing task that effectively improves the visual quality of an image. This image processing technique performs the operations on the input image in order to get an enhanced image. Histogram technique is a simple enhancement technique that leads to high degree of enhancement and reduces unnatural artifacts. In this research article, a color image enhancement algorithm for low resolution images is proposed. Also, a comparison of performance of various existing histogram enhancement techniques with the proposed algorithm is assessed using three parameters i.e. Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR), and Bit Error Rate (BER). From these parameters, it has been observed that the proposed algorithm well enhances the low resolution images by preserving original hue.

Keywords: Histogram equalization · Image enhancement · Image processing

1 Introduction

Image enhancement processes consist of number of algorithms/techniques that are meant to enhance or improve the visual appearance of digital images and also these methods tend to reconstruct the image in a suitable form for human and machine analysis. This is basically the process of changing the intensity of pixels present in that image [1]. In the process of enhancement of a digital image, the various features of an image are varied or filtered in order to reduce the noise contents present in that image and to make it more pleasant for eyes. There are number of such methods for image contrast enhancement. Global Histogram Equalization is one of the basic methods for the image enhancement which makes the use of image histogram [2]. Histogram Equalization is a method for image enhancement in accordance with the distribution of intensity over the entire range of histogram.

A number of researchers and academicians have contributed their efforts in improving the quality of the degraded images using various histogram modification techniques [4–8]. In 1987, Adaptive Histogram Equalization (AHE) technique was proposed in which the image was made to partition in several blocks and then these blocks were enhanced independently to highlight the local region [4]. The Brightness preserving Bi-Histogram Equalization (BBHE) was another algorithm in this chain proposed by Kim in 1997. In this technique the mean value is calculated in order to divide the histogram into smaller histograms [5]. Histogram technique was further

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extended by Ibrahim. The idea behind splitting the histogram into multiple sub-histograms is based on local maxima [6]. In this method, the loop holes of BBHE are removed and it improves the mean brightness of the output image. The recursive mean separated histogram considers the mean of the input image for sub-dividing the histogram into parts [7]. The process of sub-division continues until each part gets equalized independently. The number of sub-divisions occurred are based on the parameter called minimum mean square error (calculated between the input and output image). The method has a disadvantage that it has very high computational cost that was resolved by Dynamic Histogram Equalization (DHE) [8].

The complete paper is arranged as follows: Sect. 2 deals with the detailed study of BPDHE algorithm. Section 3 briefs out the proposed algorithm. Section 4 shows the results of the proposed algorithm and also comparison of the proposed method with the various existing techniques. Finally, Sect. 5 deals with the conclusion based on PSNR, MSE, and BER.

2 Related Work

The base of the proposed algorithm works on the theory of Brightness Preserving Dynamic Histogram Equalization (BPDHE) and Discrete Wavelet Transformation (DWT).

2.1 Brightness Preserving Dynamic Histogram Equalization

The major steps of the BPDHE are as follows:
Step 1: The histogram is leveled up by using 1-D Gaussian filter. The Gaussian filter is specified by the following equation:

$$G(x) = exp\left(-x^2/2\sigma^2\right) \tag{1}$$

where x represents the coordinate relative to the centre of the kernel, and σ represents the standard deviation.
Step 2: The leveled histogram is used for the process of splitting original histogram into sub-histogram and this process is based on local maxima. Here local maxima are used for separating the pixel intensities instead of local minima.
Step 3: Now, assign each sub-divided histograms a new dynamic range using Eq. (2).

$$width_i = L_h - L_I \tag{2}$$

$$f_i = width_i \times log10\, M \tag{3}$$

where M represents the total number of pixels in a width.

$$Span_i = Span_i / \sum_{k=1}^{n+1} f_i \tag{4}$$

The range $Span_i$ starts from P and ends at Q.

$$P_i = \sum_{k=1}^{i-1} Span_{k+1} \tag{5}$$

$$Q_i = \sum_{k=1}^{i-1} Span_k \tag{6}$$

Step 4: The next processing step is to equalize each sub-divided histograms separately. For sub-histogram with the range $[P_i, Q_i]$, the equalization is followed by the transformation (Fig. 1).



a) Original image b) Enhanced using BPDHE

Fig. 1. Enhancement of an image using BPDHE.

Step 5: Finally, the reconstructed image is obtained using the Eq. (7), where M_i is the mean brightness of the input image, M_o is the mean brightness of the output image and *f(x,y)* is the original input image

$$g(x, y) = (M_i/M_o) f(x, y) \tag{7}$$

This technique of enhancement normalizes the intensity of the output image by carrying out the mean intensity of the output image near to the mean intensity of the input image. But the histogram in this technique is divided into too many histograms that lead to the insignificant amount of improvement.

2.2 Discrete Wavelet Transformation

Output from the DWT has two components:

a) Approximate coefficients (from low pass filter).
b) Detailed coefficients (from high pass filter).

The pictorial representation is shown in the Fig. 2 where *f(x, y)* is an input image. The input is processed using two different filters i.e. low pass filter (LPF) and high pass filter (HPF). The LPF produces the approximate coefficient while HPF produces the

detailed coefficients. The low-frequency component contains approximation information of the image. The high-frequency component contains most noises and all the detail information of image [9]. The output of the LPF and HPF are down sampled by 2 (Fig. 3).

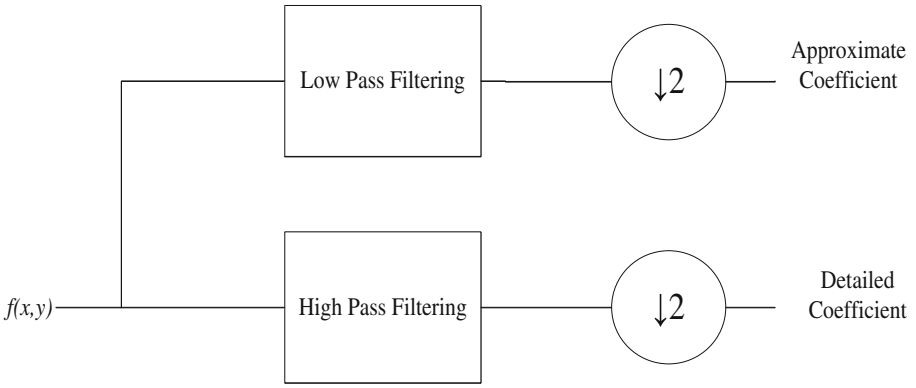


Fig. 2. Illustration of DWT [10].

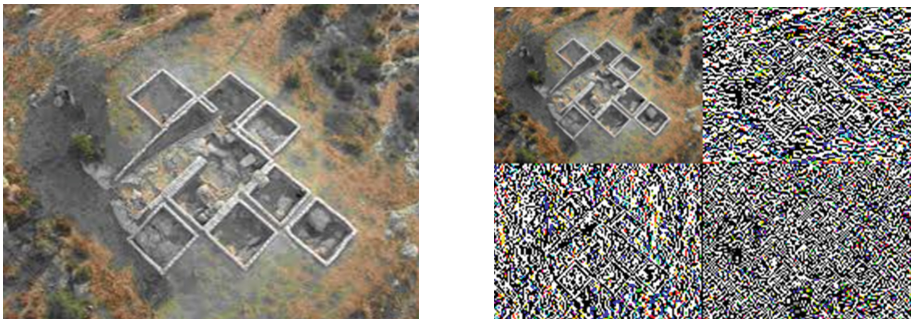


Fig. 3. Image obtained using DWT.

3 Work Methodology of Proposed Work

This section provides the complete steps of the proposed work for the image enhancement (Fig. 4).

The basic steps are given below:

Step I: Decompose the acquired image into low and high components in frequency domain by single level DWT using Haar wavelet transformation. This wavelet makes the hardware implementation easier as it is simple.

Step II: Enhance the lower coefficients using Brightness Preserved Dynamic Histogram Equalization.

Step III: The high-frequency coefficients are filtered using Gaussian filter so as to remove the noise.
Step IV: Reproduce the improved image by taking inverse DWT using modified coefficients.

Here, LF and HF represent the low and high frequency components respectively.

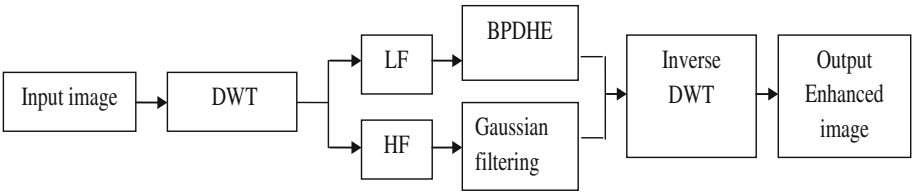


Fig. 4. A typical block diagram of the proposed algorithm.

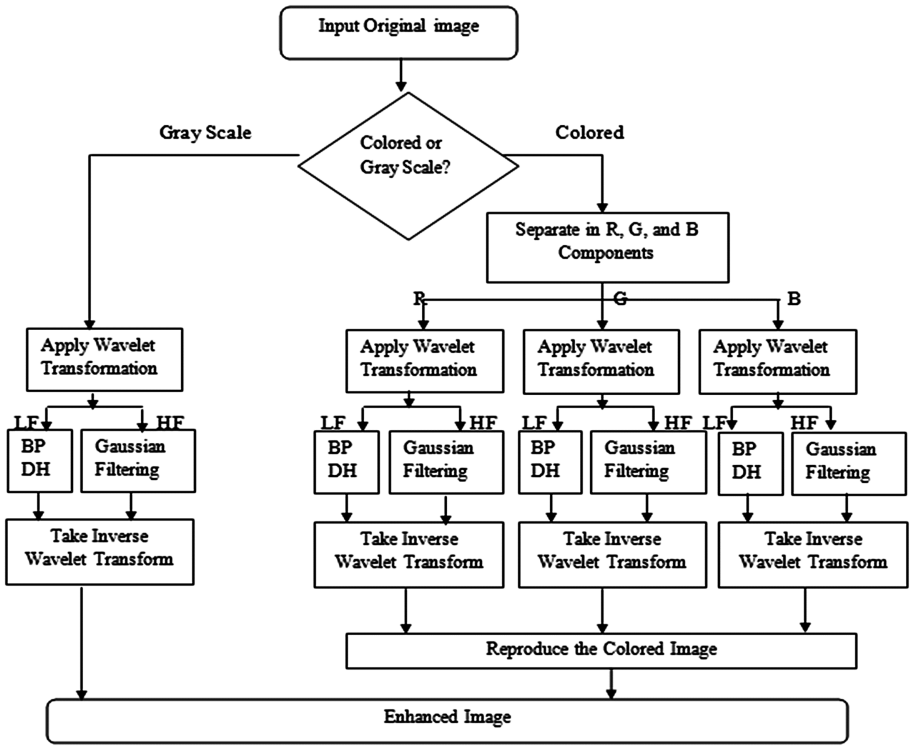


Fig. 5. Flow chart of the proposed algorithm.

Detailed Steps of the proposed algorithm described in Fig. 5 are given under as:

1. Acquire the input image.
2. Check whether it is a colored or gray scale image.

3. If gray scale image then follow steps 3(a)–(e)
   a) Divide the image into low and high frequency components using wavelet transformation.
   b) Apply Enhancement technique BPDHE on the lower frequency component to enhance it.
   c) Higher frequency components are then filtered using Gaussian filter.
   d) Take inverse wavelet transform using modified low and high components.
   e) Go to step 5.
4. If image is colored then follow steps 4(a)–(d)
   a) Separate the image in Red, Green and Blue components.
   b) Follow steps 3(a)–(d) for all the three components separately.
   c) Reproduce the single colored image from three components.
   d) Go to step 5
5. Output the final image as an enhanced image.

4 Results and Discussions

This research proposes a modified algorithm for color improvement of digital images. The performance of proposed algorithm is compared with the four existing color enhancement algorithms i.e. Global Histogram Equalization (GHE) (or simply Histogram Equalization) [1], Contrast Limited Adaptive Histogram Equalization (CLAHE) [3], Brightness Preserved Dynamic Histogram Equalization (BPDHE) [6] and

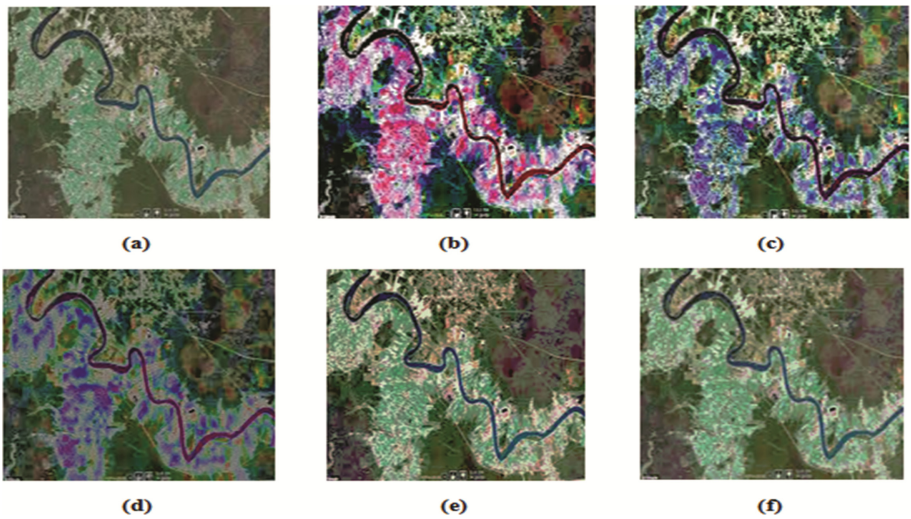


Fig. 6. (a) Original input image 1, Enhanced using (b) Global Histogram Equalization (GHE), (c) Contrast Limited Adaptive Histogram Equalization (CLAHE), (d) Combination of Contrast Limited Adaptive Histogram Equalization and Discrete Wavelet Transformation (CLAHE-DWT), (e) Brightness Preserved Dynamic Histogram Equalization (BPDHE), (f) Proposed algorithm.

Combination of Contrast Limited Adaptive Histogram Equalization and Discrete Wavelet Transformation (CLAHE-DWT) [9]. Figures 6, 7, 8 and 9 are colored images of size 256 x 256. The evaluation of different techniques has been done on the basis of MSE, PSNR and BER.

Figures 6, 7, 8 and 9 show the original and the image enhanced by the different algorithms. It is clear from the figure that colors of the image are changed in case of CLAHE and CLAHE-DWT techniques but the color has been preserved by BPDHE and proposed method and at the same time image is better enhanced by the proposed algorithm with the better PSNR, MSE and BER. The different parameters are tabulated in Table 1. It shows that the improvement in terms of PSNR is best in case of proposed algorithm. The CLAHE has least PSNR and CLAHE-DWT has more PSNR value than CLAHE but less than BPDHE and BPDHE has a less PSNR value than proposed technique. The comparison of different parameters for the different images due to various algorithms is shown in the Figs. 10, 11 and 12.

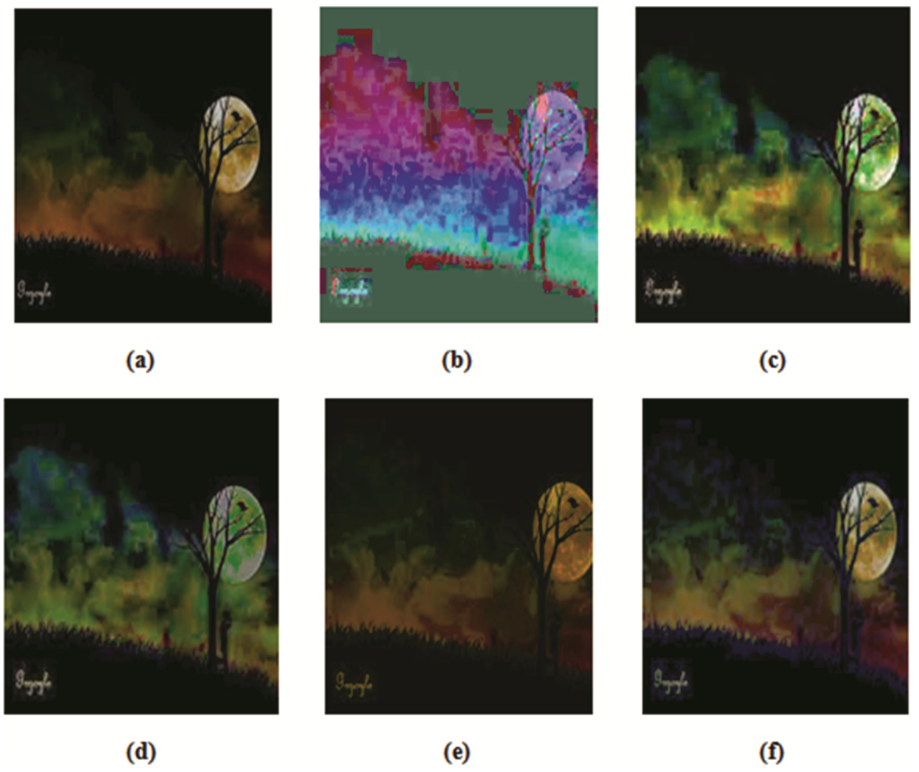


Fig. 7. (a) Original input image 2, Enhanced using (b) Global Histogram Equalization (GHE), (c) Contrast Limited Adaptive Histogram Equalization (CLAHE), (d) Combination of Contrast Limited Adaptive Histogram Equalization and Discrete Wavelet Transformation (CLAHE-DWT), (e) Brightness Preserved Dynamic Histogram Equalization (BPDHE), (f) Proposed algorithm.

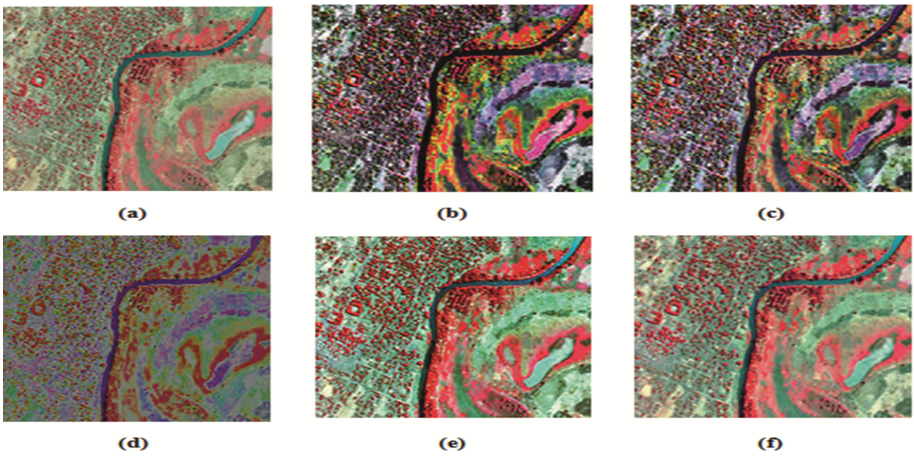


Fig. 8. (a) Original input image 3, Enhanced using (b) Global Histogram Equalization (GHE), (c) Contrast Limited Adaptive Histogram Equalization (CLAHE), (d) Combination of Contrast Limited Adaptive Histogram Equalization and Discrete Wavelet Transformation (CLAHE-DWT), (e) Brightness Preserved Dynamic Histogram Equalization (BPDHE), (f) Proposed algorithm.

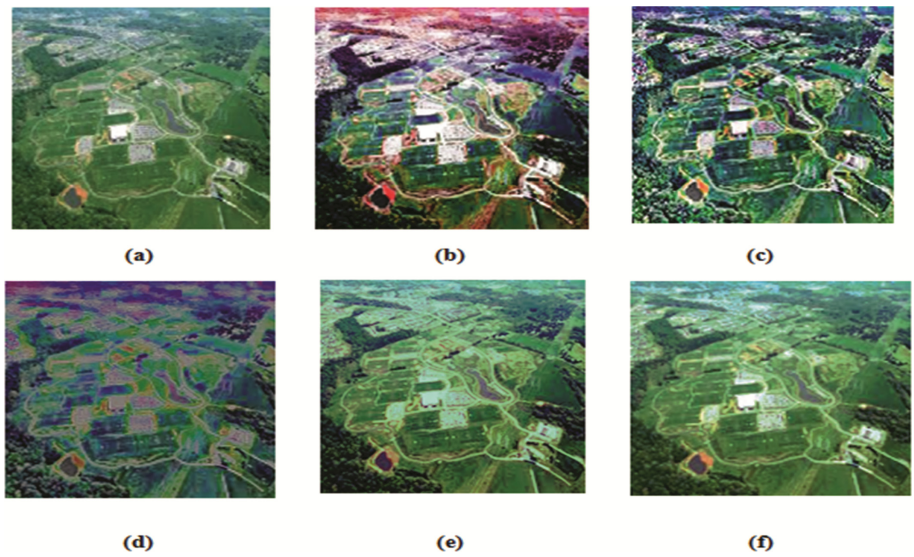


Fig. 9. (a) Original input image 4, Enhanced using (b) Global Histogram Equalization (GHE), (c) Contrast Limited Adaptive Histogram Equalization (CLAHE), (d) Combination of Contrast Limited Adaptive Histogram Equalization and Discrete Wavelet Transformation (CLAHE-DWT), (e) Brightness Preserved Dynamic Histogram Equalization (BPDHE), (f) Proposed algorithm.

Table 1. Comparison of different algorithms with the proposed algorithm for different images.

Image	Method	MSE	PSNR	BER
Image 1	**GHE**	0.0313	62.4165	0.0160
	CLAHE	0.0198	65.1676	0.0153
	CLAHE-DWT	0.0177	65.6532	0.0152
	BPDHE	0.0057	70.5497	0.0142
	PROPOSED	**0.0028**	**73.6144**	**0.0136**
Image 2	**GHE**	0.1691	55.8498	0.0179
	CLAHE	0.0159	66.1212	0.0151
	CLAHE-DWT	0.0059	70.4041	0.0142
	BPDHE	0.0027	73.8727	0.0135
	PROPOSED	**0.0019**	**75.2985**	**0.0133**
Image 3	**GHE**	0.0523	60.9499	0.0164
	CLAHE	0.0401	62.1001	0.0161
	CLAHE-DWT	0.0369	62.4657	0.0160
	BPDHE	0.0128	67.0734	0.0149
	PROPOSED	**0.0042**	**71.8707**	**0.0139**
Image 4	**GHE**	0.0325	63.0153	0.0159
	CLAHE	0.0259	64.0028	0.0156
	CLAHE-DWT	0.0232	64.4772	0.0155
	BPDHE	0.0056	70.6865	0.0141
	PROPOSED	**0.0039**	**72.2671**	**0.0138**

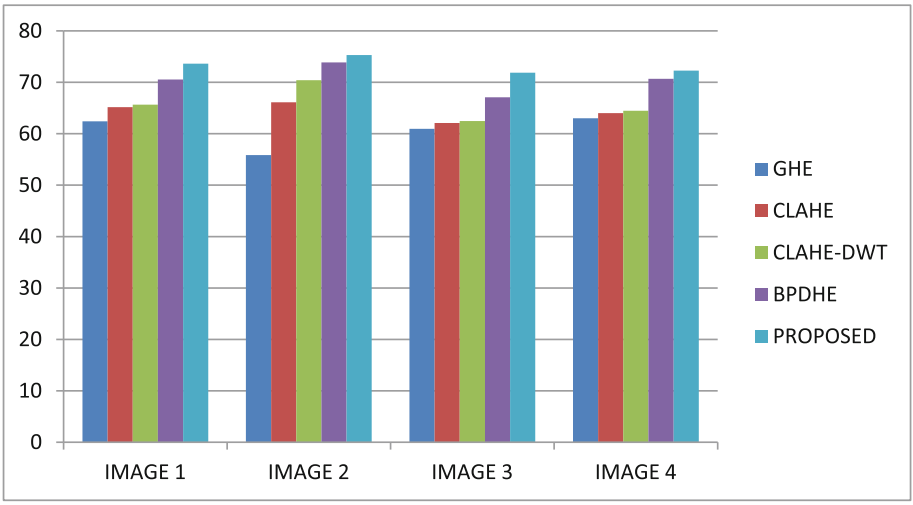


Fig. 10. Comparison of PSNR

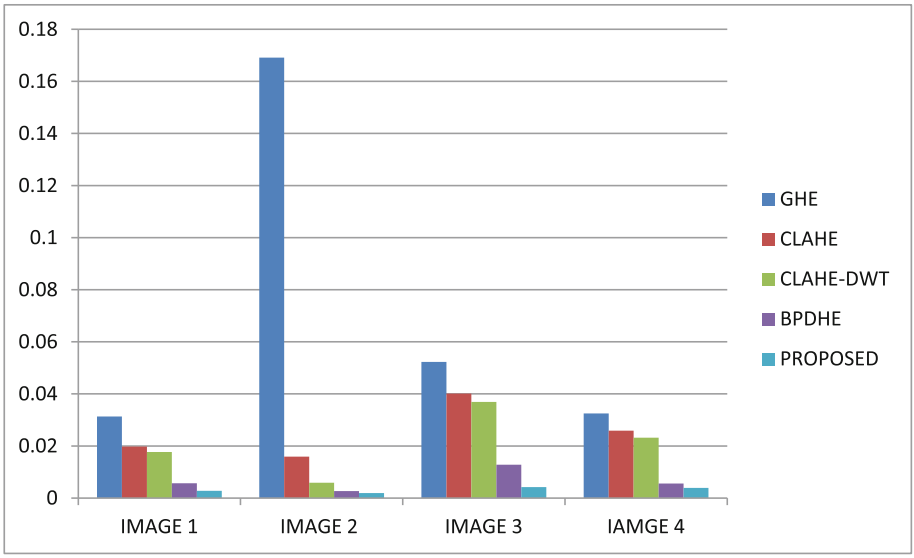


Fig. 11. Comparison of MSE

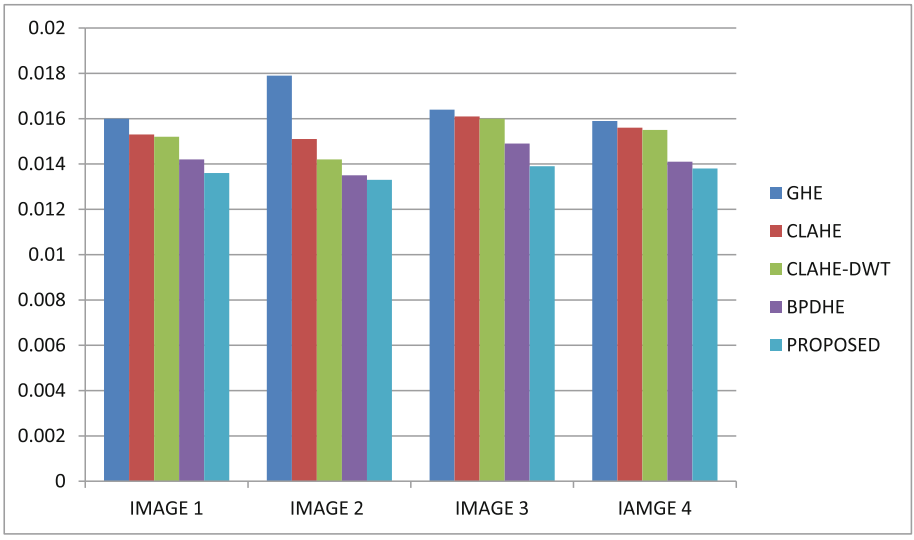


Fig. 12. Comparison of BER

5 Conclusion

This research article proposes a modified algorithm for the color enhancement of low resolution digital images. As discussed in Sect. 2, the high-frequency component contains most noises and all the detail information of image. Therefore, to limit the noise

enhancement and protect the detail information from over-enhancement, only the low-frequency component is enhanced and the high-frequency component is kept unchanged. The enhancement of the lower components is only done and the higher components which contain detailed components are only filtered using Gaussian filter. The division into the lower and detailed components is done using DWT [9]. The enhancement of the lower component is performed using the BPDHE algorithm for image enhancement. The method is thus called as the modified BPDHE technique. In this, the comparison of the proposed algorithm with the existing techniques is made on the basis of three parameters called as Peak- Signal to Noise Ratio, Mean Square Error and Bit Error Rate. From the results in Figs. 6, 7, 8 and 9, it has been observed that proposed method can very efficiently preserves the original color of the image and capable of having higher PSNR values than other histogram techniques as CLAHE, CLAHE-DWT and BPDHE. The graphs of parameters PSNR, MSE and BER are shown in Figs. 10, 11 and 12 respectively. As shown in Fig. 10, higher PSNR is obtained for proposed technique compared to the other equalization methods. It has been observed that the proposed algorithm yields maximum PSNR, minimum MSE and BER. The comparison from visual appearance of Figs. 6, 7, 8 and 9, it has been observed that the proposed algorithm improves the information contents present in that image while preserving the original hue.

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