IMAGE CONTRAST ENCHANCEMENT USING BRIGHTNESS PRESERVATION DYNAMIC HISTOGRAM EQUALIZATION

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Abstract

In the digital image processing domain, image enhancement plays an important role for various applications like astronomy, satellite image processing, geographical imaging, and consumer electronics etc. This work gives the implementation of brightness preserved histogram specification-controlled histogram equalization techniques for enhancing the image quality by preserving the brightness and by enhancing contrast of image by the usage of dynamic stretching. The proposed method provides the better quantitative and qualitative approach compared to the various other schemes; algorithms proposed by various researchers in this field of image enhancement.

Keywords: image processing domain, image enhancement, dynamic stretching, histogram equalization, histogram specification.

1. Introduction

In recent years, the wide-ranging concern in the pitch of digitization to advance the quality of an image is frequently increasing. The most important application of colour image enhancement is for digital video enhancement [1] applications. This field of enhancing low light images has captured the attention of many researchers because it enhances the recognition of objects in poorly illuminated images. So, the target can be set to upgrade the quality of less illuminated images to easily extract the image details. These algorithms will be further [2] useful for computer aided processing. In hot times, the quality of the images taken by cell phones and cameras are often degraded because of the bad environmental conditions, poor light availability, images captured at night, and let-down of picture capturing devices themselves. Hence for better visual perception, contrast enhancement is very essential and can be further [3] used for pattern recognition and computer vision applications. Due to the external environment such as noise and lighting or the device itself, the quality of the original digital image we obtain is usually not very high. Therefore, it is generally necessary to enhance the original digital image before performing operations such as edge detection and image segmentation on the image. Image enhancement [4] is to improve the image, make it more suitable for human vision, or highlight certain features for automatic recognition by the machine. Image enhancement, which creates favourable conditions for subsequent image processing and video follow-up, is an important way to improve image quality and visual results. It is also thought to be a technology for improving image visual effects or transforming images into technologies suitable for human observation and machine analysis [5]. The general definition of image contrast enhancement is related to the image's overall intensity and the edges of the object. The image created by the space observation image on the camera image surface is typically low in contrast, with a concentrated intensity distribution in the histogram and the target submerged in a complex background. Image denoising and enhancement have always been important research objects in the field of image science and engineering because of the factors that will undoubtedly cause image quality degradation [6] during imaging equipment and processes.

The extraction of regions which are having different properties like colour, brightness, texture, or any other is mainly founded on [7] discontinuity characteristics. So, enhancing the contrast of an image interns included enhancing boundaries, edges, details, and brightness that help for figure print recognition, image classification, biomedical applications, underwater image enhancement etc. All the efforts should be made to make an image valuable and more pleasant by uniformly distributing contrast over the entire image [8]. There are numerous ways to boost the contrast in less illuminated images, such as Histogram Equalization (HE)- based, gamma correction, fuzzy transformed, wavelet transformed-based methods, spatial filtering methods. However, quite a lot of techniques are unsuccessful to advance the image's visual quality if the image is captured in bad light conditions. But histogram advancement-based algorithms [9] gained additional recognition for enhancing weakly illuminated colour images. The HE method does the elongation of the intensity range in the image to uniformly distribute pixels across the image. In other words, it suggests mapping one with the other distribution to become a uniform and broader distribution of pixel intensities [10]. This can be attained by normalization of the distribution of intensities using cumulative distribution function so the output can have uniformity. Rest of the paper is organized as follows: Section 2 details about literature survey, section 3 details about the proposed methodology, section 4 details about the results with discussion, and section 5 concludes article with references.

2. Literature Survey

Mnassri, Besma, et al. (2022) [11] proposes comparative research across some contrast enhancement methods mainly: Global Histogram Equalization (GHE), Adaptive Gamma Correction (AGC) and knee function and gamma correction based on Singular Value Decomposition with Discrete Wavelet Transform (SVD-DWT) method (KGC-DWT-SVD). These methods had been applied on brain and spinal cord MR (Magnetic Resonance) images of patients affected with multiple sclerosis. The obtained results had been evaluated according to the following measurement metrics: the entropy (H), peak signal to noise ratio (PSNR), mean squared error (MSE), structure similarity index measurement (SSIM) and feature similarity index measurement (FSIM). Zhang, Weidong, et al. (2022) [12] proposed this method to address the degradation issues via attenuated colour channel correction and detail preserved contrast enhancement. Concurrently, they first proposed an underwater image colour correction method. Considering the differences between superior and inferior colour channels of an underwater image, the inferior colour channels are compensated via especially designed attenuation matrices. Kumar, Ravi, et al. (2022) [13] proposed to improve the luminosity and contrast of the colour retinal image. This algorithm is applied to the publicly available structured analysis of the retina (STARE) image dataset, and promising results are obtained. Contrast enhancement and luminosity enhancement are the two sections of the proposed method. Gamma adjustment on the V channel in hue, saturation, and value (HSV) colour model gives a luminosity gain matrix, which improves the image luminosity. Weighted average histogram equalization (WAHE) acts on the luminosity channel (L) of the LAB (luminosity and chromaticity) model for contrast improvement. Bhandari, Ashish Kumar, et al. (2022) [14] Maurya proposed a novel Gamma Corrected Reflectance for Image Enhancement (GCRIE) using Multi-Scale Retinex (MSR) theory, filtering procedure is used to acquire rough illumination components, refined through a guided filtering function. A final value of reflectance is obtained through nonlinear logarithmic operation and visual contrast measure-based weighting procedures. Finally, a series of metrics such as entropy, structure similarity index (SSIM), peak signal-to-noise ratio (PSNR), visual colour naturalness index (CNI), contrast measure (VCM), and gradient magnitude deviation (GMSD) was used to assess the quality of the enhancement. Simulation outcomes confirm that the projected scheme can visually be pleasing enhanced images superior to those computed by classical methods. Jebadass, J. Reegan, et al. (2022) [15] proposed method, first the given low-light image is fuzzified by normal fuzzification. Then the fuzzified image is converted to an interval-valued intuitionistic fuzzy image. This image will be proposed enhanced image after applying the contrast limited adaptive histogram equalization (CLAHE). The experimental results reveal that the proposed method gives better results when compared with other existing methods like histogram equalization (HE), CLAHE, brightness preserving dynamic fuzzy histogram equalization (BPDFHE), histogram specification approach (HSA). Based on the performance analysis like entropy and correlation coefficient (CC), the proposed method gives better results.

An enhancement approach is proposed by Vijayalakshmi, D., et al. (2022) [16] to improve the quality of the satellite images to improve the accuracy of the cloud detection process. The enhancement process utilizes the edge information extracted from the input image. The extracted edge information creates a variational map to equalize the intensities by distributing them to occupy the whole dynamic gray scale. Paul, Abhisek, et al. (2022) [17] proposed a novel histogram modification-based bi histogram equalization (HE) approach for contrast enhancement on digital images is presented. At first, a power-logarithm transformation function is used to change the histogram of the input image. The logarithm operation reduces the input histogram's excessive peaks, while the power function restores the histogram structure. The adjusted histogram is then separated into two sub-histograms at the threshold limit, using the input image's minimum intensity and standard deviation. Sub-histograms are clipped based on their individual plateau limit parameters, which are based on the median value of the individual sub-histogram, to control the over-enhanced outcomes. Yang, Fan, et al. (2022) [18] proposed a method to improve Brightness Preserving Dynamic Histogram Equalization (BPDHE). First, the image is subjected to bilinear interpolation. Then, the probability density function of the grey level of the image is divided into two parts according to its mean value. Finally, different methods are used to find local maximums for each of these two parts. In this paper, Absolute Mean Brightness Error (AMBE), Structure Similarity Index Measure (SSIM), Information Entropy (Entropy) and Peak Signal to Noise Ratio (PSNR) are used to compare with the different methods. Ghous, Mujtaba, et al. (2022) [19] proposed a technique for the contrast enhancement of both types of images the colour images as well as gray scale images. The proposed method calculates two parameters' statistics and phase congruency of the image. Furthermore, we use optimal histogram method which is RIQMC (reduced reference image quality metric for contrast changes) based and histogram equalization which is nonparametric is used to perform the contrast enhancement. Kaur, Manpreet et al. (2021) [20] proposed the retinal image enhancement techniques using histogram equalization, adaptive histogram equalization, brightness preserving bi-histogram equalization, dual-tree complex wavelet transform, and contrast limited adaptive histogram equalization techniques are discussed. For comparison of these techniques, parameters like mean square error, peak signal-to-noise ratio, structural similarity index metrics, absolute mean brightness error, and root mean square error are available. These parameters can help in an early-stage diagnosis of retinal complications.

3. Proposed Methodology

Image contrast enhancement is a method which is used to increase the visibility of images. Here, the intensity of the pixel grey level is modified based on a function. Intensity based methods are of the form:

$$Io\ (x, y) = f\ (I\ (x, y)) \quad (1)$$

The original image is $I\ (x,\ y)$, the output image is $Io\ (x,\ y)$ and f is the transformation function. Intensity based methods transmute the grey levels over the entire image. Even after the transformation pixels with the same grey levels throughout the image remain the same. Contrast stretching is a generally used method that falls into this group. Figure 1 represents the proposed method of image enhancement with contains the dynamic stretching based brightness preserving histogram equalization as its operational function f $(I(x,\ y))$.

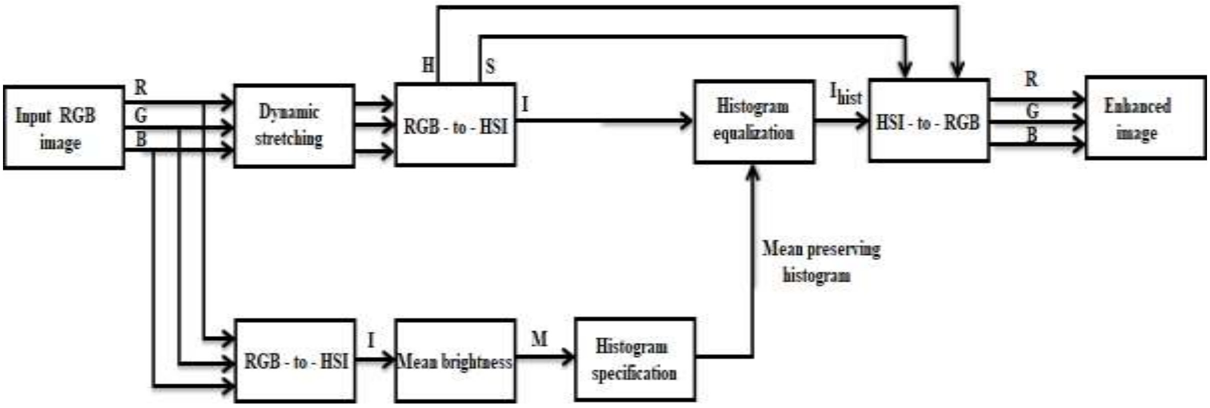


Figure 1: Proposed block diagram for brightness preserving histogram equalization approach.

The step wise operation of proposed method as follows:

Step1: RGB conversion: Generally, histogram equalization methods are applied on black & white and grey scale images. In order to apply the histogram equalization for colour images, If I be the colour input image,it is divided into Red, green and blue colour channel as follows:

$$R = I\,(:,:,1):\ G = I(:,:,2)\ and\ B = I(:,:,3) \qquad (2)$$

The Red, green, and blue colour channels are separately applied to both dynamic stretching and RGB-to-HSI operations.

Step 2: RGB to Hue saturation and intensity (HSI) conversion: the RGB to HSI conversion as follows.

$$H = \cos^{-1}\left(\frac{(R-G)+(R-B)}{2\sqrt{(R-G)^2+(R-B)(G-B)}}\right) \qquad (3)$$

$$S = 1 - \frac{3}{(R+G+B)}[min(R,G,B)] \qquad (4)$$

$$I = \frac{1}{3}[R+G+B] \qquad (5)$$

Step 3: Dynamic stretching:

Dynamic stretching is the method of removing additional and unrealistic colour casts produced by the environment. In underwater environment due to scattering and wavelength selective absorption, additional colour casts are introduced. To remove these effects, Dynamic stretching method is used. The most common and widely used Dynamic stretching algorithm is grey world theory. The grey world algorithm is based on the property that average colour of the image is grey. This condition does not hold by the underwater images, because as the depth of the ocean increases the red channel of the image attenuates faster than the other colour channels. To obtain the colour cast free underwater images, grey world algorithm is modified. The first step of the grey world algorithm is calculating the averages of R, G and B channel, i.e., R_{avg}, G_{avg}, and B_{avg}as in eqn. 6to 8.

$$R_{avg} = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} I_r(x, y) \qquad (6)$$

$$G_{avg} = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} I_g(x, y) \qquad (7)$$

$$B_{avg} = \frac{1}{MN} \sum_{x=1}^{M} \sum_{y=1}^{N} I_b(x, y) \qquad (8)$$

where, $I_r\ (x, y)$, $I_g(x, y)\ and\ I_b(x, y)$ are the intensity values of red, green, and blue channel of the image respectively. After finding out the individual channel average values, the average of these three can be found out. The average value $Aavg$ is calculated by averaging the values obtained from following equations.

$$Aavg = \frac{R_{avg} + G_{avg} + B_{avg}}{3} \qquad (9)$$

The individual colour value of each pixel is adjusted as follows.

$$I'r = \frac{Ir(x, y)Aavg}{Ravg} \qquad (10)$$

$$I'g = \frac{Ig(x, y)Aavg}{Gavg} \qquad (11)$$

$$I'b = \frac{Ib(x,y)Aavg}{Bavg} \qquad (12)$$

Ir, $Ig\ and\ Ib$ are the original pixel values and $Ir\ '$, $Ig\ '\ and\ Ib'$ are the adjusted values by the grey world method. As the R channel value in the intensified image is very low, color correction becomes erroneous. To equalize the channels, the grey world algorithm is modified as in eqns 13 to 15 which gives better results over the existing algorithm.

$$I'r = Ir\,(x,y) + (Aavg - Ravg) + (Iavg - Ir\,(x,y)) \qquad (13)$$

$$I'g = Ig\,(x,y) + (Aavg - Gavg) + (Iavg - Ig\,(x,y)) \qquad (14)$$

$$I'b = Ib\,(x,y) + (Aavg - Bavg) + (Iavg - Ib\,(x,y)) \qquad (15)$$

where $Iavg$ = (Ir + Ig + Ib)/3, the average intensity value though Dynamic stretching removes additional and unrealistic colour casts, it alone cannot solve the problem. Hence colour correction is required after fusion. The white balanced output, which is the first derived input is then converted to HSI Colour space model for applying histogram equalization to the interested colour channel as per the design.

Step 4: Mean brightness

The intensity output of the HSI is applied to implement Mean brightness, we used morphological based operation, which is computationally not exhaustive. We are essentially extracting pixel block centered also referred to as patch at Ω(x,y). We determine the minimum value for each block. Hence, we get three values corresponding to each colour for every block of pixels. From these three minimum intensity values we chose the minimum value and replace it at the center location of the processed patch Ω(x,y). This step is repeated till the entire image is operated upon. Finding the minimum value for a pixel block in a grayscale image is same as carrying out a morphological operation. In this case, we can separately apply this operation on individual colour channels corresponding to H, S and I. This step is then followed with finding the minimum out of the three colour planes for any structuring element. Inspired from mean channel prior, we derive the modified red colour priority depth map image, which is given as

$$I^{mean}(x,y) = \min(\quad \min \quad (I^{n}(x,y))) \qquad (16)$$

where Ω(x,y) is the structuring element, n corresponds to the number of partitions, I corresponds to the intensity colour channel. This depth map gives the pictorial estimate of the presence of haze in an image and is useful for estimating the mean transmission map.

Step5: Histogram specification

The output of the mean brightness operation applied to histogram specification (HS). Histogram specification used the means for dividing the image input into two different parts. The sub images first part consists of pixels values that are up to mean, and the second part consists of pixels that are higher than mean of original image. After these two different histogram ranges which don't overlap were attained. After these two sub-parts i.e., sub-histograms were equalized by histogram specification. From the results it was found that histogram specification was proficient of preserving the actual brightness to level when input histogram of the image had quasi- symmetrical distribution near to its mean. In this technique, the mean intensity of image's every pixel with a range of histogram from 0 to M-1 is presented by input mean. The 1st histogram consists of pixels that are from zero to mean and the 2nd consists of from mean+1 to M-1. Histogram specification has been implemented to these two sub images separately, and after that both equalized images are integrated. Histogram specification can improve input image and can be utilized for user electronic by preserving the mean brightness. It will be represented in mathematical form that Histogram specification much considerably preserves the images' mean brightness than usual HE by improving the contrast. Consequently, it gives more enhancements which can be used in user electronic devices. Assume that mean of image X is Xm which is given as:

$$X_m \in \{X_0, X_1, \ldots\ldots, X_{l-1}\} \qquad (17)$$

On the basis of mean, the decomposition of image is done into 2 sub images i.e., X_L and X_U

In this, X_L consists of:

$$(X_0, X_1 \ldots\ldots, Xm) \quad (18)$$

And X_U consist of:

$$(X\ m+1,\ \ X\ \ m\ \ +2\ \ \ldots\ldots, X\ L-1) \quad (19)$$

Same as HE, in this, the CDF is utilized in the form of transform function as:

$$f_L(x)\ = X_L +\ (X_m - X_L)\ XU \quad (20)$$

And

$$f_U(x)\ =\ X_U + (X_{L-1} - X_{m+1})\ XL \quad (21)$$

Based on above equation, the equalization of the divided sub images is performed separately, and ensuing sub images' composition comprises the Histogram specification output i.e., finally, the Histogram specification output image Y is given as:

$$Y =\ f_L(X_L)\ \cup\ f_U(X_U) \quad (22)$$

Step 6: Histogram Equalization:

Output of the histogram specification applied as input to the Dynamic histogram equalization (DHE). Also, Dynamic histogram equalization (DHE) has been proposed which is the enhanced version of conventional HE. It generates more comprehensive results exclusive of any information loss. In DHE, the separation of the input histogram is done into various sub parts and after that the allocation of ranges of dynamic grey level is done to every part. In this technique, the division of original image is done into various sub images on the basis of their local maxima, and after that the DHE is implemented to every sub-image and at last, sub images are integrated. With this help of this, input image's washout effect can be prevented and also it presents moderate of input image. Fundamentally, 5 major steps are involved in DHE i.e.:

- Histogram smoothing with filter
- Identification of local maximums location from histogram
- Mapping of every partition novel dynamic range
- Equalization of every part separately
- Normalization of image brightness

This section defines the histogram equalization. CDF and PDF are defined in this section with the help of equalizations. Effects of histogram equalization on contrast of the image are discussed here. PDF (X^k) for the provided image X, is given as:

$$p([X])^k = \frac{X^k}{n} \quad (23)$$

Here k= 0, 1... L-1, where $n\ k$ is the count of the levels in which Xk is demonstrated in image X and n denotes the total count of samples present in image of input. Here it is to be noted that p(Xk) in incorporated with input image's histogram which shows the pixel numbers having particular intensity Xk. Depending upon the PDF, cumulative density function is given as:

$$c(x) \sum_{j=0}^{k} p(Xj) \qquad (24)$$

In the equation 24, Xk =x, value for k=0, 1…L-1. By definition c is defined as the c (XL- 1) =1.DHE technique is used by CDF for mapping of input image with whole dynamic range, (X0,XL-1) in form of transform function. Depending on the CDF, transform function f(x) is defined as:

$$F(x) = X_0 + (X_{l-1} - X_0)\, c(x) \qquad (25)$$

Output image from the equalization of histogram is given as follows:

$$Y = f(x) = \{f\ (X\ (I, j)\ |\forall\ X\ (i, j) \in X \qquad (26)$$

DHEs great performance enhances the image contrast as the result of dynamic range expansion, however histogram itself is flattened by HE.

Step 7: HSI to RGB: the HSI to RGB conversion as follows.

- RG sector ($0 \leq H < 120$)

  B = I (1-S)

  $$R = I\left[1 + \frac{S\ COS\ H}{\cos\ (60 - H)}\right]$$

  G =1- (R+B)

- GB sector ($120 \leq H < 240$)

  R = I (1-S)

  $$G = I\left[1 + \frac{S\ COS\ (H-120)}{\cos(60-(H-120))}\right]$$

  B =1- (R+B)

- BR sector ($240 \leq H < 360$)

  G = I (1-S)

  $$B = I\left[1 + \frac{S\ COS\ (H-240)}{\cos(60-(H-240))}\right]$$

  R =1- (G +B)

Finally concatenated RGB image gives the contrast enhanced colour image.

4. Results and Discussion

This section gives the results comparison of multiple images, such as low light image, low light image, dusty image, hazy image, and so on.

Low light image: In the FIGURE 2, (a) shows the input low light image, which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and image details are clearer compared to the existing method.

(a)

(b)

(c)

Figure 2: (a)Input image (b)Existing output image (c)Proposed output image.

Dusty image: In the FIGURE 3, (a) shows the input Dusty image, which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE where some details in the image are missing and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and image details are clearer compared to the existing method.

(a)

(b)

(c)

Figure 3: Input dusty image (b)Existing output image (c)Proposed output image.

Hazy image: In the FIGURE 4, (a) shows the input Hazy image, which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE which is over enhanced and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and image details are clearer compared to the existing method.

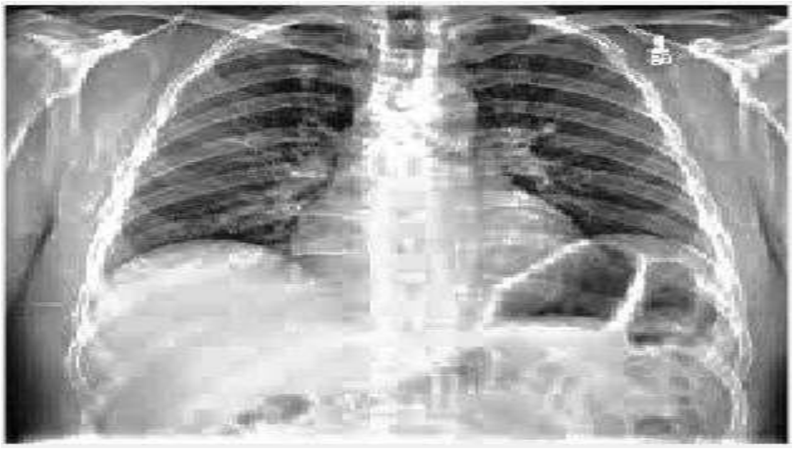
(a)

(b)

(c)

Figure 4: Input hazy image, (b)Existing output image, (c)Proposed output image.

Medical image: In the FIGURE 5, (a) shows the input Medical image which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE which is over enhanced and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and image details are more clear compared to the existing method.



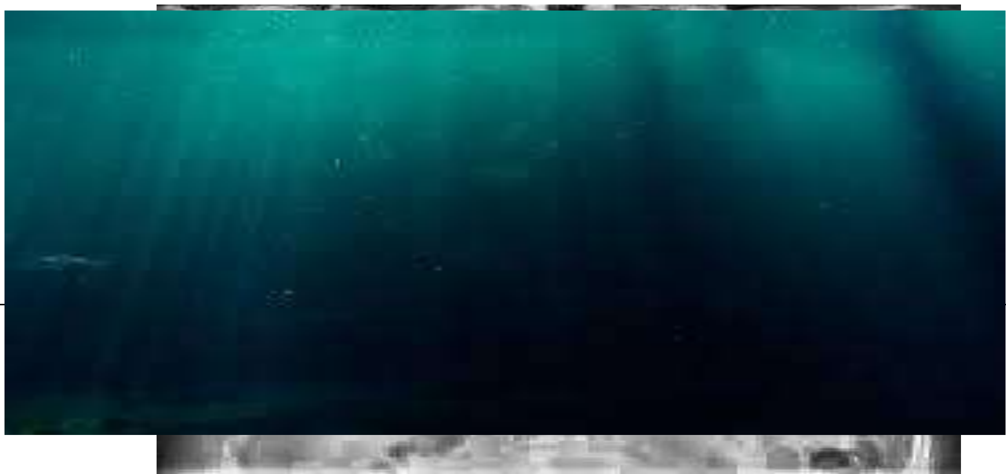
(a)

(b)

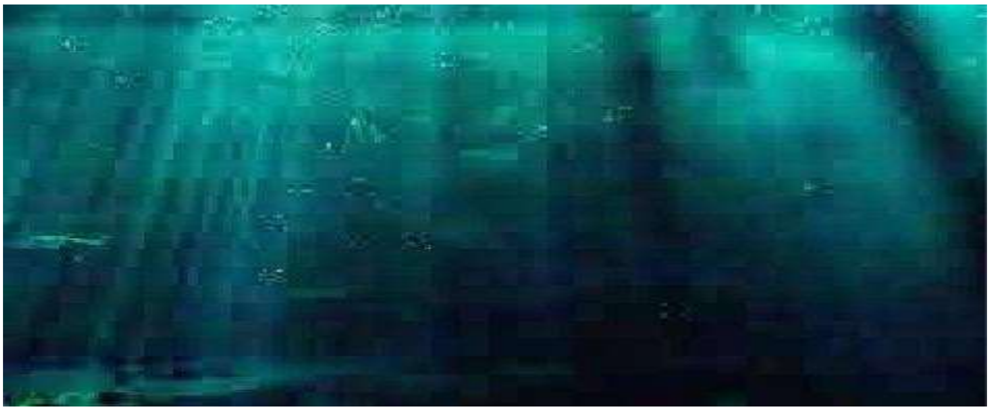
(c)

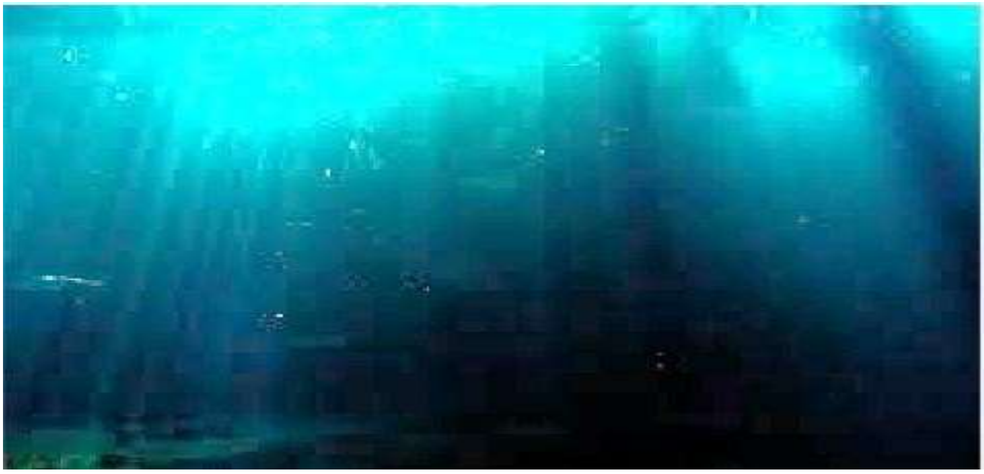
Figure 5: (a) Input Medical image, (b)Existing output image, (c)Proposed output image.

Underwater image: In the FIGURE 6, (a) shows the input Under water image, which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and details are clearer compared to the existing method.



(a)





(b)

(c)

Figure 6: (a) Input underwater image, (b)Existing output image, (c)Proposed output image.

Satellite Image: In the FIGURE 7, (a) shows the input Satellite image which is to be enhanced, (b) shows the output enhanced image obtained by existing method i.e., CLAHE which is over enhanced and (c) shows the output enhanced image obtained by the proposed method which has better visual quality and details are more clear compared to the existing method.

(a)

(b)

(c)

Figure 7: (a) Input Satellite image, (b)Existing output image, (c)Proposed output image.

Table 1: Comparison of PSNR and SSIM for various methods.

IMAGE TYPE	METHOD	PSNR (in dB)	SSIM

LOW LIGHT IMAGE	CLAHE	18.94	0.52
	PROPOSED	**61.99**	**0.93**
DUSTY IMAGE	CLAHE	25.06	0.82
	PROPOSED	**65.44**	**1.00**
HAZY IMAZE	CLAHE	26.45	0.84
	PROPOSED	**45.29**	**0.95**
MEDICAL IMAGE	CLAHE	18.38	0.76
	PROPOSED	**75.17**	**1.00**
UNDER WATER IMAGE	CLAHE	21.58	0.30
	PROPOSED	**69.76**	**1.00**
SATELLITE IMAGE	CLAHE	12.76	0.49
	PROPOSED	**67.14**	**1.00**

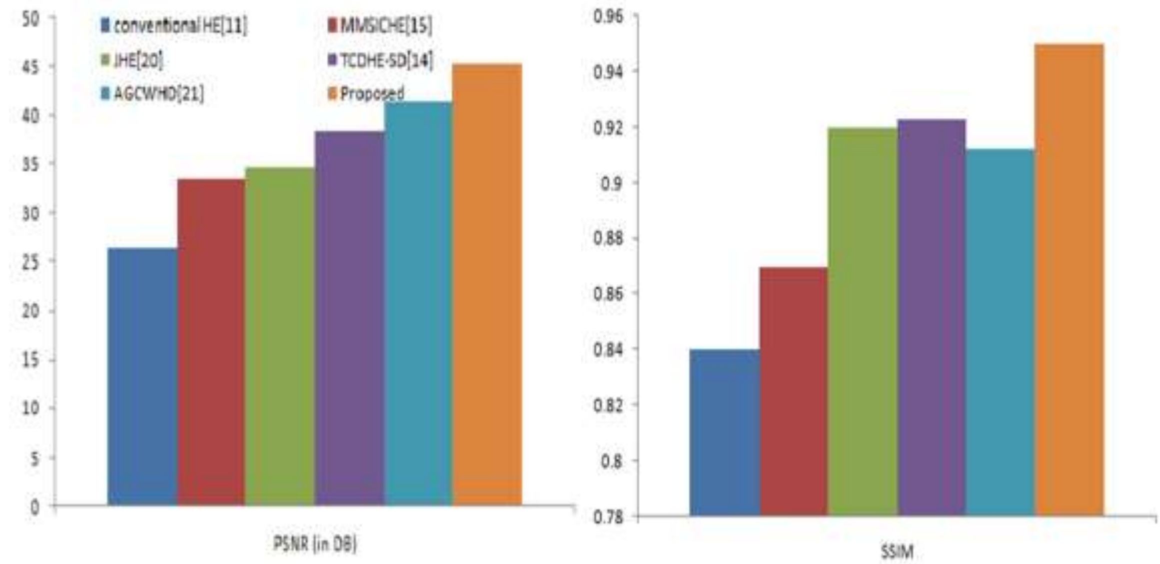


Figure 8: Comparison of PSNR and SSIM for various methods.

From the table 1 and figures 2 to 7, it is clearly observed that the proposed method provides the better visual enhancement results as the existing methods failed to provide the perfect enhancement for dusty, low light images, hazy image, underwater image, medical image, satellite images. And from the figure 8, it is proved that the proposed method provides the better quantitative evaluation compared to the conventional approaches such as conventional HE [11], MMSICHE [15], JHE [20], TCDHE-SD [14] and AGCWHD [21] with respect to the various metrics such as PSNR and SSIM.

5. Conclusion

In the processing of images, the role of image enhancement is very significant. This paper gives the implementation of histogram equalization techniques for enhancing the image quality by preserving the brightness and by enhancing contrast of image. Various HE schemes like conventional HE is compared with the proposed method in this paper along with quantitative evaluation and working concept which reveals that all these techniques work on different concepts such as, image decomposition using mean value, median value and local minima or maxima, respectively. Using the brightness preserved histogram specification-controlled histogram equalization techniques for enhancing the image quality gives outstanding results compared to the existing approaches. This work can be extended to implementing satellite image processing applications for haze removal. There are various techniques for enhancing the image. After implementing some of the techniques, which all are based on the histogram equalization, it is concluded that the enhancement of any image is application dependent. From the tables shown above in results, it is concluded that proposed methodology is better than other existing techniques in terms of Mean Square Error (MSE), Peak Signal to Noise Ratio (PSNR) and Structure similarity index (SSIM) for different images. The visual quality of the images using the proposed methodology is better as compared to others. In future, for the enhancement purpose, more images can be taken. This work can be extended to implement the medical image processing applications for better enhancement than other existing methodologies. Also, the different other techniques can also be compared to check the consistency of the proposed method. Further, like other HE-based algorithms, is easy to implement because of its simplicity. Also, the new modification in the proposed technique is also beneficial for the enhancement purposes. Moreover, this method is simple and computationally effective that makes it easy to implement. Also, the optimization of various techniques can be done to reduce the complexity as much as possible.

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