

CONTRAST ENHANCEMENT TECHNIQUES USING HISTOGRAM EQUALIZATION METHODS ON COLOR IMAGES WITH POOR LIGHTNING

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ABSTRACT

Histogram equalization (HE) is a simple and widely used image contrast enhancement technique. The basic disadvantage of HE is it changes the brightness of the image. In order to overcome this drawback, various HE methods have been proposed. These methods preserve the brightness on the output image but, does not have a natural look. In order to overcome this problem the, present paper uses Multi-HE methods, which decompose the image into several sub images, and classical HE method is applied to each sub image. The algorithm is applied on various images and has been analysed using both objective and subjective assessment.

KEYWORDS

Contrast enhancement, Histogram equalization, Multi Histogram Equalization, Multi-threshold selection.

1. INTRODUCTION

Image contrast enhancement [1] and [2] is a classical problem in image processing and computer vision. Image enhancement is considered as a preprocessing step in many areas like video/image processing applications [17] and [18] speech recognition, texture synthesis etc. Enhancement techniques mainly fall into two broad categories: spatial domain methods and frequency domain methods [15]. Spatial domain techniques are more popular than the frequency based methods, because they are based on direct manipulation of pixels in an image. Myriad spatial domain methods have been developed for visualizing the effect. Some of these methods use simple linear or non-linear intensity level transformation functions, whereas others use complex analysis of different image features such as the edge and connected component information.

Contrast enhancement problem in digital images can be resolved using various methodologies, but Histogram Equalization (HE) [15] technique is the widely used one. Histogram Equalization method flattens the histogram and stretches the dynamic range of intensity values by using the cumulative density function. However, there are major drawbacks in Histogram Equalization [10] especially when implemented to process digital images. Firstly, HE transforms the histogram of the input image into a uniform histogram by distributing the entire range of gray levels uniformly over the histogram of an image, with a mean value that is in the middle of gray level range. Accordingly, the mean brightness of the output image is always at the middle – or near to it in the case of discrete implementation. In the case of images with high and low mean brightness

value, there is a significant change in the view of the enhanced image. Secondly, histogram equalization performs the enhancement based on the global content of the image. In other words, histogram equalization highlights the borders and edges between different objects, but may reduce the local details of these objects, and not adequate for local enhancement. Another consequence for this merge is the production of over enhancement and saturation artifacts [16].

In order to overcome these drawbacks, variants of Histogram Equalization method are proposed. These include Brightness BI Histogram Equalization Method (BBHE) [1],[5] and [11], Dualistic sub image Histogram Equalization Method (DSIHE) [2] ,[6] and [14], Minimum Mean Brightness Error BI Histogram Equalization Method (MMBEBHE) [3] and [14]. BBHE Method divides the image in to two sub images based on the mean intensity value of the input image, and Histogram Equalization technique is applied for each sub image separately. Based on the Equal Area Property DSIHE method decomposes the image in to two sub images and Histogram Equalization technique is applied for both the sub images. MMBEBHE method also decomposes the image in to two sub images based on the intensity value that yields minimum Absolute Mean Brightness Error (AMBE) [3]. Recursive Mean Separate Histogram Equalization Method (RMSHE) [19] and [22] decomposes the input image recursively based on mean, up to a level r , hence 2^r sub images are generated. These sub images are equalized individually to obtain the desired result. Recursive Sub-Image Histogram Equalization (RSIHE) [9] and [22] is a generalization of DSIHE, so the median-based histogram segmentation is performed more than once. RSIHE uses the medians of sub histograms instead of the means of sub-histograms. Sub-Region Histogram Equalization (CESRHE) [20] is a contrast enhancement method which separates the intensity range of the histogram into k sub-regions and redistributes the pixel intensities based on Sub-Intensity Range of output histogram. This method enhances the contrast while preserving mean brightness. The weighted average multi segment histogram equalization method [21] first smooths the global histogram and decomposes it into multiple segments via optimal thresholds, and then HE is applied to each segment independently. These methods outperform the conventional methods by producing enhanced image with details preserving ability.

The paper is organized as follows. Section 2 presents a detailed description about different Histogram Equalization Variants. Section 3 introduces two methodologies using Multi Histogram Decomposition. Section 4 includes results and discussions. Finally, conclusion is presented in Section 5.

2. HISTOGRAM EQUALIZATION VARIANTS

In this section, we briefly describe conventional histogram equalization [10] and its variant methods. The CHE method was the base for all the other methods. The BBHE, DSIHE and MMBEBHE methods use Conventional Histogram Equalization which will be later described in this section. Notice that all the above CHE Variants decomposes the input image into sub images based on some criteria, and each sub image is equalized separately. BBHE uses mean intensity value, equal area property for DSIHE and MMBEBHE uses minimum AMBE as a criteria for division of sub images.

2.1. Conventional Histogram Equalization Method

This sub section describes the CHE [15] for color images in detail, since this method is the core of the present work. The goal of CHE method is to distribute uniformly the entire range of gray levels over the histogram of an image, increasing the image contrast.

Let $\mathbf{X}=\{X(i, j, l)\}$ is an input image with L discrete gray levels $\{X_0, X_1, \dots, X_{L-1}\}$, where $X(i, j, l)$ is the intensity of the image at the 3D position (i, j, l) and $X(i, j, l) \in \{X_0, X_1, \dots, X_{L-1}\}$, $H(\mathbf{X}) = \{n_0, n_1, \dots, n_k, \dots, n_{L-1}\}$ is the histogram of the image and \mathbf{N} is the total number of pixels in an image. The probability density function (PDF) of the image is given in equation (1)

$$P(k)=n_k/N \quad (1)$$

where n_k is the number of pixels whose gray level is X_k .

Cumulative distribution function (CDF) can be calculated using the Probability Density Function (PDF) as shown in equation (2)

$$C(k)=\sum_{j=0}^k P(j) \quad (2)$$

Histogram equalization $T[i]$ can be calculated using CDF by using equation (3)

$$T[i]=\{(G-1)/(a*b)\} * c[i]; \quad (3)$$

where G is the number of gray level in an image and a, b is number of rows and number of columns in the image.

2.2. Brightness Preserving Bi-Histogram Equalization

BBHE [11] first divides the input histogram $H(\mathbf{X})$ into two sub-histograms $h1(\mathbf{x})$ and $h2(\mathbf{x})$ by using the mean x_m , where $h1(\mathbf{x})$ is associated with the gray levels $\{x_0, x_1, \dots, x_m\}$ and $h2(\mathbf{x})$ is associated with the gray levels $\{x_{m+1}, x_{m+2}, \dots, x_{L-1}\}$. Then it performs conventional histogram equalization on $h1(\mathbf{x})$ and $h2(\mathbf{x})$ independently.

2.3. Dualistic Sub Image Histogram Equalization

The basic idea used in the DSIHE method is similar to by the BBHE method. Dividing the input image into two sub-images and equalizes the histograms of the sub-images separately. Instead of dividing the image based on its mean gray level, the DSIHE method divides the image based on equal area property [13] i.e., both the sub images contain the equal number of pixels, being one dark and one bright.

2.4. Minimum Mean Brightness Error BI Histogram Equalization Method

This method also decomposes the input image in to two sub images and Histogram Equalization method is applied for both the sub images. In MMBEBHE we find the threshold level lt which decomposes the image I into two sub-images $I[0, lt]$ and $I[lt + 1, L - 1]$, so that the minimum brightness difference is achieved between the input image and the output image. The threshold level l_t is the value that yields minimum AMBE. Once the input image is decomposed, both the sub images are enhanced separately using the Classical HE process

3. MULTI HISTOGRAM EQUALIZATION METHODS

Multi Histogram Equalization [7] and [8] is a technique in which the input image is divided in to multiple sub images and then Histogram Equalization technique is applied for each sub image. The intensity value that divides the image in to sub images is the optimal threshold [12] set. The optimal threshold can be calculated using different methods but here we use two methods to

calculate the threshold set. The first algorithm calculates the optimal threshold set based on the within class variance and divides the input image in to different sub images based on the threshold set which is given in 3.1. The second algorithm divides the input image in to several sub images based on the optimal threshold set generated using Otsu method as shown in 3.2. The image is divided up to a scale r, so that 2^r sub images are generated. Where r can any predefined value.

The main idea behind the Multi Histogram Equalization Methods is to find an optimal threshold set $T^k = \{ t_1^k, t_2^k, \dots, t_{k-1}^k \}$. The given input image is divided in to two sub images based on the mean value. The optimal threshold set is then calculated for each sub image and the original image is then divided in to K sub images $I[l_s^1, l_e^1], \dots, I[l_s^k, l_e^k]$, where l_s^1 referred to the minimum threshold value in the first sub image and l_e^1 referred to the maximum threshold in the first sub image. After dividing the image in to sub images apply Histogram Equalization Method for all the sub images and combine the equalized images to obtain the desired result.

3.1 Minimum Variance Multi Histogram Equalization

Step 1: Calculate the histogram of the image.

Step 2: Based on the mean Brightness value, divide the histogram in to two classes.

Step 3: Calculate the within class variance for both the classes. Within class variance is calculated as shown in equation (4)

$$\text{Disc}(i) = (i - I_m)^2 * p(i) \quad (4)$$

Where I_m is the average of all the intensity values within each class.

$p(i)$ is the probability density function and
'i' is the intensity value.

Step 4: Consider the intensity value that yeilds Minimum Within Class variance and divide each class in to different sub images.

Step 5: Apply Histogram Equalization technique for all the sub images.

Otsu method [4] is used to perform histogram shape-based image thresholding. The method assumes that the input image contains two classes of pixels or bi-modal histogram i.e., foreground and background, and then calculate the threshold separating these two classes. The extension of multi-level thresholding is referred to as the Multi Otsu method, in which multiple threshold values are identified to divide the image in to multiple sub images.

3.2 Optimal Thresholding Multi Histogram Equalization

Step 1: Calculate the histogram of the image.

Step 2: Based on the mean Brightness value, divide the histogram in to two classes.

Step 3: Calculate the optimal threshold set using otsu[4] method.

Step 4: Based on the optimal threshold set divide the image in to different sub images.

Step 5: Apply Histogram Equalization technique for all the sub images.

4. RESULTS AND DISCUSSIONS

It is always desirable to have subjective and objective assessment to compare contrast enhancement techniques. The subjective assessment is an assessment of quality where there is no pre established measure or standard and is based solely on the opinion of the evaluator. The

quantitative measures are used for objective assessment. However we have used the Absolute Mean Brightness Error (AMBE) and Mean Squared Error (MSE) as the quantitative measures. The Absolute Mean Brightness Error is calculated as the absolute difference between the means of the input and output image. MSE is a statistical measure of randomness that can be used to characterize the texture of the input image.

4.1 Subjective Assessment on Color Images

Fig1 shows the original image and their corresponding contrast enhancement versions. The various HE methods are compared. Fig1(a) shows the jar image which is poor lightened. Generally HE method utilizes the dynamic range of the pixel values for maximum contrast. The main drawback of HE method is over illumination which is observed in Fig1(b). By applying BBHE method, the patterns in the jar are clearly visible than in HE method and is shown in Fig1(c).

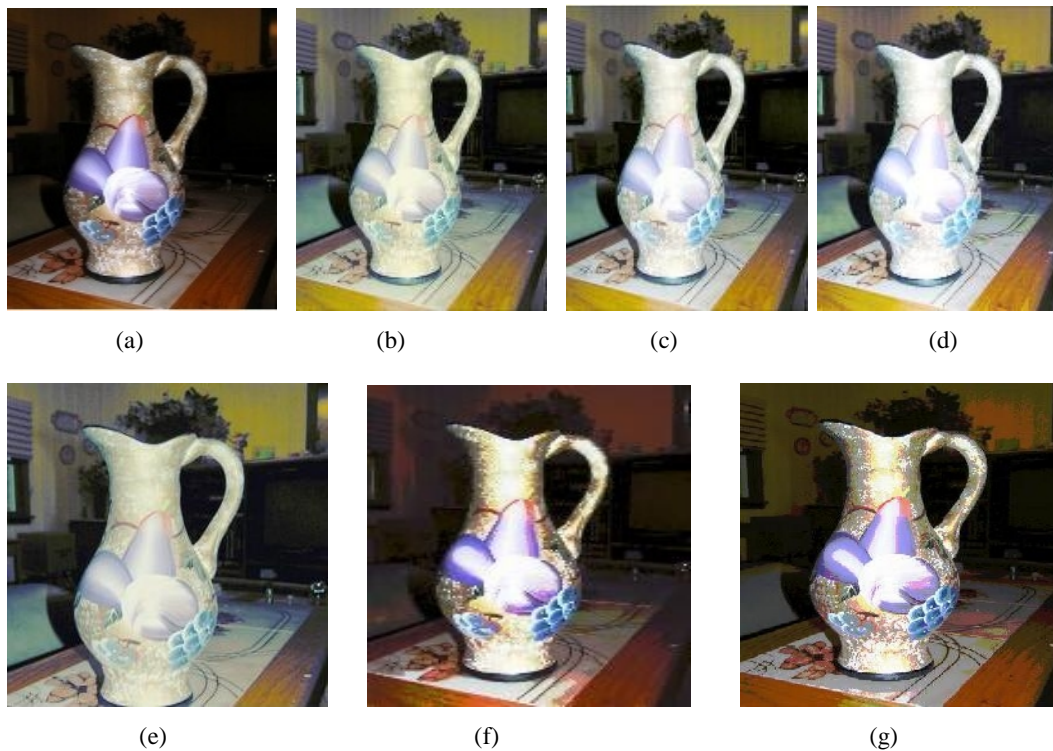


Fig1: Results for jar: (a) Original Image (b) Enhanced Image by applying HE Method (c) Enhanced Image by applying BBHE Method (d) Enhanced Image by applying DSIHE Method (e) Enhanced Image by applying MMBEBHE Method (f) Enhanced Image by applying MVMHE Method (g) Enhanced Image by applying OTMHE Method

In DSIHE Method, both the foreground and background parts are clearly visible than in the HE and BBHE methods. It can be seen in Fig1(d). In MMBEBHE method, the contrast is improved but the image does not have a natural look and it is shown in Fig 1(e). By applying the MVMHE method, the image has a natural look with a good contrast but there are unnecessary artifacts in the image. It is seen in Fig1(f). The OTMHE method preserves the brightness and increases the contrast of the entire image when compared to other methods and is shown in Fig1 (g).

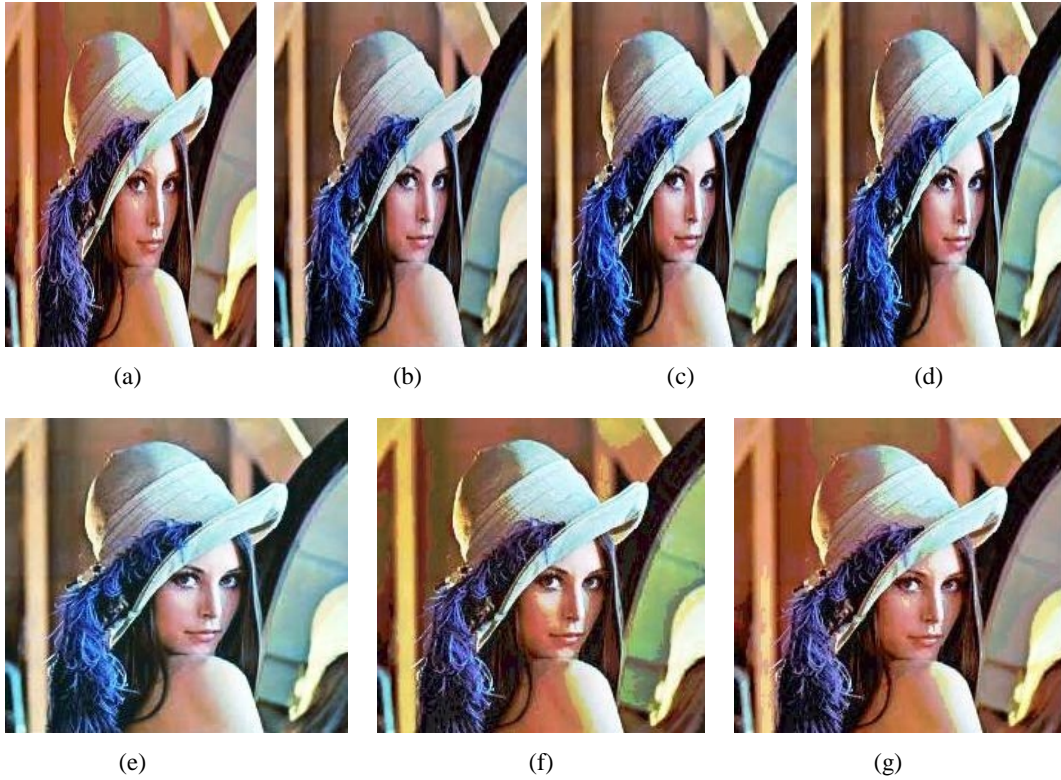


Fig 2: Results for Lena: (a) Original Image (b) Enhanced Image by applying HE Method (c) Enhanced Image by applying BBHE Method (d) Enhanced Image by applying DSIHE Method (e) Enhanced Image by applying MMBEBHE Method (f) Enhanced Image by applying MVMHE Method (g) Enhanced Image by applying OTMHE Method

Fig.2 shows the Lena image and their corresponding contrast enhancement versions. The various HE methods are compared. Fig2(a) shows the original brightened image. HE method increases the contrast which results in over illumination of the image. This situation is observed in Fig2(b). By applying BBHE method, the foreground part of the image is more clearly which is shown in the Fig2(c). In DSIHE Method, the fore ground as well as the back ground has a pleasing look and is shown in Fig2(d). In MMBEBHE method, the contrast is only improved and the image does not have a natural look and is shown in Fig2(e). By applying the MVMHE method, the fore ground has a clear look and the background part contains unnecessary patterns as shown in Fig2(f).The OTMHE method preserves the brightness and increases the contrast of the entire image. It is observed in Fig2(g).



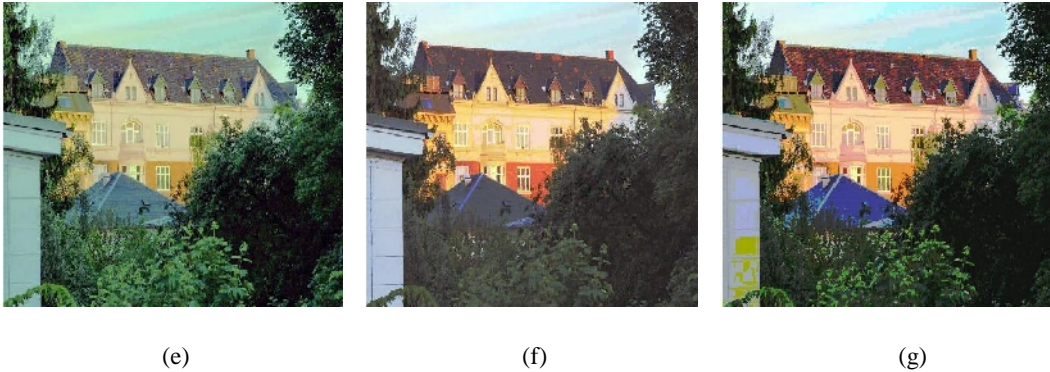
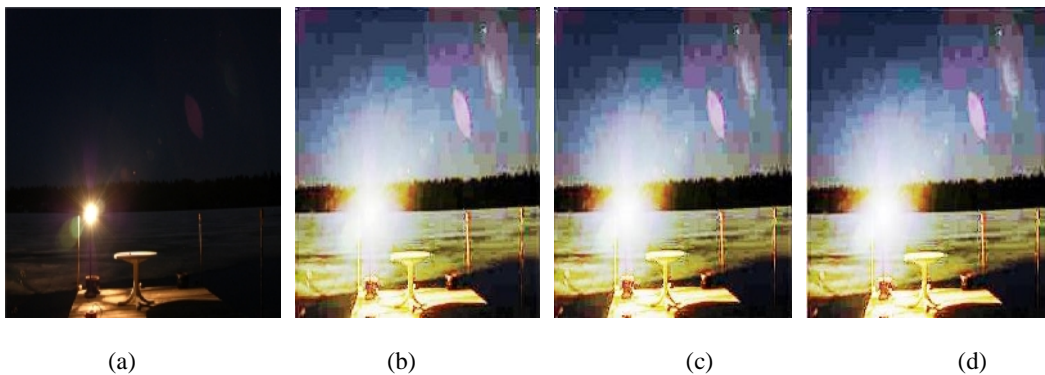


Fig3: Results for House: (a) Original Image (b) Enhanced Image by applying HE Method (c) Enhanced Image by applying BBHE Method (d) Enhanced Image by applying DSIHE Method (e) Enhanced Image by applying MMBEBHE Method. (f) Enhanced Image by applying MVMHE Method (g) Enhanced Image by applying OTMHE Method

Fig3 shows the House image and their corresponding contrast enhancement versions. The various HE methods are compared. Fig3(a) is the original image with good contrast. HE method enhances the image but the image does not have a natural appearance and shown in Fig3(b). By applying BBHE method, the foreground part is brightened as in Fig3(c). In DSIHE method, both the foreground and background are brightened more which can be observed in Fig3(d). In MMBEBHE method, the contrast is improved but brightness is not preserved. Hence the output image does not give a natural look which is shown in Fig3(e). By applying the MVMHE method, the contrast is enhanced and the background appears brighter as in Fig3(f). The MWCVMHE Method preserves the brightness and also improves the contrast of the image. It is observed in Fig3(g).

Fig4 shows the Sea image and their corresponding contrast enhancement versions. The various HE methods are compared. In Fig4 (a), there are very dark and bright regions. HE method enhances the darker regions but the brighter regions are over enhanced and do not have pleasing appearance. It is observed in Fig4 (b). By applying BBHE method, the brighter regions are over enhanced and the image does not have a natural look which can be observed in the Fig4 (c). In DSIHE method, the brighter regions are still over enhanced but the darker regions provides the details of the background part and is shown in Fig4 (d). In MMBEBHE method, the details in the darker region are hidden and only the brighter regions of the image are appeared as shown in Fig4 (e). By applying the MVMHE and OTMHE methods, the contrast is enhanced but there are some non existing artifacts in the images which does not gives the natural appearance. It is observed in Fig4 (f) and Fig4 (g).



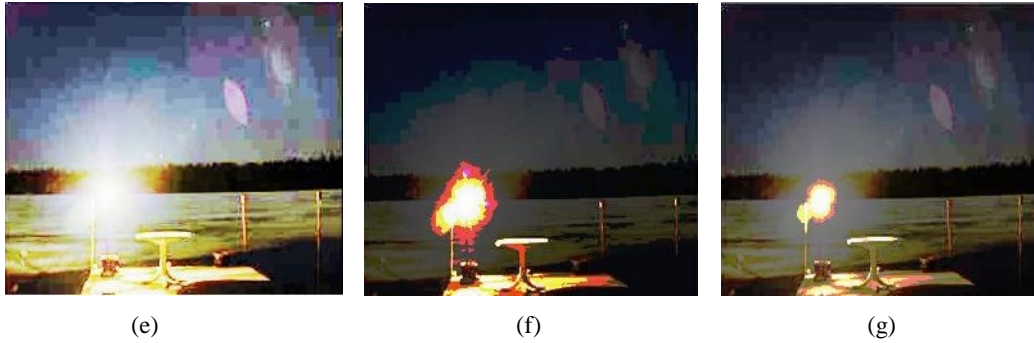


Fig 4: Results for Sea: (a) Original Image (b) Enhanced Image by applying HE Method (c) Enhanced Image by applying BBHE Method (d) Enhanced Image by applying DSIHE Method (e) Enhanced Image by applying MMBEBHE Method (f) Enhanced Image by applying MVMHE Method (g) Enhanced Image by applying OTMHE Method

4.1 Objective Assessment on Color Images

AMBE for all the intensity values with in an image is calculated.

$$AMBE = |M_i - M_o|$$

Where, M_i is the mean intensity value of input image
 M_o is the mean intensity value of output image.

Mean squared error (MSE) method is used to evaluate the performance of a predictor or an estimator. The mean squared error of the estimator or predictor is calculated as

$$MSE [T(Y); U] = E [(T(Y) - U)^2]$$

Where, $T(Y)$ is the intensity value

U is the Mean intensity value of the input image.

Method	HE	BBHE	DSIHE	MMBBHE	MVMHE	OTMHE
Jug	53.4377	49.92	64.1578	55.3254	19.9987	21.552
Lena	9.6505	12.873	14.8883	10.5379	11.3436	10.1969
Sea	100.6366	85.982	93.5739	73.982	11.1976	14.0923
House	42.7876	38.928	41.9275	54.641	17.9376	29.0906

Table 1: AMBE Values of Different Images

Method	HE	BBHE	DSIHE	MMBBHE	MVMHE	OTMHE
Jug	0.0089	0.0096	0.0130	0.0230	0.0013	0.0004
Lena	0.0012	0.0011	0.0013	0.0041	0.0002	0.0003
House	0.0015	0.0013	0.0014	0.0019	0.0011	0.0009
Sea	0.0412	0.0315	0.0357	0.1398	0.0017	0.0011

Table 2: Mean Square Error Values of Different Images

The various HE methods to enhance the contrast have been applied on different color images taken with different illumination. It has been observed that enhanced image using MVMHE Method gives good contrast but generates additional patches at the brightest region of an image. It has been observed that OTMHE Method results in generating natural look for the output image. The patches generated using MVMHE method has been taken care in the case of OTMHE method. The algorithm is basically used on the color images with poor lighting which helps us identifying those objects which are completely invisible in the images. It is obvious from Table 1 and Table 2 that Multi Histogram Equalization Methods produce minimum MSE and AMBE values when compared to all the other methods, which shows that these two methods are more efficient when compared to the other methods.

5. CONCLUSION

Multi Histogram Equalization technique improves image contrast by brightness preserving and generates natural looking images. An objective comparison among all the HE methods has been performed using quantitative measures AMBE (Absolute Mean Brightness Error) and Mean Square Error. It can be seen from the Tables that Multi Histogram Equalization Methods preserves the brightness more efficiently than other methods and the Mean Square Error is also reduced.

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