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Color Image Enhancement using Adaptive Sigmoid Function with Bi-Histogram Equalization

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Abstract **--Image enhancement is very impotent tool in the field of image processing that aims to improve the image quality. Histogram equalization is the most popular method for image enhancement. The main drawback of histogram equalization is over enhance and creates an unnatural look. These can be overcome by the Bi-Histogram Equalization. Bi-Histogram Equalization is splitting the image histogram into two sub-histograms, using mean as threshold, and replacing cumulative distribution function with two smooth sigmoid of the sub-Histograms. An image quality metrics are carried out. AMBE, MSE and PSNR are used to evaluate the effectiveness of the proposed method.**

Keywords: Image enhancement, Color image, Histogram equalization, Color space.

I. INTRODUCTION

Image enhancement is changing the pixels intensity of the input image; to make the output image subjectively look better [1] Contrast enhancement is an important area in image processing for both human and computer vision. It is widely used for medical image processing and as a pre-processing step in speech recognition, texture synthesis, and many other image/video processing applications [2-5].Contrast is created by the difference in luminance reflectance from two adjacent surfaces. In our visual perception, contrast is determined by the difference in the color and brightness of an object with other objects. If the contrast of an image is highly concentrated on a specific range, the information may be lost in those areas which are excessively and uniformly concentrated. The problem is to enhance the contrast of an image in order to represent all the information in the input image .Brightness preserving methods are in very high demand to the consumer electronic products. Histogram equalization (HE) based brightness preserving methods tend to produce unwanted artefacts [6]. The enhancement methods can broadly be divided in to the following two categories**:** ***Spatial Domain and Frequency Domain Methods***

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred in to frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc.

Histogram equalization is a well-known contrast enhancement technique due to its performance on almost all types of image. Generally, histogram equalization can be categorized into two main processes: global histogram equalization (GHE) and local histogram equalization (LHE).In GHE, the histogram of the whole input image is used to compute a histogram transformation function. As a result, the dynamic range of the image histogram is flattened and stretched and the overall contrast is improved. The computational complexity of GHE is comparatively low, making GHE an attractive tool in many contrast enhancement applications. The major drawbacks of GHE are that it cannot adapt the local information of the image and preserve the brightness of the original image. In contrast, LHE uses a sliding window method, in which local histograms are computed from the windowed neighbourhood to produce a local intensities remapping for each pixel. The intensity of the pixel at the centre of the neighbourhood is changed according to the local intensity remapping for that pixel. LHE is capable of producing great contrast results but is sometimes thought to over-enhance images. It also requires more computation than other methods because a local histogram must be built and processed for every image pixel and the implementation of contrast enhancement in consumer electronic products it is advised that the loss of intensity values by the histogram processing should be minimized in the output image. The first challenge of modified histogram has been proposed by Kim, in 1997 [7] using bi-histogram equalization (BHE) technique. In this paper, histogram equalization based bi-histogram equalization.

II. HISTOGRAM EQUALIZATION TECHNIQUES

There are numerous methods by which Histogram of an image can be equalized. Depending upon the area of Application, we can choose the different histogram equalization techniques. We will see the following four types of Histogram Equalization methods in detail:

A. Classical Histogram Equalization (CHE):

Classical Histogram equalization (CHE) is most popular technique for contrast enhancement. The HE method enhancing the contrast of given image in accordance with the simple distribution. The HE is simple and effective contrast enhancement technique which distributes pixel values uniformly such that enhanced image have linear cumulative histogram [8].

Let X={X(i, j)} denotes a image composed of L discrete levels denotes as

$$X=\{X_0 \quad X_1 \quad X_2 \quad \cdots \quad X_{L-1}\} \qquad (1)$$

For a given Image X, the probability density function P(X_k)

$$\mathbf{P}(\boldsymbol{X_k})=\frac{\boldsymbol{n^k}}{\boldsymbol{n}} \qquad (2)$$

Where k=0,1,..........L-1 ,represents the number of times that the level, *n* is the total number of samples in the input image, Based on the probability density function, the Cumulative density function is defined as

$$\mathbf{C}(\boldsymbol{x}) = \sum_{j=0}^{k} \mathbf{P}(\boldsymbol{X_k}) \qquad (3)$$

Where $\boldsymbol{X_k} = \boldsymbol{x}$for k=0,1,..L-1 and c($\boldsymbol{X_{L-1}}$)= 1 by definition. HE is a scheme that maps the input image into the entire dynamic range (X_0, X_{L-1}) by using the cumulative density function, then the output of HE expressed as Y={Y(i, j)}

$$\mathbf{Y} = \boldsymbol{X_0} + (\boldsymbol{X_{L-1}} - \boldsymbol{X_0})\mathbf{C}(\boldsymbol{x}) \qquad (4)$$

B. Adaptive Histogram Equalization (AHE):

Adaptive Histogram Equalization (AHE) is used to improve the contrast in an image. AHE is brilliant contrast enhancement for both natural images and medical images and other initially non visual images. It differs from classical histogram equalization (CHE) in the respect that the adaptive method computes the histograms, each corresponding to a distinct section of the image, and uses them to redistribute lightness value of the image. The advantage is that it is automatic, reducible, and locally adaptive and usually produces superior images [9].

C. Contrast Limited Adaptive Histogram Equalization (CLAHE):

Contrast Limited Histogram Equalization (CLHE) is the advance version of the adaptive histogram equalization, in which histogram is cut at some threshold and then equalization is applied. Contrast limited adaptive histogram equalization (CLAHE) is an adaptive contrast histogram equalization method [10], and it over come the drawback of the AHE is over-amplifying noise in some homogeneous regions of an image

D. Bi-Histogram Equalization (Bi-HE):

Bi-Histogrram Equalization (Bi-HE) is overcome the major drawback of the classical histogram equalization, In Bi-histogram equalization methods divide the histogram into two sub-histograms based on different dividing points and each sub-histogram is equalized individually based on histogram equalization. These methods can preserve image brightness more, when compared to Classical Histogram Equalization method. In this method an input image X is divided into two sub-images based on the mean as threshold. The first sub-images (X_L) is the less than or equal to the mean, whereas the second image (X_U) is the greater than the mean, so, $X=X_L \cup X_U$. The sub-image X_L is composed of {X_0, X_1, X_2…X_m} and the other sub-image X_U is composed of {X_{m+1}, X_{m+2}…X_{L-1}}. Then, the respective probability density functions of the sub-images, followed by the cumulative density functions of sub-images $C_L(x)$ and $C_U(x)$ are defined. Cumulative density function is used as a transformation function in the case of histogram equalization. Cumulative density function is used as a transformation function in the case of histogram equalization. The transformation functions of sub-images $F_L(x)$ and $F_U(x)$ and then based on these transformation functions the decomposed sub-images are equalized independently. Then, the resulted composition of equalized sub-images gives the output of the BBHE; Y is expressed as shown in eq. (5), eq. (6) and eq. (7)

$$\mathbf{Y=\{Y(i,j)\}= F_L(X_L) \cup F_U(X_U)} \qquad (5)$$

Where

$$\mathbf{F_L(X_L)} = \{F_L(X(i,j)) | \forall X(i,j) \in X_L\} \qquad (6)$$

$$\mathbf{F_U(X_U)} = \{ F_U(X(i,j)) | \forall X(i,j) \in X_U\} \qquad (7)$$

Here the cumulative density functions of sub-images are in the range of $0 \leq C_L(x)$ and $C_U(x) \leq 1$. So, $F_L(X_L)$ equalizes the sub-image X_L over the range (X_0, X_m), whereas $F_U(X_U)$ equalizes the sub-image X_U over the range (X_{m+1}, X_{L-1}). As a consequence, the input image X is equalized over the entire dynamic range (X_0, X_{L-1}) with the constraint that the samples less than the input mean are mapped to (X_0, X_m) and the samples greater than the mean are mapped to (X_{m+1}, X_{L-1}).

III. PROPOSED METHODOLOGY

Our method, colour image enhancement using ASFBiHE, contains four modules: colour space conversion, histogram splitting, sigmoid transform and mapping. The first module is colour space conversion in which the RGB colour image to be convert into CIEL**a***b*,, and second module is histogram splitting , consists to calculating the splitting point and then splitting the histogram into two sub-histogram of the image, third module is sigmoid transform and it consists of normalizing the input intensities to fit the desired range of input values for the sigmoid functions, and the two resulting function will be placed with their origin on median of each sub-histogram and final module is mapping and it describe to perform the histogram equalization and stretching.

Block Diagram

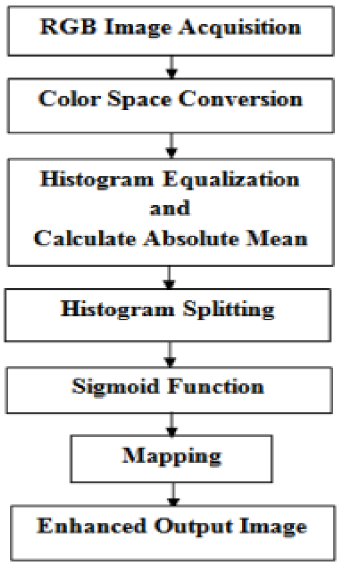

Figure: Color Image Enhancement

1. Color Space Conversion:

A range of colours can be created by the primary colours of pigment is called as colour space. The colour space also known as colour model or colour system. The colour system is mathematical model which simply describes the range of colours as tuples of numbers, typically as 3 or 4 values or colour components Ex. RGB colour space. Color space is an elaboration of coordinates system and subspace. Each colour in the system represented by a single dot. Color space is a useful method for understanding the colour capabilities of particular digital devices or file. There are variety of colour space such as RGB, CMYK, HSV, HIS, CIELAB, CIELCH, etc. In this paper we are using colour space as follow srgb2lab and lab2lch are used.

2. Histogram Equalization:

Lets ***X*** denoted as an input image of size ***MxN*** with ***I*** possible intensity levels. ***I*=256** has been assumed and compute mean intensity is denoted as ‘***m***’ (see **Eq. 2**)

$$X=\begin{bmatrix} X_{0,0} & X_{0,1} & X_{0,2} & \cdots & X_{0,N-1} \\ X_{1,0} & X_{1,1} & X_{1,2} & \cdots & X_{1,N-1} \\ \vdots & \vdots & \vdots & \ddots & \vdots \\ X_{M-1,0} & X_{M-1,1} & X_{M-1,2} & \cdots & X_{M-1,N-1} \end{bmatrix} \quad (8)$$

$$m = |H - X| \quad (9)$$

Where H is histogram equalization of an image, X is Original image. By using the mean ‘***m***’ as a splitting point, we split the image histogram ’***H***’ into two sub-histograms $\mathbf{h_l}$ and $\mathbf{h_u}$ respectively.

$$H = h_l \cup h_u \quad (10)$$

$$h_l = \{h_0, h_1, h_1, \cdots h_m\} \quad (11)$$

$$h_u = \{h_{m+1}, h_{m+2}, h_{m+3}, \cdots h_{I-1}\} \quad (12)$$

After splitting the image histogram, we calculate the probability density function of two image sub-histograms using Eq.(13)

$$pdf(k)=\begin{cases} \frac{h_L(k)}{\sum_{n=0}^{m} h_L(n)} & if \quad k \le m \\ \frac{h_U(k)}{\sum_{n=m+1}^{I-1} h_U(n)} & if \quad k > m \end{cases} \quad (13)$$

Where $k \in \{0,1,2,\ldots I-1\}$and it represent an intensity level. Then calculate the median is to calculate the cumulative distribution functions for both sub-histogram which have been shown in Eq. (14)

$$cdf(k)=\begin{cases} \sum_{n=0}^{k} pdf(n) & if \quad k \le m \\ \sum_{n=m+1}^{k} pdf(n) & if \quad k > m \end{cases} \quad (14)$$

Then, the median of h_l and h_u can be found when Eq. (15) and Eq. (16) are satisfied.

$$cdf(hl) = 0.5 \quad if \quad k \le m \quad (15)$$

$$cdf(hu) = 0.5 \quad if \quad k > m \quad (16)$$

3. Sigmoid Transform:

It is a point process approach[11].In this two parametric non-linear sigmoid function are created see Eq. 18 with their origin located on the medians of their corresponding sub-histogram, their input values are normalized for the reason of fit the sigmoid desired range (see Eq. 17) after this normalization , generating *z(k)*∈[-5,5].

$$z(k) = \begin{cases} \frac{5(k-hl)}{m} & if \quad k \le m \\ \frac{5(k-hu)}{I-1-m} & if \quad k > m \end{cases} \quad (17)$$

This range convenient for the values beyond these limits will be practically 0 and 1 with parameter $\gamma \ge 1$. Fact that sigmoid function described Eq. (18) will take the value inside the ranges of [*0, m*] for **k≤*m*** and **[*m, I-1*]** for *k > m*. We can also see that when these functions are used for mapping and smooth transitions, hence avoiding severe affections by peaks on the histogram and also avoiding sudden changes on the cumulative distribution function. The sigmoid function ***s(k)*** is

$$S(k)=\begin{cases} \frac{1}{1+e^{-\gamma z(k)}} & if \quad k \le m \\ \frac{1}{1+e^{-\gamma z(k)}} & if \quad k > m \end{cases} \quad (18)$$

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Where γ is a parameter that controls the smoothness of the sigmoid function, lower values create smoother sigmoid functions, which generate a lower contrast enhancement, and better mean preservations.

4. Mapping

The last module performs the mapping through histogram equalization and stretching, in order to perform the histogram equalization, Eq. (19).

$$u(k)=\begin{cases} hl = Lo + (m - Lo)s(k) & if \quad k \le m \\ hu = m + (Lf - m)s(k) & if \quad k > m \end{cases} \quad (19)$$

Where L_0 and L_f represent the desired lower and upper limits respectively, for dynamic range of the output image. Here $L_0 = 0$ and $L_f = I-1$. After obtaining the mappings ***u (k)*** and perform the histogram stretching by using Eq. (22). For this purpose we calculate the α_l and α_u values given by Eq. (20) and Eq. (21)

$$\alpha_l = \frac{(m - L0)}{max(hl) - min(hl)} \quad (20)$$

$$\alpha_u = \frac{Lf - m}{max(hu) - min(hu)} \quad (21)$$

$$T(K)=\begin{cases} L0 + \alpha l(hl(k) - min(hl)) & k \le m \\ m + \alpha u(hu(k) - min(hu)) & k > m \end{cases} \quad (22)$$

The mapping function can applied to each pixel of the image R, in order to obtained the enhanced outcome Y as shown in Eq. (23)

$$\mathbf{Y = T(X)} \quad (23)$$

Where T(R) is enhanced output image

IV. IMAGE QUALITY METRICS

The metrics used in this paper are the Absolute Mean Brightness Error (AMBE), for measuring brightness preservation and Peak Signal to Noise Ratio (PSNR), for measuring contrast enhancement.

Absolute Mean Brightness Error (AMBE):

Absolute Mean Brightness Error is measure the absolute mean difference between the two images. Thus lower value indicate a better mean preservation, this metric defined by Eq.(24)

$$\mathbf{AMBE = |E(Y) - E(X)|} \quad (24)$$

Where X represents the input image, Y represents the output image

Peak Signal to Noise Ratio (PSNR):

Let X(i,j) be the input image and Y(i,j) is the output image , assume that M *X* N is the total number of pixel in the input or output image. The value of PSNR is show the ratio between output image and input image, PSNR calculates through the MSE (Mean Squared Error). The MSE metric defined following Eq.(25)

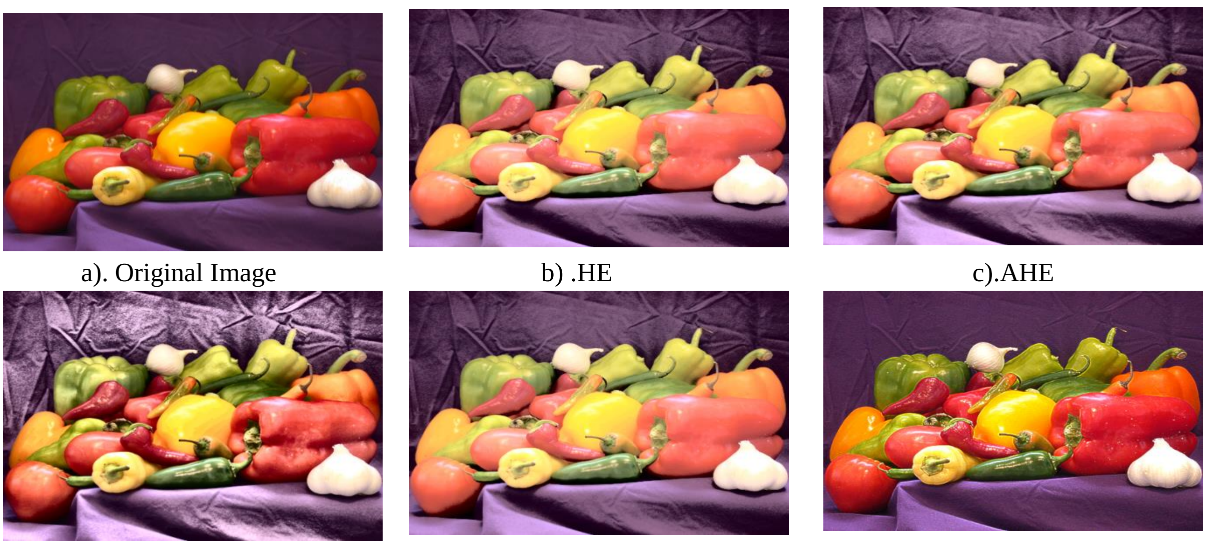
$$\mathbf{MSE} = \frac{\sum_i \sum_j |Y(i,j) - X(i,j)|^2}{MN} \quad (25)$$

By the help of MSE, We calculate the value of PSNR. PSNR metric defined by Eq.(26)

$$\mathbf{PSNR} = 10\log_{10} \frac{255^2}{MSE} \quad (26)$$

V. Result and Discussion

In this work color image enhancement is carried out using the proposed method Adaptive Sigmoid Function with Bi-Histogram Equalization (ASFBiHE). The input images are RGB images and also carried out the enhancement using earlier methods.



a). Original Image b) .HE c).AHE

d). CLAHE e). BBHE f). ASFBiHE ($\gamma = 0.25$)

Figure1.Peppers: a).Original, b).HE, c).AHE, d).CLAHE, e).BBHE, f).ASFBiHE($\gamma = 0.25$)

The figure 1.a) shows the original RGB image, fig 1.b) shows the Histogram Equalization image, which indicates the enhancement, fig 1.c) shows the Adaptive Histogram Equalization image, which indicates the advance method of Histogram Equalization image, fig 1.d) shows the Contrast Limit Adaptive Histogram Equalization image, which indicates the advance method of Adaptive Histogram Equalization and clipping the image in between 0 to 1, fig 1.e) shows the Brightness Bi-Histogram Equalization image, which is the extension of the Histogram Equalization, fig 1.f) shows the Adaptive Sigmoid Function with Brightness Bi-Histogram Equalization image, which is the extension of the Brightness Bi-Histogram Equalization. These images are compared with original image and better vision perception than previous methods.

a). Original Image b) .HE c).AHE

d). CLAHE e). BBHE f). ASFBiHE ($\gamma = 0.25$)

Figure2. Girl : a).Original, b) .HE, c).AHE, d). CLAHE, e). BBHE, f).ASFBiHE ($\gamma = 0.25$)

a).Original Image b). HE c).AHE

d). CLAHE

e). BBHE

f). ASFBiHE ($\gamma = 0.25$)

Figure3.Aero Plane: a).Original, b).HE,c).AHE, d).CLAHE, e).BBHE, f).ASFBiHE($\gamma = 0.25$)

Images	HE	AHE	CLAHE	BBHE	Proposed Method
Peppers	36.1086	39.5563	40.1647	37.0292	**7.4467**
Girl	63.0877	67.9632	68.7171	64.0589	**4.9601**
Aeroplane	45.8623	53.5976	58.3111	46.7910	**7.0478**

TABLE 1: Comparison of AMBE values

The results shown in the table-1 presents the performance of brightness preservation of various methods discussed in the paper. An observation based on the table-1, we see that the best value represented by the lowest one for each image is shown in bold face and how the mean brightness is shifted much more than the other methods, which is an undesirable effect that cause a brightening on the output image.

Images	HE	AHE	CLAHE	BBHE	Proposed Method
Peppers	60.7857	64.9638	57.5501	61.1872	**25.7457**
Girl	74.5855	78.2967	74.0788	75.3686	**13.0137**
Aeroplane	55.5682	56.9276	64.7255	56.0356	**16.7657**

TABLE 2: Comparison of MSE values

The results shown in the table-2 present the MSE value. MSE is a metric for image quality assessment. The lower MSE value is indicates the better image quality. An observation based on the table-2, we see that the best value represented by the lower one for each image is shown in bold face.

Images	HE	AHE	CLAHE	BBHE	Proposed Method
Peppers	30.2928	30.0041	30.5303	30.2642	**34.0238**
Girl	29.4043	29.1934	29.4339	29.3589	**36.9868**
Aeroplane	30.6825	30.5776	30.0200	30.6462	**35.8866**

TABLE 3: Comparison of PSNR values

The results shown in the table-3 present the PSNR value. PSNR is a metric for image quality assessment. The greater PSNR value is indicates the better image quality. An observation based on the table-3, we see that the best value represented by the higher one for each image is shown in bold face and how the contrast is shifted much more than the other methods, which is an undesirable effect that cause a contrasting on the output image.

In addition with brightness preservation and contrast enhancement an image quality is also an important factor in image processing. The processed image should be visually acceptable to human eye and should have natural appearance. We have tested number of images with all methods discussed in the paper. Some of them are presented here. Figure 1 to 3 shows original image of “Peppers, Girl and aero plane” with processed images by HE, AHE, CLAHE, BBHE and proposed methods (ASFBiHE). The same processes are carried for the some more RGB images and shown above.

VI. CONCLUSION

This project is implemented using color image enhancement based on adaptive sigmoid function with Bi-Histogram Equalization and evaluated on the color image, an output image that is visually appealing moreover our method displayed the parametrices, such as brightness and contrast preservation. The possible future work is to test our approach with different sigmoid function and various filter function. Another possibility is to test our approach with different color model along with good γ parameter.

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