THE INTERNATIONAL JOURNAL OF SCIENCE & TECHNOLEDGE

Efficient Brightness Preserving Enhancement Algorithm for Images in Consumer Electronic Devices

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Abstract:
Image enhancement improves the image quality so that the resultant image is better than the original image for a specific application or set of objectives. Image enhancement is the task of applying certain alterations to an input image so as to obtain a more visually pleasing image. A simple and effective enhancement method, the Histogram Equalization (HE) technique has its major disadvantage of hampering the mean brightness of the image. So, it is not likely to use HE in consumer electronic products. The main objective of this paper is to propose an efficient enhancement algorithm for images in consumer electronic devices which will produce a vivid colored enhanced image with better PSNR. In this regard, a novel technique which is a modification of Minimum Mean Brightness Error Dynamic Histogram Equalization (MMBEDHE) has been proposed.

Keywords: *HE, PSNR, MMBEDHE*

1. Introduction

The goal of image enhancement is to process an image so that the outcome is suitable than the original image for a specific application. This improves the visual interpretability for human viewers and also increases the actuity of information contained within the image. Digital color image enhancement, preserving brightness is an emerging research issue in the field of digital image processing for consumer electronics. Histogram Equalization (HE) is the most reliable, acceptable and commonly applied algorithm to perform image enhancement. HE also flattens and stretches the dynamic range of image histogram resulting in overall image contrast enhancement. In HE, frequently occurring gray levels in the image dominate other gray levels with lower frequency of occurrence. This results in loss of brightness of the original image. HE is not used in consumer electronics like television, digital camera and video surveillance as it considerably changes the brightness of an input image and it results in undesirable artifacts in the output image. To apply the image enhancement techniques in consumer electronics, it is recommended that the image enhancement techniques should be able to maintain the original brightness of the input image in the output image.

In the early researches, there were several attempts on image contrast enhancement to overcome these difficulties.

Bi Histogram Equalization (BBHE) proposed by Kim et al [1] in which image histogram is divided into two parts based on the mean value. Dualistic Sub – Image histogram Equalization (DSIHE) [3] method decomposes the images aiming at the maximization of the Shannon's entropy of the output image. Recursive Mean Square Histogram Equalization (RMSHE) and Minimum Mean Square error Bi – Histogram Equalization (MMBBHE) are the extensions of BBHE.

In all these methods, the brightness preservation was not robust as they were capable of preserving the brightness only to a certain extent. An innovative solution for image enhancement called Minimum Mean Brightness Error Dynamic Histogram Equalization (MMBEDHE) has been developed by M.F. Hossain et al. This method is based on minimization of the mean brightness error which is used in consumer electronics. MMBEDHE considers two properties: Preservation of brightness and improvement of PSNR. MMBEDHE applies Dynamic HE to partition the input histogram into sub – histograms in order not to contain any dominating part in them. The advantages of MMBEDHE are overall contrast enhancement and very low computational load. So, it is validated to be superior to other brightness enhancement techniques mentioned above. Most of the existing image enhancement methods suffer from lack of brightness preservation, produce more brightness errors and need more memory for the enhancement of color images in consumer electronics [6].

2. Proposed Method
The proposed method has the goal to preserve brightness while improving the contrast by eliminating the domination of higher histogram components on lower histogram components in image histogram. Instead of processing the whole histogram at a time, it has been divided into a number of sub-histograms based on the local minima value. Then, a dynamic gray level is allocated to each sub-histogram to which its gray levels can be mapped by HE. Then HE is applied to each sub-histogram. The details of each step are described in the following subsections.

2.1. Convert the Image into Appropriate Color Space
The input image is first converted into 'Lab' color space. Here, L represents the luminance value, 'a' represents a color balanced between green and magenta and 'b' represents a color between blue and yellow. The 'a' and 'b' color spaces are preserved while the L component is altered.

2.2. Smooth the Histogram
The histogram of the input image is smoothed by using one dimensional Gaussian filter of size 1*9 to get rid of insignificant minima. This help to reduce the fluctuations of the histogram. The Gaussian filter is defined by the following equation:

$G(x) = e^{(-x2/2\sigma 2)}$ (1)

Where x is the coordinate relative to the centre of kernel and σ (0.5) is the standard deviation. A smaller filter size cannot reduce the unsteadiness of the histogram which results in too many local minima. On the other hand, a larger filter size results in a very flat histogram and less minima can be detected. So, dominating portion of the histogram remains in each sub-image.

2.3. Detection of Local Minima from the Smoothed Histogram
The histogram is then divided into sub-sections based on local minima using the smoothed histogram. In this step, the smoothed histogram is partitioned taking the portion of histogram that falls between two local minima. Mathematically, if $m_0, m_1,..., m_n$ are (n+1) gray levels that correspond to (n+1) local minima in the image histogram, then the first sub histogram will contain histogram components of the GL range $[m_0, m_1]$ the second one will contain $[m_1, m_2]$ and so on until the last sub histogram$[m_{n-1}, m_n]$. This histogram partitioning helps to prevent some parts of the histogram from being dominated by others.

2.4. Map Each Partition into a New Dynamic Range
The divided sub-histograms are still within small range. To ensure good enhancement it is need to span each sub- histogram before applying the HE to each sub histogram. This is done based on the ratio of the span of the gray levels that the sub-histograms occupy in the input image histogram. This function is described by the following equations:

$span_i = mi - mi - 1$ (2)

$factor_i = spani \ * \ log10\,M$ (3)

$range_i = \frac{(L-1) * factor}{\sum_{k=1}^{n+1} factork}$ (4)

Where, m_i is the highest intensity value in the sub-histogram *i*, m_{i-1}, is the lowest intensity value in that section and M is
the total pixels contained in that section. The dynamic gray level range used by sub-histogram *i* in the input image is $span_i$ and the dynamic gray level range used for sub-histogram *i* in the output image is given by $range_i$

Let the range of the output sub-histogram *i* is $[start_i, end_i]$. If we set the first sub-histogram of the output is in the range of $[0, range_i]$, then the $start_i$ and end_i (for i>1) can be calculated as follows:

$start_i = \sum_{k=1}^{i-1} rangek + 1$ (5)

$end_i = \sum_{k=1}^{i} rangek$ (6)

This relation shows that the order of the gray levels allocated for the sub-histograms in the input image did not change from the order of the gray levels in the input image.

2.5. Apply Histogram Equalization in Each Partition
Consider the histogram of the input image is divided into *i* sub-histograms, where $i = i_0, i_1, \ldots\ldots, i_{p-1}$. Range of sub-histogram *i* is $[m_{i-1}, m_i]$.

So, the input image is decomposed of *i* sub-images as:

$X_{io} = \{X(i, j) \mid X(i, j) \leq X_{mi0}$, for all $X(i,j) \in X$,

$X_{i1} = \{X(i,j) \mid X_{mi0} < X(i,j) \leq X_{mi1}$, for all $X(i,j) \in X\}$,And so on.

Here, the sub-histogram X_{i0} is composed of $\{X_0, X_1, \ldots, X_{mi0}\}$ gray levels and the sub-histogram X_{in} is composed of $\{X_{min-1+1}, X_{min-1+2}, \ldots, X_{min}\}$.

In this step, the HE method is applied to each sub-histogram independently. For the sub-histogram *i* with the range of $[m_{i-1}, m_i]$,

$Y(x) = mi - 1 \ + \ (mi - mi - 1) \ \sum_{k=mi-1}^{x} nk/M$ (7)

Where, n^k is the total number of pixels with intensity k and M is the total pixels contained in this section.

3. Results and Analysis
A variety of input images are tested for the effectiveness of the proposed method. The images include a low contrast image, an image captured in the evening, a fog covered image and a multi-colored image as shown in figure 1.

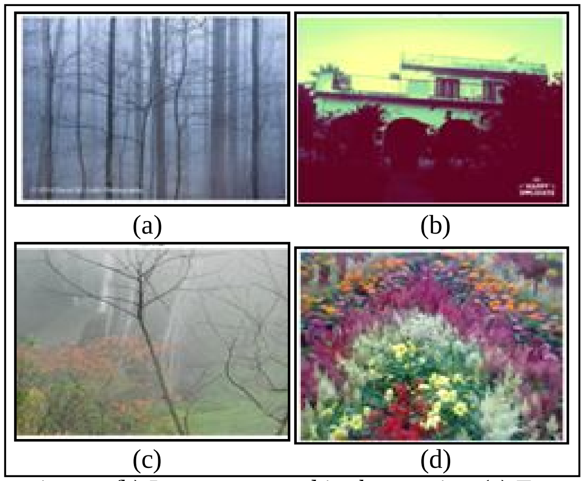

Figure 1: Input images (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

The output after applying Gaussian filter is as shown in figure 2.

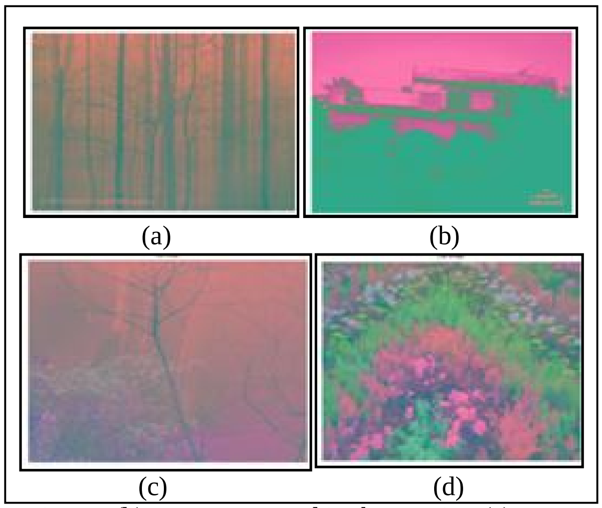

Figure 2: Lab images (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

Smoothened histogram is then divided into number of sub-histograms based on local minima. Detected local minima are plotted as shown in figure 3.

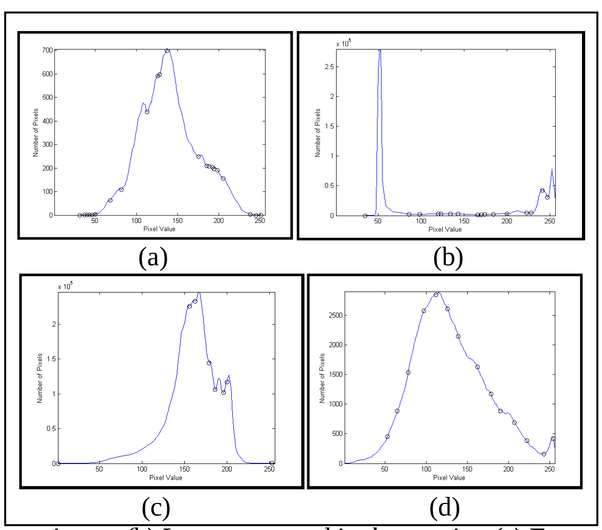

Figure 3: Local minima (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

Each sub-histogram is then mapped into a new dynamic range and HE is applied to each sub-histogram. The output image is as shown in figure 4

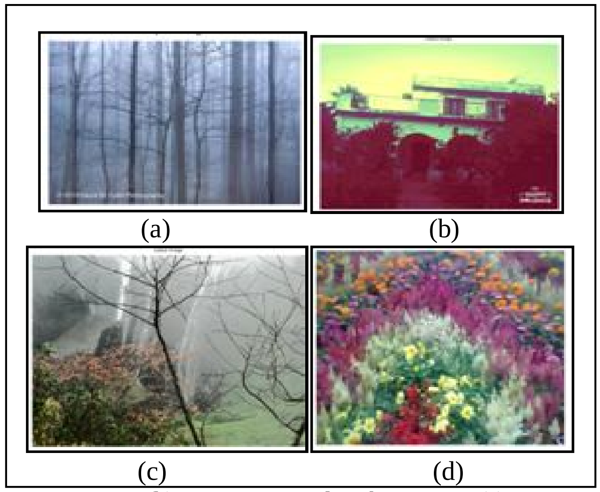

Figure 4: Output images (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

The histograms of input and output images are plotted as shown in figures 5 and 6.

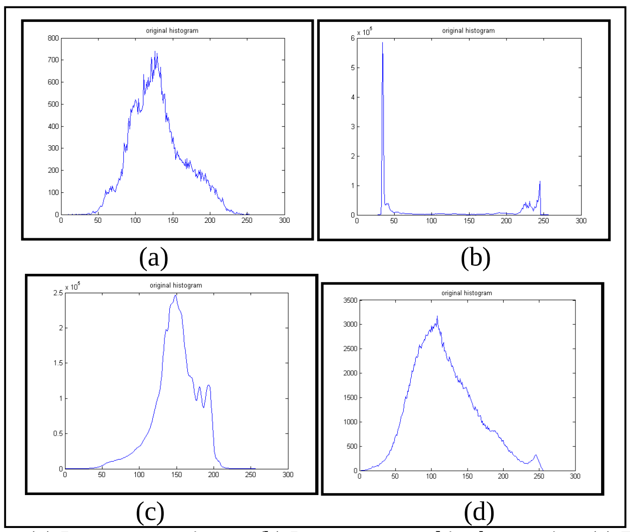

Figure 5: Histograms of input images minima (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

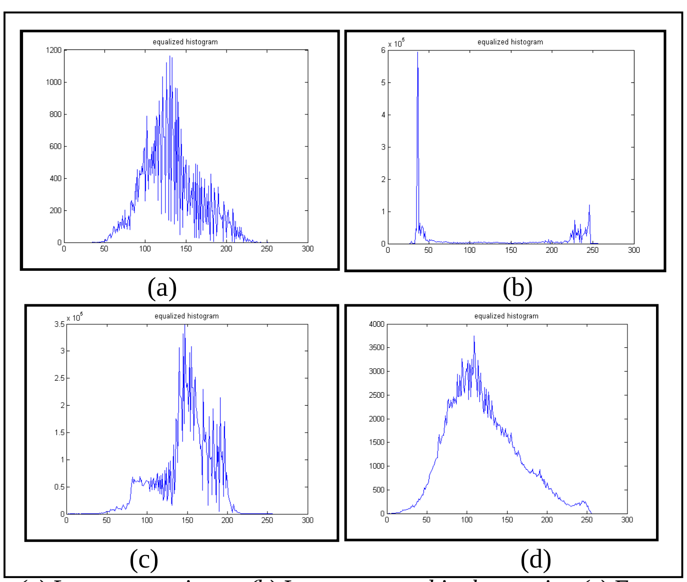

Figure 6: Histograms of output image (a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

As seen from figure 6, the histograms of input image are spread out and flattened which preserves the brightness of the input image.

3.1. Image quality measurement tools

The image quality measurement tools used to evaluate the ability of the enhancement techniques are Peak Signal-to-Noise ratio (PSNR), Mean Square Error (MSE) and Brightness Error (BE). The mean squared error (MSE) of the reconstructed image is calculated as:

$$MSE = \frac{\sum_{i=1}^{M}\sum_{j=1}^{N}[X(i,j)-Y(i,j)]^{\wedge}2}{(M*N)} \qquad (8)$$

Then the PSNR in decibels (dB) is computed as:

$$PSNR = 20\ log\,(\frac{255*255}{MSE}) \qquad (9)$$

Greater the value of PSNR better the contrast enhancement of the image.

The mean Brightness Error is calculated as:

$$Input\ mean=\frac{1}{3}\{mean(R) + mean(G) + mean(B)\} \qquad (10)$$

$$Output\ mean=\frac{1}{3}\{mean(R') + mean(G') + mean(B')\} \qquad (11)$$

Where, R, G, B are the values of input image and R’, G’, B’ are the values of output image.

$$Brightness\ Error = output\ mean - input\ mean \qquad (12)$$

Lesser the brightness error better is the preservation of brightness of the image.

The parameters are computed for the input images and tabulated in table 1for comparison.

Parameters	(a)	(b)	(c)	(d)
PSNR	45.00	44.76	32.68	45.67
MSE	2.05	2.17	35.09	1.76

Table 1: Comparison of Parameters

(a) Low contrast image (b) Image captured in the evening (c) Fog covered image (d) Multi-colored image

To evaluate the effectiveness of the proposed method over the MMBEDHE method proposed by M.F. Hossain et al [7] the brightness error is computed for images shown in figure 7. The values obtained from [7] are compared with the computed values as shown in table 2.

(a) (b) (c)

Figure 7: Images from Kodak photo sampler (a) Girl (b) Hat (c) Light house

Brightness Error	Method in [7]	Proposed method
Girl	2.81	1.24
Hat	3.18	1.27
Light house	4.1	1.18

Table 2: Comparison of Brightness Error
(a) Girl (b) Hat (c) Light house

3.2. Analysis

To show the performance of the proposed method the results are evaluated subjectively based on visual inspection and also objectively by numerical results. From visual evaluation, the quality of fog covered image is better than other images and also the contrast for the low contrast image has been improved.

For objective measurement, MSE, PSNR and Brightness Error are calculated. It can be noticed from table 1 that the PSNR values for low contrast and multi-colored images are better than that obtained for fog covered image whereas, the brightness of fog covered image increases than for low contrast and multi-colored images.

It can be validated from table 2 that brightness error is reduced for the proposed method. Thus the proposed method succeeds greatly in preserving the brightness of the input image which makes its use in consumer electronics very effective.

4. Conclusion

The proposed method is a novel extension of typical MMBEDHE. Digital color image with brightness preservation is the burning issue in the field of digital image processing especially for consumer electronics. The proposed method produces images that can preserve brightness of the original image. The visual quality of the output image produced by this method is better than the other methods. This method produces less brightness error than MMBEDHE and images will be of natural outlook. Hence, the proposed method is an efficient enhancement method for consumer electronic devices.

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