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Superiority Of MMBEDHE Technique In Image Enhancement

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Abstract: The simple and effective Histogram Equalization technique of Image Enhancement has its major disadvantage of hampering the mean brightness of image. So, it is always not affordable to use HE in consumer electronic products. In order to overcome this drawback a novel technique known as Minimum Mean Brightness Error Dynamic Histogram Equalization (MMBEHDE) was proposed to attain maximum brightness preservation.

Keywords: Color Image enhancement, MMBEDHE – Mean Brightness Error Dynamic Histogram Equalization, Brightness preservation, Histogram equalization

INTRODUCTION

The goal of image enhancement is to process an image so that outcome is more suitable than the original image for any specific application. This increases the visual interpretability and sharpness of image. So, it is important to develop better image processing techniques. Under this aspect, in digital color image enhancement, preserving brightness is an emerging research issue in digital image processing, mainly in consumer electronics. Histogram Equalization (HE) is one of the most reliable, acceptable and extensively applied algorithms to perform image enhancement. HE also fattens and stretches the dynamic range of image histogram and it results in overall image contrast enhancement. But it results in loss of brightness of image due to domination of frequently occurring gray levels on the ones with lower frequency of occurrence. That is why HE is not much used in consumer electronics as it changes the brightness of an input image and causes undesirable artifacts in the output image. In the early researches, there were several attempts on image contrast enhancement to overcome these difficulties. The methods can be listed as below

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

However, 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) was developed. This method was based on minimization of the mean brightness error which is used in consumer electronics. MMBEDHE considers two properties

- Preservation of Brightness
- Improvement of PSNR

MMBEDHE has applied Dynamic HE to make partition of the input histogram into sub – histograms in order not to contain any dominating part in them. The advantages of MMBEDHE are as follows.

- Overall contrast enhancement
- Preserve the brightness of the original image
- Gives the PSNR in the desired range
- Computational load is very low

So, it was 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. So, it is necessary to enlarge the method for color image to fulfill the current requirements. This paper mainly demonstrates the alternatives to explore MMBEDHE for applications in color images. The previously mentioned advantages of MMBEDHE make it suitable for practical implementation of color image enhancement for consumer electronics products.

MINIMUM MEAN BRIGHTNESS ERROR DYNAMIC HISTOGRAM EQUALIZATION (MMBEDHE)

MMBEDHE method has the goal to preserve brightness while improving the contrast by eliminating the domination of higher histogram components on lower histogram components. Instead of processing the whole histogram at a time, it has been divided into a number of sub – histograms based on the threshold value in between two local minima, where no dominating portion is present. The threshold value between two local minima is selected which gives minimum Absolute Mean Brightness Error (AMBE). Then a dynamic gray level is allocated to each sub – histogram to which its gray levels can be mapped by HE. Lastly, HE is applied to each to each sub – histogram. This method consists of five – steps.

- Smooth the histogram

Te histogram of the input image is smoothed by using one dimensional Gaussian filter of size 1*9 to get rid of insignificant minima. This reduces fluctuations of the histogram. The Gaussian filter is defined by the following equation.

$$G(x) = \exp(-x^2/2\sigma^2) \quad (1)$$

Where x is the coordinate relative to the center of the kernel and σ is the standard deviation.

Small filter size – many local minimums

Large filter size – less minima

- Detection of local minima from the smoothed histogram

The histogram is primarily subdivided into sub – sections based on local minima using the smoothed histogram. In this step, the smoothed histogram is made partition taking the portion of histogram that falls between two local minima. Mathematically, if $m0, mi, \ldots\ldots mn$ are $(n+1)$ grey levels (GL) corresponding to $(n+1)$ local minima in the image histogram, then the first sub-histogram will contain the histogram component of the GL range $[m_0, m_1]$ the second one will contain $[m_1, m_2]$ and so on until the last histogram $[m_{n-1}, m_n]$. this histogram partition will prevent some parts of the histogram from being dominated by others.

- Determination of the threshold in each portion using AMBE

Here, a threshold value in each portion of the primarily divided sub – histogram is determined. The value that makes the absolute difference between the input sub – image and the output sub – image is taken as the threshold value.

$$\text{diffrence} = E(X) - E(Y) \quad (2)$$

E(X) represents mean of the input sub– image. E(Y) represents mean of the output sub–image. Lower difference provides better brightness preservation. The gray level value within a sub-histogram that makes this difference minimum is selected as a threshold value. Using these threshold values, the original histogram is again divided into sub-histograms. This brings tonality of output image consistent with the input image.

- Map each partition into a new dynamic range

The divided sub – histograms are still within the small range. To ensure good enhancement it is needed 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 s described by the following equations.

$$\text{span}_i = m_i - m_{i-1} \quad (3)$$

$$\text{factor}_i = \text{span}_i - \log_{10} M \quad (4)$$

$$\text{range} = (L-1) \times \text{factor} / \sum \text{factork} \quad (5)$$

Where m_i is the highest intensity value in the sub-histogram. 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 dynamic gray level range used by sub-histogram I in the output image is $\text{range}_{i..}$Let the range of the output sub-histogram I is $[\text{start}_{i,} \text{end}_i]$

$$\text{start}_i = \sum \text{rangek} + 1 \quad (6)$$

$$\text{end}_i = \sum \text{rangek} \quad (7)$$

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

- 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,……i_{p-1}. Range of sub – histograms I is $[m_{i-1}, m_i]$. So, the input image is decomposed of I sub-images as

$$X = X_{i0} \cup X_{i1} \cup \ldots\ldots X_{ip-1} \quad (8)$$

Where

$$X_{io} = \{X(i,j) | X(i,j) \le X_{mi\,0}, \forall X(i,j) \in X\} \quad (9)$$

$$X_{i1} = \{X(i,j) | X_{mi\,0<} X(i,j) \le X_{mi\,1}, \forall X(i,j) \in X\} \quad (10)$$

X_{i0} is composed of $\{X_{i0}, X_{i1} \ldots .. X_{mi0}\}$ gray levels.

In this step, the HE is applied to each sub histogram independently

$$y(x) = m_{i-1} + (m_i - m_{i-1)} \textstyle\sum_{k=m_{i-1}}^{x} n^k / M \quad (11)$$

COLOR IMAGE ENHANCEMENT USING MMBEDHE

Here, we have discussed color image enhancement techniques in different color space using MMBEDHE. Majority of the consumer electronics produce using RGB color space. The nine conventional techniques of color image enhancement using MMBEDHE are as follows.

- 1.1 Equalize R,G and B independently
  -Most commonly used method
  -Image enhancement methods are usually applied to each R,G and B component image independently.

- 1.2 Equalize I channel from HIS color Space
  -The input image in RGB is needed to transform to hue, intensity and saturation color space. The transformations are given by

$$I = \frac{R+G+B}{3} \quad (12)$$

$$S = 1 - \left[\frac{\min(R,G,B)}{I}\right] \quad (13)$$

$$H = \begin{cases} \theta & \text{if } B \le G \\ 360 - & \text{if } B > G \end{cases} \quad (14)$$

Where

$$\theta = \cos^{-1}\left\{\frac{2R-G-B}{2\left(\sqrt{(R-G)^2}\right)+(R-B)(G-B)}\right\} \quad (15)$$

Only I component is enhanced using MMBEDHE. The enhanced I component is represented as I'. Then we need to use inverse conversion from His color space to RGB with H, S, I' components as follows.

$\text{if } (0° \le H \le 120°)$

$$B' - I'(1-s) \quad (16)$$
$$R' = [1 + \frac{S\cos(H)}{\cos(60-H)}] \quad (17)$$
$$G' = 3I' - (R' + B') \quad (18)$$

$\text{if}(120° \le H \le 240°)$

$$R' = I'(1-S) \quad (19)$$
$$G' = I'[1 + \frac{S\cos(H-120°)}{\cos(60°+H)}] \quad (20)$$
$$B' = 3I' - (R' + G') \quad (21)$$

$\text{if } (240° \le H \le 360°)$

$$G' = I'(1-S) \quad (22)$$
$$B' = I'[1 + \frac{S\cos(H-120°)}{\cos(60°+H)}] \quad (23)$$
$$R' = 3I' - (G' + B') \quad (24)$$

- 1.3 Equalize S channel from HIS color **space**
  Here, the S channel is enhanced using MMBEDHE and create new channel S'

- 1.4 Equalize V channel from HSV color space
  - HSV stands for hue, saturation and luminance.
  - It's the representation of points in an RGB color model that attempts to describe perceptual color relationships more accurately than RGB while remaining computationally simple.
  - Transformation from RGB to HSV is as follows
  -

$$S=\begin{cases}0, & \text{if max} = 0\\ 255 * \frac{(\max - \min)}{\max}, & \text{otherwise}\end{cases} \quad (25)$$

$$V = 255 \times \max \quad (26)$$

$$H=\begin{cases}(\text{undefined, if max} = \min\\ (60° \times \frac{g-b}{(\max - \min)} + 0°), \text{if max} = rg \ge b\\ \left(60° \times \frac{g-b}{(\max - \min)} + 0°\right), \text{if max} = rg < b\\ \left(60° \times \frac{b-r}{(\max - \min)} + 120°\right), \text{if max} = g\\ 60° \times \frac{r-g}{(\max - \min)}, \text{if max} = b\end{cases} \quad (27$$

Backward transformation from HSV to RGB is as follows

$$h_i = \left[\frac{H}{60}\right] \text{mod}6 \quad (28)$$
$$f = \left[\frac{H}{60}\right] - \left[\frac{H}{60}\right] \quad (29)$$
$$p = v \times (1-s) \quad (30)$$
$$q = v \times (1-f-s) \quad (31)$$
$$t = v \times (1-(1-f) \times s) \quad (32)$$

For each color vector (r,g,b),

$$(r,g,b) = \begin{cases}(v,t,p), \text{if } h_i = 0\\ (q,v,p), \text{if } h_i = 1\\ (p,v,t), \text{if } h_i = 2\\ (p,q,v), \text{if } h_i = 3\\ (t,p,q), \text{if } h_i = 4\\ (v,p,q), \text{if } h_i = 5\end{cases} \quad (33)$$

And the values of RGB are as follows:

$$R = r \times 256, G = g \times 256 \text{ and } B = b \times 256 \quad (34)$$

- 1.5 Equalize S channel from HSV color space
  -convert RGB color space to HSV using above equations and enhance S channel instead of H by MMBEDHE.

- 1.6 Equalize Y channel from YUV color space
  - Encodes a color image taking human perception into account
  - Allows reduced bandwidth
  - Transmission errors or compression artifacts are more efficiently masked by human perception than using a direct RGB representation.

The transformation from RGB to YUV is as follows

$$\begin{bmatrix}Y\\U\\V\end{bmatrix} = \begin{bmatrix}0.299 & 0.587 & 0.114\\ -0.1471 & -0.28886 & 0.436\\ 0.615 & -0.51449 & -0.1000\end{bmatrix}\begin{bmatrix}R\\G\\B\end{bmatrix} \quad (35)$$

Then backward transformation from YUV to RGB

$$\begin{bmatrix}R\\G\\B\end{bmatrix} = \begin{bmatrix}1 & 0 & 1.13983\\ 1 & -0.39465 & 0.58060\\ 1 & 2.03211 & 0\end{bmatrix}\begin{bmatrix}Y'\\U\\V\end{bmatrix} \quad (36)$$

- 1.7 Equalize Y channel from YIQ color space
  - YIQ is the color primary system adopted by NTSC for color television broadcasting.
  - Actual color seen on the monitor depends on what kind of monitor being used and what settings are.

Forward transformation

$$\begin{bmatrix}Y\\I\\Q\end{bmatrix} = \begin{bmatrix}0.299 & 0.587 & 0.114\\ 0.596 & -0.274 & 0.322\\ 0.211 & -0.523 & 0.312\end{bmatrix}\begin{bmatrix}R\\G\\B\end{bmatrix} \quad (37)$$

Backward transformation

$$\begin{bmatrix}R\\G\\B\end{bmatrix} = \begin{bmatrix}1 & 0.956 & 0.621\\ 1 & -0.272 & -0.647\\ 1 & -1.106 & 1.703\end{bmatrix}\begin{bmatrix}Y'\\I\\Q\end{bmatrix} \quad (38)$$

- 1.8 Equalize one band of RGB color space
  Here, we need to find the smallest channel of R,G,B and enhance that channel with MMBEDHE.

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Then the remaining channels are calculated as below.

$$R' = \begin{cases} X' : & X = R \\ \left(\frac{R}{X}\right) X' : & X \neq R \end{cases} \quad (39)$$

$$G' = \begin{cases} X' : & X = G \\ \left(\frac{B}{X}\right) X' : & X \neq B \end{cases} \quad (40)$$

$$B' = \begin{cases} X' : & X = B \\ \left(\frac{B}{X}\right) X'' : & X \neq B \end{cases} \quad (41)$$

- 1.9 Equalize only G channel
  - Extension to equalize one band color image
  - G channel in RGB represents luminance component.
  - The success of demosaicking for
  - digital camera depends on the perfect reconstruction of G channel
  - So, we enhance G channel of RGB color space using MMBEDHE
  - The enhanced G' component is used to enhance G and B component
  - Using r, B and G' we enhance R and B as follows

$$R' = \begin{cases} 0: & \alpha < 0 \\ \beta: & 0 \leq \beta \leq 255 \\ 255: & \beta > 255 \end{cases} \quad (42)$$

Where

$$\alpha = R + \left(\frac{1}{2}\right)(|G' - G|) \quad (43)$$

$$\beta = B + \left(\frac{1}{2}\right)(G' - G) \quad (44)$$

RESULTS

In order to adjudicate the effectiveness of the proposed MMBEDHE approach, the experimental results are compares with the results of existing nine techniques. All these images have been collected by Kodak photo sampler. We can evaluate the results subjectively based on visual inspection and numerical results. For visual evaluation: It can be observed that the results produced by the method described by equation 22 is not similar with the input image. The brightness of the output image has been changed. Image due to 1.1 looks better but, it changes the color. Images due to 1.2 and 1.3 appear to be distorted. The results due to 1.4 to 1.6 produce acceptable and tolerable results. But, they require transformation from RGB to another color space and backwards. The methods 1.7 and 1.8 cannot produce images keeping brightness of the input image and requires a transformation from RGB to YIQ. The image due to 1.9 produce image much near to input image and can preserve more brightness than others. It's also simple to implement. Numerical results can be calculated using:

$$\text{Input mean} = 1/3[\text{Mean}(R) + \text{Mean}(G) + \text{Mean}(B)] \quad (45)$$

$$\text{Outpu tmean} = 1/3[\text{Mean}(R') + \text{Mean}(G') + \text{Mean}(B')] \quad (46)$$

$$\text{Brightnes error} = \text{output mean} - \text{input mean} \quad (47)$$

Experimental results:

The original image is compared with all the nine techniques in terms of brightness preservation and brightness error.

Fig1.(a).Original Image

(b)Method described in equation 22

(c). Method described in 3.1

(d). Method described in 3.2

(e).Method described in 3.3

(f). Method described in 3.4

(g). Method described in 3.5

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(h). Method described in 3.6

(i). Method described in 3.7


(j). Method described in 3.8

(k). Method described in 3.9

Below table compares all the brightness errors for various methodologies.

BE due to equation 22	20.86
BE due to method 1.1	4.52
BE due to method 1.2	3.01
BE due to method 1.3	138.16
BE due to method 1.4	110.05
BE due to method 1.5	138.44
BE due to method 1.6	82.57
BE due to method 1.7	82.13
BE due to method 1.8	137.93
BE due to method 1.9	2.81

Table 1.1

CONCLUSION

A range of alternatives has been demonstrated to explore the MMBEDHE method in the field of consumer electronics for color images. Digital color image with brightness preservation is the burning issue in the field of digital image processing especially for consumer electronics.
MMBEDHE is very superior in its performance for different color spaces. The advantages can be listed below.

1. It produces images that can preserve brightness of the original image.
2. The visual quality of the output image using MMBEDHE is better than the other methods.
3. The proposed method produces less brightness error than other methods and
4. Images will be of natural outlook.
5. The computational load of this method is less than the other methods.
6. This method can be easily implemented with less hardware and less memory for real time processing.

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