CONTRAST ENHANCEMENT METHODS BASED ON HISTOGRAM EQUALIZATION TECHNIQUE: SURVEY

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ABSTRACT

Image enhancement techniques are used to emerge out hidden details in an image, or to increase the contrast in digital images. In other words, contrast enhancement techniques allow the important image features to be visible through increase the width of dynamic range. Although, the Histogram Equalization technique is more popular issue because of its effectiveness and simplicity, this technique suffers from some drawbacks, for example, change the image brightness and annoying artifacts. Therefore, number of methods are proposed depending on the histogram equalization to overcome these drawbacks. In this paper, a brief survey for most important methods based on histogram equalization used to enhance the image contrast are produced. The reviewed methods in this paper are categorized into three groups: partitioning histogram methods, dynamic range methods, and matching histogram methods.

Keyword: histogram equalization; BBHE; RSIHE; DHE; NMHE.

INTRODUCTION

Purity and brightness of image are greatly influenced by lighting, weather, or equipment that used for image capturing. Excessive exposure to previous conditions may result in loss of image information. Besides that, when a picture is converted from one form to other such as digitizing, some degradation will be happen at output (Moustafa 2000). Image enhancement techniques are used to emerge out hidden details in an image, or to increase the contrast in a low contrast image. Contrast enhancement techniques are used to increase the visibility of images through increase the width of dynamic range of important objects in an image (Joung 2001). In general, contrast enhancement methods classified into two major groups according to data domain they are applied: 1) frequency domain methods and 2) spatial domain methods. One of the most important methods in spatial domain is histogram equalization (HE) technique. The HE technique distributes pixel values uniformly and results in an enhanced image with linear cumulative histogram, as shown below:

$$Y(i,j) = X_0 + (X_{L-1} + X_0)c(X_k) \quad (1)$$

where X_0, X_{L-1} are the minimum and maximum gray levels values, $c(X_k)$ is cumulative distribution probability and calculated by equation (2).

$$c(X_k) = \sum_{j=0}^{k} p(X_j) \quad (2)$$

where

$$P(X_k) = \frac{n_k}{n} \quad (3)$$

where, $k=0,1,\ldots,L-1$ is the intensity level, n^k is the number of intensity level k, n is number of total pixel in image, and X_k value of intensity level k.

This paper is organized as follows. Section II explain briefly partitioning histogram methods and Section III is about dynamic range methods. Section IV is on matching histogram methods and Section V is about comparison. Lastly, Section VI will conclude this study.

METHODS BASED ON PARTITIONING HISTOGRAM

1-Brightness Preserving Bi -HE (BBHE): In this method, an image histogram is divided into two parts based on the original image mean brightness (the average intensity of all pixels that construct the input image), then equalize each part independently. Mathematically the method is represented as below (Kim 1997): Denote by X_m the mean of the image **X** and assume that $X_m \in [X_O,\ldots,X_{L-1}]$. Based on the mean, the input image is decomposed into two sub images $\mathbf{X_L}$ and $\mathbf{X_U}$ as shown in equation (4):

$$X = X_L \cup X_U \qquad (4)$$

where

$$X_L = \{X(i,j) | X(i,j) \le X_m, \forall X(i,j) \in X\} \qquad (5)$$

and

$$X_U = \{X(i,j) | X(i,j) > X_m, \forall X(i,j) \in X\} \qquad (6)$$

then the probability density function is defined as below:

$$P_L(X_k) = \frac{n_L^k}{n_L} \qquad (7)$$

where $k=0,1,\ldots.,m$. And

$$P_U(X_k) = \frac{n_U^k}{n_U} \qquad (8)$$

where $k=m+1, m+1,\ldots.,L-1$.

The respective cumulative density function for X_L and X_U are defined below:

$$c_L(x) = \sum_{j=0}^{k} P_L(X_j) \qquad (9)$$

and

$$c_U(x) = \sum_{j=m+1}^{k} P_U(X_j) \qquad (10)$$

By definition, $c_L(X_m)=1$and $c_U(X_{L-1})=1$. Then the transform function become:

$$f_L(x) = X_0 + (X_m - X_0)c_L(x) \qquad (11)$$

and

$$f_U(x) = X_{m+1} + (X_{L-1} - X_{m+1})c_U(x) \qquad (12)$$

lastly, output image **Y** for BBHE method is calculated from equation (13) below:

$$Y = f_L(X_L) \cup f_U(X_U) \qquad (13)$$

From previous, we see that the $f_L(X_L)$ equalize the sub image X_L over the range (X_0,X_m) and $f_U(X_U)$ equalize the sub image X_U over the range (X_{m+1},X_{L-1}), as a result the original image **X** is equalized over all dynamic range (X_0,X_{L-1}), where X_L in (X_0,X_m) and X_U in (X_{m+1},X_{L-1}).

2-Equal Area Dualistic Sub-Image Histogram Equalization(DSIHE): The principle and algorithm of this method is similar to previous method but histogram median separated (Yu 1999). The author proved that the segmentation entropy will achieved the maximum value when the two sub-image have equal area. As shown in equation (14), average brightness of output image is depending on average segmentation gray level and middle gray level.

$$E(Y) = \frac{X_m + (\frac{X_{L-1}+X_0}{2})}{2} \quad (14)$$

However, this method was not enough to keep the average luminance in some cases.

3-Minimum Mean Brightness Error Bi-HE (MMBEBHE): This method is similar to BBHE method but the separation level is the intensity level with minimum mean brightness error. The Mean Brightness Error (MBE) for threshold level T is calculated as below (Soong 2003):

$$MBE_T = MBE_{T-1} + \frac{1}{2}[1 - LP(X_T)] \quad (15)$$

where

$$\begin{aligned} MBE_0 &= E_0(Y) - E(X) \\ &= \frac{1}{2}\left[L\big(1 - p(X_0)\big)\right] - E(X) \end{aligned} \quad (16)$$

here L is the number of gray levels, $P(X_T)$ is the probability of threshold level X_T, $E(X)$ is the input mean. Lastly, the *MBE* will be scaled to find the threshold level at minimum MBE. In this strategy, the brightness of output image calculated without generating the output image for each suggested threshold level X_T, where this is suitable for real time implementation.

METHODS BASED ON DYNAMIC RANGE

1-Dynamic Histogram Equalization (DHE): In this method, treatment of dominant problem produced to enhance the contrast without loss in details of image. Disposal of dominant problem is achieved by dividing the original image histogram based on local minima and continuous in separation process to ensure that no dominant portion is presented in any of the newly created sub-histograms (M.A.-Al-Wadud 2007). Then each sub-histogram is mapped by HE over all dynamic range. Finally, the transformation function to each sub-histogram is calculated after calculation of the cumulative density function for histogram values. Equations (17-19) used for gray level range distribution for each sub-histogram.

$$span_i = m_i - m_{i-1} \quad (17)$$

$$factor_i = span_i \times (\log CF_i)^x \quad (18)$$

$$range_i = \frac{factor_i}{\sum_{k=1}^{t} factor_k} \times (L-1) \quad (19)$$

where $span_i$ is gray level range used by sub-histogram i in original image, m_i is ith local minima in the original image histogram, t number of sub-histogram, CF_i is the summation of all histogram values of ith sub-histogram, x is amount of emphasis given on frequency, $range_i$ is dynamic gray level range for sub-histogram i in output image. Depending on mean μ and standard deviation σ of gray level, the author decided if any dominating portion is exist, where in a sub-histogram if the number of gray levels in range ($\mu-\sigma$) to ($\mu+\sigma$) becomes more than 68.3% of the total of gray levels that mean no dominating portion. Otherwise, there are dominating portion and DHE splits the sub-histogram into three smaller sub-histograms by partitioning it at gray levels (μ–σ) and (μ+σ).

MATCHING HISTOGRAM METHOD

1-Normal Matching Histogram Equalization (NMHE): Novel method proposed in this paper based on changing the original image histogram using normal distribution theory. Depending on the fact that most of random variables approximately obey the normal distribution and because of the an image histogram is random variables of pixels, therefore the author proposed using normal distribution function to change the original image histogram (Bin X. 2010). Probability density function of normal distribution shown in equation (20).

$$p(x) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(x-\mu)^2}{2\sigma^2}} \tag{20}$$

where μ is mean of variable x, σ^2 is the variance of variable x. By replace original image mean brightness (m) and contrast (σ_r^2) by μ and σ^2 in (20) respectively, the equation (20) become:

$$p(r_k) = \frac{1}{\sqrt{2\pi\sigma}} e^{\frac{-(r_k-m)^2}{2\sigma_r^2}} \tag{21}$$

After some of arithmetic operations, cumulative density function of NMHE is calculated by equation (22), and transform function of NMHE is getting in equation (23).

$$c'(r_k) = \sum_{j=0}^{k} P_r'(r_k) = \frac{\sum_{j=0}^{k} e^{\frac{-(j-m)^2}{2\sigma_r^2}}}{\sum_{j=0}^{L-1} e^{\frac{-(j-m)^2}{2\sigma_r^2}}} \tag{22}$$

$$s_k' = (L-1)c'(r_k) \tag{23}$$

This method will transfer the gray-levels of original image to wider range and enhance the contrast significantly. As well, this method can preserve the original image brightness as shown in equation (24) below:

$$P_s(s) = P_r(r)\frac{1}{P_r'(r)} \tag{24}$$

where $P_s(s)$, $P_r(r)$, and $P'_r(r)$ are probability density functions of output image Y, original image X, and NMHE respectively. Equation (24) show that the mean brightness of output image will be nearest to the middle of dynamic range when $P_r(r) = P'_r(r)$. However, $P_r(r) \neq P'_r(r)$, therefore this method can preserve the mean brightness of original image.

COMPARISON

In this section, we produce comparison between reviewed methods in two directions. First direction: we show the advantages and drawbacks for each method, see Table 1 below.

TABLE 1 Advantages and disadvantages of reviewed methods.

Algorithms	Advantages	Disadvantages
HE	Simple and effective Uniform histogram	Don't preserving the input brightness
BBHE	Preserve the brightness. Fast.	Details loss. Low preserving brightness
DSIHE	Low loss details. produce optimal contrast.	Not enough to keep the luminance in some cases.
MMBEBHE	Natural appearance. Low weight color noise.	Complex. Slowly.
DHE	High degree of contrast. Preserving details.	Low preserving brightness. High noise.
NMHE	Good contrast and simple. Decreasing details loss.	Not totally eliminate Noise. Low preserving brightness.

Second direction: depending on results of Bin X. (2010) and Haidi I. (2007), we compared between reviewed methods in term of quantity parameters such as contrast, entropy, and AAMBE. Table 2 shows our result of calculation of the average of tests result of Bin X. (2010) for contrast and entropy. From Table 2, we see that the DSIHE method is the best method to keep the information from loss, while the best contrast is obtained by NMHE method.

TABLE 2 Average of results (Bin X. 2010)

Algorithms	**Parameters**	
	Contrast	Entropy
Original	1510	5.1500
HE	3737	4.9490
BBHE	5116	4.9281
DSIHE	6055	**5.0195**
MMBEBHE	3541	4.8845
NMHE	**6960**	4.999

TABLE 3 AAMBE measure

Method	AAMBE
HE	29.04
BBHE	13.82
DSIHE	24.74
MMBEBHE	**1.86**
DHE	8.05

The AAMBE can be calculated from equation below (Haidi I. 2007):

$$AAMBE = \frac{1}{N}\sum_{n=1}^{N}|E_n(X) - E_n(Y)| \quad (26)$$

where N is the total number of test images, $E_n(X)$ is the average intensity of test image n, while $E_n(Y)$ is the average intensity of the corresponding output image. From result of Haidi I. (2007) which shown in Table 3, result appears that the MMBEBHE is best method to preserve the mean brightness of original image.

CONCLUSION

Several methods based on HE technique are reviewed in this paper. Some methods enhance the contrast by splitting the histogram and other methods based on change the histogram then applying the HE technique. We conclude that the MMBEBHE method is better in brightness preserving as shown in theoretical and practical result as in Table 3. The DSIHE method is very good in preserving the information from loss, while the best contrast was obtained using the NMHE method. The advantages and disadvantages to all surveyed methods are listed.

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