



Study of Image Enhancement Techniques: A Review

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Abstract:- The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide 'better' input for other automated image processing techniques. Histogram equalization (HE) is one of the effective & simple technique for enhancing image quality. However, the conventional histogram equalization methods usually result in excessive contrast enhancement. This paper presents a review of histogram techniques for image contrast enhancement. The major difference among the methods is only the criteria used to divide the input histogram.

Keywords:- image enhancement, contrast enhancement, histogram equalization, absolute mean brightness error, histogram partition.

I. Introduction:-

Contrast enhancement has great significance in digital image processing. Histogram Equalization (HE) is one of the most popular, computationally fast and simple to implement techniques for contrast enhancement of digital images [1]. A histogram is a graphical representation of the distribution of data. An image histogram is a graphical representation of the number of pixels in an image as a function of their intensity. The histogram equalization technique is used to stretch the histogram of the given image. Greater is the histogram stretch greater is the contrast of the image [2]. In other words if the contrast of the image is to be increased then it means the histogram distribution of the corresponding image needs to be widened. Histogram equalization is the most widely used enhancement technique in digital image processing because of its simplicity and elegance. In an image processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. The histogram is a graph showing the number of pixels in an image at each different intensity value found in that image. For an 8-bit grayscale image there are 256 different possible intensities, and so the histogram will graphically display 256 numbers showing the distribution of pixels amongst those grayscale values. Histograms can also be taken of color images - either individual histogram of red, green and blue channels can be taken, or a 3-D histogram can be produced, with the three axes representing the red, blue and green channels, and brightness at each point representing the pixel count. The exact output from the operation depends upon the implementation, it may simply be a picture of the required histogram in a suitable image format, or it may be a data file of some sort representing the histogram statistics. The gray level in the image are remapped in order to uniformly distribute intensities of pixels in output image using Histogram Equalization techniques. It flattens and stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement. However, there are several cases that are not well managed by BHE especially when implemented to process digital images. Histogram equalization transforms the histogram of the original image into a flat uniform histogram with a mean value that is in the middle of gray level range [3]. Accordingly, the mean brightness of the output image is always at the middle - or close to it in the case of discrete implementation - regardless of the mean of the input image. For images with high and low mean brightness values, this means a significant change in the image outlook for the price of enhancing the contrast. Several variations are made for improvement of histogram equalization based contrast enhancement such as mean preserving bi-histogram equalization (BBHE), equal area dualistic sub-image histogram equalization (DSIHE) and minimum mean brightness error bi-histogram equalization (MMBEBHE). BBHE divides the image histogram into two parts. In this method, the separation intensity is presented by the input mean brightness value, which is the average intensity of all pixels that construct the input image. After this separation process, these two histograms are independently equalized. DSIHE follows the same basic ideas used by the BBHE method of decomposing the original image into two sub-images and then equalizes the histograms of the sub-images separately, proposed the so called equal area dualistic sub-image HE (DSIHE) method. MMBEBHE is the extension of BBHE method that provides maximum brightness preservation.. Recursive Mean-Separate Histogram Equalization (RMSHE) is another improvement of BBHE.

II. Histogram Equalization:

For a given image X , the probability density function $P(X_k)$ is defined as

$$P(X_k) = n_k / n \quad (1)$$

For $k=0,1,\dots,L-1$, where n_k represents the number of times that the level X_k appears in the input image X and 'n' is the total number of samples in the input image [4] [5]. Note that $P(X_k)$ is associated with the histogram of the input image which represents the number of pixels that have a specific intensity X_k . Based on the probability density function, the cumulative density function is defined as:

$$\sum_{j=0}^k P(X_j)$$

Where $X_k = X$, for $k=0,1,\dots,L-1$. Note that $C(x_{L-1}) = 1$ 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 as a transform function. Let's define a transform function $f(x)$ based on the cumulative density function as

$$f(x) = X_0 + (X_{L-1} - X_0)C(x) \quad (3)$$

Then the output image of the HE, $Y = \{Y(i,j)\}$, can be expressed as

$$Y = f(X) \quad (4)$$

$$= \{f(X(i,j)) \mid \forall X(i,j) \in X\} \quad (5)$$

The high performance of the HE in enhancing the contrast of an image as a consequence of the dynamic range expansion. Besides, HE also flattens a histogram. Base on information theory, entropy of message source will get the maximum value when the message has uniform distribution property. As addressed previously, HE can introduce a significant change in brightness of an image, which hesitates the direct application of HE scheme in consumer electronics.

A. Brightness Preserving Bi-Histogram Equalization (BBHE) :

This method divides the image histogram into two parts. In this method, the separation intensity is presented by the input mean brightness value, which is the average intensity of all pixels that construct the input image[4]. After this separation process, these two histograms are independently equalized. By doing this, the mean brightness of the resultant image will lie between the input mean and the middle gray level. The histogram with range from 0 to L-1 is divided into two parts, with separating intensity. This separation produces two histograms. The first histogram has the range of 0 to, while the second histogram has the range of to L-1.

B. Dualistic Sub-Image Histogram Equalization (DSIHE):

Equal area dualistic sub-image HE follows the same basic idea of BBHE method. It decompose the original image into two sub-images and then equalizes the histograms of the sub-images separately[6]. Instead of decomposing the image based on its mean gray level, The input image is decomposed into two sub-images, being one dark and one bright, respecting the equal area property (i.e., the sub-images has the same amount of pixels). In , it is shown that the brightness of the output image O produced by the DSIHE method is the average of the equal area level of the image I and the middle gray level of the image, i.e., $L / 2$. The authors claim that the brightness of the output image generated by the DSIHE method does not present a significant shift in relation to the brightness of the input image, especially for the large area of the image with the same gray-levels (represented by small areas in histograms with great concentration of gray levels), e.g., images with small objects regarding to great darker or brighter backgrounds.

C. Minimum Mean Brightness Error Bi-HE Method (MMBEBHE)

It also follows the same basic principle of decomposing an image and then applying the HE method to equalize the resulting sub-images independently[3][7]. The main difference between these technique is that previous consider only the input image to perform the decomposition while the MMBEBHE searches for a threshold level that decomposes the image I into two sub-images I [0, l_t] and I [$l_t + 1$, L - 1], such that the minimum brightness difference between the input image and the output image is achieved, that is called as absolute mean brightness error (AMBE),

$$AMBE = |E(X) - E(Y)|$$

X and Y denotes the input and output image, respectively. Lower AMBE indicates that the brightness is better preserved. Once the input image is decomposed by the threshold level l_t , each of the two sub-images I[0, l_t], and I[l_t+1 , L-1] has its histogram equalized by the classical HE process, generating the output image.

MMBEBHE is formally defined by the following procedures:

- (1) Calculate the AMBE for each of the possible threshold levels.
- (2) Find the threshold level, X_T that yield minimum AMBE.
- (3) Separate the input histogram into two based on the X_T found in Step 2 and equalize them independently as in BBHE.

D. Recursive Mean-Separate HE Method (RMSHE):

RMSHE is an extended version of the BBHE method. The design of BBHE indicates that performing mean-separation before the equalization process does preserve an image's original brightness[8]. In RMSHE instead of decomposing the image only once, it perform image decomposition recursively to further preserve the original brightness up to scale r. HE is equivalent to RMSHE level 0 ($r = 0$). BBHE is equivalent to RMSHE with $r = 1$. The brightness of the output image is better preserved as r increases.

E. Mean brightness preserving histogram equalization (MBPHE):

The mean brightness preserving histogram equalization (MBPHE) methods basically can be divided into two main groups, which are bisections MBPHE, and multi-sections MBPHE. Bisections MBPHE group is the simplest group of MBPHE[3]. Fundamentally, these methods separate the input histogram into two sections. These two histogram sections are then equalized independently. However, bisections MBPHE can preserve the mean brightness only to a certain extent. However, some cases do require higher degree of preservation to avoid unpleasant artifacts. Furthermore, bisections MBPHE can only preserve the original mean brightness if and only if the input histogram has a quasi-symmetrical distribution around its separating point. But, most of the input histograms do not have this property. This

condition leads to the failure of bisections MBPHE in preserving the mean intensity in real life applications. Multi-sections MBPHE group has a better mean brightness preservation as compared with the group of bisections MBPHE. In multi-sections MBPHE, the input histogram is divided into R sub-histograms, where R is any positive integer value. Each sub-histogram is then equalized independently. The creation of the sub-histograms can be carried out recursively (e.g. by using the mean or median intensity value), or based on the shape of the input histogram itself (e.g. using the locations of local maximum or local minimum). Yet, in these methods, the detection of the separating points process normally requires complicated algorithms, which then associated with relatively high computational time. Furthermore, these methods usually increase the hardware requirement in the implementations for consumer electronic products. In addition, most of these methods put too much constrain on keeping the mean intensity value. As a consequence, not much enhancement could be obtained from most of these methods.

F. Dynamic Histogram Equalization:

The Dynamic Histogram Equalization (DHE) technique takes control over the effect of traditional HE so that it performs the enhancement of an image without making any loss of details in it. DHE divides the input histogram into number of sub-histograms until it ensures that no dominating portion is present in any of the newly created sub-histograms. Then each sub histogram is allotted a dynamic gray level (GL) which further can be mapped by HE[9]. This is done by distributing total available dynamic range of gray levels among the sub-histograms based on their dynamic range in input image and cumulative distribution (CDF) of histogram values. This allotment of stretching range of contrast prevents small features of the input image from being dominated and washed out, and ensures a moderate contrast enhancement of each portion of the whole image. At last, for each sub-histogram a separate transformation function is calculated based on the traditional HE method and gray levels of input image are mapped to the output image accordingly. The whole technique can be divided in three parts partitioning the histogram, allocating GL ranges for each sub histogram and applying HE on each of them.

G. Brightness Preserving Dynamic Histogram Equalization:

The brightness preserving dynamic histogram equalization (BPDHE), which is an extension to HE, fulfils the requirement of maintaining the mean brightness of the image, by producing the output image with the mean intensity almost equal to the mean intensity of the input. This method is actually an extension to both MPHEBP and DHE[3]. Similar to MPHEBP, the method partitions the histogram based on the local maximums of the smoothed histogram. However, before the histogram equalization taking place, the method will map each partition to a new dynamic range, similar to DHE. As the change in the dynamic range will cause the change in mean brightness, the final step of this method involves the normalization of the output intensity. So, the average intensity of the resultant image will be same as the input. With this criterion, BPDHE will produce better enhancement compared with MPHEBP, and better in preserving the mean brightness compared with DHE.

III. Conclusion:

The study of Histogram Equalization based methods shows that there are several cases which require higher brightness preservation and not handled well by HE, BBHE and DSIHE, have been properly enhanced by RMSHE. MMBEBHE is the extension of BBHE method that provides maximal brightness preservation. Though these methods can perform good contrast enhancement, they also cause more annoying side effects depending on the variation of gray level distribution in the histogram. DHE ensures consistency in preserving image details and is free from any severe side effects. BPDHE can preserve the mean brightness better than BBHE, DSIHE, MMBEBHE, RMSHE, MBPHE, and DHE.

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