ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

Review of Contrast Enhancement Techniques Based on Histogram Equalization

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Abstract

Contrast enhancement techniques are used for improving visual quality of low contrast images. Histogram equalization (HE) method is one such technique used for contrast enhancement. Histogram equalization (HE) has proved to be a simple and effective image contrast enhancement technique. However, the conventional histogram equalization methods usually result in excessive contrast enhancement, which causes unnatural look visual artifacts of the processed image. This paper presents a review of new forms of histogram for image contrast enhancement the ultimate aim of these techniques is to preserve the input mean brightness so that the image looks natural in appearance.

Keywords

Histogram Equalization, Contrast Enhancement, Histogram, Brightness Preservation, Dual histogram equalization, Brightness Preserving Bi-Histogram Equalization.

I. Introduction

Image enhancement is one of the most important areas of digital image processing. Image enhancement has received much interest in many digital image analysis applications, such as, space imagery, medical research, microscopic imaging, remote sensing, military, printing industry, textiles, forensic studies, graphic arts etc. example of image enhancement include edge enhancement, contrast enhancement, pseudo-coloring, noise filtering and sharpening etc. out of these contrast enhancement is a popular one.

There are several reasons for an image/video to have poor contrast:

A) The poor quality of the used imaging device,
B) Lack of expertise of the operator, and
C) The adverse external conditions at the time of acquisition

Contrast enhancement is one of the most important technique for image enhancement in this technique, contrast of an image is improved to make the image better for human vision. There are various techniques that can be used for contrast enhancement process. But the most common one is the histogram equalization (HE). The HE technique flattens the histogram and stretches dynamic range of gray levels to perform overall contrast enhancement. Histogram equalization well distributes the pixels intensity over the full intensity range. But HE has “mean shift” problem, it shifts the mean intensity value to the middle gray level of the intensity range. So this technique is not useful where brightness preservation is required. This technique is not commonly used in consumer electronics as it significantly changes brightness of input image and unnecessary visual deterioration is introduced. Therefore researchers have proposed some other brightness preserving techniques as an improvement in the traditional histogram equalization process.

Brightness preserving bi-HE(BBHE), dualistic sub image histogram equalization(DSIHE), recursive mean separate histogram equalization(RMSHE), minimum mean brightness error bi-HE (MMBEBHE), recursive separated and weighted histogram equalization(RSWHE), dynamic HE (DHE), brightness preserving dynamic HE (BPDHE) etc are some of the techniques that aim to preserve the brightness of the image.

II. Image Enhancement

Image enhancement is among the simplest and most appealing areas of digital image processing. The fundamental goal of image enhancement is to process the input image in such a way that the output image is more suitable for interpretation by the humans as well as by machines. The process of image enhancement is application specific, thereby meaning that a method which is suitable for enhancing images for one type of application might not be suitable for other. There are numerous available techniques in the literature that can use for image enhancement. Improvement in quality of these degraded images can be achieved by using application of enhancement technique

Image enhancement techniques can be broadly classified into two categories:

a) spatial domain
b) frequency domain

In Spatial domain methods directly process the pixels of an input image.

In Frequency domain image enhancement involves modifying the Fourier transform of the image. In frequency domain methods the original input image is first transformed into frequency domain using 2D Fourier transforms. The image is then processed in frequency domain. Finally, the output image is obtained using 2D inverse Fourier transforms.

The block diagram showing the main steps in frequency domain image processing is shown below:

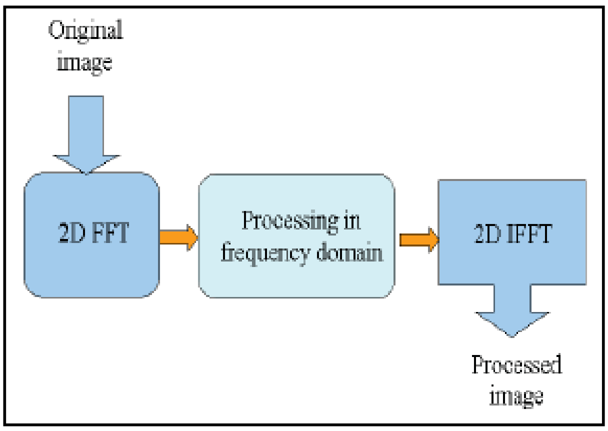


Fig. 1: image enhancement technique

III. Histogram Equalization

Histogram equalization is an important image enhancement technique commonly used for contrast enhancement. 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. 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 elegancy. In an image processing context, the histogram of an image normally refers to a histogram of the pixel intensity values. This 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. It flattens and stretches the dynamic range of the image's histogram and resulting in overall contrast enhancement. Contrast enhancement by histogram equalization is one such technique.

Fig. (a) : Original image of warplane

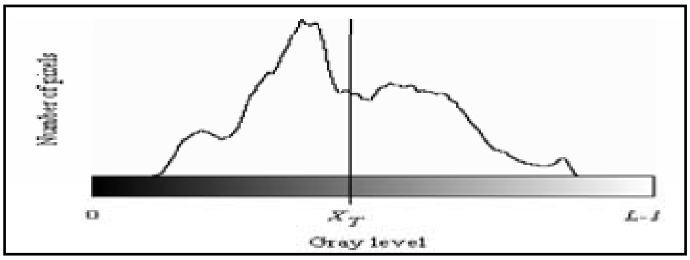
Fig. (b) : Histogram Equalized image of warplane

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.

IV. Existing Contrast Enhancement Techniques

A. Brightness Preserving Bi-Histogram Equalization (BBHE)

The BBHE firstly decomposes an input image into two sub image based on the mean of the input images. One of the sub images is the set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub images independently based on their respective histograms with the constraint that the samples in the formal set are mapped into the ranges from the minimum gray level to the input mean and the samples in the latter set are mapped into the ranges from the mean to the maximum gray level. In other words, one of the sub images is equalized over the range up to the mean, based on the respective histogram. Thus, the resulting equalized sub images are bounded by each other around the input mean, which has an effect of preserving mean brightness.



B. Dual Sub-image Histogram Equalization (DSIHE)

The DSIHE technique for contrast enhancement decomposes an image into two equal area sub-images, one dark and one bright, following the equal area property (*i.e.*, both sub-images have same amount of pixels) This decomposition is done on the bases of the gray level cumulative probability density which is equal to 0.5. Then the two sub images are taken in equalization process respectively. After enhancement, these two sub images are composed into one image. Finally, result of enhancement provides an enhanced image with its original luminance that makes it possible to be used in the video system directly. There is no doubt that these two sub images represent the dark and bright areas of original image respectively. So, the gray level can be remained in its original scale respectively after sub image histogram equalization. Furthermore, contrast of the original image is also enhanced effectively post processing. The DSIHE method decomposes the images aiming at the maximization of the Shannon's entropy of the output image.

C. Recursive Mean-separate Histogram Equalization (RMSHE)

Mean-separation means to separate an image based on the mean of input image. However, RMSHE technique is an extension of BBHE (where mean-separation was done only once). In RMSHE, instead of decomposing the input image only once, it is decomposed recursively up to a
recursion level r, therefore 2r sub images will be generated. Each sub image is then equalized independently with histogram equalization method. If r=0, that means no sub image decomposition is done, i.e. it is equivalent to HE method only. When one mean separation

ISSN : 2394-2975 (Online)
ISSN : 2394-6814 (Print)

is done before equalization, i.e. r=1, this is equivalent to BBHE .This increases a level of brightness preservation. Similarly, two mean-separations before equalization will result in much higher level of brightness preservation as compared to r=0 and r=1 levels. The above discussion concludes that the level of brightness preservation will increase with the increase of number of recursive mean separations. This technique aims to bring more extends of brightness preservation than HE and BBHE techniques.

D. Minimum Mean Brightness Error Bi- Histogram Equalization (MMBEBHE):

In MMBEBHE method the input image is decomposed into two sub images according to the threshold gray level, (but this threshold is calculated on the basis of minimum Absolute Mean Brightness Error) and then the histogram equalization is applied on each sub image and then they are combined but it provides very good preservation of brightness level.

MMBEBHE method

MMBEBHE employs the following steps:

1. Calculation of Absolute Mean Brightness Error (AMBE) for each of the threshold level.
2. Determination of threshold level XT which yields minimum Mean Brightness Error (MBE).
3. Separation of input histogram into two based on the XT, which is found in step 2 and their equalization is done independently as in BBHE.

Step 3 is same as BBHE. Step 1 requires considerable amount of computation as one full BBHE process is required to calculate the AMBE for each of the possible threshold level. This will be very time consuming process. Hence, MMBEBHE is not used for real time application.

E. Dynamic Histogram Equalization (DHE)

The Dynamic Histogram Equalization (DHE) technique performs well than the traditional HE so that it can enhance an image without making any loss of details in the image. DHE divides the histogram of input image in to a number of sub-histograms until it ensures that no dominating portion is present in any of the newly created sub-histograms. Then a dynamic gray level (GL) range is allocated for each sub-histogram to which its gray levels can be mapped by HE. To perform this, total available dynamic range of gray levels is distributed among the new sub-histograms based on their dynamic range in input image and the cumulative distribution function (CDF) of histogram values. In nutshell, the whole technique of DHE can be divided into following three parts – partitioning the histogram, allocating GL ranges for each sub histogram and applying histogram equalization on each of them.

F. Brightness Preserving Dynamic Histogram Equalization (BPDHE)

The brightness preserving dynamic histogram equalization is an extension to the traditional HE method that can produce output image with the mean intensity that is almost equal to the mean intensity of input image. Thus BPDHE maintains the mean brightness of the image and hence overcomes the limitation of histogram equalization. This method is actually an extension to the DHE. However, before the histogram equalization has taken place, the BPDHE will map each partition to a new dynamic range, similar to DHE. The change in the dynamic range will cause the change in mean brightness. And the final step involves normalization of the output intensity. So, the average intensity of resultant output image will be same as the input image. Hence, BPDHE proves itself better in performing enhancement task as compared to traditional
HE method, and better in preserving mean brightness when compared with DHE.

V. Conclusion

This paper presents comparative study of different histogram equalization based image enhancement methods. Histogram equalization is a simple and effective technique that can be used for image contrast enhancement. However, it is not suitable for the consumer electronic products as it changes the mean brightness in the output image and introduces unwanted visual deterioration. Various other brightness preserving contrast enhancement techniques are used. The major goal of all these contrast enhancement techniques is to produce the output images in which mean brightness is preserved and the image looks better in appearance. From our study it is observed that a huge work has already been done in this field but still there exist much space for future work.

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