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A Comparative Study of Widely Used Histogram Equalization Based Image Contrast Enhancement Methods

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Abstract— Contrast enhancement is considered as one of the important characteristic in the field of image enhancement and histogram equalization is a simple and well known method for image contrast enhancement, this method uses the histogram of images in its processing. Although the conventional histogram equalization method is widely accepted but this method suffers from the drawback of "mean-shift" problem, i.e. mean brightness of processed image will always be the middle gray level regardless the mean brightness of the input image. So it is not considered as the best method for contrast enhancement with brightness preservation. Several other histogram equalization based methods have been introduced to overcome the drawback of mean shift problem. In this paper we will review widely used histogram equalization methods used for contrast enhancement and brightness preservation.

Keywords— Histogram Equalization, Contrast Enhancement, Brightness Preservation.

I. INTRODUCTION

In the field of digital image processing contrast enhancement is mostly used in computer vision and it is also used for improvement of pictorial information for human visual perception. It is generally used for medical image processing, speech recognition, texture synthesis and various other applications. Several methods have been introduced in the field of image contrast enhancement [2]-[11]. Let us review some of the important methods.

Low contrast digital image analysis is a challenging problem in digital image processing. Low contrast digital images reduces the ability of observer in analyzing the image. Histogram equalization (HE) is the one of the popular method of image contrast enhancement [1]. The histogram of the discrete gray-level image represent the frequency of occurrence of all gray-levels in the image [5]. This method is mainly used because of its simplicity of implementation and computationally less expensiveness than other methods. Although the HE method is widely accepted but many time histogram equalized image suffers from the "mean-shift" problem [5], i.e. it shifts the mean intensity value to the middle gray level of the intensity range. So this technique is not useful in situations, where mean brightness preservation is required. To overcome this problem a number of variations of HE method have been proposed. In this paper we are going to provide a systematic review on widely used HE based methods.

The organization of this work is as follows. After providing a brief introduction in section 1, in section 2 we will cover the histogram equalization method in detail. Section 3 covers in details all the widely used HE based algorithms. Finally section 4 concludes the entire context.

II. HISTOGRAM EQUALIZATION\

Histogram equalization is a well known method for image contrast enhancement that uses histogram of image in its processing. HE is a spatial domain technique in which modification of pixels intensity values is done directly which leads to enhancement of image.

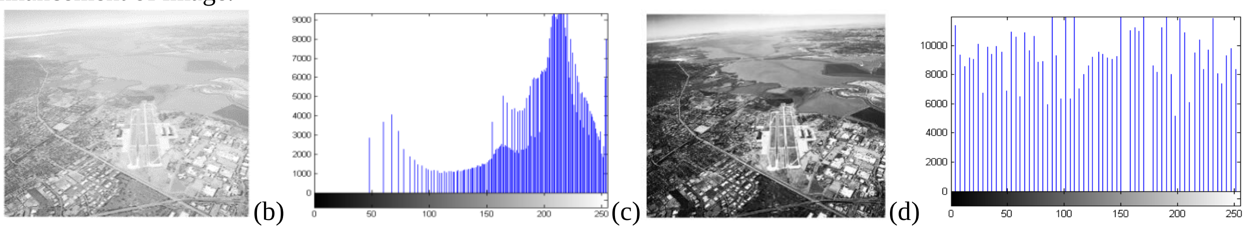
(a) (b) (c) (d)


Fig. 1. (a) shows input image having low contrast, (b) shows histogram of input image, (c) shows histogram equalized image and (d) shows histogram of processed image

III. HISTOGRAM EQUALIZATION BASED METHODS

A. Adaptive Histogram Equalization (AHE):-

Adaptive histogram equalization (AHE) [2] is a technique of image contrast enhancement used in digital image processing. It is different from conventional histogram equalization technique in the way that the AHE computes various histogram equalization independently, each of which belongs to different sections of images. The main advantage of AHE is that it is able to enhance the local contrast of image and hence, preserve more brightness.

Conventional histogram equalization uses the same transformation to transform all pixels. HE proves better in cases where pixels values are distributed uniformly in the image. But fails in cases where image consists of different brighter and darker regions as it is not able to enhance the contrast of image. Thus unable to preserve brightness of image.
AHE overcomes the drawback of HE by enhancing local contrast of image. AHE enhance this transformation function by transforming each pixel values. Based on the histogram of square, which is surrounded by pixel value each pixel value is transformed as shown in figure. The pixel value of neighborhood is proportional for each transformation function and cumulative distribution function. The ordinary histogram equalization is similar to the transformation function derived from each pixel value

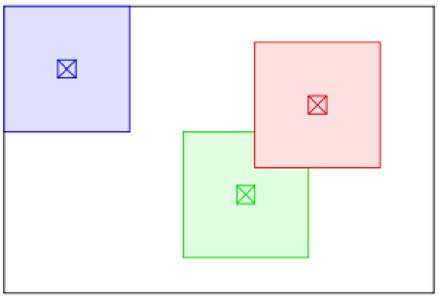


Fig. 2 Concept of Adaptive Histogram Equalization (source[3]).

B. Contrast Limited Adaptive Histogram Equalization (CLAHE):-

Contrast Limited AHE (CLAHE) [4] facilitates the contrast limiting functionality that makes them different from adaptive HE. AHE is able to enhance the local details only while contrast limiting functionality of CLAHE is able to enhance the global details as well. The main advantage of CLAHE is that it is able to prevent distortions like noise amplification which is not in case of AHE. The contrast limiting functionality of CLAHE is applied for each neighbor from which we derive transformation function.
CLAHE performs noise amplification by applying contrast limiting functionality in AHE. The slope of transformation function determines the contrast amplification for each of the pixel value and the area surrounded by pixel value. This is similar to the value of histogram for each pixel value. It is also similar to the slope of cumulative distribution function(CDF). CLAHE perform this amplification function by trimming the part of histogram before applying the CDF which simply leads to limit the slope of transformation. Depending on the normalization of this histogram, clip limit is the term defined as the value through which histogram is trimmed.

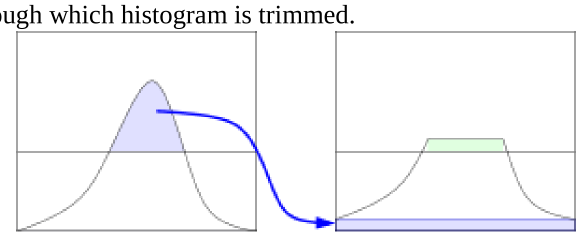


Fig. 3 Concept of Contrast Limited Adaptive Histogram Equalization (source[3]).

C. Brightness Preserving Bi-Histogram Equalization (BBHE)-

The method was proposed by Kim [5]. This method overcomes the drawback of histogram equalization. BBHE segments the image histogram into two sub-histograms: (based on mean value of input image histogram) one from minimum gray level to the mean value and other from the mean value to the maximum gray level. After this the BBHE method apply HE on each sub-histogram independently. Now let input image X is decomposed into two sub-histograms namely X_L and X_U by using the input mean X_m, where $X_m \in \{X_0, X_1, X_2 \dots X_{L-1}\}$. Now it is clear that $X_L = [X_0, X_m]$ and $X_H = (X_m, X_{L-1}]$.

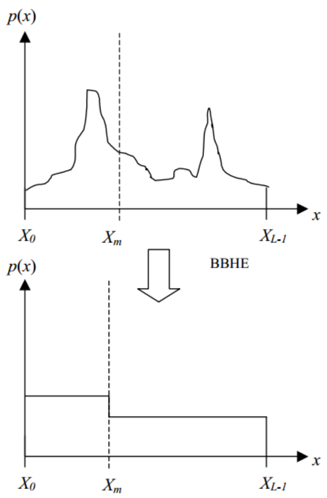


Fig. 4 Shows the concept of BBHE, here the input image histogram is divided into two sub-histograms (source [7]).

D. Equal Area Dualistic Sub-Image Histogram Equalization (DSIHE):-

The BBHE method solved the mean-shift problem up to some extent, but this method was not able to preserve fine details present in the input image. To solve this problem Equal Area Dualistic Sub-Image Histogram Equalization (DSIHE) was proposed [6]. This method follows the same approach as that of the BBHE except DSIHE segments the image histogram based on the median of the input image. Let input image X is decomposed into two sub-histograms namely X_L and X_U by using the input median X_D, where $X_D \in \{X_0, X_1, X_2 \dots X_{L-1}\}$. Now it is clear that $X_L = [X_0, X_D]$ and $X_H = (X_D, X_{L-1}]$.

E. Recursive Mean Separate Histogram Equalization (RMSHE):-

This method is an extension of BBHE, the RMSHE [7] provides more brightness preservation than BBHE. In BBHE the mean based segmentation is preformed only once but in RMSHE this segmentation is performed more than once. This recursive nature of the RMSHE method implies scalable preservation which is very useful in consumer electronic products.

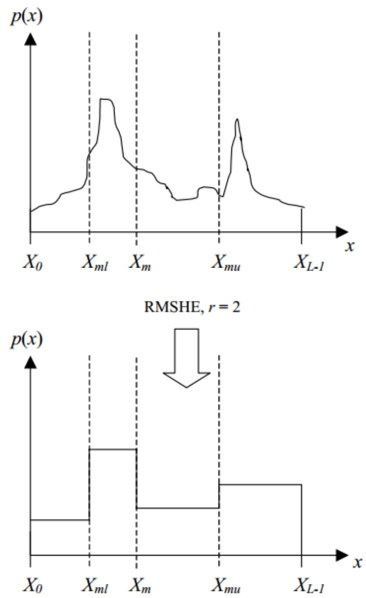


Fig. 5 Shows the concept of RMSHE, here the input image histogram is divided into four sub-histograms (source [7]).

F. Recursive Sub-Image Histogram Equalization Applied To Gray Scale Image (RSIHE):-

RSIHE follows the similar characteristic as that of RMSHE in separating the input image and then equalizing it. The difference arises between RSIHE [8] and RMSHE is that RMSHE follows mean separation approach for brightness preservation and RSIHE separates the image histogram with median values using cumulative probability density function.

G. Dynamic Histogram Equalization (DHE):-

The tradition HE method has tendency to make undesirable artifact in the processed image and sometimes this may lead in loosing important visual details present in the image. The DHE [9] method takes control over this effect of the HE method. This method divides the input image histogram into number of sub-histograms such that there is not dominating portion present in any of newly created sub-histograms. After that the method assigns a new dynamic range to each sub-histograms. At last the DHE method performs HE on each sub-histogram independently. The new dynamic range is allocated using dynamic range of each sub-histogram in input image and its cumulative distribution function (CDF). The DHE produces images in which small details are not dominated by any other parts of the image and hence no information is washed out.

The DHE method can be divided in three parts –

1. Division of input image histogram into number of sub-histograms.
2. Allocation of new dynamic range for each sub-histogram.
3. Applying HE on each of the sub-histograms independently.

H. Brightness Preserving Dynamic Histogram Equalization (BPDHE):-

This method was proposed to solve the mean-shift problem. This method produces image with mean intensity almost equal to that of input image. Whole processing of this method is divided into following steps [10].

1. Generation of histogram from input image.
2. Applying the Gaussian filter in the input image histogram to make it smooth.
3. Dividing the input image smoothed histogram into sub-histograms based on local minimums.
4. Applying new dynamic range to each sub-histograms.
5. Applying HE on each sub-histogram of step 4 separately.

I. Recursively Separated and Weighted Histogram Equalization for Brightness Preservation and Contrast Enhancement (RSWHE):-

The essential idea of RSWHE [11] is to segment an input histogram into two or more sub-histograms recursively, to modify the sub-histograms by means of a weighting process based on a normalized power law function, and to perform histogram equalization on the weighted sub-histograms independently.

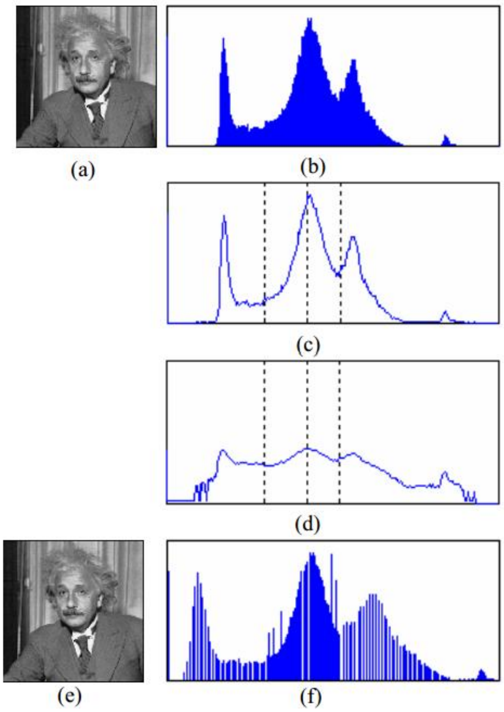


Fig. 3. Intermediate results of RSWHE: (a) input image, (b) input histogram, (c) segmented histogram, (d) weighted and normalized PDF, (e) output image, and (f) output histogram (source [12]).

J. Multilevel Component Based Histogram equalization (MCBHE):-

Multilevel Component Based Histogram equalization (MCBHE) [12] is the technique which combines the global histogram equalization method, multiple gray level thresholding, BPBHE and connected component analysis that enhance the global and local contrast of an image without creating much side effects i.e. with less distortion. MCBHE is quite different from BPBHE in a way that BPBHE uses the conventional histogram equalization technique for equalizing each sub-image while MCBHE uses multiple gray level thresholding and of connected component for equalizing gray level of each sub-image. This analysis is generally used in various applications of image segmentation like tumor detection and recognizing handwriting. In this approach image is threshold at various predetermined gray levels. Sequential labeling is then used at each of these threshold levels to determine those connected components which are below or above the current threshold. This approach proves to be advantageous because as the threshold value changes, it helps in determining the variation of gray levels. This is the main reason for adopting this approach in MCBHE and it helps in enhancement of local contrast as well.

IV. CONCLUSION

This paper provides the review of different histogram equalization methods. The study of various histogram equalization methods shows that brightness is not preserved efficiently by histogram equalization technique. Various other methods like BBHE and DSIHE are introduced which tries to remove the drawback of histogram equalization up to some extent. RMSHE overcomes the drawback of BBHE and DSIHE. Apart from these methods, MMBEBHE is introduced which is able to preserve more brightness and helps in contrast enhancement. But this method suffers from the drawback of creating more distortions based on variation of gray level distribution in histogram[6].

DHE is then introduced which does not have any severe side-effects and able to preserve the details of image. BPDHE is able to preserve the mean brightness of the image comparatively better than several other methods like BBHE, DSIHE, MMBEBHE, RMSHE, MBPHE and DHE. MCBHE is able to enhance the contrast without creating much distortion in the image. MCBHE is able to enhance the global and local contrast of image as well.

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