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A TECHNICAL SURVEY ON IMAGE CONTRAST ENHANCEMENT TECHNIQUES VIA HISTOGRAM EQUALIZATION

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ABSTRACT

Image processing methods process an image so as to make it suitable for applications like medical image analysis, video conferencing, remote sensing, HDTV, industrial x-ray image processing, Underwater image enhancement, microscopic imaging etc. Enhancement improves image quality in such a way that it is suitable for further processing. Contrast enhancement techniques increase the contrast of an image by making lighter colors more lighter and darker colors more-darker. Histogram Equalization is normally used for contrast enhancement. There are many histogram equalization techniques which differ in the input histogram separation style based on mean, median etc. In this paper, we discuss various image contrast enhancement techniques that employ histogram equalization.

Keywords----- Contrast enhancement - Brightness preservation -Histogram equalization - Histogram Partition.

I. INTRODUCTION

The image contrast enhancement is frequently analyzed over the last few years. Contrast enhancement is supposed to produce an image that looks better than the original image by converting pixel intensities. Among the numerous contrast enhancement approaches in literature, histogram modification based methods are commonly used due to their simplicity and effectiveness.

The histogram of an image shows the number of pixels for each intensity value found in the image. The histogram of an image is a discontinuous function and if the image has intensity levels in the range [0, L – 1]

$$h(r_k) = n_k$$

where r_k is the intensity value at position k and n_k is the number of pixels in the image with intensity r_k. If a grayscale image is 8-bit, then there will be 256 different intensities and hence the histogram graphically displays 256 numbers which displays how the different pixels are distributed among the grayscale values. For color images, individual histograms of red, green and blue channels can be used. We can otherwise use a 3-D histogram with the three axes representing the three channels red, blue and green, and we can produce the pixel count representing the brightness at every point.

Histogram equalization is a technique which is common, simple and effective. It is used for adjusting image intensities in such a way to enhance contrast. For mapping the input grey levels, the probability distribution is used. By using this technique, we flatten and stretch the dynamic range of the histogram of the image, which improves the overall contrast e. HE has the following disadvantages

- It assigns one grey level to two nearest grey levels with its different strength.
- It has washout effects if it assigns grey level to the higher intensity.

In particular, global histogram equalization (GHE) over enhances the image. The approach of dividing an image histogram into many sub histograms and modify each sub histogram separately can be used as an alternative to GHE. Such methods highly depend on how we partition the image histogram. One approach is to model image histogram using Gaussian mixture model (GMM) and divide using the intersection points of the Gaussian components. We can stretch the histograms using Gaussian parameters.

II. IMAGE ENHANCEMENT

Fig.1 Image Enhancement example

Image Enhancement is used to enhance the quality of image so that the image can be used for applications like medical image analysis, remote sensing, video conferencing, HDTV, industrial x-ray image processing, underwater image enhancement, microscopic imaging etc.

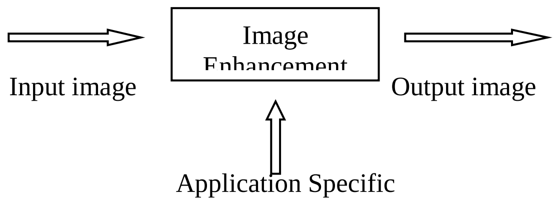

Fig.2 Image Enhancement

There are two broad categories of Image Enhancement techniques.

*A.Spa*tial Domain Techniques: These techniques directly deal with image pixels. These techniques directly manipulate the grey levels of individual pixels and thus improve the overall contrast of the image.

1) *Point operations*
   They are applied to individual pixels.
2) *Mask operations*
   In mask operation, we modify each pixel in relation with its neighboring values.
3) *Global Operation*
   In Global operation, we consider all pixel values in the image for performing the operation.

B. Frequency Domain Techniques: These techniques utilize the orthogonal transform of an image. The principle method is to compute the orthogonal transform of an image (DFT, DCT, Hartley transform etc.), and then manipulate the transform coefficients using an operator. Finally, we apply the inverse transform. The orthogonal transform will have two components magnitude representing frequency content of the image and phase which can be used to restore the image.

III. CONTRAST ENHANCEMENT: Contrast enhancement technique makes the image brighter, and it efficiently uses the colors on the display or output device. Contrast Enhancement techniques can be classified into two methods.

A. Direct methods: In direct method, a contrast measure is modified by a mapping function (square root, exponential etc.) and thus the image is enhanced. They have the disadvantage that the results are sensitive to noise and will have digitization effects and computational complexity will be more.

B. Indirect methods: Indirect methods improve the contrast by using the underutilized regions. They are further classified into

- Techniques for decomposing an image into low and high frequency signals for operation e.g. homo orphic filtering.
- Histogram modification techniques.
- Transform based techniques.

Histogram modification techniques are straight forward and easy to implement and hence they are popular.

IV. HISTOGRAM EQUALIZATION:Histogram equalization technique is common, simple and effective and is used for adjusting image intensities to enhance contrast. In this technique, we map the gray levels depending on the probability distribution of the input gray levels and thus flatten and stretch the dynamic range of the image's histogram which boosts the overall contrast.

Suppose we have an image x whose dynamic range for the intensity r_k varies from 0 (black) to L – 1 (white). The pdf can be obtained as follows

$$pdf(x) = pdf(r_k) = \text{Pixels with intensity } r_k / \text{total no. of pixels}$$

From the pdf, we can calculate the cumulative density function (cdf) as

$$cdf(x) = \sum p(r_k)$$

The output from the histogram equalization is then equal to the cdf of the image

$$p(s_k)= \sum p(r_k)$$

To get the value of the pixel, we multiply $p(s_k)$ by L – 1 which is finally rounded to the nearest integer value.

One drawback is that the histogram equalization changes the brightness of an image. Hence to preserve visual quality, it is rarely utilized in consumer electronic products. Several variations to the technique have been presented in literature.

V. Brightness preserving Bi Histogram Equalization (BBHE): In BBHE [23] an input image is split into two parts depending on its mean value. The first part will contain pixel values up to the mean and the second part will contain pixel values above the mean. He is then applied to the two parts independently and then both are combined. In this method, the separation intensity is the average intensity of all pixels that constitute the input image. The resultant mean brightness will lie in between the middle gray level and the mean of the input.

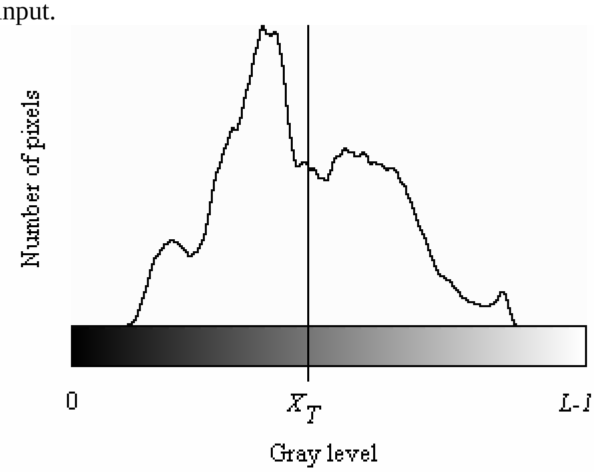

Fig .3: Brightness preserving Bi Histogram Equalization [2]

A. *Dualistic Sub Image Histogram Equalization (DSIHE):* DSIHE [6] uses the median value to splits an image into two parts. The first part contains pixel values up to the median and the second part contains pixels above the median. HE is applied to the two images independently and then both the images are combined.

B. *Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE):* MMBEBHE [13] splits the image based on a threshold value. First, Calculate mean brightness and then Select a threshold based on the Absolute Mean Brightness Error (AMBE).Finally, split the histogram depending on the minimum AMBE into two equal parts and equalize them independently.

C. *Recursive Mean Separate Histogram Equalization (RMSHE):* RMSHE [37] recursively decomposes the given image depending on mean r times and produce 2r sub images, which are enhanced independently by using HE. This technique not only preserves the brightness and it also effectively enhances the image. When r=0, RMSHE is HE and when r=1, it is BBHE.

D. *Mean Brightness Preserving Histogram Equalization (MBPHE):* In multi section MBPHE [49], the input histogram is equalized by taking the median or mean value recursively. Its hardware implementation is complicated and more computational time is required for consumer electronics.

E. Brightness Preserving Dynamic Histogram Equalization (BPDHE)

In BPDHE [32], local maxima is used to split the input image into many sub images. The first step in the technique is to apply the Gaussian filter and smoothen the histogram and then identify local maxima. Then each partition is mapped into a new dynamic range and equalized independently. Finally, the brightness of the image is normalized.

F. Dynamic Histogram Equalization (DHE)

DHE [37] partitions the input histogram into number of subparts and then the dynamic grey level ranges are allocated to each part and finally HE is performed. It produces results with more detail and without loss of information.

G. Multilevel Component Based Histogram Equalization (MCBHE)

MCBHE [43] splits input image into background and foreground sub images. The sub images are then analyzed and components below and above threshold value are identified. This technique is efficiently used for enhancing the local details.

H. Weighted Mean Square Sub Histogram Equalization (WMSHE)

By applying this technique [44], the input histogram is split into several sub parts depending on the weighted mean function and then transformation is applied to each part. This technique is better suited for digital images to get better contrast.

I. Adaptive Contrast Enhancement Method Preserving Brightness

In this technique [45], the original histogram is divided using threshold value to effectively remove the image from the background. Mean brightness is calculated between original and equalized images. It preserves brightness of the image and also enhances it.

J. Contrast Stretching Recursively Separated Histogram Equalization (CSRSHE)

In CSRSHE [41], a new grey level is assigned to both local and global pixels of that image. The histogram recursively separated based on mean and each part will be equalized independently. It enhances the contrast and also preserves brightness.

K. BiHistogram Equalization with Neighborhood Metric (BHENM)

In BHENM [42], we divide the histogram into sub bins using mean and then each part is enhanced. This enhances image contrast, thus preserving brightness.

L. Recursively Separated and Weighted Histogram Equalization (RSWHE)

RSHWE [38] consists of splitting the image based on the mean and median value and the sub histogram is changed based on normalized power law function through weighting process. Finally, equalize the weighted sub histograms independently.

M. Global Transformation Histogram Equalization (GHE)

In GHE [26], the input histogram is divided based on the mean recursively r times. The resulting 2r histograms are equalized independently. The global transformation function enhances contrast by stretching the dynamic range of the image histogram. Based on user preference, the recursion level adjust the brightness level, providing scalability.

N. Local Transformation Histogram Equalization (LHE)

LHE [19] performs block overlapped HE. A sub block is defined, and HE is applied on the sub block. We move the sub block by one pixel and HE is performed until the end of input is reached. The optimal block size selection is a difficult task.

O. Local and Global Contrast stretching

LCS [2] is performed on an image by adjusting each pixel value so that the visualization of structures is improved in both the light and dark regions of image simultaneously. It is performed by moving windows and then adjusting the center element.

GCS [2] takes into consideration all color palette range and determine the minimum and minimum values which will be used for contrast stretching.

V. Analysis and applications

BBHE can enhance images without producing unnecessary artifacts. BBHE can be used for consumer electronic while preserving brightness.

DSIHE preserves the originality and also enhances the image. The aim of the division of the image is for maximizing the entropy. If in the image large area has same grey levels, then DSIHE doesn’t preserve the brightness.

MMBEBHE achieves minimum brightness. It is used for real time applications.

RMSHE technique effectively enhances the image and also preserves the brightness. RMSHE allows scalable brightness preservation, and hence it is used in consumer electronics.

In MBPHE, the hardware implementation is complicated and much computational time is required for consumer electronics.

BPDHE successfully enhance the image and also maintain the mean input brightness.

DHE produces results with more detail and without loss of information. This prevents washout effect of the input image.

RSWHE more accurately preserves the image brightness and also the resultant images have with better contrast.

MCBHE is effectively utilized for enhancing local details of the image.

WMSHE is better suited for digital images to get better contrast.

Adaptive Contrast Enhancement methods preserve brightness by dividing the histogram using values of threshold.

CSRSHE improves the contrast better and also accurately preserves the image brightness.

BHENM enhances the local contrast and also presserves the brightness of the original image.

RSWHE preserves the image brightness more accurately and produce images with better contrast enhancement.

Global histogram equalization is fast and simple, but resulting image has poor contrast.

Local histogram equalization effectively enhances overall contrast, but computational complexity is very high because the sub blocks are fully overlapped.

Local contrast stretching (LCS) improves the visualization in both lighter and darker regions of the image.

VI. Metrics to access image quality

For comparing the performance of different image enhancement algorithms, Quantitative performance measures are used.

A. Peak Signal To Noise Ratio (PSNR)

The PSNR ratio measures the image quality between the enhanced and original image. The higher the value of PSNR, the reconstructed image quality will be better.

$$PSNR = 10 \log_{10} (Max_i^2 / MSE)$$

B. Absolute Mean Brightness Error (AMBE)

AMBE measures the level of disagreement between given and enhanced images.

$$E(y) – AMBE = E(x)$$

Where E(y) is average intensity of enhanced image and E(x) is average intensity of input image.

C. Entropy

Image entropy is a quantity that describes the amount of information that is to be coded.

$$Entropy = - \sum P_i \log_2 P_i$$

D. Mean Square Error (MSE)

MSE gives the mean of the squares of the errors i.e., the difference between the original and the enhanced images.

$$MSE = 1/n \sum (y_i - y_i)^2 \bar{}$$

E. Signal-To-Noise Ratio (SNR)

SNR is stated as the ratio of the average signal value to the standard deviation of the background.

$$SNR = P_{signal} / P_{noise}$$

VII. Conclusion

A detailed review of HE techniques reveal that BBHE and DSIHE both partition input histogram into two parts based on the median and mean respectively. RMSHE divides the histogram into multiple sections based on the mean values. BPDHE partitions the histogram into several sub partitions which are equalized based on local maxima. RSWHE splits the histogram into two or more subsections and normalized power law function is used for modifying them. DHE retains image details. WMSHE achieves good image visual quality. Adaptive contrast enhancement methods split the histogram using threshold thus preserving brightness. BHENM can efficiently enhance the image and also preserve brightness. Global and local transformation techniques produce better contrast enhancement.

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