A Review of Image Contrast Enhancement Techniques

Seema Rani
Research Scholar Computer Science Department
Yadavindra College of Engineering Talwandi Sabo,
Bhatinda, India.

Manoj Kumar
Assistant Professor Computer Science
Yadavindra College of Engineering Talwandi Sabo,
Bhatinda, India.

Abstract— Images are an important part of today's life. Images are captured through many devices such as cameras, mobile phones, scanners etc. The quality of images is degraded due to many reasons. The reasons may include adverse weather conditions, motion of objects or less power of capturing device. To improve these images for human viewing or to make it suitable for further analysis, it is necessary to enhance the quality of images. Image contrast enhancement is one of the methods to improve image quality. There exist a number of contrast enhancement techniques. This paper provides overview of basic concepts and various techniques of contrast enhancement. This paper mainly focuses on histogram modification based contrast enhancement techniques.

Keywords*:* Image enhancement, contrast enhancement, histogram equalization.

I. INTRODUCTION

The image enhancement is one of the significant techniques in digital image processing. It has an important role in various fields where images are to be understood and analyzed. Image enhancement is done on an image to improve its visual effects and quality or to make it more appropriate for further processing by another application. An image can have low contrast or bad quality due to a number of reasons like poor quality of imaging device, adverse external conditions at the time of image acquisition and many more. The contrast enhancement is one of the commonly used image enhancement method [1].

The contrast is the difference in visual properties that distinguish an object from other object and from the background. In other words it is the difference between the darker and the lighter pixels of image. If the difference is large the image will have high contrast otherwise the image will have low contrast. The contrast enhancement increases the total contrast of an image by making light colors lighter and dark colors darker at the same time. This is done by setting all color components below a particular lower bound to zero and all color components above a particular upper bound to the maximum intensity value 255. Color components between the upper and the lower bounds are set to a linear ramp of values between 0 and 255. As the upper value must be greater than the lower bound so the lower bound must range from 0 to 254 and upper bound must range from 1 to 255 [2]. Enhanced image can also be described as if a curtain of fog has been removed from the image. An example of contrast enhancement is shown in figure 1.

Original Image Enhanced Image

Figure 1: Image Enhancement [3]

The enhancement methods can be divided in two categories:

1. Spatial domain methods
2. Frequency domain methods

In spatial domain technique we directly deal with the image pixels. The pixel values are modified to achieve desired enhancement. Point processing methods and histogram equalization techniques are spatial domain methods [2]. The paper focuses on histogram equalization based techniques.

II. LITERATURE REVIEW

Traditional Histogram Equalization method may change the original brightness and can deteriorate visual quality of image. To solve these problems Y.T. Kim proposed Brightness preserving Bi-Histogram Equalization method (BBHE) that equalizes two sub histograms produced by histogram separation techniques and calculates mean intensity as threshold [4]. Another technique Dualistic Sub Image Histogram Equalization (DSIHE) uses median as threshold to separate histograms instead of mean [5]. The Minimum Mean Brightness Error Bi-Histogram Equalization (MMBEBHE) has the feature of minimizing the difference between input and output image's mean. MMBEBHE can preserve brightness better than BBHE and DSIHE. MMBEBHE, but it has limitation of high computational complexity. Thus a generalization of BBHE referred to as Recursive Mean-Separate Histogram Equalization (RMSHE) was introduced. RMSHE was featured with scalable brightness preservation [6]. The Brightness Preserving Histogram Equalization with Maximum Entropy (BPHEME) method maximizes the entropy by the variational approach under the constraints that the mean brightness remains fixed [7]. The Recursive Sub Image Histogram Equalization (RSIHE) technique extends DSIHE by recursively separating histogram and multi-equalizations to solve above problems [8]. But the problems were not effectively solved in spite of its recursive nature and scalable brightness preservation techniques. Another histogram separation technique Recursively Separated and Weighted Histogram Equalization (RSWHE) uses a weighting function to smooth each sub histogram and to effectively solve the mean-shift problem [9]. Renjie He, Sheng Luo, Zhanrong Jing and Yangyu Fan developed a method in which the weighted average of histogram equalization and exponential transformation are combined and the level of the contrast improvement is adjustable by changing the weighting coefficients. The algorithm achieved adjustable contrast enhancement for color images and also decreased the effect of rising intensity on colors of image [1].

Shih-Chia Huang, Fan-Chieh Cheng and Yi-Sheng Chiu proposed a hybrid HM (histogram modification) method Adaptive Gamma Correction with Weighting Distribution (AGCWD) by combining TGC (Transform based gamma correction) and THE (Traditional histogram equalization) methods. This paper presented an automatic transformation technique that improved the brightness of dimmed images via the gamma correction and probability distribution of grey levels. For enhancement of videos, the technique used temporal information regarding the differences between each frame to reduce computational complexity [3].

III. HISTOGRAM ENHANCEMENT

Histogram is a statistical expression of an image which reflects the statistical situation of different gray levels. Gray histogram of an image is a one dimensional discrete function, which is as:

$$h(k) = n_k \quad (1)$$

in which n_k is the number of pixels with the gray level value of k in image X (i, j). Let X= {X (i, j)} denote a given image composed of L discrete levels denoted as $\{X_0, X_1 \ldots X_{L-1}\}$, where X (i, j) represents an intensity of the image at the spatial location (i, j) and $X(i, j) \in \{X_0, X_1 \ldots\ldots X_{L-1}\}$. For a given image X, the probability density function (PDF) can be obtained according to equation (1) as:

$$p(X_k) = n^k / n \quad (2)$$

Where X_k denotes the kth gray level of X (i, j) and n is the total number of pixels in the image. Therefore, the cumulative distribution function (CDF) can be obtained on the basis of PDF as:

$$c(X_k) = \sum_{j=0}^{k} p(X_j) \quad (3)$$

Histogram equalization is a scheme that maps the input image into the entire dynamic range, (X_0, X_{L-1}), by using CDF as a transform function. The transform function f(x) based on CDF is as:

$$f(x) = X_0 + (X_{L-1} - X_0)c(x), \quad (4)$$

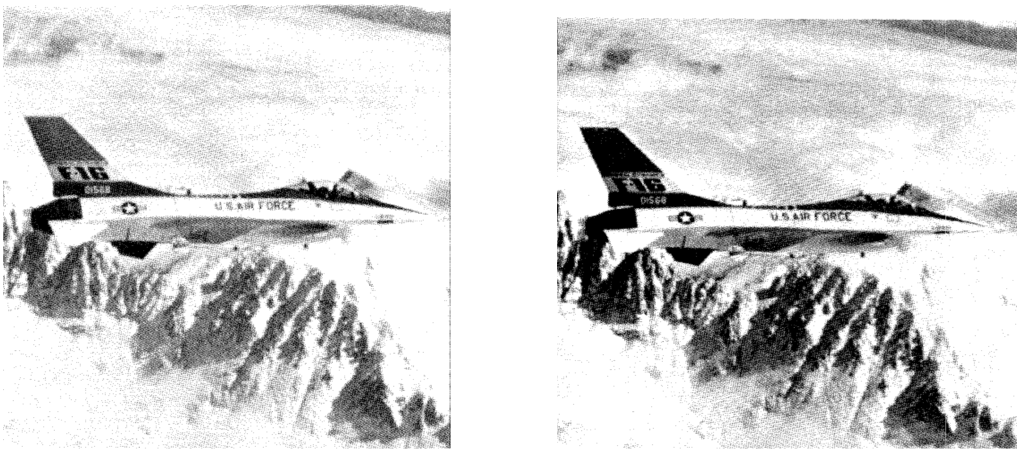
Theoretically the gray-scale or the probability density function of an image will produce a perfectly equalized histogram through such a mapping mechanism. However the gray-scale and the probability density function may not be exactly uniform in practical applications because of the discrete nature of the pixel intensities. As a result, pixels with a high probability of gray level may be over enhanced and pixels with a lower probability of gray level may be lack of enhancement or even be removed. Therefore, HE always enhances the background of an image excessively and decreases the saturation of the small area with most interesting features [1].

IV. CONTRAST ENHANCEMENT TECHNIQUES

A. BRIGHTNESS PRESERVING BI- HISTOGRAM EQUALIZATION (BBHE)

In the Brightness preserving Bi-Histogram Equalization (BBHE), two separate histograms from the same image are formed and then equalized independently, where the first one is the histogram of intensities that are less than the mean intensity and the second one is the histogram of intensities that are greater than the mean intensity [4].

BBHE reduces the mean brightness variation but it cannot solve enhancement problem effectively as it can result in unnatural enhancement in some cases and suffers from over enhancement and under enhancement effects. Effect of BBHE is shown in fig 2.



Original Image Result of BBHE

Figure 2: Effect of BBHE [4]

B. DUALISTIC SUB IMAGE HISTOGRAM EQUALIZATION (DSIHE)

In Dualistic Sub image Histogram Equalization (DSIHE), two separate histograms are created according to the median gray intensity instead of the mean intensity [5]. Although DSIHE can maintain the brightness and entropy better, but both DSIHE and BBHE cannot adjust the level of enhancement and are not robust to noise. Consequently, several problems will emerge like spikes in the histogram. Effect of DSIHE is shown in fig 3.

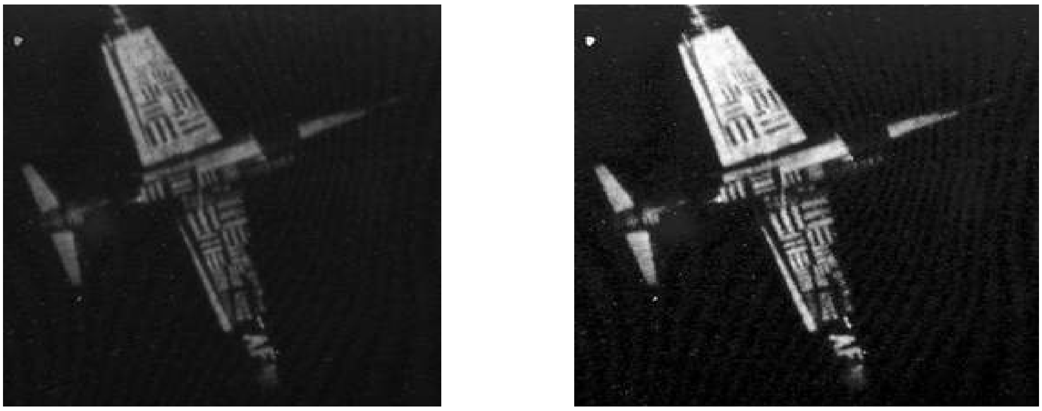
C. MINIMUM MEAN BRIGHTNESS ERROR BI-HISTOGRAM EQUALIZATION (MMBEBHE)

Minimum mean brightness error bi-histogram equalization (MMBEBHE) had the feature of minimizing the difference between input and output image’s mean. In this method histogram is separated into two based upon threshold level which would result in minimum AMBE (Absolute Mean Brightness Error). Some integer based computation is performed to calculate AMBE [6].

MMBEBHE is better than BBHE and DSIHE in terms of preserving brightness but MMBEBHE has limitation of high computational complexity. Effect of MMBEBHE is shown in fig 4.

Original Image Result of DSIHE

Figure 3: Effect of DSIHE [5]



Original Image Result of MMBEBHE

Figure 4: Effect of MMBEBHE [6]

D. RECURSIVE MEAN-SEPARATE HISTOGRAM EQUALIZATION (RMSHE)

The Recursive Mean Separation Histogram Equalization (RMSHE) method recursively separates input histogram based on mean brightness level. Then histogram equalization is performed separately on each sub histogram. Result of RMSHE is shown in fig 5.

Then enhanced image is obtained by combining all sub histograms and mapping that into output image. The mean intensity of the output image will converge to the average brightness of the original image when the iteration increases [6].

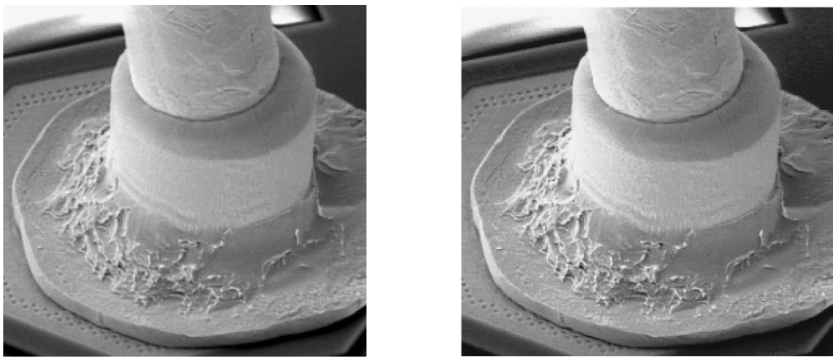
Thus significant enhancement is performed when recursion level is high.

E. RECURSIVE SUB IMAGE HISTOGRAM EQUALIZATION (RSIHE)

Recursive sub image histogram equalization (RSIHE) that yielded better enhancement results for grayscale images as compared to some of conventional HE methods such as bi-histogram equalization and recursive mean separate histogram equalization. RSIHE recursively separates a histogram based on its median instead of mean as in RMSHE [8]. Result of RSHE is shown in fig 6.

Original Image Result of RMSHE

Figure 5: Effect of RMSHE [6]

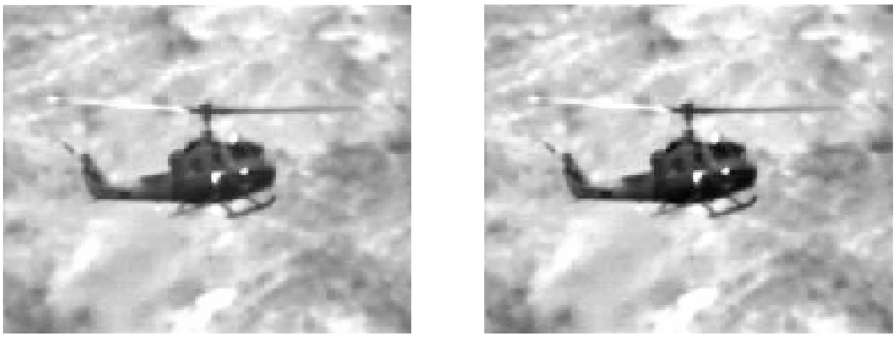


Original Image Result of RSIHE

Figure 6: Effect of RSIHE [8]

F. RECURSIVELY SEPARATED AND WEIGHTED HISTOGRAM EQUALIZATION (RSWHE)

The recursively separated and weighted histogram equalization (RSWHE) preserves the image brightness and enhance the image contrast by first splitting an input histogram into two or more sub histograms recursively based on the mean or median of the image. Then the sub histograms are modified through a weighting process based on a normalized power law function. Lastly, sub weighted histograms are equalized independently [9]. Effect of RSWHE on a image is shown in fig 7.

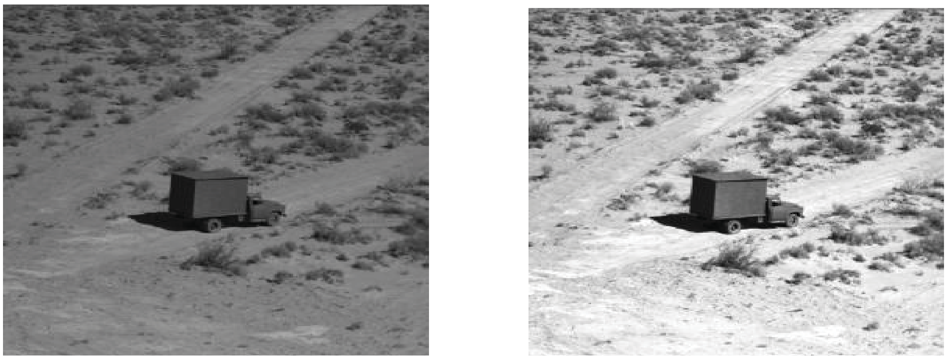


Original Image Result of RSWHE

Figure 7: Effect of RSWHE [9]

G. ADAPTIVE GAMMA CORRECTION WITH WEIGHTING DISTRIBUTION (AGCWD)

The technique Adaptive gamma correction using weighting distribution (AGCWD) modifies histograms and enhances contrast in digital images. This is a hybrid HM (histogram modification) which combines TGC (Transform based gamma correction) and THE (Traditional histogram equalization) methods. In this method cumulative distribution function (CDF) is utilized directly and normalized gamma function is applied to modify the transformation curve [3]. Effect of AGCWD is shown in fig 8.



Original Image Result of AGCWD

Figure 8: Effect of AGCWD [3]

V. COMPARISON ANALYSIS

The comparison of various techniques of contrast enhancement is shown in Table I.

TABLE I: Comparison of Contrast Enhancement Techniques

Enhancement Technique	Advantage	Disadvantage
BBHE	Solves mean shift problem of traditional histogram equalization technique to some extent	Contrast enhancement done is not much effective. Unnatural enhancement can occur.
DSIHE	Preserves mean better than BBHE in some cases.	Enhancement achieved is not satisfactory.
MMBEBHE	Maximum brightness preservation.	Computational complexity is high.
RMSHE	Better enhancement as number of recursion level increases.	Enhancement is not satisfactory at low recursion levels.
RSIHE	Good contrast enhancement effect.	Time consumption is high because of multi equalizations.
RSWHE	Weighting function used smoothes each sub histogram.	Time consumption is high due to recursion.
AGCWD	Enhancement is better because of combination of gamma correction and weighting distribution.	Mean brightness is not preserved.

VI. CONCLUSION

Histogram based contrast enhancement techniques are most popular because of easy and fast implementation. In this paper various techniques BBHE, DSIHE, MMBEBHE, RMSHE, RSIHE, RSWHE and AGCWD are discussed. The selection of technique highly depends on application, but a comparison is shown according to which if computational complexity does not matter then MMBEBHE is best to use. Recursion based techniques can be used in case enhancement is more significant than time complexity. AGCWD is most recent and effective technique and has less computational and time complexity. It is a combination of gamma correction and histogram equalization, which are modified to effectively use in this technique.

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