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Review of Different Contrast Enhancement Techniques for a Digital Image

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Abstract*— *Image enhancement process improves the visual quality of the image to make the image better in visual perception. Image enhancement is one of the most common problems in low level image processing. Contrast enhancement is an important factor for image enhancement. Histogram based techniques are most commonly used image processing techniques that are used for enhancement tasks. Histogram equalization is a very effective approach to contrast enhancement. However, histogram equalization tends to change the brightness of the image. Some other brightness preserving techniques like BBHE, DSIHE, RMSHE, MMBEBHE, RSWHE etc. are used. The present paper describes a review of different contrast enhancement techniques for a digital image.

Keywords*— *Image Processing, Contrast Enhancement, Histogram Equalization, BBHE, Histogram.

I. INTRODUCTION

Digital image processing may be defined as the study of any algorithm that takes an image as input and returns an image as output. This may include image display and printing, image editing and manipulation, image enhancement, feature detection, image compression etc. Most of the techniques in image processing developed during the last four to five decades are used for enhancing images obtained from cameras or image sensors that are placed on satellites or pictures taken in day-to-day life for various applications. Image Processing systems are becoming popular day-by-day because many graphics softwares, personnel computers, large size memory devices etc. are easy available [28]. Image processing has contributed to research advancement in a variety of fields like medical image analysis, high definition television (HDTV), industrial X-ray image processing, microscopic imaging, remote sensing, military, printing industry, textiles, forensic studies, graphic arts etc. The most common steps used for image processing include image scanning, image storing, image enhancement and interpretation. Figure 1 shows schematic diagram of basic image enhancement process.

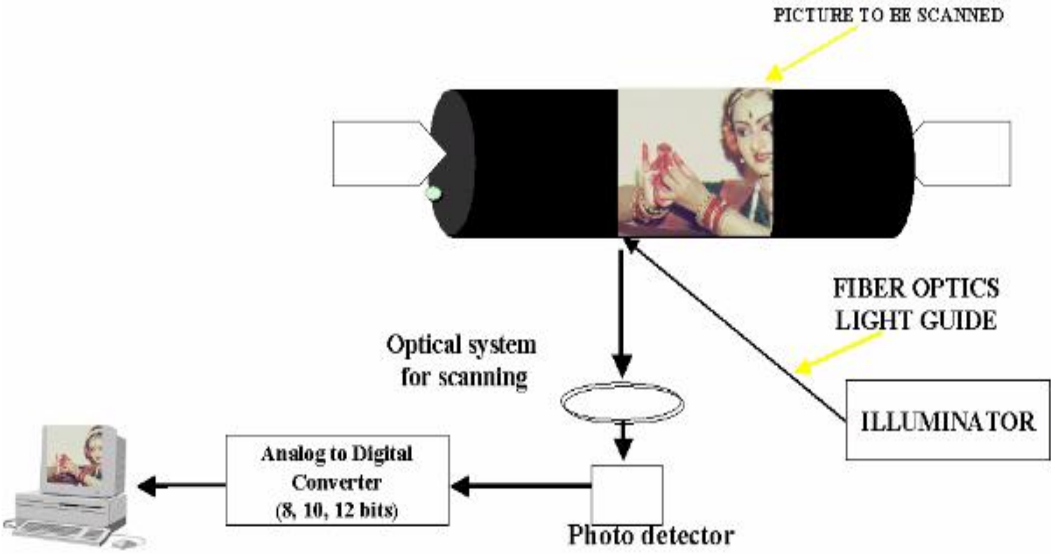

Fig. 1: Basic Image Processing Technique

Image processing can be performed on images via two main methods. These are: Analog Image Processing and Digital Image Processing [28]. In analog image processing, the alteration of image takes place through electrical means. The most common example is the television image. In digital image processing, digital computers are used to process the image. The image will be converted to digital form using a scanner–digitizer [29] (as shown in Fig. 1) and then it is processed. The principle advantage of Digital Image Processing methods is that the original data precision in the image is preserved. Different Image Processing techniques include Image representation, Image preprocessing, Image enhancement, Image restoration, Image analysis, Image reconstruction, Image data compression etc [2] [28].

Image enhancement is one of the challenging issues in low level image processing. It is often observed that the images obtained from satellites and other conventional and digital cameras sometimes lack in contrast and brightness value because of the limitations of imaging sub systems and illumination conditions while capturing the image. Images may have different types of noise. For such reasons, the image undergoes enhancement processes.
In image enhancement process, the input image is manipulated so that resulting image is more suitable than the original one. The goal is to achieve a better quality image. Examples of image enhancement include edge enhancement, contrast enhancement, pseudo-coloring, noise filtering and sharpening etc [23]. Image enhancement processes are useful in feature extraction, image analysis and display, image restoration etc. The enhancement processes does not at all increase the information content in the image, but they highlight certain features of interest in the image and emphasizes certain specified image characteristics.
In the image enhancement process, an image is taken as input and enhancement algorithm is applied on it. After that enhanced image is taken as output as shown in figure 2.

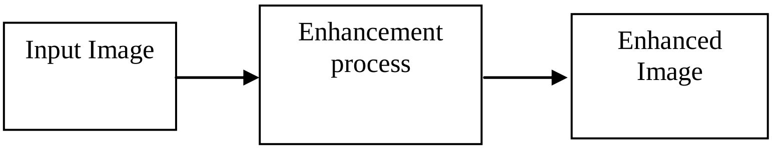

Fig. 2: Basic enhancement process

Image enhancement has contributed to research advancement in a variety of fields like medical image analysis, high definition television (HDTV), industrial X-ray image processing, microscopic imaging, remote sensing etc.

II. CONTRAST ENHANCEMENT TECHNIQUES

The commonly used techniques for image enhancement are removal of noise, edge enhancement and contrast enhancement. Out of these contrast enhancement is a popular one. Contrast enhancement is one of the most important techniques for image enhancement [1]. In this technique, contrast of an image is improved to make the image better for human vision. In Contrast enhancement process, the relative brightness and darkness of objects in the scene is adjusted to improve the visibility. The present paper describes a review of different techniques that are used for contrast enhancement process. These techniques are categorized as: Global Contrast Enhancement Techniques and Local Contrast Enhancement Techniques. Global enhancement techniques are fast, simple and easy to use, and are suitable for overall enhancement of the image. However, these techniques do not enhance the local brightness features of the input image because only global histogram information over the whole image is used [25]. Different techniques for contrast enhancement are discussed below.

Histogram Equalization (HE):

One of the most common contrast enhancement methods is the histogram equalization (HE) [10]. Histogram equalization (HE) is a widely used technique for contrast enhancement because it is simple to use and has good performance on all types of images. It is most commonly used in the areas like medical image processing, radar signal processing etc. HE works by flattening the histogram of input image and stretches dynamic range of gray levels by using cumulative density function (CDF) of the image. An image's histogram represents the relative frequency of occurrence of gray levels to preserve mean brightness of the input image [3]. The HE method re-maps the gray levels of input image by re-assigning intensity values of pixels to make a uniform intensity distribution. For a given image $X = \{X(i,j)\}$, composed of L discrete gray levels denoted as $\{X_0, X_1, ...X_{L-1}\}$, where $X(i,j)$ represents an intensity of image at the spatial location (i,j) and $X(i,j) \in \{X_0, X_1, ...X_{L-1}\}$. For image X, probability density function $p(X_K)$ is defined as:

$$p(X_K) = \frac{n^k}{n} \qquad (1)$$

for $k = 0,1,...,L-1$, where n^k represents number of times X_k appears in input image X and n is total number of samples in input image.
Here $p(X_K)$ is associated with histogram of input image which represents number of pixels having specific intensity X_k. A plot of n^k vs. X_k is known as histogram of X. The cumulative density function (CDF) $c(x)$ is defined on the bases of PDF,

$$c(x) = \sum_{j=0}^{k} p(X_j) \qquad (2)$$

where $X_k = x$, for $k = 0,1,...,L-1$. Here $c(X_{L-1}) = 1$ by definition. HE is a scheme which maps input image into the entire dynamic range, (X_0, X_{L-1}) by using CDF as a transform function [3].

However, histogram equalization possesses some drawbacks. First, histogram equalization transforms histogram of original input image into a flat histogram where mean value lies somewhere in middle of gray level range, i.e. mean brightness of output image almost lies at the middle. Hence it does not take into account mean brightness of input image. Second, the HE method performs enhancement based on global content, i.e. it enhances borders and edges among objects in the image but local enhancement is negligible. Third, HE may result in over enhancement due to stretching of the gray levels of input image over the full gray level range [10].
Some other disadvantage includes change in the brightness of image after HE is applied. Moreover, this technique is not commonly used in consumer electronics as it significantly changes brightness of input image and unnecessary visual deterioration is introduced [9] [13].

Brightness Bi-Histogram Equalization (BBHE):
In this technique, the input image is decomposed and two sub images are formed on the bases of mean value. One subimage contains the set of samples that are less than or equal to mean whereas the other subimage is the set of samples greater than mean. Then the method equalizes both sub images independently according to their respective histograms with a constraint that samples in the first subimage are mapped in the range from minimum gray level to input mean and samples in second subimage are mapped in the range from mean to maximum gray level [10]. That means one subimage is equalized over the range up to mean and other subimage is equalized over the range from mean based on the respective histograms. The resultant equalized sub images are bounded by each other around input mean, which has an effect of preserving the mean brightness [1] [3].

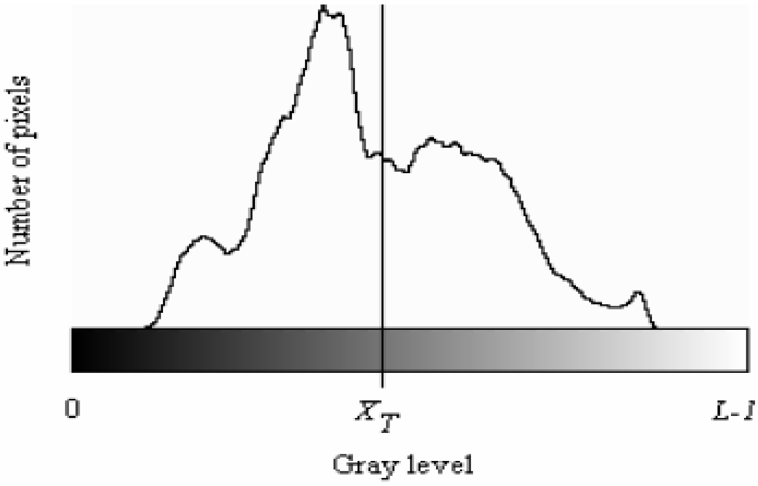

Fig. 3: Bi-Histogram Equalization

BBHE has an advantage that it preserves mean brightness of the image while enhancing the contrast and, thus, provides natural enhancement. Due to this, it can be utilized in the consumer electronic products [3].

Dualistic Subimage Histogram Equalization (DSIHE):
Some enhancement techniques change the luminance of image significantly with equalization. Such techniques can never be utilized in video systems directly. 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) [10] [14]. This decomposition is done on the bases of its 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 [11]. There is no doubt that these two sub images represent the dark and bright area of original image respectively. So, the gray level can be remained in its original scale respectively after subimage 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 [1] [6].

Recursive Mean-Separate Histogram Equalization (RMSHE):
Mean-separation means to separate an image based on the mean of input image [7]. 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, and hence 2r sub images are generated. Each subimage is then equalized independently with histogram equalization method. If r=0, that means no subimage decomposition is done, i.e. it is equivalent to HE method only [1] [10]. When one mean separation is done before equalization, i.e. r=1, this is equivalent to BBHE [14]. 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 [7]. 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.

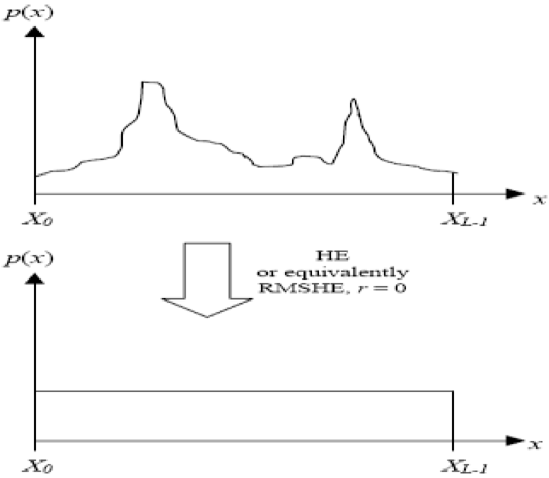

Fig. 4 (a): Histogram before and after HE or equivalently RMSHE, r = 0

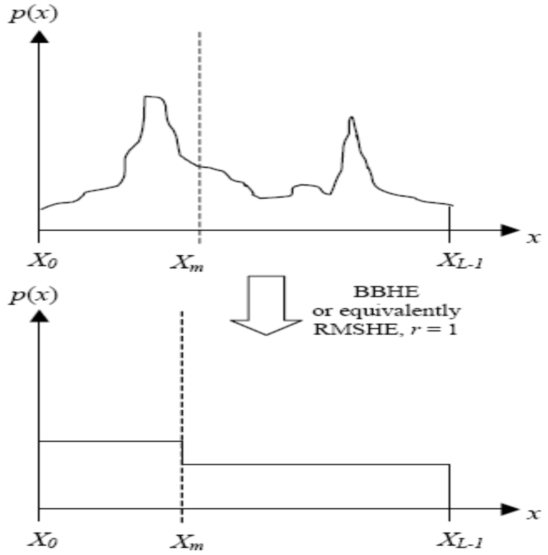

Fig. 4 (b): Histogram before and after HE or equivalently RMSHE, r = 1

Minimum Mean Brightness Error Bi-HE (MMBEBHE):

This is based on the principle of BBHE and DSIHE, i.e. decomposition of image into two sub images and applying equalization process independently to the resulting sub images [1][10]. But MMBEBHE is slightly different. This technique searches for a threshold level l_t, which decomposes input image into two sub-images in such a way that the brightness difference between the input image and the obtained output image is minimum. This is called absolute mean brightness error (AMBE) [15]. After decomposing input image by the threshold level, each of the two sub-images undergo histogram equalization process to generate the output image. The technique is summarized as follows:

a. Calculate the absolute mean brightness error (AMBE) for each possible threshold level.
b. Find a threshold level XT that yield minimum absolute mean brightness error (AMBE).
c. Separate the input histogram into two histograms based on X_T found in Step 2 and equalize both the histograms independently [14].

This technique aims to produce a method that is suitable for real-time applications.

Recursive Separated and Weighted Histogram Equalization (RSWHE):

The RSWHE technique is slightly different from the techniques discussed so far in this section. The main difference between RSWHE and other histogram equalization techniques is that RSWHE first modifies the input histogram and then runs the equalization procedure. This technique works in three modules. These are: histogram segmentation, histogram weighting and histogram equalization [1] [17].
The idea behind each module in RSWHE technique is explained as follows:

i) Histogram segmentation module It takes the input image, computes the input histogram. The input histogram is decomposed recursively into two or more sub-histograms based on the mean and median value [16].
ii) Histogram weighting module In this module, sub-histograms computed in step 1 are modified through histogram weighting process using a normalized power law function.

iii) Histogram equalization module In this, histogram equalization process is individually applied over each of the weighted sub-histograms that were modified in step 2. A better contrast enhancement is achieved by equalizing each sub-histogram independently and annoying side effects are also reduced through RSWHE [1].

Recursive sub-image histogram equalization (RSIHE) and recursive mean separate histogram equalization (RMSHE) are some methods that are similar to RSWHE, but weighting process is not carried out in RSIHE and RMSHE.

III. CONCLUSION

In this paper, a general review of different contrast enhancement techniques is presented. Histogram equalization is a simple and effective technique that can be used for image contrast enhancement. However, histogram equalization is not suitable for consumer electronic products because it changes brightness of the image and introduces unwanted visual deterioration. Due to the disadvantages observed in histogram equalization, various other brightness preserving contrast enhancement techniques are used. BBHE and DSIHE separate the input image into two sub-images based on mean value and median value respectively. The RMSHE technique can handle higher brightness preservation than HE, BBHE and DSIHE. The RSWHE technique divides the input histogram into two or more subsections recursively, to modify sub histogram by means of weighting process based on normalized power law function. MMBEBHE is an extended version of BBHE technique and provides maximal brightness preservation comparatively. All these techniques are used globally, i.e. the global histogram information over the whole image is used. The major goal of image contrast enhancement methods is to produce such images in which input mean brightness is preserved.

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