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A Review of Contrast Enhancement Techniques

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***Abstract*: Most of the time, the digital images while capturing are affected by weather, acquiring the device itself and by poor lighting, they suffer from poor contrast. Sufficient Contrast in an image makes an object distinguishable from the other objects and the background. Contrast enhancement basically improves the quality of images for human observer by expanding the dynamic range of input gray level. In such a scenario, it plays important role to provide a comprehensive survey of these contrast enhancement techniques used in digital image processing.**

***Keywords*: histogram equalization, frequency domain and spatial domain methods, histogram equalization, adaptive histogram equalization, contrast limited adaptive histogram equalization.**

1. Introduction

Digital images are very important and have become very important part of everyday life. It finds numerous applications where digital images are pre-processed and used in like: surveillance, general identity verification, criminal justice systems, civilian or military video processing etc. Such applications require sufficient contrast that makes an object distinguishable from other objects and the background. In human visual perception, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. It is also the difference between the darker and the lighter pixel of the image. Due to the poor quality of the imaging device, lack of expertise operator and the external adverse conditions, quality of the image or video will be in inadequate contrast.

The type of image enhancement approach through which it is easy to adjust the range of pixel intensity distribution is known as Contrast enhancement. In order to enhance the visual quality, recognize the patterns and perform digital image processing, CE plays a plays a very important role. There are various factors due to which the quality of the digital images is affected due to very poor contrast or presence of abnormal brightness in the real applications. These factors occur when images are taken from un-experienced sources and the imaging devices include several inherent deficiencies in them. There is reduction in the contrast quality after capturing the regions in which the luminance intensity is either less or high.

The applications of digital image hampered due to low contrast regardless of visual quality degradation, also affect the image analysis and understanding, object recognition and digital printing and many more. Therefore, before implementing the images within other applications, the contrast of these distorted images needs to be improved at first. Digital images are very important and have become essential part of everyday life. Now days, everything is depending upon on pictures like the view of lakes, images of cars to sell, face detection, satellite images, images in medical fields and many more. If the image will not be clear means if it will be blur, then we do not get proper information or can get wrong information. So, digital images play very important role in everyday life. There are many applications where digital images are pre-processed and used in such as surveillance, general identity verification, criminal justice systems, civilian or military video processing etc. Such applications require sufficient contrast that makes an object perceptible from other objects. In human visual perception, contrast is determined by the difference in the color and brightness of the object and other objects within the same field of view. It is also defined as the difference between the darker and the lighter pixel of an image. Image Contrast enhancement techniques can be broadly categorized into spatial domain methods and frequency domain methods or transform based methods. In Spatial domain methods, the direct manipulation of pixels is done. whereas in transform based methods, they are first transformed into frequency domain by transforms like Fourier Transform (FT), Discrete Cosine Transform (DCT), Wavelet Transform (WT), Curvelet Transform (CT) for the enhancement of images. In past decades, some contrast enhancement techniques based on gray level transformation techniques, like: sigmoidal (Naglaa and Norio, 2004), logarithmic and power law transformations (Snehal and Shandilya, 2012) have been suggested for improving the contrast of the image. Contrast enhancement using Retinex theory was first introduced by Land (2007). Jobson et al. (1997a) has explored contrast enhancement method for color images using single-scale retinex theory. In recent years, many algorithms based on Retinex theory such as Multi Scale Retinex (MSR) (Rahman et al., 1996), Multi Scale Retinex with modified Color Restoration (MSRCR) (Jobson et al., 1997b). The limitation of these approaches is that it requires more computation complexity. There have been uncountable approaches proposed so far for improving the image contrast. The broader classification of all such methods is done into direct and indirect methods. For providing ease and explicitness, an indirect approach known as histogram modification approach is utilized commonly. Thus, histogram

equalization (HE) is one of the most commonly utilized approaches today. Generating the histogram of improved image is the fundamental principal of HE, which is approximate to a uniform distribution. This is done in order to exploit the dynamic range of the image. In order to utilize the maximum possible bins, the pixel intensity of the input image is changed by the contrast enhancement.

In image processing context, the histogram 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. In general, a histogram is the estimation of the probability distribution of a particular type of data. It is used in CT image processing. A good histogram is that which covers all the possible values in the gray scale, which is used. This type of histogram suggests that the image has good contrast and that details in the image may be observed more easily. Histogram Equalization is a computer image processing technique. Histogram equalization is used to improve the contrast of images. Histogram equalization is one of the tool, used to improve the contrast in digital photography, remote sensing, medical imaging, and scientific visualization. It accomplishes this by effectively spreading out the most frequent intensity values, i.e. stretching out the intensity range of the image. This allows for areas of lower local contrast to gain a higher contrast. Histogram equalization is the technique in which the dynamic range of the histogram of an image is increased. Histogram equalization assigns the intensity values of pixels in the input image so that the output image contains a uniform distribution of intensities. At the output, the uniform distribution of the intensity values will be there. This improves contrast of an image. The goal of histogram equalization is to obtain a uniform histogram. This technique can be used on a whole image or just on a part of an image. If the histogram of any image has many peaks and valleys, it will still have peaks and valley after equalization, but those peaks and valley will be shifted. In histogram equalization, each pixel is assigned a new intensity value based on its previous intensity level.

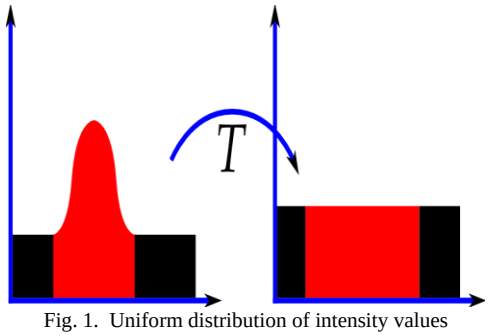

Fig. 1. Uniform distribution of intensity values

In this study we aim to provide a survey of existing enhancement techniques with their descriptions and present a detailed analysis of them. Since most of the images while capturing are affected by weather, poor lighting and the acquiring device itself, they suffer from poor contrast. Sufficient Contrast in an image makes an object distinguishable from the other objects and the background. Contrast enhancement improves the quality of images for human observer by expanding the dynamic range of input gray level. Plethora enhancement techniques have though emerged, none of them deem to be a universal one, thus becoming selective in application. In such a scenario, it has become imperative to provide a comprehensive survey of these contrast enhancement techniques used in digital image processing.

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. It is used in CT image processing.

Histogram based methods: Histogram Equalization (HE) is one of the typical enhancement techniques in spatial domain methods. This technique is commonly employed for image enhancement because of its simplicity and comparatively better performance on almost all types of images. The operation of HE is performed by remapping the gray levels of the image based on the probability distribution of the input gray levels. The probability density of each gray level in the image is given as in Eq. (2):

$$pk = \frac{Nk}{N}, \text{ k=0,1,…..m-1} \quad (2)$$

Where, m is the maximum gray level used in histogram equalization. The cumulative density function for the image is defined as:

$$C(k) = \sum_{j}^{k-1} Pj \quad (3)$$

Using this cumulative density function the transform function for the image is written as:

$$f(k) = Xo + (Xt - Xo)c(k) \quad (4)$$

The enhanced image of HE is obtained using:

$$Y = f(X(i,j), X(i,j)\ \varepsilon\ X \quad (5)$$

It flattens and stretches the dynamic range of the images histogram and resulting in overall contrast enhancement as in Eq. (5).

This example shows the use of histogram equalization to adjust the contrast of a grayscale image. The original image has low contrast, with most pixel values in the middle of the intensity range. The function “histeq” produces an output image with pixel values which are evenly distributed throughout the range. Let us take another example of histogram equalization. Figure 3 shows the histogram for the image before and after histogram equalization. The original histogram shows the low intensity values, but a sharp peak is not present

in it. The equalized histogram stretches a larger contrast range, and introduces a number of pixels of higher intensity. Because there was no sharp, narrow spikes in the histogram of the original image, histogram equalization works well in this example.

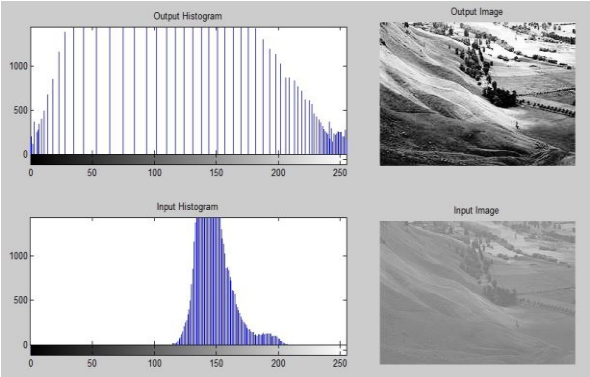

Fig. 2. Adjust the contrast of grayscale image using histogram equalization

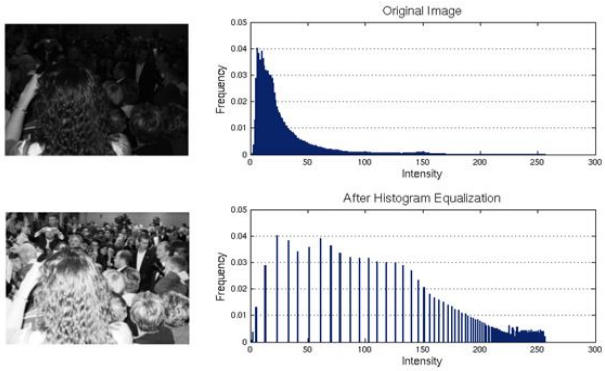

Fig. 3. Image before and after histogram equalization

A. *Adaptive histogram equalization*

The Histogram equalization (HE) suffers from the major drawbacks especially when it is implemented to process digital images and also this conventional HE fails with images having more homogeneous image regions. The background contrast has improved after the histogram equalization, but most of the information is lost due to over-brightness. To overcome the limitations of HE, many advanced histogram-based contrast enhancement techniques have been explored, but most of them are modified version of conventional HE technique. Regional histograms are used to create locally varying gray scale transformations so that in smaller regions, the contrast of an image can be improved. This procedure is known as Adaptive Histogram Equalization (AHE) (Ketcham et al., 1976). The only parameter to be determined in AHE method is the block size. It is seen that this efficient AHE worked well for many images like for chest radiographs and CT images. The problem of excessive enhancement in ordinary histogram equalization is solved by a procedure called Contrast-Limited Adaptive Histogram Equalization(CLAHE).

Adaptive histogram equalization (AHE) is a computer image processing technique used to improve contrast of images. It differs from ordinary histogram equalization in the manner that the adaptive method computes several histograms. Therefore, it is used to improve the local contrast and for enhancing the edges in each region of an image. However, AHE has a proneness to over amplify the noise in comparative to homogeneous regions of an image. A modification of adaptive histogram equalization called contrast limited adaptive histogram equalization (CLAHE). CLAHE prevents the over amplification by limiting the amplification.

B. *Contrast limited adaptive histogram equalization*

The ordinary AHE over amplify the contrast in near-constant regions of the image, since the histogram in such regions is highly concentrated.so, AHE may cause noise to be amplified in near-constant regions. Contrast Limited AHE (CLAHE) is a modification of adaptive histogram equalization in which the contrast amplification is limited, so that the problem of over amplification can be reduced [3].

In CLAHE, the contrast amplification in the vicinity of a given pixel value is given by the slope of the transformation function. This is proportional to the slope of the neighborhood cumulative distribution function (CDF). CLAHE limits the amplification by clipping the histogram at a predefined value before computing the CDF. This will limit the slope of the CDF

Table 1
Techniques and its advantages, disadvantages, applications

S. No.	Name of technique	Advantages	disadvantages	Applications
1.	Histogram Equalization	This technique is best for the visual perception, when the image have close contrast data.	In some cases, histogram equalization can create undesirable artifacts. This happens because here contrast was a desirable effect. Balancing the contrast can spoils the quality of the image.	Histograms equalization is used for brightness purpose and for contrast enhancement.
2.	Adaptive Histogram Equalization	This is the best technique when the global histogram equalization cannot produce good results.	The main disadvantage of this technique is the noise amplification when the image has major low intensity values. This technique over amplifies the images.	AHE is used in chest radiographs and CT images.
3.	Contrast Limited Adaptive Histogram Equalization	It is used to prevent over amplification of noise which occurs in adaptive histogram equalization. It increases contrast more than other techniques. It introduces the large changes in the pixel gray levels.	Noise amplification in flat region and ring artifacts at strong edges.	Contrast enhancement for mammogram images to highlight the finer hidden details in mammogram images. It is used for Face identification.

of the transformation function. The value at which the histogram is clipped, the is called clip limit. Most Common values can limit the resulting amplification between 3 and 4.

It is good not to discard the part of the histogram that exceeds the clip limit but to redistribute it equally among all histogram bins [3].

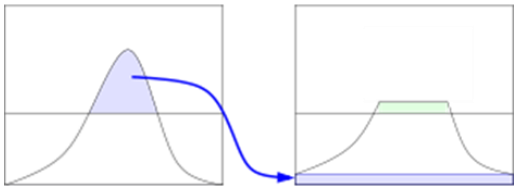

Fig. 4. Equalization

2. Conclusion

A survey on various contrast enhancement methods and techniques is presented. In this survey, the review is focused on various contrast enhancement methods such as spatial domain methods and frequency domain methods, histogram equalization, adaptive histogram equalization and contrast limited adaptive histogram equalization techniques. The advantages and disadvantages of the respective algorithms and the applicability of these techniques in various application domains are also discussed.

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