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A Review on Image Enhancement Techniques

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Abstract: - **The quality of an image is mostly affected due to weather, lighting or equipment that has been used for image capture. Image enhancement is the process of adjusting or enhancing the digital images by altering its structural features like contrast and resolution so that the results are more suitable for display or further image analysis. The enhancement process includes removal of noise, sharpen or brighten the image and making it clearer to identify the key features. In this paper, Image Enhancement techniques such as Point processing and Histogram Equalization techniques are reviewed and discussed. Point processing operations contain image negative, contrast stretching, thresholding transformation, gray level slicing, logarithmic transformation and power-law transformation. Under Histogram Equalization, Contrast Limited Adaptive Histogram Equalization (CLAHE), Equal Area Dualistic Sub-Image Histogram Equalization (DSIHE), Dynamic Histogram Equalization (DHE) Algorithms are reviewed. The concepts of all these techniques are discussed, compared and their performances are evaluated based on the parameters Absolute Mean Brightness Error (AMBE), Contrast and Peak-Signal-to-Noise-Ratio (PSNR) values.**

Keywords: **Image Enhancement, Point processing, Histogram Equalization, contrast stretching.**

I. INTRODUCTION

Image Enhancement techniques are widely used in many applications of image processing. The main objective is to process the quality of images which is important for human interpretation. Image Enhancement is the modification of an image that is to enhance the attributes of an image to make it more suitable for a given task and a specific observer. During this process, one or more attributes of the image are modified based on a given task.

Image Enhancement falls into two categories: Enhancement in spatial domain and Frequency domain. The term spatial domain refers to the Image Plane itself which is the direct manipulation of pixels ie, point processing. And Frequency domain processing techniques are based on modifying the Fourier transform of an image.

In this paper, a literature review is carried out based on Point processing operations and Histogram Equalization.

II. POINT PROCESSING OPERATIONS

Point processing operations (Intensity transformation function) are the simplest spatial domain operations performed on a single pixel only. The pixel values of the processed image depend on pixel values of the original image. Point processing operations take the form

$$S=T(r) \quad \text{-- (1)}$$

where, T: Transformation function, r, S: The intensity values of pixels before and after processing an image.

The point processing operation can be classified into Image negative, Contrast stretching, Threshold transformation, Gray level slicing, Logarithmic transformation, Power law transformation and Histogram equalization.

A. Image negative

In this technique the areas which are not required are diminished or turned to negative.

$$N(r, c) = 255 - I(r, c) \quad \text{-- (2)}$$

The equation (2) explains how negative image is obtained. Where, I: input image, N: Negative of original image, (r, c) is coordinate of the pixel. Each pixel of the original image is subtracted from 255 which will be the negative image

Figure1 (a) Original Image (b) Negative Image

B. Contrast stretching

Intensity difference between two adjacent pixels is defined as contrast. The quality of the picture can be improved by increasing its contrast in some cases. So, contrast stretching technique is used to enhance the image by increasing the dynamic range of gray level in the input image.

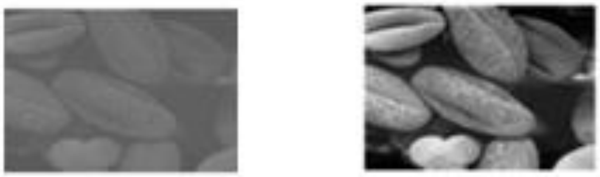

Figure2 (a) Original Image (b) Contrast Enhanced Image

C. Threshold transformation

Threshold transformation is used in the areas where image needs to be segmented. In this the desired portion of the image is separated from the background. If f(x,y) is the original image and g(x,y) is normalized or processed image then we can easily locate threshold image because it possess pixel value of '0' or '1'.

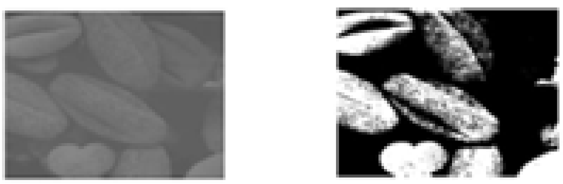

Figure3 (a) Original Image (b) Processed Image

D. Gray level slicing

Gray level slicing is used to highlight and diminish the gray levels based on the interest. The gray level at the area of interest are enhanced by using contrast level in order to brighten those areas in the image and the remaining area is left as such or diminished according to the need. Gray level slicing is used to enhance the imperfections in the X-Ray or to enhance water areas in satellite image.

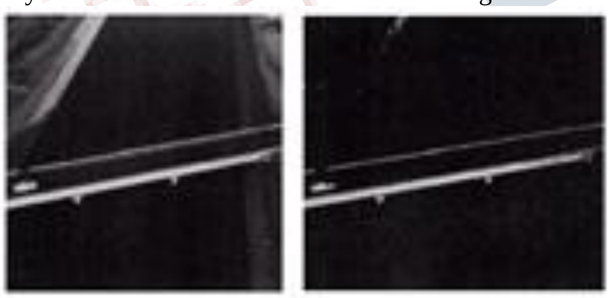

Figure4 (a) Original Image (b) Enhanced Image

E. Logarithmic Transformation

Logarithmic transformations are used in the situation where input values of gray level are very large.
General formula for this type of transformation is,

$$S = C * \log(1+r) \qquad \text{-- (3)}$$

Mostly, C is taken as '1' and gray level values must be limited between (0.0 – 1.0). This transformation converts the low range of input values into higher range of output values. We can also use the inverse of log to obtain opposite results using the representation,

$$S = \log(1+r) \qquad \text{-- (4)}$$

F. Power-Law Transformation

This transformation shows the relation between the pixels of f(x, y) and g(x, y) that is of original and enhanced image. General notation used in this transformation is,

$$s = cr^{\gamma} \qquad \text{-- (5)}$$

In Power Law Transformation each pixel value is raised to a fixed power. This transformation is used for converting small and dark range of input pixel into larger and brighter range of output pixels or vice-versa. In equation (5), c and γ, are positive constants, possible transformations can be obtained by varying the values of γ and keeping c= 1; r results in increasing the contrast of certain regions in input image with high value against low regions.

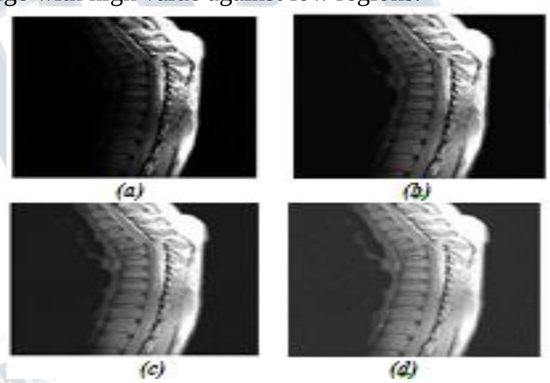

Figure5 (a) Original Image (b) When c=1, (c) When c=1, (d) When c=1,

G. Histogram Equalization

The gray levels that take on discrete values, we deal with probabilities,

$$p_r(r_k) = n_k/n, k=0,1,..., L-1 \qquad \text{-- (6)}$$

The plot of pr(rk) versus rk is called a histogram and the technique used for obtaining a uniform histogram is known as histogram equalization.

$$s_k = T(r_k) = \sum_{j=0}^{k} \frac{n_j}{n} = \sum_{j=0}^{k} p_r(r_j) \qquad \text{-- (7)}$$

Histogram Equalization (HE) results are similar to contrast stretching but offer the advantage of full automation, since HE automatically determines a transformation function to produce a new image with a uniform histogram.

1. Adaptive Histogram Equalization method

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This is an extension to traditional Histogram Equalization technique. It enhances the contrast of images by transforming the values in the intensity image. The AHE process can be understood in different ways. In one perspective the histogram of grey levels (GL's) in the output is maximally black; if it has the median value in its window the output is 50% gray's window around each pixel is generated first. The cumulative distribution of GL's, that is the cumulative sum over the histogram, is used to map the input pixel GL's to output GL's.

Figure 6 (a) Original Image (b) Enhanced Image

2. Dualistic Sub-Image Histogram Equalization method

This is a novel histogram equalization technique in which the original image is decomposed into two equal area sub-images based on its gray level probability density function. Then the two sub-images are equalized respectively. At last, we get the result after the processed sub-images are composed into one image. In fact, the algorithm can not only enhance the image visual information effectively, but also constrain the original image's average luminance from great shift. This makes it possible to be utilized in video system directly.

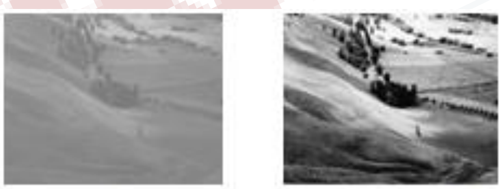

Figure7 (a) Original Image (b) Enhanced Image

3. Dynamic Histogram Equalization For Image Contrast Enhancement

It employs a partitioning operation over the input histogram to chop it into some sub histograms so that they have no dominating component in them. Then each sub histogram goes through HE and is allowed to occupy a specified gray level range in the enhanced output image. Thus, a better overall contrast enhancement is gained by DHE with controlled dynamic range of gray levels and eliminating the possibility of the low histogram components being compressed that may cause some part of the image to have washed out appearance.

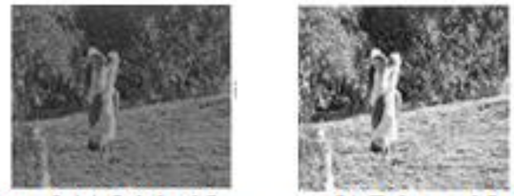

Figure 8 (a) Original Image (b) Enhanced Image

4. Contrast Limited Adaptive Histogram Equalization Method

Algorithm Steps

Obtain all the inputs: Image, Number of regions in row and column directions, Number of bins for the histograms used in building image transform function (dynamic range), Clip limit for contrast limiting (normalized from 0 to 1). Pre-process the inputs: Determine real clip limit from the normalized value if necessary, pad the image before splitting it into regions. Process each contextual region (tile) thus producing gray level mappings: Extract a single image region, make a histogram for this region using the specified number of bins, clip the histogram using clip limit, and create a mapping (transformation function) for this region. Interpolate gray level mappings in order to assemble final CLAHE image: Extract cluster of four neighbouring mapping functions, process image region partly overlapping each of the mapping tiles, extract a single pixel, apply four mappings to that pixel, and interpolate between the results to obtain the output pixel; repeat over the entire image.

Figure9 (a) Original Image (b) Enhanced Image

III. METRICS FOR GRAY SCALE IMAGES

A. Absolute Mean Brightness Error (AMBE)

AMBE is defined as

$$AMBE(x,y) = \left| Xm - Ym \right| \quad \text{-- (8)}$$

Where Xm is mean intensity of input image x={x (i, j)} and Ym is mean intensity of output image y={y (i, j)}. The value of AMBE should be least for the better brightness preservation.

B. Contrast

Contrast defines the difference between lowest and highest intensity level. Higher the value of contrast means more difference between lowest and highest intensity level.

C. Peak-signal-to-noise-ratio (PSNR)

PSNR is the evaluation standard of the reconstructed image quality, and is important measurement feature. PSNR is measured in decibels (dB) and is given by,

$$PSNR = 10\log(2552/MSE) \quad \text{-- (9)}$$

where 255 is the highest possible value can be attained by the image signal. Mean square error (MSE) is defined as Where M*N is the size of the original image. Higher the PSNR value is, better the reconstructed image.

Example of Equalized Histograms for "Rice" image

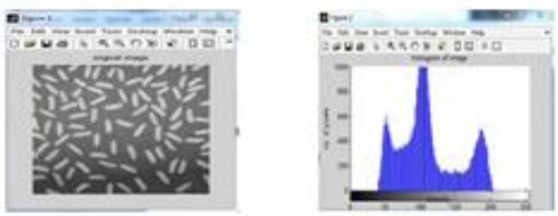

Figure10 (a) Original Image (b) Its Histogram

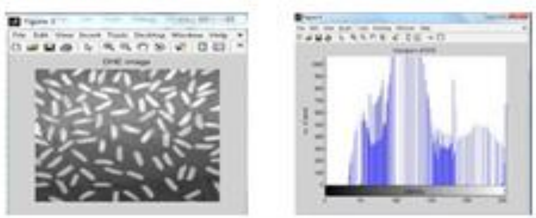

Figure11 (a) DHE Image (b) Its Histogram

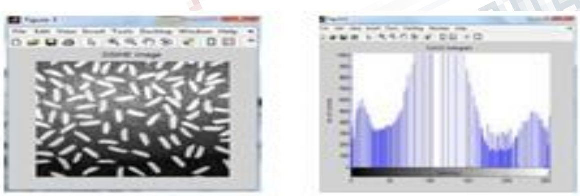

Figure12 (a) DSIHE Image (b) Its Histogram

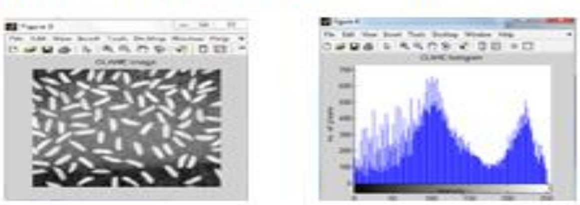

Figure13 (a) CLAHE Image (b) Its Histogram

Table 1: Comparison of Various Parameters for "Rice" Image

Parameter Technique	AMBE	Contrast	PSNR
CLAHE	10.576	21.681	0.0266
DSIHE	3.908	31.876	0.0244
DHE	10.476	9.154	0.1021

IV. CONCLUSION

In this paper, Image Enhancement techniques Point processing operation and Histogram Equalization are reviewed and discussed. In point processing operation, image negative, contrast stretching, thresholding transformation, gray level slicing, logarithmic transformation, power-law transformation are discussed. In Histogram Equalization various techniques like Image enhancement schemes like Contrast Limited Adaptive Histogram Equalization (CLAHE), Equal area Dualistic Sub-Image Histogram Equalization (DSIHE), Dynamic Histogram Equalization (DHE) Algorithms are reviewed. The concepts of all these techniques are discussed, compared and their performances are evaluated based on the parameters Absolute Mean Brightness Error (AMBE), Contrast and Peak-Signal-to-Noise-Ratio (PSNR) values. From the result we conclude that in terms of Absolute Mean Brightness Error (AMBE), DSIHE technique is best, in terms of Peak-Signal-to-Noise-Ratio (PSNR), DHE technique is best and in terms of Contrast, CLAHE technique is best.

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