ISSN: 2455-2631 © July 2017 IJSDR | Volume 2, Issue 7

Comparative Analysis of Digital Image Enhancement Techniques

[1]J.J.Lokare, [2]Y.B.Torase, [3]R.K.Vaigude, [4]P.R.Narawade, [5]B.P.Khot

[1,2,3,4]Students, [5]Assistant Professor
Electronics and Communication Engineering Department,
HIT Nidasoshi, Belgaum, India

***Abstract*— Image Enhancement is one of the most important and difficult techniques in image research. The aim of image enhancement is to improve the visual appearance of an image, or to provide a "better transform representation for future automated image processing. Many images like medical images, satellite images, aerial images and even real life photographs suffer from poor contrast and noise. It is necessary to enhance the contrast and remove the noise to increase image quality. One of the most important stages in medical images detection and analysis is Image Enhancement techniques which improves the quality (clarity) of images for human.**

***Keywords*—Image Enhancement, Preprocessing, MSE, PSNR**

I. INTRODUCTION

Digital images play a important role in daily life applications. The main objective of image enhancement is to provide details that are hidden in an image, or to increase the contrast in a low contrast image. Image enhancement produces an output image that looks better than the original image by changing the pixel's intensity of the input image. Image enhancement is the process of improving appearance or quality of a given image so that the result is more suitable than the original image for a specific application. It sharpens image features such as edges, boundaries, or contrast to make a graphic display more helpful for display and analysis.

The data value of input images will suffer from various kinds of Contaminations. These Contaminations (noise) mostly in the form of external interferences like atmospheric disturbances; imperfect instruments will cause perturbations to the system. These perturbations can produce wrong information in the system operation. The random disturbances in the images are shown as noise and are often caused by malfunctioning pixels in camera sensors, or during transmission through a noisy channel. Image enhancement can effectively reduce the noise and make the image smooth. Many techniques have been developed known as image enhancement techniques to recover the information from an image like Contrast stretching, Power Law Transformation, Log Transformation, Histogram Equalization, Two Stage adaptive Histogram Equalization, Contrast limited adaptive Histogram Equalization, Unsharp Masking.

II. ENHANCEMENT TECHNIQUES

Enhancement approaches are used to improve the quality of images for specific applications and a lot of effort is put in designing efficient rules towards the development of these approaches. Enhancement approaches are so varied that it's approaches and hence the approaches of interest are described as follows:

1. CONTRAST STRETCHING (CS)

Image may result into low contrast because of poor background lighting, lack of dynamic range in the imaging sensor, improper setting of focus etc. at the time of image acquisition. Contrast stretching is used to increase the dynamic range of gray levels in the image being processed. Contrast stretching is considered here because image generally have low contrast. It aids in identification of suspicious regions in the image.

2. POWER LAW TRANSFORMATION (PLT)

The power law transformation can also be used for improving the dynamic range. It can be expressed as a set of nth power and nth root curves. The transformation is represented mathematically by

$$s = cr^{\gamma} \quad \ldots\ldots\ldots (1)$$

Where, s is the output gray level, r is the input gray level, c is constant and γ is the correction factor. It is also called as gamma correction. Varying the values of γ will give transformations corresponding to different enhancements levels.

3. LOG TRANSFORMATION (LT)

The log transformation has the important characteristic that it compresses the dynamic range of image with large variations in intensity values. It narrows the range of low input grey level values into wider range of output values. The Log Transformation can be described by the following equation:

$$s=c*\log(1+r) \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Where c is a constant and it is assumed that $r \geq 0$.

In Thresholding one threshold level is set and pixel values below threshold level are set as 0 and pixel values above that threshold level are set as 255. Thresholding is also used to filter the output or input to other operators.

If A (i,j)<T then B (i,j)=0;
Else B (i,j)=255;

Where T is the threshold level and A, B are input and output image matrices.

4. HISTOGRAM EQUALIZATION (HE)

Histogram Equalization is a technique that generates a gray map which changes the histogram of an image and redistributing all pixels values to be as close as possible to a user –specified desired histogram. HE allows for areas of lower local contrast to gain a higher contrast. Histogram equalization automatically determines a transformation function seeking to produce an output image with a uniform Histogram. Histogram equalization is a method in image processing of contrast adjustment using the image histogram. This method usually increases the global contrast of many images, especially when the usable data of the image is represented by close contrast values. Through this adjustment, the intensities can be better distributed on the histogram. Histogram equalization accomplishes this by effectively spreading out the most frequent intensity values. Histogram equalization automatically determines a transformation function seeking to produce an output image with a uniform Histogram.

Let **f** be a given image represented as a matrix of integer pixel intensities ranging from 0 to L-1. L is the total number of possible intensity values, often 256. Let p denote the normalized histogram of **f.**

$$Pn = \frac{\text{Number of pixels with intensity n}}{\text{Total no of pixels}} \quad \ldots\ldots\ldots\ (3)$$

Where n = 0, 1, 2… n – 1

$$g(i,j) = \text{floor}\{(L-1) \sum_{n=0}^{f\,i,j} Pn\} \quad \ldots\ldots\ldots(4)$$

Where floor(x) rounds to the greatest integer less or equal.

5. TWO STAGE ADAPTIVE HISTOGRAM EQUALIZATION (TSAHE)

In Two stage adaptive histogram equalization there are many algorithms to enhance the contrast, which maximizes the intensity contrast of the image and bringing out more details. Image intensity distribution is one of the important parameter in adaptive histogram equalization (AHE) since it plays a major role in the histogram shape and specifies the desired histogram. In addition, AHE applies the algorithm on the small regions in the image call tiles rather than the entire image. Contrast in the tile is enhanced, so that the histogram of the output region approximately matches the uniform distribution. In addition to useful image statistics, the information inherent in histogram is also useful in image contrast enhancement.

6. CONTRAST LIMITED ADAPTIVE HISTOGRAM EQUALIZATION (CLAHE)

One of the most popular image enhancement methods is Histogram Equalization (HE). HE becomes a popular technique for contrast enhancement because this method is simple and effective. HE technique can be applied in many fields like medical image processing, sonar image processing and radar image processing. The basic idea of HE method is to re-map the gray levels of an image based on the image's gray levels cumulative density function. HE normally changes the brightness of the image significantly, and thus makes the output image to become saturated with very bright or dark intensity values.

Consequently, adaptive histogram equalization is considered an image enhancement technique capable of improving an image's local contrast, bringing out more detail in the image. However, it also can produce significant noise. A generalization of adaptive histogram equalization called contrast limited adaptive histogram equalization, also known as CLAHE, was developed to address the problem of noise amplification. CLAHE operates on small regions in the image, called tiles, rather than the entire image. Each tile's contrast is enhanced, so that the histogram of the output region approximately matches the histogram specified by the 'Distribution' parameter.

7. UNSHARP MASKING (USM)

It is a common method of pre-processing employed for Sharpening. It works by subtracting the smoothed image from original. Thus it enhances high frequency components like edges in the image and attenuate low frequency information giving a much sharper image. This may make more prominent in the processed image. Un-sharp masking is performed using the equation

$$g(x,y)=f(x,y) - f^1 (x,y)$$

Where, f(x, y) is the original image, f^1 (x, y) is a smooth version of original image. g(x,y) is the enhanced image after Unsharp masking.

III. IMAGE QUALITY MEASURES

Although many image quality measures have been described in the literature like signal to noise ratio (SNR), peak signal to noise ratio (PSNR), here we use MSE and PSNR to evaluate our subject image.

A. MEAN SQUARE ERROR (MSE)

MSE measures the difference between values of original image and the resultant image. MSE is a function corresponding to the expected values of the squared error. MSE measures the average of the squares of the errors. The error is the difference between the value implied by the estimator and the quantity to be estimated

$$MSE = \frac{1}{MN} \sum_{i=0}^{M-1} \sum_{j=0}^{N-1} (Iij - Kij)^2 \ldots\ldots\ldots\ldots\ldots (5)$$

Where matrix I represents input image and matrix K represents output image.

B. PEAK SIGNAL TO NOISE RATIO (PSNR)

PSNR is used to measure the quality of reconstructed image from the original image. PSNR is expressed in terms of logarithmic decibel scale. Higher PSNR generally indicates that the output image is of higher quality. PSNR is defined in terms of MSE as:

$$\text{PSNR} = 10\log_{10} \frac{[(\text{peak to peak value of original data})^2]}{MSE} \ldots\ldots\ (6)$$

IV. RESULTS AND DISCUSSIONS

This section presents the simulation results illustrating the performance of the image enhancement approaches discussed above. The experimental image is an Standard Lena image. The size of the image is 256×256. The performance of the enhancement approaches can be seen from the Table.1 below. The CLAHE and USM are better as compared to other techniques because they improve the perception of information from the image. The below all seven technique figures show the comparison of original image with all digital image enhancement techniques.

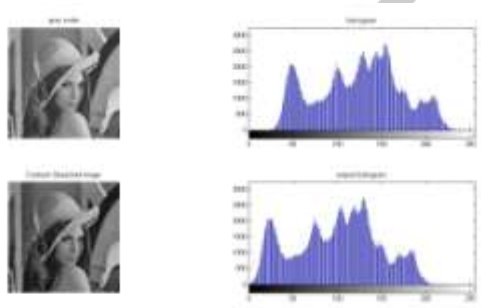

Figure 1: Original Image with Resultant contrast stretching.

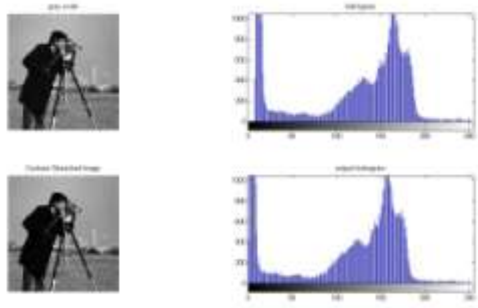

Figure 2: Original Image with Resultant contrast stretching

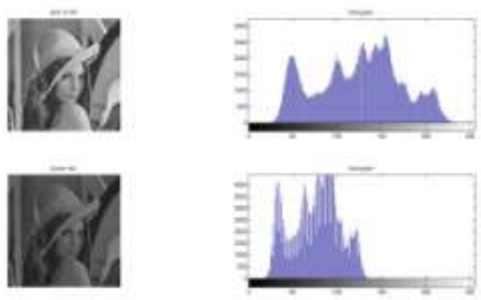

Figure 3: Original Image with Resultant power law Image.

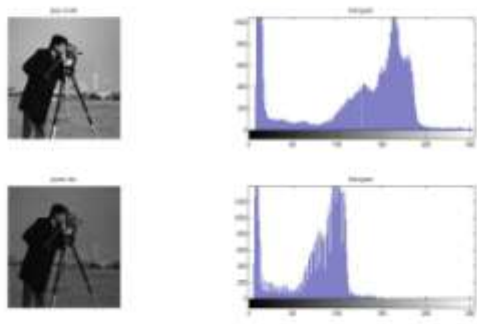

Figure 4: Original Image with Resultant power law Image.

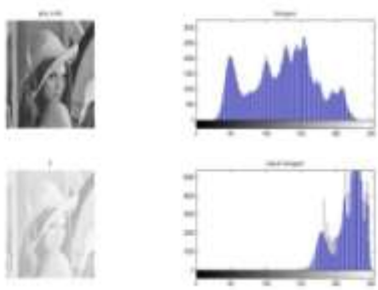

Figure 5: Original Image with Resultant log transformation Image

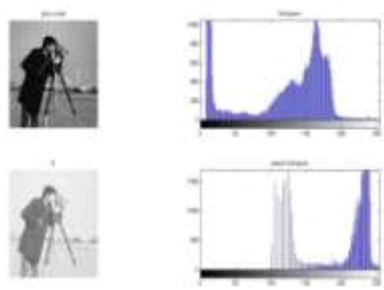

Figure 6: Original Image with Resultant log transformation Image

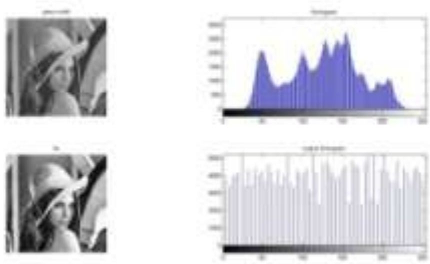

Figure 7: Original Image with Resultant HE Image

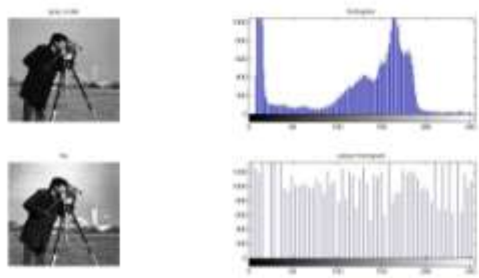

Figure 8: Original Image with Resultant HE Image

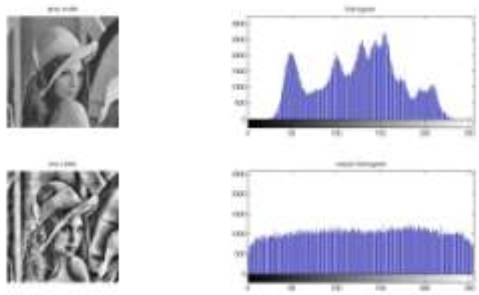

Figure 9: Original Image with Resultant TSAHE Image

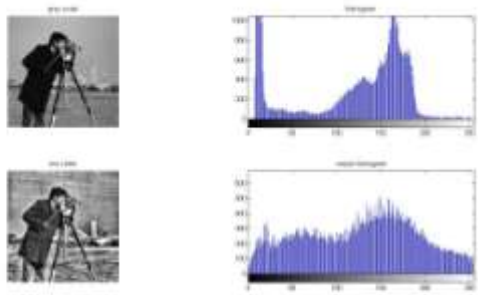

Figure 10: Original Image with Resultant TSAHE Image

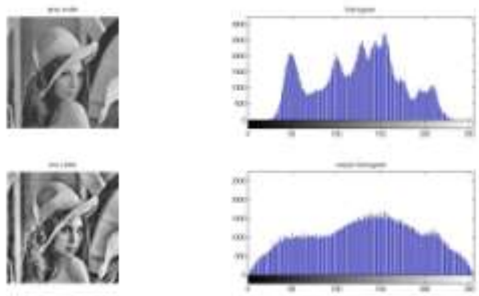

Figure 11: Original Image with Resultant CLAHE Image

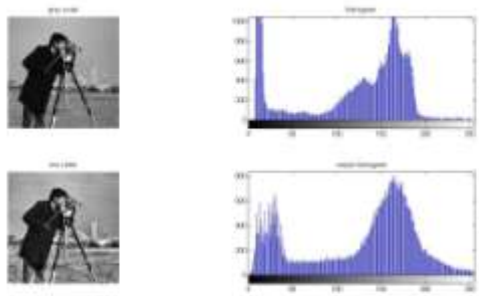

Figure 12: Original Image with Resultant CLAHE Image

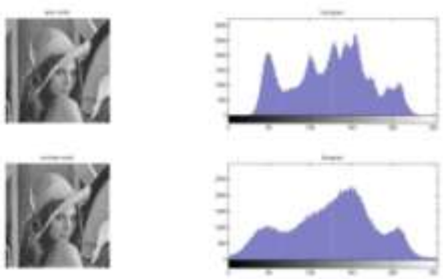

Figure 13: Original Image with Resultant US Image

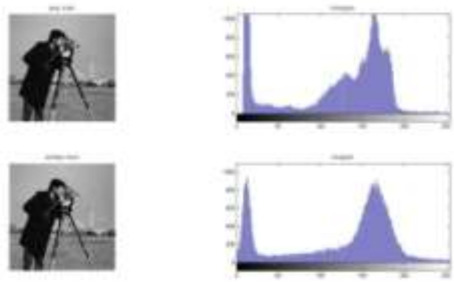

Figure 14: Original Image with Resultant US Image

Image Enhancement Technique	MSE	PSNR
CS	254.2779	24.0777
PLT	249.39	24.16
LT	149.3168	26.3897
HE	107.3985	27.8208
TSAHE	97.3763	28.2463
CLAHE	69.1692	29.7317
USM	48.17	31.30

Table I: MSE and PSNR values for Lena image of all Enhancement Techniques

Image Enhancement Technique	MSE	PSNR
CS	208.8329	24.9328
PLT	202.75	25.0542
LT	166.3385	25.9209
HE	73.9938	29.44
TSAHE	85.0055	28.8363
CLAHE	40.1438	32.0946
USM	48.6018	31.8425

Table II: MSE and PSNR values for Lena image of all Enhancement Techniques

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