

# **Comparative Study of Different Techniques of Image Enhancement for Grayscale and Colour Images**

A Thesis submitted in partial fulfillment of the requirements  
for the award of degree of

**Master of Engineering  
in  
Electronic Instrumentation and Control**



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## DECLARATION

I hereby certify that the work which is being presented in the thesis entitled “ **Comparative study of Different Techniques of Image Enhancement for Grayscale and Colour Images**” in partial fulfillment of award of degree of **Master of Engineering in Electronics Instrumentation and Control** submitted in Electrical and Instrumentation Engineering department, Thapar University, Patiala is an authentic record of my own work carried under the supervision of **Dr. Yaduvir Singh**, Associate Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala, Punjab.

Date: 14/6/11

  
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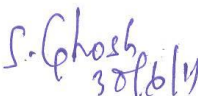
I certify that the above statement made by the student is correct to the best of my knowledge and belief.


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## ACKNOWLEDGEMENT

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I am highly grateful to **Dr. Smarajit Ghosh**, Head, Department of Electrical & Instrumentation Engineering, Thapar University, Patiala (Formerly known as Thapar Institute of Engineering and Technology, Patiala), for providing this opportunity to carry out the present work.

I would like to express a deep sense of gratitude and thanks profusely to my supervisor, **Dr. Yaduvir Singh**, Associate Professor, Department of Electrical and Instrumentation Engineering, Thapar University, Patiala. Without his wise counsel and able guidance, it would have been impossible to complete the present work.

I also express my gratitude to other faculty members of the department for their intellectual support throughout the course of this work.

The copious help received from the technical staff of the department for the excellent laboratory support is also acknowledged.

Finally, I am indebted to all whosoever have contributed to provide help to carry out the present work.

**Date:**

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## ABSTRACT

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### **“Image Enhancement Is As Much An Art As It Is A Science”**

Image enhancement is used to emphasize and sharpen image features for display and analysis. Image enhancement is the process of applying these techniques to facilitate the development of a solution to a computer imaging problem. Consequently, the enhancement methods are application specific and are often developed empirically. The type of techniques includes point operations, where each pixel is modified according to a particular equation that is not dependent on other pixel values; mask operations, where each pixel is modified according to the values of the pixel's neighbors (using convolution masks); or global operations, where all the pixel values in the image (or sub image) are taken into consideration. Spatial domain processing methods include all three types, but frequency domain operations, by nature of the frequency (and sequence) transforms, are global operations. Of course, frequency domain operations can become "mask operations," based only on a local neighborhood, by performing the transform on small image blocks instead of the entire image. Enhancement is used as a preprocessing step in some computer vision applications to ease the vision task, for example, to enhance the edges of an object to facilitate guidance of a robotic gripper. Enhancement is also used as a preprocessing step in applications where human viewing of an image is required before further processing. Image enhancement is used for post processing to generate a visually desirable image. Overall, image enhancement methods are used to make images look better.

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## RELATED PUBLICATIONS

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- ✓ Komal Vij, Yaduvir Singh, “Enhancement of Images Using Histogram Processing Techniques” published in International Journal of Computer Technology and Applications, vol. 2, no.2, pp. 309-313, 2011.
- ✓ Komal Vij, Yaduvir Singh, “Comparison between Different Techniques of Image Enhancement” published in International Journal of VLSI and Signal Processing Applications, vol.1, no.2, pp. 112-117, 2011.

# INTRODUCTION

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**“A book begins with an image or character or situation that I care about deeply”**

**Danielle Steel**

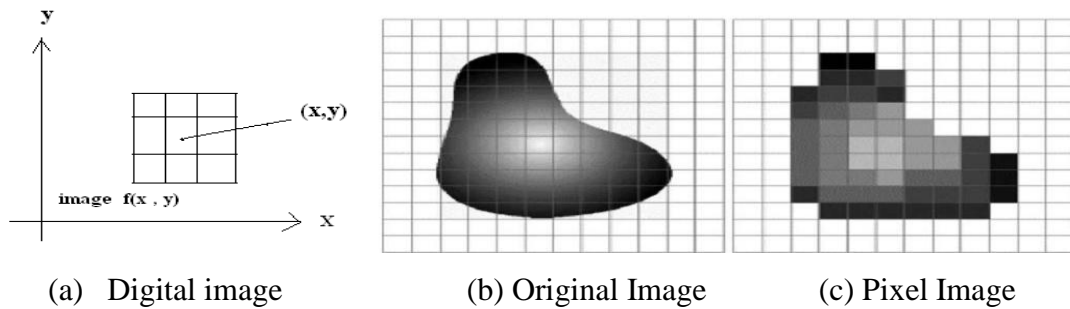
## 1.1 BACKGROUND AND MOTIVATION

Whenever an image is converted from one form to another, such as, digitizing, scanning, transmitting, storing, etc., some degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement. Histogram equalization (HE) is a very popular technique for enhancing the contrast of an image. Its basic idea lies on mapping the gray levels based on the probability distribution of the input gray levels. It flattens and stretches the dynamics range of the image's histogram and resulting in overall contrast improvement. HE has been applied in various fields such as medical image processing and radar image processing. Nevertheless, HE is not commonly used in consumer electronics such as TV because it may significantly change the brightness of an input image and cause undesirable artifacts. In theory, it can be shown that the mean brightness of the histogram-equalized image is always the middle gray level regardless of the input mean. This is not a desirable property in some applications where brightness preservation is necessary. Mean preserving Bi-histogram equalization (BBHE) has been proposed then, to overcome the fore mentioned problems. BBHE firstly separate the input image's histogram into two based on its mean; one having range from minimum gray level to mean and the other ranges from mean to the maximum gray level. Next, it equalizes the two histograms independently. It has been analyzed both mathematically and experimentally that this techniques capable to preserve the original brightness to a certain extends.

## 1.2 DIGITAL IMAGE PROCESSING

An image may be defined as a two-dimensional function  $f(x, y)$ , where  $x$  and  $y$  are spatial (plane) coordinates, and the amplitude of  $f$  at any pair of coordinates  $(x, y)$  is called the intensity or gray level of the image at that point. When  $x, y$ , and the amplitude values of  $f$  are all finite, discrete quantities, we call the image a digital image. The field of digital image

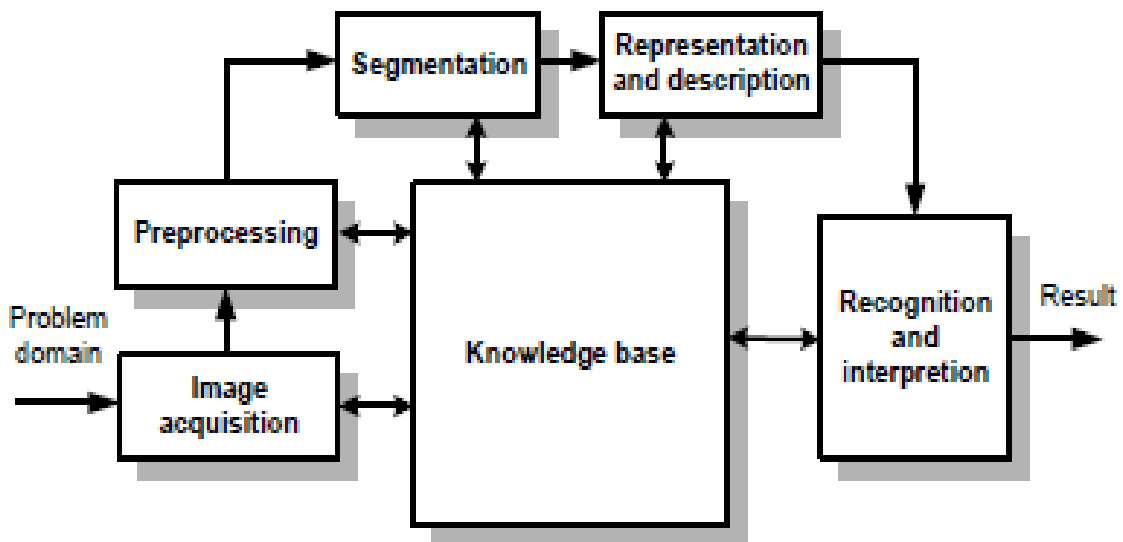
processing refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image .



**Figure 1.1: (a) Digital Image (b) Original image(c) Pixel Image**

Image processing generally involves following steps:-

1. Import an image with an optical scanner or directly through digital photography.
2. Manipulate or analyze the image in some way. This stage can include:-



**Figure 1.2: Fundamental steps in Digital Image**

### **Image Segmentation:**

The process of partitioning a digital image into multiple regions (set of pixel) is called image segmentation. Segmentation of an image entails the division or separation of the image into regions of similar attribute.



(a) Original

(b) Segmentation

**Figure 1.3: (a) Original Image (b) Segmentation image**

### **Image Data Compression:**

Image data compression techniques are concerned with reduction of the number of bits required to store or transmit images without any appreciable loss of information.



(a) Original

(b) Compressed Image

**Figure 1.4: (a) Original Image (b) Compressed image**

### **Image Restoration:**

Image restoration refers to removal or minimization of degradations in an image. Image restoration differs from image enhancement. Restoration techniques often depend only on the

class or ensemble properties of a data set .where as image enhancement techniques are much more image dependent.

3. Output the result. The result might be the image altered in some way or it might be a report based on analysis of the image.

### 1.3 Image Enhancement

The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide better input for other automated image processing techniques. Image Enhancement (IE) transforms images to provide better representation of the subtle details. It is an indispensable tool for researchers in a wide variety of fields including (but not limited to) medical imaging, art studies, forensics and atmospheric sciences. It is application specific: an IE technique suitable for one problem might be inadequate for another.

For example forensic images or videos employ techniques that resolve the problem of low resolution and motion blur while medical imaging benefits more from increased contrast and sharpness. Thus, for example, a method that is quite useful for enhancing X-ray images may not be the best approach for enhancing satellite images taken in the infrared band of the electromagnetic spectrum.

There is no general —theory of image enhancement. When an image is processed for visual interpretation, the viewer is the ultimate judge of how well a particular method works.



**Fig 1.5: (a) Original image (b) Enhanced Image**

## 1.4 Image Enhancement Techniques

Producing digital images with good brightness/contrast and detail is a strong requirement in several areas like vision, remote sensing, biomedical image analysis, fault detection. Producing visually natural images or transforming the image such as to enhance the visual information within, is a primary requirement for almost all vision and image processing tasks. Methods that implement such transformations are called image enhancement techniques. The task of image enhancement is a difficult one considering the fact that there is no general unifying theory of image enhancement at present, because there is no general standard of image quality that can serve as a design criterion for an image enhancement processor. Most of the enhancement techniques in existence to date are empirical or heuristic methods, dependent on the particular type of image.

More important, most of these techniques require interactive procedures to obtain satisfactory results, and therefore are not suitable for routine application. Besides requiring the user interaction, many such methods require specification of external parameters, which sometimes are difficult to fine-tune. Finally, the enhancement methods most widely employed treat the spatial information in the image in a global fashion, while in many cases it is necessary to adapt the transformation to the local features within different regions of the image.

The Image enhancement techniques can be divided into three broad categories:

- 1. Spatial domain methods**, which operate directly on pixels, and
- 2. Frequency domain methods**, which operate on the Fourier transform of an image.

Spatial operations are performed directly on the pixels of a given image. We classify spatial operations into three broad categories:

- (1) Single pixel operations: The simplest operation we perform on a digital image is to alter the values of its individual pixels based on their intensity. This type of process may be expressed as a transformation function,  $T$  of the form:

$$s = T(z) \quad (1)$$

Where  $z$  is the intensity of a pixel in the original image and  $s$  is the (mapped) intensity of the corresponding pixel in the processed image.

- (2) Neighbourhood operations: Neighbourhood operations are those that combine a small area or neighborhood of pixels to generate an output pixel. The most important neighborhood operator is convolution. To convolve something means to roll together. In

digital imagery, this means that a local area of pixels is combined in various ways to achieve some desired result. Almost as important as convolution is the process of sampling. Many neighborhood operators result in sub pixel addressing, which means that data values that exist between the discrete pixels of a digital image must be derived. Different methods for sampling allow this to occur. The applications of neighborhood operators are many, ranging from digital filters to techniques for sharpening, transforming, and warping images. When implementing the point operations, it is possible to perform a given function and, if desired, save the resulting pixels in the same memory buffer, thereby destroying the original input pixels. For point operations this is allowable, because once an input pixel has been processed its original value is no longer needed. This is not possible with neighborhood operators because, even after an output pixel has been calculated, the corresponding input pixel at that location is included in other neighborhoods. Therefore no input pixels can be overwritten until all relevant output pixels have been calculated.

**3. Geometric spatial transformations and image registration:** Geometric transformations modify the spatial relationship between pixels in an image. A geometric transformation consists of two basic operations:

- (a) A spatial transformation of coordinates, and
- (b) Intensity interpolation that assigns intensity value to the spatially transformed pixels.

The transformation of coordinates may be expressed as:

$$(x,y) = T \{(v,w)\} \quad (2)$$

Where (v,w) are pixel coordinates in the original image and (x, y) are the corresponding pixel coordinates in the transformed image.

For example, the transformation

$$(x,y) = T \{(v,w)\} = (v/2,w/2) \quad (3)$$

shrinks the original image to half.

## 1.5 Objective

The main objective of image enhancement is to modify 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. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. There exist many techniques that can enhance a digital image without spoiling it. For both grayscale and color images, different enhancement techniques are used. Based on different attributes, best enhancement method found for both the grayscale and color images.

## **1.6 Organization of the Thesis**

This thesis has seven chapters, including an introduction (Chapter I) and conclusion (Chapter VII). Chapter II describes the types of the images and noises in an image. Different types of image enhancement techniques are discussed in Chapter III. The chapter describes that the task of image enhancement is a difficult one considering the fact that there is no general unifying theory of image enhancement at present, because there is no general standard of image quality that can serve as a design criterion for an image enhancement processor. Thus, for example, a method that is quite useful for enhancing X-ray images may not be the best approach for enhancing satellite images taken in the infrared band of the electromagnetic spectrum. All the spatial domain operations are discussed in this chapter. Chapter IV discusses the relevant literature published related to image enhancement. Based on different parameters, best technique will be found out in Chapter V. With the help of GUI environment in MATLAB, results are obtained for all the four techniques. Various parameters like PSNR, MSE, RMSE, LMSE, and NCC are calculated for all the techniques individually for four types of images i.e. Grayscale images, Grayscale image with noise, Color image and Color image with noise. Based on the value of PSNR, MSE Results are discussed in Chapter VI. Chapter VII concludes the thesis.

## **LITERATURE SURVEY**

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**“The image is more than an idea. It is a vortex or cluster of fused ideas and is endowed with energy”**

**Ezra Pound**

### **2.1 INTRODUCTION**

A great deal of study on Image Contrast Enhancement has been done. It will be useful to analyze the existing method for both the grayscale and color images which help to do future research. An Image is often corrupted during its acquisition or transmission. Many images such as Medical images, remote Sensing Images, electron-microscopy images even real life photographic pictures suffer from Poor contrast. Therefore it is necessary to enhance the contrast. Histogram of images provides a global description of the appearance of an image. The information obtained from Histogram is enormous and hence Histogram modeling through a spatial domain technique is of utmost important in Digital Image Processing and has been implemented on various platforms. Some of the available literature and / or papers are discussed here.

### **2.2 LITERATURE REVIEW**

Yeong- Taeg- kim in [1] “Contrast Enhancement using Brightness Preserving Bi-Histogram Equalization” discussed Brightness preserving Bi Histogram Equalization as an emerging new technology. In this paper, a novel extension of the Histogram Equalization, which will be referred to as the mean preserving bi-histogram equalization (BBHE) is proposed to overcome the problems of the typical Histogram Equalization .The ultimate goal of the proposed algorithm is to preserve the mean brightness of a given image while the contrast is enhanced. The BBHE firstly decomposes an input Image into two sub images based on the mean of the Input Image. One of the sub image is the set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub images independently based on their respective histograms with the

constraint that the samples in the formal set are mapped into the range from the minimum gray level to the input mean and the samples in the latter set are mapped into the range from the mean to the maximum gray level. Means one of the sub image is equalized over the range up to the mean and the other sub image is equalized over the range from the mean based on the respective histograms. Thus, the resulting equalized sub images are bounded by each other around the input mean, which has an effect of preserving mean brightness. The ultimate goal behind the BBHE is to preserve the mean brightness of a given image while enhancing the contrast of a given image. The BBHE is a novel extension of a typical histogram equalization, which utilizes independent histogram equalizations over two sub images obtained by decomposing the input image based on its mean. The ultimate goal behind the BBHE is to preserve the mean brightness of a given image while enhancing the contrast of a given image. Analysis on the (output mean of the BBHE for a given analog image having symmetric distribution is also established mathematically, which indicates that the BBHE is capable of preserving the mean brightness of a given image. Simulation results also demonstrate the brightness-preserving function of the BBHE while enhancing contrast.

WANG Zhiming, TAO Jianhua [2] in “A Fast Implementation of Adaptive Histogram Equalization” discussed Adaptive Histogram Equalization (AHE) is a popular and effective algorithm for image contrast enhancement. But it’s quite computationally expensive and time consuming. In this paper, a fast implementation of AHE based on pure software techniques is proposed. Three accelerative techniques are combined to form the new fast AHE: First, local histogram is acquired by an iterative approach with a sliding window; Second, in computing cumulative histogram function, not more than half of the histogram is cumulated; Third, by keep the block size  $W^2$  equal to the product of grey level number and integral power of 2, all the multiplication and division operations are replaced with fast bitwise shift.

Hojat Yeganeh, Ali Ziaei, Amirhossein Rezaie [3] in “Novel Approach for Contrast Enhancement Based on Histogram Equalization” discussed Histogram based techniques is one of the important digital image processing techniques which can be used for image enhancement. One of the advantages of histogram based techniques is simplicity of implementation of the algorithm. Also it should be mentioned that histogram based

techniques is much less expensive comparing to the other methods. Histogram based techniques for image enhancement is mostly based on equalizing the histogram of the image and increasing the dynamic range corresponding to the image. Histogram Equalization (HE) method has two main disadvantages which affect efficiency of this method. For solving the above problems, some techniques have proposed for example using Bi Histogram Equalization (BHE) algorithm instead of Histogram Equalization (HE). It should be mentioned that Bi Histogram Equalization (BHE) is one of the best proposed algorithm which has proposed until now. This paper presents a novel algorithm for contrast enhancement based on Histogram Equalization (HE).

Jeong CB, Kim KG, Kim TS, Kim SK [4] in “Comparison of image enhancement methods for the effective diagnosis in successive whole-body bone scans” discussed Whole-body bone scan is one of the most frequent diagnostic procedures in nuclear medicine. Especially, it plays a significant role in important procedures such as the diagnosis of osseous metastasis and evaluation of osseous tumor response to chemotherapy and radiation therapy. It can also be used to monitor the possibility of any recurrence of the tumor. However, it is a very time-consuming effort for radiologists to quantify subtle interval changes between successive whole-body bone scans because of many variations such as intensity, geometry, and morphology. In this paper, we present the most effective method of image enhancement based on histograms, which may assist radiologists in interpreting successive whole-body bone scans effectively. Forty-eight successive whole-body bone scans from 10 patients were obtained and evaluated using six methods of image enhancement based on histograms: histogram equalization, brightness-preserving bi-histogram equalization, contrast-limited adaptive histogram equalization, end-in search, histogram matching, and exact histogram matching (EHM). Comparison of the results of the different methods was made using three similarity measures peak signal-to-noise ratio, histogram intersection, and structural similarity. Image enhancement of successive bone scans using EHM showed the best results out of the six methods measured for all similarity measures. EHM is the best method of image enhancement based on histograms for diagnosing successive whole-body bone scans. The method for successive whole-body bone scans has the potential to greatly assist radiologists quantify interval changes more accurately and quickly by compensating for the variable nature of intensity information. Consequently, it can improve radiologists' diagnostic accuracy as well as reduce reading time for detecting interval changes.

Rajesh Garg, Bhawna Mittal, Sheetal Garg [5] in “Histogram Equalization Techniques For Image Enhancement” discussed Various enhancement schemes are used for enhancing an image which includes gray scale manipulation, filtering and Histogram Equalization (HE). Histogram equalization is one of the well known image enhancement technique. It became a popular technique for contrast enhancement because this method is simple and effective. In the latter case, preserving the input brightness of the image is required to avoid the generation of non-existing artifacts in the output image. Although these methods preserve the input brightness on the output image with a significant contrast enhancement, they may produce images with do not look as natural as the input ones. The basic idea of HE method is to re-map the gray levels of an image. HE tends to introduce some annoying artifacts and unnatural enhancement. To overcome these drawbacks different brightness preserving techniques are used which are covered in the literature survey. Comparative analysis of different enhancement techniques will be carried out. This comparison will be done on the basis of subjective and objective parameters. Subjective parameters are visual quality and computation time and objective parameters are Peak signal to noise ratio (PSNR), Mean squared error (MSE), Normalized Absolute Error (NAE), Normalized Correlation, Error Color and Composite Peak Signal to Noise Ratio (CPSNR).

H.D. Cheng and X.J. Shi [6] in “A simple and effective histogram equalization approach to image enhancement” discussed one of the most commonly used methods is histogram equalization (HE). The main idea of HE-based methods is to re-assign the intensity values of pixels to make the intensity distribution uniform to utmost extent [5,10,12,18]. Suppose that the original image is normalized and the range of its intensities is  $[0, 1]$ , and  $p(x)$  is the density function of intensity distribution of the original image, where  $x$  denotes the intensity value of the normalized image. The desired density function of intensity distribution of the output image is equal to 1 after equalization, i.e., HE formula is  $y = \int_0^x p(u)du$  Here  $y$  is the intensity of the output image,  $x$  the intensity of the input image, and  $u$  is a dummy variable. Both  $x$  and  $y$  are in  $[0, 1]$ . HE is simple and effective in enhancing the low contrast image only if (a) it contains single object or (b) no apparent contrast change between object and background. Since the above conditions cannot be always met, the global methods have both

over-enhancement and under-enhancement problems. To overcome the above drawbacks, various modifications have been developed [10,12,18]. Suppose that the range of gray levels is  $[x_0, x_L]$ , one or more mid-nodes  $x_i$  ( $i = 1, 2, \dots, L-1$ ) was determined by the values of mean, median or the number of peaks in the image histogram. The original histogram is partitioned into segments between  $[x_i, x_{i+1}]$ , and they will be equalized piecewise and independently. This method is called multi-peak HE [12] that can only slightly improve HE method, and still has the drawbacks of HE.

Soong-Der Chen, Abd. Rahman Ramli [7] in “Preserving brightness in histogram equalization based contrast enhancement techniques” discussed Histogram equalization (HE) has been a simple yet effective image enhancement technique. However, it tends to change the brightness of an image significantly, causing annoying artifacts and unnatural contrast enhancement. Brightness preserving bi-histogram equalization (BBHE) and dualistic sub-image histogram equalization (DSIHE) have been proposed to overcome these problems but they may still fail under certain conditions. This paper proposes a novel extension of BBHE referred to as minimum mean brightness error bi-histogram equalization (MMBEBHE). MMBEBHE has the feature of minimizing the difference between input and output image's mean. Simulation results showed that MMBEBHE can preserve brightness better than BBHE and DSIHE. Furthermore, this paper also formulated an efficient, integer-based implementation of MMBEBHE. Nevertheless, MMBEBHE also has its limitation.

Ibrahim, H., Kong, N.S.P.[8] in “Brightness Preserving Dynamic Histogram Equalization for Image Contrast Enhancement” discussed Histogram equalization (HE) is one of the common methods used for improving contrast in digital images. However, this technique is not very well suited to be implemented in consumer electronics, such as television, because the method tends to introduce unnecessary visual deterioration such as the saturation effect. One of the solutions to overcome this weakness is by preserving the mean brightness of the input image inside the output image. This paper proposes a new method, known as brightness preserving dynamic histogram equalization (BPDHE), which is an extension to HE that can produce the output image with the mean intensity almost equal to the mean intensity of the input, thus fulfill the requirement of maintaining the mean brightness of the image. First, the method smoothes the input histogram with one dimensional Gaussian filter, and then

partitions the smoothed histogram based on its local maximums. Next, each partition will be assigned to a new dynamic range. After that, the histogram equalization process is applied independently to these partitions, based on this new dynamic range. For sure, the changes in dynamic range, and also histogram equalization process will alter the mean brightness of the image. Therefore, the last step in this method is to normalize the output image to the input mean brightness. Our results from 80 test images shows that this method outperforms other present mean brightness preserving histogram equalization methods. In most cases, BPDHE successfully enhance the image without severe side effects, and at the same time, maintain the mean input brightness.

B.-W. Yoon, W.-J. Song,[9] in “Image contrast enhancement based on generalized histogram,” discussed an adaptive contrast enhancement method based on the generalized histogram, which is obtained by relaxing the restriction of using the integer count. For each pixel, the integer count 1 allocated to a pixel is split into the fractional count and the remainder count. The generalized histogram is generated by accumulating the fractional count for each intensity level and distributing the remainder count uniformly throughout the intensity levels. The intensity mapping function, which determines the contrast gain for each intensity level, is derived from the generalized histogram. Since only the fractional part of the count allocated to each pixel is used for increasing the contrast gain of its intensity level, the amount of contrast enhancement is adjusted by varying the fractional count according to regional characteristics. The proposed scheme produces visually more pleasing results than the conventional histogram equalization.

Kim Y., Kim S., and Hwang H., [10] in “An Advanced Contrast Enhancement Using Partially Overlapped Sub-Block Histogram Equalization” discussed In this paper, an advanced histogram-equalization algorithm for contrast enhancement is presented. Histogram equalization is the most popular algorithm for contrast enhancement due to its effectiveness and simplicity. It can be classified into two branches according to the transformation function used: global or local. Global histogram equalization is simple and fast, but its contrast-enhancement power is relatively low. Local histogram equalization, on the other hand, can enhance overall contrast more effectively, but the complexity of computation required is very high due to its fully overlapped sub-blocks.

## 2.3 INFERENCES DRAWN OUT OF LITERATURE REVIEW

- ✓ Brightness of an image can be changed after the Histogram Equalization, which is mainly due to the flattening property of the Histogram.
- ✓ The HE method may result in over enhancement and saturation artifacts due to the stretching of the gray levels over the full gray level range.
- ✓ BBHE has an effect of preserving mean brightness.
- ✓ In BBHE, the computation of Histogram and the mean typically need to be done during one frame period, thus a frame memory to store the image being processed is necessary.
- ✓ In CLAHE, improving an image's local contrast, bringing out more detail in the image.

# TYPES OF IMAGES AND NOISE IN AN IMAGE

“The photographic image is a message without a code”

Roland Barthes

## 3.1 IMAGE

An image is an array, or a matrix, of square pixels (picture elements) arranged in columns and rows. In a (8-bit) grayscale image each picture element has an assigned intensity that ranges from 0 to 255. A grayscale image is what people normally call a black and white image, but the name emphasizes that such an image will also include many shades of grey. A normal grayscale image has 8 bit colour depth = 256 grayscales. A "true colour" image has 24 bit colour depth =  $8 \times 8 \times 8$  bits =  $256 \times 256 \times 256$  colours = ~16 million colours. Some grayscale images have more grayscales, for instance 16 bit = 65536 grayscales.

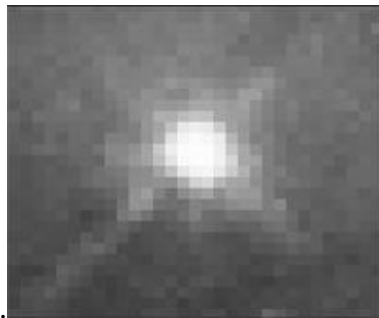


Figure 3.1: An image is an array or a matrix of pixels arranged in columns and rows.

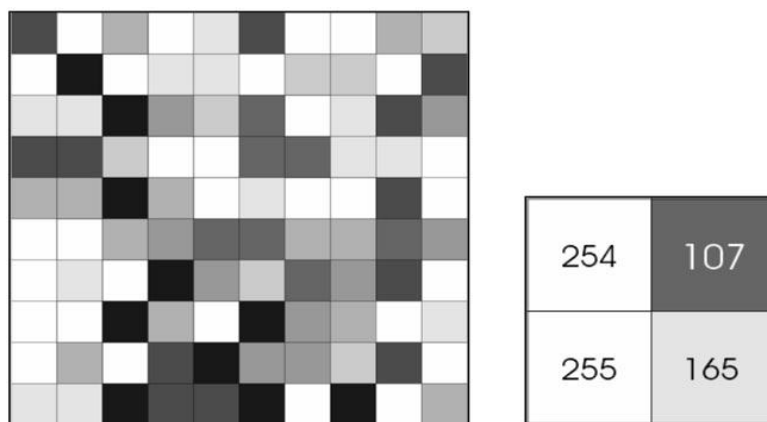


Figure 3.2: Each pixel has a value from 0 (black) to 255 (white).

## 3.2 CLASSIFICATION OF IMAGES

An image can be classified by following categories.

### 3.2.1 Intensity Images

An intensity image is a data matrix whose values have been scaled to represent intensities. When the elements of an intensity image are of class unit 8, or class unit 16, they have integer values in the range [0, 255] and [0, 65535]. respectively. If the image is of class double, the values are floating-point numbers. Values of scaled, class double intensity images are in the range [0, 1] by convention [10].

### 3.2.2 Indexed Images

Array of class logical, unit 8, Unit 16, single, or double whose pixel values are directed indices into a color map. The color map is an m-by-3 array of class double. For single or double arrays, integer values range from [1, p]. For logical, unit8, or unit 16 arrays, values range from [0, p-1]. An indexed image consists of an array and a color map matrix. The pixel values in the array are directed indices into a color map.

### 3.2.3 Binary Images

Binary images have a very specific meaning in MATLAB. In a binary image, each pixel assumes one of only two discrete values: 1 or 0, interpreted as black and white, respectively. A binary image is stored as a logical array.



Figure 3.3 Binary image

### 3.2.4 Grayscale Images

A grayscale image (also called gray-scale, gray scale, or gray-level) is a data matrix whose values represent intensities within some range. MATLAB stores a grayscale image as an individual matrix, with each element of the matrix corresponding to one image pixel. By convention, this documentation uses the variable name *I* to refer to grayscale images. Array of class `uint8`, `unit16`, `int16`, `single`, or `double` whose pixel values. For `single` or `double` arrays, values range from  $[0, 1]$ . For `uint8`, values range from  $[0, 255]$ . For `unit16`, values range from  $[0, 65535]$ . For `int16`, values range from  $[-32768, 32767]$ .



**Figure 3.4 Grayscale image**

### 3.2.5 True Color Images

A true color image is an image in which each pixel is specified by three values one each for the red, blue, and green components of the pixel's color. MATLAB store true color images as an *m*-by-*n*-by-3 data array that defines red, green, and blue color components for each individual pixel. True color images do not use a color map. The color of each pixel is determined by the combination of the red, green, and blue intensities stored in each color plane at the pixel's location. Graphics file formats store true color images as 24-bit images, where the red, green, and blue components are 8 bits each. This yields a potential of 16

million colors. The precision with which a real-life image can be replicated has led to the commonly used term true color image.



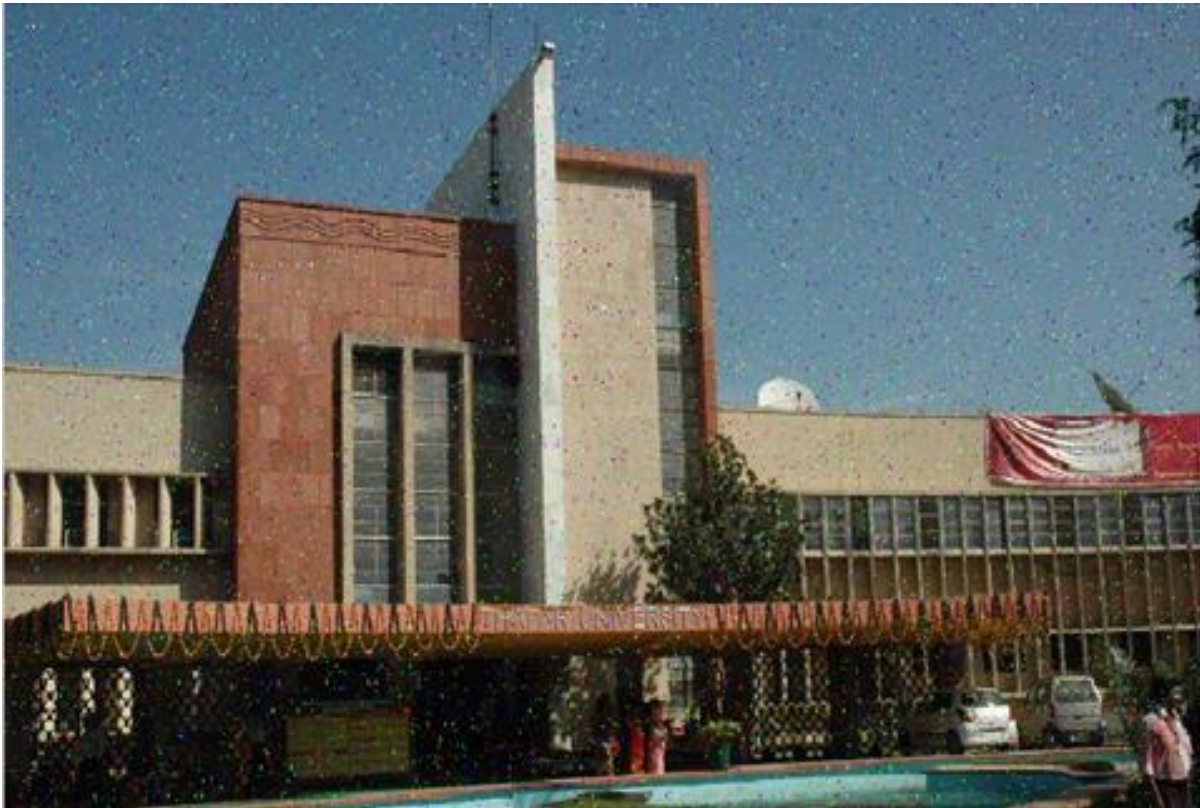
**Figure 3.5 Color image**

### **3.3 IMAGE NOISE**

Image noise is the random variation of brightness or color information in images produced by the sensor and circuitry of a scanner or digital camera. Image noise can also originate in film grain and in the unavoidable shot noise of an ideal photon detector. Image noise is generally regarded as an undesirable by-product of image capture. Although these unwanted fluctuations became known as "noise" by analogy with unwanted sound, they are inaudible and actually beneficial in some applications, such as dithering.

Image noise is the term applied to pictures, a counterpart to the white noise you would hear in an audio or video file. Analogue cameras will show image noise through grainy specs on the picture whereas digital cameras will show image noise through random speckles throughout

the picture. While most of the time image noise should be avoided, sometimes it can create the illusion of an older picture.

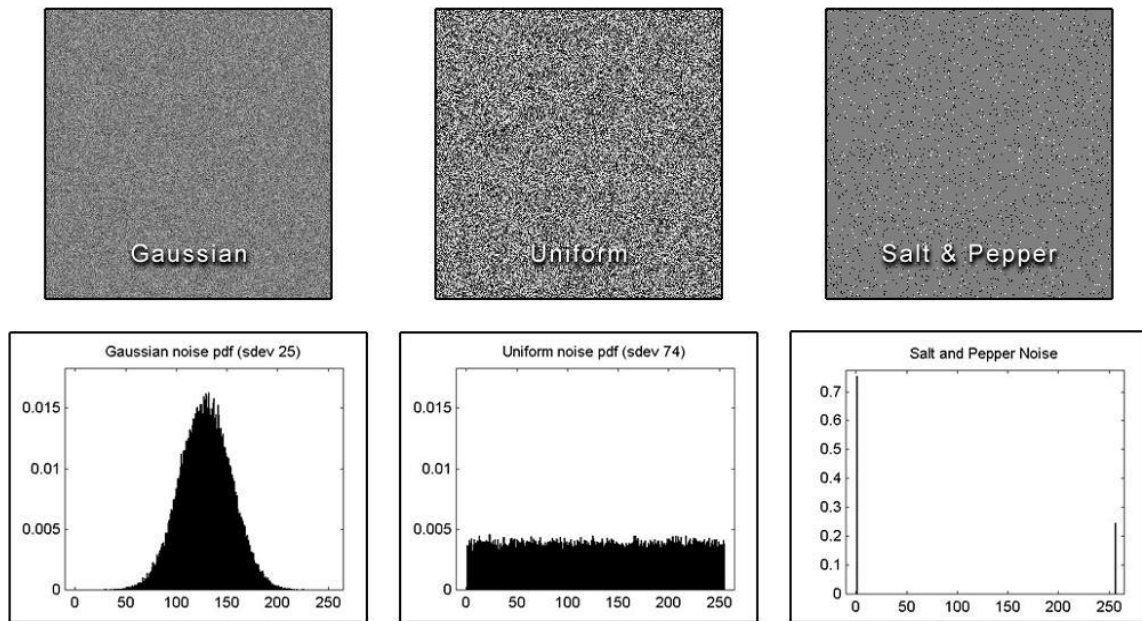


**Figure 3.6 Noisy Image**

Things such as exposure, temperature and different camera modes can affect image noise. No matter what you do to prevent image noise, some will always be present. Any electronic unit that sends or receives a signal will be susceptible to it. For digital cameras, light that enters the lens and misaligns with the sensors will cause image noise. Even if you cannot see the noise when you look at your picture, there is some form of image noise in any image you take. The same thing can be said for audio and video productions. Every type of electronic device receives some sort of noise and sends it on to what it is creating.

### **3.4 TYPES OF NOISES IN IMAGE**

There are different types of noise



**Figure 3.7: Shows Different Between Each Noise**

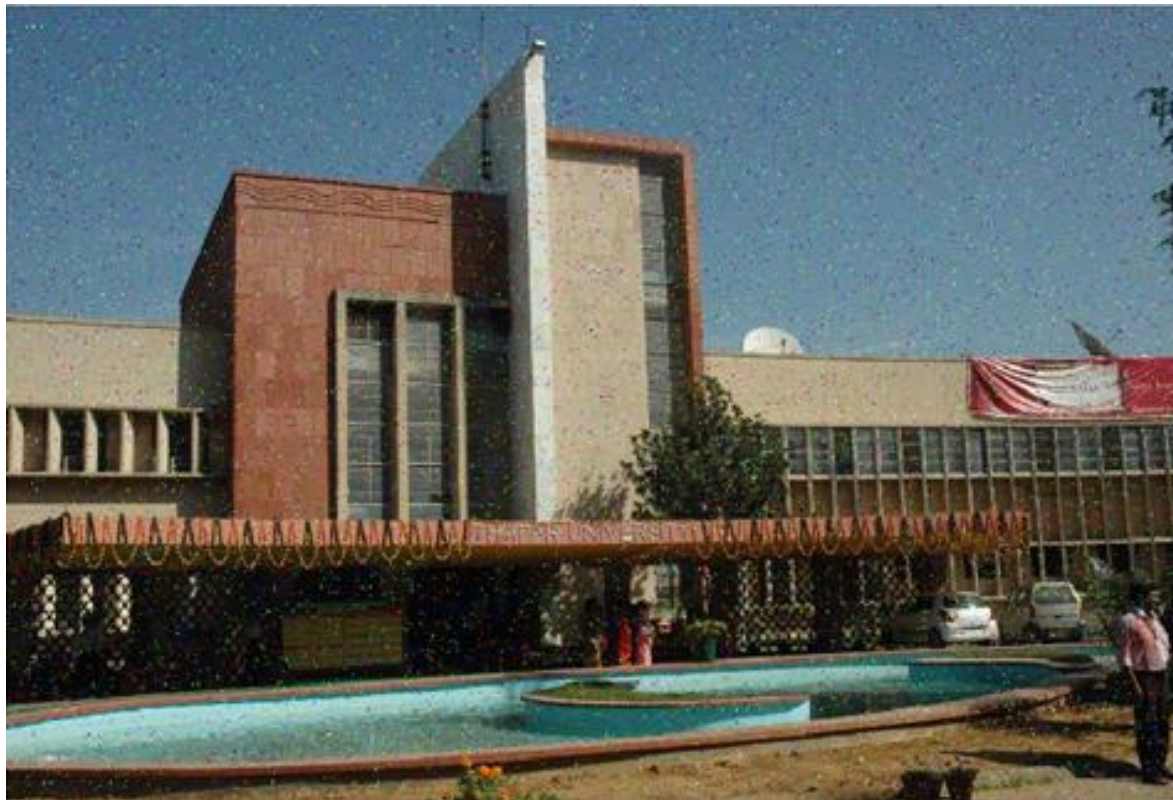
### 3.4.1 Shot noise

The dominant noise in the lighter parts of an image from an image sensor is typically that caused by statistical quantum fluctuations, that is, variation in the number of photons sensed at a given exposure level; this noise is known as photon shot noise. Shot noise has a root-mean-square value proportional to the square root of the image intensity, and the noises at different pixels are independent of one another. Shot noise follows a Poisson distribution, which is usually not very different from Gaussian.

In addition to photon shot noise, there can be additional shot noise from the dark leakage current in the image sensor; this noise is sometimes known as "dark shot noise" or "dark-current shot noise". Dark current is greatest at "hot pixels" within the image sensor; the variable dark charge of normal and hot pixels can be subtracted off (using "dark frame subtraction"), leaving only the shot noise, or random component, of the leakage; if dark-frame subtraction is not done, or if the exposure time is long enough that the hot pixel charge exceeds the linear charge capacity, the noise will be more than just shot noise, and hot pixels appear as salt-and-pepper noise.

### 3.4.2 Amplifier noise (Gaussian noise)

The standard model of amplifier noise is additive, Gaussian, independent at each pixel and independent of the signal intensity, caused primarily by Johnson–Nyquist noise (thermal noise), including that which comes from the reset noise of capacitors ("kTC noise"). In color cameras where more amplification is used in the blue color channel than in the green or red channel, there can be more noise in the blue channel. Amplifier noise is a major part of the "read noise" of an image sensor, that is, of the constant noise level in dark areas of the image.



**Figure 3.8: Image with Gaussian Noise**

### 3.4.3 Salt-and-Pepper Noise

Fat-tail distributed or "impulsive" noise is sometimes called salt-and-pepper noise or spike noise. An image containing salt-and-pepper noise will have dark pixels in bright regions and bright pixels in dark regions. This type of noise can be caused by dead pixels, analog-to-digital converter errors, bit errors in transmission, etc. This can be eliminated in large part by using dark frame subtraction and by interpolating around dark/bright pixels.



**Figure 3.9: Salt and pepper noise**

#### **3.4.4 Quantization Noise (Uniform Noise)**

The noise caused by quantizing the pixels of a sensed image to a number of discrete levels is known as quantization noise; it has an approximately uniform distribution, and can be signal dependent, though it will be signal independent if other noise sources are big enough to cause dithering, or if dithering is explicitly applied.

#### **3.4.5 Film Grain**

The grain of photographic film is a signal dependent noise, related to shot noise. That is, if film grains are uniformly distributed (equal number per area), and if each grain has an equal and independent probability of developing to a dark silver grain after absorbing photons. Quantum structure of the x-ray beam is the most significant noise source in most x-ray imaging applications, the structure of the film, intensifying screens, intensifier tube screens, or digital receptors can introduce noise into images. An image recorded on film is composed of many opaque silver halide crystals, or grains. The grains in radiographic film are quite small and are not generally visible when the film is viewed in the conventional manner. The grainy structure sometimes becomes visible when an image recorded on film is optically enlarged, as when projected onto a screen. Whenever it is visible, film grain is a form of image noise. Film-grain noise is generally a more significant problem in photography than in

radiography, especially in enlargements from images recorded on film with a relatively high sensitivity, (speed). Image-intensifying screens and the screens of intensifier tubes are actually layers of small crystals. An image is formed by the production of light (fluorescence) within each crystal. The crystal structure of screens introduces a slight variation in light production from point to point within an image. This structure noise is relatively insignificant in most radiographic applications.



**Figure 3.10: Grain noise**

### **3.4.6 Non-Isotropic Noise**

Some noise sources show up with a significant orientation in images. For example, image sensors are sometimes subject to row noise or column noise. In film, scratches are an example of non-isotropic noise.

## **3.5 QUALITATIVE ATTRIBUTES OF AN IMAGE**

1) **PSNR** (peak signal-to-noise ratio):- Ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation.

- Measure of quality of reconstruction
- Signal in this case is the original data, and the noise is the error.

2) **MSE (Mean Square Error)**:- The MSE is the cumulative squared error between the compressed and the original image, whereas PSNR is a measure of the peak error.

$$PSNR = 20 \log_{10} \left( \frac{255}{\sqrt{MSE}} \right) \quad (4)$$

- A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So, having a lower MSE (and a high PSNR), it is a better one.

3) **RMSE (Root-Mean-Square Error):-** To get a measure of how similar two images are, you can calculate the root-mean-square (RMS) value of the difference between the images. If the images are exactly identical, this value is zero. The following function uses the difference function, and then calculates the RMS value from the histogram of the resulting image.

4) **LMSE:** - Producing the least mean squares of the error signal (difference between the desired and the actual signal). "Least mean square" means that you:-

- Calculate the difference between the data value and the model prediction at several different places (this is called the error).
- Square the error to make all values positive (square).
- Calculate the average (mean square).
- find the model alternative that gives the smallest error (least mean square)

5) **Normalized Cross Correlation:** - The Cross-Correlation function can be described as

$$CrossCorr(s,t) = \sum_x \sum_y R(x,y)I(x-s,y-t) \quad (5)$$

Where, I-input image intensity

R-reference image intensity

And the summation is taken over the region (s,t) where R and I overlap. For any value of (s,t) inside R(x, y) the cross-correlation function yields one value of CrossCorr. The maximum value of Cross Corr(s, t) indicates the position where I(x, y) best matches R(x, y).

$$NCC = \frac{1}{\text{var}(Y)} \sum_b \frac{\text{num}Y(b)}{\text{numTot}Y} \text{var} Y(b) \quad (6)$$

The correlation ratio ranges from 0 for very good image to 1 for very bad image. Based Upon these parameters, image can be judged either it's a good or bad image.

# IMAGE ENHANCEMENT TECHNIQUES

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**“The image is more than an idea. It is a vortex or cluster of fused ideas and is endowed with energy”**

**Ezra Pound**

## 4.1 IMAGE ENHANCEMENT

Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing 'better' input for other automated image processing techniques. The principal objective of image enhancement is to modify 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. The choice of attributes and the way they are modified are specific to a given task. Moreover, observer-specific factors, such as the human visual system and the observer's experience, will introduce a great deal of subjectivity into the choice of image enhancement methods. There exist many techniques that can enhance a digital image without spoiling it.

The enhancement methods can broadly be divided into the following two categories:

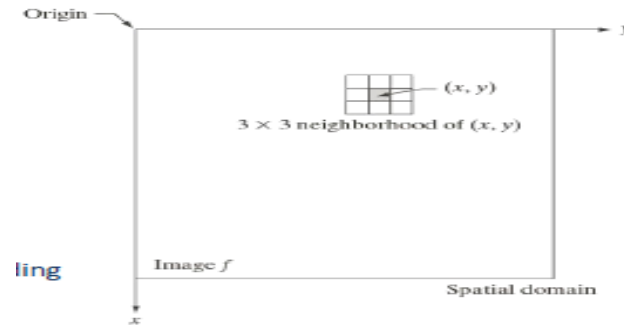
- ✓ Spatial Domain Methods
- ✓ Frequency Domain Methods

In spatial domain techniques, we directly deal with the image pixels. The pixel values are manipulated to achieve desired enhancement. In frequency domain methods, the image is first transferred into the frequency domain. It means that, the Fourier Transform of the image is computed first. All the enhancement operations are performed on the Fourier transform of the image and then the Inverse Fourier transform is performed to get the resultant image. These enhancement operations are performed in order to modify the image brightness, contrast or the distribution of the grey levels. As a consequence the pixel value (intensities) of the output image will be modified according to the transformation function applied on the input values.

Image enhancement is applied in every field where images are ought to be understood and analyzed. For example, medical image analysis, analysis of images from satellites etc. Image enhancement simply means, transforming an image  $f$  into image  $g$  using  $T$ . (Where  $T$  is the transformation). The values of pixels in images  $f$  and  $g$  are denoted by  $r$  and  $s$ , respectively. As said, the pixel values  $r$  and  $s$  are related by the expression,

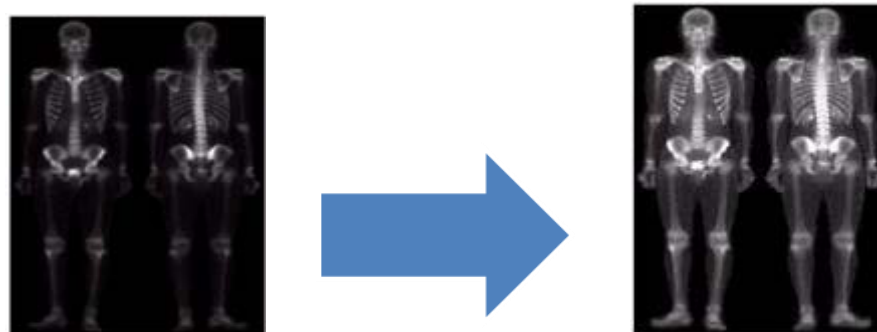
$$s = T(r) \tag{7}$$

Where  $T$  is a transformation that maps a pixel value  $r$  into a pixel value  $s$ .



**Figure 4.1: A 3\*3 neighborhood about a point(x,y) in an image in the spatial domain.**

The results of this transformation are mapped into the gray scale range as we are dealing here only with grey scale digital images. So, the results are mapped back into the range  $[0, L-1]$ , where  $L=2^k$ ,  $k$  being the number of bits in the image being considered. So, for instance, for an 8-bit image the range of pixel values will be  $[0, 255]$ . A digital gray image can have pixel values in the range of 0 to 255.



**Figure 4.2: Showing the effect of Image Enhancement**

Two principal categories of spatial processing are intensity transformations and spatial filtering. Intensity transformations operate on single pixels on an image, principally for the purpose of contrast manipulation and image thresholding. Spatial filtering deals with

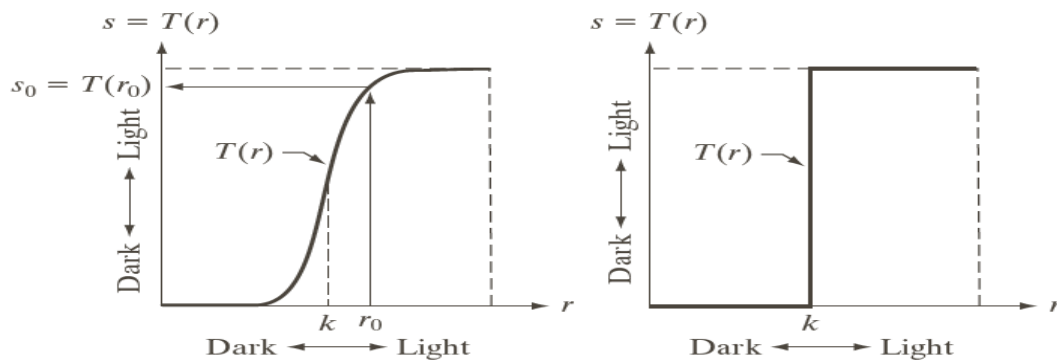
performed operations such as image sharpening, by working in a neighborhood of every pixel in an image.

## 4.2 BASIC INTENSITY TRANSFORMATION FUNCTIONS

Intensity transformations are among the simplest of all image processing techniques. The values of pixels, before and after processing, will be denoted by  $r$  and  $s$ , respectively.

$$s = T(r) \quad (8)$$

Where  $T$  is the transformation that maps a pixel value  $r$  into a pixel value  $s$ .



**Figure4.3: Intensity transformation functions**

### 4.2.1 Create Negative of an Image

The most basic and simple operation in digital image processing is to compute the negative of an image. The pixel gray values are inverted to compute the negative of an image. For example, if an image of size  $R \times C$ , where  $R$  represents number of rows and  $C$  represents number of columns, is represented by  $I(r, c)$ . The negative  $N(r, c)$  of image  $I(r, c)$  can be computed as

$$N(r, c) = 255 - I(r, c) \text{ where } 0 \leq r \leq R \text{ and } 0 \leq c \leq C \quad (9)$$

It can be seen that every pixel value from the original image is subtracted from the 255. The resultant image becomes negative of the original image. Reversing the intensity levels of an image in this manner produces the equivalent of a photographic negative. Negative images are useful for enhancing white or grey detail embedded in dark regions of an image.

$$s = L - 1 - r \quad (10)$$

There are three basic types of functions (transformations) that are used frequently in image enhancement. They are: Linear, Logarithmic and Power-Law.

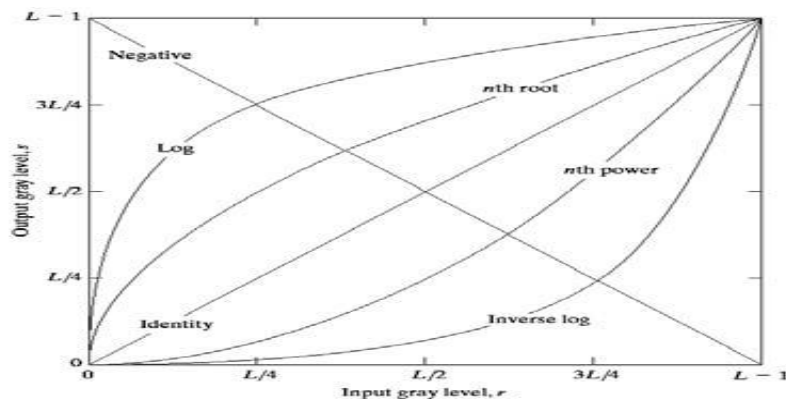


Figure 4.4: Figure shows basic grey level Transformations

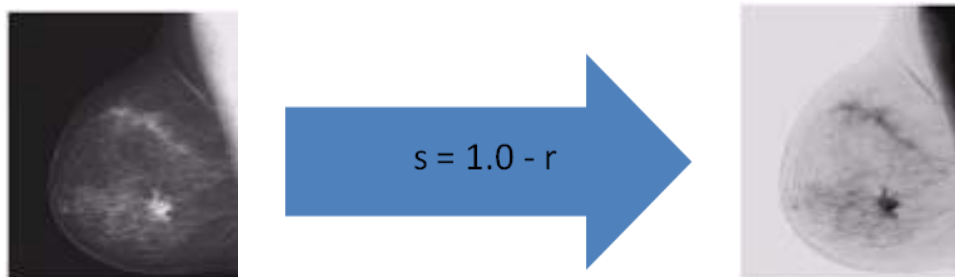


Figure 4.5: Negative image of the mammogram

#### 4.2.2 Thresholding Transformations

From a grayscale image, thresholding can be used to create binary images. Thresholding transformations are particularly useful for segmentation in which we want to isolate an object of interest from a background as shown in figure below.

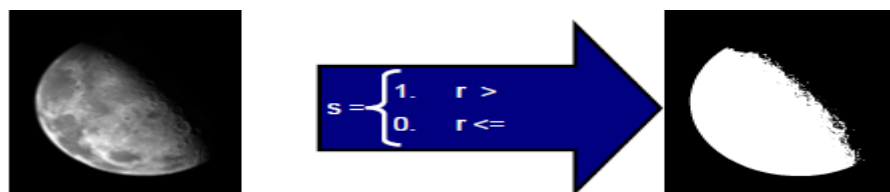


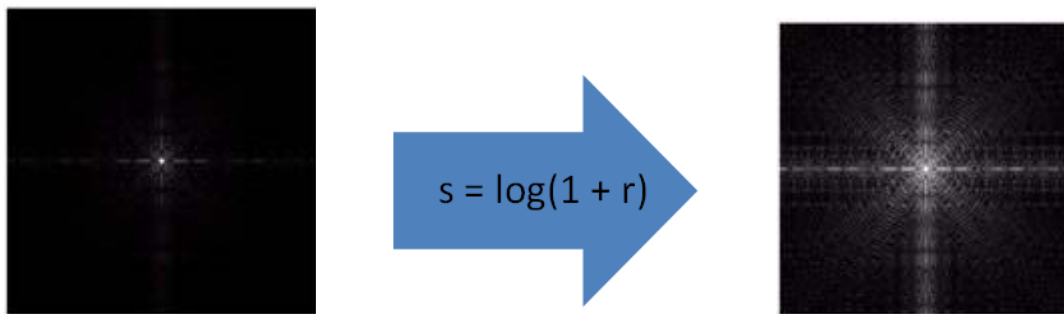
Figure 4.6: Showing effect of thresholding transformation for isolating object of interest

#### 4.2.3 Logarithmic Transformations

The general form of the log transformation is

$$s = c * \log (1 + r) \tag{11}$$

The log transformation maps a narrow range of low input grey level values into a wider range of output values. The inverse log transformation performs the opposite transformation. Log functions are particularly useful when the input grey level values may have an extremely large range of values. In the following example the Fourier transform of an image is put through a log transform to reveal more detail



**Figure 4.7: Example showing effect of Logarithmic transformation**

$$s = \log(1 + r) \quad (12)$$

We usually set  $c$  to 1. Grey levels must be in the range  $[0.0, 1.0]$

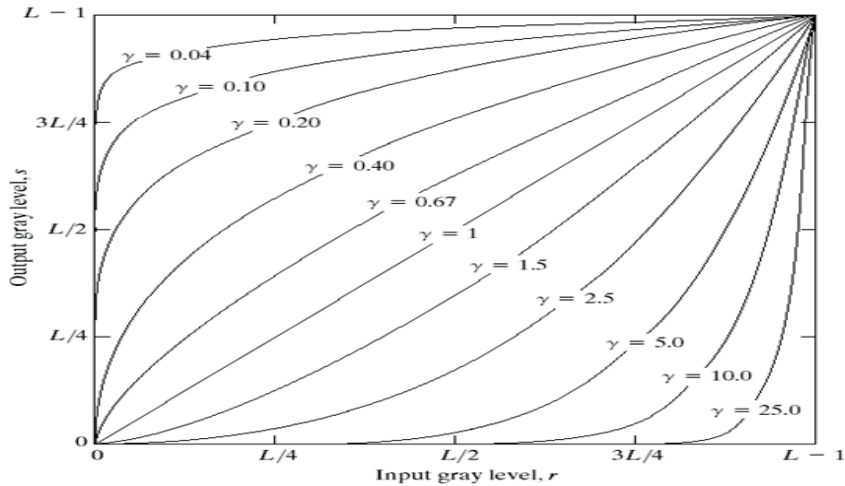
#### 4.2.4 Powers-Law Transformations

The  $n$ th power and  $n$ th root curves shown in fig. A can be given by the expression,

$$s = cr^\gamma \quad (13)$$

This transformation function is also called as *gamma* correction. For various values of  $\gamma$  different levels of enhancements can be obtained. This technique is quite commonly called as Gamma Correction. If you notice, different display monitors display images at different intensities and clarity. That means, every monitor has built-in gamma correction in it with certain gamma ranges and so a good monitor automatically corrects all the images displayed on it for the best contrast to give user the best experience. The difference between the log transformation function and the power-law functions is that using the power-law function a family of possible transformation curves can be obtained just by varying the  $\gamma$ . These are the three basic image enhancement functions for grey scale images that can be applied easily for any type of image for better contrast and highlighting. Using the image negation formula given above it is not necessary for the results to be mapped into the grey scale range  $[0, L-1]$ . Output of  $L-1-r$  automatically falls in the range of  $[0, L-1]$ . But for the Log and Power-Law transformations resulting values are often quite distinctive, depending upon control

parameters like  $\gamma$  and logarithmic scales. So the results of these values should be mapped back to the grey scale range to get a meaningful output image. For example, Log function  $s = c \log(1 + r)$  results in 0 and 2.41 for  $r$  varying between 0 and 255, keeping  $c=1$ . So, the range  $[0, 2.41]$  should be mapped to  $[0, L-1]$  for getting a meaningful image.



**Figure 4.8: Plots of equation  $s = cr^\gamma$  for the various value of  $\gamma$**

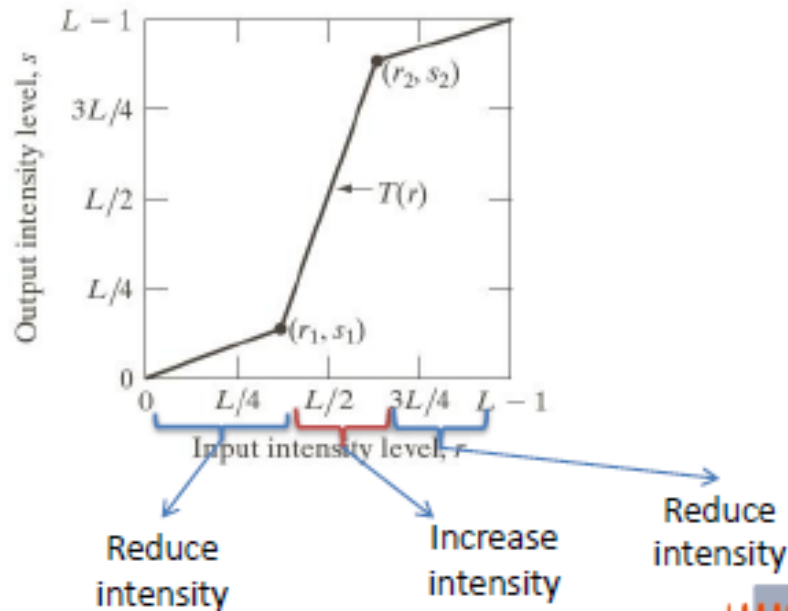


**Figure 4.9: Results of applying the transformation**

## 4.2.5 Contrast Stretching

Contrast stretching is a process that expands the range of intensity levels in an image so that it spans the full intensity range of the recording medium or display device. Contrast stretching (often called normalization) is a simple image enhancement technique that attempts to improve the contrast in an image by 'stretching' the range of intensity values it contains to span a desired range of values, *e.g.* the full range of pixel values that the image type concerned allows. Low contrast images can be due to the poor illumination, lack of dynamic range in the imaging sensor, or due to the wrong setting of the lens. The idea behind

the contrast stretching is to increase the dynamic range of intensity level in the processed image.

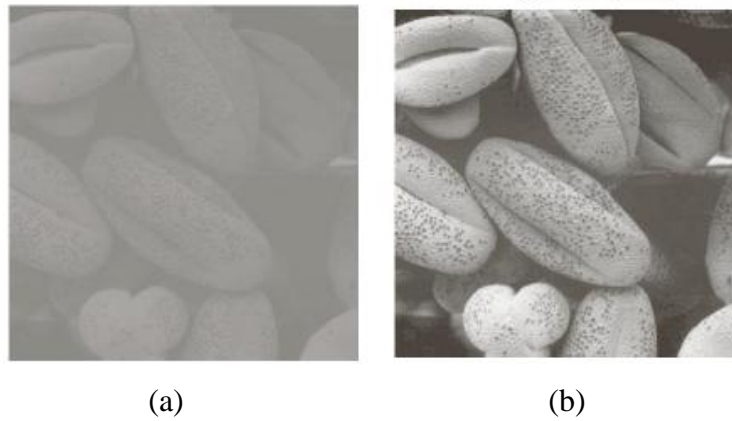


**Figure 4.10: Form of transformation function of contrast stretching**

Before the stretching can be performed it is necessary to specify the upper and lower pixel value limits over which the image is to be normalized. Often these limits will just be the minimum and maximum pixel values that the image type concerned allows. For example for 8-bit gray level images the lower and upper limits might be 0 and 255. Call the lower and the upper limits  $a$  and  $b$  respectively. The simplest sort of normalization then scans the image to find the lowest and highest pixel values currently present in the image. Call these  $c$  and  $d$ . Then each pixel  $P$  is scaled using the following function:

$$P_{out} = (P_{in} - c) \left( \frac{b-a}{d-c} \right) + a \quad (14)$$

Values below 0 are set to 0 and values about 255 are set to 255.

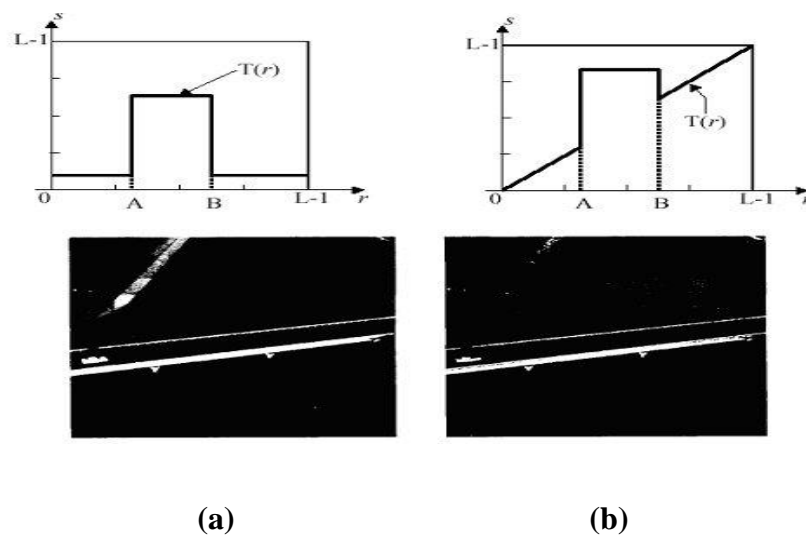


**Figure 4.11 : (a) Low contrast image (b) After contrast stretching**

### 4.2.6 Intensity Level Slicing

Highlighting a specific range of gray-levels in an image is often desired. Applications include enhancing features such as masses of water, crop regions, or certain elevation area in satellite imagery. Another application is enhancing flaws in x-ray. There are two main different approaches:

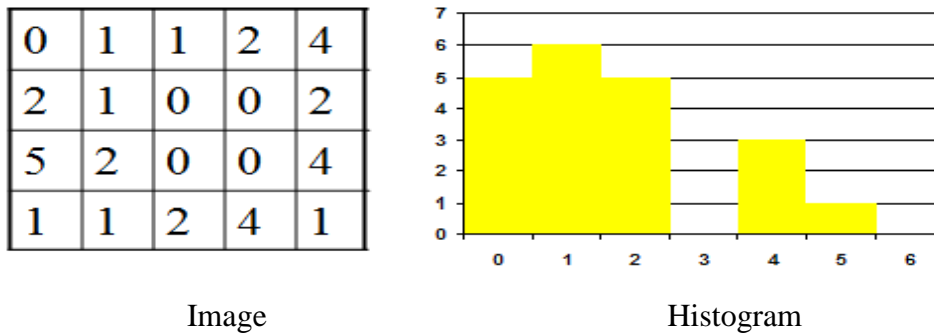
- Highlight a range of intensities while diminishing all others to a constant low level.
- Highlight a range of intensities but preserve all others.



**Figure 4.12 (a) This transformation highlights intensity range [A, B] and reduces all other to lower level (b) This transformation highlights intensity range [A, B] and preserves all**

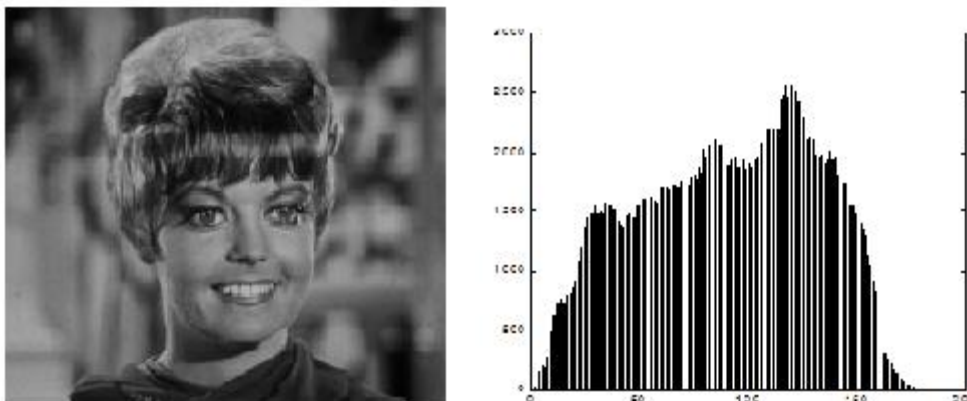
## 4.2.7 Histogram

The (intensity or brightness) histogram shows how many times a particular grey level (intensity) appears in an image. For example, 0 - black, 255 – white.



**Figure 4.13: Histogram**

Histogram of an image represents the relative frequency of occurrence of various gray level in the image.



**Figure 4.14: Histogram of an image**

The horizontal axis of the graph represents the tonal variations, while the vertical axis represents the number of pixels in that particular tone. The left side of the horizontal axis represents the black and dark areas, the middle represents medium grey and the right hand side represents light and pure white areas. The vertical axis represents the size of the area that is captured in each one of these zones. Thus, the histogram for a very bright image with few dark areas and/or shadows will have most of its data points on the right side and center of the graph. Conversely, the histogram for a very dark image will have the majority of its data points on the left side and center of the graph.

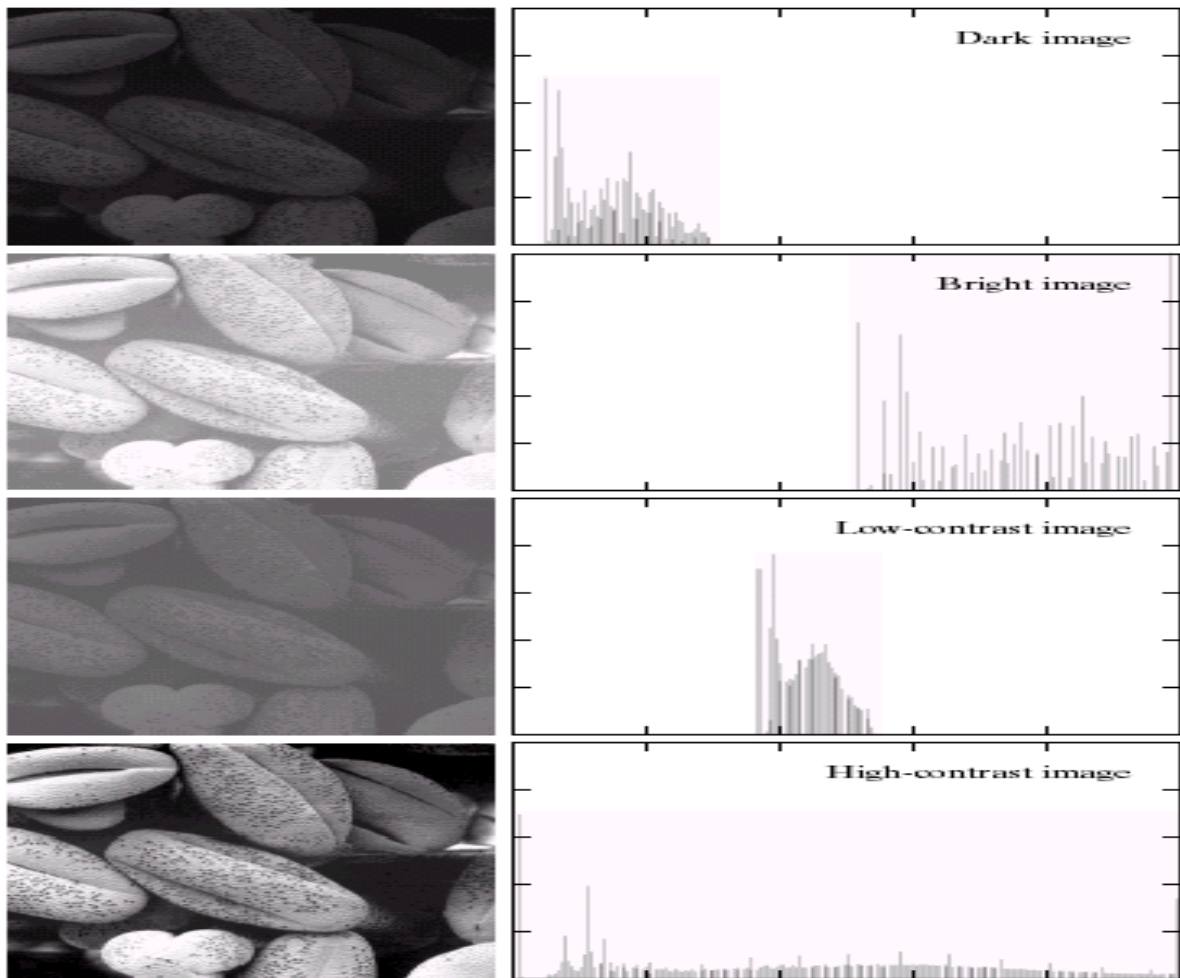


Figure 4.15: Histogram of Various images

#### 4.2.7.1 Histogram Processing

Histogram processing is the act of altering an image by modifying its histogram. Common uses of histogram processing include normalization by which one makes the histogram of an image as flat as possible. This is also known as contrast enhancement.

Intensity transformation functions based on information extracted from image such as enhancement, compression, segmentation and description.

The Histogram of digital image with the intensity levels in the range  $[0, L-1]$  is a discrete function.

$$h(r_k) = n_k \quad (15)$$

Where

- $r_k$  is the intensity value.

- $n_k$  is the number of pixels in the image with intensity  $r_k$ .
- $h(r_k)$  is the histogram of the digital image with Gray Level  $r_k$ .

Histograms are frequently normalized by the total number of pixels in the image. Assuming a  $M \times N$  image, a normalized histogram.

$$p(r_k) = \frac{n_k}{MN}, \quad K = 0, 1, 2, 3, \dots, L-1 \quad (16)$$

is related to probability of occurrence of  $r_k$  in the image.

Where

- $p(r_k)$  gives an estimate of the probability of occurrence of gray level  $r_k$ .
- The Sum of all components of a normalized histogram is equal to 1.

Histograms are Simple to calculate in software and also lend themselves to economic hardware implementations, thus making them a popular tool for real-time image processing.

#### 4.2.7.2 Histogram Processing Techniques

Image enhancement processes consist of a collection of techniques that seek to improve the visual appearance of an image or to convert the image to a form better suited for analysis by a human or machine.

#### 4.2.7.3 Imadjust

Imadjust is inbuilt function in MATLAB.

`J = imadjust(I)`

`J = imadjust(I,[low_in; high_in],[low_out; high_out])`

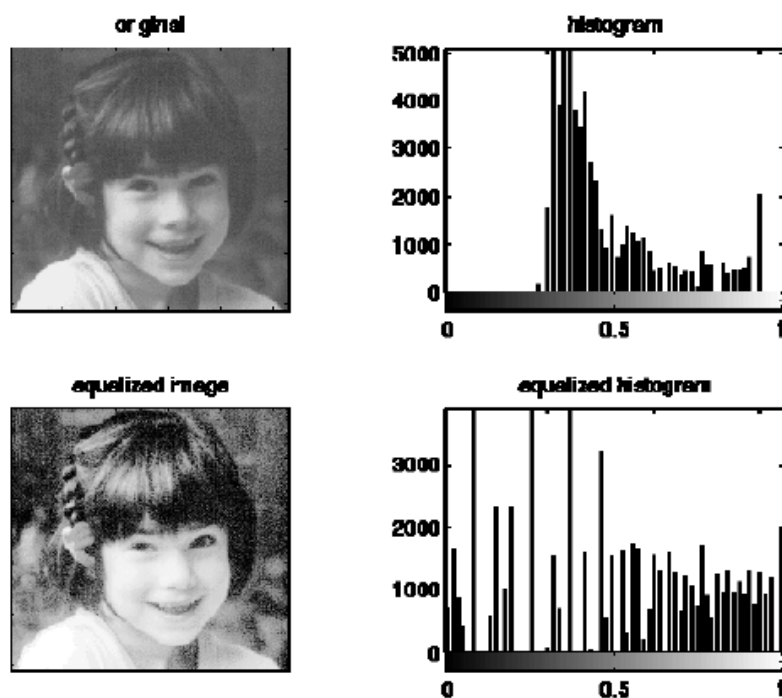
`J = imadjust(I)` maps the intensity values in grayscale image `I` to new values in `J` such that 1% of data is saturated at low and high intensities of `I`. This increases the contrast of the output image `J`. This syntax is equivalent to `imadjust(I,stretchlim(I))`.

`J = imadjust(I,[low_in; high_in],[low_out; high_out])` maps the values in `I` to new values in `J` such that values between `low_in` and `high_in` map to values between `low_out` and `high_out`. Values for `low_in`, `high_in`, `low_out`, and `high_out` must be between 0 and 1. Values below `low_in` and above `high_in` are clipped; that is, values below `low_in` map to `low_out`, and

those above high\_in map to high\_out. You can use an empty matrix ([]) for [low\_in high\_in] or for [low\_out high\_out] to specify the default of [0 1].

#### 4.2.7.4 Histogram Equalization

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.



**Figure 4.16: The original image and its histogram, and the equalized versions. Both images are quantized to 64grey levels.**

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.

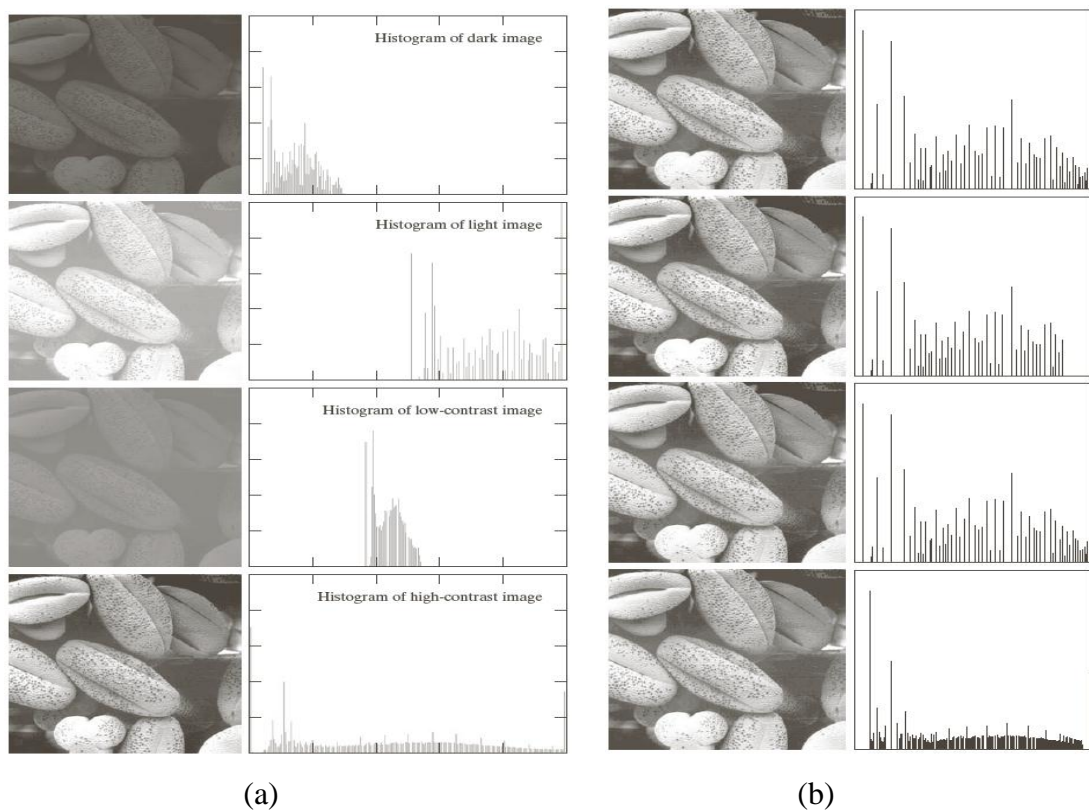
Let  $X=\{X(i,j)\}$  denotes a image composed of L discrete gray levels denotes as

$X = \{X_0, X_1, \dots, X_{L-1}\}$  For a given Image X, the probability density function  $p(X_k)$ .

$$p(X_k) = \frac{n^k}{n} \quad (17)$$

Where

- $K= 0,1,\dots,L-1$
- $n^k$  Represents the number of times that the level  $X_k$  appears in the input image X.
- N Is the total number of samples in the input image.
- $\{P(X_k)\}$  Is associated with the histogram of the input image which represents the number of pixels that have a specific intensity  $X_k$ .



**Figure 4.17: (a) Simple Histogram (b) After applying Histogram equalization**

Based on the probability density function, the cumulative density function is defined as

$$c(x) = \sum_{j=0}^k p(X_j) \quad (18)$$

Where

- $X_k = x$  for  $k=0,1,\dots,L-1$
- $C(X_{L-1}) = 1$  by definition.
- HE is a scheme that maps the input image into the entire dynamic range,  $(X_0, X_{L-1})$  by using the cumulative density function as a transform function.

A transform function  $f(x)$  based on the cumulative density function defined as:

$$f(x) = X_0 + (X_{L-1} - X_0)c(x) \quad (19)$$

Based on information theory, entropy of message source will get the maximum value when the message has uniform distribution property.

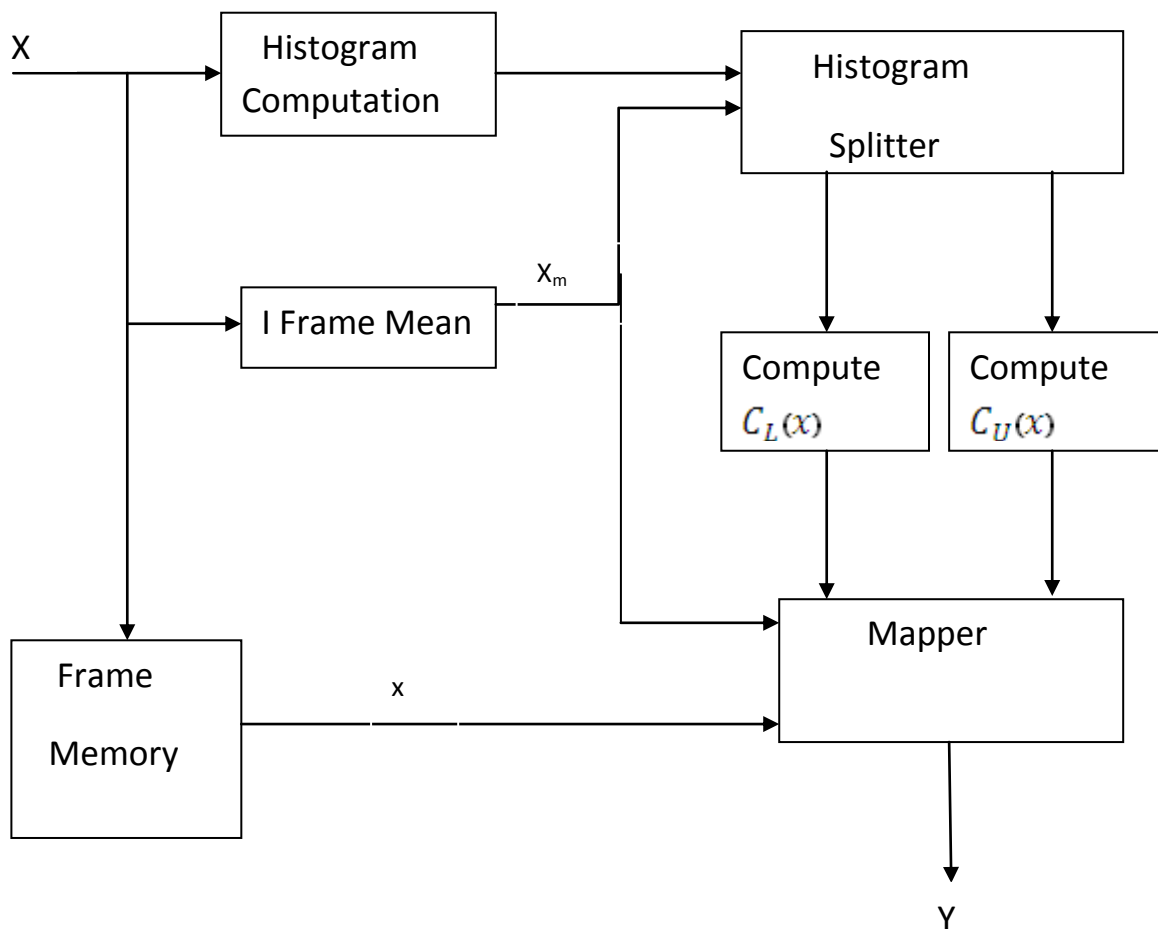
#### 4.2.7.4.1 PROBLEMS IN HISTOGRAM EQUALIZATION

1. The Histogram Equalization method does not take the mean brightness of an image into account.
2. The HE method may result in over enhancement and saturation artefacts due to the stretching of the gray levels over the full gray level range.
3. Histogram equalization can be found on the fact that the brightness of an image can be changed after the histogram equalization.
4. Nevertheless, HE is not commonly used in consumer electronics such as TV because it may significantly change the brightness of an input image and cause undesirable artefacts.
5. It can be observed that the mean brightness of the histogram-equalized image is always the middle gray level regardless of the input mean.

#### 4.2.7.5 Brightness Preserving Bi Histogram Equalization

The Brightness preserving bi histogram equalization firstly decomposes an input image into two sub-images based on the mean of the input image. One of the sub-image is set of samples less than or equal to the mean whereas the other one is the set of samples greater than the mean. Then the BBHE equalizes the sub-images independently based on their respective

histograms with the constraint that the samples in the formal set are mapped into the range from the minimum gray level to the input mean and the samples in the latter set are mapped into the range from the mean to the maximum gray level. Means one of the sub image is equalized over the range up to the mean and the other sub-image is equalized over the range from the mean based on the respective histograms. Thus, the resulting equalized sub-images are bounded by each other around the input mean, which has an effect of preserving mean brightness.



**Figure 4.18 Block Diagram**

In this the computation unit counts and store the respective number of occurrences  $n_k$  for  $k=0,1,\dots,L-1$  the Histogram Splitter the splits the number of occurrences as  $(n_0, n_1, \dots, n_m)$  and respectively and where the mapped outputs  $Y(i, j)$ . The computation of Histogram and the mean typically need to be done during one frame period, thus a frame memory to store the image being processed is necessary.

#### **4.7.2.6 Adaptive Histogram Equalization (AHE)**

It is used to improve contrast in images. It differs from ordinary histogram equalization in the respect that the adaptive method computes several histograms, each corresponding to a distinct section of the image, and uses them to redistribute the lightness values of the image. Ordinary histogram equalization simply uses a single histogram for an entire image. 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.

#### **4.2.7.7 Contrast Limited Adaptive Histogram Equalization (CLAHE)**

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. The neighboring tiles are then combined using bilinear interpolation to eliminate artificially induced boundaries. The contrast, especially in homogeneous areas, can be limited to avoid amplifying any noise that might be present in the image. CLAHE was originally developed for medical imaging and has proven to be successful for enhancement of low-contrast images such as portal films.

The CLAHE algorithm partitions the images into contextual regions and applies the histogram equalization to each one. This evens out the distribution of used grey values and thus makes hidden features of the image more visible. The full grey spectrum is used to express the image. Contrast Limited Adaptive Histogram Equalization, CLAHE, is an improved version of AHE, or Adaptive Histogram Equalization, both overcome the limitations of standard histogram equalization. A variety of adaptive contrast-limited histogram equalization techniques (CLAHE) are provided. Sharp field edges can be maintained by selective enhancement within the field boundaries. Selective enhancement is accomplished by first detecting the field edge in a portal image and then only processing

those regions of the image that lie inside the field edge. Noise can be reduced while maintaining the high spatial frequency content of the image by applying a combination of CLAHE, median filtration and edge sharpening. This technique known as Sequential processing can be recorded into a user macro for repeat application at any time. A variation of the contrast limited technique called adaptive histogram clip (AHC) can also be applied. AHC automatically adjusts clipping level and moderates over enhancement of background regions of portal images.

## PROBLEM FORMULATION

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“Once you get the right image the details aren't that important”

Abbie Hoffman

### 5.1 DESIGN METHODOLOGY

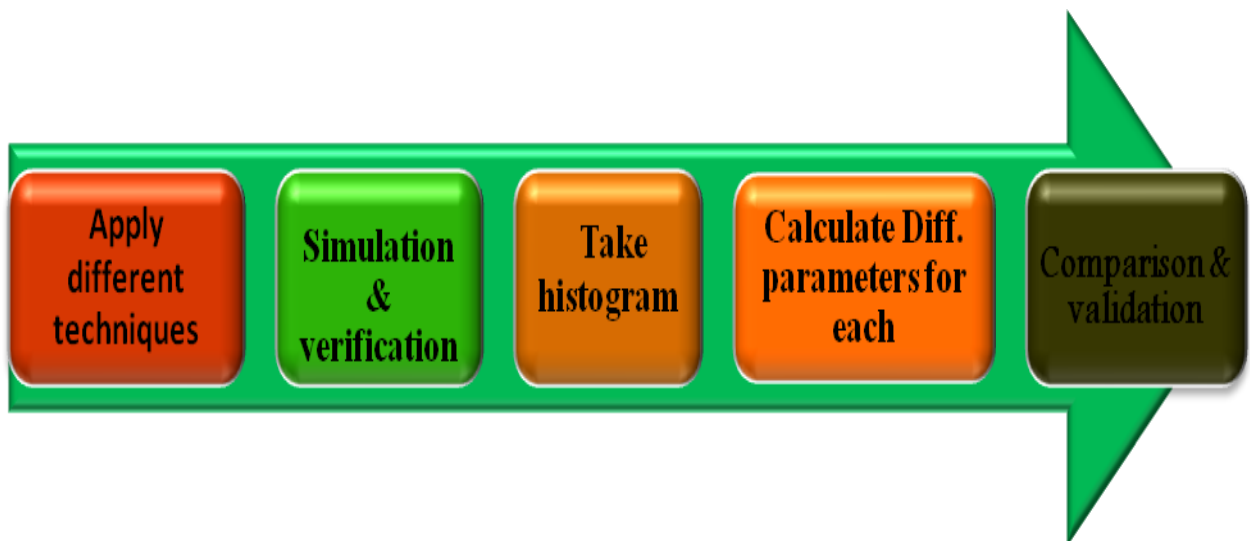


Figure 5.1 : Design methodology of problem

Design Methodology involves:-

1. Apply different techniques like Imadjust, Histogram equalization, Adaptive Histogram equalization, Brightness preserving bi-histogram equalization on grayscale image, colour image, grayscale and colour image with noise.
2. Take histogram of selected image after applying different techniques.
3. Calculate the value of different parameters like PSNR, MSE ,LMSE, RMSE and NCC.
4. Based on these, results compare results.
  - A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So, having a lower MSE (and a high

PSNR),it is a better one. For grayscale image BBHE (Brightness Preserving Bi-Histogram Equalization Technique) has the lowest RMSE and highest PSNR. High PSNR means less noise in image and Low value of RMSE indicates good contrast. Hence BBHE gives best result for grayscale image.

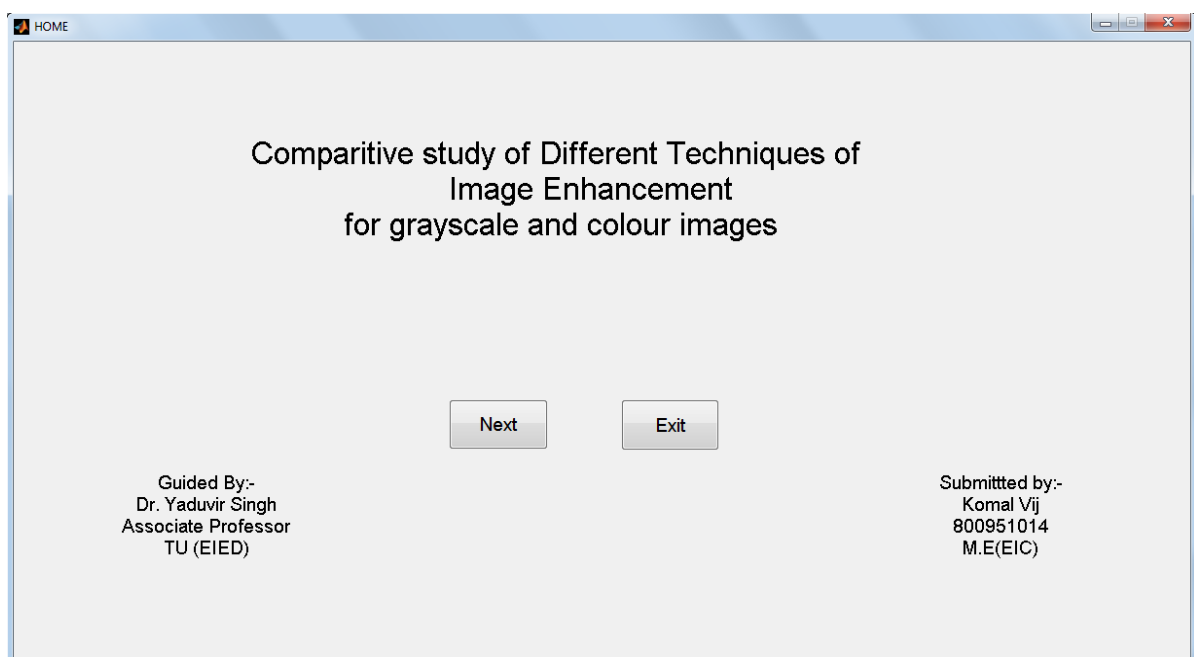
- If RMSE approaches zero,it should be in very good contrast.
- The correlation ratio ranges from 0 for very good image to 1 for very bad image.

## 5.2 Proposed Work

In GUI, steps followed are:-

### 5.2.1 Welcome Screen

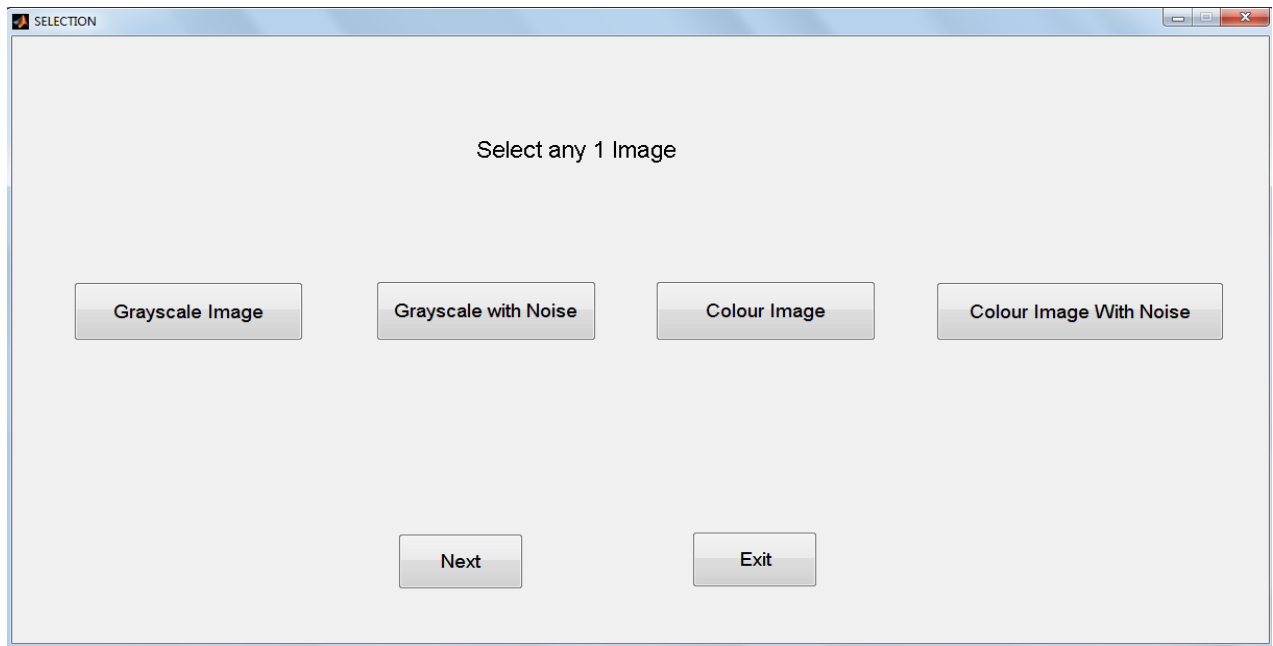
This is the welcome screen of the project .On clicking 'NEXT', the screen for selecting the one of the four types of images will be displayed. If user wants to close the application at this time then he can click the 'EXIT' button.



**Figure 5.2: Welcome Screen**

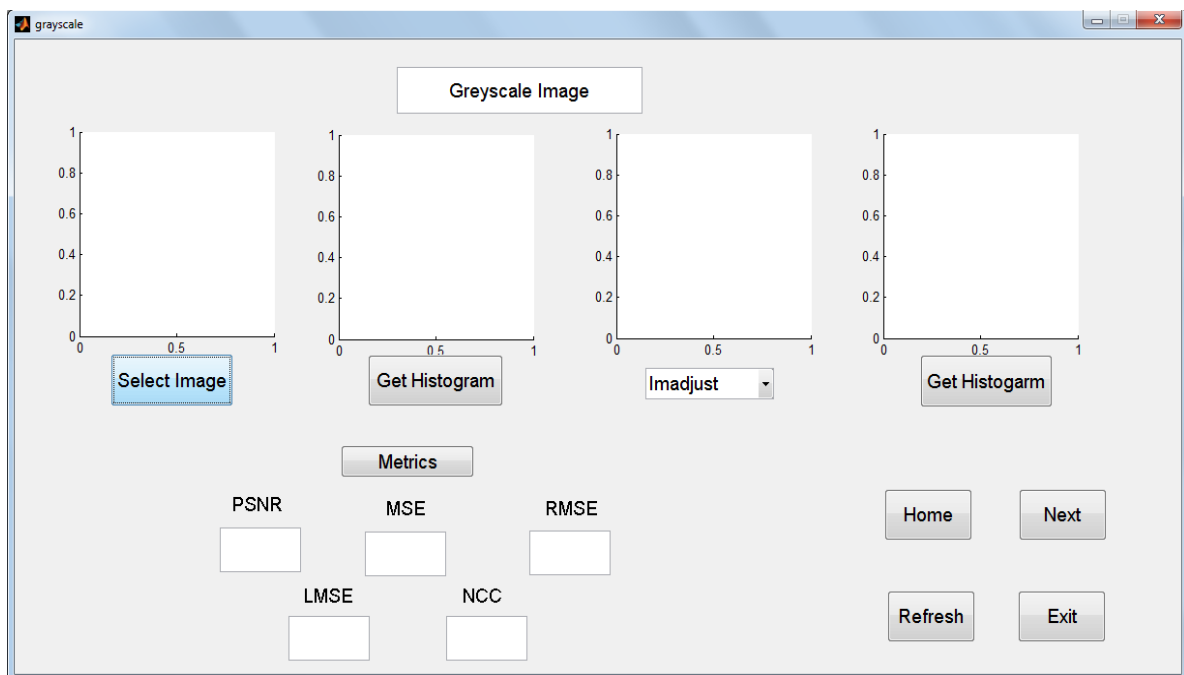
**5.2.2 Selection Screen:-** On clicking the 'NEXT' button ,selection screen comes. Select any one of the four types of images. Clicking on 'NEXT', the screen for grayscale image will be displayed. If user wants to close the application at this time then he can click the 'EXIT'

button.



**Figure 5.3: Selection Screen**

**5.2.3 Screen for Grayscale Image:-** Clicking on 'NEXT', the screen for grayscale image with noise will be displayed. If user wants to close the application at this time then he can click the 'EXIT' button. On clicking the 'Home' button, the previous form i.e. selection screen will be opened again. Results for all types of images will discussed in next chapter.



**Figure 5.4: Grayscale image Screen**

## RESULTS AND DISCUSSIONS

“It's much easier to consume the visual image than to read something”

Lawrence Ferlinghetti

Following are the results of different parameters for various techniques for four different types of images i.e. Grayscale Image, Grayscale image with noise, Colour Image and Colour Image with Noise.

### 6.1 Select Image For Grayscale Image

On clicking ‘Select Image’ button the following dialog box will be displayed. After selecting an image, the selected image will be shown in the desired axes as shown below.

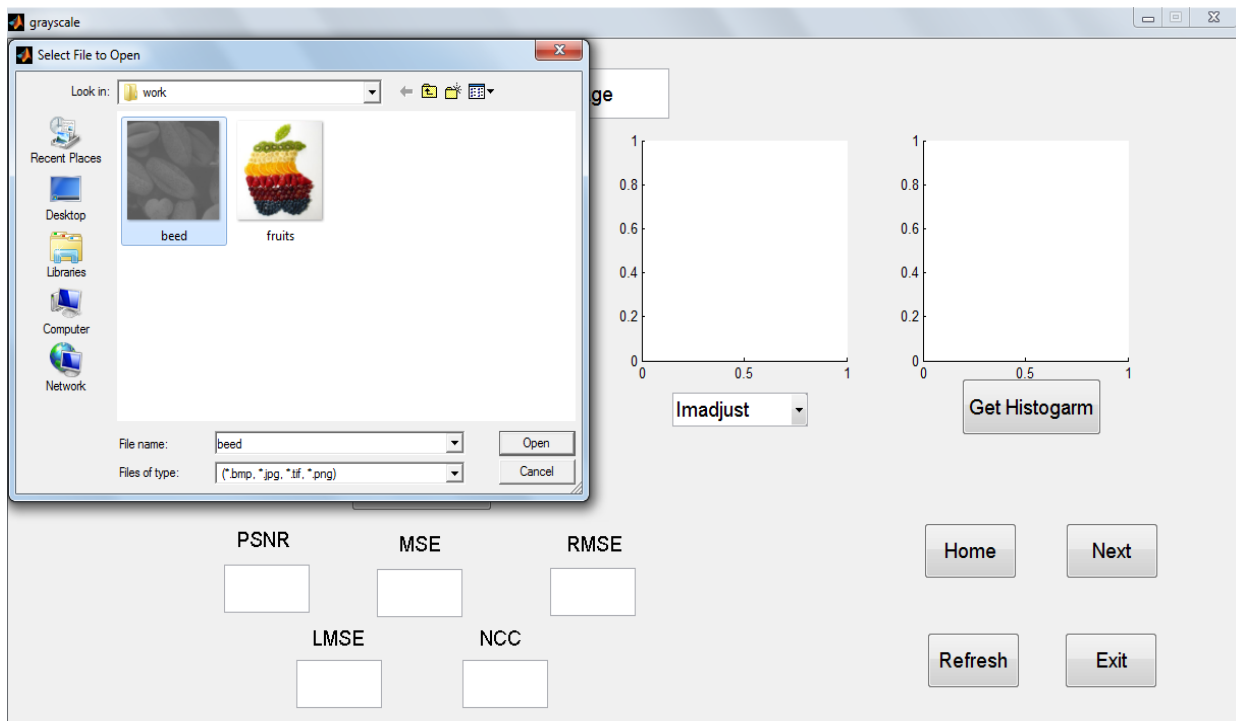
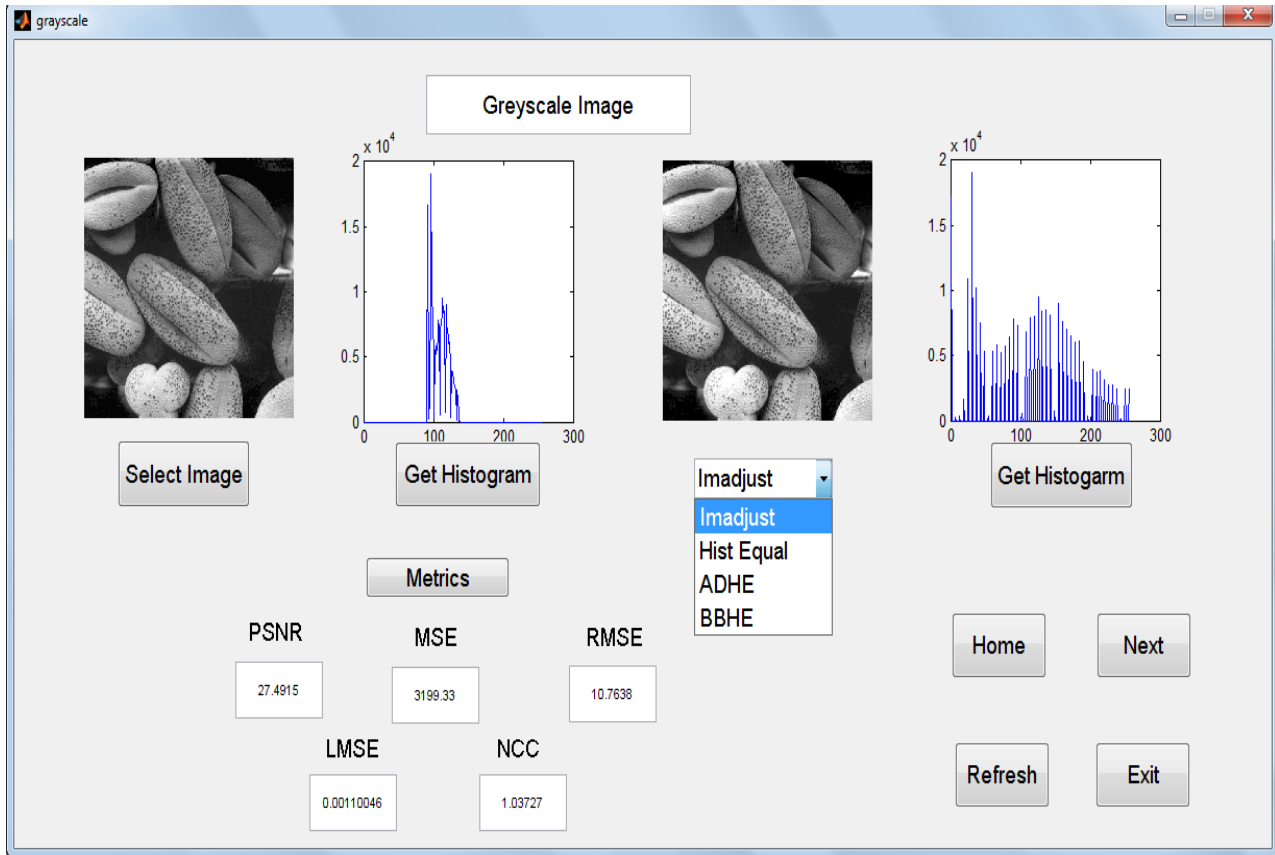


Figure 6.1: Select Image for grayscale image

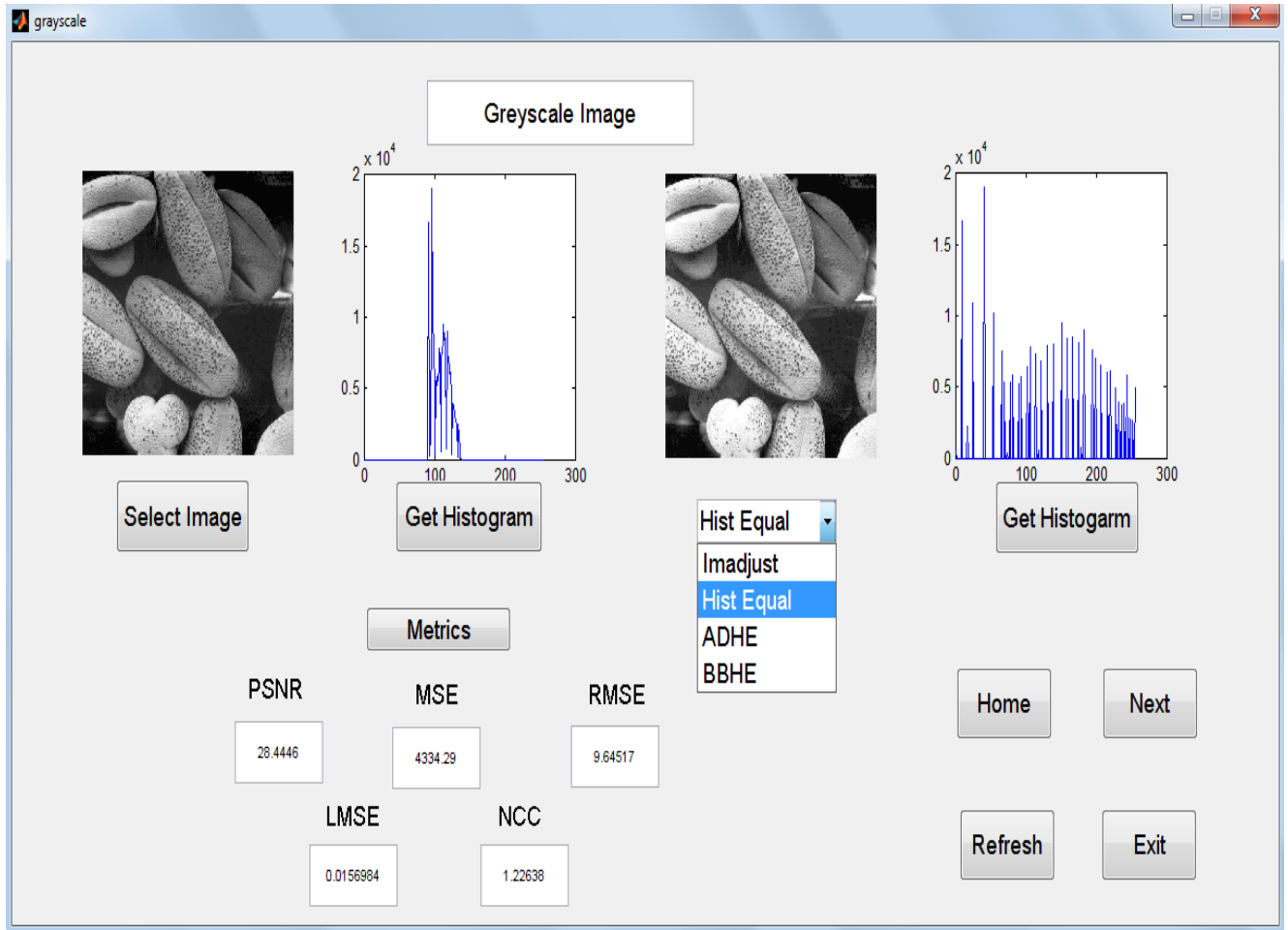
**6.1.1 Imadjust for Grayscale Image:-** ‘Get Histogram’ button the following screen will appear. The histogram will be shown in the desired axes as shown below. Now apply Imadjust contrast enhancement technique on the original Image so that we can get enhanced image. Click

on 'Get Histogram' button to get the Histogram of the Image after the application of the Imadjust Contrast Enhancement Technique. We now check for the PSNR, MSE, RMSE, LMSE, NCC values. On clicking the 'Metrics' button we will get the following values in the following Edit controls.



**Figure 6.2: Imadjust for grayscale image**

**6.1.2 Histogram equalization for Grayscale Image:-** After selecting an image, the selected image will be shown in the desired axes as shown below. Clicking 'Get Histogram', the histogram will be shown in the desired axes as shown below. Now from the popup menu, apply histogram equalization contrast enhancement technique on the original Image so that we can get enhanced image. Click on 'Get Histogram' button to get the Histogram of the Image after the application of the Histogram Equalization Contrast Enhancement Technique. We now check for the PSNR, MSE, RMSE, LMSE, NCC values. On clicking the 'Metrics' button we will get the following values in the following Edit controls.



**Figure 6.3: Histogram equalization for grayscale image**

**6.1.3 ADHE for Grayscale Image:-** After selecting an image, the selected image will be shown in the desired axes as shown below. Clicking ‘Get Histogram’, the histogram will be shown in the desired axes as shown below. Now from the popup menu, apply Adaptive histogram equalization enhancement technique on the original Image so that we can get enhanced image. Click on ‘Get Histogram’ button to get the Histogram of the Image after the application of the Histogram Equalization Contrast Enhancement Technique. We now check for the PSNR, MSE, RMSE, LMSE, NCC values. On clicking the ‘Metrics’ button we will get the following values in the following Edit controls.

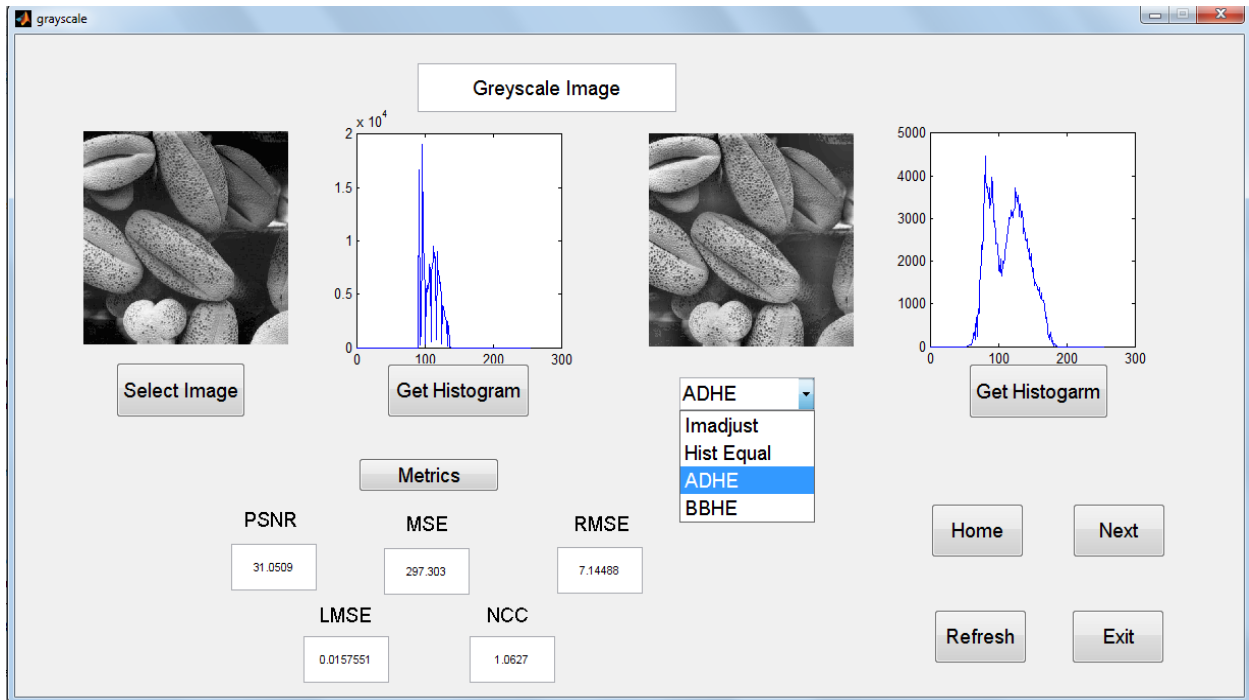


Figure 6.4: ADHE for grayscale image

### 6.1.4 BBHE for Grayscale Image

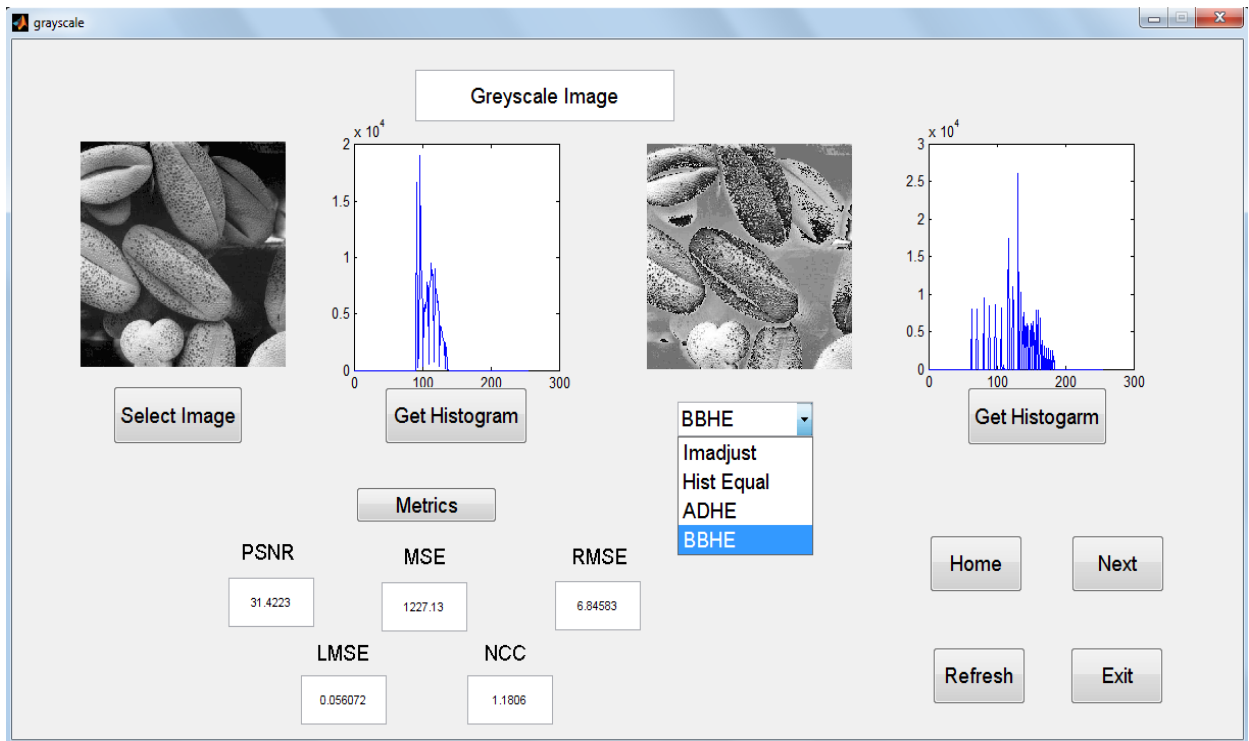
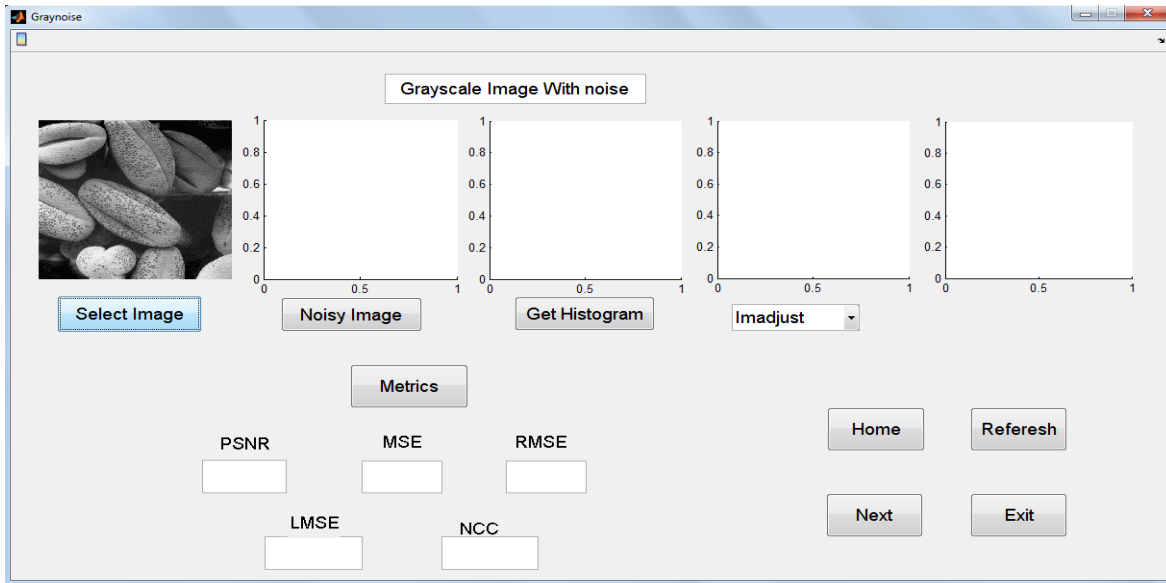


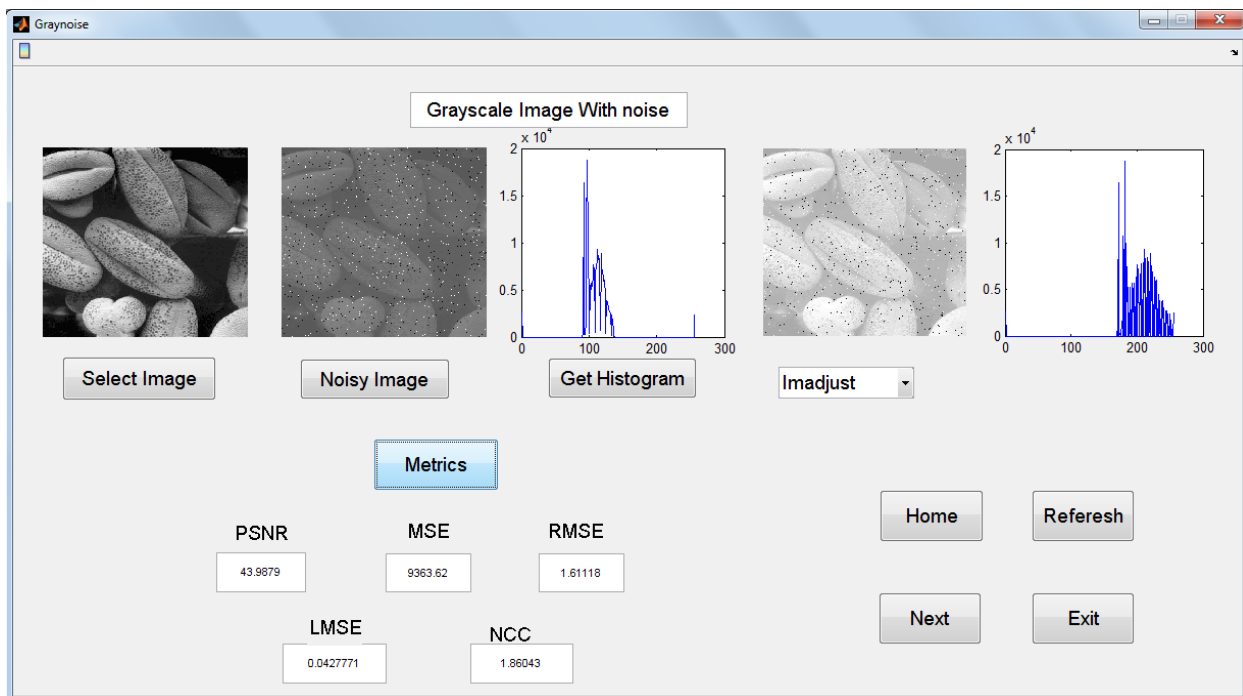
Figure 6.5: BBHE for grayscale image

**6.2 Select Image for Grayscale Image with Noise:-**Clicking the ‘NEXT’ button on grayscale image, the screen for grayscale image with noise will be displayed. If user wants to close the application at this time then he can click the ‘EXIT’ button. On clicking the ‘Home’ button, the previous form i.e. selection screen will be opened again. Select image for this.



**Figure 6.6: Select image for grayscale image with noise Screen**

### 6.2.1 Imadjust for Grayscale Image with Noise



**Figure 6.7: Imadjust for grayscale image with noise**

## 6.2.2 Histogram Equalization for Grayscale Image with Noise

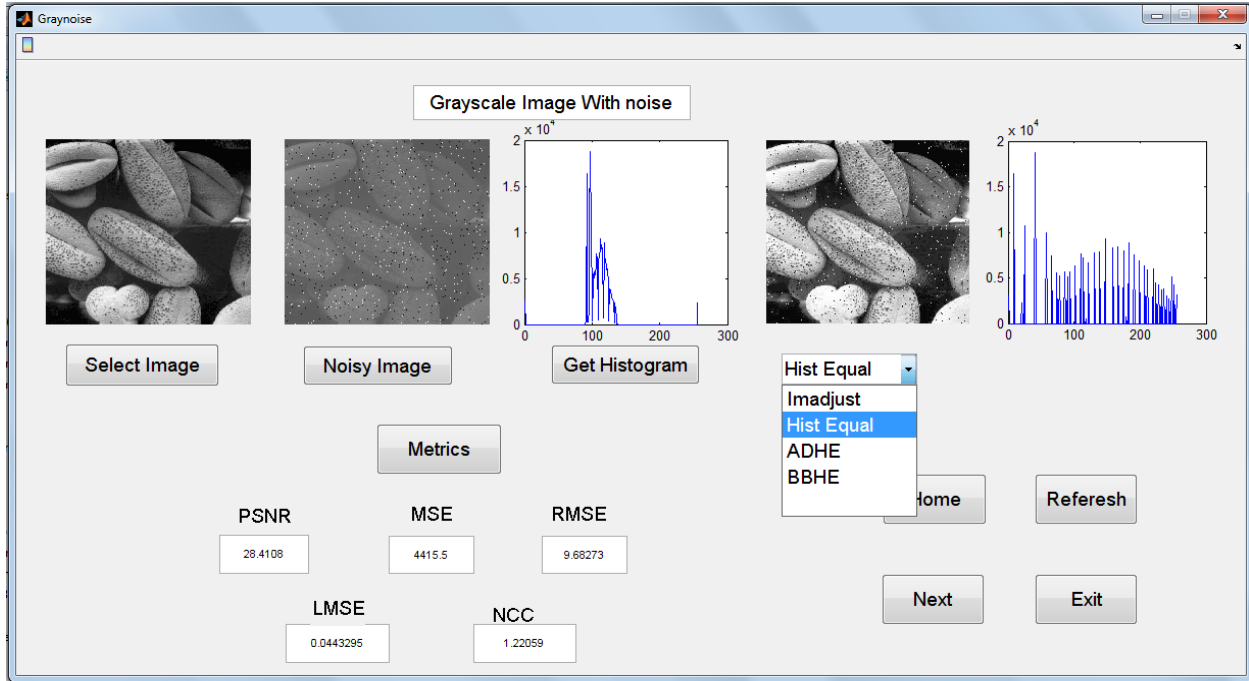


Figure 6.8: histogram equalization for grayscale image with noise

## 6.2.3 ADHE for Grayscale Image with Noise

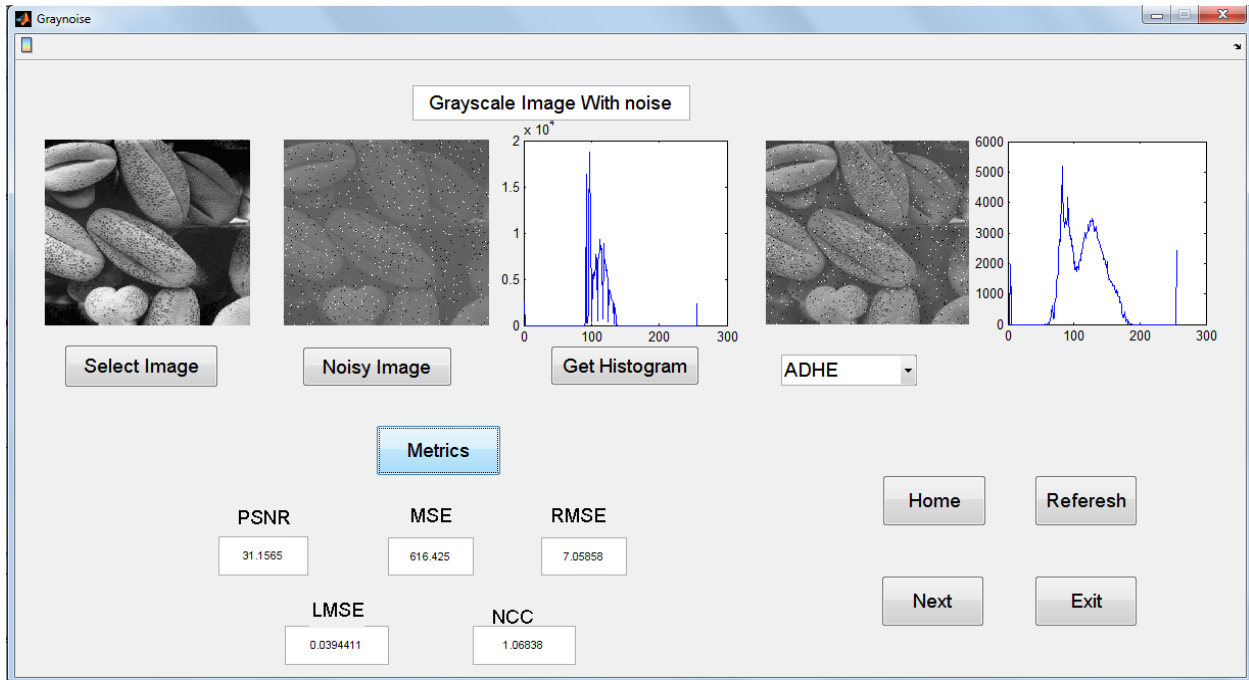


Figure 6.9: ADHE for grayscale image with noise

## 6.2.4 BBHE for Grayscale Image with Noise

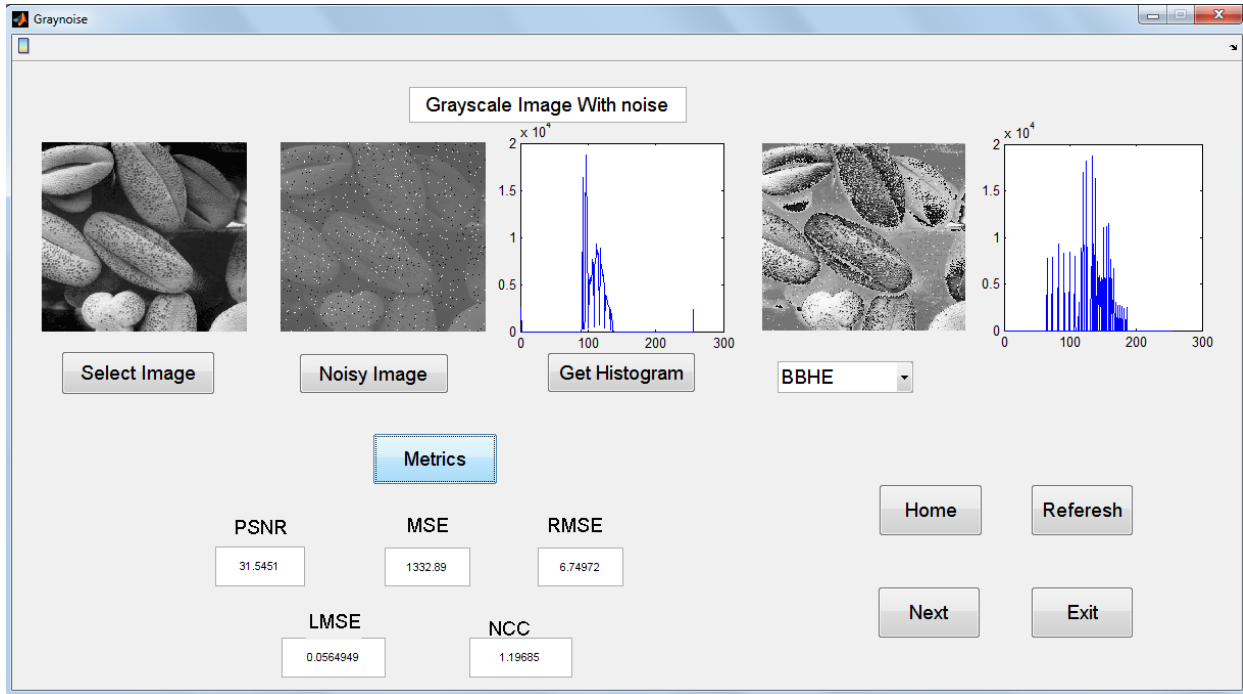


Figure 6.10: BBHE for grayscale image with noise

## 6.3 Select image for Color Image

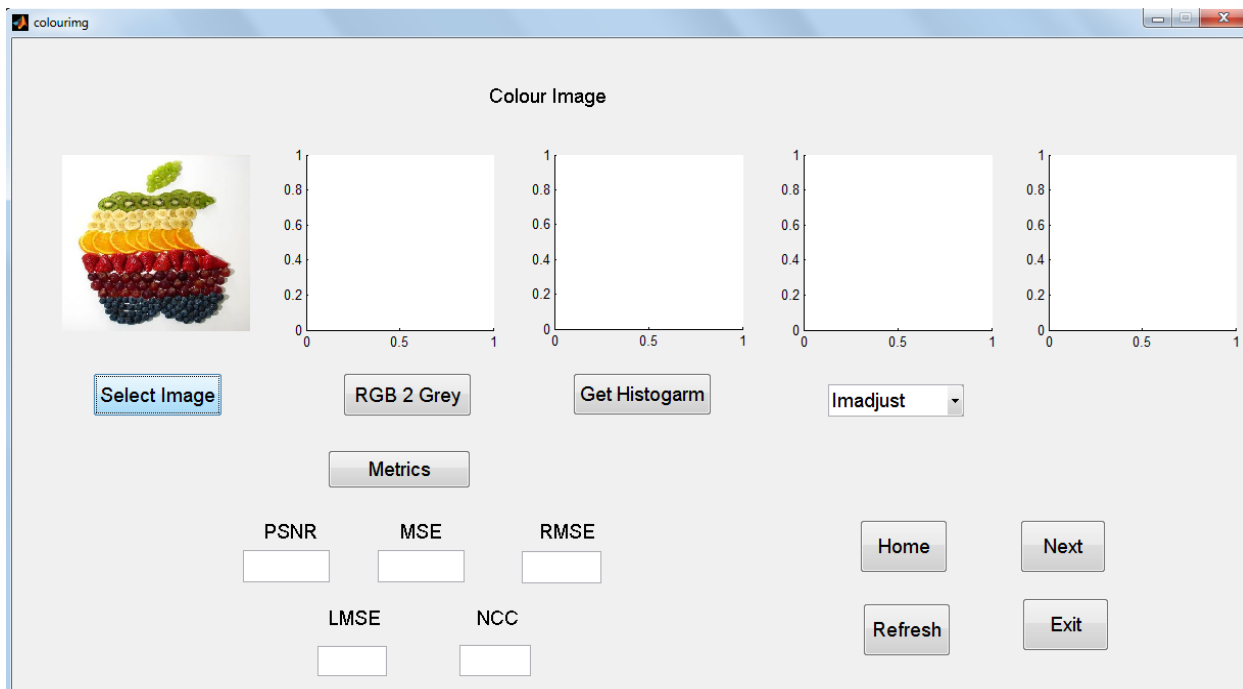


Figure 6.11: Select Image for Color image

### 6.3.1 Imadjust for Color Image

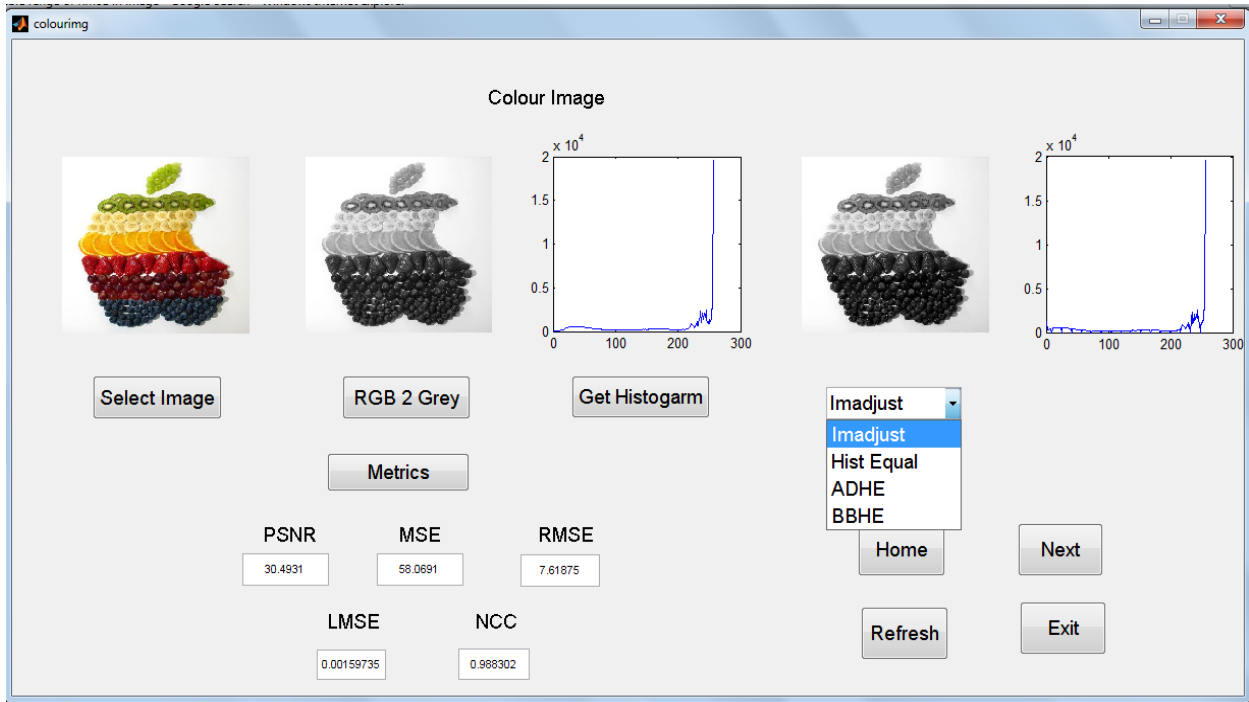


Figure 6.12: Imadjust for Color image

### 6.3.2 Histogram Equalization for Color Image

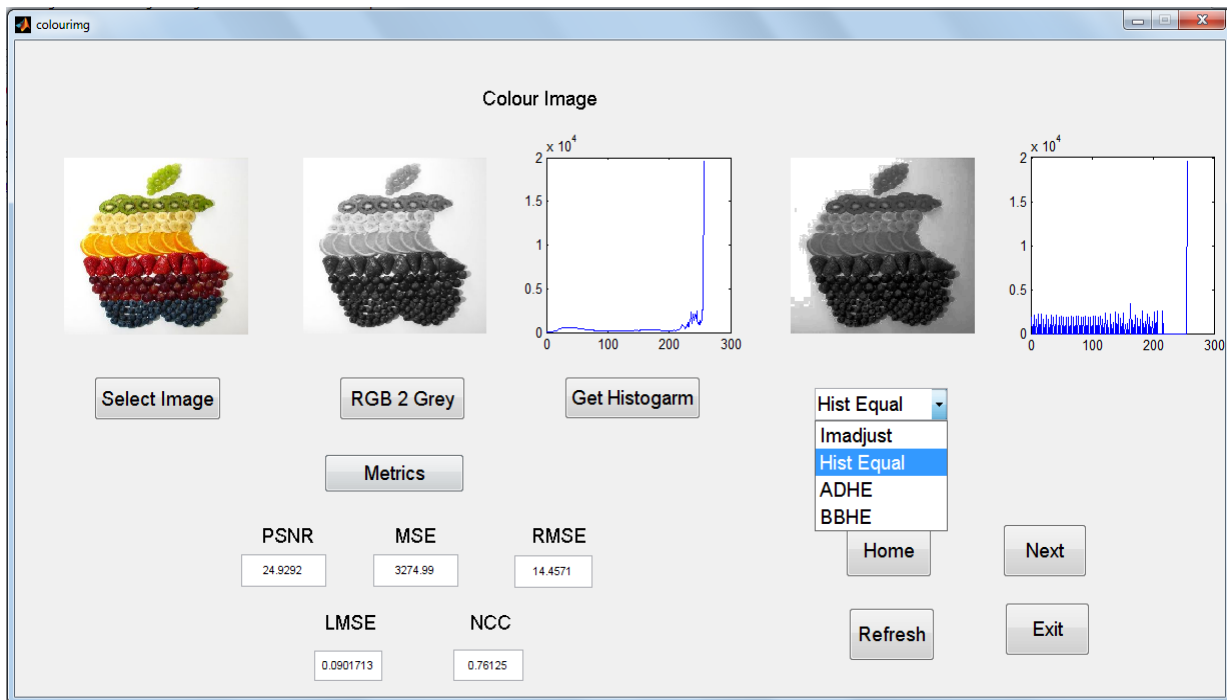


Figure 6.13: Histogram Equalization for Color image

### 6.3.3 ADHE for Color Image

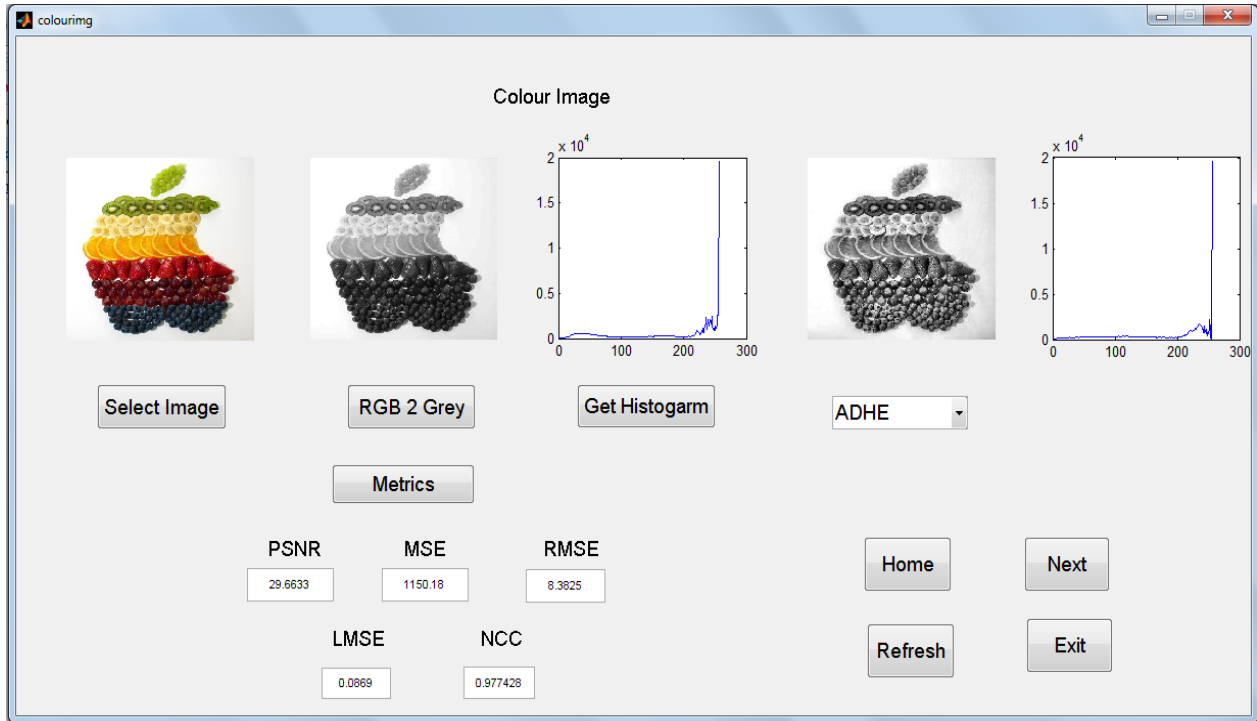


Figure 6.14: ADHE for Color image

### 6.3.4 BBHE for Color Image

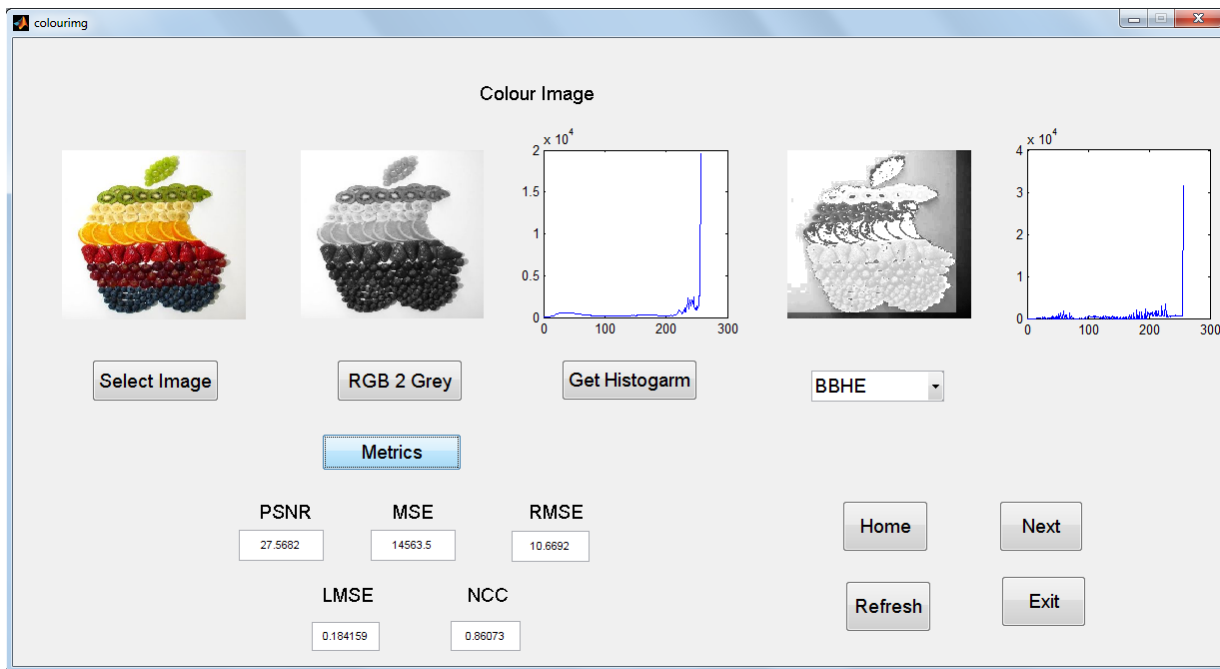


Figure 6.15: BBHE for Color image

## 6.4 Select image for Color Image with Noise

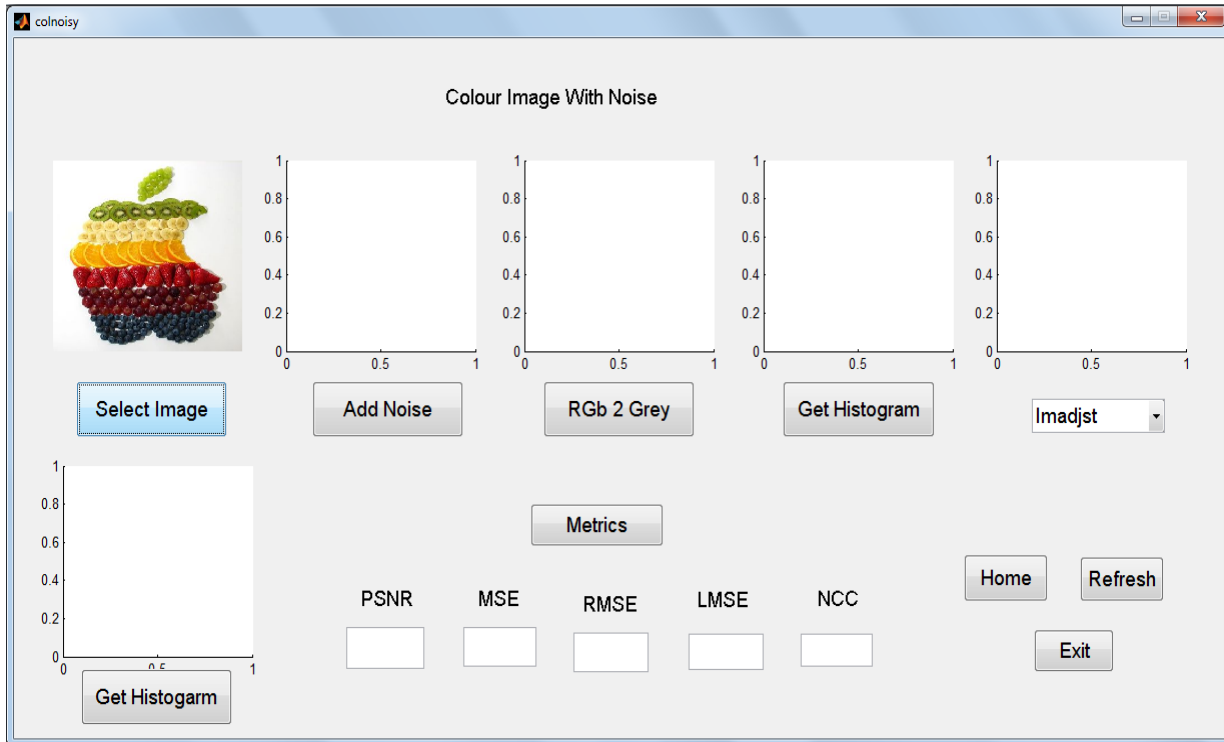


Figure 6.16: Select image for Color image with noise Screen

### 6.4.1 Imadjst for Color Image with Noise

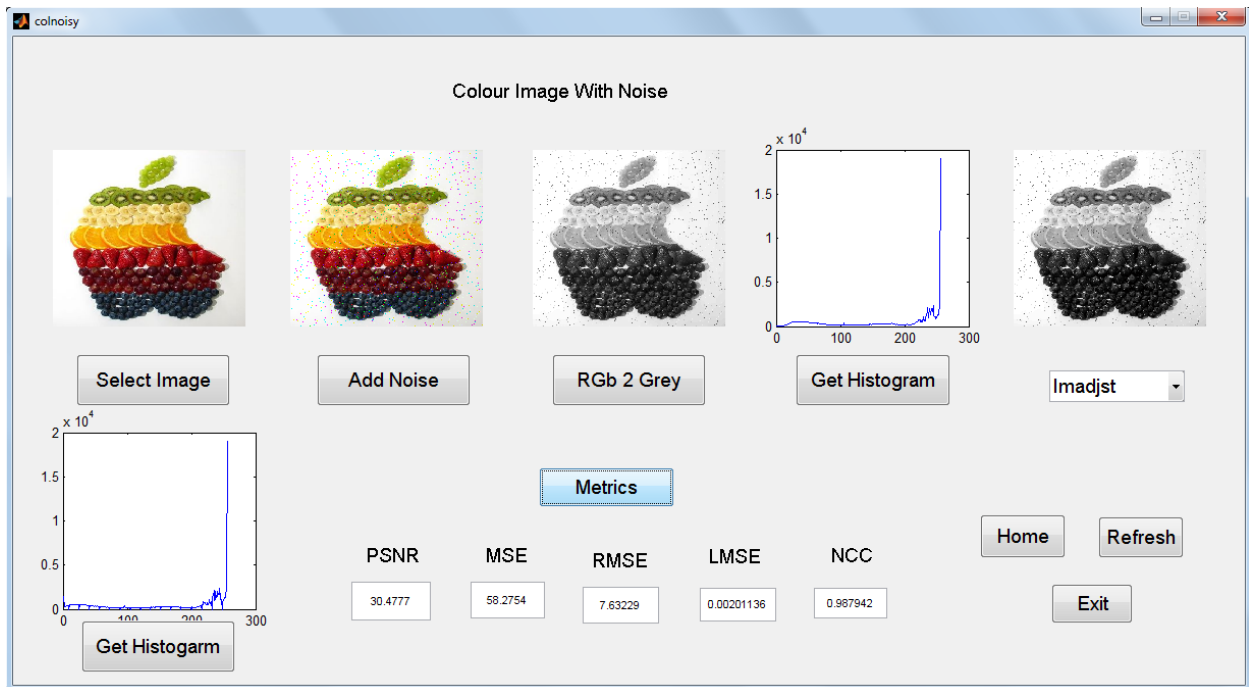


Figure 6.17: Imadjst for Color image with noise

## 6.4.2 Histogram Equalization for Color Image with Noise

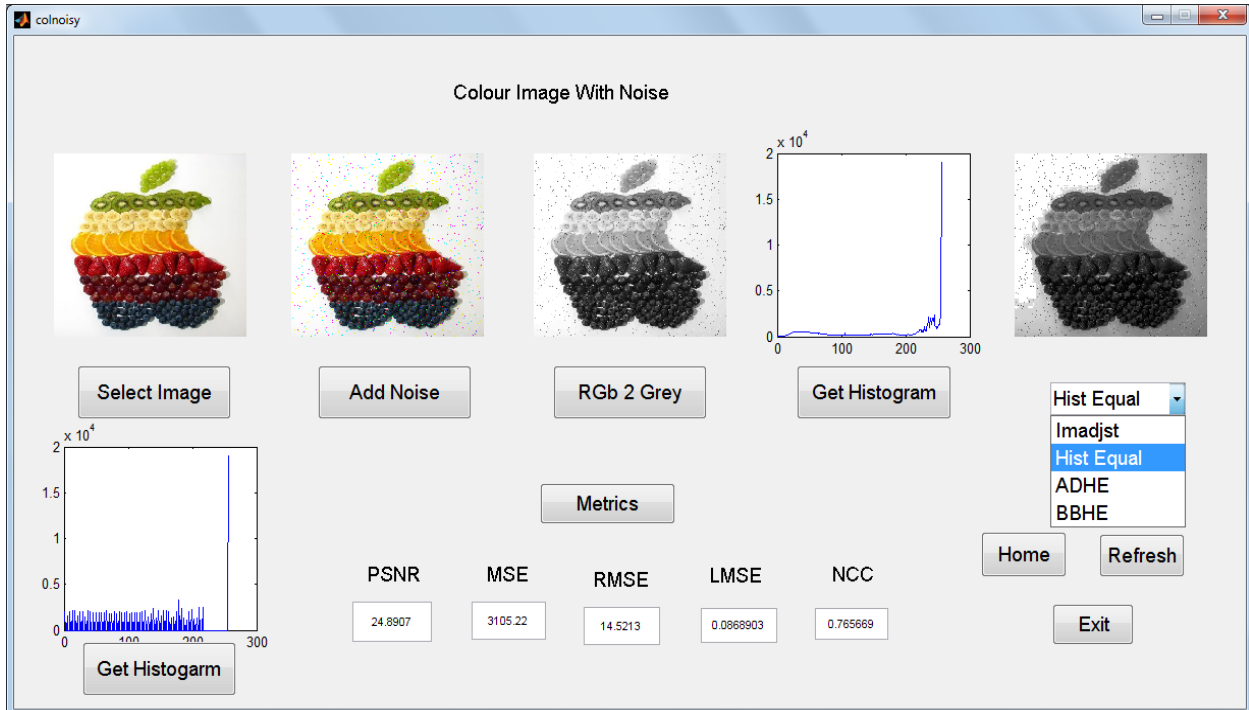


Figure 6.18: Histogram Equalization for Color image with noise

## 6.4.3 ADHE for Color Image with Noise

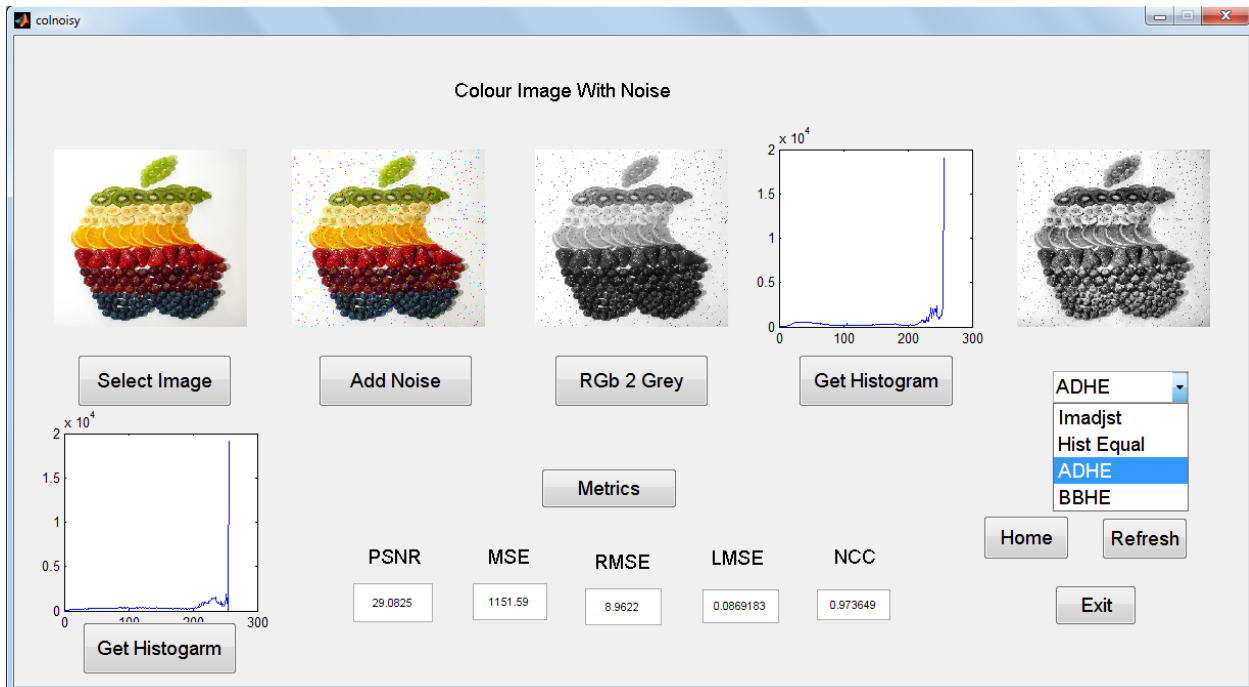


Figure 6.19: ADHE for Color image with noise

## 6.4.4 BBHE for Color Image with Noise

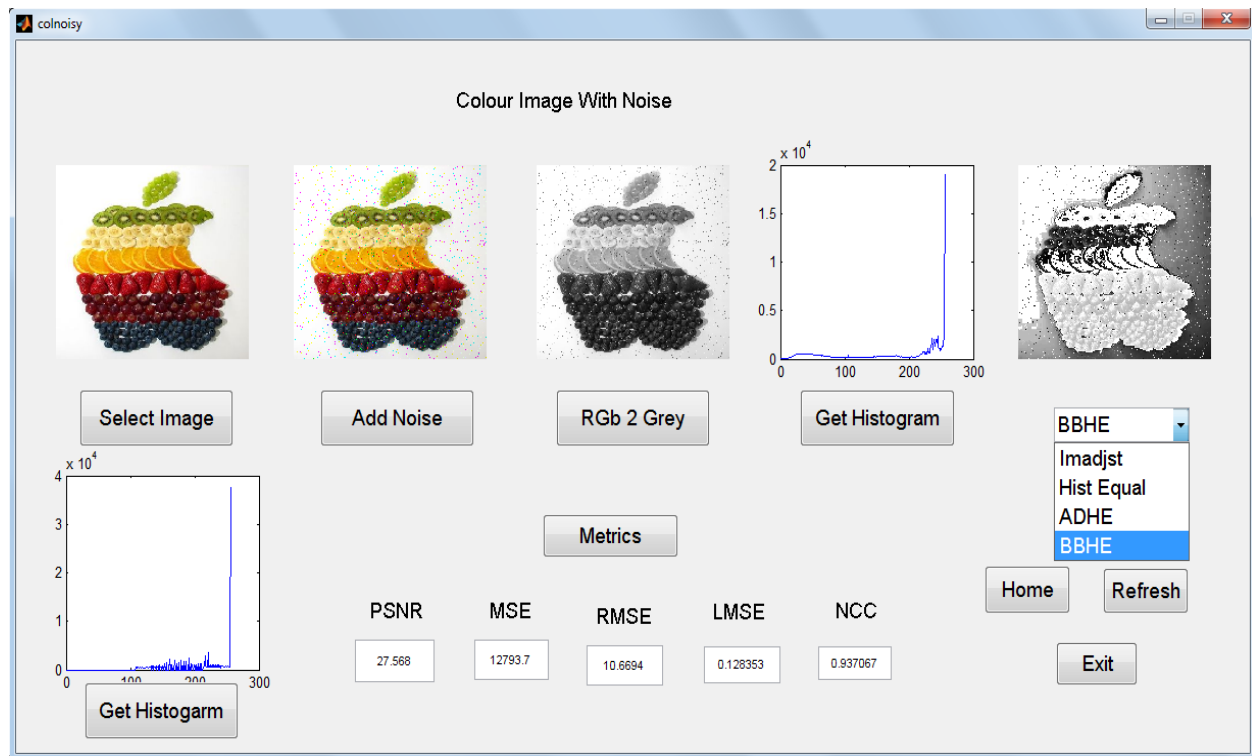


Figure 6.20: BBHE for Color image with noise

## 6.5 Based on following, results calculate:-

- A lower value for MSE means lesser error, and as seen from the inverse relation between the MSE and PSNR, this translates to a high value of PSNR. Logically, a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. Here, the 'signal' is the original image, and the 'noise' is the error in reconstruction. So, having a lower MSE (and a high PSNR), it is a better one. For grayscale image BBHE (Brightness Preserving Bi-Histogram Equalization Technique) has the lowest RMSE and highest PSNR. High PSNR means less noise in image and Low value of RMSE indicates good contrast. Hence BBHE gives best result for grayscale image.
- If RMSE approaches zero, it should be in very good contrast.
- The correlation ratio ranges from 0 for very good image to 1 for very bad image.

**Table 6.1: For grayscale image**

	<b>PSNR</b>	<b>MSE</b>	<b>RMSE</b>	<b>LMSE</b>	<b>NCC</b>
<b>Imadjust</b>	27.4915	3149.33	10.7638	0.00110	1.03727
<b>HE</b>	28.4446	4334.29	9.64517	0.01569	1.22638
<b>AHE</b>	31.0509	2973.03	7.14488	0.15755	1.0627
<b>BBHE</b>	31.4233	1227.13	6.8458	.056072	1.0206

BBHE has high PSNR value and Less value of MSE. Lower value for MSE means lesser error and a higher value of PSNR is good because it means that the ratio of Signal to Noise is higher. As PSNR is high, noise is less. Value of LMSE Lies between 0-1.

**Table 6.2: For grayscale image with noise**

	<b>PSNR</b>	<b>MSE</b>	<b>RMSE</b>	<b>LMSE</b>	<b>NCC</b>
<b>Imadjust</b>	43.9879	363.62	1.61118	0.04277	1.06043
<b>HE</b>	28.4108	4415.5	9.68273	0.04432	1.22059
<b>AHE</b>	31.1565	616.425	7.05858	0.03944	1.06838
<b>BBHE</b>	31.5451	1332.89	6.74972	0.06564	1.19685

Imadjust has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others i.e. image is good in contrast. Value of NCC is also good, which indicates good image after enhancement with Imadjust.

**Table 6.3: For color image**

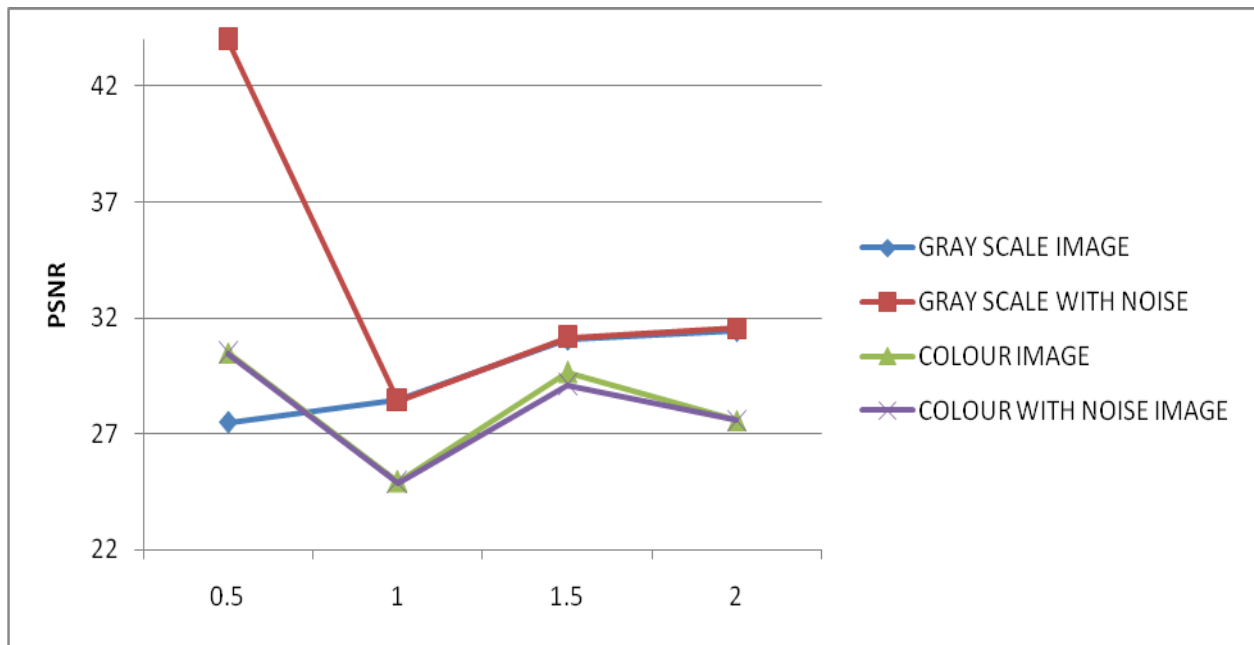
	<b>PSNR</b>	<b>MSE</b>	<b>RMSE</b>	<b>LMSE</b>	<b>NCC</b>
<b>Imadjust</b>	30.4931	58.0691	7.61875	.00519735	.0988302
<b>HE</b>	24.9292	3274.99	14.4571	0.0901713	0.76125
<b>ADHE</b>	29.6633	1150.18	8.3825	0.0869	0.977428
<b>BBHE</b>	27.5682	14563.5	10.6692	0.184159	.86073

Imadjust has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others i.e. image is good in contrast. Value of NCC is also good, which indicates good image after enhancement with Imadjust.

**Table 6.4: Color image with noise**

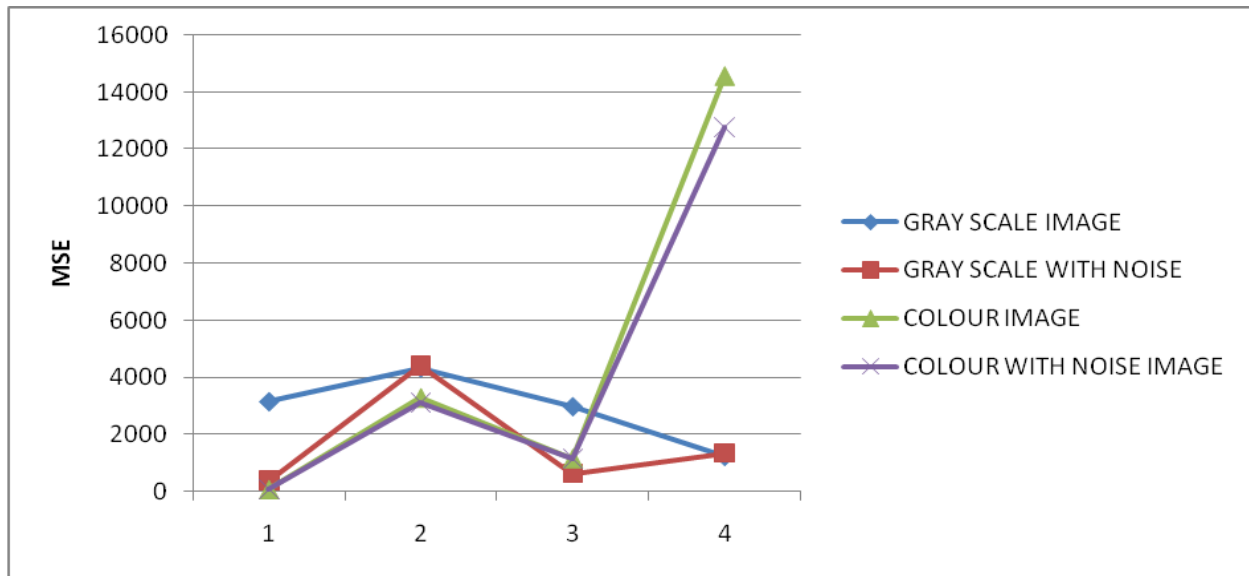
	PSNR	MSE	RMSE	LMSE	NCC
<b>Imadjust</b>	30.4778	58.2754	7.63229	.0020136	.987942
<b>HE</b>	24.8907	3105.22	14.5213	.0868903	.765664
<b>AHE</b>	29.0825	1151.59	8.9622	.08691	.97364
<b>BBHE</b>	27.5681	12793.7	10.6694	.128353	.937067

Imadjust has high PSNR value and Less value of MSE Value of RMSE is also very less from all others i.e. image is good in contrast.



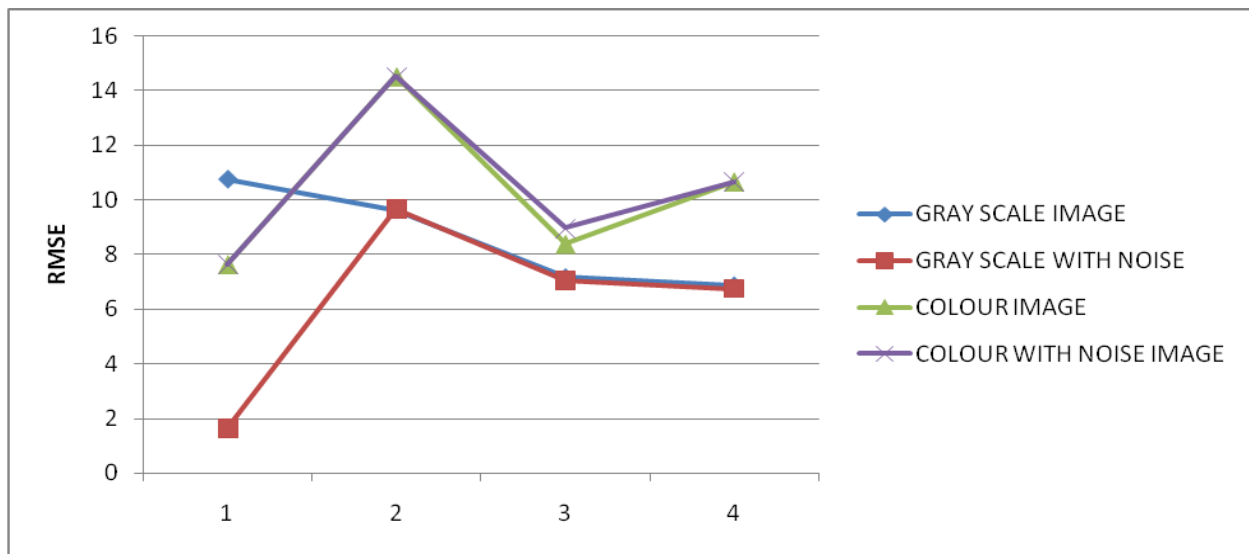
**Figure 6.21: Graph showing PSNR for different images**

Graph showing PSNR for all different types of images. Four different points shows different techniques. In this PSNR is high for Imadjust for colour, colour with noise and grayscale with noise image. For grayscale image BBHE has high PSNR.



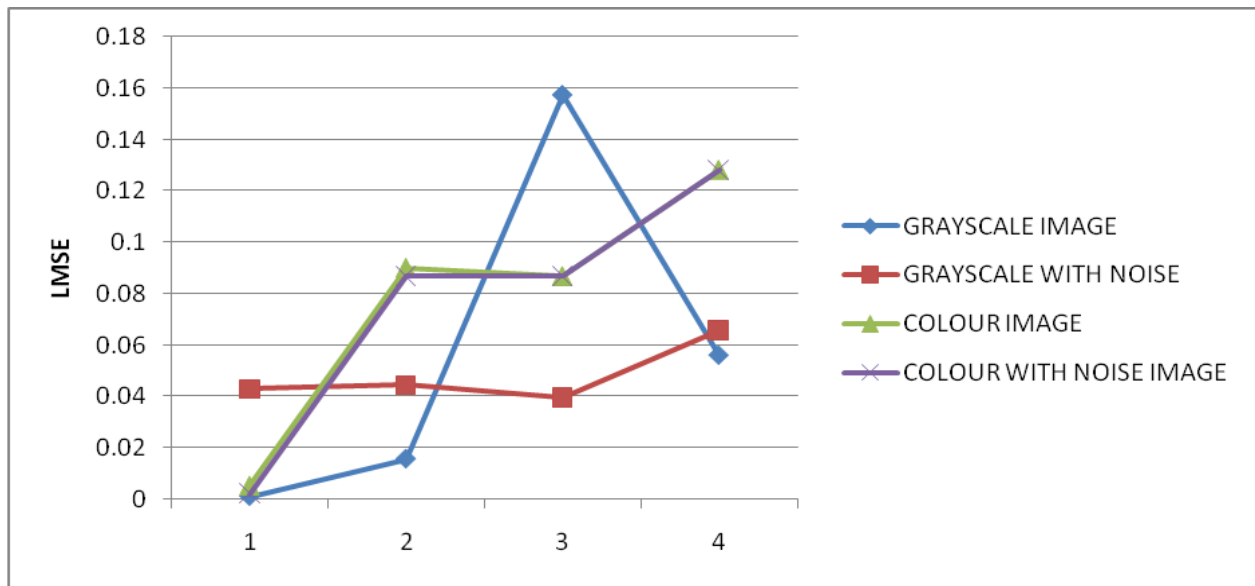
**Figure 6.22: Graph showing MSE for different images**

Graph showing MSE for all different types of images. Four different points shows different techniques. In this MSE is low for Imadjust for colour, colour with noise and grayscale with noise image. For grayscale image BBHE has Low MSE.



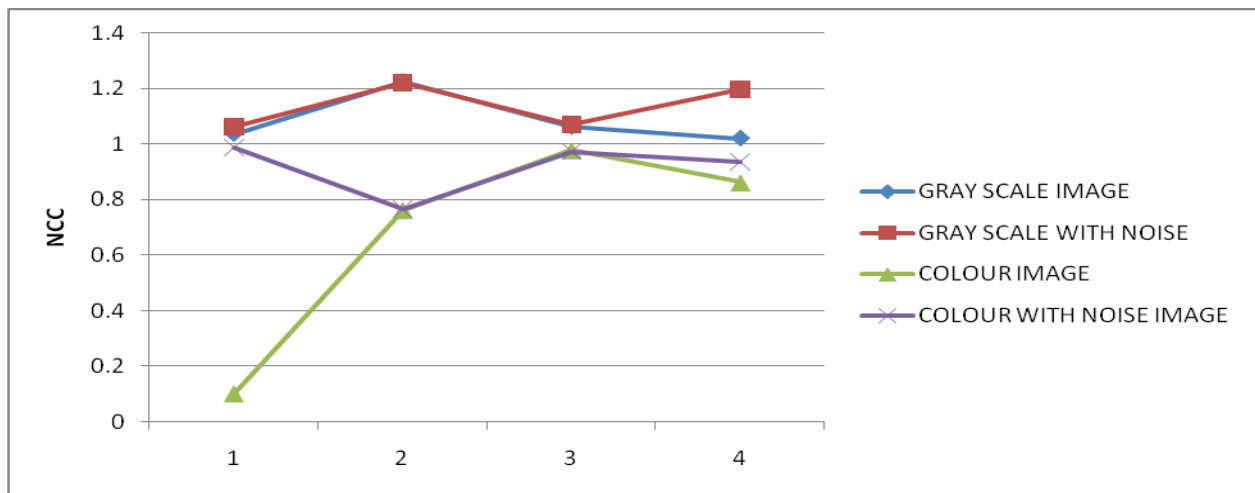
**Figure 6.23: Graph showing RMSE for different images**

Graph showing RMSE for all different types of images. Four different points shows different techniques. In this RMSE is low for Imadjust for colour, colour with noise and grayscale with noise image. For grayscale image BBHE has Low RMSE.



**Figure 6.24: Graph showing LMSE for different images**

Graph showing LMSE for all different types of images. Four different points shows different techniques. In this LMSE is low for Imadjust in colour, colour with noise and grayscale image. For grayscale image with noise, ADHE has Low LMSE.



**Figure 6.25: Graph showing NCC for different images**

Graph showing NCC for all different types of images. Four different points shows different techniques. In this NCC is low for Imadjust for colour image. For grayscale and grayscale with noise image, NCC is low. For colour with noise image, HE has Low MSE.

## CONCLUSION AND FUTURE SCOPE

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### 7.1 For Grayscale Image

BBHE has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others. BBHE gives best results for these types of images.

### 7.2 For Grayscale Image with Noise

Imadjust has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others i.e. image is good in contrast. Value of NCC is also good, which indicates good image after enhancement with Imadjust. Imadjust gives best results for these types of images.

### 7.3 For Colour Image

Imadjust has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others i.e. image is good in contrast. Value of NCC is also good, which indicates good image after enhancement with Imadjust. Imadjust gives best results for these types of images.

### 7.4 For Colour Image with Noise

Imadjust has high PSNR value and Less value of MSE i.e. low noise in image. Value of RMSE is also very less from all others i.e. image is good in contrast. Imadjust gives best results for these types of images.

### 7.3 Future Scope

The better result for image enhancement has also used in real time enhancement of neuro evolution of augmenting. Image enhancement techniques are used for forest mapping classification techniques, Project scope definition, scope verification, scope change control, Global and Indian Geo informatics Market. Image enhancement techniques used in many areas such that Forensics, Astrophotography, Fingerprint matching etc.

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