Novel hybrid method for the enhancement of low exposure images

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

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in

Computer Science and Engineering

Submitted By

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CERTIFICATE

I hereby certify that the work which is being presented in the thesis entitled, "Novel hybrid method for the enhancement of low exposure images", in partial fulfilment of the requirements for the award of degree of Master of Engineering in Computer Science and Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of Karun Verma and Rajkumar Tekchandani which are duly listed in the reference section.

The matter presented in the thesis has not been submitted for award of any other degree of this or any other University.

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This is to certify that the above statement made by the candidate is correct and true to the best of my knowledge.

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ABSTRACT

Capturing of the images through smart phones or digital cameras has become very common activity in recent years. Even if there had been a lot of advancement in the cameras' quality in the recent years, but still the images taken by them in underwater medium or dim light conditions are subject to low exposure problem. This conditions, results in low contrast images where the finer and the valuable information is often lost for further processing. Hence, their enhancement is necessary to retrieve the information of the interest. The proposed method is hybrid method that is very effective in enhancing the images taken in underwater medium and in dim light conditions such as night vision images. The method undergoes three main steps: first, the image that is to be enhanced is passed to neural network which will give the value by which the enhancement in the image can be done. In second step, the clipping of the histogram is done according to the value calculated in the first step. In third step: the image's histogram is divided into four parts based upon exposure values then histogram equalization method is applied to all the four parts individually. The performance of the proposed method is assessed on the basis of three parameters. Entropy i.e. information content in the image and two error matrices: Mean Square Error (MSE) and Peak Signal to noise ratio (PSNR) values are used for the assessment the performance of the method.

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CHAPTER 1: INTRODUCTION

1.1 INTRODUCTION TO IMAGE PROCESSING

Image is a two dimensional function defined by mathematical function f(r, c), where r and c are coordinates and (r, c) is the value of function that gives intensity at that point. If the value of amplitude of f and the values of r and c are finite and discrete then it is called as digital image. The (r, c) point is called a pixel. Pixels are the building blocks or the elements of a digital image which have a particular value and a particular location. They are also called image elements, picture elements, pixels and pels. There is always finite number of pixels in digital image processing [1].

Digital image processing is a field of performing some operations on digital images through computer algorithms so as to extract some useful information from it or to enhance it. It is a very broad field. It involves various operations. Most common operations are contrast enhancement, noise reduction, sharpening of image, removal of blurredness. In these operations both the input to the system and output from the system are image .Other operations are segmentation that is to partition an image in regions or objects, classification of the objects, recognition of the objects. In these operations the input to the system are images and attributes retrieved from these images are outputs.

Most of systems of image processing prefer that the images must be present in digital form, i.e., in the form of arrays of binary words of fixed length. In the process of digitization, sampling of image is done with the help of discrete grid and quantization of each pixel sample is done using a fixed number of bits. Then further processing of digitized image is done with the help of a computer. It may be converted to analog signal to display the image.

Before processing of an image, it needs to be converted to a digital state. Digitization introduces sampling of images and sampled pixels values are quantized. After digitization and quantization processes further processing are performed. Different processing techniques may fall in these categories: image enhancement, image restoration and image compression [2, 3].

Digital image processing requires computer algorithms for doing image processing on digital images. It may be subclass of digital signal processing. It offers a number of merits over analog signal processing because it offers a wide range of algorithms that are applied on input digital images for their processing. It may avoid problems such as noise, distortion of signal. Most of the images are defines over two dimensions but in digital image processing images could be defined over multidimensional systems.

1.2 APPLICATIONS OF DIGITAL IMAGE PROCESSING

Digital image processing is growing rapidly now-a-days. It has many applications in different fields related to studies and researches of science and technology. The various fields in which it is used are security surveillance applications, medicine field, image transmission through the remote stationary like satellite transmission, astronomy, in the film and game industries, photography fields, fingerprint analysis in forensics, Remote sensing, Machine/Robot vision, Pattern recognition, Video processing, photoshop applications and many more.

- **Photoshop applications:** The most common and popular application of digital image processing is photoshop. A lot of applications have been developed for photoshop purposes like to crop, edit, discarding the unwanted areas, red eye correction, blurring of particular portion and much more . To fulfil the mentioned purposes, these applications provide Graphical user interface to the users.
- **Videos surveillance:** Another popular application of digital image processing is in surveillance cameras. The security authorities use these cameras to stream videos in work places and public areas. However, higher authorities like police and crime investigation agencies use more sophisticated technologies to closely analyze the suspicious behaviour like zooming in to analyze suspect behaviour, which is not possible manually or otherwise. This mechanism of image processing, help the authorities to detect suspects through video surveillance. A suspect can even be detected from a huge crowd using this technology. The video can be used to identify the primary suspect. Police and intelligence agencies use the video surveillance for their investigation.

- **Medical field:** It is also used in the area of medicine. It is used in the detection of tumors, fractures and also aberration of blood vessels. Raw images were obtained by expert practitioners prior to the image processing. Image processing made it much easier to study the sources efficiently. By this technique, an image is generated and now the expert practitioners and the doctors use these in surgeries. These images allow doctors to perform well executed surgeries, as it gives the information about the insertions and incisions in the human body. It helps in the planning of various treatments like that in tumor. The target tumor is detected and the doctors get complete information about it and also the region, part or area that should not be touched or disturbed is detected using digital image processing.
- **Satellite transmissions:** This technique is also used in satellite transmissions. Scientists use this technique to know about various atmospheric conditions or soil characteristics. A lot of information about the planet earth might have been obtained. But image processing helps by providing more information for any kind of deeper study. The presence of craters is also obtained by using this.
- **Recognition Tasks :**
  - **Face Recognition:** A digital image or video frame is used to identify a person using a video source. This can be done by comparing facial features from facial and image database.
  - **Fingerprint Recognition:** Fingerprint recognition or fingerprint authentication verifies a match between human fingerprints by automated techniques.
  - **Iris Recognition:** Iris recognition is a biometric verification technique using mathematical pattern-recognition on video images on one or both the irises of a person's eyes.

Based upon their applications, the fundamental classes of digital image processing are grouped depending on following operations:

- Image enhancement: This class deals with enhancing the quality of the images by enhancing the contrast, frequency domain filtering, edge enhancements and noise reduction.

- Image restoration: As the name suggests, this class restores various images into their original form by using different correction methods like feature extraction and inverse filtering.
- Image analysis: It deals with examination of the information in an image which in turn helps in the image enhancement and restoration. Segmentation of image, feature extraction and classification of the objects are major tasks in image analysis.
- The major tasks in image analysis Image compression: It deals with the compression of images i.e. reducing the size of the images for easy storage etc. This compression can be either by reducing the size and maintaining the quality or losing the quality by keeping the size constant.
- Image synthesis: This basically deals with the visualization especially in the games. Gaming industries are now advancing to various new productions like 3D and 4D technologies. In such kind of game production, this class of image processing is useful.

1.3 PRIMARY STEPS IN DIGITAL IMAGE PROCESSING:

1. **Attainment:** to get a digital image
2. **Pre- processing**: enhances the Image
3. **Segmentation**: to separate an attained image into its vital parts.
4. **Depiction**: converts input data into a appropriate form which is suitable for processing by the computer.
5. **Explanation**: shunt those features that are constructive information
6. **Recognition**: define object descriptors
7. **Elucidation**: give a meaning to a group of known objects [1].

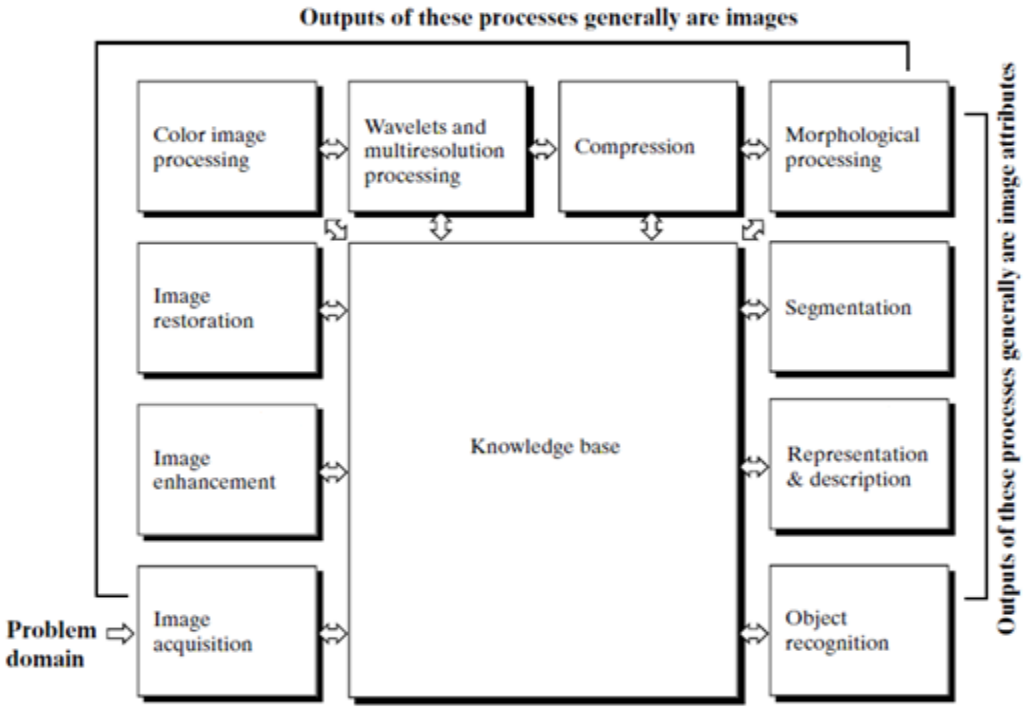


Fig.1 Overview of Digital Image processing

1.4 INTRODUTION TO IMAGE ENHANCEMENT

Image processing is the process to make certain necessary alterations in the original or the input image, so that it is visually better than the original one for various applications. A human supervision and feedback is needed for the alteration purposes.

Image enhancement is a very appealing and simple area. It involves enhancing image quality without previous knowledge of the source. It is a process of improvement of information perceived by the viewers in an image. Image enhancement brings out the details that are not visible in the images. Images can be visualized better my altering the contrast or enhancing luminance [4, 5].

Image enhancement is also used in restoring the images that has suffered any sort of deterioration, which might be due to reasons like optics etc. The main motive for which the enhancement is done on image depends upon the application for which the image is enhanced. The image enhancement algorithm can be simple, complex, ad-hoc or qualitative. An algorithm for image enhancement that gives good results for one application may not give good results for another application [6].

The process of image enhancement involves a collection of techniques that improve visual appearance of an image or converts a particular image to a better image to be

analyzed by a human or computer. The major motive of image enhancement is to make the image more suitable for any task, by modifying the attributes of the image. One or more attributes are modified during this process. A multitude of choices are provided by image enhancement for improving the quality of an image. These choices must be made appropriately according to the viewing conditions and the task at hand. Various applications of image enhancement are [7]:

1. Medical imaging
2. Digital camera application
3. Aerial imaging
4. Satellite imaging
5. Remote sensing etc.

Enhancing the quality of images is very essential. The images might have different types of noise. These noises could be visible in the form of dots or dark shadows while the photographs are taken especially when taken under low light conditions. The motive of image enhancement techniques is to remove such kind of noises. Here is a problem of enhancement [8]:

$$U=C+M$$

Where U represents the image with noise, C represents the original image; M represents noise with variance σ. The enhancement algorithm has a purpose that is to find the best possible estimate of C.

Fig.2 Image with and without noise

In various processing like recovering the images from capacity processes, transmitting it etc, the quality of the image gets ruined or degraded. Images clicked under low lightening conditions show undesirable signs also known as noise. This noise can ruin the quality and the features of the image, hence ruining the picture. To prevent such ruining of image, image enhancement calculations came into use. Various image

organizing calculations, like design acknowledgement requires a clear and clean image to work properly. Also, some images with irregular noise cannot be compressed. Such things of concern brought into picture the importance and necessity of image enhancement and feature handling [9].

1.5 NEED OF IMAGE ENHANCEMENT

Images are now-a-days being used as a source of inspection and interpretation. Using image enhancement, various images can be altered to get an image as that is pleasing visually or can be of further help. In doing this, the input image is processed and altered to get a clear and refined output image. It has become really necessary to remove noises from images and to enhance contrast as well to get a quality picture. Even real life photograph, medical images and images of satellites are affected by such noisy effects and this makes it essential for these noises to be removed [10].

Our daily life now involves a wide use of smart phones cameras and other similar devices, which we use to take pictures. However, these devices have a limited dynamic range as compared to the human eyes. Human eyes can perceive a high quality of picture of what they see, but these devices give out results which are of very low range as compared to the eyes. Some common anomalies found in real life images are as followed [11]:

1. Low-Contrast image, which may be due to insufficient exposure or improper lightening/illumination.
2. Sometimes there might be proper lightening or exposure but still some regions might be left unexposed or not properly exposed.
3. Images taken in dark or during night especially without using flash. Such images are barely clear with improper illumination. Even with the photoflash ON, the images yielded may not be as desired or clear as needed. Post processing of such images using image enhancements a method needed to cope up with the quality that should have actually been. To deal with many such problems, large varieties of the software or image enhancement methods have now been developed.
4. Images having over or under-exposed regions.

Medical area also uses images for various applications. Medical field is advancing more and more in terms of technology and instruments. So to cope with this advancement, even the images used in this field are also expected to be more

enhanced for better results. More enhanced images are expected so that it becomes easier for the practitioners to examine the medical conditions as compared to poor contrast noise elements containing images [10].

Due to lack of ample amount of lighting, focusing or staining etc, the quality of the images suffer, in particularly the lack of contrast and other noises like presence of shading etc. There are features in images which are hard to detect by a human eye easily. So, to overcome this, images are often transformed before using image enhancement, which henceforth improves the image quality and vision to make is adaptable to be processed further by computers.

This problem rises due to illumination which plays an important role in any imaging process. Many experts say, it is very important to select proper illumination/lightening before using an application. Most techniques depend on the input image for further processing. These techniques treat input images globally and not on the basis of local features of different regions. However, there may be some more complex situations like the poor contrast, but not in the entire image but in some parts of the image. It might be fine in some parts and not adequate in others. In such cases adaptive contrast enhancement provides a significant advantage.

Evaluation of enhancement result has always been a challenge. Usually it is evaluated by a person via his vision only. But the main problem arises when all the algorithms are parametric and the one with the best algorithm has to be selected from an entire class of algorithms or image enhancement procedures.

Properties of the images which are to be processed mainly focused upon by the existing methods of contrast enhancement but observer characteristics are not taken in consideration. But in the medical field which uses the images for the diagnosis purposes, effective contrast enhancement is achieved by using human visual properties. As human visual properties are so well, the contrast enhancement can be improved by including some characteristics of human visual system into this design. In fact enhancement methods have now been designed using human visual systems with improved performances. Methods have been designed that automatically selects the method to be used, or the parameters that can be chosen to give the best results. This new technique has proven to produce better results and also can be applied on a variety of pictures/images.

1.6 STRUCTURE OF THE REPORT

Chapter 2: Literature Review. This chapter introduces the related work that has been done in the field of image enhancement.

Chapter 3: Problem Statement and objective. In this chapter the gaps in the field of image enhancement algorithms and objectives of proposed research work has been described.

Chapter 4: Tools and Techniques used. This chapter describes the tools and the techniques that are used in the proposed algorithm for image enhancement.

Chapter 5: Proposed Methodology. This section describes the proposed algorithm and calculations of the various parameters used in it.

Chapter 6: Results and discussions. This section describes the results by the proposed algorithm are shown along with their assessment on the basis of various parameters.

Chapter 7: Conclusion and Future Scope. The whole work presented in thesis is summarized in this chapter.

CHAPTER 2:
LITERATURE SURVEY

Y.T. Kim *et.al* [12] claimed to remove the limitation in the histogram equalization technique that is changing the brightness of the image while enhancing the contrast. In this method, the input image was decomposed into parts based upon the mean the mean of the image in which one part in the image was less than or equal to the mean value and the other part had higher than the mean value. Then, on these individual sub images, histogram equalization was applied independently. The main motive the author in this method was to enhance the contrast of the input images while preserving its brightness.

Although histogram equalization is a simple technique, but its application leads to the significant change of the luminance and because of this disadvantage it had never been used in video systems in past. So, in order to overpower this limitation of histogram equalization method, **Y. Wan, B.M. Zhang ,Q. Chen *et.al* [13]** proposed a method in which was partitioned the input image into parts based upon the PDF (probability distribution function) of the original input image. After that these two parts the image were separately equalized and finally these separate parts are clubbed together to obtain the final image.

A.R. Ramli , S.D. Chen *et.al* [14] gave a method called as RMSHE which was extension of the already existing method named as BBHE. In this image, is separated on the basis of mean value and this separation is done recursively and histogram equalization is applied on the sub parts of the images. This is repeated until the average brightness of the output image converges to that of the input image.

Wangmeng [15] proposed a technique based on gradient method for image enhancement. This paper implement a method called novel gradient histogram preservation (GHP) algorithm in which noise was removed and texture features are enhanced. The simulation results concluded that the method worked well in removing the noise from the image and made them look much natural.

Anisimova. E [16] presented that image acquisition under low light conditions. It also presented two approaches for image enhancement that are lifting wavelet transforms and discrete wavelet transform. Discrete method enhances image quality and also decreases noise signal. The author compared lifting and discrete enhancement methods with the help of MSE, PSNR and elapsed time. In lifting method, image is

decomposed into four sub images, then gain coefficient was calculated and finally lifting wavelet inverse transform was applied. Better results were obtained from lifting wavelet transform method that gives a wide range of gray scale and details are clearer as comparability to traditional wavelet algorithms.

Yiang Xang [17] presented two approaches for image enhancement that are lifting wavelet transforms and discrete wavelet transform. Discrete image enhancement method enhanced the image quality and decreased the noise signal from the image. In this paper lifting and discrete methods were compared using MSE, PSNR and elapsed time. In lifting method, image is divided into four sub parts, then gain coefficient was calculated and finally lifting wavelet inverse transform was applied. In the end SVM has been utilised for better noise reduction. Better results are obtained from lifting wavelet transform method that gives a wide range of gray scale and details are clearer as comparability to traditional wavelet algorithms.

Knous [18] presented an image enlargement technique which was based on the grey polynomial interpolation (GPI) with edge enhancement (EE). Image was enhanced with the help of laplacian filter and canny edge detector. Results indicate that enlarged image obtained with GPI/EE has good visual quality.

Talebhi.H [19] presented a hybrid approach of the image denoising method by using a fusion method that involves bilateral filter, wavelet thresholding and multiscale products wavelet thresholding. In this method, firstly image containing noise was passed through the bilateral filter and it reduced some noise from it. For preserving edge details and reducing blur effect, output of bilateral filter was passed through wavelet thresholding method and adaptive wavelet thresholding methods. For achieving better results, dyadic wavelet transforms was applied. The performance of this fusion method was measured with the help of MSE and PSNR. This method not only preserved edges while removing noise but also enhanced performance. It provides an efficient model for image denoising.

Timony Rumbel [20] proposed SOM for image denoising. The SOM has been useful in many applications. It maps the high dimensional space to map units for preserve mapping. Neuron units commonly made lattice onto a plane. Preserving property means reserving the distance between points. In addition to that Self-Organizing Map has the capability of generalizing. It means recognizing the patterns that never met before.

Yi Qing [21] represents a novel technique for enhancing and sharpening medical color digital images. Major problems in the medical images are low contrast and poor quality. To overcome them, first of all, wavelet transform was applied to given image. Then haar transform was applied to all high frequency sub images. For noise reduction, soft thresholding method was applied to high frequency components. Different values of weight were added in different sub images for enhancing high frequency components. Then, inverse wavelet transforms and inverse haar transform was applied to obtain an enhanced image. Lastly, Sobel and Laplacian filters are applied to sharpen the image. This novel technique with Laplacian filter yields better result as compare to Sobel filtering technique. In the end neural network has been used.

Kuldeep Singh [22] presented two enhancement techniques for contrast. The idea behind this approach was to minimize the impact pixels in the non-textured areas and to obtain features in the texture for obtaining histogram needed for the process of histogram equalization. The variance in the image and decomposition algorithm was used to classify the patches of the images as non-dominant, dominant or smooth. In first algorithm, it took only dominant patches into account for application of histogram equalization. In second method, edges which were significant were calculated and the neighbourhood of the edges were taken into account to construct the histogram. The CDF of the formed histogram was mapped on the entire range of the input image to produce image enhanced in contrast. The author claimed that method performed better as against the other histogram equalization methods.

Sunaya U. Shirodkar [23] used spatial resolution techniques for image enhancement. It also involves interpolation, stationary wavelet transform and integer wavelet transform. First of all, stationary wavelet transforms and integer wavelet transform divides the original input image into sub bands for which frequency coefficients are different. Then interpolation of low resolution input image and high frequency sub bands images was done with bi cubic interpolation. Finally, inverse discrete wavelet transform was used to merge all these sub bands.

Rahman .S [24] proposed a novel histogram mapping function that visualizes voxels local means along with grey scales of the images. A technique combines fast local feature generation technique with representing voxels as well as grey scale images**.** Various sections of this combined histogram, decomposed by separate peaks, are profiled independently into the target histogram scale with the constraint to maintain

the uniformity of overall histogram. Thus the hurry of histogram equalization was refined this way, and the required enhancements results are also achieved**.**

Doulgeris [25] gave a novel adaptive filtering technique that provides an architecture to construct high level knowledge of images. Very often, these algorithms guide filtering parameters by using low level knowledge like gradient information. These filters do not require any kind of knowledge beforehand. This can adapted to various of images. Experimental results validate a clear benefit of this method.

Bagawade Ramdus [26] represented the comparison of image enhancement techniques using Wavelet Transform. Resolution was the one of the major issues in image enhancement. Basic functions of Wavelet Transform are small waves that are placed in different times and that are obtained from scaling function and wavelet function using scaling and translation. The Techniques used are bilinear interpolation, bi-cubic interpolation, regularity preserving image interpolation, edge-directed interpolation, wavelet zero padding –cycle spanning based image resolution enhancement, dual tree-complex wavelet transform based image enhancement, image enhancement using SWT and DWT. Image enhancement using SWT and DWT gives better results than other techniques.

Sara Izadpanahi [27] gave a new video resolution technique for enhancement of low resolution video sequences. The proposed technique uses edge directional interpolation (EDI) and dual-tree complex wavelet transform (DT-CWT). Low frequency components are generated by super resolution process and high frequency components are created by DTCWT decomposition succeeded by EDI. At the end, inverse DTCWT revamps the super resolved output. Results of experiments on numerous benchmark video sequences with regard to their PSNR measures validate that this method is better as compared to other video resolution enhancement methods.

Abhijit Nayak et. al. [28] proposed a step by step method for detecting suspicious lesions in digital mammograms. This technique used undecimated wavelet transform (UWT) and adaptive thresholding techniques. UWT was used to create a multi resolution visualization of the original mammogram. It uses adaptive global and local thresholding approaches on segment possible malignancies. Then segmented areas are enhanced by using morphological filtering and seeded region growing.

Rajapriyadarshani et.al [29] used directional wavelet transform and LDA for image enhancement. Directional wavelet transform break downs the given image into a 4D

space which augments the given image with information about scale and direction. This helps to improves image quality as compare to traditional techniques. Proposed image enhancement technique used the multi scale singularity detection along with adaptive threshold value which was computed using maximum entropy. It was applied on synthetic images and clinical images and given method was robust and worked accurately on noisy images. From experiment results it has been shown that noise is properly removed using proposed algorithm.

CHAPTER 3:
PROBLEM STATEMENT AND OBJECTIVE

3.1 PROBLEM STATEMENT

Now days, capturing images through smart phones or digital cameras is very common activity. Even if there had been a lot of advancement in the cameras' quality in the recent years, but still the images taken by them in underwater medium or dim light conditions are subject to low exposure problem. The dynamic range of the smart phone cameras and digital cameras is limited, so the images taken in scenes with high dynamic range are often subject to underexposure artefacts problems in the shadow regions. The image taken in low or insufficient illumination/exposure environment such as at nights without use of the flash lights or in underwater conditions where the intensity of the light decreases exponentially, the images suffers from low contrast problems. Moreover, the non ideal camera aperture settings and speed of shutter often results in low exposure problem in the images captured in low light environment. These images have low visibility, have low contrast and the finer details in them are not visible. So, the valuable information from these images is often lost for further processing. Therefore, processing of these images is needed to improve their quality and to retrieve the information of the interest. For this, image enhancement techniques are needed. Image enhancement improves the fine details present in the image and makes their visual quality better

3.2 OBJECTIVE

1. To propose a novel hybrid enhancement method for the enhancement of low exposure images using sub-image histogram equalization and artificial neural network.
2. To assess the proposed method's performance of on the basis of the following parameters:
    - Visual appearance
    - Mean Square Error (MSE)
    - Peak Signal to Noise Ratio (PSNR)
    - Entropy

CHAPTER 4:
TOOLS AND TECHNIQUES USED

4.1 MATLAB

MATLAB is a popular tool that is used in education and research at universities, various areas of applied mathematics and in the industry. MATLAB is a platform named as matrix laboratory which provide the numerical computing in multi-pattern. It is also called as the 4th generation language of programming. It is software that is works using matrices and vectors. By utilizing MATLAB, exploitation of matrix become easy, the in sequence and functions can be plotted easily, calculations can be executed, an algorithm can be implemented, unusual client interfaces can be made additionally interfacing should be probable with the projects which are actualized in varied programming languages like JAVA, C++, C and Python. The MATLAB application is fabricated around the MATLAB scripting languages. It also supports the concepts of object oriented programming like classes, packages, inheritance. It ropes to develop the applications with GUI (graphical user interface). It likewise has firmly integrated diagram plotting apparatus. Several technical and computing problems can solve by using MATLAB. Lots of researchers used MATLAB for their replication. MATLAB is also especially useful in the field of Sensor network where it consist inbuilt sensor signal, routing Simulink and various tool boxes like signal processing toolbox, sensor network etc.

4.1.1 Typical use of MATLAB

Typical uses of matlab are: math and computation, data acquisition and its analysis, exploration, and visualization, algorithm development, scientific and engineering graphics and prototyping application development including graphical user interface building.

4.1.2 Advantages of MATLAB

1. Ease of Use

- Expression typed at the command window
- Built-in integrated editor/debugger

2. Platform Independent

- Windows 95/98/ME/NT/2000 & Unix
- Program written on one platform may run on other
- Data files written may be used on other platform

3. Predefined Functions

- Extensive Library of Predefined Functions: Arithmetic mean, Standard Deviation, Median (No need to write subroutines)
- Special Purpose Toolboxes to solve complex problems

4. Visualization

- Many plotting and Imaging Commands to visualizing technical data

5. Graphical User Interface

- Provide inbuilt commands which help the inexperienced users to build the GUI based applications.

4.2 HISTOGRAM EQUALIZATION

The histogram is basically a graphical representation of an image. It shows how the pixel values of different intensities in the image are distributed over various gray levels. It shows the frequency of the intensity values at each gray level and the range of brightness from dark to bright. With the help of histogram we can get the information regarding the contrast and brightness of the image. Histogram equalization is very commonly used techniques for enhancement of the contrast because it is very simple and easy to implement. This method works on the histogram of the image. It improves overall contrast of image. It flattens the probability distribution of the image and stretches the grey levels' dynamic range. Suppose an image Y is given, then its probability density function $p(Y_k)$ is given as [30, 31]:

$$p(Y_k) = \frac{n^k}{n} \tag{1}$$

where k represents the gray levels from 0 to L-1, n^krepresents frequency of a particular level in the image Y and n is the number of picture elements in it. Equation (2) shows calculation of the cumulative density function:

$$C(y) = \sum_{K=0}^{k} p(Y_K) \tag{2}$$

where $Y_k = x$, $\forall\ k = 0$ to $L-1$. The motive of the HE method is to increase the image's contrast by distributing the levels up to the entire dynamic range i.e. $Y_0\ to\ Y_{L-1}$. Transform function $f(y)$ is defined on the basis of the cumulative density function as

$$f(y) = Y_0 + (Y_{L-1} - Y_0)c(y) \tag{3}$$

Then the output image, $Z = \{Z(n, m)\}$, by equalization of histogram is given as

$$Z = f(Y) \tag{4}$$

$$Z = \{f(Y(n,m)| \forall Y(n,m) \in Y\} \tag{5}$$

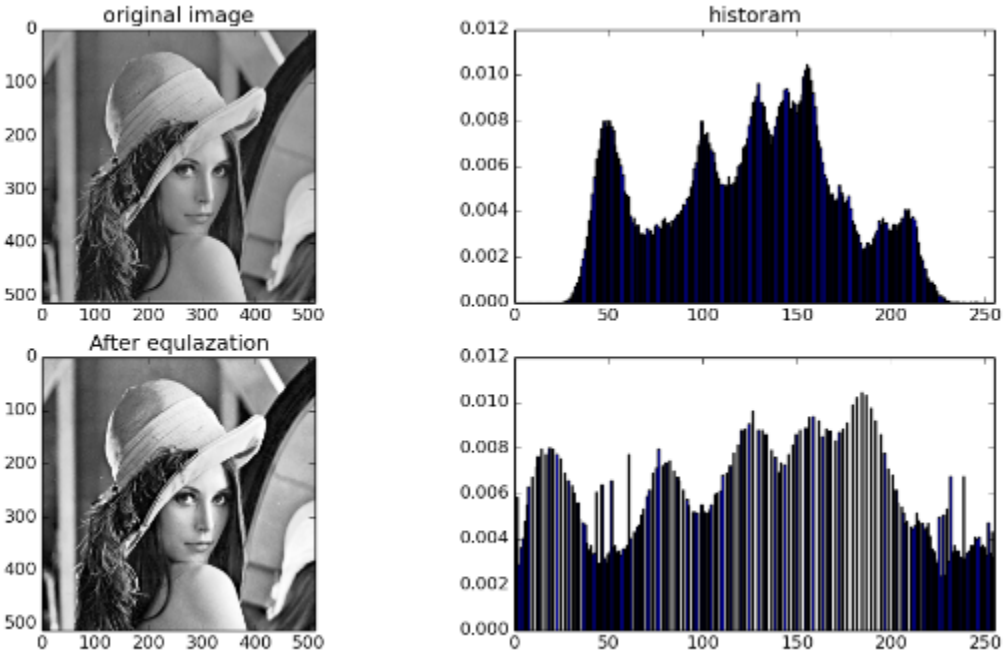


Fig.3 Results by the application of histogram equalization

The above figure shows the application of the histogram equalization technique on a low contrast image. The above figure clearly depicts the impact of the technique on the image and even the comparison between the histograms of the unenhanced image and the enhanced image is noticeable. The histogram of the enhanced image is more distributed as compared to the original.

4.2 ARTIFICIAL NEURAL NETWORK

The artificial neuron used in various field of science and technologies is a well established computational model which is inspired by the natural neurons. In general, the signals to natural neurons are received through synapses which are located on the membrane or dendrites of the neuron. In case, the signals which is received by natural neuron surpasses a certain threshold, i.e. strong enough then the process of activating the neuron starts and it also emits a signal through axon. This process of activation can be continued by sending the signals to another synapse in order to activate other neurons.

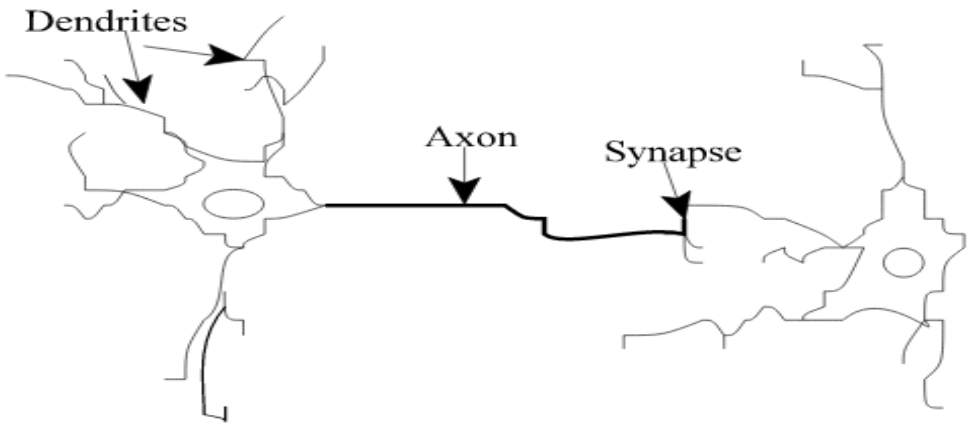


Fig.4 Structure of biological neuron

The abstraction of real neurons is much high as compared to the artificial neurons which consists input which can be related to the synapse of natural neuron. Afterwards, it is multiplied by weights which are nothing but the strength of the respective signals. Then finally it is computed by a mathematical function upon which the decision of neuron's activation is taken. Further on this, for the computation of outputs of the neurons a different function is used which is again depends on a certain threshold. The Artificial Neuron network then collaborate all the artificial neurons for the processing of the information.

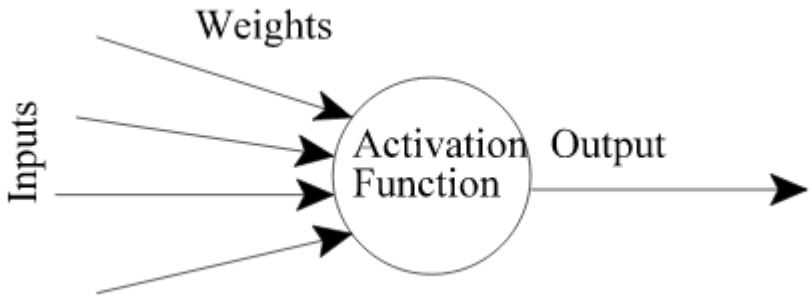


Fig.5 Structure of Artificial Neuron

Frank Rosenblatt was the first psychologist to discover the first artificial neuron, which is popularly known as perceptron. Initially, the perceptron was proposed to model the working of human brains, especially the processing of visual data by human brain. It further learnt to recognize the objects. The capabilities of perceptron

like pattern matching and learning allowed them to recognize many issues that were tough or close to impossible to solve by using any standard computational and statistical methods. These neurons can further physically constructed or simulated by a digital computer. The input to each neuron is many signals that are weighted and the output the single output signal on the basis of the internal weighting system. This output signal from one neuron is sent to another neuron as input signal. The neural network, in this way has several layers of the neurons with are interconnected tightly. There is one input layer that receives the input, one output layer that produces final output and one or more hidden there are there in between these two layers.

CHAPTER 5:
PROPOSED METHODOLOGY

5.1 CALCULATIONS OF THE PARAMETERS USED

5.1.1 Calculation of the parameter by artificial Neural Network

Neural network is used in extracting the meaningful information from imprecise or complicated data. It has the ability to derive meaning out of such complicated data. Some trends or patterns which are too complicated for humans to figure out or even notice can be extracted by this technique. Back propagation neural network technique is used to find that pixels values that need improvement and it outputs the value that is used for the improvement of the original image. The following steps are followed:

a. Select original image as an input of neural network for training and testing data.

b. Compute the bits value (b_v) which is used to enhance the image.

To calculate the parameter(b_v) , nntraintool i.e. neural network training tool in Matlab is used. Fig.6 depicts the training of the neural network in which 40 epochs and 6 validation checks has been utilised. Training is done using inbuilt Levenberg-Marquardt method and in this method the data division for training and testing purposes is random. The input image is passed to this tool. The each pixel of the image will act as input to the neural network. It will evaluate which pixel values need the improvement and compute the total variation that exists in the pixels values and it will output one value that is used for the improvement of the original image. This output value basically describes that by how much value the improvement can be done in the input image by looking at the pattern of the image.

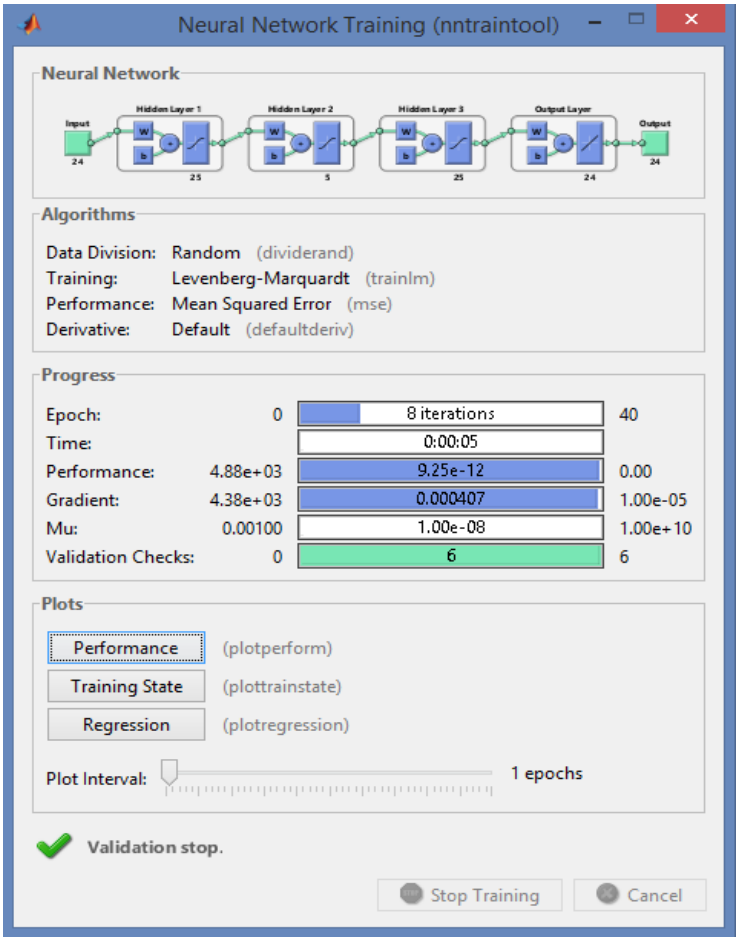


Fig.6 Neural network training tool

5.1.2 Exposure Threshold Calculation

In an image, the exposure determines the darkness and brightness of each pixel. The images are categorized as low exposure or high exposure based upon the value of the exposure threshold. The exposure value has the range in between 0 and 1. The exposure for the images that contain the majority of the low exposure region is in between 0 to 0.5. Whereas the exposure value of high exposed images is in between 0.5 to 1. Equation (6) gives the Image intensity exposure value

$$Exposure\_value = \frac{\sum_{k=0}^{L-1} h(k) * k}{L \sum_{k=0}^{L-1} h(k)} \quad (6)$$

Here $h(k)$ represents image's histogram and L represents the number of grey levels. Three threshold parameters: X_a, X_{al}, X_{au} are calculated as shown in equations (7-9). X_a is the value that is used to divide the histogram of the image into two regions: over exposed and under exposed. The parameter X_{al} further

divides the under exposed into two regions and X_{au} divides the over exposed area into two regions (as shown in fig.6). Therefore, the histogram is divided into four regions based upon these values.

$$X_a = L(1\text{-}Exposure\_value) \tag{7}$$

$$X_{al} = L\left[\frac{X_a}{L} - \frac{\sum_0^{X_a-1} h(k)*k}{L\sum_0^{X_a-1} h(k)}\right] \tag{8}$$

$$X_{au} = L\left[1 + \frac{X_a}{L} - \frac{\sum_{X_a}^{L-1} h(k)*k}{L\sum_{X_a}^{L-1} h(k)}\right] \tag{9}$$

Fig.6 describes how the partitioning of the histogram of the original unenhanced histogram is done. X_a divides the histogram of the original image into two parts. X_{al} divides the under exposed part of the histogram into two sub regions and X_{au} divides the overexposed part of the histogram into two sub regions.

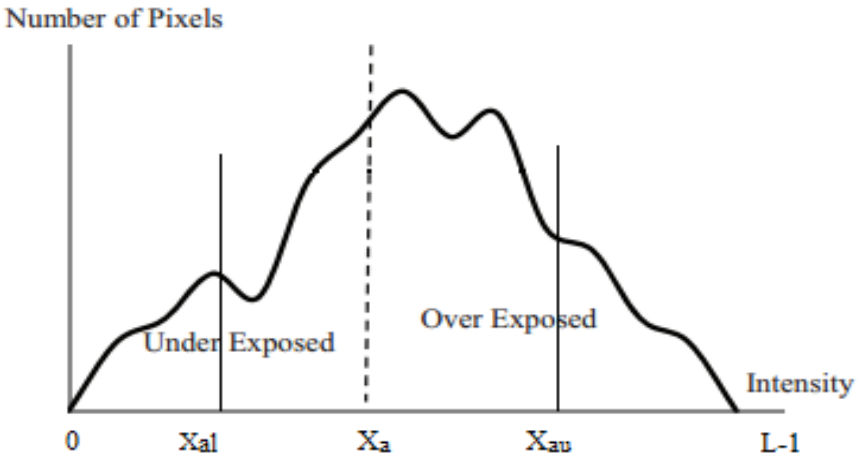


Fig.7 Division of histogram on the basis of clipping thresholds

5.1.3 Calculation of clipping threshold

The clipping of the histogram is done on the basis using two parameters: Clipping threshold (Tc) and value (b_v) returned by the neural network. The clipping of the histogram is done so as to avoid over enhancement of the image. Equation (10) gives the clipping threshold. It is represents the average of the values at the each gray level.

$$Tc = \frac{1}{L}\sum_{k=0}^{L-1} h(k) \quad (10)$$

5.1.4 Histogram subdivision and equalization

The division of the histogram is done into four parts according to the above calculated exposure threshold value. The values $P_{Lu}(k), P_{Ll}(k), P_{Ul}(k)$ *and* $P_{Uu}(k)$ are the PDFs of each of the sub images.

$$P_{Ll}(k)=\frac{h_c(k)}{N_{Ll}} \; for \; 0 \leq k \leq X_{al} - 1 \quad (11)$$

$$P_{Lu}(k)=\frac{h_c(k)}{N_{Lu}} \; for \; X_{al} \leq k \leq X_a - 1 \quad (12)$$

$$P_{Ul}(k)=\frac{h_c(k)}{N_{Ul}} \; for \; X_a \leq k \leq X_{au} - 1 \quad (13)$$

$$P_{Uu}(k)=\frac{h_c(k)}{N_{Uu}} \; for \; X_{au} \leq k \leq L - 1 \quad (14)$$

N_{Lu}, N_{Ll}, N_{Uu} and N_{Ul} are the number of the pixels in the corresponding sub parts of the histogram. After calculation of the PDF values of all the sub parts their CDF values are calculated. Equations (15-18) shows the calculation of the CDF of sub Images.

$$C_{Ll}(k) = \sum_{K=0}^{X_{al}-1} P_{Ll}(k) \quad (15)$$

$$C_{Lu}(k) = \sum_{K=X_{al}}^{X_a-1} P_{Lu}(k) \quad (16)$$

$$C_{Ul}(k) = \sum_{K=X_a}^{X_{au}-1} P_{Ul}(k) \quad (17)$$

$$C_{Uu}(k) = \sum_{K=X_{au}}^{L-1} P_{Uu}(k) \quad (18)$$

Now, all the four sub histograms are equalized separately. For this purpose the transfer functions are used. Equations (19-22) describes the transfer function for histogram equalization

$$T_{Ll} = X_{al} C_{Ll} \quad (19)$$

$$T_{Lu} = (X_{al} + 1) + (X_a - X_{al} + 1) C_{Lu} \quad (20)$$

$$T_{Ul} = (X_a + 1) + (X_{au} - X_a + 1) C_{Ul} \quad (21)$$

$$T_{Uu} = (X_{au} + 1) + (L - X_{au} + 1) C_{Uu} \quad (22)$$

The four sub histograms are equalized separately according to the transfer functions: T_{Ll}, T_{Lu}, T_{Ul} and T_{Uu} as mentioned in the equations (19-22). The combination of all these four transfer function produces the output image.

5.2 PROPOSED ALGORITHM

1. Input an original unenhanced Image

2. Apply Neural Network on image for finding the value of the parameter b_v.

3. Compute the histogram $h(k)$ of the image.

4. Compute the parameter Exposure_value and threshold parameter X_a.

5. Compute the value of clipping threshold (Tc) and perform the clipping operation on the original histogram, in order to get new clipped histogram $h_c(k)$. Clipping is done as follow using two parameters Tc and b_v .

a. If $h(k) > Tc$, then $h_c(k) = Tc$

b. else if $h(k) = 0$, then $h_c(k) = b_v$

c. else

calculate the value sum as:

$sum = h(k) + b_v$

if $sum > Tc$ then $h_c(k) = Tc$

else $h_c(k) = sum$

6. The clipped histogram obtained from step 5 is divided into two sub parts using the value of threshold parameter X_a.

7. Compute two more exposure thresholds: X_{au} and X_{al}. Use these values to divide the histogram. Use the value X_{au} for division of the under exposed are into two parts and use value X_{al} for the division of over exposed are into two parts. In this way, four individual sub parts of the histogram are obtained.

8. Apply the technique of histogram equalization separately on all the four subparts obtained and combine the subparts into one part for analysis using transfer function. This will provide us the final enhanced output image.

CHAPTER 6:
RESULTS AND DISCUSSIONS

6.1 EVALUATION PARAMETERS USED

1. **MSE:** In statistics, the mean squared error of an estimator is one of the many ways to quantify the difference between values implied by an estimator and the true values of the quantity being estimated. It is the cumulative squared error between the original and the enhanced image. It is given as:

$$MSE=\frac{1}{AX\ B}\sum_{A,B}[f1(A,B)-f2(A,B)]^2 \quad (23)$$

Where $f1(A,B)$ represent the Original image and $f2(A,B)$ represents the enhanced image. $A\ X\ B$ denotes the size of the image.

2. **PSNR:** Peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. PSNR is given by

$$PSNR=10log_{10}\frac{(2^t-1)^2}{MSE} \quad (24)$$

Here, 't' represents the bits per sample. In image processing, low value of MSE and high value of PSNR is preferred.

3. **Entropy:** The entropy is a valuable tool to measure the richness of the details in the image. It is measured in units as bits. It is defined as:

$$E= -\sum_{g=0}^{G-1}P(g)logP(g) \quad (25)$$

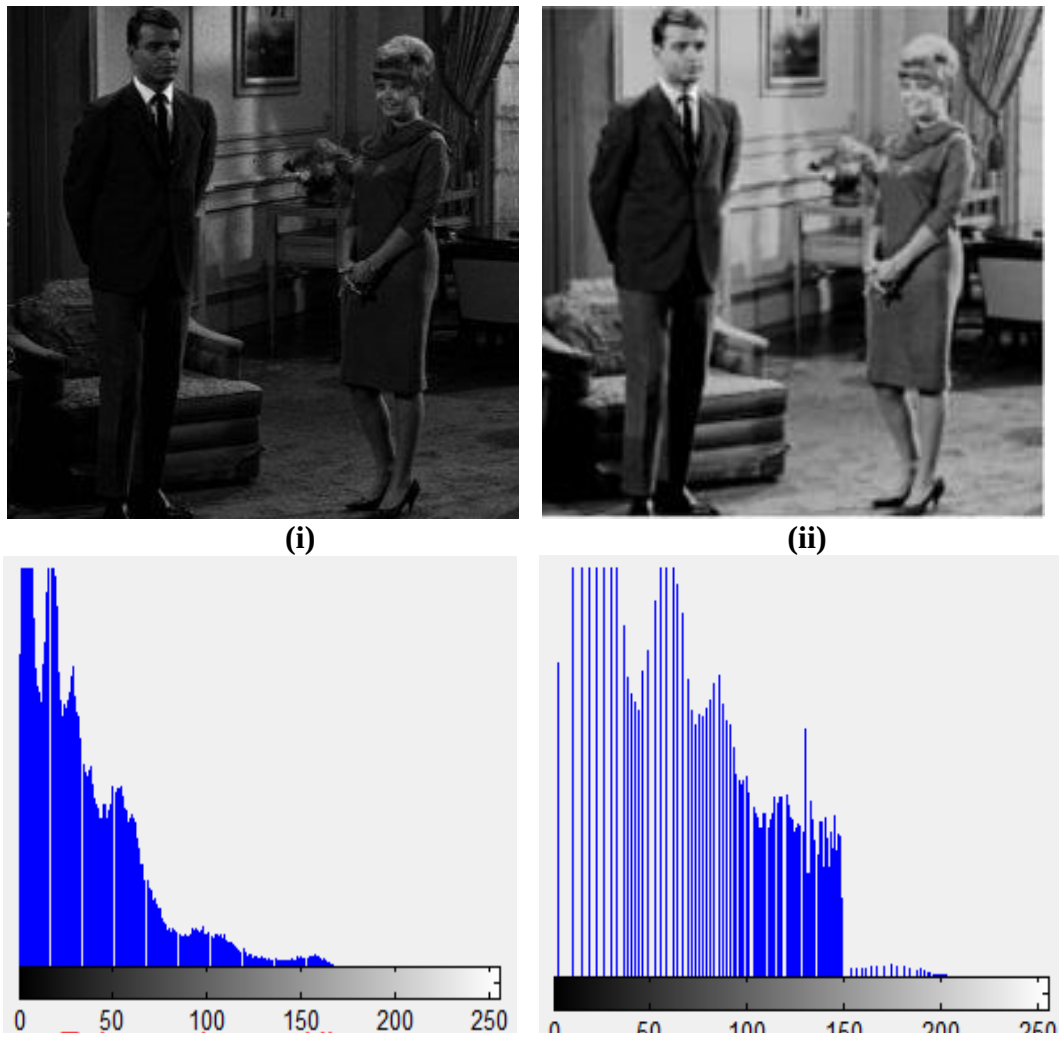
Where $P(g)$ is probability density function of a given image at intensity level g and G is number of grey levels in the image. An image having high entropy value is considered to be having high details and have better quality.

6.2. ASSESSEMENT OF THE PERFORMANCE OF THE PROPOSED METHOD

6.2.1. On the basis of visibility

For the assessment of the output images given by the proposed method on the basis visual appearance, four low exposure images are used. The two images are taken in underwater environment and the rest two images are taken in dim light environment.

IMAGE 1:

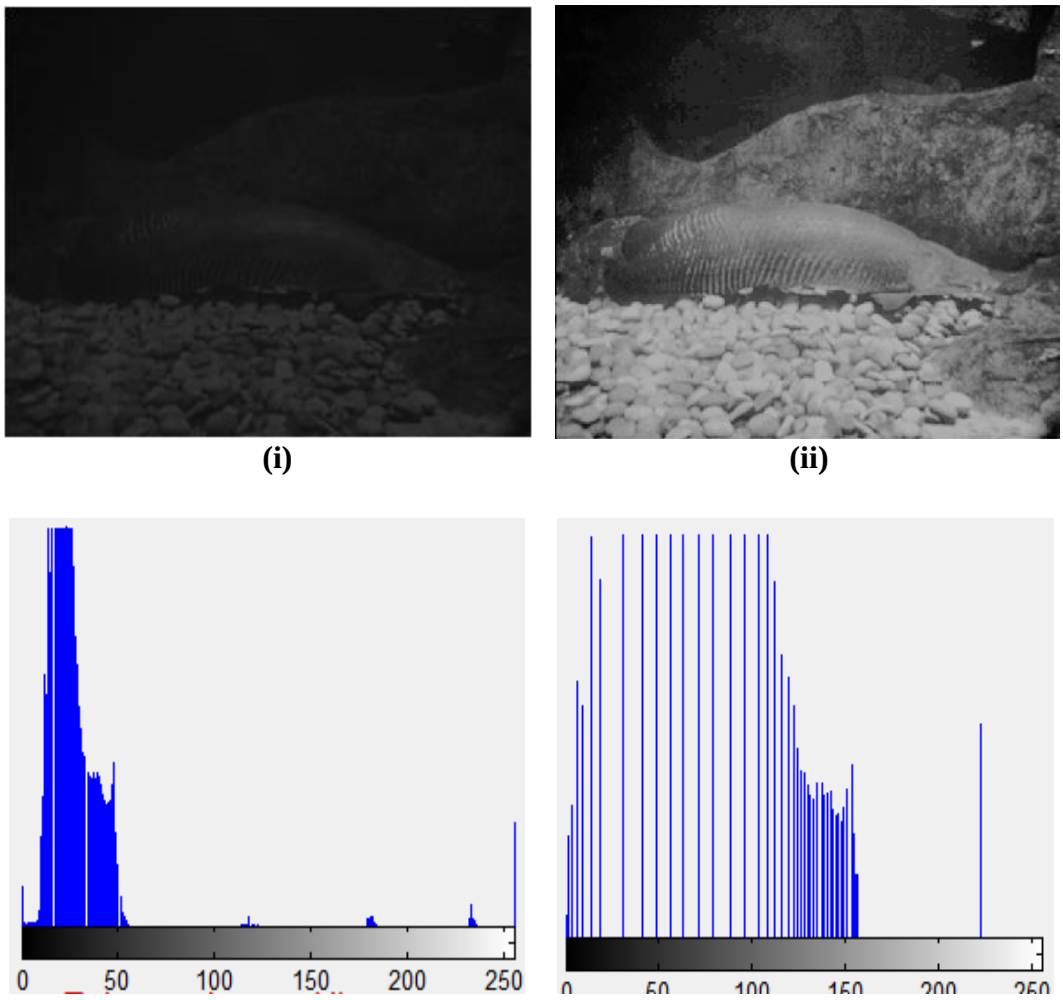


(i) **(ii)**

(iii) **(iv)**

Fig.8 Results for test image 1 (i) original, (ii) Enhanced by proposed method, (iii) histogram of the original image and (iv)histogram of the enhanced image

IMAGE 2:

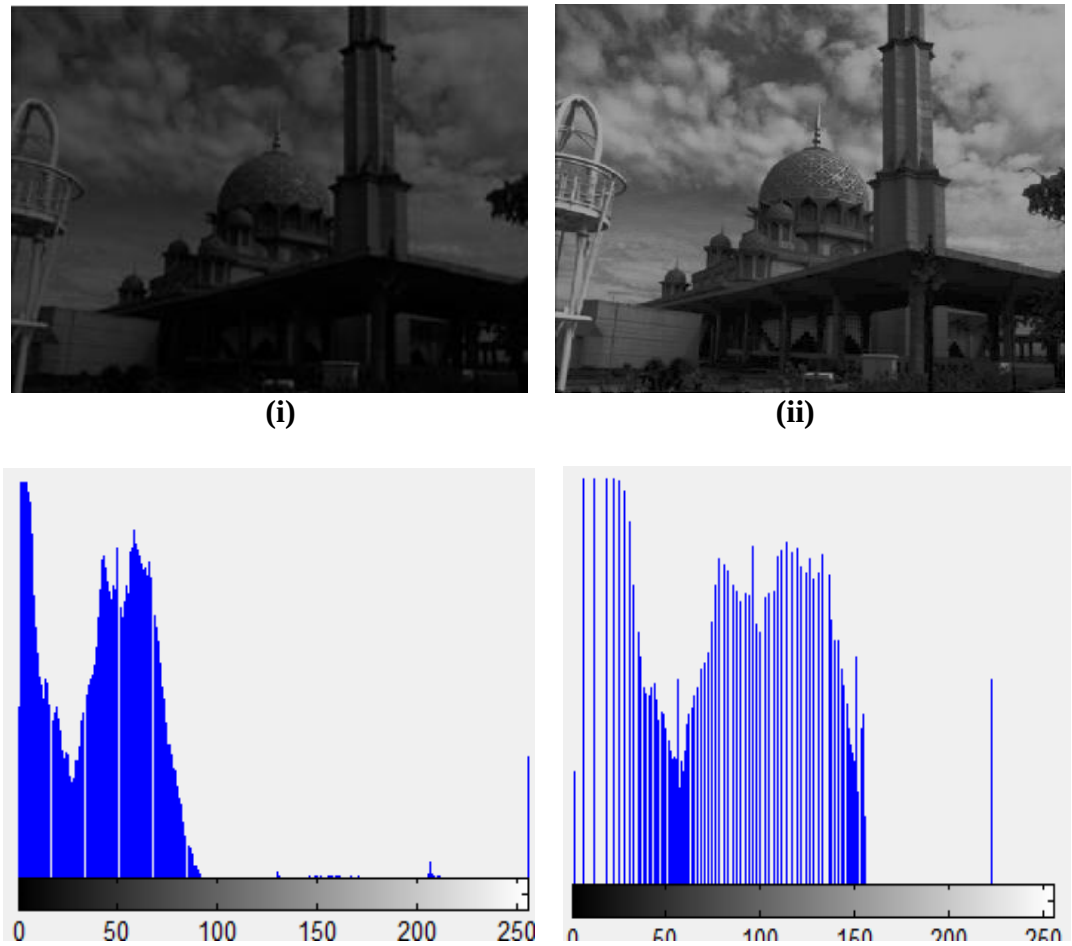


(i) **(ii)**

(iii) **(iv)**

Fig.9 Results for test image 2 (i) original, (ii) Enhanced by proposed method, (iii) histogram of the original image and (iv)histogram of the enhanced image

IMAGE 3

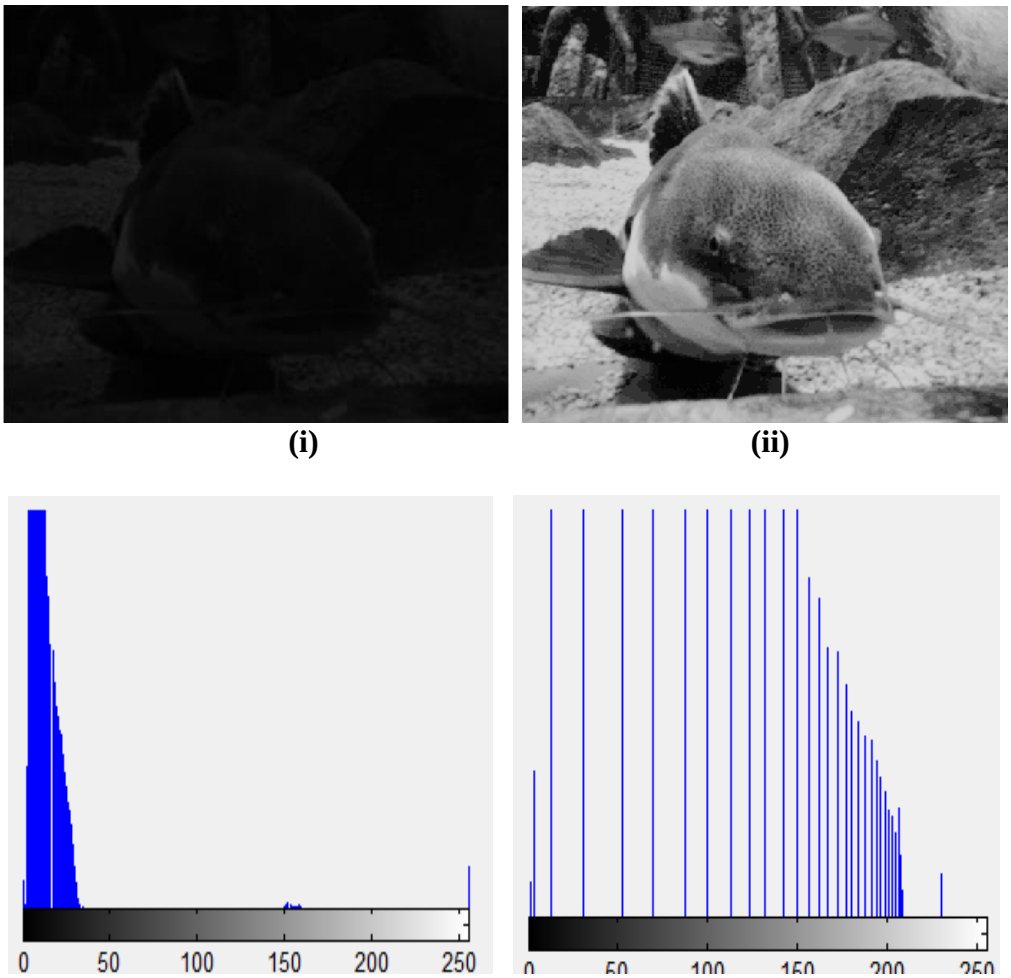


(i) **(ii)**

(iii) **(iv)**

Fig.10 Results for the test image 3 (i) original, (ii) Enhanced by proposed method, (iii) histogram of the original image and (iv)histogram of the enhanced image

IMAGE 4



(i) (ii)

(iii) (iv)

Fig.11 Results for test image 4 (i) original, (ii) Enhanced by proposed method, (iii) histogram of the original image and (iv)histogram of the enhanced image

6.2.2. On the basis of entropy:

The assessment of proposed method is shown in table 1 on the basis of value of the entropy of the image. The performance of the proposed is evaluated by taking ten images. Entropy shows how much information or details are present in the image. Entropy's value should be nearby to the original image for the optimum performance. The entropy values by the given method are very close to that of original values of the images, therefore making the method suitable for enhancement without much loss of the information in the images.

Image No.	Original	Proposed Technique
1.	6.4703	6.2420
2.	5.0505	5.0393
3.	4.4905	4.4834
4.	4.2632	4.4834
5.	7.3118	7.1840
6.	6.7093	6.4955
7.	7.3424	7.1945
8.	5.7055	5.7042
9.	6.0274	5.8535
10.	5.9087	5.7416
Average	5.9279	5.8371

Table 1 Results of the average information content

6.2.3. On the basis of values of MSE and PSNR:

The Values of the MSE and PSNR are depicted in table 2. MSE and PSNR are two error matrices. In image processing, low MSE and High PSNR are preferred and an enhancement algorithm is said as good if the value of PSNR is greater than 45 dB. The proposed method is tested on ten low exposure images in which are acquired in underwater environment and in low light conditions. The proposed method gives an average PSNR value of 69.3669 dB when applied on these images.

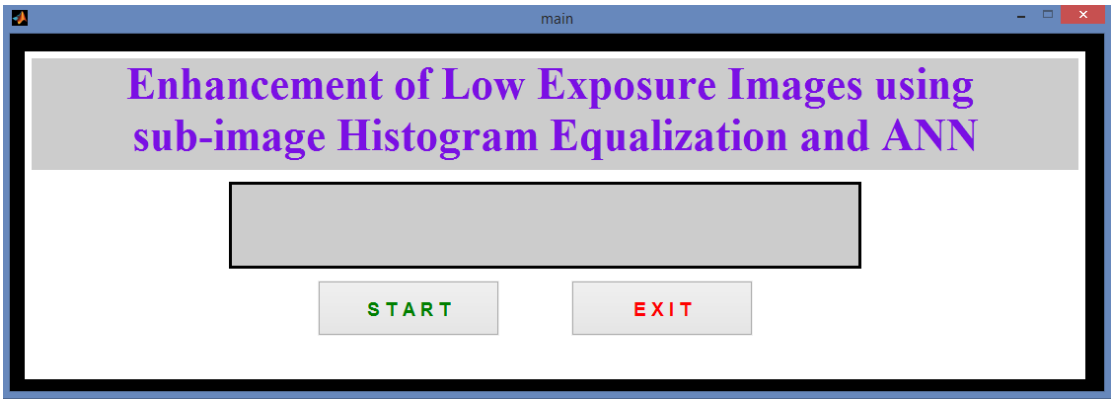
Image No.	MSE	PSNR
1.	0.0177	65.6722
2.	0.0435	61.7745
3.	0.1022	58.0679
4.	0.0201	65.1128
5.	0.0029	73.4072
6.	0.0097	68.2599
7.	0.0012	77.2673
8.	0.0007	79.3482
9.	0.0043	71.7572
10.	0.0033	72.9027

Table 2 MSE and PSNR Values for different images

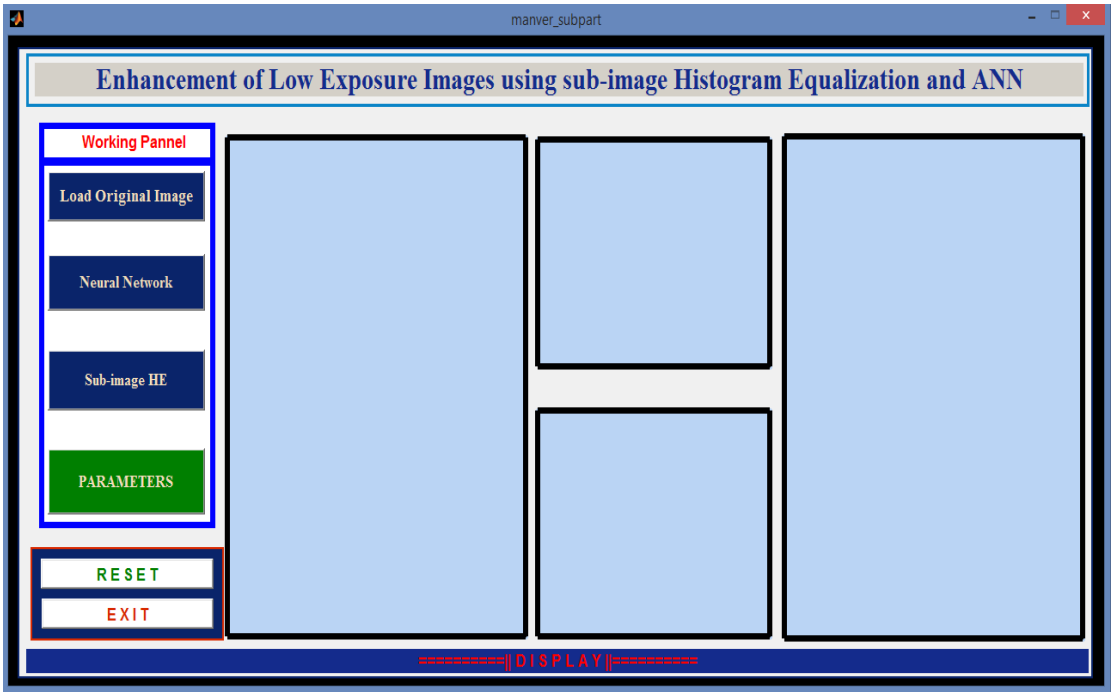
6.3 SNAPSHOTS OF THE GUI

A graphical interface has also been created for easy testing of the proposed method on various images. The advantage of creation of the GUI is that it making the selection of the images and the application of the proposed algorithm easy with just simple click on the buttons.

Fig.11 to fig.14 shows the screen shots the main GUI of the working model of the proposed method.



(i)



(ii)

Fig.12 (i) and (ii) depicts the GUI of the proposed model

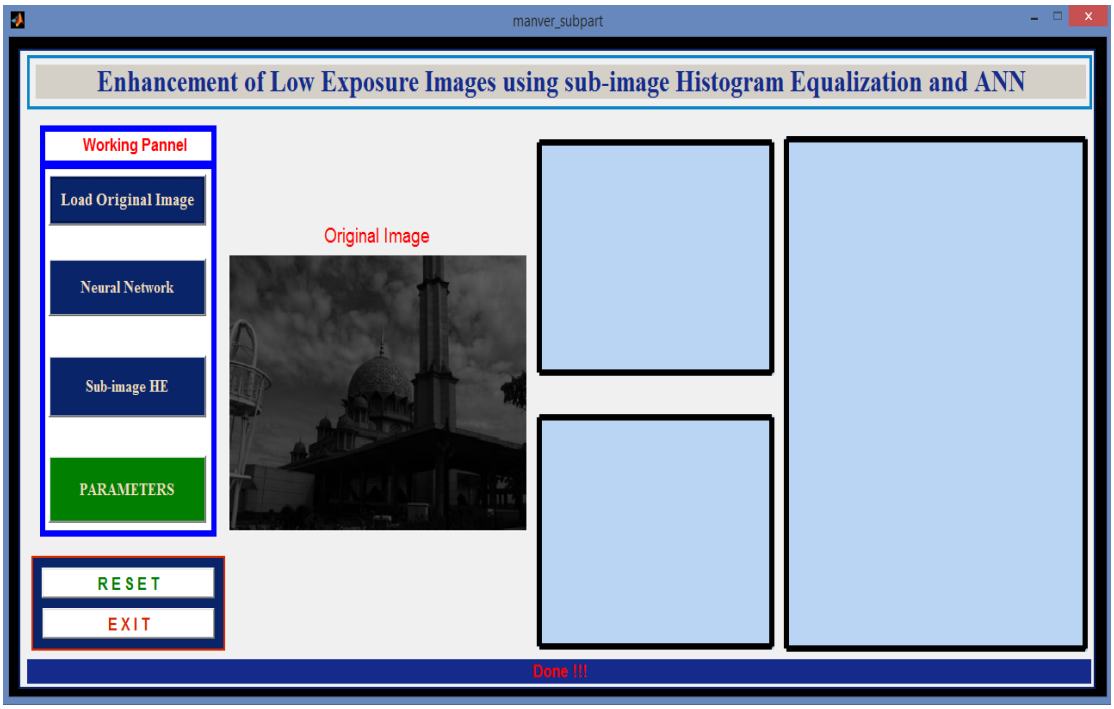


Fig.13 Uploaded original image which has to be enhanced

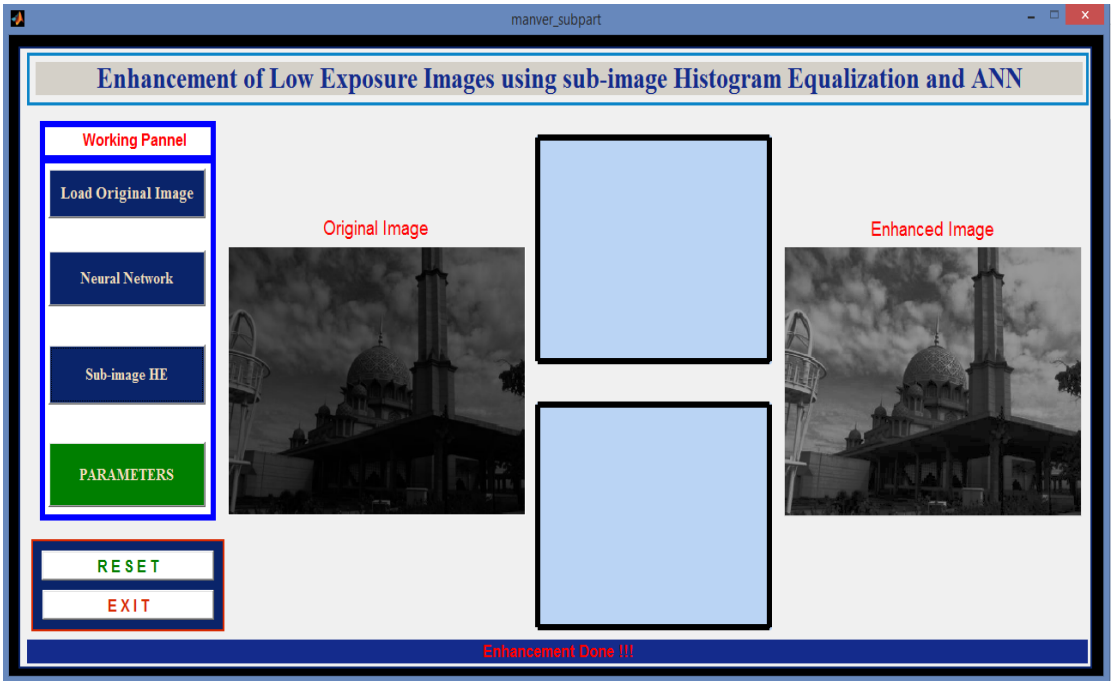


Fig.14 GUI showing Original image and enhanced image

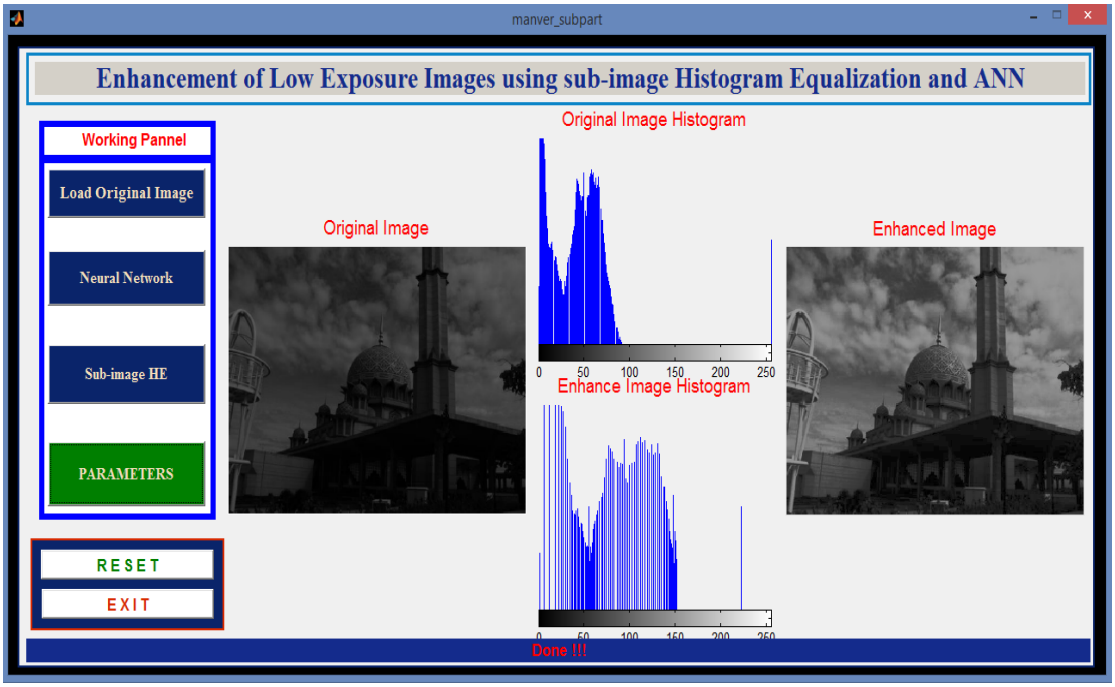


Fig.15 GUI showing original image and enhanced image along with their corresponding histograms

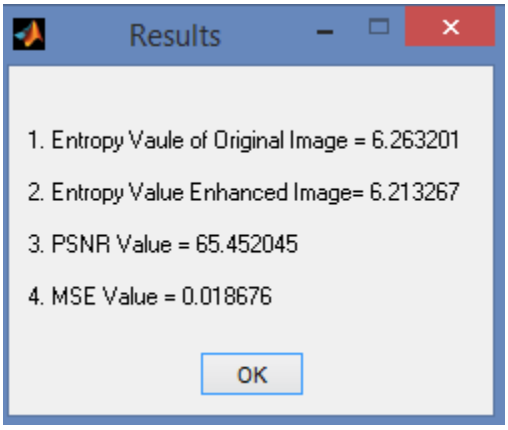


Fig.16 Parameter Evaluation

CHAPTER 7:
CONCLUSION AND FUTURE SCOPE

In this thesis work, a hybrid technique for the enhancement of low exposure images is presented. It uses sub-image histogram equalization method which is hybridized by the results given by the back propagation neural network technique. The neural networks have the capability to enhance the images at higher rates by examining the pattern of the image. Histogram equalization shows enhancement in the contrast of the image by distribution of the intensity values over the entire range. The proposed method undergoes three main steps: first, the image that is to be enhanced is passed to neural network which will give the value by which the enhancement in the image can be done. In second step, the clipping of the histogram is done according to the value calculated in the first step. In third step: the image's histogram is divided into four parts based upon exposure values then histogram equalization method is applied to all the four parts individually. The hybridization using both these methods shows significant improvements in the performance of the enhancement algorithm. The performance the proposed technique is also assessed on the basis of various parameters like information content in the image, PSNR and MSE values. The value of the parameters describes the performance of the proposed method is effective.

In future, this method can be applied to other problem domains for the enhancement of images. It can act as pre processing phase in various application fields related to digital image processing domain like segmentation of the object from the enhanced image for the purpose of objection detection or feature extraction.

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VIDEO LINK

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ORIGINALITY REPORT

10%	8%	8%	0%
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