

# **FUZZY TECHNIQUES FOR IMAGE ENHANCEMENT**

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

**Master of Engineering**

in

**Software Engineering**

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COMPUTER SCIENCE AND ENGINEERING DEPARTMENT

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PATIALA-147004

**June 2010**

## Certificate

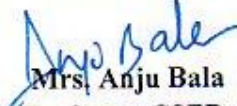
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I hereby certify that the work which is being presented in the thesis entitled, “**Fuzzy Techniques for Image Enhancement**”, in partial fulfillment of the requirements for the award of degree of Master of Engineering in Software Engineering submitted in Computer Science and Engineering Department of Thapar University, Patiala, is an authentic record of my own work carried out under the supervision of **Mrs. Anju Bala** and refers other researcher’s works which are duly listed in the reference section.

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


  
**Nitin Kumar Kansal**

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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Patiala.

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Finally, my special thanks go to authors whose works I have consulted and quoted in this work. Finally my special thanks go to authors whose works I have consulted and quoted in this work.

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## Abstract

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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. Fuzzy techniques can manage the vagueness and ambiguity efficiently (an image can be represented as fuzzy set). Fuzzy logic is a powerful tool to represent and process human knowledge in form of fuzzy if-then rules. The manipulation of these concepts leads to theory of approximation using fuzzy systems in image processing. In recent years, many researchers have applied the fuzzy logic to develop new image processing algorithms. The fuzzy image processing is one of the important application areas of fuzzy logic.

In this thesis the algorithm is proposed using fuzzy membership function. This algorithm enhances image contrast very effectively. If the observed data are disturbed by random noise then the intensifier operator should convert the probabilistic data into fuzzy data. Some images are not available to good quality, so proposed fuzzy algorithm can be used for image enhancement to improve the quality of images. All the implementation work has been done in MATLAB 7.5 image processing tool box. Experimental results show that the quality of image is improved.

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# Chapter 1

## Introduction

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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 a machine. Enhancement of noisy image data is a very challenging issue in many research and application areas. Image enhancement techniques can be divided into three broad categories:

- 1) Spatial domain methods, which operate directly on pixels.
- 2) Frequency domain methods, which operate on the Fourier transform of an image.
- 3) Fuzzy domain methods, which involves the use of knowledge-base systems that are capable of mimicking the behavior of a human expert.

Fuzzy logic represents a good mathematical framework to deal with uncertainty of information. Fuzzy image processing is the collection of all approaches that understand represent and process the images, their segments and features as fuzzy sets. In the last few years, nonlinear filters based on fuzzy models have been shown to be very effective in removing noise without destroying the useful information contained in the image data.

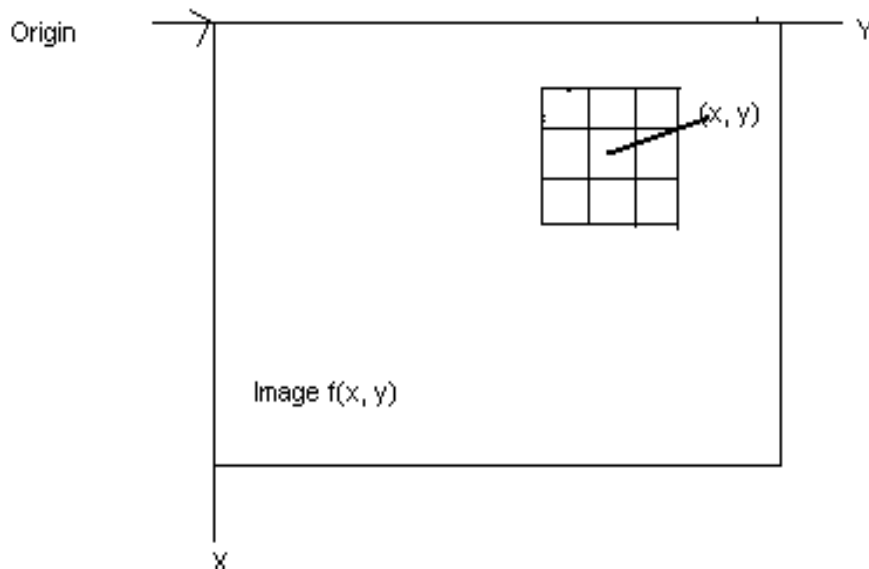
In this thesis work the algorithm is proposed using fuzzy membership function. This algorithm enhances image contrast very effectively. If the observed data are disturbed by random noise then the intensifier operator should convert the image data into the fuzzy domain and process some morphological operation. So apply proposed algorithm then find the good contrasted image compare to the original image, preserving the all the image data. All the implementation work has been done in MATLAB 7.5 image processing tool box. Experimental results shows improve the quality of images. The proposed algorithm tested more than 30 images, and compared these results with some existed methods.

## 1.1 Image

Image can be defined as a two dimensional light intensity function  $f(x, y)$ , where  $x$  and  $y$  denotes spatial co-ordinates and the value of 'f' at any point is directly proportional to the brightness (gray level) of the image at that point.

## 1.2 Digital image processing

Digital image processing an image may be defined as two dimensional function  $f(x, y)$  where  $x$  and  $y$  are spatial (plane) coordinates and amplitude of  $f$  at any pair of coordinates  $(x, y)$  is called the intensity or gray level of image at that point. Where  $x, y$  and amplitude values of  $f$  are all finite, discrete quantities then it called digital image processing. Digital image processing starts with one image and produces a modified version of that image. Digital image analysis is a process that transforms a digital image into something other than a digital image, such as a set of measurement data, alphabet text, or a decision. Image digitization is a process that converts a pictorial form to numerical data. Spatial domain: spatial domain methods are procedures that operate directly on these pixels spatial domain process will be denoted by the expression.  $g(x, y) = T[f(x, y)]$  where  $f(x, y)$  input image,  $g(x, y)$  is processed image and  $T$  is an operate on  $f$  defined over some neighborhood of  $(x, y)$  [16].



**Figure 1.1: 3\*3 neighborhoods about a point (x, y) in an image [16]**

## 1.3 Types of digital image

Basically three types of digital images are there those are

- i) Grayscale images
- ii) Color images
- iii) Binary images

### 1.3.1 Grayscale images

Grayscale images can be represented as a binary images in a three dimensional space, with the third dimension representing brightness. Grayscale image can then be viewed as three dimension surface, with the height at each point equal to the brightness value. A black & white image is made up of pixels, each of which holds a single number corresponding to the gray level of the image at a particular location. These gray levels span the full range from black to white in a series of very steps, normally 256 different grays. Assuming 256 gray levels, each black and white pixel can be stored in a single byte (8 bits) of memory [32].



**Figure 1.2: Lena Grayscale Image [32]**

### 1.3.2 Color Images

A color image is made up of pixels, each of which holds three numbers corresponding to the red, green and blue levels of the image at a Particular location. Assuming 256 levels, each color pixel can be stored in three bytes (24 bits) of memory. Note that for images of the same size, a black & white version will use three times less memory than a color version.



**Figure1.3: Lena Color Image [32]**

### 1.3.3 Binary Images

Binary images use only a single bit to represent each pixel. Since a bit can only exist in two states- on or off, every pixel in a binary image must be one of two colors, usually black or white. This inability to represent intermediate shades of gray is what limits their usefulness in dealing with photographic images.

#### **Different Types of Noise:**

There are several noises that may degrade the quality of an image.

- Amplifier noise (Gaussian noise)
- Salt-and-pepper noise
- Quantization noise (uniform noise)

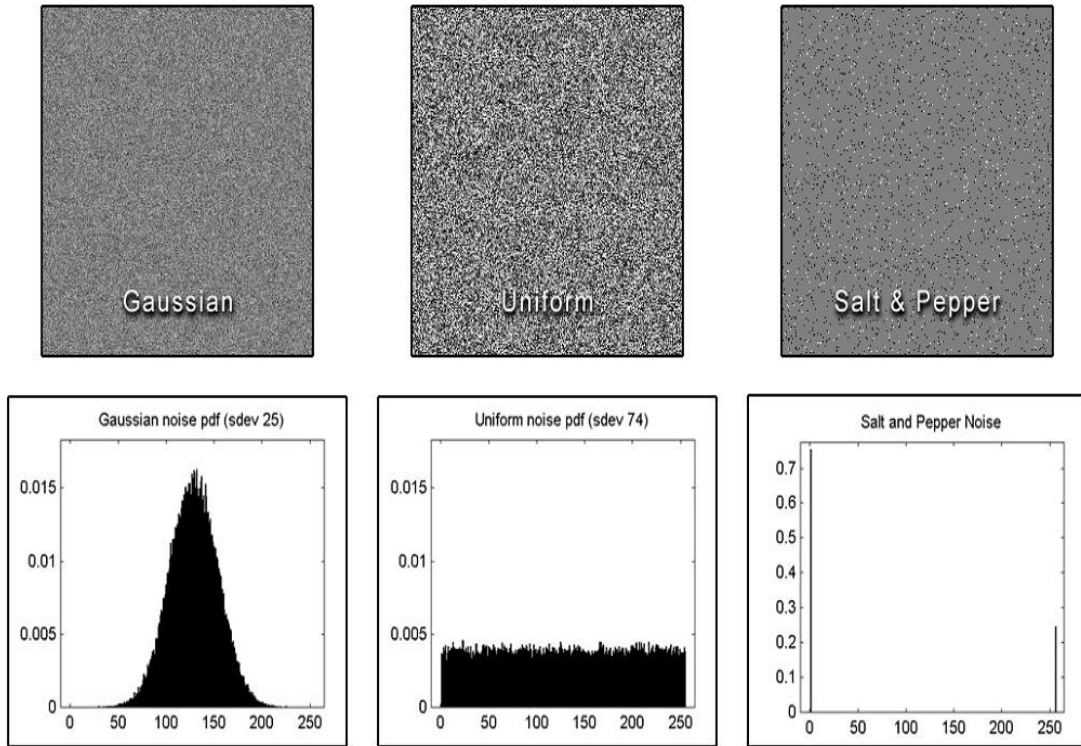


Figure 1.4: Shows Different Between Each Noise [16]

### Gaussian Noise Image:

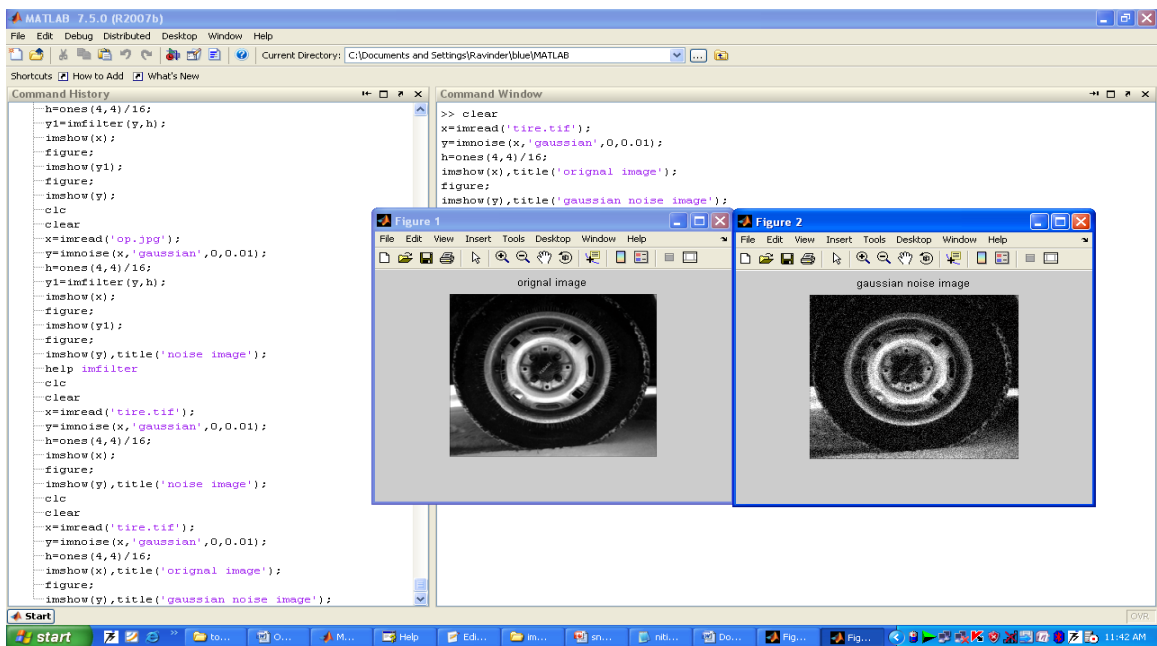


Figure 1.5: Gaussian Noise Image

## Salt and Pepper Noise:

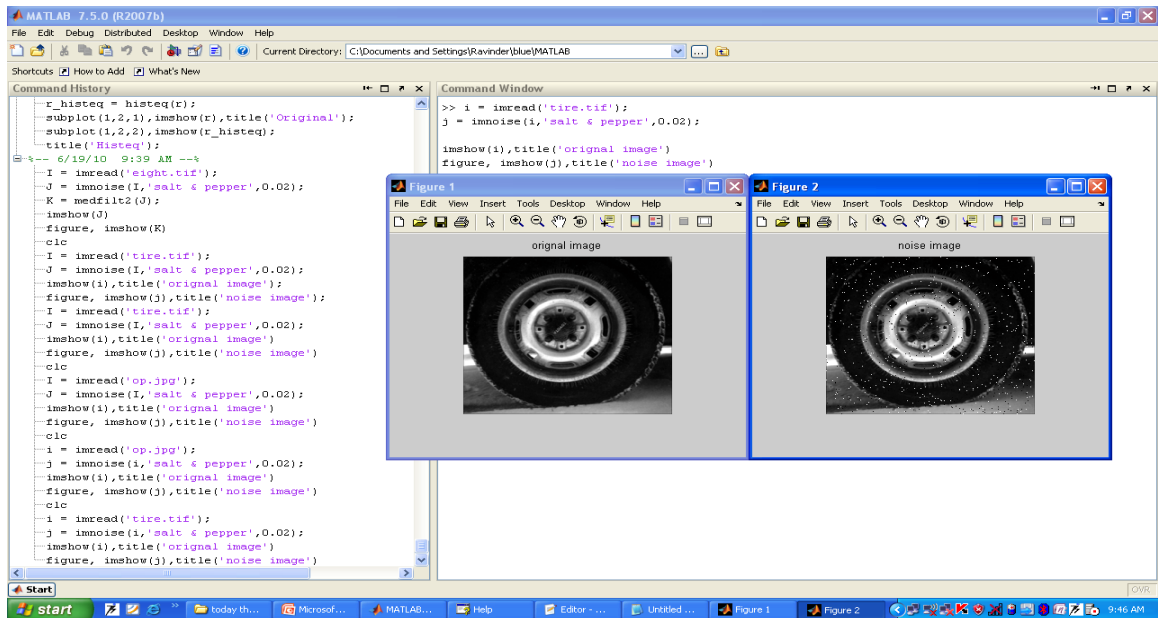


Figure 1.6: Salt and Pepper Noise image

## 1.4 Examples of Fields that Use Digital Image Processing

Today there is almost no area of technical endeavor that is not impacted in some way by digital image processing. The areas of application of digital image processing are so varied that some form of organization is desirable in attempting to capture the breadth of this field. One of the simplest ways to develop a basic understanding of the extent of image processing applications is to categorize images according to their source (e.g., visual, X-ray, and so on). The principal energy source for images in use today is the electromagnetic energy spectrum. Other important sources of energy include acoustic, ultrasonic, and electronic. Synthetic images, used for modeling and visualization, are generated by computer [16].

## 1.5 Fundamental Steps in Digital Image Processing

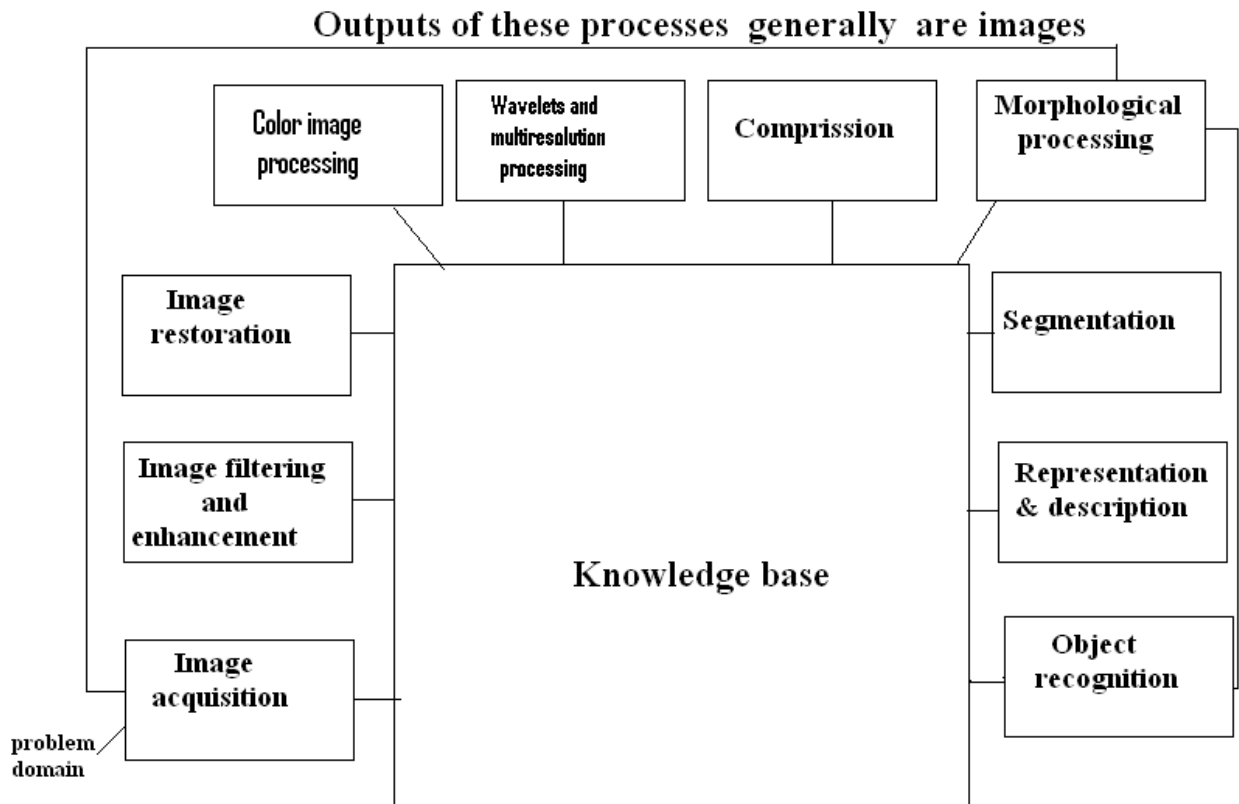


Figure 1.7: Fundamental steps in Digital Image [16]

**Image acquisition:** Camera/digitizer converts the image into a form suitable for input to digital computer.

**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.

**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.

**Color image processing:** Color image processing is an area that has been gaining in importance because of the significant increase in the use of digital images over the internet.

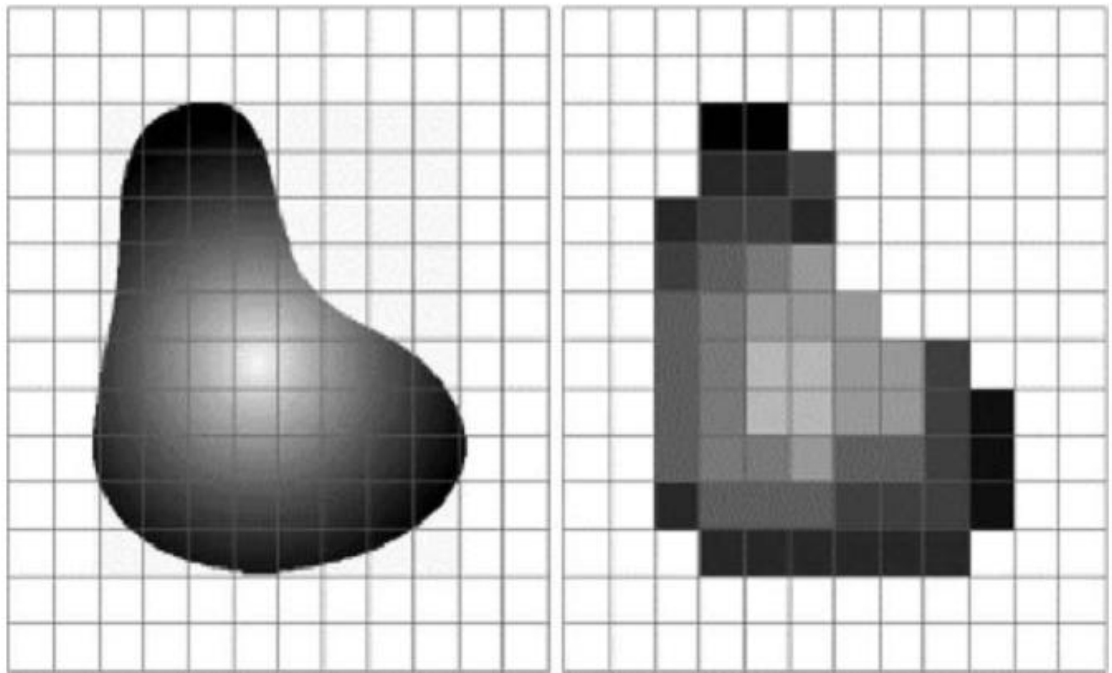
## **1.6 Image processing**

In computer science and electronic engineering image processing, image processing is any form of signal processing for which the input is an image, such as photographs or frames of video the output of image processing can be either an image or a set of characteristics or parameters related to the image [35]. Image processing techniques have been developed tremendously during the past five decades Image processing is used for two somewhat different purposes:

- a) Improving the visual appearance of images to a human viewer, and
- b) Preparing images for measurement of the features and structures present.

Sometimes a distinction is made by defining image processing as a discipline in which both input and output of a process are image. Most image-processing techniques involve treating the image as a two-dimensional-signal and applying standard signal processing techniques to it. Image processing is used to solve identification problems, such as in forensic medicine or in creating weather maps from satellite pictures.

Although large-scale image processing systems still are being sold for massive imaging applications, such as processing of satellite images, the trend continues toward miniaturizing and blending of general-purpose small computers with specialized image processing hardware [36].



(a) Original Image

(b) Pixel Image

**Figure 1.8: (a) Original Image (b) Pixel Image [32]**

## **1.7 Image Processing Operation**

Image processing operation can be divided into four categories:

### **1.7.1 Image Enhancement**

Image enhancement means getting a clearer image. Image enhancement can be treated as transforming one image to another so that the look and feel of an image can be improved or machine analysis or visual perception of human beings [24].



**Figure 1.9: (a) Original Image (b) Enhancement Image [31]**

### 1.7.2 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 1.10: (a) Original Image (b) Segmentation image [31].**

### 1.7.3 Image Compression

Image compression means minimizing the size in bytes of graphics file without degrading the quality of image to an unacceptable level. The reduction in file size allows more images to store in a given amount of disk or memory space. It also reduces time required for image to be sent over internet or download from web [24].



(a)

(b)

**Figure1.11: (a) Original Image (b) Compression Image [24]**

### 1.7.4 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.

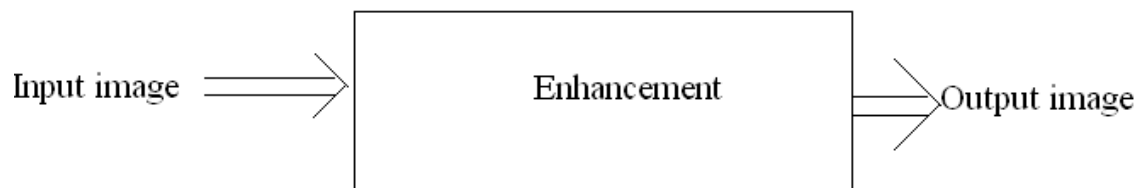
# Image Enhancement, Fuzzy Set and Fuzzy Image Processing

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## 2.1 Enhancement

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 a machine. The principle objective of image enhancement techniques is to process an image so that the result is more suitable than the original image for a specific application. It is often used to increase the contrast in images that are substantially dark or light. Image enhancement entails operations that improve the appearance to a human viewer, or operations to convert an image to a format better suited to machine processing.

Image enhancement refers to those image processing operations that improve the quality of input image in order to overcome the weakness of the human visual system.



**Figure 2.1: Image Enhancement Operation [28]**

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

**2.1.1 Spatial domain methods.**

**2.1.2 Frequency domain methods (DFT).**

**2.1.3 Fuzzy Domain.**

### 2.1.1 Spatial domain methods

Spatial domain methods which are operate directly on pixels. Spatial domain method pixel values may be modified according to rules that depend on the original pixel value (local or point processes). Alternatively, pixel values may be combined with or compared to others in their immediate neighborhood in a variety of ways [33].

Consider the input image  $f(x,y)$  and processed image  $g(x,y)$  then the transformation  $g(x,y)=T[f(x,y)]$ , Where T is an operator on f defined over some neighbourhood of  $(x,y)$ . The operator T is applied at each location  $(x,y)$  to yield output g at that location. The process uses pixels in the area of image spanned by neighbourhood [16].

Example: Thresholding

### 2.1.2 Frequency domain methods (DFT)

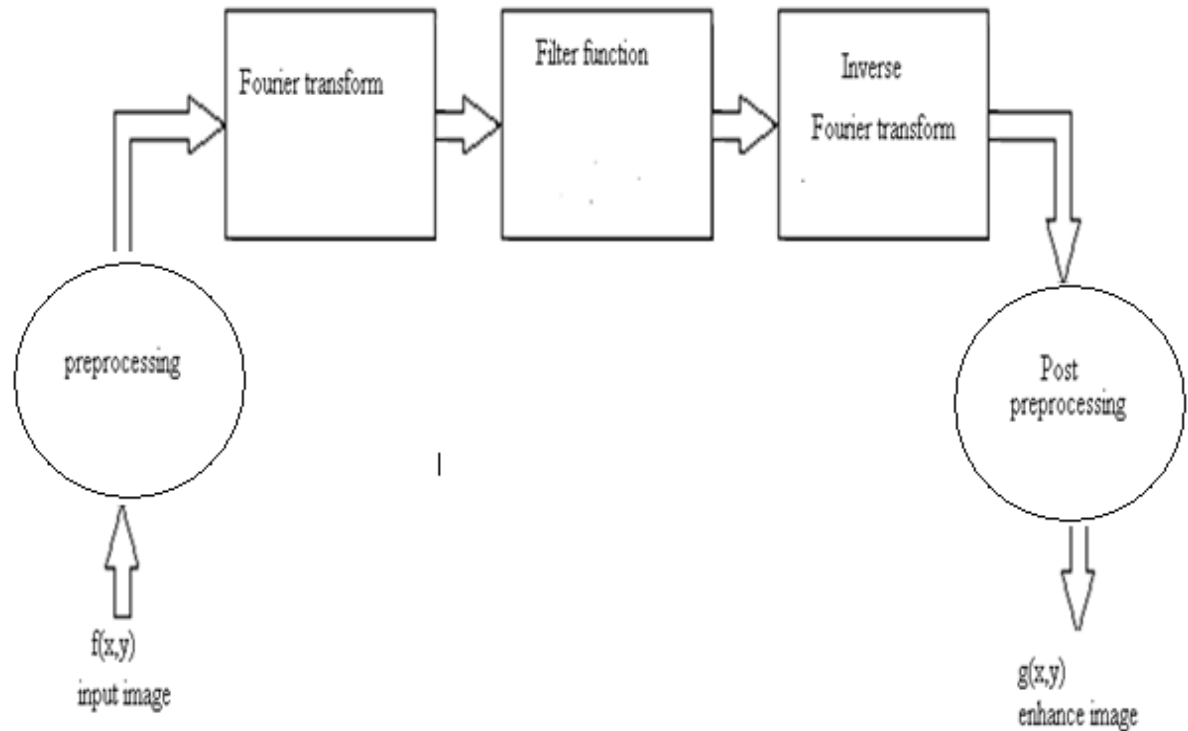
Frequency domain which operate on the Fourier transform of an image [16].

- Edges and sharp transitions (e.g., noise) in an image contribute significantly to high-frequency content of Fourier transform.
- Low frequency contents in the Fourier transform are responsible to the general appearance of the image over smooth areas.

The concept of filtering is easier to visualize in the frequency domain. Therefore enhancement of image  $f(x,y)$  can be done in the frequency domain based on DFT. This is particularly useful in convolution .if the spatial extent of the point spread sequence  $h(x,y)$  is large then convolution theory.

$$g(x,y)=h(x,y)*f(x,y)$$

Where  $g(x,y)$  is enhanced image.



**Figure 2.2: Basic steps for Frequency Domain [16]**

### 2.1.3 Fuzzy domain

Fuzzy set theory is thus useful in handling various uncertainties in computer vision and image processing applications. Fuzzy image processing is a collection of different fuzzy approaches to image processing that can understand, represent, and process the image. It has three main stages, namely, image fuzzification, modification of membership function values, and defuzzification. Fuzzy image enhancement is based on gray level mapping into membership function. The aim is to generate an image of higher contrast than the original image by giving a larger weight to the gray levels that are closer to the mean gray level of the image that are farther from the mean.

## 2.2 Fuzzy Set

In classical set theory, a set is defined as a collection of element having a certain property, each of belongs to the set. So the characteristic function takes either the value of 0 or 1 [25].

Let us consider a classical set, X, called the universe, whose elements are denoted as x, that is,  $X = \{x_1, x_2, \dots, x_n\}$ . Consider a subset A of the set X such that an element x of X is a member of A if

$$\mu_A(x) = 1 \quad \text{If } x \in A$$

$$\mu_A(x) = 0 \quad \text{Otherwise}$$

So fuzzy set A is defined as:

$$A = \{(x, \mu_A(x)) : x \in X\}$$

Where  $\mu_A(x)$  is a membership function for a fuzzy set. Examples of membership functions (triangular, trapezoidal, Gaussian, [16]) can be seen in figure 2.3 and described with the following formulas:

**Triangular Membership Function:** Triangular membership function is defined as a following equation:

$$0 \quad \text{if } x \leq a$$

$$\text{Triangular}(x; a, b, c) = \frac{x-a}{b-a} \quad \text{if } a \leq x \leq b$$

$$\frac{c-x}{c-b} \quad \text{if } b \leq x \leq c$$

$$0 \quad \text{if } c \leq x$$

**Trapezoidal Membership Function:** Trapezoidal membership function is defined as a following equation:

$$0 \quad \text{if } x \leq a$$

$$\frac{x-a}{b-a} \quad \text{if } a \leq x \leq b$$

$$\text{Trapezoidal}(x; a, b, c, d) = 1 \quad \text{if } b \leq x \leq c$$

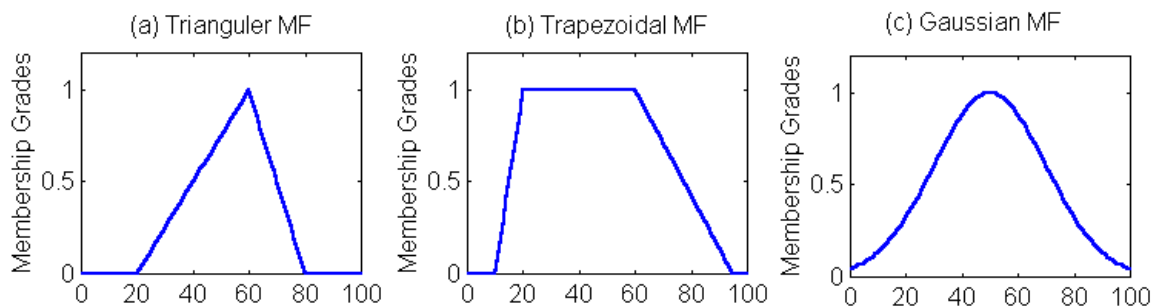
$$\frac{d-x}{d-c} \quad \text{if } c \leq x \leq d$$

$$0 \quad \text{if } d \leq x$$

**Gaussian Membership Function:** Gaussian Membership Function is defined as following equation:

$$\text{Gaussian}(x; m, \sigma) = e^{-\left(\frac{(x-m)^2}{2\sigma^2}\right)}$$

Where  $m$  = mean, and  $\sigma$  is the standard deviation.



**Figure 2.3: Examples of Membership Function [16]**

### 2.2.1 Linguistic Variables

The concept of linguistic variables was introduced by Zadeh [15] to provide a basis for approximate reasoning. A linguistic variable was defined as a variable whose values are words or sentences. For instance, Age can be linguistic variable if its values are linguistic rather than numerical, i.e., young, middle age; old are represented by the membership function

Example

0-10                      40-50

10-20                    50-60

20-30                    60-70

70 and above

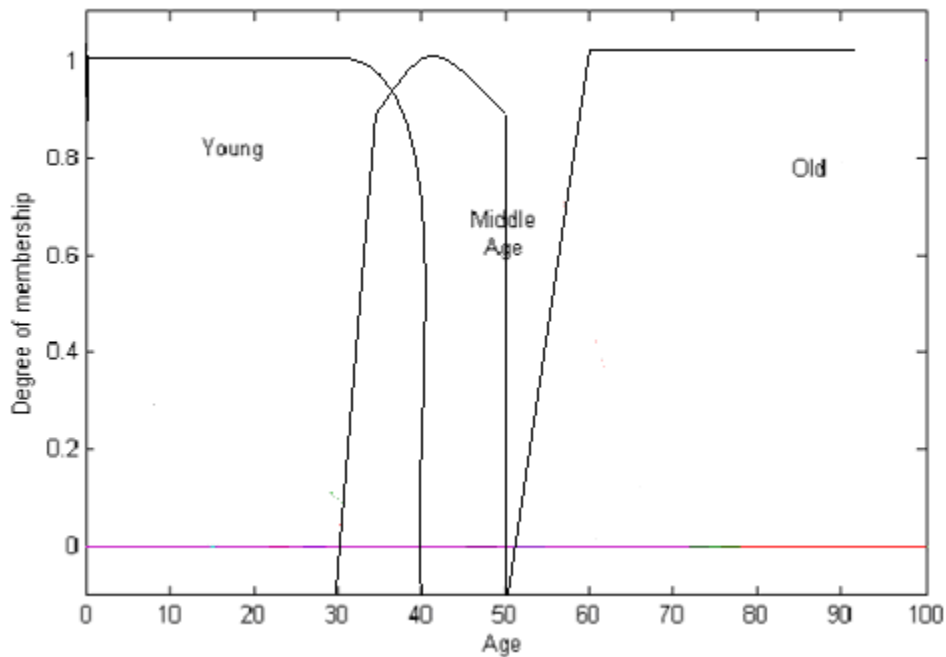


Figure 2.4: Membership Function of the Term Set age [15]

### 2.2.2 Rule Based System

The theory of fuzzy IF-THEN rules was proposed by Zadeh [15]. The general form of a rule is as follows:

If x is A THEN y is B

Where A and B are linguistic values defined by fuzzy sets. “x is A” is called “antecedent” or “premise”, while “y is B” is called the “consequence” or “conclusion” respectively. Some of the if-then rule examples can be given below:

- If the speed is low and the distance is small, then the force on brake should be small.
- If pixel is dark AND its neighborhood is also dark AND homogeneous THEN it belongs to the background.

### **2.2.3 Fuzzy Reasoning**

Fuzzy reasoning, approximate reasoning, is an inference procedure whose outcome is conclusion for a set of fuzzy if-then rules. The steps of fuzzy reasoning can be given as follows:

- “Input variables are compared with the membership function on the premise part to obtain the membership values of each linguistic label (fuzzification).
- The membership values on the premise part are combined through specific fuzzy set operations such as: min, max, or multiplication to get firing strength (weight) of each rule.
- The qualified consequent (either fuzzy or crisp) is generated depends on the firing strength.
- The qualified consequents are aggregated to produce crisp output according to the defined methods such as: cancroids of area, bisector of area, mean of maximum, smallest of maximum and largest of maximum ( defuzzification ).

#### **Rules of fuzzy reasoning:**

Rules

- If x is A1 and y is B1  
Then z is C1
- If x is A2 and y is B2  
Then z is C2

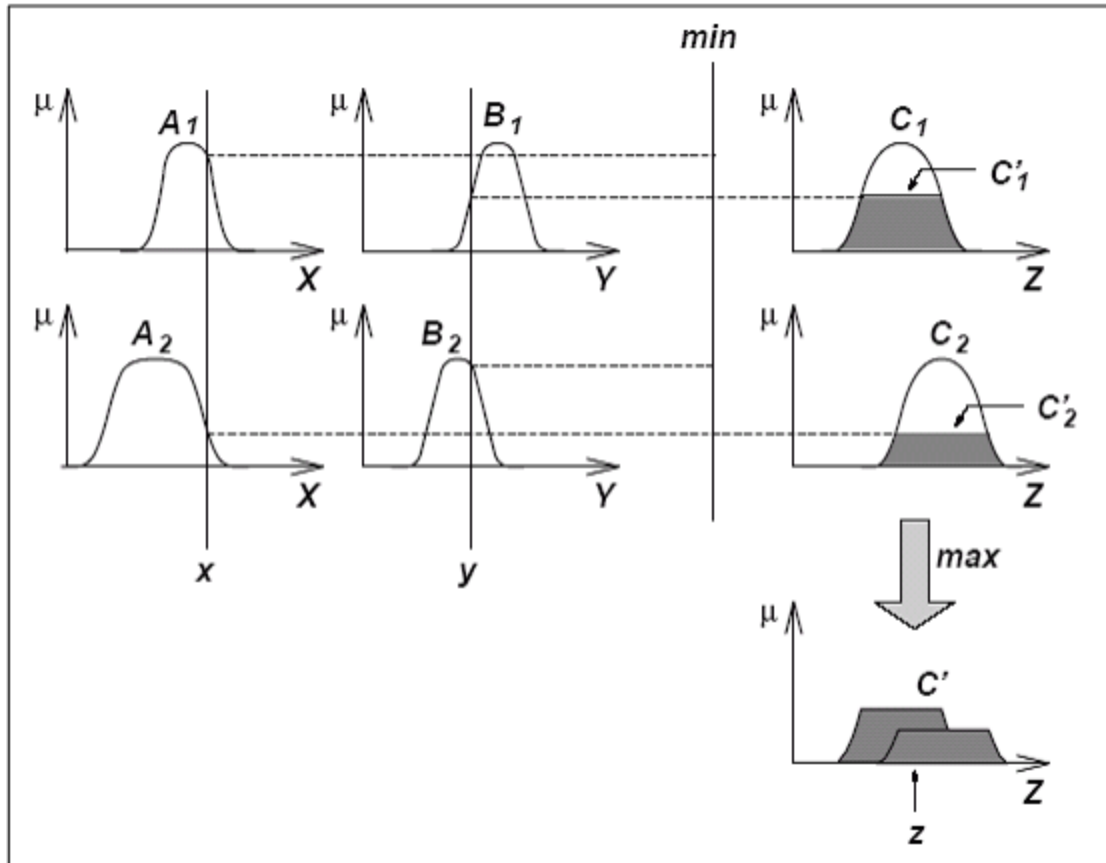


Figure 2.5: Rules of Fuzzy Reasoning [29]

### 2.2.4 Fuzzy Inference System

Fuzzy systems are made of a knowledge base and reasoning mechanism called fuzzy inference system. A fuzzy inference system (FIS) consists of four functional blocks as shown in Figure

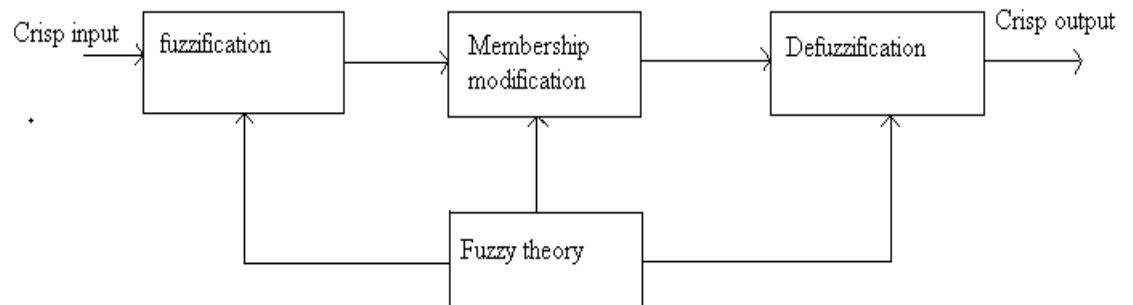
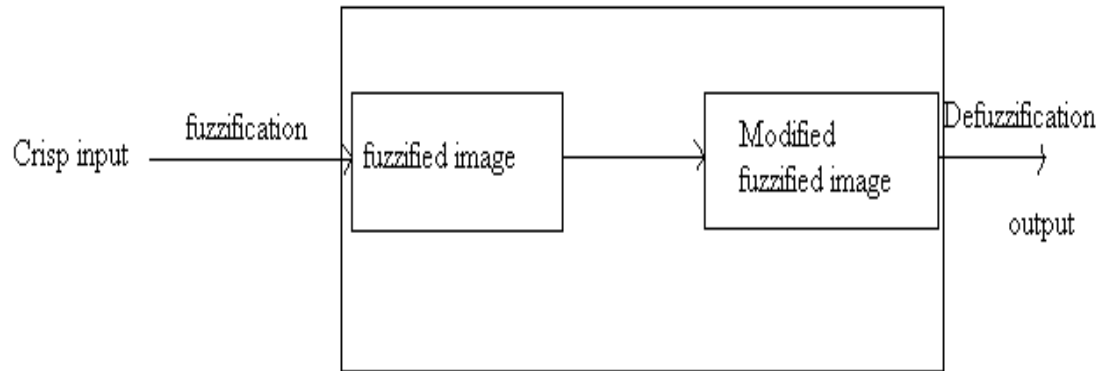


Figure 2.6: Fuzzy Inference System [30]

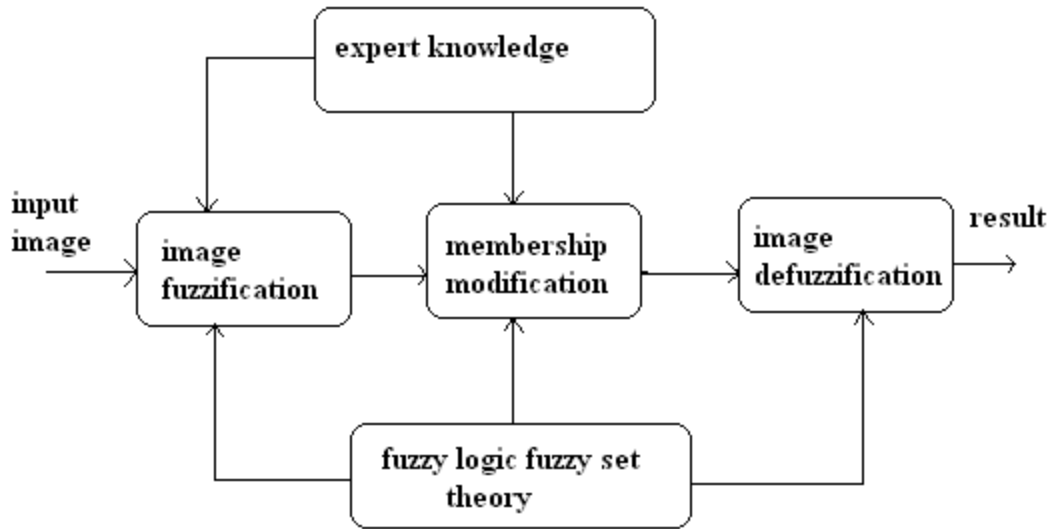


**Figure 2.7: Membership Function Modification [30]**

- **Fuzzification:** Transforms the crisp inputs into degrees of match with linguistic values. Reverse process of defuzzification.
- **Knowledge Base:** Consists of a rule base and a database. A rule base contains a number of fuzzy if-then rules. A database defines the membership function of the fuzzy sets used in the fuzzy rules.
- **Fuzzy Inference Engine:** Fuzzy Inference engine performs the inference operations on the rules.
- **Defuzzification:** This conversion of fuzzy set to single crisp value is called defuzzification.

### 2.3 Fuzzy Image Processing

Fuzzy image processing is collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved [18].



**Figure 2.8: Fuzzy Image Processing [30]**

The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques. The main power of fuzzy image processing is in the middle step (membership modification) [18].

### **2.3.1 Motivation behind Fuzzy Image Processing**

There are many reasons to do this. The most important of them are follows:

- Fuzzy is powerful tool to knowledge representation and process human knowledge in form of fuzzy if then rules.
- Fuzzy techniques can manage the ambiguity efficiently and vagueness (an image can be represented as a fuzzy set).

**General observations about the fuzzy techniques are:**

- Fuzzy logic is flexible. With any given system, it's easy to manage it or layer more functionality on top of it without starting again from scratch.
- Fuzzy logic is conceptually easy to understand. The mathematical concepts behind fuzzy reasoning are very simple.

- Fuzzy logic is tolerant of imprecise data. Everything is imprecise if we look closely enough, but more than that, most things are imprecise even on careful inspection. Fuzzy reasoning builds this understanding into the process rather than tacking it onto the end.
- Fuzzy logic can be blended with conventional control techniques. Fuzzy systems don't necessarily replace conventional control methods. In many cases fuzzy systems augment them and simplify their implementation.
- Fuzzy logic is based on natural language. The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic.
- Fuzzy logic can model nonlinear functions of arbitrary complexity.
- Fuzzy logic can be built on top of the experience of experts [34].

## Chapter 3

### Literature Review

---

There is a lot of work has been done in the field of image enhancement. In this section, work done in the area of image enhancement and fuzzy set is focus has been made on improve the quality of image.

#### 3.1 Survey on Fuzzy Set

Even though fuzzy sets were introduced in their modern form by Zadeh in 1965, the idea of a multi-valued logic in order to deal with vagueness has been around from the beginning of the century. Fuzzy sets provide means to model the uncertainty associated with vagueness, imprecision, and lack of information regarding a problem. Peirce was one of the first thinkers to seriously consider vagueness; he did not believe in the separation between true and false and believed everything in life is a continuum. In 1905 he stated: "I have worked out the logic of vagueness with something like completeness". Other famous scientists and philosophers probed this topic further. Russell claimed, "All language is vague" and went further saying; "vagueness is a matter of degree" (e.g., a blurred photo is vaguer than a crisp one, etc.). Table shows brief the history of fuzzy set and fuzzy logic [34].

Fuzzy set theory generalizes classical set theory in that the membership degree of an object to a set is not restricted to the integers 0 and 1, but may take on any value in  $[0,1]$ . The fuzzy theory provides a mechanism for representing linguistic constructs such as "many," "low," "medium," "often," "few." In general, the fuzzy logic provides an inference structure that enables appropriate human reasoning capabilities [34]. By elaborating on the notion of fuzzy sets and fuzzy relations we can define fuzzy logic systems (FLS). FLSs are rule-based systems in which an input is first fuzzifier (i.e., converted from a crisp number to a fuzzy set) and subsequently processed by an inference engine that retrieves knowledge in the form of fuzzy rules contained in a rule-base. The fuzzy sets computed by the fuzzy inference as the output of each rule are then composed

and defuzzified (i.e., converted from a fuzzy set to a crisp number). A fuzzy logic system is a nonlinear mapping from the input to the output space.

Fuzzy Logic (FL) is a powerful problem solving methodology in the past few years. The Fuzzy Logic tool was introduced in 1965, also by Lotfi Zadeh, and is a mathematical tool for dealing with uncertainty. It shows a rapid growth in the applications of FL, especially in the image understanding applications, such as edges detection, image enhancement, classification and clustering. FL provides a simple and easy way to draw a definite conclusion from ambiguous, imprecise or vague information. The human decision making, which provide a precise solution from approximate data. It is more similar with the way of human thinking which generate solution from the expertise experiences (represent in rules), knowledge and even skill. Although we know that the rule-based systems have a long history in the field of Artificial Intelligence (AI), but the conventional rule-based system have difficulty to tackle the fuzzy consequents and fuzzy antecedents' problems.

The if-then rules in FL will combine with an inference engine to be more flexible. From the official web page of fuzzy tech [19], we find that the Fuzzy Logic technology has very good results in two main application fields, which consists of industrial applications and business and finance applications. Those Fuzzy Logic applications can categorize under automated control or decision-making support.

1965 Lotfi A. ZADEH	Description on fuzzy set
1966 ZADEH	Pattern recognition as interpolation of membership function
1969 Ruspini	Concept of fuzzy portioning
1970 Prewitt	First approach towards fuzzy image Understanding
1973 Dunn, Bezdek	First fuzzy cluster algorithm
1977 Pal	Fuzzy approach to speech recognition
1979 Rosenfeld	Fuzzy geometry
End of 1980s-90s Dave/Krishnapuram/ Bezdek	Different fuzzy cluster algorithm
Russo/ Krishnapuram	Rule based filter
Bloch et al. / Di Gesu / Sinha et al./De Baets /and many others...	Fuzzy morphology

**Table 3.1: History of Fuzzy Set [18]**

### **3.2 Survey on Image Enhancement(IE) has contributed to research advancement in a variety of fields**

Image Enhancement alters an image to makes its meaning clearer to human observers. It is often used to increase the contrast in images that are substantially dark or light. Enhancement algorithms often pay attention to humans' sensitivity to contrast. The main objective of image enhancement is to process the image so that the result is more suitable than the original image. Image enhancement techniques such as contrast stretching, map each grey level into another gray level by predetermined transformation.

Some of the areas in which IE has wide application are noted below.

- Face recognition, IE techniques when applied to pictures and videos help the visually impaired in reading small print, using computers, television and face recognition [1]. Several studies have been conducted that highlight the need and value of using IE for the visually impaired.
- Virtual restoration of historic paintings and artifacts [2] often employs the techniques of IE in order to reduce stains and crevices. Color contrast enhancement, sharpening and brightening are just some of the techniques used to make the images vivid. IE is a powerful tool for restorers who can make informed decisions by viewing the results of restoring a painting beforehand. It is equally useful in discerning text from worn-out historic documents .
- In the field of e-learning, IE is used to clarify the contents of chalkboard as viewed on streamed video; it improves the content readability and helps students in focusing on the text Similarly, collaboration [3] through the whiteboard is facilitated by enhancing the shared data and diminishing artifacts like shadows and blemishes.
- Astrophotography faces challenges due to light and noise pollution that can be minimized by IE [4]. For real time sharpening and contrast enhancement several

cameras have in-built IE functions. Moreover, numerous softwares allow editing such images to provide better and vivid results.

- Medical imaging [5] uses IE techniques for reducing noise and sharpening details to improve the visual representation of the image. Since minute details play a critical role in diagnosis and treatment of disease, it is essential to highlight important features while displaying medical images. This makes IE a necessary aiding tool for viewing anatomic areas in MRI, ultrasound and x-rays to name a few.
- In forensics [6]IE is used for identification, evidence gathering and surveillance. Images obtained from fingerprint detection, security videos analysis and crime scene investigations are enhanced to help in identification of culprits and protection of victims.
- In atmospheric sciences [7] IE is used to reduce the effects of haze, fog, mist and turbulent weather for meteorological observations. It helps in detecting shape and structure of remote objects in environment sensing . Satellite images undergo image restoration and enhancement to remove noise.
- Other fields including law enforcement, microbiology, biomedicine, bacteriology, climatology, meteorology, etc., benefit from various IE techniques. These benefits are not limited to professional studies and businesses but extend to the common users who employ IE to cosmetically enhance and correct their.

### **3.3 Survey on Fuzzy Set and Image Enhancement**

In this section detail of work has been done on fuzzy set and image enhancement field is given:

*In 1991 J.S. Kim, H.S. Cho and S.K. Kim used to fuzzy rule based enhancement algorithm for noisy image. In contrast to the classical approach, the fuzzy approach makes use improve the quality of image. A new edge relaxation algorithm that enhances the noisy*

boundary information's in image. The algorithm employs relaxation process that reduces or even eliminates of derivative operator response via contextual information. The contextual information's are the neighborhoods patters of a central edge which are estimated using the fuzzy pattern matching techniques [8].

*In 1994 Kaijun Tang, Jaakko Astola, Member, IEEE, and Yrjo Neuvo, Fellow, IEEE* worked multichannel Edge Enhancement in Color Image Processing. A multichannel edge enhancing filter (MEEF) based on the vector median is introduced for enhancing degraded edges in color images. An input multichannel signal is filtered with three sub filters, and the final output is determined by comparing the outputs of the sub filters and their vector median. Root signal and edge enhancement properties of the MEEF are examined in detail[9].

*In 1998 Farzam Farbiz, Seyed Ahmad Motamedi, Mohammad Bagher Menhaj Electrical Engineering Department of Amirkabir University of Technology* worked an iterative method for image enhancement based on fuzzy logic ,A new filtering approach based on fuzzy logic which has high performance in mixed noise environments. This filter is mainly based on the idea that each pixel is not allowed to be uniformly fired by each of the fuzzy rules. It performs several test experiments in order to highlight the merit of the proposed method. The results are very promising and indicating the high performance of the proposed filter in image restoration in compared with those of the filters which have been recently cited in image processing literature. As an important task in image enhancement, noise filtering can be viewed as replacing the gray-level value of each pixel in the image with a new value depending on the local context. Ideally, the filtering algorithm should vary from pixel to pixel based on the local context. For example, if the local region is relatively smooth, then the new value of the pixel is worth being determined by averaging neighboring pixels values. On the other hand, if the local region contains edge or impulse noise pixels, a different type of filtering should be used. However, it is extremely hard, if not impossible, to set the conditions under which a certain filter should be selected, since the local conditions can be evaluated only vaguely in some portions of an

image. Therefore, a filtering system needs to be capable of performing reasoning with vague and uncertain information[10].

*In 2000 I.Nedeljkovic, Zahumska Belgrade, Serbia and Montenegro* worked image classification based on fuzzy logic worked Fuzzy logic is relatively young theory. Major advantage of this theory is that it allows the natural description, in linguistic terms, of problems that should be solved rather than in terms of relationships between precise numerical values. This advantage, dealing with the complicated systems in simple way, is the main reason why fuzzy logic theory is widely applied in technique. It is also possible to classify the remotely sensed image (as well as any other digital imagery), in such a way that certain land cover classes are clearly represented in the resulting image. A prior knowledge about spectral information for certain land cover classes is used in order to classify SPOT image in fuzzy logic classification procedure. Basic idea was to perform the classification procedure first in the supervised and then in fuzzy logic manner. The later was done with Matlab's Fuzzy Logic Toolbox. Some information, needed for membership function definition, was taken from supervised maximum likelihood classification [11].

*In 2008 Milindkumar V. Sarode, Dr. S.A.Ladhake, Dr. Prashant R. Deshmukh* worked Fuzzy system for color image enhancement. This paper involves the use of knowledge-base (fuzzy expert) systems that are capable of mimicking the behavior of a human expert. Fuzzy approach of knowing severity of tumor is essential to determine if there is a need for the biopsy and it gives to user a clear idea of spread and severity level of tumor. Fuzzy based enhancement of color feature of tumor is an application of fuzzy in the area of color feature extraction for enhancement of a peculiar feature. It has been found that RGB color model is not suitable for enhancement because the color components are not decoupled. On the other hand, in HSV color model, hue (H), the color content, is separate from saturation (S), which can be used to dilute the color content and V, the intensity of the color content. By preserving H, and changing only S and V, it is possible to enhance color image. Therefore, we need to convert RGB into HSV for the purpose. A Gaussian type membership function is used to model S and V property of the image. This membership function uses only one fuzzifier and is evaluated by maximizing fuzzy

contrast. Our aim is to analyze and enhance the features related to a specific disease. The biomedical images will be sent for fuzzification and decisions related to classification of colors will be done and accordingly output will be consisting of only the serious tumor region and noisy pixels will be filtered and image will be enhanced in the features we desire. Fuzzy logic addresses such applications perfectly as it resembles human decision making with an ability to generate precise solutions from certain or approximate information. It fills an important gap in engineering design methods left vacant by purely mathematical approaches (e.g. linear control design), and purely logic-based approaches (e.g. expert systems) in system design [12].

*In later 2009 Sasi Gopalan, Madhu S Nair and Souriar Sebastian Cochin University of Science and Technology (CUSAT), worked an approximation Studies on Image Enhancement Using Fuzzy Technique and fuzzy entropy measuring the image which increases the sharpness of its argument image decreases and uses three parameters such as the intensification parameter the fuzzifier and crossover point. It considered five different types of images and enhanced an image [13].*

*In later 2009 Mr. Harish Kundra, Er. Aashima, Er. Monika Verma worked Image Enhancement Based on Fuzzy Logic in this paper a filter is introduced which will remove the noise and improve the contrast of the image. To achieve this goal fuzzy-logic-control based approach is used. The filter is tested on the colored images [14].*

#### 4.1 Problem Statement

In today's world many techniques are used for image enhancement. But fuzzy is the most popular and modern technology for image enhancement. An image that contain high contrast and well defined ridges and valleys, are called as good quality image , while a poor quality image is marked by low contrast and ill-defined boundaries between the ridges.

The main objective of the thesis work is to implement an algorithm based on fuzzy rule for image enhancement. In literature survey the existed methods are able to enhance gray scale images. But depending on application they designed the enhancement method is different for different type of images.

The objective of the thesis work contains the following steps as described below:

- To study the concept of enhancement and fuzzy set.
- To study of various existed image enhancement techniques by using MATLAB.
- Study of existed fuzzy techniques for image enhancement.
- To propose an algorithm to enhance the poor quality image to good quality images by increase the contrast.
- Implement a fuzzy algorithm in MATLAB.

#### 4.2 Methodology

The step-by-step methodology to be followed for image enhancement using fuzzy theory:

- Study and analyze various fuzzy techniques and image enhancement techniques.
- Based upon above analysis algorithm is developed for image enhancement by using MATLAB 7.5 version.

- Results achieved after the execution of program are compared with the earlier outputs.

**5.1 Define the Membership Function**

Fuzzy logic concept, an image is a property set. An image X of size M\*N .in fuzzy set the image is expressed as:

$$X = \sum_{m=1}^M \sum_{n=1}^N X_{mn}, \mu_{mn}$$

Where  $m = 1,2,\dots, M, n = 1,2,\dots, N,$  and  $(0 \leq \mu_{mn} \leq 1)$  denotes the grade of the membership function. Then define the membership function

$$\mu_{mn} = e^{-(X_{max}-X_{min})^2} / (X_{max} - X_{min}) \dots\dots\dots (1)$$

Where,  $X_{max}$  is the maximum grey level of the pixel in an image , $X_{min}$  is the minimum grey level pixel in an image.

1. If  $(X_{max}- X_{min}) \rightarrow 0$  then  $\mu_{mn} \rightarrow 1.$   $\mu_{mn} =1$  then maximum pixel grey level implies a bright pixel. Thus as the value of  $\mu_{mn}$  approaches 1 the pixel tends to become brighter and darker if  $\mu_{mn} \rightarrow 0.$

2. If  $X_{min}=0$  then consider  $\mu_{mn}$  has a finite value r,

Where  $r = e^{-X_{max}^2} / X_{max}$

So fuzzy membership grade between [r 1].Then the grey values of the image change to membership values. The values of membership values are different for different values of  $X_{max}.$

5. Define the one intensifier operation

$$I = 2[\mu_{mn}]^2 \quad \text{if } 0 \leq \mu_{mn} \leq 0.5$$

$$= 1-2[1 - \mu_{mn}]^2 \quad \text{if } 0.5 \leq \mu_{mn} \leq 1$$

It transforms the membership values that are above 0.5(default value) to much higher values and membership values that lower than 0.5 to much lower values in a nonlinear manner to obtain good enhancement image otherwise show the not enhancement image.

## 5.2 Implementation

This chapter includes detail of the process to fuzzy image enhancement and their location. All the work has been implemented in MATLAB 7.5. MATLAB is a software package developed by Math Works. It integrates computation, visualization and programming in easy to use environment. MATLAB toolbox allows learning and applying specialized technology. Areas in which toolbox are available include signal processing, image processing, control system, neural networks, fuzzy logic, wavelets, simulation, and many others. Many research have done on fuzzy the fuzzy and image enhancement [12], [17].

**Step1:** First different types of images are obtained from different sensor and saved in work space. To use of these image, the command and description are describes below

- **Command** >>imread ('tire.tif');
- **Description:** first save the image with a name as tire or if any in workspace and then call this using function 'imread'.

**Step2:** if imread image is not a form of gray image then image convert to gray image by using command >>rgb2gray (image extension);

**Step3:** DYADDOWN Dyadic downsampling.ie

$Y = \text{DYADDOWN}(X, \text{EVENODD})$ , where  $X$  is a matrix, whether  $Y$  contains the even- or odd-indexed samples of  $X$  depends on the value of positive integer even odd.

If EVENODD is even, then  $Y(k) = X(2k)$ .

If EVENODD is odd, then  $Y(k) = X(2k-1)$ .

$Y = \text{DYADUP}(X, \text{EVENODD}, \text{'type'})$ .

### Example:

$$X = \begin{bmatrix} 3 & 4 & 5 \\ 4 & 6 & 8 \\ 6 & 9 & 12 \end{bmatrix}$$

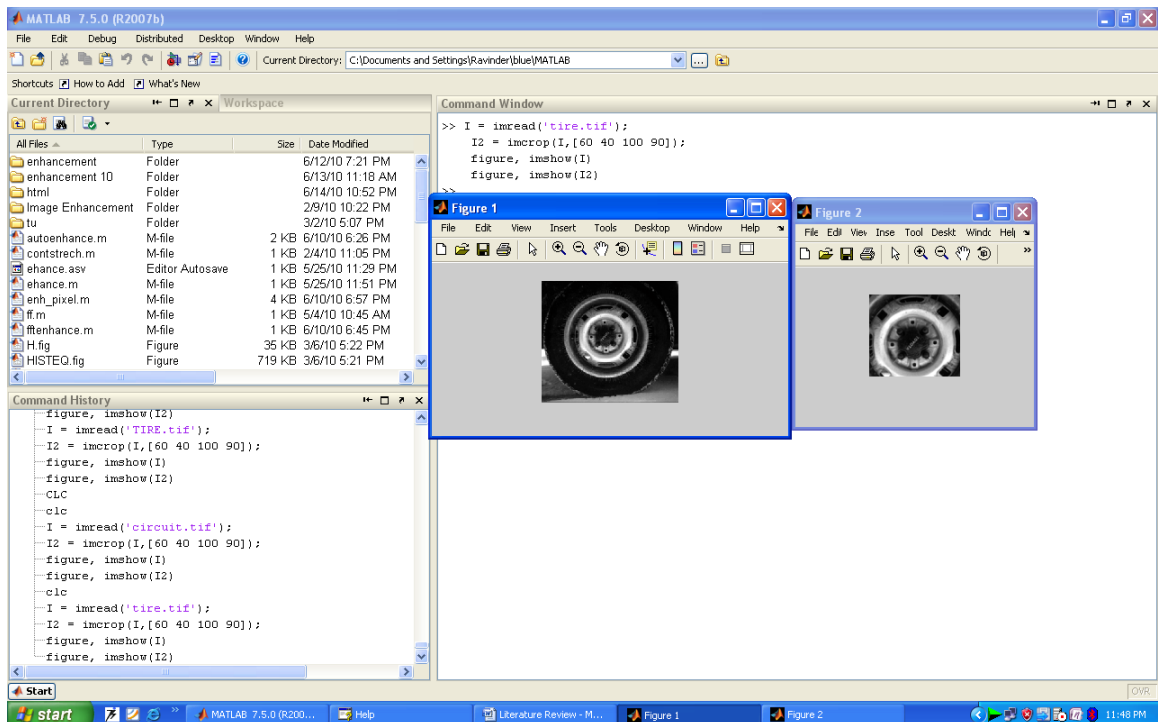
Then

$$DYADDOWN(X, 'M', 1) = \begin{bmatrix} 3 & 5 \\ 6 & 12 \end{bmatrix}$$

**Step4:** Consider image dimension, i.e. dim=235 etc.

**Step5:** Command `imcrop` (image, rect)

**Description:** The Crop Image tool is a moveable, resizable rectangle that you can position interactively using the mouse and `rect= [Xmin Ymin width height]`.



**Figure 5.1: Example of Crop Image**

**Step6:** Use the function  $mx = \max(\max(\text{crop image}))$ ;  $mn = \min(\min(\text{image}))$ . One image function  $\text{img} = (d - mn) / (mx - mn)$ .

**Step7:** Apply the define intensifier operation.

To implement the algorithm the command and description are describes below:

- **Command:** `>>imageenhance`
- **Description:** Developed a program based on above algorithm and save as by name “imageenhance” in a M-file and then use command “imageenhance” to run this program.

### Algorithm [I]

Define all the pixel (i,j)th inside the image

If (input data[i][j] >= 0 && (input data[i][j] <= 0.5))

Then find input data[i][j] =  $2 * \text{img}(\text{input data}[i][j])^2$ ;

Elseif ((input data[i][j] >= 0.5) && (input data[i][j] <= 1))

Then find input data[i][j] =  $1 - 2 * (1 - \text{img}(\text{input data}[i][j]))^2$ ;

Enhancedata[i][j]

Else return

### Algorithm [II]

For (i=0; j<height; i++)

For (i=0; j<width; j++)

If (data[i][j] < 100)

Input data[i][j] = 0

Elseif (((data[i][j] >= 100) && ((data[i][j] <= 200)))

```
Input data[i][j]=2*(0.01*data[i][j])-1)
Elseif (((data[i][j]>200)&&((data[i][j]<=255))
Input data[i][j]=1
For (i=0;j<height;i++)
For (i=0;j<width;j++)
Power[i][j]=2*input data[i][j]
For (i=0;i<=255;i++)
For (i=0;j<width;j++)
Enhancedata(i,j)=exp(power[i][j]-1)
```

## Testing & Results (Experimental Results)

Experiments done in more than 30 images and some of the results of them being shown below. Some results had shown exited enhancement techniques and other results shown proposed fuzzy algorithm.

### 6.1: Histogram Equalization Technique

Histogram Equalization Techniques enhances the contrast of images by transforming the values in an intensity image, or the values in the color map of an indexed image, so that the histogram of the output image approximately matches a specified histogram.

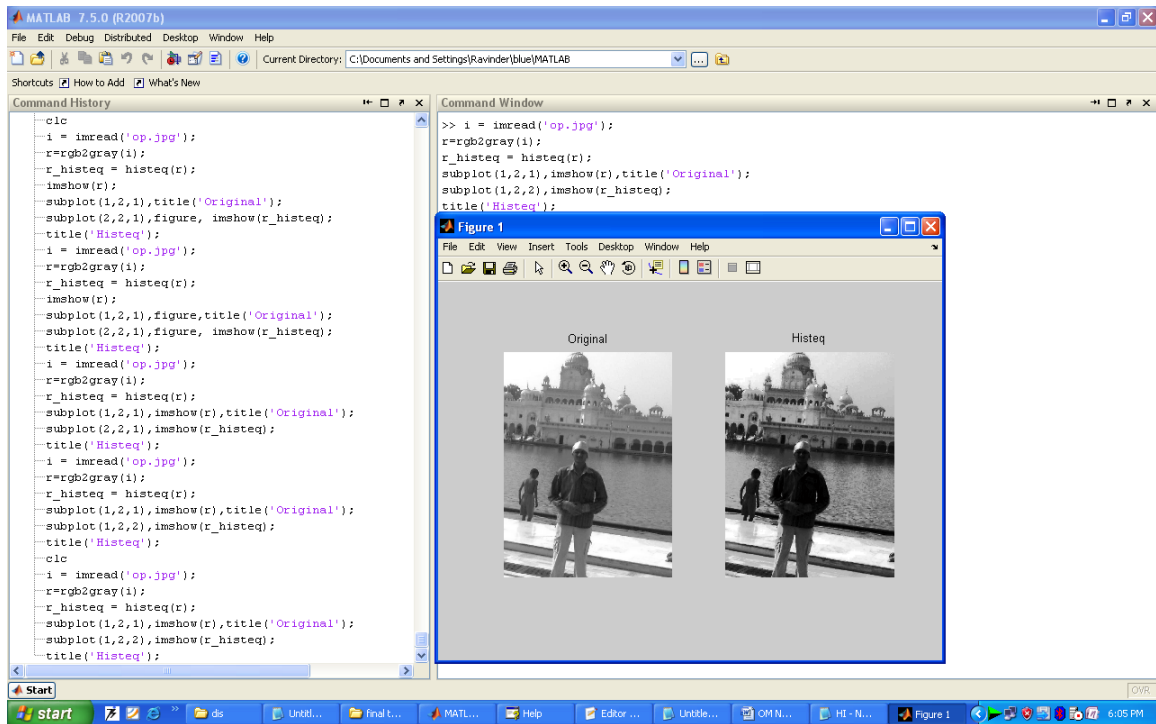


Figure 6.1: Histogram Enhancement Image with one Window



## 6.2: Adaptive Histogram Equalization Technique

Adaptive Histogram Equalization techniques enhance the contrast of the grayscale image by transforming the values using contrast-limited adaptive histogram equalization. ADAPTHISTEQ can use Uniform, Rayleigh, or Exponential distribution as the basis for creating the contrast transform function. The distribution that should be used depends on the type of the input image.

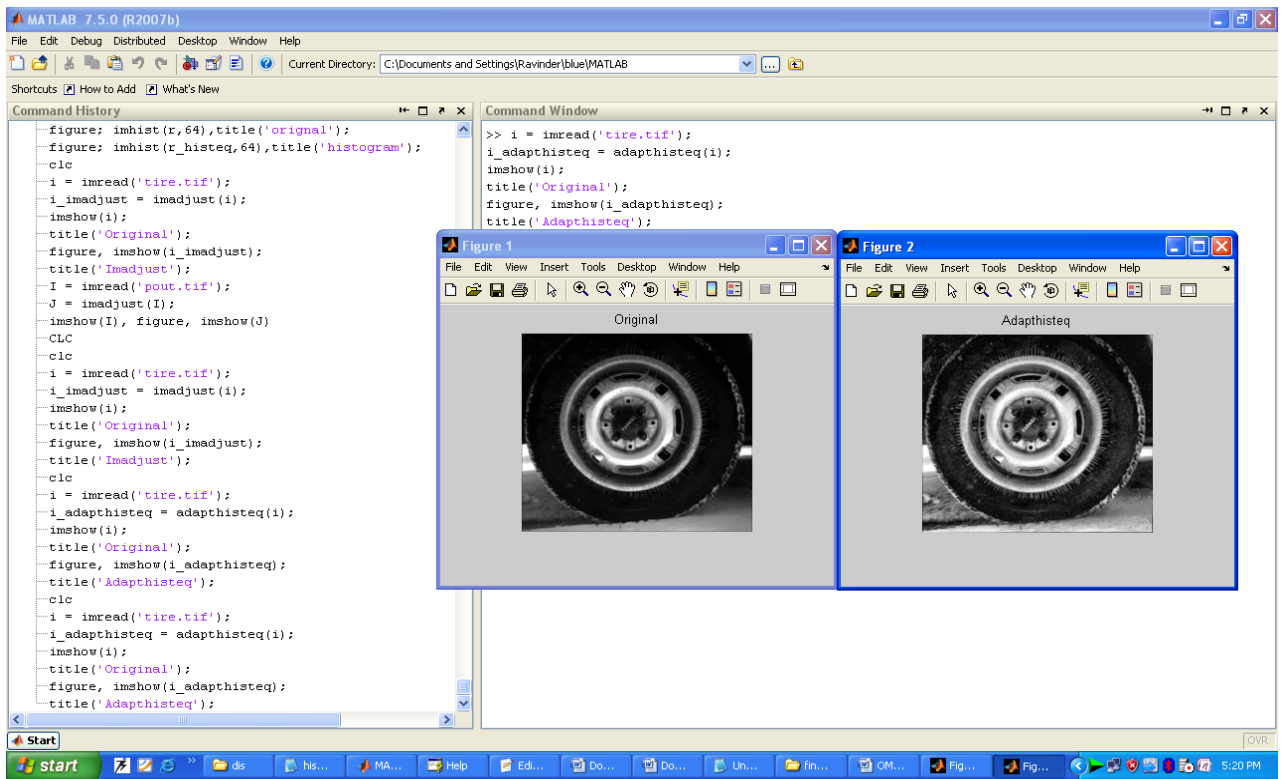


Figure 6.4: (a) Adaptive Histogram Equalization Enhancement image

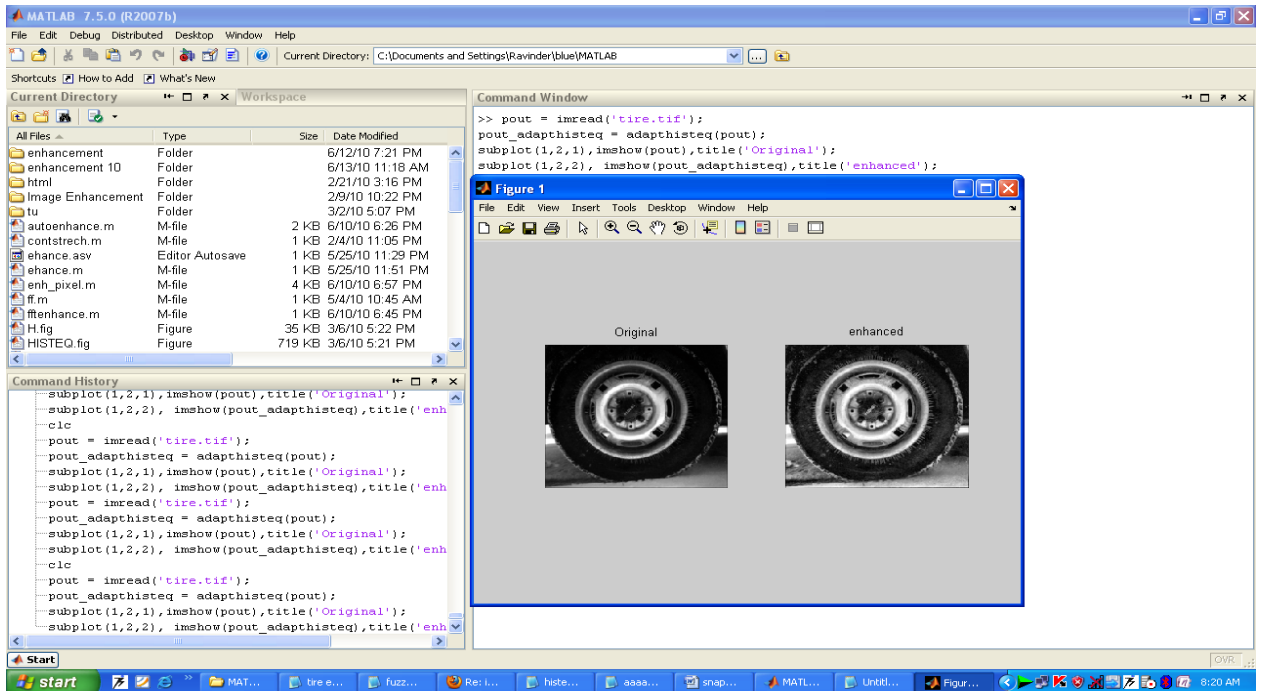


Figure 6.4: (b) Adaptive Histogram Equalization Enhancement image

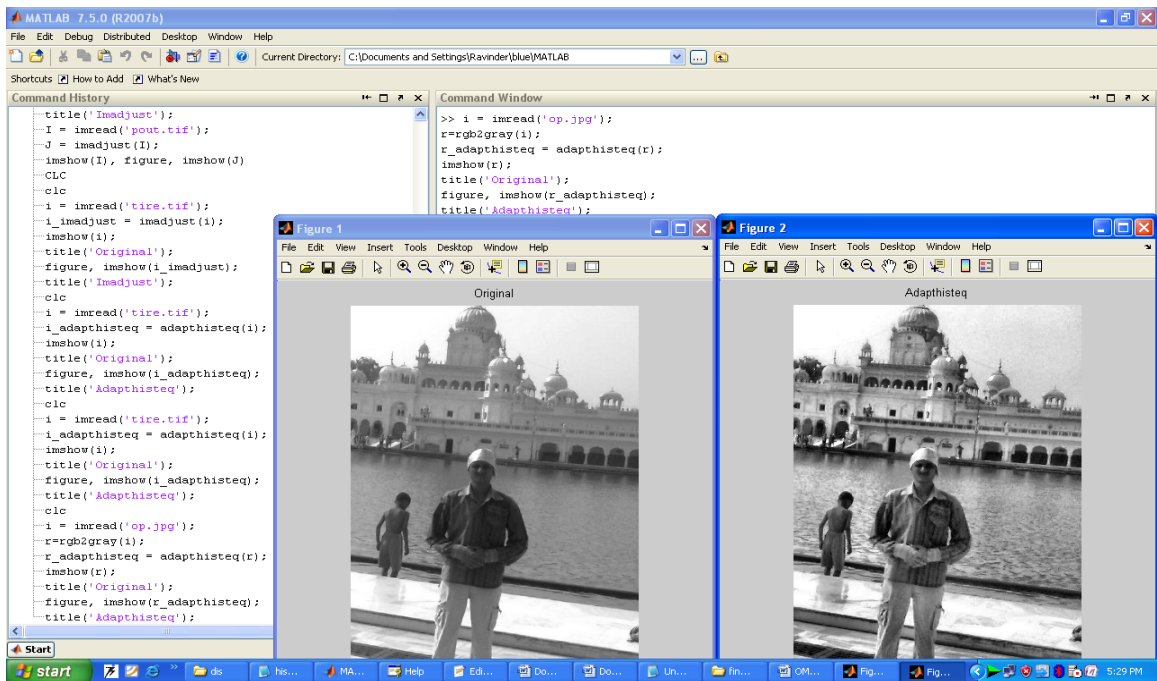


Figure 6.4: (c) Adaptive Histogram Equalization Enhancement image

### 6.3: Threshold Enhancement Technique

Let consider the original image  $f(x,y)$ , compared of light object on a dark background in such a way that object and background pixel have intensity values grouped into two dominant modes .  $T$  is the thresholding value of image.

If  $f(x,y) > T$  is called object point otherwise is called background point. So

$$g(x,y) = 1 \text{ if } f(x,y) > T$$

$$0 \text{ if } f(x,y) \leq T$$

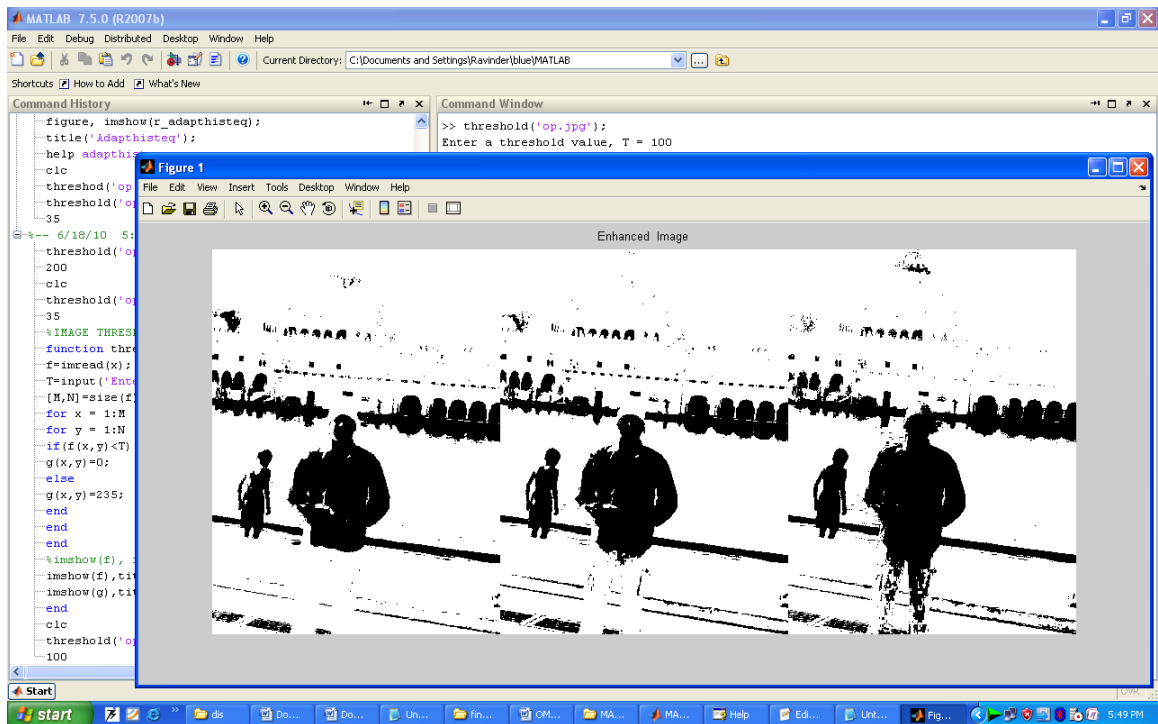


Figure 6.5: (a) Threshold Enhancement Image

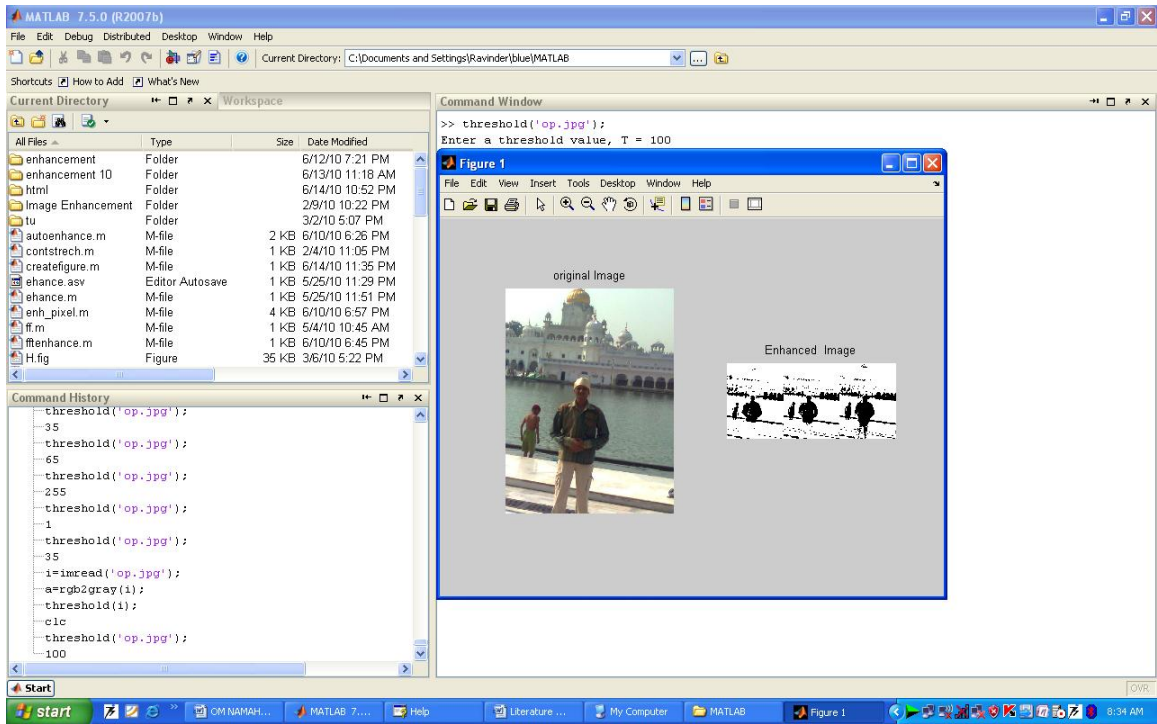


Figure 6.5: (b) Threshold Enhancement Image

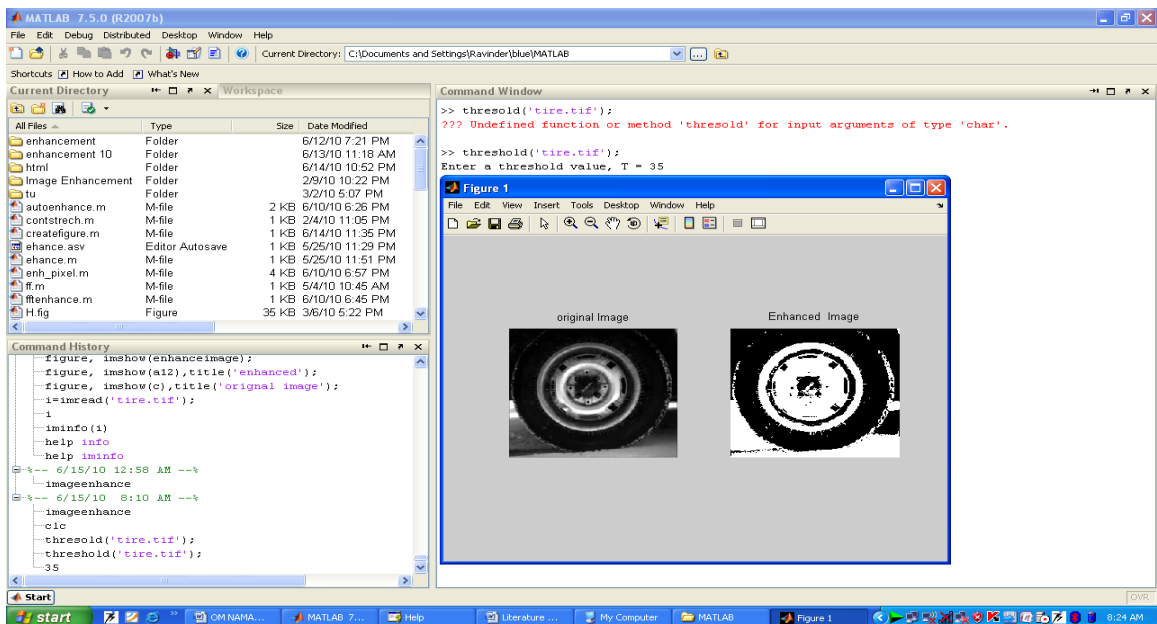


Figure 6.6: Threshold Enhancement Image with one window

## 6.4: Fuzzy Image Enhancement Techniques

Enhancement algorithms are used to reduce image noise and increase the contrast of structures of interest in image. Fuzzy image enhancement is based on gray level mapping into a fuzzy plane using the membership function transformation. Then generate the higher contrast an original image

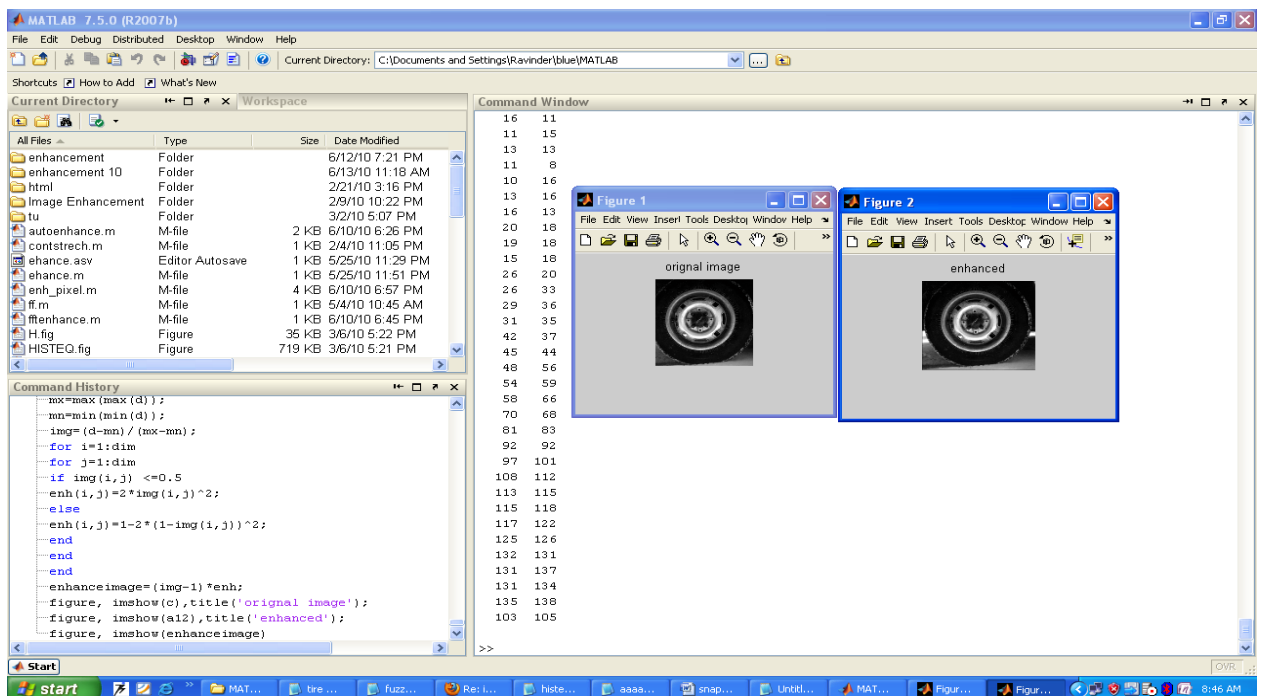


Figure 6.7: Fuzzy Tire enhancement image

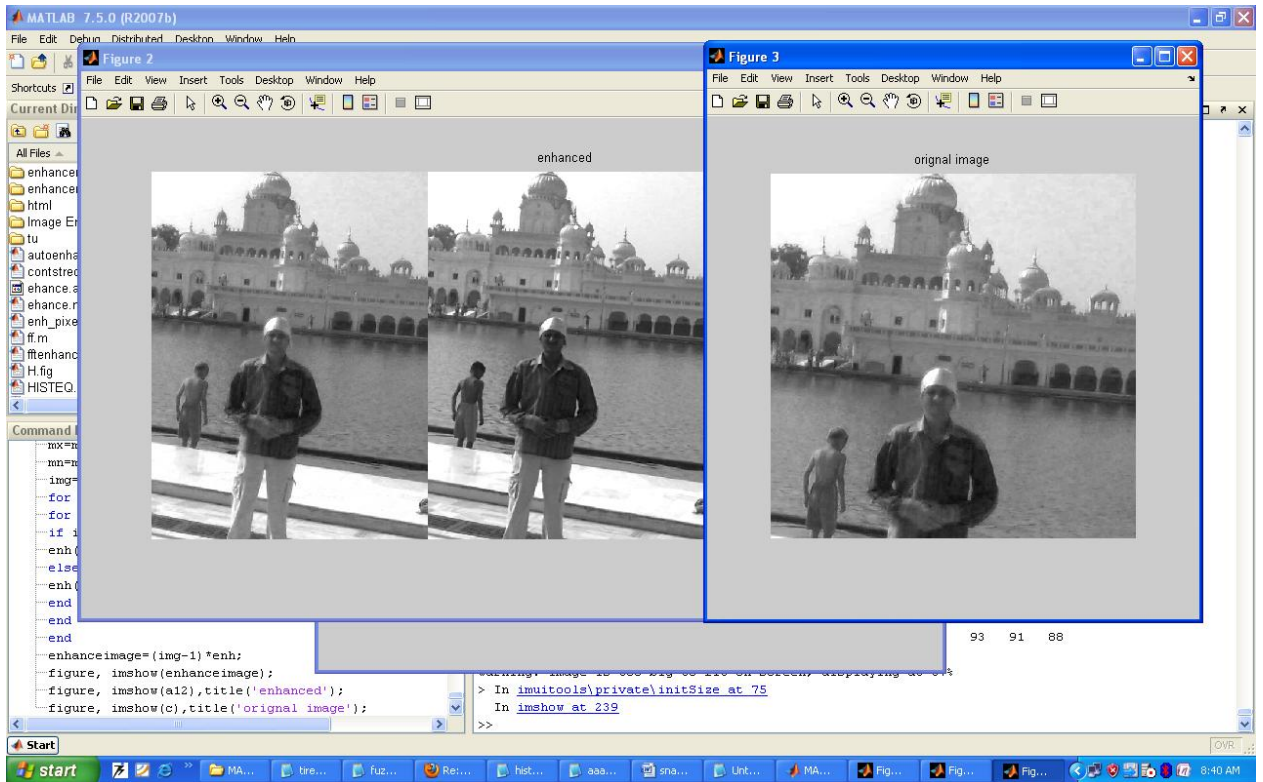


Figure 6.8:Fuzzy Enhancement Image

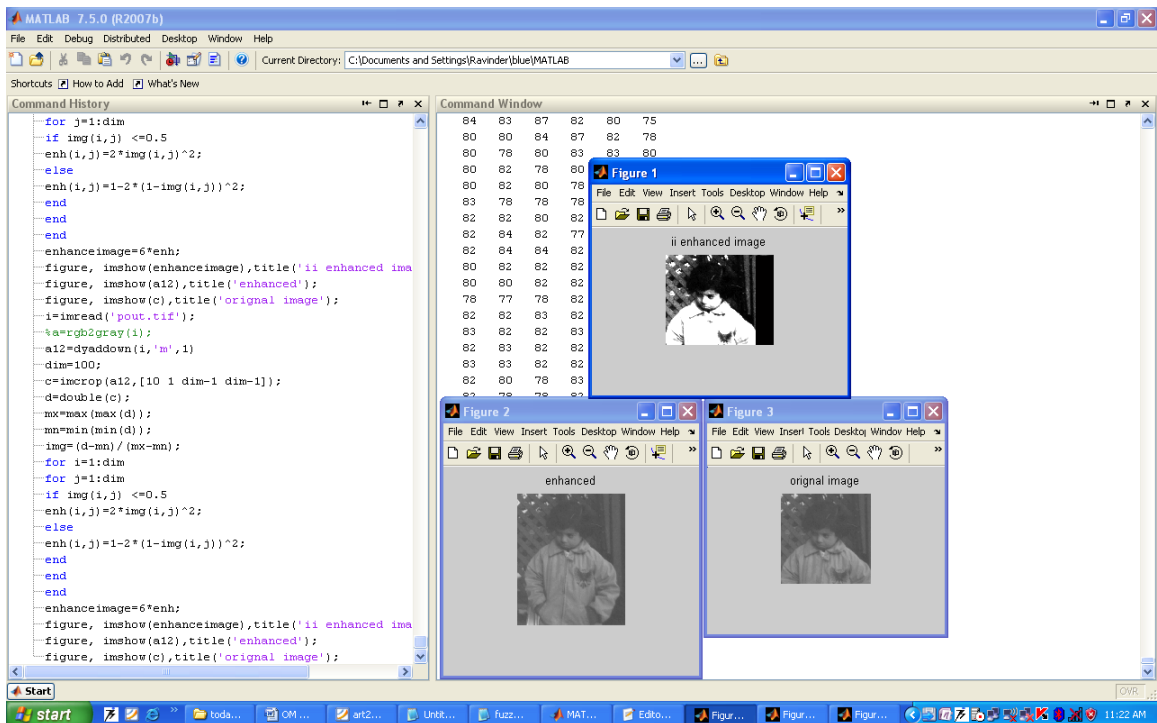


Figure 6.9: Pout Enhancement image

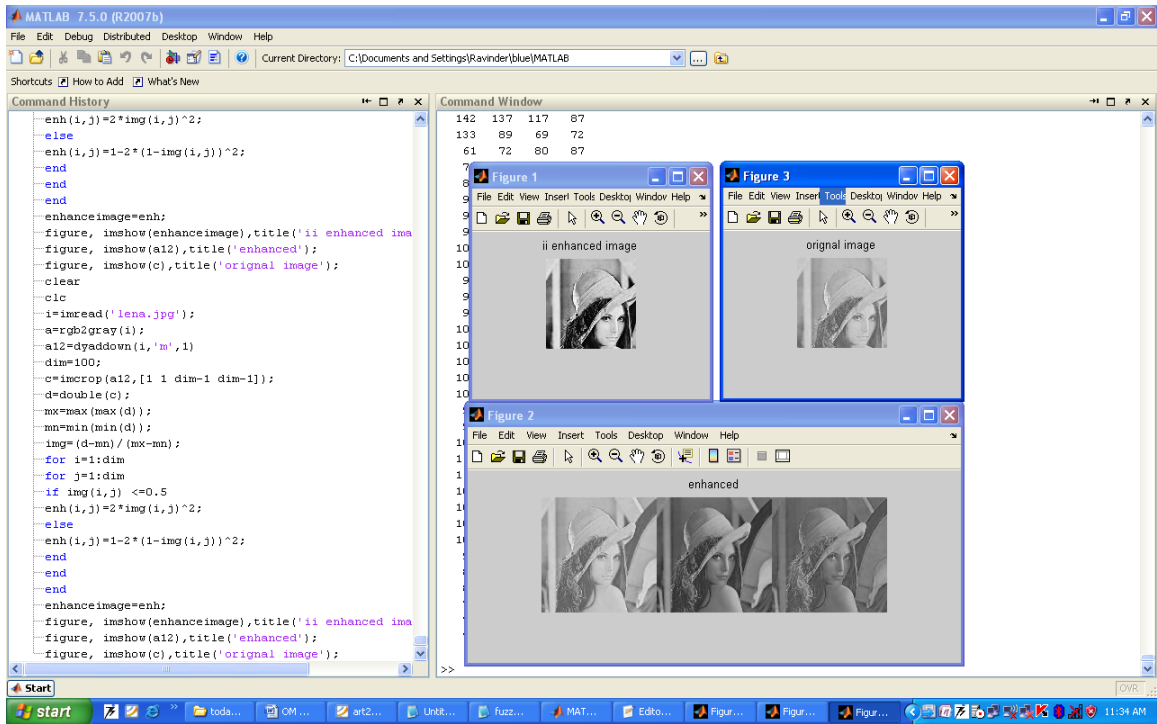


Figure 6.10: Lena Image Enhancement

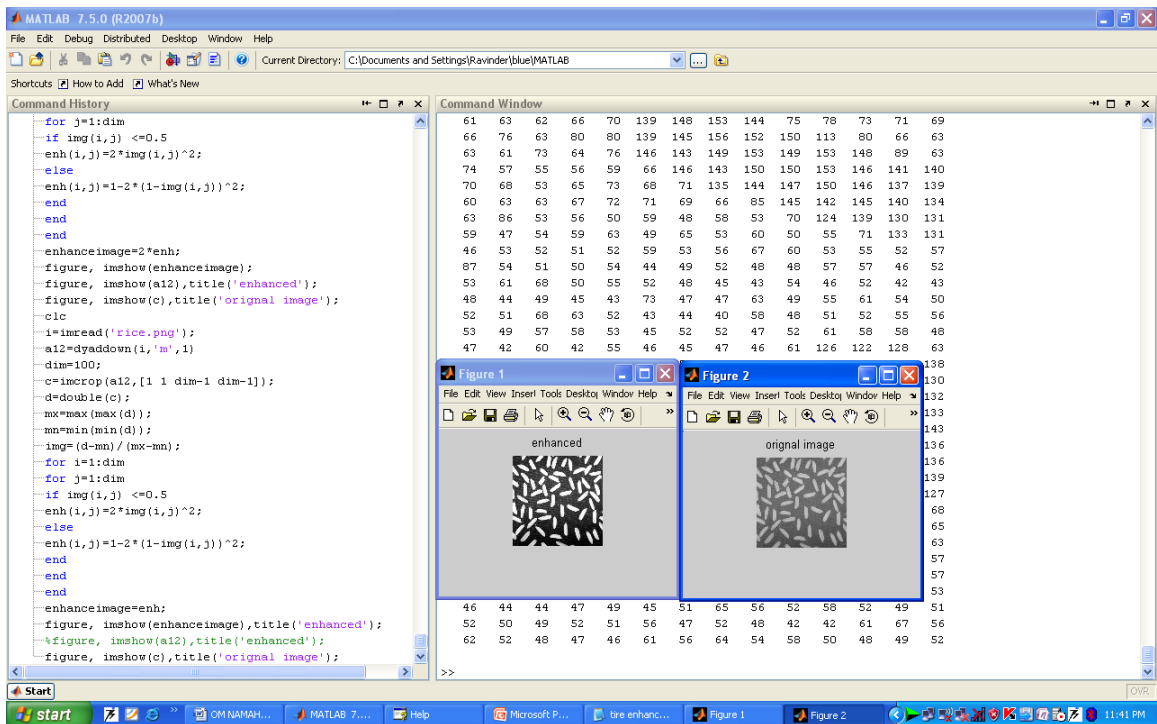


Figure 6.11: Rice Enhancement Image

## 6.5: Compression with different Enhancement Techniques

The proposed algorithm is compared for more than 10 images with some existing methods. On the basis of PSNR value we find that the proposed algorithm provides the better result.

We use the following step by step methodology to find out the PSNR value for a given gray image:

**Step1:** Find the mean of the image

$$\mu = \sum_{l=0}^{l=L-1} l * p(l)$$

Where L is maximum intensity level of the gray image and p(l) is the probability density function of the image.

**Step2:** Find the standard deviation

$$\sigma = \sqrt{\sum_{l=0}^{l=L-1} (l - \mu) * p(l)}$$

**step3:** Find the Peak signal to noise ratio (PSNR) of the image

$$\text{PSNR} = 10 \log (L- 1)^2 / \text{MSE} = 10 * \log_{10}( 256^2 / \text{MSE})$$

Where MSE is mean squared error of the image. Let two  $m \times n$  gray images  $I$  and noisy image  $K$  than MSE defined as

$$\text{MSE} = \frac{1}{m * n} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i, j) - K(i, j)]^2$$

$$\text{Or, MSE} = \text{sum}(\text{sum}(\text{mseImage})) / (\text{rows} * \text{columns})$$

A higher PSNR value indicates the higher quality of the image.

S.No.	Image name	PSNR value of the original image	PSNR value of Histogram Equalization Technique	PSNR value of Adaptive Histogram Equalization Technique	PSNR value of Proposed Algorithm
1	Tire.tif	26.12	29.71	30.62	30.54
2	Pout.tif	25.30	30.28	30.32	30.49
3	Lena.jpg	30.14	30.25	30.30	31.62
4	Rice.png	25.31	27.52	30.42	30.46
5	Girl.jpg	30.61	27.32	25.35	32,21
6	Einstein.jpg	30.50	26.32	28.35	32.14
7	Cameraman.tif	25.56	27.42	30.24	32.19
8	Forest.tif	26.77	27.52	26.34	30.35
9	Eight.tif	25.41	25.42	30.42	32.38
10	Nitin.tif	25.32	26.42	32.25	32.46

**Table 6.1: Comparison of Enhancement Techniques**

#### 7.1 Conclusion

The main focus of this research is on image enhancement using fuzzy image enhancement techniques. Experiment was done on poor quality image initially and is compared to result proposed method and previous method. In recent years, many researchers have applied the fuzzy logic to develop image processing algorithms. The fuzzy image processing is one of the important application areas of fuzzy logic.

In thesis work one membership function is defined to enhance the image and algorithm is proposed. The proposed algorithm is implemented in MATLAB 7.5. This proposed algorithm is able to overcome the drawbacks of spatial domain methods like thresholding, histogram equalization and frequency domain methods. This algorithm is able to get good contrasted image which increases the brightness of the low contrasted images. This algorithm is tested on different type of images. The experimental result shows that the brightness is increased as compared to previous one.

#### 7.2 Future Scope

Future work can be extended for other images then grayscale images to obtain better result with accuracy. In future modification of the algorithm can produce the better result for the image. 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 Geoinformatics Market. Image enhancement techniques used in many areas such that Forensics, Astrophotography, Fingerprint matching etc.

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