

Image Enhancement using Fuzzy Inference System

Thesis submitted in partial fulfillment of the requirements for the award of
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Master of Engineering
In
Computer Science & Engineering

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Certificate

I hereby certify that the work which is being presented in the thesis entitled, "Image Enhancement using Fuzzy Inference System", in partial fulfillment of the requirements for the award of degree of Master of Engineering in Computer Science & 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.



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



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Present day applications require various kinds of images and pictures as sources of information for interpretation and analysis. Whenever an image is converted from one form to another such as, digitizing, scanning, transmitting, storing, etc., some of the degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement which consists of a collection of techniques that seek to improve the visual appearance of an image. Image enhancement is basically improving the interpretability or perception of information in images for human viewers and providing 'better' input for other automated image processing techniques. The fuzzy set theory is incorporated to handle uncertainties (arising from deficiencies of information available from situation like the darkness may result from incomplete, imprecise, and not fully reliable, vague). The fuzzy logic provides a mathematical frame work for representation and processing of expert knowledge. The concept of if-then rules plays a role in approximation of the variables likes cross over point. Also the Uncertainties within image processing tasks are not always due to randomness but often due to vagueness and ambiguity. A fuzzy technique enables us to manage these problems effectively.

Fuzzy inference system is the process of formulating the mapping from a given input to an output using fuzzy logic. The process of fuzzy inference involves all of the pieces that are: Membership Functions, Logical Operations, and If-Then Rules. In this thesis work a technique is designed based on Fuzzy Inference System tool in MATLAB 7.5 (MATLAB is a software package developed by Math Works). The proposed technique used fuzzy if – then rules are a sophisticated bridge between human knowledge on the one side and the numerical framework of the computers on the other side, simple and easy to understand. The proposed technique is able to improve the contrast of the image. In this thesis work an algorithm is proposed and implemented to enhance image using fuzzy technique. This algorithm is used to convert the image properties into fuzzy data and fuzzy data into defuzzification.

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1.1 Background and Motivation

Whenever an image is converted from one form to another, such as, digitizing, scanning, transmitting, storing, etc., some degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement. Fuzzy image processing is the 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. The idea of fuzzy sets is simple and natural. For instance, we want to define a set of gray levels that share the property dark. In classical set theory, we have to determine a threshold, say the gray level 100. All gray levels between 0 and 100 are element of this set; the others do not belong to the set. But the darkness is a matter of degree. So, a fuzzy set can model this property much better. The basis for fuzzy logic is the basis for human communication. This observation underpins many of the other statements about fuzzy logic. Because fuzzy logic is built on the structures of qualitative description used in everyday language, fuzzy logic is easy to use. A filtering system needs to be capable of reasoning with vague and uncertain information; this suggests the use of fuzzy logic [1].

1.2 Digital Image Processing

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

digital image processing refers to processing digital images by means of a digital computer. Note that a digital image is composed of a finite number of elements, each of which has a particular location and value. These elements are referred to as picture elements, image elements, pels, and pixels. Pixel is the term most widely used to denote the elements of a digital image [3].

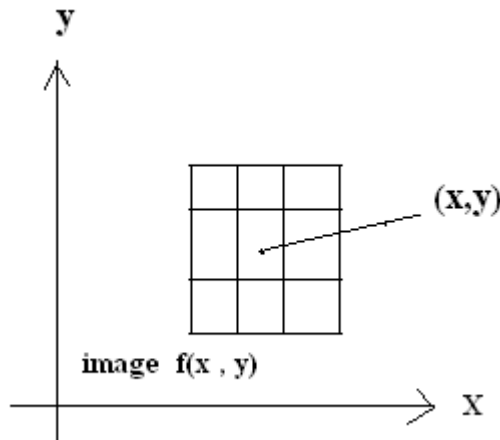


Fig1.1. Digital image [3].

1.3 Image Enhancement: The aim of image enhancement is to improve the interpretability or perception of information in images for human viewers, or to provide 'better' input for other automated image processing techniques. Image Enhancement (IE) transforms images to provide better representation of the subtle details. It is an indispensable tool for researchers in a wide variety of fields including (but not limited to) medical imaging, art studies, forensics and atmospheric sciences. It is application specific: an IE technique suitable for one problem might be inadequate for another. For example forensic images or videos employ techniques that resolve the problem of low resolution and motion blur while medical imaging benefits more from increased contrast and sharpness. To cater for such an ever increasing demand of digital imaging, software companies have released commercial softwares for users who want to edit and visually enhance the images.

Is the process of manipulating an image so that the result is more suitable than original for a specific application? The word specific is important here, because it establishes at

the outset that enhancement techniques are problem oriented. Thus, for example, a method that is quite useful for enhancing X-ray images may not be the best approach for enhancing satellite images taken in the infrared band of the electromagnetic spectrum [3].

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

1.4 Image Enhancement Techniques

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

1. **Spatial domain methods**, which operate directly on pixels, and
2. **Frequency domain methods**, which operate on the Fourier transform of an image.
3. **Fuzzy domain**, unfortunately, there is no general theory for determining what ‘good’ image- enhancement is when it comes to human perception. If it looks good, it is good! However, when image enhancement techniques are used as pre-processing tools for other image processing techniques, then quantitative measures can determine which techniques is most appropriate.

Fuzzy image enhancement is based on gray level mapping into a fuzzy plane, using a membership transformation 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 than to those that are farther from the mean. An image I of size $M \times N$ and L gray level scan be considered as an array of fuzzy singletons, each having a value of membership denoting its degree of brightness relative to some brightness levels



The Main Principles of Fuzzy Image Enhancement

Figure1. 3. The main principles of Fuzzy Image Enhancement [4].

1.5 Fuzzy Rule-Based Approach

If we interpret the image features as linguistic variables, then we can use fuzzy if-then rules to segment the image into different regions. A simple fuzzy segmentation rule may seem as follows [3]:

IF the pixel is dark AND

Its neighborhood is also dark AND homogeneous

THEN it belongs to the background.

1.6 Fuzzy Image Processing

Fuzzy image processing is not a unique theory. It is a collection of different fuzzy approaches to image processing. Nevertheless, the following definition can be regarded as an attempt to determine the boundaries:

Fuzzy image processing is the 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 [9]. Here is a list of general observations about fuzzy logic:

- Fuzzy logic is conceptually easy to understand.

The mathematical concepts behind fuzzy reasoning are very simple. Fuzzy logic is a more intuitive approach without the far-reaching complexity.

- Fuzzy logic is flexible.

With any given system, it is easy to layer on more functionality without Starting again from scratch.

- Fuzzy logic is tolerant of imprecise data.

Everything is imprecise if you 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 model nonlinear functions of arbitrary complexity.

You can create a fuzzy system to match any set of input-output data. This process is made particularly easy by adaptive techniques like Adaptive Neuro-Fuzzy Inference Systems (ANFIS), which are available in Fuzzy Logic Toolbox.

- Fuzzy logic can be built on top of the experience of experts.

In direct contrast to neural networks, which take training data and generate opaque, impenetrable models, fuzzy logic lets you rely on the experience of people who already understand your system.

- 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. Because fuzzy logic is built on the structures of qualitative de]scription used in everyday language, fuzzy logic is easy to use.

The last statement is perhaps the most important one and deserves more discussion. Natural language, which is used by ordinary people on a daily basis, has been shaped by thousands of years of human history to be convenient and efficient. Sentences written in ordinary language represent a triumph of efficient communication [3].

Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification.

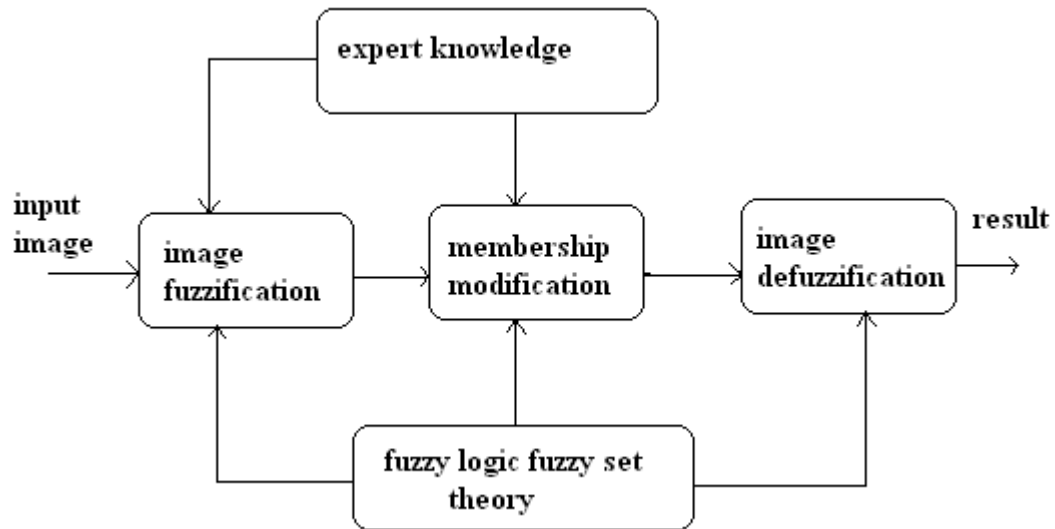


Figure1.5.1 Fuzzy Image processing [5].

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 (modification of membership values, see Fig.2). After the image data are transformed from gray-level plane to the membership plane (fuzzification), appropriate fuzzy techniques modify the membership values. This can be a fuzzy clustering, a fuzzy rule-based approach, and a fuzzy integration approach and so on.

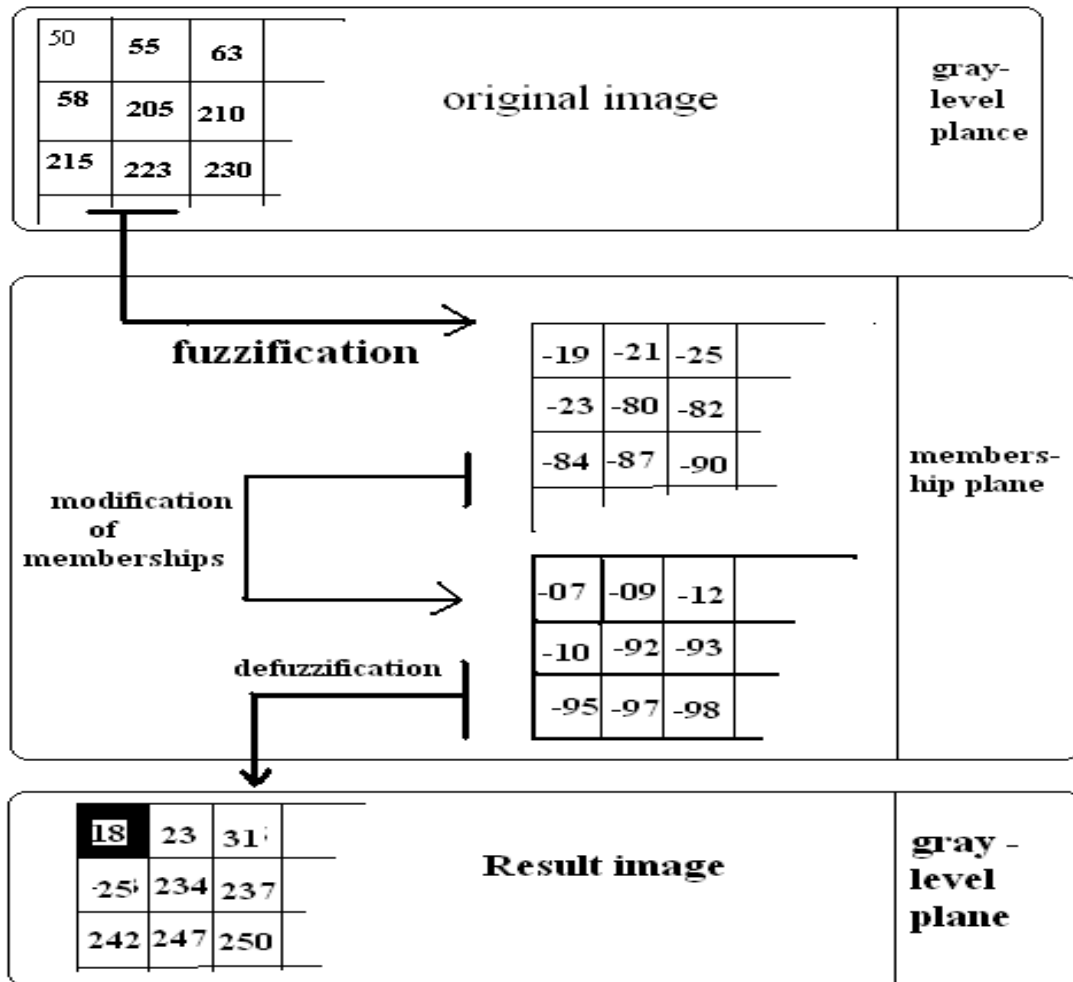


Fig.1.5.2. Example Steps of Fuzzification and Defuzzification process on image Processing [5].

1.7 The Advantages of Fuzzy Image Processing

There are many reasons to use fuzzy technique. The most important of them are as follows:

1. Fuzzy techniques are powerful tools for knowledge representation and processing.
2. Fuzzy techniques can manage the vagueness and ambiguity efficiently.

In many image processing applications, used expert knowledge to overcome the difficulties (e.g. object recognition, scene analysis). Fuzzy set theory and fuzzy logic offer us powerful tools to represent and process human knowledge in form of fuzzy if-then rules. On the other side, many difficulties in image processing arise because the data/tasks/results are uncertain. This uncertainty, however, is not always due to the randomness but to the ambiguity and vagueness. Beside randomness which can be managed by probability theory , distinguish between three other kinds of imperfection in the image processing.

- Grayness ambiguity
- Geometrical fuzziness
- Vague (complex/ill-defined) knowledge

These problems are fuzzy in the nature. The question whether a pixel should become darker or brighter than it already is, the question where is the boundary between two image segments, and the question what is a tree in a scene analysis problem, all of these and other similar questions are examples for situations that a fuzzy approach can be the more suitable way to manage the imperfection [3].

1.8 Filters

When the images are transmitted over channels, they are corrupted with impulse noise due to noisy channels. This impulse noise consists of large positive and negative spikes. The positive spikes have values much larger than the background and thus they appear as bright spots, while the negative spikes have values smaller than the background and they appear as darker spots. Both the spots for the positive and negative spikes are visible to the human eye. Also, Gaussian type of noise affects the image. Thus, filtering for both impulse noise and Gaussian noise is required before processing. There are lots of classical and fuzzy filters in the literature to remove noise. The classical filter are the mean filter, the weighted filter, the adaptive weighted filter, the adaptive Wiener filter, the Gaussian filter, the median filter, the adaptive median filter, and the extended mean filter.

The mean filter or the average filter helps in smoothing operations. It suppresses the noise that is smaller in size or any other small fluctuations in the image. It involves in calculating the average brightness values in some neighborhood $m \times n$ and replaces the gray level with an average value. Smoothing or averaging operation blurs the image and does not preserve the edges. These are not used in removing noise spikes. For a 3×3 neighborhood the convolution masks is used as

$$1/9 \begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Adaptive weighted mean filter is similar to mean filter where the gray level is replaced by a weighted average of the gray values. Weights are calculated from the gray-level difference. If this difference exceeds a certain threshold, then the pixel is a noise pixel.

Adaptive Wiener filter replaces the center value of the pixel by sum of the local mean value and a fraction of contrast, where this fraction depends on the local estimation of the variance [6].

1.9 Fuzzy Filters

Fuzzy filters provide promising result in image-processing tasks that cope with some drawbacks of classical filters. Fuzzy filter is capable of dealing with vague and uncertain information. Sometimes, it is required to recover a heavily noise corrupted image where a lot of uncertainties are present and in this case fuzzy set theory is very useful. Each pixel in the image is represented by a membership function and different types of fuzzy rules that considers the neighborhood information or other information to eliminate filter removes the noise with blurry edges but fuzzy filters perform both the edge preservation and smoothing [2].

Image and fuzzy set can be modeled in a similar way. Fuzzy set in a universe of X is associated with a membership degree. Similarly, in the normalized image where the image pixels ranging from $\{0, 1, 2, \dots, 255\}$ are normalized by 255, the values obtained

are in the interval $[0, 1]$. Thus, it is a mapping from the image G to $[0, 1]$. In this way, the image is considered as a fuzzy set and thus filters are designed [6].

1.10 Fuzzy Inference System (FIS)

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are: Membership Functions, Logical Operations, and If-Then Rules. There are two types of fuzzy inference systems that can be implemented in Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined.

Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, and fuzzy logic controllers, and simply (and ambiguously) fuzzy systems.

Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani [7] as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Sade's 1973 paper on fuzzy algorithms or complex systems and decision processes [8]. Although the inference process described in the next few sections differs somewhat from the methods described in the original paper, the basic idea is much the same.

Mamdani-type inference, as defined for Fuzzy Logic Toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set

for each output variable that needs defuzzification. It is possible, and in many cases much more efficient, to use a single spike as the output membership functions rather than a distributed fuzzy set. This type of output is sometimes known as a singleton output membership function, and it can be thought of as a pre-defuzzified fuzzy set. It enhances the efficiency of the defuzzification process because it greatly simplifies the computation required by the more general Mamdani method, which finds the centroid of a two-dimensional function. Rather than integrating across the two-dimensional function to find the centroid, you use the weighted average of a few data points. Sugeno-type systems support this type of model. In general, Sugeno-type systems can be used to model any inference system in which the output membership functions are either linear or constant.

2.1 Classification of images:

2.1.1 Intensity Images

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

2.1.2 Indexed Images

Array of class logical, unit 8, Unit 16, single, or double whose pixel values are directed indices into a color map. The color map is an m-by-3 array of class double. For single or double arrays, integer values range from [1, p]. For logical, unit8, or unit 16 arrays, values range from [0, p-1]. An indexed image consists of an array and a color map matrix. The pixel values in the array are directed indices into a color map. By convention, this documentation uses the variable name X to refer to the array and map to refer to the color map [10].

2.1.3 Binary Images

Binary images have a very specific meaning in MATLAB. In a binary image, each pixel assumes one of only two discrete values: 1 or 0, interpreted as black and white, respectively. A binary image is stored as a logical array. Thus, an array of 0s and 1s whose values are of data class, say, unit8, is not considered a binary image in MATLAB [10].

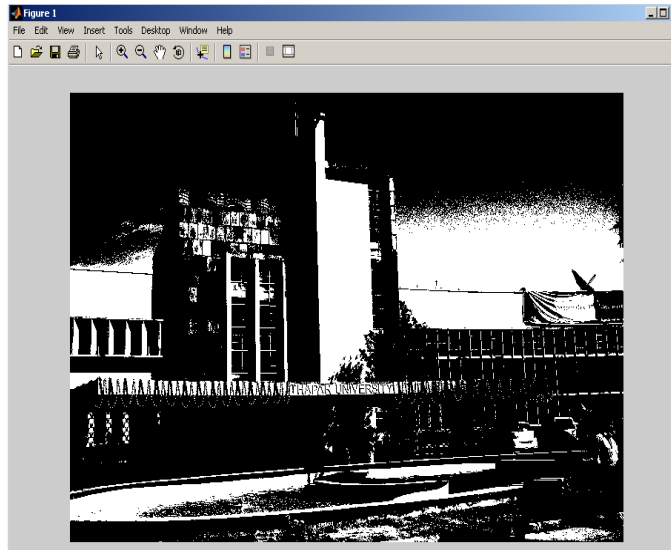


Figure 2.1 Binary image

2.1.4 Grayscale Images:

A grayscale image (also called gray-scale, gray scale, or gray-level) is a data matrix whose values represent intensities within some range. MATLAB stores a grayscale image as an individual matrix, with each element of the matrix corresponding to one image pixel. By convention, this documentation uses the variable name *I* to refer to grayscale images. Array of class `unit8`, `unit16`, `int16`, `single`, or `double` whose pixel values. For `single` or `double` arrays, values range from $[0, 1]$. For `unit8`, values range from $[0, 255]$. For `unit16`, values range from $[0, 65535]$. For `int16`, values range from $[-32768, 32767]$.

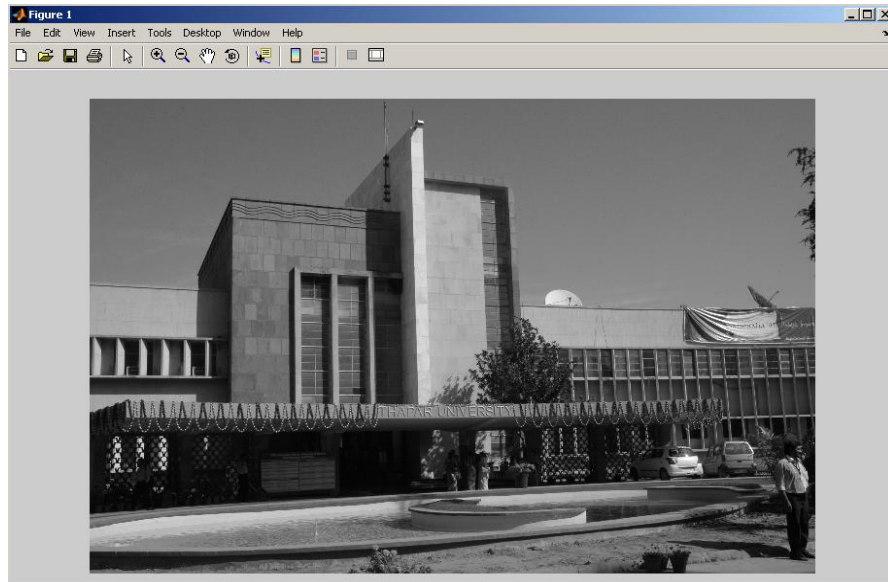


Figure 2.2 Grayscale image

2.1.5 True color Images

A true color image is an image in which each pixel is specified by three values one each for the red, blue, and green components of the pixel's color. MATLAB store true color images as an m-by-n-by-3 data array that defines red, green, and blue color components for each individual pixel. True color images do not use a color map. The color of each pixel is determined by the combination of the red, green, and blue intensities stored in each color plane at the pixel's location. Graphics file formats store true color images as 24-bit images, where the red, green, and blue components are 8 bits each. This yields a potential of 16 million colors. The precision with which a real-life image can be replicated has led to the commonly used term true color image [10].

Example of color image

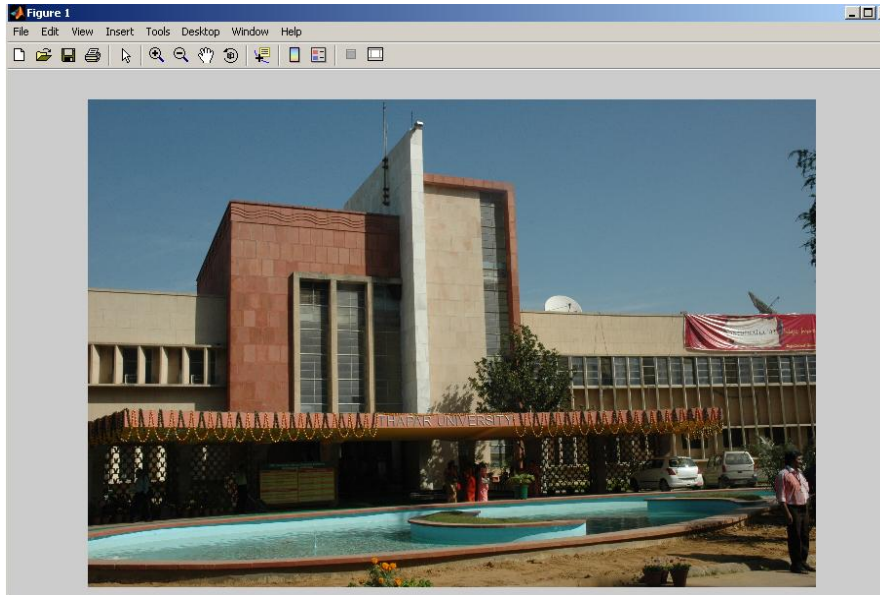


Figure 2.3 Color Image.

2.2 Noise in an images

The fundamental problem of image and signal processing is to effectively reduce noise from a digital color image while keeping its features intact (e.g., edges, color component distances, etc). The nature of the noise removal problem depends on the type of the noise corrupting the image. The two most commonly occurring types of noise are i) Additive noise (e.g. Gaussian and Impulse noise) and ii) Multiplicative noise (e.g. Speckle noise). Impulse noise is usually characterized by some portion of image pixels that are corrupted, leaving the remaining pixels unchanged. Examples of impulse noise are fixed-valued impulse noise and randomly valued impulse noise. We talk about additive noise when a value from a certain distribution is added to each image pixel, for example, a Gaussian distribution. Multiplicative noise is generally more difficult to remove from images than additive noise because the intensity of the noise varies with the signal intensity (e.g., speckle noise). In the literature several (fuzzy and non-fuzzy) filters have been studied for impulse noise reduction. Impulse noise is caused by errors in the data transmission generated in noisy sensors or communication channels, or by errors during the data capture from digital cameras. Noise usually quantified by the percentage of pixels which are corrupted. Corrupted pixels are either set to the maximum value or have single bits

flipped over. In some cases, single pixels are set alternatively to zero or to the maximum value. This is the most common form of impulse noise and is called salt and pepper noise. Noise smoothing and edge enhancement are inherently conflicting processes, since smoothing a region might destroy an edge, while sharpening edges might lead to unnecessary noise [11].

2.2.1 Impulse noise in color images

A color image can be represented via several color models such as RGB, CMY, CMYK, HIS, HSV and CIE L a* b*. Images, one for each primary color (Red, Green and Blue). Consider a color image represented in the x-y plane, then the third coordinate z= 1, 2, 3 will represent the color component of the image pixel at (x, y). Let f be the image function then f(x, y, 1) will represent the Red component of pixel at (x, y). Similarly, f(x, y, 2) and f(x, y, 3) represent the Green and Blue components respectively

Images corrupted with impulse noise contain pixels affected by some probability. This implies that some of the pixels may not have a trace of any noise at all. Moreover, a pixel can have either all or one or two of its components corrupted with impulse noise. Mathematical modeling of impulse noise in color images is as follows:

$$F(x, y, z) = \begin{cases} N(x, y, z) & \text{with probability } P_z \\ I(x, y, z) & \text{with probability } (1 - P_z) \end{cases} \dots\dots\dots (1)$$

Where, z= 1, 2, 3 represents red, green & blue components. The probabilities P_z 's can have equal or unequal values. In equation (1), f represents the final corrupted image, while N and I are the numbers of corrupted and uncorrupted pixels respectively [2].

.

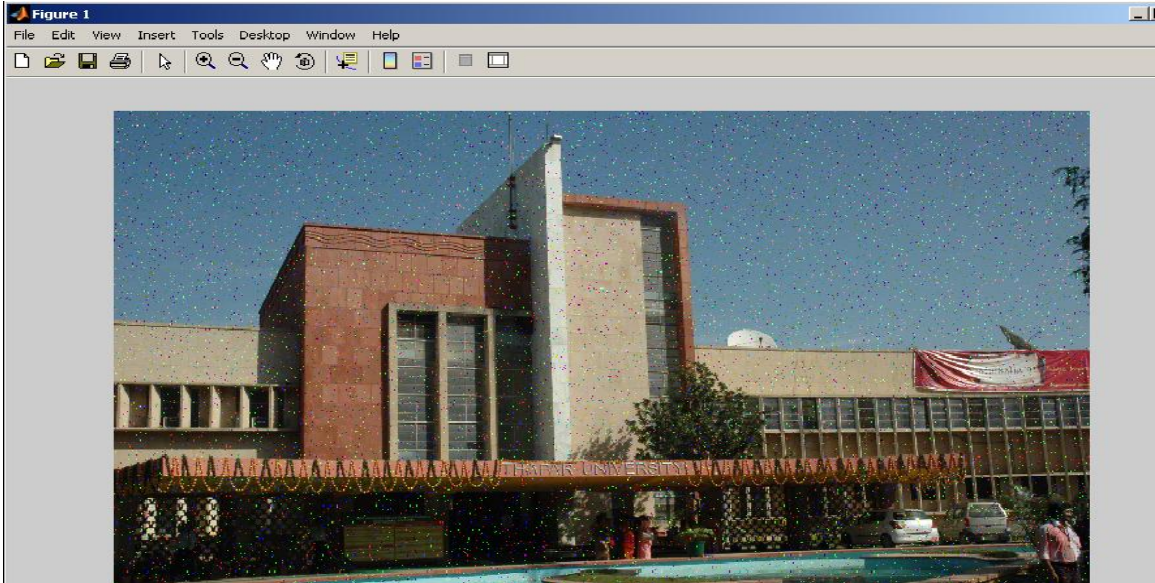


Figure 2.4 Image Effected by impulse noise

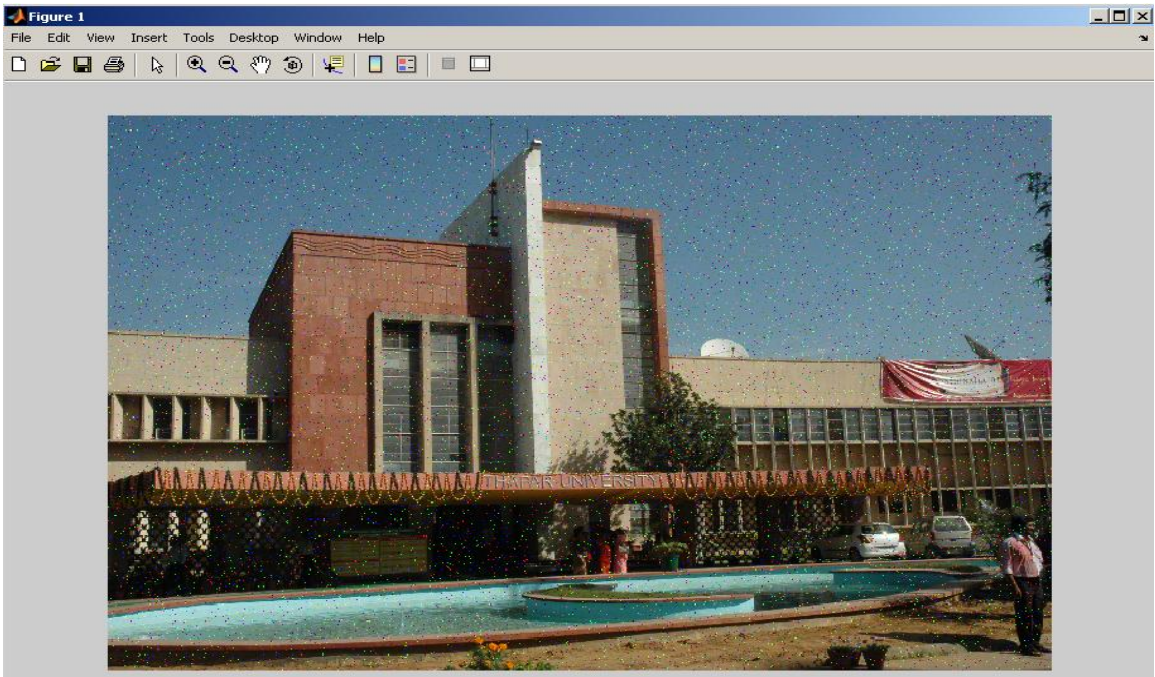


Figure 2.5 Image affected by Gaussian noise

2.3 Creating an image Histogram

An image histogram is a chart that shows the distribution of intensities in an indexed or grayscale image. You can use the information in a histogram to choose an appropriate enhancement operation. For example, if an image histogram shows that the range of intensity values is small, you can use an intensity adjustment function to spread the values across a wider range. To create an image histogram, use the `imhist` function. This function creates a histogram plot by making n equally spaced bins, each representing a range of data values. It then calculates the number of pixels within each range [10].

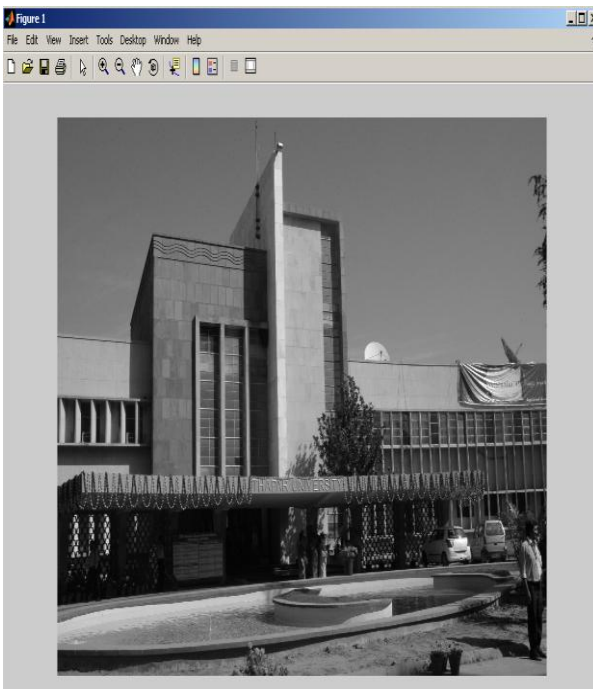


Figure 2.6(a) Gray Scale Image

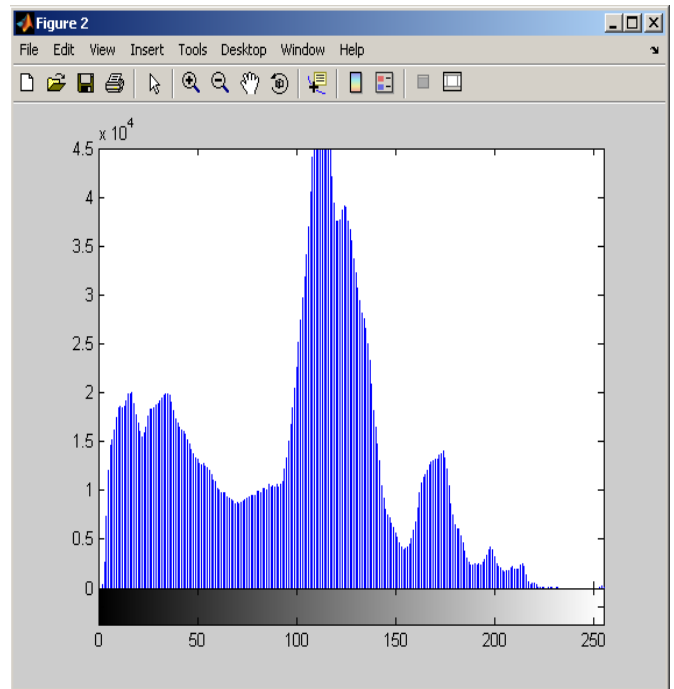


Figure 2.6 (b) Histogram of images.

Figure 2.6 Creating Histogram of an image

2.4 The Origins of Digital Image Processing

One of the first applications of digital images was in the newspaper industry, when Pictures were first sent by submarine cable between London and New York. Introduction of the Bart lane cable picture transmission system in the early 1920s reduced the time required to transport a picture across the Atlantic from more than a week to less than three hours. Specialized printing equipment coded pictures for cable transmission and then reconstructed them at the receiving end. Some of the initial problems in improving the visual quality of these early digital pictures were related to the selection of printing procedures and the distribution of intensity levels. The printing method used to obtain was abandoned toward the end of 1921 in favor of a technique based on photographic reproduction made from tapes perforated at the telegraph receiving terminal [3].

2.5 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 [3].

2.6 Classification of image pixels

Characterization of an image is generally accomplished in terms of primitive attributes called features. Image features can be mainly divided into two categories:

i) "Natural" features, that are defined by the visual appearance of an image (e.g. luminance of a region of pixels, gray scale of regions);

ii) "Artificial" features that come from image manipulation (e.g. histograms, spectral graphs) [12].

2.7 The fields that Image Enhancement has contributed .

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

1. In forensics 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 [13].

2. In atmospheric sciences 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 [14].

3. Astrophotography faces challenges due to light and noise pollution that can be minimized by IE . 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 [15].

4. In oceanography the study of images reveals interesting features of water flow, sediment concentration, geomorphology and bathymetric patterns to name a few. These features are more clearly observable in images that are digitally enhanced to overcome the problem of moving targets, deficiency of light and obscure surroundings.

5. IE techniques when applied to pictures and videos help the visually impaired in reading small print, using computers, television and face recognition . Several studies

have been conducted that highlight the need and value of using IE for the visually impaired [16].

6. Medical imaging 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 [17].

Image filters exist in three domains:

- Spatial domain
- Frequency domain and
- Fuzzy domain. The study deals with fuzzy filters which offer several advantages over classical filters even as they preserve the image structure. Moreover, fuzzy filters are easy to realize by means of simple fuzzy rules that characterize a particular noise. A brief review of well known fuzzy filters is presented in the following paragraphs.

2.8 Spatial Domain methods

The value of a pixel with coordinates (x, y) in the enhanced image \hat{F} is the result of performing some operation on the pixels in the neighborhood of (x, y) in the input image, F . Neighborhoods can be any shape, but usually they are rectangular [3].

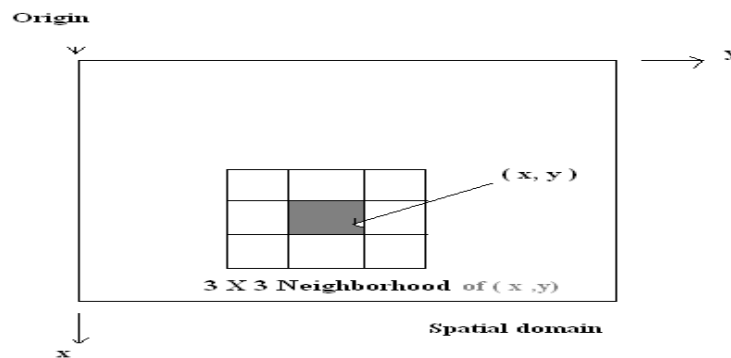


Figure 2.7 Spatial domain of an image.

Image Processing in the spatial domain can be Expressed by: $g(m, n) = T(f(m, n))$. Where $f(m, n)$ is the input image, $g(m, n)$ is the processed Image and T is the operator defining the modification process. The operator 'T' is typically a single-valued and monotone function that can operate on individual pixels or on selective value of the input Image is used to compute the corresponding pixel value for the output Image. Within the input image are used to compute the modified image at any given point. One can consider point processing as a special case of region processing where the region is composed of a single pixel. The point-processing operator can also be expressed by: $S=T(r)$, Where r and s are variables denoting the intensity level of $f(m, n)$ and $g(m, n)$ at any point (m, n) . The following sections describe several point-and region-based image enhancement techniques. The second article will also discuss spatial smoothing, which is another example of region-based image processing, and compare its advantages and disadvantages with transform domain methods.

The smallest possible neighborhood is of size 1×1 . In this case g depends only on the value of f at a single point (x, y) and T [3].

2.8.1 Creating Negative of an Image

The most basic and simple operation in digital image processing is to compute the negative of an image. The pixel gray values are inverted to compute the negative of an image. For example, if an image of size $R \times C$, where R represents number of rows and C represents number of columns, is represented by $I(r, c)$. The negative $N(r, c)$ of image $I(r, c)$ can be computed as $N(r, c) = 255 - I(r, c)$ where $0 \leq r \leq R$ and $0 \leq c \leq C$.

It can be seen that every pixel value from the original image is subtracted from the 255. The resultant image becomes negative of the original image. Negative images are useful for enhancing white or grey detail embedded in dark regions of an image [19].

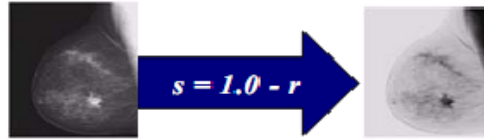
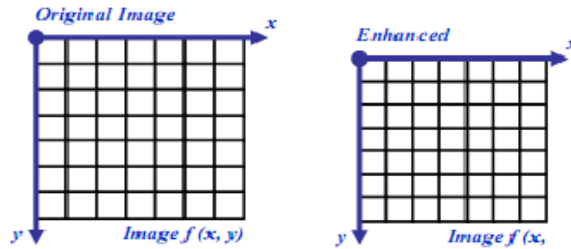


Figure Note how much clearer the tissue is in the negative image of the mammogram



$$s = intensity_{max} - r$$

Figure 2.8 Creating Negative of an image [19].

2.8.2 Intensity Transformation

Intensity transformations are among the simplest of all image processing techniques. The value of pixels, before and after processing, will be denoted by r and s , respectively. An intensity transformation function of the form $s=T(r)$ [18]. Where T is a transformation that maps a pixel value r into a pixel value s . because we are dealing with digital quantities, values of a transformation function typically are stored in a one-dimensional array and the mappings from r to s are implemented via table lookups. For an 8-bit environment, a lookup table containing the values of T will have 256 entries [19].

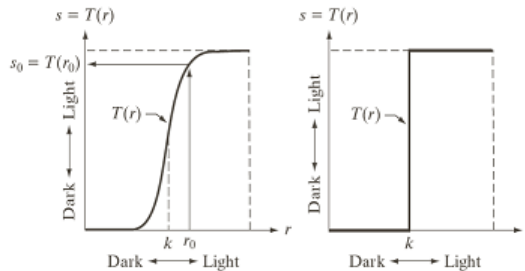


Figure 2.10 The Intensity Transformation of image [19].

2.8.3 Histogram modification

A histogram is a one-dimensional probability density function (PDF) of gray levels present in an image. The histogram describes the global gray level distribution of pixels within an image. Histogram-based enhancement techniques are devised to enhance an image by modifying its histogram.

The histogram modification problem can be formulated as follows:

Given:

- 1) PDF of the input image $P_r(r)$
- 2) PDF of the desired image $P_s(s)$

Compute: A transformation function T , to modify gray values of the input image to achieve the desired PDF [20].

2.9 Frequency Domain Filtering Fundamentals

Filtering in the frequency domain consists of modifying the Fourier transform of an image and then computing the inverse transform to obtain the processed result. Thus, given a digital image, $f(x, y)$ of size, $M \times N$, the basic filtering equation in which we are interested has the form

$$G(x, y) = T^{-1}[H(u, v)F(u, v)]$$

Where T^{-1} is the Inverse Distributive Frequency Transformation, $F(u, v)$ is the Distributive Frequency Transformation of the input image $f(x, y)$, $H(u, v)$ is a filter function and $g(x, y)$ is the filtered image [21].

2.9.1 Gaussian Low pass Filters

Gaussian low pass filters (GLPFs) of one dimension were introduced as an aid in exploring some important relationships between the spatial and frequency domains. The form of these filters in two dimensions is given by $H(u, v) = e^{-D^2(u,v)/2\sigma^2}$.

Where $D(u, v)$ is the distance from the center of the frequency rectangle. Here we do not use a multiplying constant [3].

2.10 The Fuzzy set theory

Fuzzy set theory is the extension of conventional (crisp) set theory. It handles the concept of partial truth (truth values between 1 (completely true) and 0 (completely false)). It was introduced by Prof. Lotfi A. Zadeh in 1965 as a mean to model the vagueness and ambiguity in complex systems [3].

Definition Fuzzy set: A fuzzy set is a pair (A, m) where A is a set and $m: A \rightarrow [0, 1]$. For each, $x \in A$ $m(x)$ is called the grade of membership of x in (A, m) .

For a finite set $A = \{x_1, \dots, x_n\}$, the fuzzy set (A, m) is often denoted by $\{m(x_1) / x_1, \dots, m(x_n) / x_n\}$. Let $x \in A$ Then x is called not included in the fuzzy set (A, m) if $m(x) = 0$, x is called fully included if $m(x) = 1$, and x is called fuzzy member if $0 < m(x) < 1$. The set $\{x \in A \mid m(x) > 0\}$ is called the support of (A, m) and the set $\{x \in A \mid m(x) = 1\}$ is called its kernel.

The idea of fuzzy sets is simple and natural. For instance, we want to define a set of gray levels that share the property dark. In classical set theory, we have to determine a threshold, say the gray level 100. All gray levels between 0 and 100 are element of this set; the others do not belong to the set (right image in Fig.). But the darkness is a matter of degree. So, a fuzzy set can model this property much better. To define this set, we also need two thresholds, say gray levels 50 and 150. All gray levels that are less than 50 are the full member of the set, all gray levels that are greater than 150 are not the member of the set. The gray levels between 50 and 150, however, have a partial membership in the set (left image in the below Fig.).

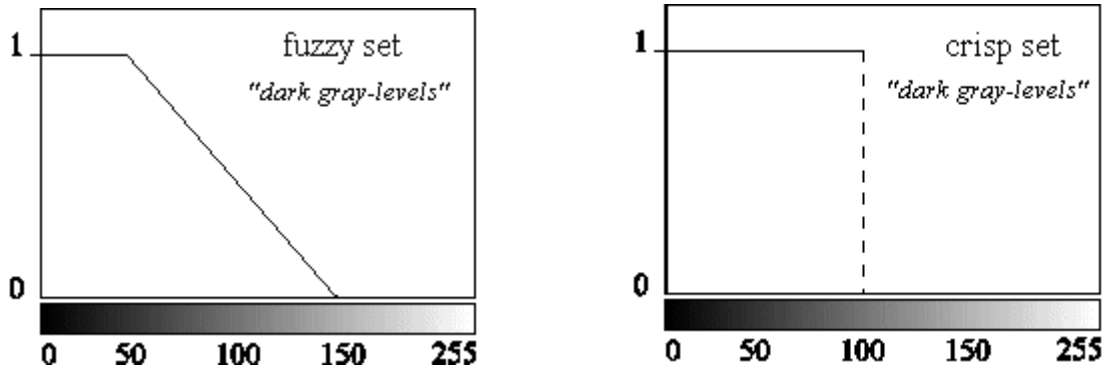


Figure 2.11 Representation of "dark gray-levels" with a fuzzy and crisp set.

2.10.1 History of Fuzzy set Theory

A pictorial object is a fuzzy set which is specified by some membership function defined on all picture points. From this point of view, each image point participates in many memberships. Some of this uncertainty is due to degradation, but some of it is inherent...In fuzzy set terminology, making figure/ground distinctions is equivalent to transforming from membership functions to characteristic functions.“ 1970, J.M.B. Prewitt.

1965 Zadeh	Introduction of Fuzzy Sets
1966, Zadeh et al.	Pattern Recognition as interpolation of membership functions
1969, Ruspini	Concept of Fuzzy Partitioning
1970, Prewitt	First Approach toward Fuzzy Image Understanding
1973, Dunn, Bezdek	First Fuzzy Clustering algorithm (FCM)
1977, Pal	Fuzzy Approach to Speech Recognition
1979, Rosenfeld	Fuzzy Geometry

1980-1986, Rosenfeld et al., Pal et al.	Extension of Fuzzy Geometry, New methods for enhancement / segmentation
End of 80s-90s Dave/ Krishnapuram/Bezdek Russo/ Krishnapuram	Different Fuzzy Clustering algorithms
Bloch et al. / Di Gesu / Sinha et al. / De Baets / and many others	Rule-based Filters, Fuzzy Morphology

Table 1: History of Fuzzy set theory

2.12 Survey on Image Enhancement methods

In the field of image noise reduction, several linear and nonlinear filtering methods have been proposed. Linear filters are not able to effectively eliminate impulse noise as they have a tendency to blur the edges of an image. On the other hand, nonlinear filters like median filters are better suited for dealing with impulse noise. Several non-linear filters based on classical and fuzzy techniques have emerged in the past few years. Recent progress in fuzzy logic allows different possibilities for developing new image noise reduction methods. The fuzzy median filter is a modification to the classical median filter. The Fuzzy Inference Rules by Else action (FIRE) filters are a family of non-linear operators that adopt fuzzy rules to remove noise from images. Russo introduced a multi-pass fuzzy filter consisting of three cascaded blocks in [22]. Khriji and Gabbouj developed a multi channel filter by combining fuzzy rational and median functions. This filter preserves the edges and chromaticity of the image [23]. Wenbin presented a novel idea of alpha trimmed mean and the similarity of pixels for the detection of impulse noise based on a large difference between the noisy pixel and the noise free pixel [24].

In rank-order mean (ROM) is modified to devise a Least-Mean Square Design for filtering out the fixed and non linear impulse noise [25]. Efforts are made in to reduce blurring at the edges due to linear filtering. A signal adaptive median filtering algorithm

is proposed in for the removal of impulse noise in which the notion of homogeneity level is defined for pixel values based on their global and local statistical properties [26]. The co-occurrence matrices are used to represent the correlations between a pixel and its neighbors, and to derive the upper and lower bounds of the homogeneity level. The use of non linear filters for both noise correction and image preservation is also suggested in [27]. Median based filters are modified for detail-preservation images Mansoor et al. introduce an iterative edge preserving filtering technique using the blur metric. Noisy pixels have been categorized into edge and non edge pixels and different filtering schemes are applied. Stefan et al. presented a fuzzy two-step color filter for the reduction of impulse noise. This filter utilizes the fuzzy gradient values and fuzzy reasoning for the detection of noisy pixels. Mansoor et al [28] developed a recursive filter images which are highly corrupted by impulse noise. This filter estimates the noise level which is required to obtain the filter parameters. All these filters were specifically designed to reduce impulse noise [29].

The performance of the median filter in removing Gaussian noise is inadequate. This drawback is overcome with some success by employing another nonlinear filter technique which makes use of moving average filters (MAV). The concept behind a standard moving average filter is to replace its central pixel by the average value of its predefined neighborhood. One of the major issues in removing Gaussian noise is to differentiate between noise and edges. Various attempts have been made in the past to solve this problem. Fuzzy derivatives are used for task in [30]. The GOA filter was designed for reducing Gaussian type noise by estimating a fuzzy gradient in each direction so as to distinguish the local variation due to noise from that of an image structure. Stefan et al [31]. Consider the fuzzy distance between color pairs as a weight to perform the weighted average filtering for the removal of the Gaussian noise in color images. Russo [32] proposes a method for Gaussian noise filtering that combines a nonlinear algorithm for detail preserving and smoothing of noisy data, and a technique for automatic parameter tuning based on noise estimation. A new filtering architecture adopting multi parameter piecewise linear (PWI) functions is devised for the restoration

of the images corrupted by the Gaussian noise [33]. Xiaofen and Qigang [34] made use of perceptual classification rules to separate noise from other relevant features of image.

In yet another interesting work [35], fuzzy smoothing of images for Gaussian as well as Impulse noise is achieved by combining the output of several filters termed as hybrid filters. Most of the methods presented in literature deal with gray scale images. It is possible to extend these techniques to color images component wise i.e. each component R, G, and B can be passed through a filter separately. Barring a few, most papers on noise removal have dealt with the individual component of RGB color space separately. In the case of Gaussian noise, where differentiating between noise and edges (i.e. finer details of image) is difficult, dealing with each component introduces artifacts in the de-noised image. Only a few research studies have actually explored the interaction between the color components.

Noise reduction is an important area for image processing. Besides classical filters, there are lots of fuzzy filters in the literature. Images can be corrupted with impulse noise, Gaussian noise, or both. Depending on the type of noise, filters can be used. The fuzzy filters are categorized into two subclasses [6]:

(a) Fuzzy-classical filters and

(b) Fuzzy filters.

(a) **Fuzzy Classical filters** are filters that use fuzzy logic and these are the modification of the classical filters. Some of the fuzzy- classical filters are

(i) **Fuzzy median filter:** Fuzzy median filter is well known for removing impulse noise. It is the fuzzy rank ordering of samples and is simply a replacement of conventional median filter with fuzzy counterparts.

(ii) **Fuzzy impulse noise detection and reduction method-** this filter by Schulte detects the impulse noise and any other noise in the image. It contains the noise-detection step and filtering step to preserve the edges. Fuzzy detection step uses fuzzy gradient values in eight directions with a 3 x 3 window, which indicates the degree of central pixel as an impulse noise pixel. A fuzzy set is constructed based on the gradient

values which are represented by a membership function such as BIG, SMALL, BIG POSITIVE, and BIG NEGATIVE. Then a fuzzy rule is applied to decide if the control pixel as a noise pixel.

(b) **Fuzzy Filters:** These are filters that are totally dependent on fuzzy logic and they do not have any connection with classical filters. A few fuzzy filters are discussed below.

(i) **Gaussian noise reduction filter (GOA)** - This filter is specially designed to remove Gaussian noise. Averaging is done for a pixel using other neighborhood pixels and simultaneously taking care of the other image structures such as edges. To achieve this, two features are required. First, in order to distinguish between the variations due to noise and the image structures, the filter uses gradient for all the eight directions. Second, the membership functions are adapted accordingly to the noise level to perform fuzzy smoothing. The filter is applied iteratively.

(ii) **Histogram adaptive filter (HAF)** – This type of filter removes high impulsive noise, preserving edge information. In HAF, each input pixel is considered a fuzzy variable and a square window of size 3X3 is sided over the entire image and the filter output is associated with each center pixel in a window. Three fuzzy sets for dark, medium, and bright are created and the membership functions for these fuzzy sets are calculated. Then fuzzy inference rules based on the Takagi-Sugeno approach with a slight difference is used in a final output decision process.

2.13 MATLAB: Dr Cleve Moler, Chief Scientist at Math Works, Inc., Originally wrote MATLAB, to provide easy access to matrix software developed in the LINPACK and EISPACK projects. The very first version was written in the late 1970s for use in courses in matrix theory, linear algebra, and numerical analysis. MATLAB is therefore built upon a foundation of sophisticated matrix software, in which the basic data element is a matrix that does not require pre dimensioning. MATLAB is a product of The Math works,Inc. and is an advanced interactive software package specially designed for scientific and engineering computation. The MATLAB environment integrates graphic

illustrations with precise numerical calculations, and is a powerful, easy-to-use, and comprehensive tool for performing all kinds of computations and scientific data visualization. MATLAB has proven to be a very flexible and usable tool for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation. Typical use includes:

- Math and computation
- Algorithm development
- Modeling, simulation, and prototyping
- Data analysis, exploration, and visualization
- Scientific and engineering graphics
- Application development, including graphical user interface building.

Problem Statement

Whenever an image is converted from one form to another such as, digitizing, scanning, transmitting, storing, etc., some of the degradation occurs at the output. Hence, the output image has to undergo a process called image enhancement which consists of a collection of techniques that seek to improve the visual appearance of an image. In the image if the local region is somewhat smooth, then the new value of the pixel can be determined by averaging neighboring pixel values. On the other hand, if the local region contains edges a different type of enhancement method should be used. However, it is extremely hard, if not impossible, to set the conditions under which a certain enhancement method should be selected, since the local conditions can be evaluated only vaguely in some portions of an image, therefore, an enhance method needs to be capable of reasoning with vague and uncertain information; this suggests the use of fuzzy logic.

In this thesis work a technique is designed by using Fuzzy Inference System in MATLAB 7.5 (is the process of mapping from a given input to an output using fuzzy logic).

Objectives:

- To study the existing enhancement methods in spatial, frequency domain and fuzzy domain methods.
- To design the technique using FIS (Fuzzy Inference System) to improve the image contrast.
- Implement it in MATLAB 7.5
- Test the designed technique using some degraded, low contrasted images.

- This designed technique is able to improve contrast of the image as compare to Thresholding method, Histogram Equalization, Gaussian Low-pass Filter and Spatial Averaging Filter.
- An algorithm is proposed and implemented to enhance image using fuzzy technique. This algorithm is used to convert the image properties into fuzzy data and fuzzy data into defuzzification.

Fuzzy inference system is the process of formulating the mapping from a given input to an output using fuzzy logic. The mapping then provides a basis from which decisions can be made, or patterns discerned. The process of fuzzy inference involves all of the pieces that are described in the previous sections: membership functions, fuzzy logic operators, and if-then rules. There are two types of fuzzy inference systems that can be implemented in the Fuzzy Logic Toolbox: Mamdani-type and Sugeno-type. These two types of inference systems vary somewhat in the way outputs are determined. Fuzzy inference systems have been successfully applied in fields such as automatic control, data classification, decision analysis, expert systems, and computer vision. Because of its multidisciplinary nature, fuzzy inference systems are associated with a number of names, such as fuzzy-rule-based systems, fuzzy expert systems; the following are the steps which are carried out in the sequence to get the desired output:

- 1) Read the original image.
- 2) Convert it into Gray Scale image if it is RGB image.
- 3) Add the noise to the image.
- 4) Calculate size of original image.
- 5) Perform morphological operation on image.
- 6) Apply fuzzy inference Engineering.
- 7) Normalization of pixel values.

8) Passing parameters to the FIS.

9) Compare the enhanced image with the other enhanced images.

4.1 Fuzzy Inference System

Fuzzy inference is the process of formulating the mapping from a given input to an output using fuzzy logic.

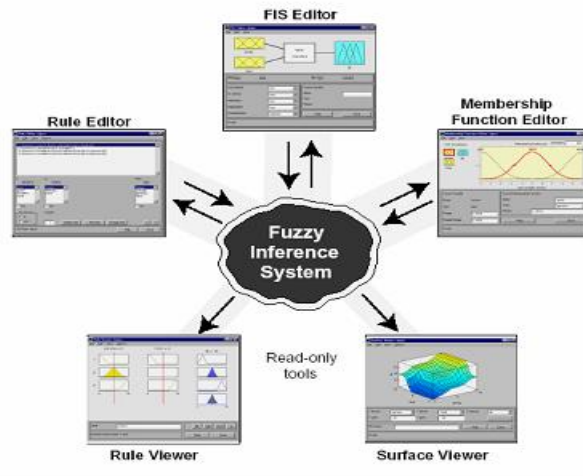


Figure 4.1 Fuzzy Inference Systems.

4.2 Fuzzy Inference System Editor:

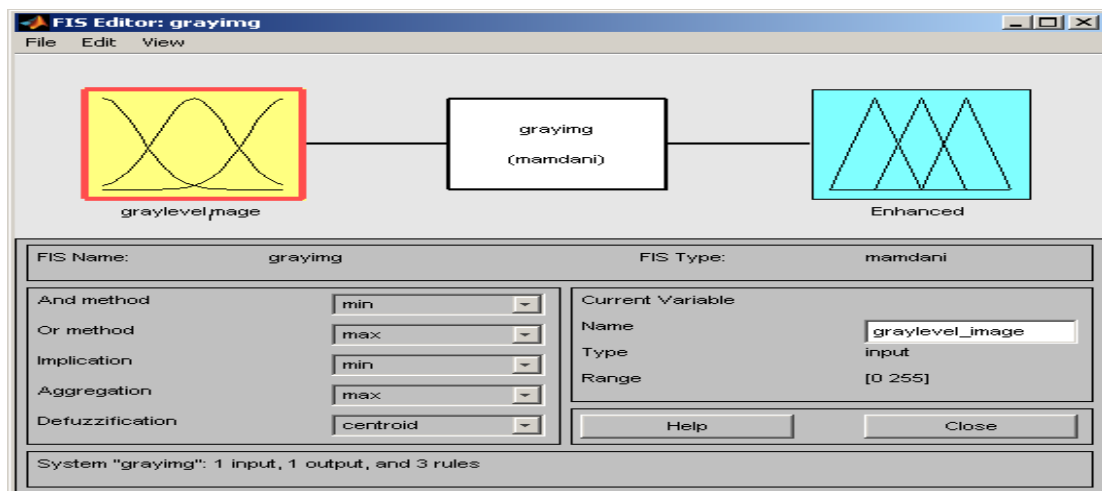


Figure4.2. Fuzzy Inference System Editor.

The FIS Editor displays general information about a fuzzy inference system. There's a simple diagram at the top that shows the names of each input variable on the left, and those of each output variable on the right. The sample membership function shown in the boxes are just icons and do not depict the actual shapes of the membership functions.

4.3 The Membership Function Editor

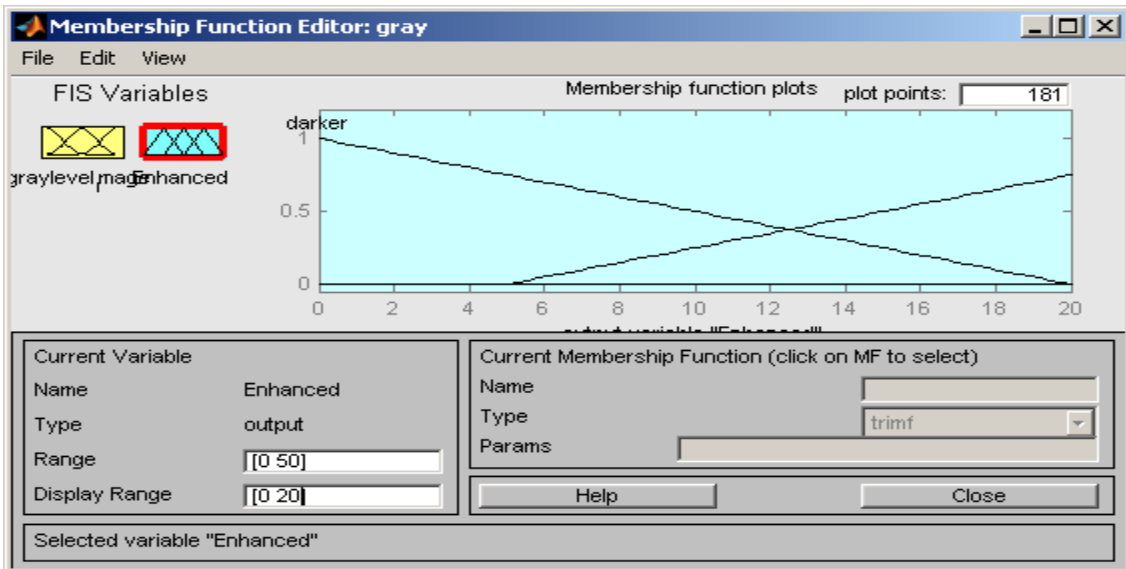
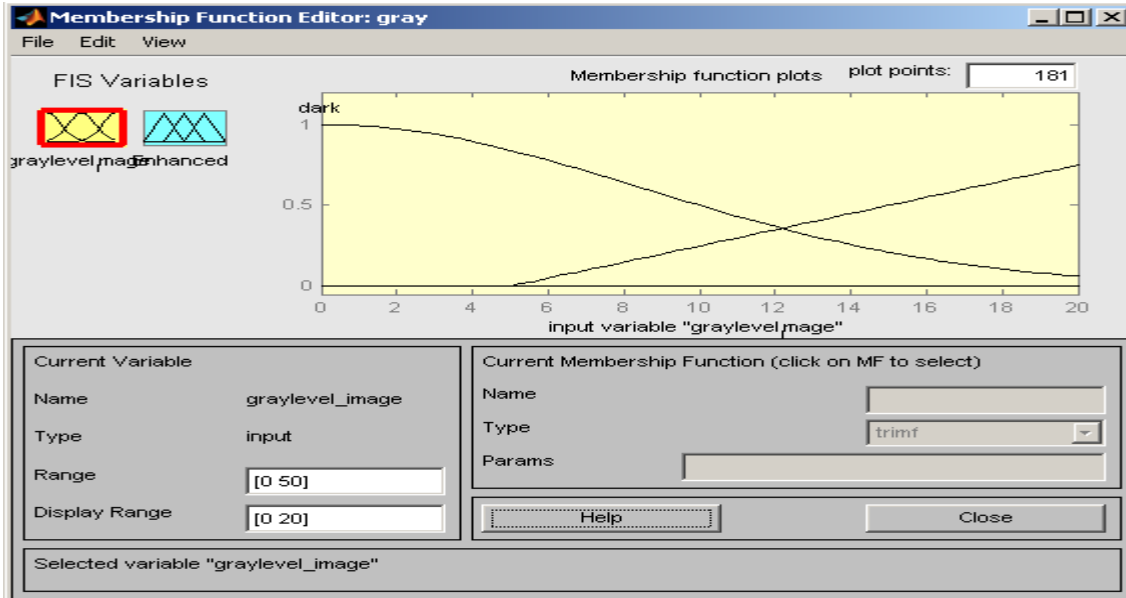


Figure 4.3 The Membership Function Editor.

4.4 The Rule Editor

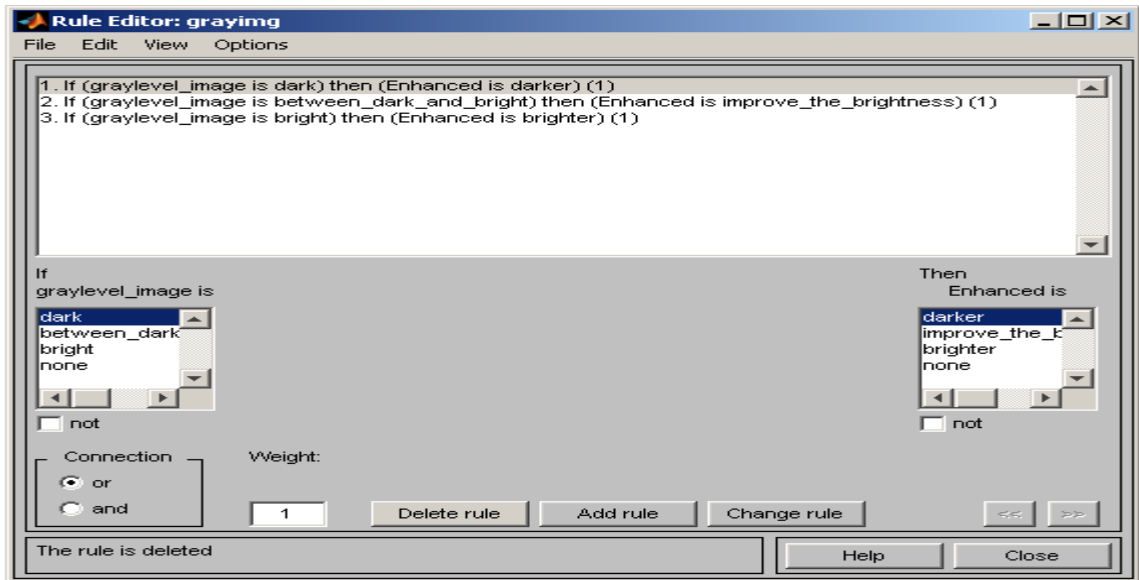


Figure 4.4 Rule Editor

Constructing rules using the graphical Rule Editor interface is fairly self-evident. Based on the descriptions of the input and output variables defined with the FIS Editor, the Rule Editor allows you to construct the rule statements automatically, by clicking on and selecting one item in each input variable box, one item in each output variable box, and one connection item. Choosing **none** as one of the variable qualities will exclude that variable from a given rule. Choosing **not** under any variable name will negate the associated quality. Rules may be changed, deleted, or added, by clicking on the appropriate button. The Rule Editor also has some familiar landmarks, similar to those in the FIS Editor and the Membership Function Editor, including the menu bar and the status line. The **Format** pop-up menu is available from the **Options** pull down menu from the top menu bar this is used to set the format for the display.

4.5 The Rule Viewer

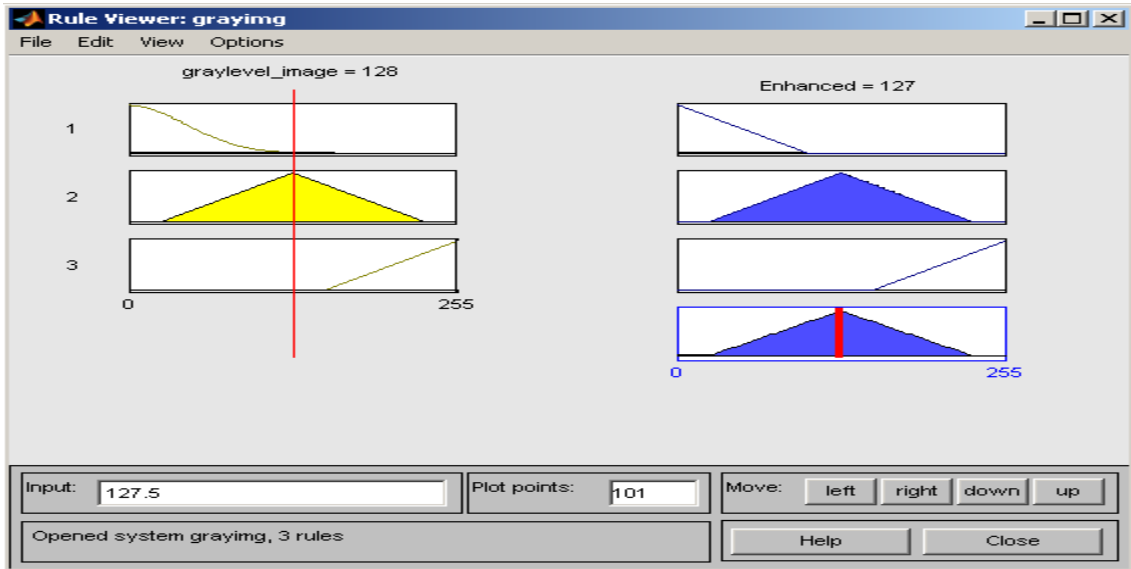


Figure 4.5 The Rule Viewer.

The Rule Viewer displays a roadmap of the whole fuzzy inference process.

4.6 The Surface Viewer

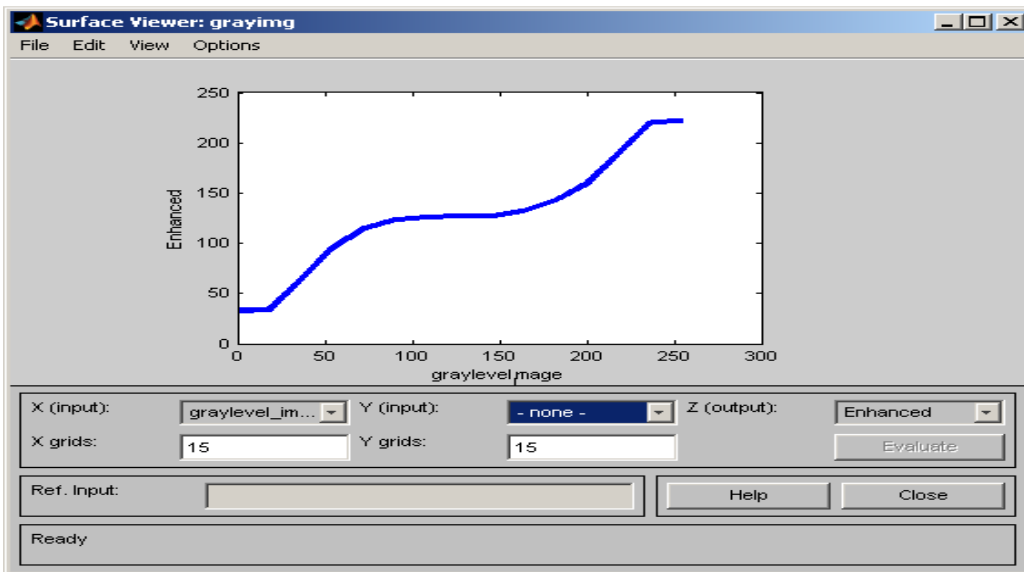


Figure 4.6 The Surface Viewer.

Upon opening the Surface Viewer, we are presented with a two-dimensional curve that represents the mapping from service quality to tip amount. Since this is a one-input one-output case, we can see the entire mapping in one plot. Two- input one-output systems also work well, as they generate three-dimensional plots that MATLAB can adeptly manage. When we move beyond three dimensions overall, we start to encounter trouble displaying the results. Accordingly, the Surface Viewer is equipped with pop-up menus that let you select any two inputs and any one output for plotting. Just below the pop-up menus are two text input fields that let you determine how many x-axis and y-axis grid lines you want to include. This allows you to keep the calculation time reasonable for complex problems. To change the x-axis or y-axis grid after the surface is in view, simply change the appropriate text field, and click on either **X-grids** or **Y-grids**, according to which text field you changed, to redraw the plot.

4.7 Algorithm to enhance image using fuzzy technique.

The algorithm starts with the initialization of the image parameters; size, minimum, mid and maximum gray level. The fuzzy rule-based approach is a powerful and universal method for many tasks in the image processing.

The algorithm is described as bellow:

Step -1: Morphological processing

- i) Read the image
- ii) Convert it into Grayscale image if it is RGB image.
- iii) Find the size of the image (M X N).
- iv) Add the noise to the image (impulse noise).
- v) Find the minimum, maximum gray level of the image also find the average gray level of the image.

Step -2: Convert the image data into Fuzzy domain data

- i) For $x=0:M$
For $y=0: N$
 - a) If gray_ value between zero and min
Then $fdata=0$;
 - b) Else if gray_ value between min and mid
Then $fdata = (1/(mid-min) * min + (1/mid- min)* data$;
 - c) If gray _ value between mid and max
Then $fdata = (1/(max-mid)) * mid + (1/(max-mid))*data$;
 - d) if gray_ level between max and 255
Then $fdata=1$;

Step -3 Membership Modifications

For $x=0: M$

For $y=0: N$

- a) If gray _ value between 0 and min

 $fdata= 0$; // **if the pixel is dark then make it darker.**
- b) If gray _ value between min and mid. // **If the pixel gray then make it gray**

for $x=0:3$
 - i) If $fdata$ between 0 and 0.5

Then $fdata=2*(fdata) ^2$;
 - ii) Else if $fdata$ between 0.5 and 1

Then $fdata= 1-2*(1-fdata) ^2$;
 - c) If gray _ value between mid and max // **if the pixel is bright then make it brighter**

for x=0; 3

- i) If fdata between 0 and 0.5
Then $fdata = 2 * (fdata)^2$;
- ii) If fdata between 0.5 and 1
Then $fdata = 1 - 2 * (1 - fdata)^2$;
- iii) If gray_ value between min and max
Then $fdata = 1$;

Step -4 Defuzzification

For x=0: M

For y=0: N

- a) If gray_ value between 0 and min
Then $enhanced_data = gray_value$
- b) If gray_ value between min and mid
Then $enhanced_data = -(mid - min) * fdata + min$
- c) If gray_ value between mid and max
Then $enhanced_data = (max - mid) * fdata + mid$;

Step -5 displaying the Enhanced image.

- i) Show the original image.
- ii) Show the enhanced image.

5.1 Evolution of FIS:

After designing the system we store this file into MATLAB workplace as a .fis extension

We execute this file in MATLAB command prompt window. For executing this file we use the following below commands:

- `>> evalfis (input, fismat)`
- `>> evalfis (input, fismat, numPts)`
- `>>[Output, IRR, ORR, ARR]= evalfis (input, fismat)`
- `>>[Output, IRR, ORR, ARR]= evalfis (input, fismat, numPts)`

Description `evalfis` has the following arguments:

- **Input:** a number or a matrix specifying input values. If input is an M-by-N matrix, where N is number of input variables, then `evalfis` takes each row of input as an input vector and returns the M-by-L matrix to the variable, output, where each row is an output vector and L is the number of output variables.
- **fismat:** a FIS structure to be evaluated.
- **numPts:** an optional argument that represents the number of sample points on which to evaluate the membership functions over the input or output range. If this argument is not used, the default value of 101 points is used.

The range labels for `evalfis` are as follows:

Output: the output matrix of size M-by-L, where M represents the number of input values specified previously, and L is the number of output variables for the FIS. The optional range variables for evalfis are only calculated when the input argument is a row vector, (only one set of inputs is applied).

These optional range variables are

➤ **IRR:** the result of evaluating the input values through the membership functions. This matrix is of the size numRules-by-N, where numRules is the number of rules, and N is the number of input variables.

➤ **ORR:** the result of evaluating the output values through the membership functions. This matrix is of the size numRules-by-numerals*L, where numerals is the number of rules, and L is the number of outputs. The first numRules columns of this matrix correspond to the first output, the next numRules columns of this matrix correspond to the second output, and so forth.

➤ **ARR:** the numPts-by-L matrix of the aggregate values sampled at numPts along the output range for each output

➤ Create a M-file and save that file in MATLAB file, input the pixel value to the function

```
>>grayfis('pout.tif', 'outputimg')
```

Output= evalfis (input, fismat) store the values in another g(x, y) then do some morphological operations and display the image.



Figure 5.1 Output of the proposed method.

Input one by one pixel to the FIS System by typing the below command on command

prompt of the tool MATLAB 7.5.0.

```
a=readfis('grayimg.fis');
```

```
output=evlfis(inptut, fismat)
```

5.2 Input pixels to the FIS System (8 x 8):

97	98	99	101	101	99	98	97
98	101	102	102	102	99	98	95
97	102	106	106	106	101	98	95
97	107	109	113	110	105	95	91
98	108	112	120	117	110	98	95
101	109	114	121	122	119	108	106
105	112	117	123	128	123	113	110
108	117	122	128	130	128	121	120

Table 5.1 input pixel to the FIS system.

5.3 Output pixels (8x8) :

124	124	124	125	125	124	124	124
124	125	125	125	125	124	124	123
123	125	126	126	126	125	124	124
124	126	126	126	126	126	124	123
124	126	126	127	127	126	124	123
125	126	126	127	127	127	126	126
126	126	127	127	127	127	126	126
126	127	127	127	127	127	126	126

Table 5.2 output pixels of the FIS system.

5.4 Image enhancement using Thresholding.

```
Editor - C:\Documents and Settings\venkatkajjam\My Documents\MATLAB\thres...
File Edit Text Go Cell Tools Debug Desktop Window Help
- 1.0 + ÷ 1.1 x % % 1
1
2  %IMAGE THRESHOLDING
3
4  function threshold(x)
5  f=imread(x);
6  T=input('Enter a threshold value, T = ');
7  [M,N]=size(f);
8      for x = 1:M
9          for y = 1:N
10             if (f(x,y)<T)
11                 g(x,y)=30;
12             else
13                 g(x,y)=250;
14             end
15         end
16     end
17     imshow(g);
18
```

Output of thresholding:

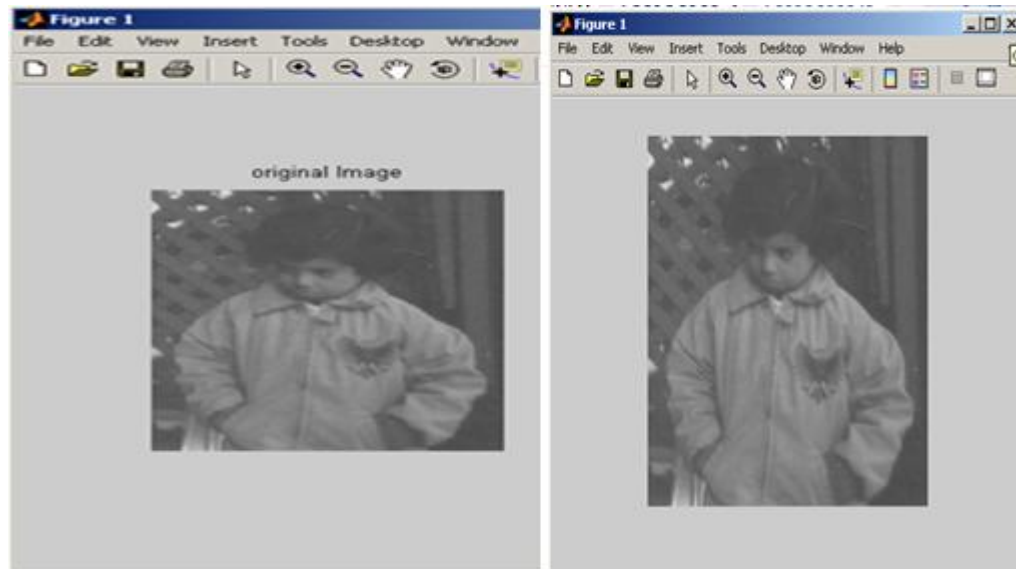


Figure 5.2 Output of image enhancement using Thresholding.

5.5 Spatial Average low pass filtering

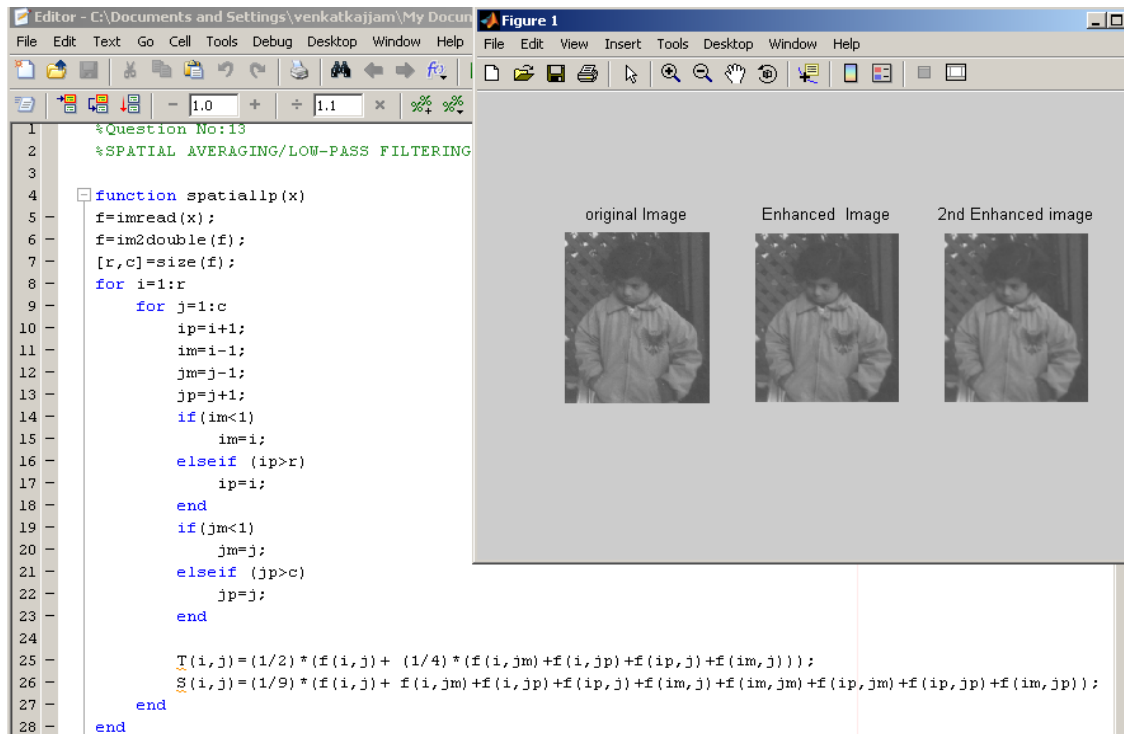


Figure 5.3 Output of image using Spatial Average Filtering.

5.6 Histogram Equalization

```
>> I = imread('pout.tif');  
    J = histeq(I);  
    figure, imshow(I), figure, imshow(J)
```



Figure 5.4. Histogram Equalization.

5.7 Frequency Domain Image filters

1. Gaussian Low-pass Filter

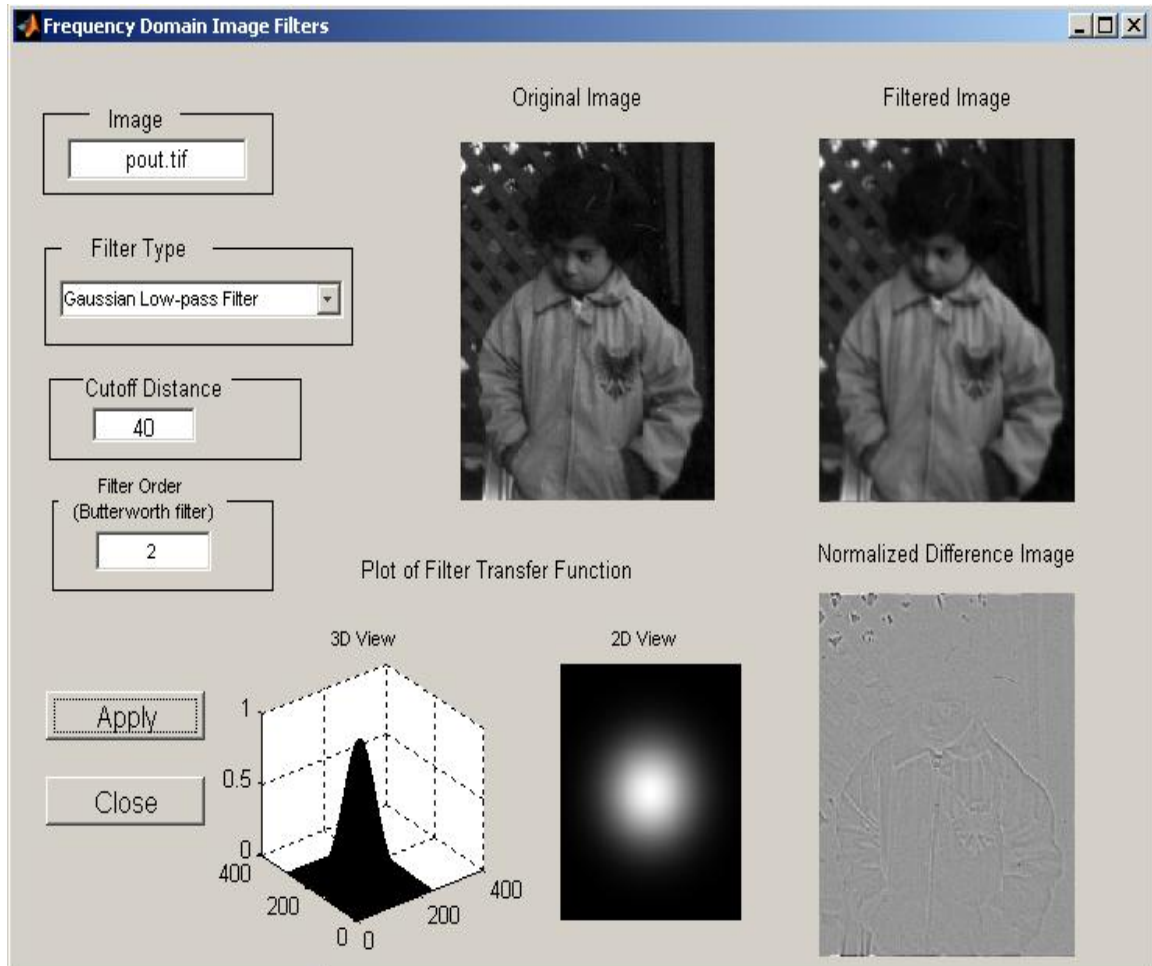


Figure 5.5 Output of the image using Gaussian Low- pass Filter.



Figure 5.6 Output of all the methods.

6.1 Conclusion

- In this thesis work a technique is designed based on Fuzzy Inference System tool in MATLAB 7.5 (MATLAB is a software package developed by Math Works). To enhance the pixels three membership functions are used. One can also use any automatic approaches for image enhancement to increase the image quality. One of the disadvantages of measure theory is the computational complexity if the number of elements is large.
- The proposed technique used fuzzy if – then rules are a sophisticated bridge between human knowledge on the one side and the numerical framework of the computers on the other side, simple and easy to understand. To achieve a higher level of image quality considering the subjective perception and opinion of the human observers.
- The proposed technique is able to overcome the draw backs of spatial domain methods like thresholding and frequency domain methods like Gaussian low pass filter. The proposed technique is able to improve the contrast of the image. The proposed technique is tested on different type of images, like degraded, low contrasted images.

6.2 Future Scope

In the future the existing systems can be modified by fuzzy set theory application. Modification of fuzzy rules can produce better results. Neuro-Fuzzy techniques can be used to enhance the images.

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List of Papers Published/Communicated

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