Designing Fuzzy Framework for Image Enrichment

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

Master of Engineering
in
Software Engineering

Submitted By

Ankita Sheoran
(Roll No. 801531004)

Under the supervision of:

Ms. Harkiran Kaur
Lecturer
Computer Science and Engineering Department

COMPUTER SCIENCE AND ENGINEERING DEPARTMENT
THAPAR UNIVERSITY
PATIALA-147004

July 2017

Certificate

I hereby certify that the work which is being presented in the thesis entitled, *"Designing Fuzzy Framework for Image Enrichment"*, 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 *Ms. Harkiran Kaur* and refers other researcher's work which are duly listed in the reference section.

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

(Ankita Sheoran)
(801531004)

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

(Ms. Harkiran Kaur)
Lecturer, CSED

Abstract

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, digitized, scanned, transmitted, stored, and so on, some of the degradation occurs at the output state. Hence, the output image has to undergo a process called image enrichment which consists of collection of techniques that seek to improve the visual appearance of an image. Image enhancement or enrichment basically improves the interpretability or perception of information in images for human viewers and provides better input for other automated image processing techniques. The fuzzy set theory is incorporated in this operation, in order to handle uncertainties (arising from deficiencies of information available in situations such as the dark areas of image, may be the outcome obtained from incomplete, imprecise, and not fully reliable or vague pixel information). The fuzzy logic provides a mathematical framework for representation and processing of expert knowledge that is, the Rule Base. The concept of if-then rules play a role in approximation of the variables like 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 the situation to manage these problems effectively.

In this thesis, Image Enhancement Fuzzy Algorithm (IEFA), a technique for image enhancement has been proposed and developed. IEFA formulates the mapping from a given input to an output using fuzzy logic. IEFA improves the contrast of low contrast images. This algorithm supports all the extension types of images. The technique begins the process of image enrichment by modifying membership functions and designing fuzzy if – then rules that exist as a sophisticated bridge between human knowledge on one side and the numerical framework of the computers on the other side. It has the capability of handling vague image data effectively. The algorithm converts image properties into fuzzy data and further, fuzzy data into crisp output through Defuzzification. Further, to evaluate the performance of the proposed technique, the developed technique has been compared with Histogram Equalization (HE) and Contrast Limited Adaptive Histogram Equalization (CLAHE). It has been observed that PSNR and CII of the proposed algorithm (using a test image) are 25.56 and 1.13 respectively. These metrics are 0.078% and 6.603% effective than the metrics of existing algorithms.

Acknowledgement

First of all I would like to thank the Almighty, who has always guided me to work on the right path of the life. It is a great privilege to express my gratitude and admiration towards my respected supervisor **Ms. Harkiran Kaur** Lecturer Computer Science & Engineering Department. She has been an esteemed guide and great support behind achieving this task. This work would not have been possible without the encouragement and able guidance of her. I also thank my supervisor for her time, patience, discussions and valuable comments. Her enthusiasm and optimism made this experience both rewarding and enjoyable. I am truly grateful to her for extending her total co-operation and understanding whenever I needed help and guidance from her. I am also heartily thankful to **Dr. Maninder Singh**, Associate Professor and Head, Computer Science & Engineering Department and **Dr. Rupali Bhardwaj**, PG coordinator, for motivation and providing uncanny guidance and support throughout the preparation of the thesis report.

I will be failing in my duty if I do not express my gratitude to **Dr. S. S. Bhatia**, Senior Professor and Dean of Academic Affairs, for making provisions of infrastructure such as library facilities, computer labs equipped with net facilities, immensely useful for the learners to equip themselves with the latest in the field.

I am also thankful to staff members of Computer Science and Engineering Department for their help, cooperation, love and affection, which made my stay at Thapar University memorable. Last but not least, I would like to thank my family for their wonderful love and encouragement, without their blessings none of this would have been possible.

Ankita Sheoran

(801531004)

Table of Contents

List of Figures

List of Tables

Chapter 1

Introduction

Image enhancement techniques have wide number of applications in the field of medical science imaging, atmospheric science, forensic science and art studies. It increases the quality of the image so as to prevail over the limitations of the human visual system. The incentive of image enhancement techniques include higher visual quality, extracting the hidden details in the image, increasing the contrast of low contrast image, enhancing image features for further processing and many more.

In image enhancement, the low quality image is transformed into high quality with the intent of improving the look of the image [1]. Instead of increasing the inherent information of the data, enhancement upsurges the range of features. Many of the image features get altered during enhancement process such as change in image brightness, change in pixel gray level and introduction of artifacts. An artifact is the little amount of noise which is introduced by every enhancement method.

An image can be described as a two dimensional light strength function f(i, j), where i and j denotes spatial co-ordinates and the value of f at any point is directly proportional to the pixel intensity of the image at that point.

1.1 Digital Image Processing

In the aforesaid definition of image when i, j, and the attribute values of f are all discrete and finite numbers, the image is termed as a "digital image". The handling of digital images by a digital computer is known as "digital image processing". It is a collection of a finite number of components, in which each has a specific position and value. These components are denoted as image elements, picture elements, pels, and pixels [11]. The commonly used term to refer digital image element is Pixel. The pixel address is given by its physical co-ordinates (i, j).

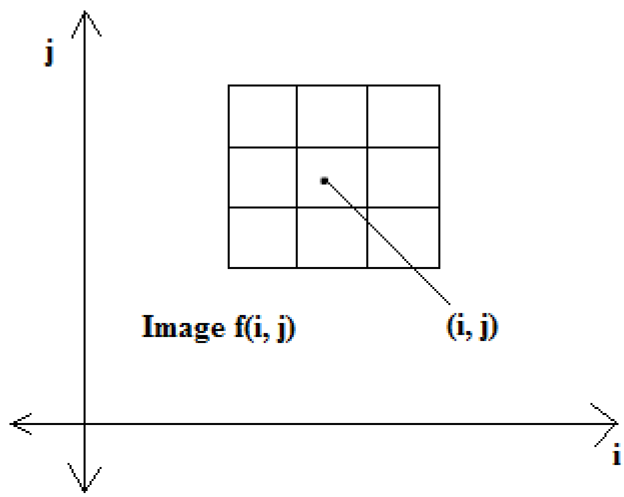

Figure 1.1: A point f (i, j) in a Digital Image

Image Processing is a signal processing technique in which input can be a video frame or a photograph, and the output is an image with a set of details of the input image. Image processing techniques have been advanced immensely in the previous years. Image processing has two main purposes:

a. Refining the visual form of images to human viewer, and
b. Pre-processing images for assessment of the features and structures present.

The image is handled as a two-dimensional signal and further conventional signal processing practices are applied to it. It solves the problems where identification of objects is an issue, such as in forensic labs or in generating weather maps from pictures received from satellites. Even though massive imaging applications are performed by large-scale image processing organizations; for which they are being retailed mostly; For instance satellite images processing, the fashion continues toward scaling down and merging of expert image processing hardware with general-purpose small computers [38].

Image processing's application include: detecting license plate, removing straight lines, scanning whiteboard contents, separating aggregate objects, extracting forest areas in google maps aerial images, detecting text in still images, enhancing X-Ray images, extracting serous cell nuclei, extracting urban areas in google maps aerial images, detecting template in image, extracting agricultural fields in google maps aerial images, and detecting racing bib number. Image processing techniques consist of image restoration, image segmentation, image compression, image enhancement and so on.

1.1.1 Image Restoration

Image Restoration is an operation in image processing where input is degraded that is corrupt or noisy image and output is the clean, original image. Camera mis-focus, motion blur and noise may lead to corruption. The purpose of image restoration is to recover resolution loss and lessen noise.

1.1.2 Image Segmentation

The procedure of segregating a digital image into various divisions (sets of pixels, also recognized as super-pixels) is known as image segmentation. The goal is to make the representation simple or modify the image into some form which is additionally expressive and easier to study. It is commonly used to trace boundaries such as lines and curves and objects in images. To be accurate, in image segmentation every image pixel is allocated a label such that the pixels that share certain characteristics are assigned same labels.

In image segmentation the resultant image is entirely covered with a set of collective segments, or a set of outlines withdrawn from the edge detection of image. In a region, every pixel is similar concerning some property or calculated attribute, for example texture, intensity, or color. Neighboring regions are notably different in context with same characteristics. On applying to a pile of images, typically in medical imaging, the resultant contours can be used to make 3D reconstructions using “interpolation algorithms” such as marching cubes.

1.1.3 Image Compression

It is a kind of data compression technique useful for graphic files, to reduce their storage or transmission cost without corrupting the quality of the image up to a tolerable level. More images can be stored in a set amount of memory or disk space with reduced file size. Moreover, time to send these images over internet or downloaded from web is also reduced.

Image compression can be lossless or lossy. Lossy methods are chosen in applications in which slight (occasionally unnoticeable) loss of fidelity is bearable to accomplish a considerable decrease in bit rate. Lossy compression that yields negligible differences can be taken as visually lossless. Lossless compression is suitable for archival purposes and usually in medical imaging, and technical drawings.

1.1.4 Image Enhancement- The Definition

Image enhancement increases the understandability or observation of data in images for human views. It provides improved input for other automated image processing techniques. The difference between image enhancement and image restoration is that in the latter the features of the image are accentuated to make it more pleasing but does not essentially yield realistic data from scientific perspective.

1.2 Contributions of Image Enhancement (IE)

Image Enhancement finds its application in the following areas:

i. Forensics: In Forensics, security videos investigation, crime scene studies, and images gained from fingerprint recognition are enhanced to support in recognition of offenders [14].

ii. Atmospheric Sciences: In atmospheric sciences, to decrease the consequence of mist, fog, haze and turbulent weather for meteorological interpretations. In environment sensing, IE helps in identifying the structure and shape of remote entities. Image restoration and Enhancement of satellite images are done to eliminate noise [14].

iii. Astrophotography: Challenges faced by Astrophotography because of light and noise pollution are reduced by IE. Nowadays, a number of digital cameras have in-built photo editing functions. Furthermore, photo editing software provides advance editing features that provide vivid results.

iv. Oceanography: The study of images in the field of Oceanography exposes exciting features of water stream, residue concentration, bathymetric and geomorphology forms and so on. These features are clearly more noticeable in digitally enhanced images. The enhancement is performed to overcome the problems arising due to moving targets, ambiguous surroundings and absence of light.

v. For visually impaired, IE has proved to be of great importance. As for them, pictures with small print can be difficult to read, using computers, and viewing television is also challenging.

vi. Medical imaging: In Medical imaging, since small details have a serious part in diagnosis and for dealing with the disease, it is necessary to high spot the chief feature, reduce noise, and sharpen the details. This marks IE an essential assisting tool for inspecting anatomic areas that is X-rays, MRI, and many more [14].

1.3 Image Enhancement

In IE process, the visual look of image is perked up or is converted in a form that can be easily understood by human eyes or machines. Noisy image data is very difficult to enhance, which is necessary in many research and application areas. There are three main categories in image enhancement technique:

i. Method operating directly on pixels is spatial domain method.
ii. Method operating on the Fourier transformation of the image is Frequency domain method (DFT).
iii. Fuzzy domain method which involves Knowledge Base systems.

i. Spatial domain methods

"Spatial domain method" functions directly on pixels. In Spatial domain method, according to rules the pixel values are adapted that are dependent on the original pixel value (local or point processes). On the other hand, in many ways the pixel values can be merged with or compared to other pixels within instant neighborhood. Consider the input image r(j,k) and processed image s(j,k) then the transformation s(j,k)=Q[r(j,k)], where Q is an operator on r defined over some region of (j, k). The operator Q is applied at every position (j, k) to yield output s at that position. The process uses pixels in the area of image spanned by vicinity [14]. The two most popular conventional methods in spatial domain are histogram: specifications and equalization and adaptive neighborhood histogram equalization [15].

ii. Frequency domain methods (DFT)

In frequency domain method Fourier Transformation of image is used. Transformation of image into two dimensions even with fast transformation is a very time consuming task, thus making it less appropriate for real time processing [15]. Sharp conversions and edges in image give extensively to high-frequency content of Fourier transformation [14]. The overall appearance of the image over smooth areas is due to low frequency content in Fourier transformation. It is easy to study the idea of filtering in frequency domain so improvement of image r(j,k) can be completed in the frequency domain based on DFT [14]. This is chiefly beneficial in convolution if the spatial extent of the point spread sequence h(j,k) is larger than the convolution theory.

$$s(j,k)=h(j,k) * r(j,k) \qquad \text{……………………………………..(1)}$$

where, s(j,k) is enhanced image, and r(j,k) is input image.

iii. Fuzzy domain method

Fuzzy set theory is suitable in handling diverse uncertainties in image processing and computer vision applications. Fuzzy approaches comprises of different sets that helps in recognizing, characterizing and processing of image which as a whole describes the fuzzy theory. Fuzzy logic has three processes: image fuzzification of crisp value to fuzzy values, membership function modification and defuzzification to get back the crisp values. Fuzzy image enhancement involves mapping of gray level into membership function with the intent of generating an image of greater contrast than the input image. This is achieved by assigning a higher influence to the pixel intensity that is nearer to the average pixel intensity and to those that are beyond the average intensity of the image.

1.4 Spatial domain methods

The enhanced value of a pixel with coordinates (j, k) in the resultant image Â is the outcome of carrying out some task on neighboring pixels of (j, k) in the input image, A. Neighboring pixels can together form any shape, but usually neighboring pixels form a rectangle around (j, k) [11].

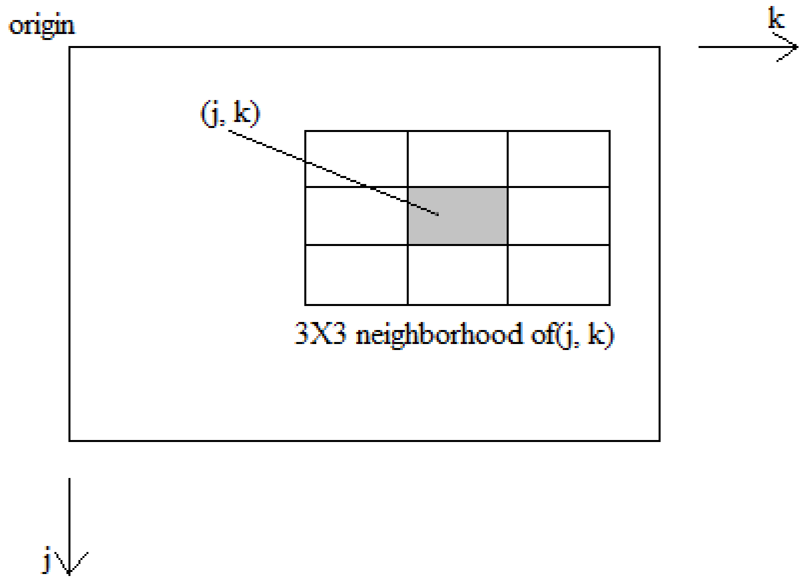

Figure 1.2: Spatial Domain of image

1.4.1 Histogram Equalization (HE)

The histogram defines the overall gray level dissemination of pixels within an image. It is the graphical depiction of the brightness distribution of a digital image that is number of pixels versus the brightness value. So X – axis will be having the brightness value variation and corresponding to one particular range the Y – axis will be having number of pixels that lie in that brightness range.

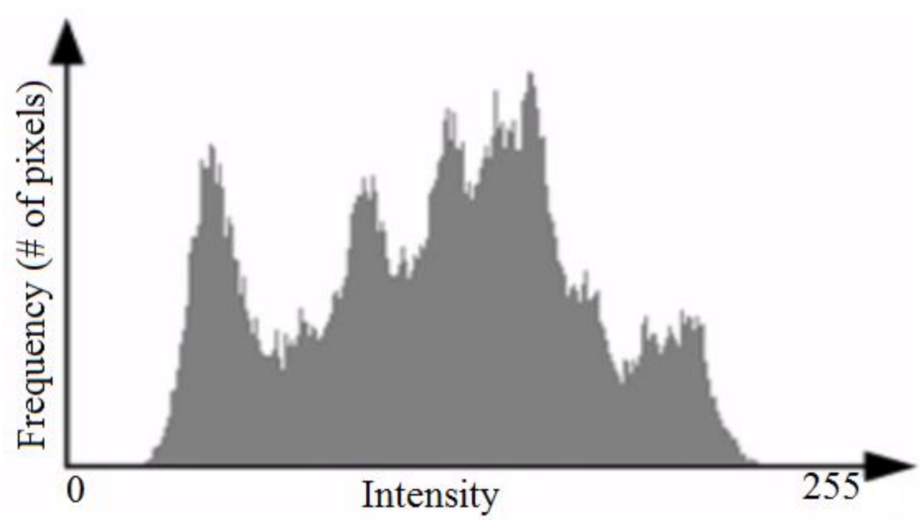

Figure 1.3: Histogram of a digital image

Histogram-based enhancement techniques are planned to improve an image by altering its histogram plot. This technique enhances the quality of a given image by distributing the intensities of the pixels over its brightness values. HE improves the contrast of the image. "Contrast is how well an image utilizes the range of pixel values" [19]. The gray values in the output image are uniformly distributed in image value range. Histogram Equalization transfers the gray altitudes such that the histogram of the resultant image is equalized to be a constant.

$$h[k] = \text{constant}; \quad \text{for all } k \qquad \ldots\ldots(2)$$

1.4.2 Contrast Limited Adaptive Histogram Equalization (CLAHE)

An addition to simple conventional "Histogram Equalization technique" is CLAHE. It augments the contrast of image by altering the values in the intensity image. In contrast to conventional HE, it works on small pixel sections called tiles, rather than operating on the whole image. The contrast of every tile is improved, such that the histogram plot of the output section nearly matches the specified histogram by "distribution" parameter. The adjacent tiles are then united with bilinear interpolation as to remove the artificially originated borders. In homogeneous areas, contrast can be restricted so as to evade over amplification of noise present in the image.

1.4.3 Thresholding

Thresholding sets all pixels below or above the threshold value to black or white. In the limiting case of contrast stretching, if the intensities are more than the threshold value (consider threshold=130, i>=130) the intensity is set to the maximum intensity (that is 255) and intensities lesser than the threshold (i<130) are set to the minimum intensity (that is 0), the changed image adopts the procedure of thresholding.

1.5 Fuzzy Set Theory

In traditional set theory, a conventional set is termed as a group of components which totally includes or excludes any specific component and every component has a certain property. Therefore, the characteristic function adopts the value either 0 or 1. For instance, the set of days of the week contains Tuesday, Wednesday, and Saturday and undoubtedly excludes January, March, and so on.

In real life, we deal with situations where individual insights must be taken into interpretation. In this domain the strict, yes-no logic is not helpful. For example: some people would place Friday in set of weekend, but officially it is omitted from the weekend set. “In fuzzy logic, the truth of any statement becomes a matter of degree and any statement can be fuzzy”. The foremost benefit of fuzzy reasoning is the capability to answer a “yes-no” query through a “not-quite-yes-or-no” response.

How does Fuzzy logic work?

Fuzzy logic reasoning involves generalizing the well-known “yes-no (Boolean) logic”. Assigning false to the mathematical value of 0 and true to the mathematical value of 1, this assignment of value shows fuzzy logic also authorize in-range values for example 0.3, 0.7891, 0.7890 and 0.8743.

For instance:

Question: Can Friday be considered as a weekend day?

Answer: 0.8 (mostly yes, but not completely)

Question: Can Saturday be considered as a weekend day?

Answer: 1 (yes, or true)

1.6 Fuzzy Logic

It is a multi – valued logic in which variables can have truth values in the range 0 to 1 and can be any real number. Whereas, the truth values of variables in the classical Boolean logic can only be the "crisp" values “0 or 1” that is “completely true” or “completely false”. Fuzzy logic is engaged to deal with the impression of partial truth, in which the truth value may vary between “completely true” and “completely false” in which membership function manages the degree.

The theory of Fuzzy logic advances from classical two valued set logic. It uses a continuous range of true values in the interval [0, 1], instead of strict binary values. Fuzzy logic is a form of knowledge depiction which is appropriate for notations that can't be well-defined on their contexts. It aims at modelling the imprecise modes through reasoning with rules that is approximate rather than fixed reasoning. The theory Fuzzy logic delivers a framework to deal with ambiguity of information.

Process:

a) Fuzzifying input values that is pixel data into fuzzy membership functions.
b) Implement all applicable rules from the Rule Base to calculate the fuzzy output functions.
c) De-fuzzify the output membership functions to for "crisp" output values.

Fuzzy logic systems can perform well even with imprecise and incomplete input data or even if data is not reliable; because in fuzzy logic the output is an agreement of the inputs and all the defined rules in the Rule Base. By optionally adding weights to each rule, the degree up to which it affects the output can be controlled. These rule weights can also be based on outputs of other rules. The weights can be changed or can be kept static. The criterion for deciding the weights is consistency or reliability and how important the rule is.

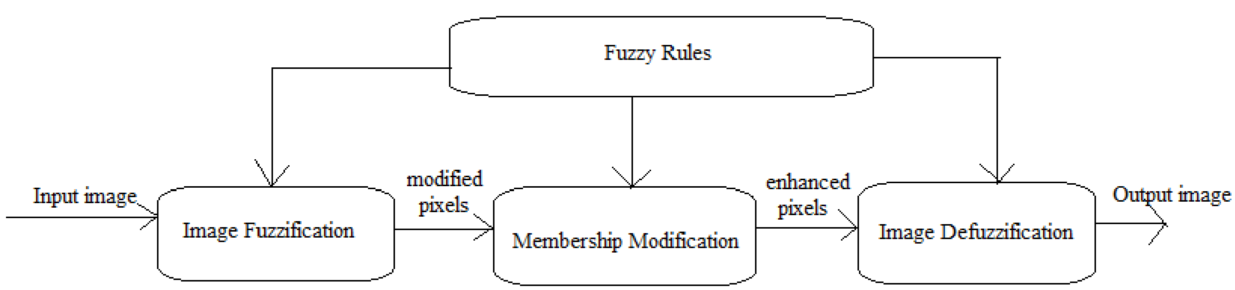

Figure 1.4: Fuzzy Model for Image Processing

1.7 Fuzzy Image Enhancement

In the last few decades, fuzzy set theory has achieved remarkable fame in the field of image processing. A nonlinear knowledge-based fuzzy logic can process imperfect data, if this imperfection initiates from vagueness and ambiguity instead of randomness [2].

Fuzzy Logic technology has very superior results in two main application fields: Industrial applications and Business and Finance applications. These are categorized as automated control or decision making support [14].

The two main assets for gray image smoothening and enhancement are:

I. **IF… THEN ELSE Rules**

In this approach, the pixel enhancement is done using the directive fuzzy rules, which are generated using the neighborhood pixels. For greater flexibility these rules are united with the inference engine.

II. **Rule-Based Smoothing**

Filter classes are classified on basis of neighborhood pixels compatibility. Properties of pixels such as gray tone or color intensity use membership functions which structure fuzzy sets. Different fuzzy membership functions help in improvement of factors for instance, speed and quality for gray scale images.

1.8 Advantages of Fuzzy Theory

i. Fuzzy logic is easy to understand conceptually.

The idea at the back of fuzzy reasoning is mathematical notions which are very simple. Fuzzy logic is an instinctive tactic deprived of the wide-ranging complexity.

ii. Flexibility in Fuzzy logic.

Without Starting over from scratch, additional functionality can easily be layered in any given system.

iii. Fuzzy logic can handle vague data.

If we look closely, in everyday life maximum things are inexact even on cautious examination. Fuzzy knowledge forms process of this understanding instead of appending it at the end.

iv. Fuzzy logic is a framework of nonlinear functions that can handle arbitrary complexity.

According to any input set data or output set data, a fuzzy system can be created. This process can be implemented with ease by adaptive approaches like “Adaptive Neuro-Fuzzy Inference Systems (ANFIS)”.

v. Fuzzy logic is constructed on highest experience of specialists.

On contrary to neural networks, that intakes training data and produces impassable, opaque models, fuzzy logic allows to count on the knowledge of individuals who have knowledge of the system.

vi. It can be combined with Conventional control techniques.

Traditional control approaches cannot be necessarily replaced by fuzzy systems. In most of the situations they are augmented with fuzzy systems which simplify their implementation.

vii. The basis for fuzzy logic is natural language.

Foundation for fuzzy logic is how humans communicate. This inspection supports many other declarations about fuzzy logic. Fuzzy logic can be easily applied because it is constructed on the norms of qualitative account used in daily language. This is the asset of fuzzy logic. Natural language is molded in thousands of centuries of human history so that it is suitable and efficient. Sentences expressed in everyday language signify an accomplishment of effective communication [11].

Chapter 2

Literature Survey

2.1 Fuzzy Logic Concepts used in Implementation

2.1.1 Fuzzification

It is the task of assigning membership function to the image, in which the image data is transformed from pixel plane to fuzzy plane that is the crisp values are converted to their fuzzy equivalent values. The input image is changed to membership plane through membership function where its value varies in the interval 0 to 1. The membership function can take countless values in the interval 0 to 1. The membership functions for both input and output are chosen at different pixel levels of the image. The ranges of both input and output membership functions are considered while defining fuzzy rules for the system.

2.1.2 Membership functions (MF)

A curve defining mapping of every point in the input space onto the degree of membership in the range 0 to 1 is called membership function denoted by ‘μ’. Sometimes the input space is referred to as the “*universe of discourse”* [7]. For instance, consider a classical set expressed as

$S = \{s \mid s > 6\}$

An add-on to classical set is a fuzzy set.. If S is the universal set and its members are represented by s, then a fuzzy set F in S is defined as a set of ordered pairs.

$F = \{s, \mu F(s) \mid s \in S\}$

Where, $\mu F(s)$ is known as membership function of s in F. The membership function plots every component ‘s’ of S on to a value between 0 and 1 which is known as membership value.

Fuzzy Logic has 11 inbuilt membership functions. These 11 functions are, built from numerous basic functions, these are: Gaussian distribution function, the sigmoid curve, piecewise linear functions, quadratic polynomial curve, and cubic polynomial curves [8].While determining the MF, characteristics of the image should be considered [12].

The simplest MFs are the ones which are made using straight lines. One is triangular membership function whose function *trimf* is a group of three points that form a triangle.

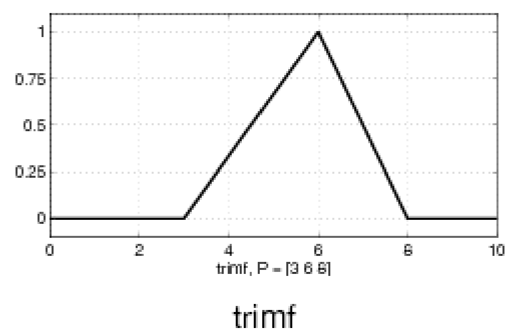

Figure 2.1: Triangular Membership Function [7]

While selecting a membership function, the purpose can probably be fulfilled well with only one or two kinds of MF, for instance triangle and trapezoid functions. The options are vast for exploring the potentials, but extensive membership functions are not essential for good FIS.

2.1.3 Fuzzy if-then rules

For defining fuzzy rules, linguistic variables are used. The variables whose values are “sentences or words” are Linguistic variables [16]. In mathematics, variables usually take numerical values. To define the rules, non – numeric variables are used. These variables can be atomic or compound sentences. Further, it consists of ‘if-then’ fuzzy rules. The structure of fuzzy if-then rule is:

If a is P then b is Q

Where, P and Q are linguistic values defined by fuzzy sets on the universal set A and B, respectively, which are the ranges. The part consisting of if condition in the rule "a is P" is known as “antecedent or premise or input”, whereas the part consisting of then condition in the rule "b is Q" is known as “consequent or conclusion or output”.

Generally, one rule alone is not effectual. Two or more rules that can go against one another are required. Every rule’s output is a fuzzy set. A single output fuzzy set is obtained after combining these output fuzzy sets. Lastly the resultant set is defuzzified, that is determined to a single number.

2.1.4 Defuzzification

The inverse process of fuzzification is defuzzification. The fuzzy value is converted back to crisp values. Defuzzification is an optional step in fuzzy process. Incense of the defuzzification process is to find single crisp value which enters it from the inference system. The fuzzy data is converted to the pixel data from the fuzzy data. While doing defuzzification, new membership values are set for the system.

2.1.5 Fuzzy Inference Systems (FIS)

The procedure of framing the mapping from a set input to an output by fuzzy logic is Fuzzy inference. The mapping then delivers a foundation that makes settlements, or recognizes designs. The process of fuzzy inference comprises of all the parts explained above: “Membership Functions, Logical Operations, and If-Then Rules”. Figure 2.2 classifies two kinds of FIS that can be realized in the toolbox.

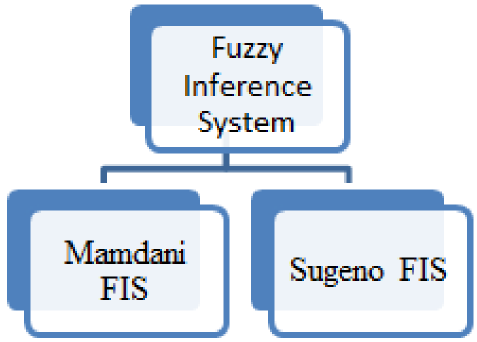

Figure 2.2: Categorization of FIS

The difference in the two inference systems lies in how the outputs are resolved. Figure 2.3 shows processing in a FIS. In Mamdani-type inference, fuzzy sets are the output membership functions. At the end of combination of processes, each output variable has a fuzzy set that requires defuzzification. For output membership function, using a single spike instead of a distributed fuzzy is much more efficient in most of the cases. This sort of output is at times identified as a singleton output membership function, and can be assumed as a pre-defuzzified fuzzy set. By finding the centroid of the two-dimensional function, the calculation required by the Mamdani method is simplified. This enhances the efficacy of the defuzzification process. To get the centroid, the weighted mean of a few data points is taken instead of integrating over the two-dimensional function. This type of model is adopted by "Sugeno-type systems". Mainly, Sugeno-type systems are used to design an inference system that has either constant output membership functions or linear output membership functions

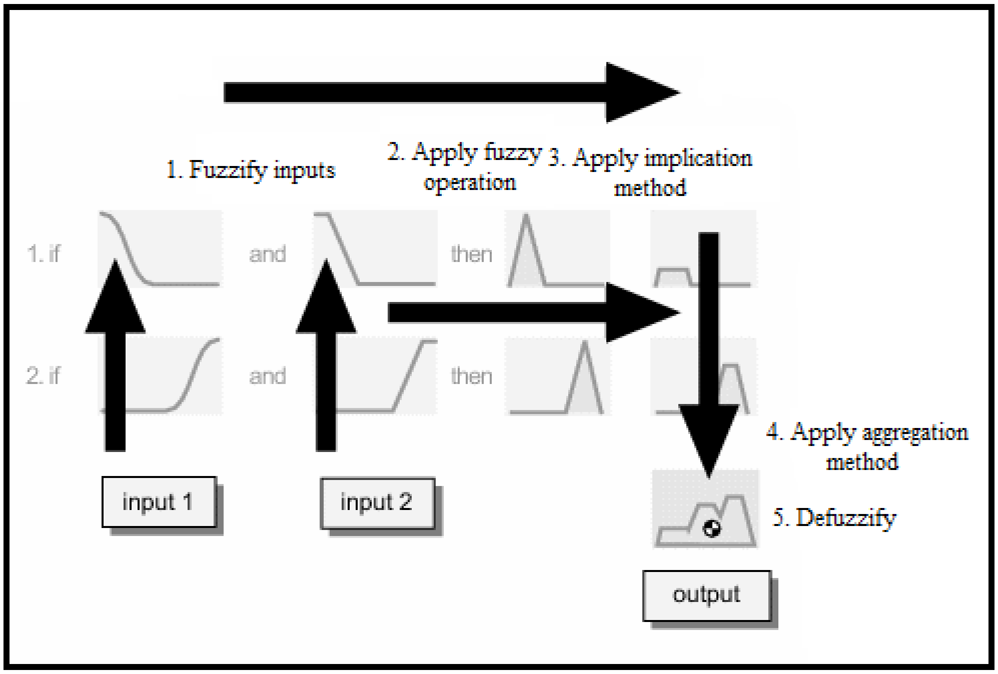

Figure 2.3: Fuzzy Inference Diagram

2.2 Survey of Enhancement Techniques

An extensive literature survey has been conducted in the area of fuzzy logic image enhancement and Histogram methodologies. Presently there subsists a number of tactics for the said purpose.

In [14], the author has proposed a fuzzy based contrast enhancement method to overcome the limitations of Conventional methods, like bilinear interpolation and histogram equalization either under expose or over expose the contrast of the image which result in poor image quality. The author has adopted fuzzy entropy principle and fuzzy set theory, which itself determines the parameters related to the nature of the image [3]. An important factor contributing in performance of fuzzy enhancement is the membership function. The shape of the membership function is decided by parameters a, b and c for S-function, therefore their selection becomes a vital issue. The goal while determining the membership function in [3] was to minimize the loss of information and reduce noise. The input membership functions were sigma and triangular and output membership function was bell.

F is used for constructing an intensity transformation function, T=F(z)

Intensity of image p (m, n) is transformed using T transformation function:

q (l,m) = T(p (l,m)) ..…..[14]

Where, p (l,m) is low contrast image and q (l,m) is transformed image and T is transformation function like log, gamma, stretch and specified transform.

The results in [14] showed that the proposed algorithm is more elective and adaptive in comparison to other traditional methods. Because of its better adaptive capability it also reduced the problem of over enhancement or under enhancement.

In [15], the objective of the author was to overcome the statistically taken value of contrast parameter 'K' in fuzzy technique and to make contrast dynamic an optimized fuzzy technique was developed. The value of 'K' was taken as 128. The aim was to optimize this statistically set value of 'K'. The different optimization techniques adopted were "Ant Colony Optimization (ACO)", "Particle Swarm Optimization (PSO)", and "Artificial Bee Colony algorithm (ABC)"; and the technique which had the best optimized value was selected. Numerical function has a key role in optimization for optimizing the objective function. Optimization aims at finding the best solution in the solution space while handling complex problems. Figure 2.4 describes Optimization Algorithms which are classified into two categories for optimizing the numerical function. There are numerous optimization techniques like ACO [14], PSO [5], and ABC [25].

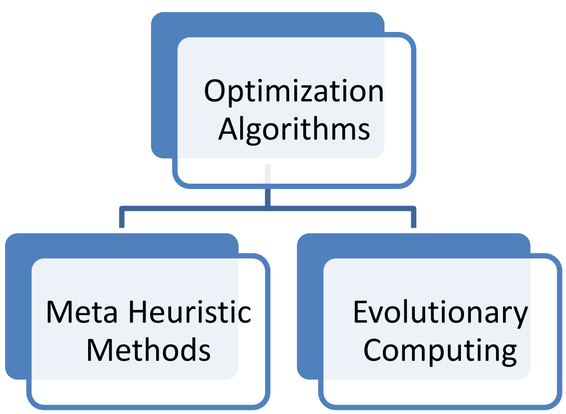

Figure 2.4: Categories of Optimization Algorithm

ACO is used to find path in a graph with minimum cost. Artificial ants' traverse the graph and find the optimal paths. Ants work in a parallel fashion in ACO. PSO provides solution to qualitative and numerical problems and is established from flock intelligence. The base of PSO is the study of bird and fish swarm movement behavior**.** In this to find food, the birds either fly together or fly individually. Artificial bees are the agents, which are used for solving complex combinatorial optimization problems. In this every artificial bee contributes some feasible solution to the problem. The Algorithm computes solution in two phases that is forward and backward passes. In forward pass, the artificial bees explore the search space. The number of moves is predefined and with that every bee forms a new solution and also improves it. After finding the partial solution, the bees move to the nest and shift to the next pass that is backward pass. In backward pass, all the artificial bees contribute their solutions. Dancing ceremonies is performed by the bees, and the bees signal about the information of food they have collected and the distance they have travelled to the nest.

In the methodology proposed in [15], the input RGB image is first converted into HSV. Different optimization techniques were combined with fuzzy technique for calculating the value of "K" that is intensification factor. Then H and S are concatenated with V. Finally, the gotten HSV is changed into its RGB form. For analyzing the performance of the proposed method images with low contrast and brightness were chosen. Various qualitative performance measures were used such as "MSE (Mean Square Error)", "PSNR (Peak Signal To Noise Ratio)", CII (Contrast Improvement Index), and execution time. It is concluded from the comparison that the solution attained by PSO technique is more optimal than ACO and ABC technique. Minimum value of MSE, higher value of PSNR, higher value of CII and lower value of execution time shows that the recreation is of higher quality.

In [16], the contrast is increased using triangular MF and creating fuzzy rules in Mamdani inference system. To reduce the amount of data to be processed and to remove irrelevant information, the image is first processed for edge detection. The points where pixel value of the image changes quickly or where discontinuities in pixel values occur are the edges of the image. Edge detection gives the set of connected points that identify the borders of the objects in the image. For applying membership function, the intensity levels are needed which were gained through edge detection. The image data is converted to fuzzy data from pixel data by using triangular membership function. Three triangular MF were chosen for each input and output with their ranges. The range of first membership function is 0 to 100; second membership function has range from 25 to 225 and third from 150 to 250. Fuzzy rules were applied which are statements of linguistic variables and defuzzification is done to get the enhanced image. For defuzzification centroid method was used.

In [17], fingerprint enhancement algorithm is presented using fuzzy technique by enhancing the minute details to increase the quality of the degraded noisy image. Normalization of input image is performed to decrease the dynamic range of the gray scale intensity between rims and vales of the image estimation and the change of the filter parameters. The algorithm was designed for finger print enhancement and for degraded, dark and unclear images.

In this paper, the membership function for each gray level is set:

$$\mu(a, b) = e^{-\left(\frac{\left(L-\frac{f(a,b)}{s}\right)}{2}\right)^2} \quad \ldots\ldots\ldots\ldots[17]$$

Where, L, f(a, b), s denote maximum intensity gray level, any gray level, variance between gray values respectively.

In [18], a gray scale image enhancement technique is proposed. The algorithm has adopted fuzzy logic. Fig. 4 shows the result of [18]. By visually analyzing the two images it is inferred that clarity and visibility was destroyed by the algorithm and hence made it the darker.

a. Original image b. Improved image

Figure 2.5: Result of algorithm [18]

The proposed algorithm in [19] produced high contrast images. For analyzing the effectiveness of the proposed algorithm, it was experimented on various images and variance of different techniques was compared. “The measure of how far an image is spread out is variance” [19]. For suggested algorithm, the variance was small as compared to other algorithms such as adaptive histogram equalization whose output image had reduced background noise but transformed it into an unnatural looking image. Small variance indicates that the input image and output images are identical. The proposed algorithm produced high contrast images with natural look.

The algorithm in [20] employs fuzzy decision which reduced the time consumption and removed the overhead of complicated calculations for enhancing the contrast without affecting the details of the image.

The algorithm proposed in [21] uses fuzzy rules which act as a link between human knowledge and mathematical framework of the computers. The algorithm was successful in overcoming the limitations of “frequency domain methods” such as Gaussian low pass filters which is a frequency domain method and spatial domain methods such as thresholding.

The technique proposed in [22] works on the image histogram namely "*Brightness Preserving Dynamic Fuzzy-Histogram Equalization* (BPDFHE)". The technique proposed is for digital pathology applications. It works such that the gray level values in the vales area between the two successive crests redistributes without any shift in the histogram peaks. This increases the contrast with the advantage of preserving the average image brightness. First, the fuzzy histogram is computed for the image. Fuzzy statistics have the advantage of intrinsically capable of handling the imprecision of pixel intensity and therefore produces an evenly distributed histogram. Smooth evenly distributed histogram benefits in making meaningful partitions which is required for brightness preservation. Next step is splitting of the histogram with the intent of identifying the local maxima and obtaining multiple sub-histograms, each of the sub-histogram comprises of the vales area between two successive local maxima. The implementation of this technique has undertaken further two steps: detection of local maxima and then creation of partitions. The "DHE (Dynamic Histogram Equalization)" technique individually equalizes each sub-histograms obtained. The operations in DHE include dynamic range mapping of individual partitions which is followed by histogram equalization of sub-histograms. After the dynamic histogram equalization of each sub histogram the modified image has average brightness varying than the original image. The output image normalization process is applied to remove this difference. For maintaining the average intensity of the image after the whole process the "image brightness normalization" is done.

The algorithm was tested on various oral and breast histopathology slides. Results obtained in [22], show that the algorithm preserved the brightness of the input image better than "*Histogram Equalization* (HE)" and "*Contrast Limited Adaptive Histogram Equalization* (CLAHE)" techniques. The result has been summarized in Table 2.1.

Table 2.1: Comparison of BPDFHE and CLAHE techniques

Parameters	**CLAHE**	**BPDFHE**
Computational Efficiency	Less efficient	More efficient than the other and has smaller execution time.

Increase In Contrast	Increases contrast more than other histogram equalization techniques	When trying to preserve brightness, the contrast enhancement capability limits
Change in Pixel Gray Level	Generates large change in pixel gray level	Less change in pixel gray levels
Introduction of Artifacts	Introduce processing artifacts due to tremendous change in pixel gray level	Introduces less artifacts
Preservation of image brightness	Less than BPDFHE	Preserves image brightness better than CLAHE and HE technique

The proposed algorithm in [23] overcomes the drawback of other techniques such as over enhancement and under enhancement. Logarithmic function of the image is taken to fuzzify the image data from pixel plane to fuzzy plane. The algorithm adaptively improves the details in the image if a specific pixel needs to be smoothened, darkened or sharpened. This happens due to the use of transformation function for modification of membership function, which further exposes the details of the images while preserving the other image characteristics. The transformation function enhances the flat and sharp portions of an image. The exponential function 'cos' smoothens the intensity of the pixels and improves the contrast whereas the 'tan' function enhances the edges of the image. With the function proposed in the paper, errors and artifacts were not introduced in the output image.

In [24], an image enhancement framework established from Histogram Equalization has been implemented. Various enhancement techniques for example, "Contrast limited Adaptive Histogram Equalization (CLAHE)", "Dynamic Histogram equalization (DHE)", "Equal area dualistic sub-image histogram equalization (DSIHE)" have been implemented and further their comparative analysis has been presented in this article. HE preserves brightness in the output image with a noteworthy improvement in contrast, but produces output that does not appear natural. Re-mapping the pixel intensity of an image is the basic idea of HE. It is also likely to introduce some annoying artifacts. To succeed in dealing with these drawbacks of HE other advanced brightness preserving techniques are used such as

CLAHE and DSIHE. The Performance of these Methods is analyzed by applying the techniques on real images. The results justified that these techniques produce different conclusions for different parameters. The PSNR value of the techniques is compared in Table 2.2. Higher the value of PSNR, better the technique.

Table 2.2: Comparison of PSNR of techniques [24]

Technique	**PSNR**
DSIHE	0.0327
CLAHE	0.0366
DHE	0.1107

In [27], the proposed method used both indirect and direct method of image enhancement. The proposed method implemented optimization of parameters and defuzzification technique. The initial step is histogram equalization of input image. The parameters are determined with the highest value of CII. Using membership function, the resultant image from histogram equalization is mapped from space domain to fuzzy domain and further enhanced using the fuzzy processes. The proposed methodology produced superior results which eradicated over enhancement because it takes due care of fuzziness using fuzzy entropy principle; automatically on the basis of nature of image it decides the parameter which offers better adaptability.

The author in [28] proposed an algorithm for enhancement of dark images, sharpening the edges, revealing details in rough areas, and conserves the evenness of plane areas. To maximize the enhancement, the mapping functions are adjusted with every characteristic of the image. The methodology created ad-hoc transformation of the image. The contrast of the image is analyzed at various regions such as textured and boundary regions, and collect information bearing similar characteristics. These collections model the relations within the image; which lead to extraction of transformation function. By taking human vision system features into account and adaptively collaborating the results, the details of the image had been boosted.

The method proposed in [29] applied image enhancement only to the V (luminosity) component of the HSV image. To maintain color balance between the HSV components, the H and S components were left unchanged. The enhancement of V component was carried out in two stages. Firstly, the third channel image was partitioned into small overlapping chunks and luminance enhancement was applied on every pixel in the chunk using nonlinear transfer function. The Second step included enhancement of every pixel for adjusting image contrast subjected upon the central and neighborhood pixel intensity. At last, the unchanged H and S channel and enhanced luminosity channel were transformed back to RGB image.

In [30], a methodology for contrast enrichment is designed, particularly for multi-peak images. The methodology aims at eliminating the shortcomings of HE that is convolution of input image by Gaussian filter using optimal parameters. Then, the original histogram is partitioned into several regions on the basis the vale values of the histogram. The algorithm outdoes others because of adaptability. Moreover, this algorithm can be implemented in consumer electronics and simple hardware because of its easiness.

In [31], a strategy for improvement of local sector by HE is described. The image is segmented into areas and each segment is independently improved by histogram equalization. By making use of this methodology, in-between images are incited recursively. On the basis of an ‘intensity gradient’ measure, resulting image is achieved by aggregation of weighted sum. Local segments with greater contrast lead the others consequently accomplish total global contrast enhancement.

In [32], an approach for handling the problem of over-enhancement is presented which detects over-enhancement. Detailed analysis of reasons that generate over-enhancement is performed, which led to presentation of effective criterion and objective. The results prove that to assess the over enhanced levels a quantitative criterion is suggested in which the over enhanced areas are located efficiently and accurately. The proposed method vigorously monitors the quality of the improved image and for contrast improvement algorithms the settings of parameter is also optimized.

The author in [33], suggested a “dehazing algorithm” projected on contrast enhancement and dark channel prior approaches. The traditional dark channel prior technique eliminates haze with the advantage of restoring the colors of objects in the image; however it does not enhance the contrast. Whereas, the image contrast method increases the contrast of the objects, but as a consequence of over-stretching of contrast the colors are mostly distorted. The suggested algorithm amalgamates the benefits of these two conventional methods for preserving the color while dehazing. The proposed approach reimburses the shortcomings of traditional methods, and boosts the contrast having less color distortion.

In [34], a technique for enrichment of low contrast color images based on fuzzy logic algorithm and histogram have been presented. It is centered on two main parameters M and K, where M is the mean pixel value obtained from the histogram and K is contrast intensification. To maintain the chromatic information, the RGB image is transformed into HSV. For enhancement, only the V channel is extended through the control of M and K. Based on the visual quality, computational time and CII, the performance of various contrast enhancement algorithms is analyzed.

The author in [35] used local contrast measure to design an algorithm to distinguish and classify relating images having dissimilar contrast level. By using the model, the image is classified under high contrast or low contrast image. The low contrast image is then enriched with Stochastic Resonance principle. The outcomes were superior to conventional enhancement methods.

In [36], the algorithm transforms input from pixel plane to membership level and then to enhancement level. With help of ‘Fuzzy set’ which is a mathematical tool, the limitations of subsisting contrast enhancement methods are resolved. The fuzzy set modules handle the ambiguity related to the images. This algorithm proved enhancement over various other techniques predicted on fuzzy sets.

In [37], to regulate the contrast level of images, “Histogram Modified Contrast Limited Adaptive Histogram Equalization (HM CLAHE)” is proposed. The resulting image has a high contrast and locates the details for precise explanation. The optimization technique involves both “Contrast Limited Adaptive Histogram Equalization (CLAHE)” and Histogram modifications. The suggested method preserves the neighborhood information and was demonstrated on mammogram images.

2.3 Comparative Analysis

As per the constraints discussed in these papers, feature set has been designed. These features have been designed with color codes. Further, the comparative analysis of the algorithms discussed in earlier sections of this thesis has been compiled in Table 2.3.

Table 2.3: Feature Set Selection

Features	Code
Adaptive and elective	
Reduction in amount of data to be processed	
Reduced execution time	
Minute details enhanced	
Suitable for dark unclear images	
Clarity and visibility destroyed, made images darker	
Produced high contrast	
Preserved natural look	
Successful in dealing limitations of "Frequency and spatial domain methods"	
Maintained mean brightness	
Enhancement of flat and sharp portions	
Removed problem of over or under enhancement	
Errors and artifacts not introduced	
Smoothens intensity of pixels and enhances edges of image	

Table 2.4: Comparative Analysis of Image Enhancement algorithms

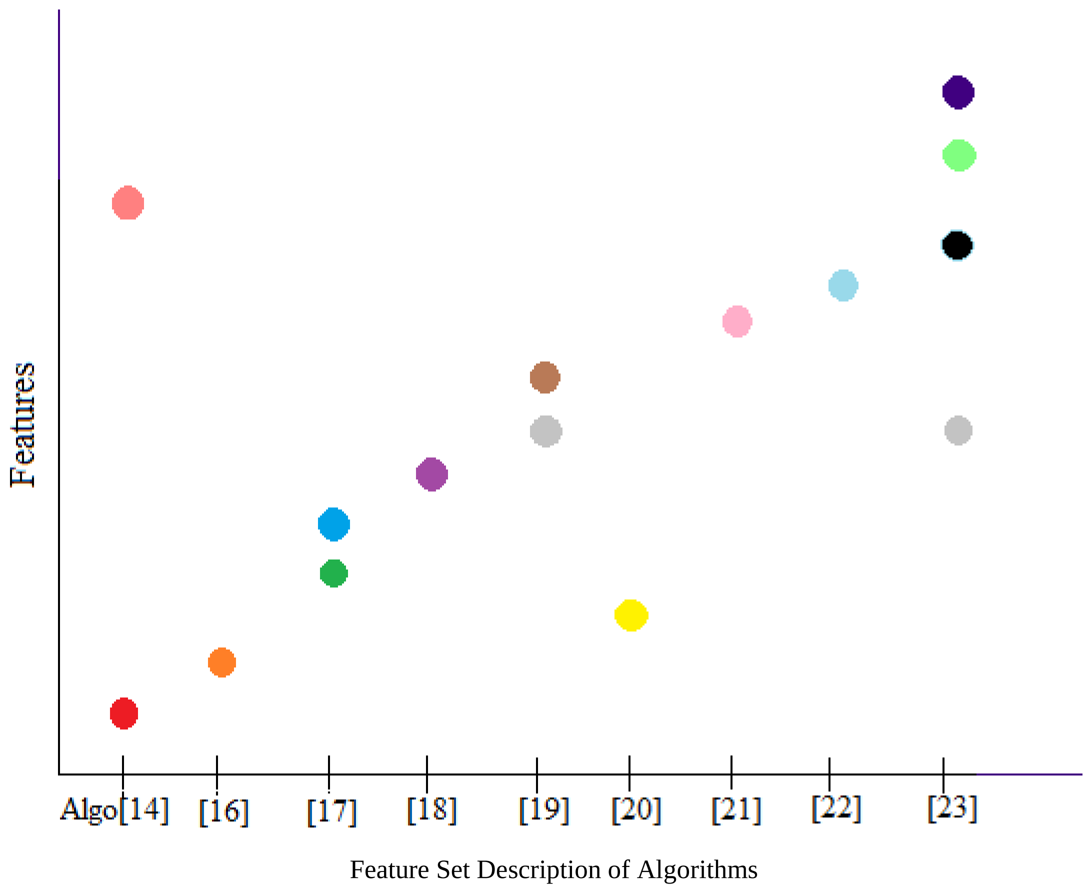

Table 2.5: Criteria 1: Clarity

Clarity Features	Algo[14]	Algo[17]	Algo[18]	Algo[19]	Algo[22]	Algo[23]
Suitable for dark unclear images	No	Yes	No	No	No	No
Clarity and visibility destroyed, made images darker	No	No	Yes	No	No	No
Produce high contrast	No	No	No	Yes	No	Yes
Preserve natural look	No	No	No	Yes	No	No
Maintain mean brightness	No	No	No	No	Yes	No
Enhance flat and sharp portions	No	No	No	No	No	Yes
Remove problem of over or under enhancement	Yes	No	No	No	No	No
Does not introduce Errors and artifacts	No	No	No	No	No	Yes

Smoothens intensity and enhances edges	No	No	No	No	No	Yes

Table 2.6: Criteria 2: Response time

Response Time Features	**Algo[14]**	**Algo[16]**	**Algo[18]**	**Algo[20]**
Reduction in amount of data to be processed	No	Yes	No	No
Reduced execution time	No	No	No	Yes

From, the aforesaid comparative analysis, it has been concluded that algorithm [23] is the most rich algorithm for criteria 1 clarity and for criteria 2 response time, algorithm [16] and [20] are best.

2.4 Categorization of image pixels

Classification of an image is usually achieved with respect to primitive attributes known as features. These are mostly of two types:

i. The visual appearance of an image that defines the features (for instance intensity of a section of pixels, gray scale of sections) are “Natural Features”.

ii. The features which originate from image manipulation (such as histograms and spectral graphs) are “Artificial Features” [39].

Digital images can be classified as color images, binary image and grayscale image.

a. Color Image

A true color image or simply a color image is a set of pixels in which each pixel provides three color channels that is RGB (red, green, blue), which aggregates the intensity and chrominance of light. Supposing 256 levels, 24 bits (three bytes) 24 bits of memory is required for storing each color pixel. A true color version will occupy three times more memory that a black and white version, with images of the same size.

Figure 2.6: A Colored Image

b. Binary Image

It is stored as a logical array in which every pixel undertakes one of the two discrete values 0 or 1; Where 0 is interpreted as white and 1 is interpreted as Black. Here only a single bit represents each pixel. The intermediate shades of gray are not presented in binary images. This limits their practicality in areas dealing with photographic images.

Figure 2.7: A Binary Image

b. Grayscale Images

Grayscale images have shades of gray. There are 256 different shades of gray ranging from 0 to 255 for representing the gray level intensity of pixel. The pixel intensity is expressed within a range between a minimum and a maximum, both inclusive. In an abstract way, range is taken from 0 to 1, with any fractional values in between; where 0 indicates total absence that is black and 1 indicates total presence that is white.

Figure 2.8: A Grayscale Image

Chapter 3

Research Problem and Motivation

3.1 Research Gaps

In literature survey, it has been discussed that, there exist a number of tactics to improve gray scale images. Contingent on the application, the enhancement methods had been designed for diverse type of images. Several research gaps have been found during this study:

i. Many of the Image Enhancement methods destroy the natural look of the image.
ii. Many of the IE techniques do not maintain the mean brightness of the image.
iii. Many IE techniques influence the original color constitution of the image that leads to introduction of color artifacts.
iv. Some of the techniques increase the background noise of the image.
v. If the image has large peaks then most of the techniques over-enhance the image contrast.

3.2 Problem Statement

In the last few decades numerous techniques have emerged for image enhancement. But fuzzy logic is the most prevalent and powerful technology for image enhancement. An image that comprises high contrast and clearly determined rims and vales, is termed as a good quality image; whereas, a poor quality image is clearly noticeable by low contrast and vague edges. The core objective of the work is to design and implement an algorithm, considering fuzzy rules as a base that aims at improving the contrast by reducing the noise, without over-enhancing the contrast and, by assigning larger weights to gray level.

The objectives of this thesis are:

i. To study the idea of image enrichment and theory of fuzzy set.

ii. To study and implement existing image enhancement techniques in spatial domain in MATLAB.
iii. To conduct literature survey of existing fuzzy practices for image enhancement.
iv. To suggest an algorithm in Fuzzy Inference System, that goals at enhancing the low quality image to a fine quality image by escalating the contrast.
v. To implement the proposed fuzzy algorithm in MATLAB.
vi. To assess and compare the performance of the suggested technique with available techniques, by inputting poor contrast images set.

3.3 Motivation of the Proposed work

If the local area in the image is smooth up to a certain extent, at that point the modified pixel intensity can be set by averaging neighboring pixel intensities. Whereas, this doesn't work when the local area contains boundaries; for this an advanced enhancement method must be used. Setting the circumstances, on the basis of which an enhancement technique should be chosen, is extremely challenging. For the reason that the local details can be estimated only imprecisely at some parts of an image therefore, the enhancement technique should handle reasoning of imprecise and indeterminate information; this recommends the usage of fuzzy logic.

3.4 Methodology of the proposed work

The methodology to be followed for proposed IE using fuzzy theory:

i. Conducting literature survey and analyze various fuzzy image enhancement techniques.
ii. Based on this analysis, design and develop an algorithm for image enhancement in MATLAB 9.0 fuzzy toolbox.
iii. Feature Selection of performance metrics for assessing the quality of the image.
iv. Evaluate performance of the results obtained after the execution of the proposed algorithm by comparing with other existing techniques.

Chapter 4

Proposed Work and Implementation

4.1 Design of Implementation Framework

The fuzzy inference process comprises of: "Membership Functions, Fuzzy Logic Operators, and if-then rules". In this work, the "Mamdani Fuzzy Inference System" is chosen over "Sugeno Fuzzy Inference System" because the system has to take care of three diverse ranges of pixel strength namely bright, dark and gray. In Sugeno FIS, it is beyond the bounds of possibility to unite rules designed for the system as single spike is used for every designed rule. Figure 4.1 presents the block diagram of the designed system for IEFA (Image Enhancement Fuzzy Algorithm). The input image format for the system in .jpeg or .png (but supports all the image extensions), which is further treated for enhancement.

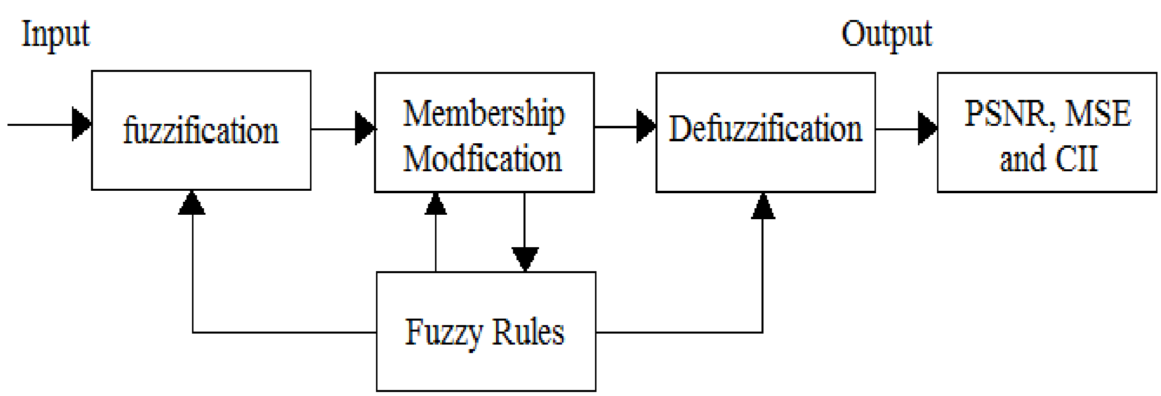

Figure 4.1 Design of the System

4.2 Implementation

This chapter comprises of detailed process of fuzzy enhancement. The work has been realized in MATLAB 9.0. MATLAB is a software suite by Math Works. It incorporates visualization, programming and computation in comprehensible environment. MATLAB toolbox permits applying expert knowledge in the form of rules. The fields in which MATLAB toolbox are offered are aerospace, bioinformatics, signal processing, control system, image processing, neural networks, wavelets, fuzzy logic, simulation, database and many more.

Workflow of the System

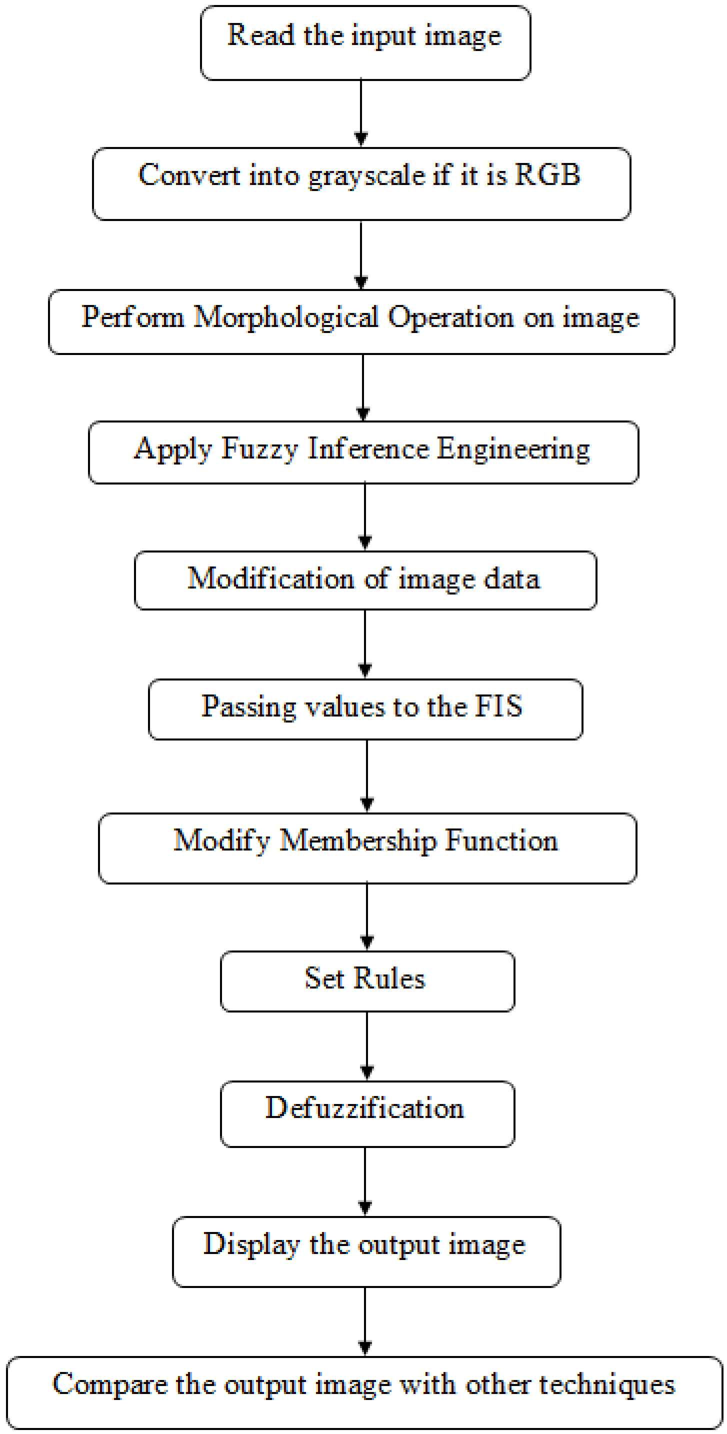

Figure 4.2: Flowchart of IEFA

Detailed Process of Image Enhancement Fuzzy Algorithm (IEFA)

Step1: Various low contrast images are collected from different sources and saved in the system. To read image, the command is:

Command: imread('C:\Users\MLSHARMA\Desktop\index.jpg');

Step2: If the read image is not in grayscale form then convert into grayscale with command: Command: rgb2gray(real_image);

Step3: Morphological processing which includes:

i. Convert the image into double format.
ii. Evaluate size of the image.
iii. Calculate minimum, maximum and mean gray level intensity of the image.

Step4: Transforming the image data into Fuzzy domain data that is performing Fuzzification.

Figure 4.3 presents FIS toolbox of MATLAB, which comprises of "FIS editor, rule editor, rule viewer, and membership function editor". The FIS Editor shows overall information of FIS. It displays the input variable at the left hand side and output variable at the right hand side. Here, the input variable is 'pel_in' and output variable is 'pel_out'. The 'ALGORITHM I' converts the image pixel data into fuzzy data. The 'pel_in' takes the output of ALGORITHM I, that is fuzzified pixel value. The 'pel_out' is further processed using other FIS toolbox in subsequent steps.

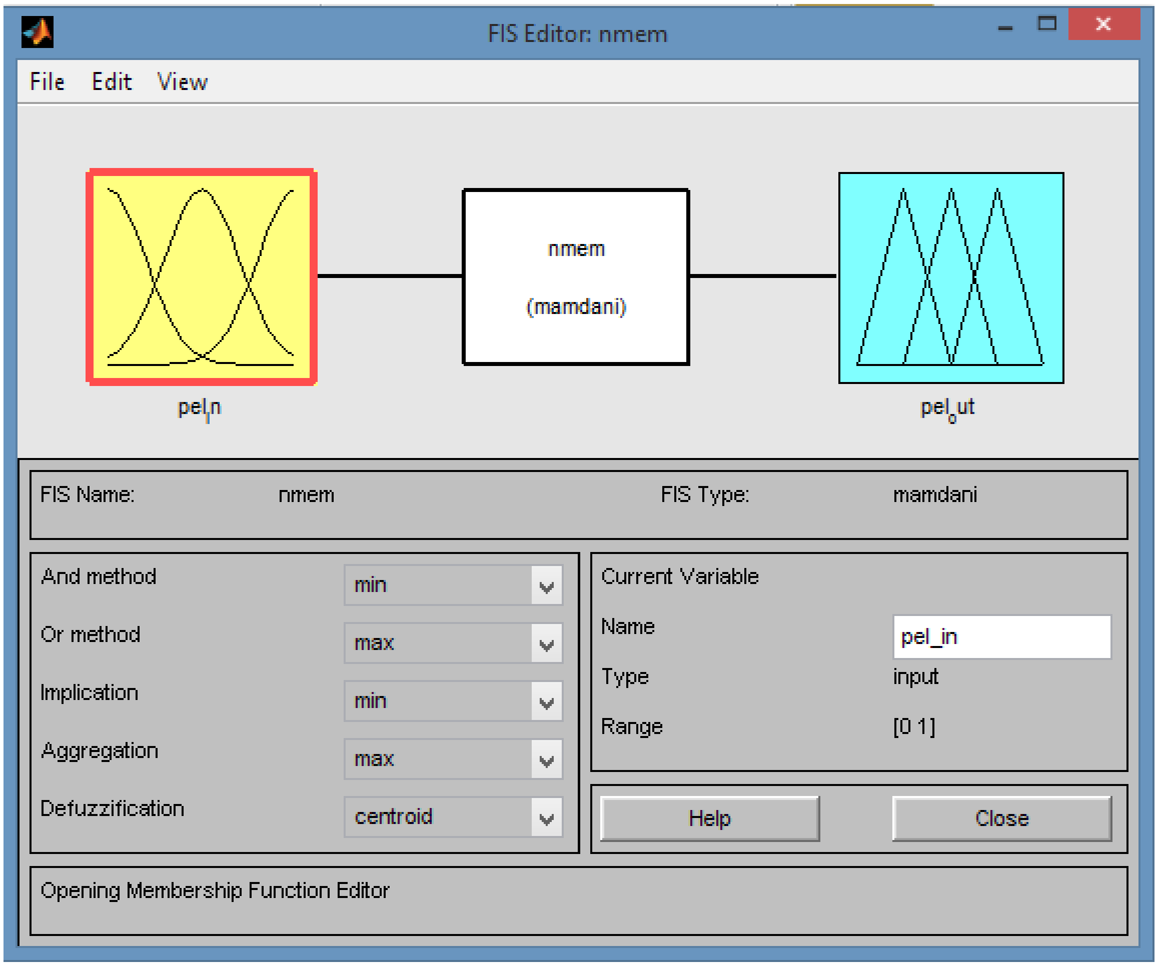

Figure 4.3: FIS Editor displaying variable 'pel_in' and variable 'pel_out'.

LOGICAL STRUCTURE OF ALGORITHM I

```
FOR grayvalue = each pixel of the image
    IF  (grayvalue is between 0 AND minimum)
        fuzzy=0;
    ELSE IF (grayvalue is between minimum AND mean)
        fuzzy = (1/ (mean - minimum)) * minimum + (1/( mean - minimum)) *  grayvalue;
    ELSE IF (grayvalue between mean and maximum)
        fuzzy = (1/ (maximum - mean)) * mean + (1/ (maximum - mean)) * grayvalue;
    ELSE (grayvalue between maximum AND 255)
```

Fuzzy = 1;

END
END

The low contrast input image is converted to membership plane with MF where its values lie in the range 0 to 1. The MF adopts any value in the interval 0 to 1. "Triangular membership function" is adopted to transform image data from pixel plane to membership plane. For each 'pel_in' and 'pel_out', three membership functions are taken at three intensity levels of the image respectively. For every MF, range is adjusted in MF Editor tool box of FIS.

Triangular Membership Function

As described in the Figure 4.4, three triangular MF are taken for each input and output that is Dark, Gray and Bright. The range of the Dark is 0 to 0.4; Gray has range from 0.1 to 0.9 and Bright is having range from 0.6 to 1. X – axis is specifies the pixel values and Y – axis shows the degree of assigned membership to the pixels pertaining to their intensity variation.

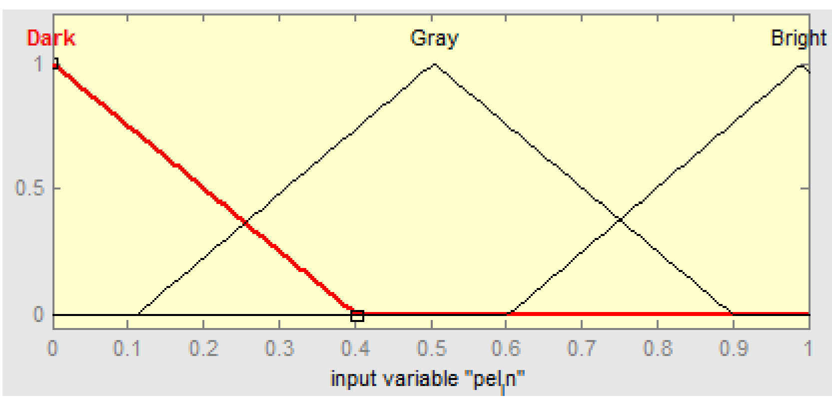

Figure 4.4: MF for the system

Step5: Membership Modification

Using Fuzzy Inference System (FIS) tool box the membership values are modified. FIS consists of in – built MFs for both input and output variables. New membership values are defined for the pixels pertaining to their input pixel intensity and based on variation in their intensity level, membership values are assigned. We set a membership value for image gray level: minimum, maximum and variance between gray levels. The membership values are modified for the pixel elements considering their gray level intensity values and hence, membership values are allotted to the pixels on the basis of variation in their intensity level.

LOGICAL STRUCTURE OF ALGORITHM II

```
FOR pixel = every pixel value

    IF (pixel_value is between 0 AND 0.5)

        new_pixel = 5 * ( pixel ^ 3 );

    ELSE

        new_pixel = 1 – 5 * ((1 – pixel) ^ 3);

    END

END
```

Figure 4.5 shows Membership Function Editor for editing the MF for input and output variables. It has in–built MFs and also allows customizing the MF. They are well-defined in the tool box. The membership function and its range are selected for both input and output in the toolbox. X – axis depicts the pixel range and Y – axis depicts the degree of membership of pixel.

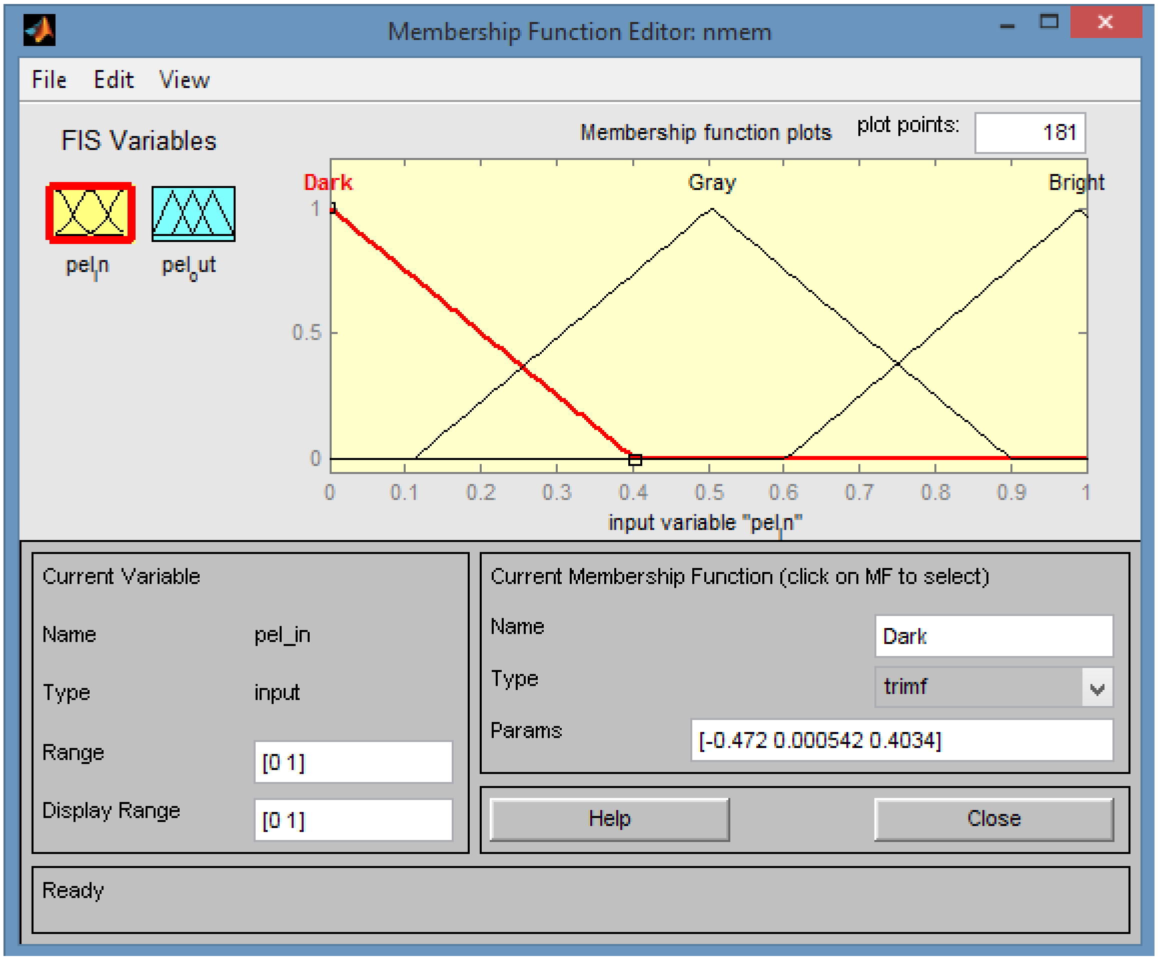

Figure 4.5: MF Editor

Step6: Set Rules

The rules are constructed in the graphical Rule Editor interface of Fuzzy Inference System tools. Fuzzy rules are defined for the membership values which are modified pertaining to the pixel intensity. The ranges of the both output and input MF have been considered in defining the fuzzy rules. The rules can be deleted or added on the basis of the selected membership functions and on the range of mapping. The Rule Editor allows designing the rule statements directly, by choosing an item from every input variable box, one item from every output box, and a connection item.

The rules are added by taking into account the parameters of the selected triangular membership function for the system. IEFA has been designed and implemented on the basis of the following fuzzy rules:

i. If pel_in is Dark then pel_out is More_dark.
ii. If pel_in is Gray then pel_out is More_gray.
iii. If pel_in is Bright then pel_out is More_bright.

The notion Dark', 'Gray', and 'Bright' is denoted as a number between 0 and 1, and therefore the "premise" is a rendition that gives back a single number between 0 and 1. Whereas, 'More_dark', 'More_gray', and 'More_bright' is denoted as a fuzzy set, and therefore the "consequent" is a task that allocates the complete fuzzy set 'More_dark', 'More_gray' or 'More_bright' to the output variable 'pel_out'. As a whole, the input of the if-then rule is the present value of the input variable (pel_in) and the output is the whole fuzzy set (More_dark, More_gray or More_bright). This set is later defuzzified, which assigns single value to the output. Figure 4.6 displays implementation of these rules in FIS.

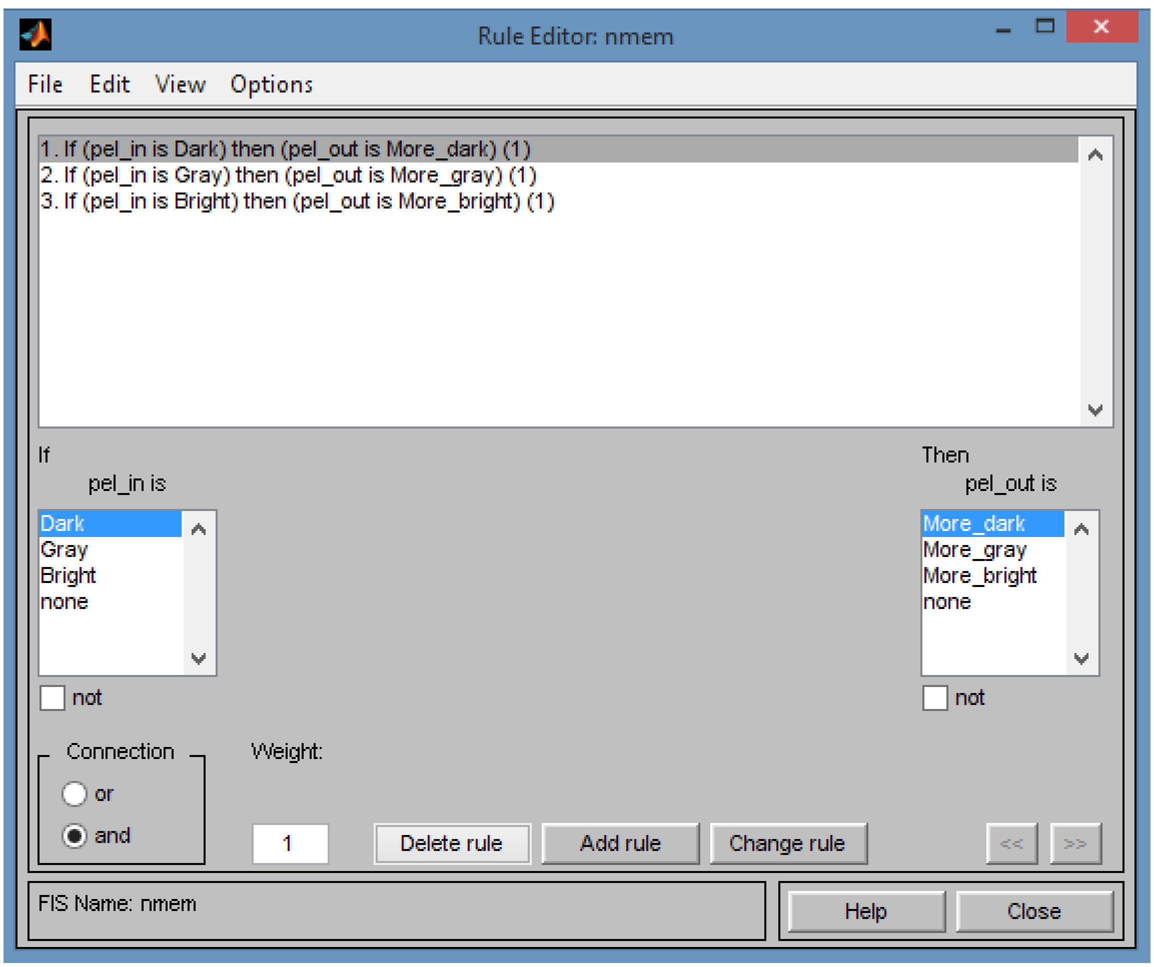

Figure 4.6: Rules defined in FIS Rule Editor

Step7: Convert fuzzy data into grayscale enhanced data that is performing defuzzification.

Defuzzification is the final step in Mamdani FIS. For defuzzification process combine output fuzzy collection and the final output is a single crisp number. The image is converted to the pixel plane from fuzzy plane. The output of Algorithm III is crisp number that enhanced pixel values.

LOGICAL STRUCTURE OF ALGORITHM III

Set maximum intensity and minimum intensity for enhanced image as:

```
maxI = 255;
minI = 0;

FOR new_pixel = each pixel value

    IF (pixel <= minimum)
       pixel_enhanced = 0;
    ELSE IF (pixel is between minimum AND maximum)
        pixel_enhanced = ((maxI - minI) * result (x,y) + minI);
    ELSE
        pixel_enhanced = 255;
    END
END
```

Step8: Display the Enhanced image

The file is saved in MATLAB with .m extension. After designing the system in Fuzzy Inference System store file with .fis extension. For executing the file use the command:

```
fismat = readfis ('nmem.fis');

result  = evalfis (fdata,fismat);
```

Chapter 5

Performance Evaluation and Result of IEFA

5.1. Experimental Setup

To assess the proposed technique, various low contrast images have been taken. The following image enhancement techniques have been applied on the input images. The techniques are:

i. "Histogram Equalization (HE)"
ii. "Contrast Limited Adaptive Histogram Equalization (CLAHE)"
iii. Image Enhancement Fuzzy Algorithm (IEFA)

5.1.1 Histogram Equalization Technique

MATLAB offers 'imhist' function to plot the histogram. The image supplied to it should be a single channel image, only then it will be able to plot the pixel versus brightness. Figure 5.1 shows the original low contrast image and the histogram representation of it.

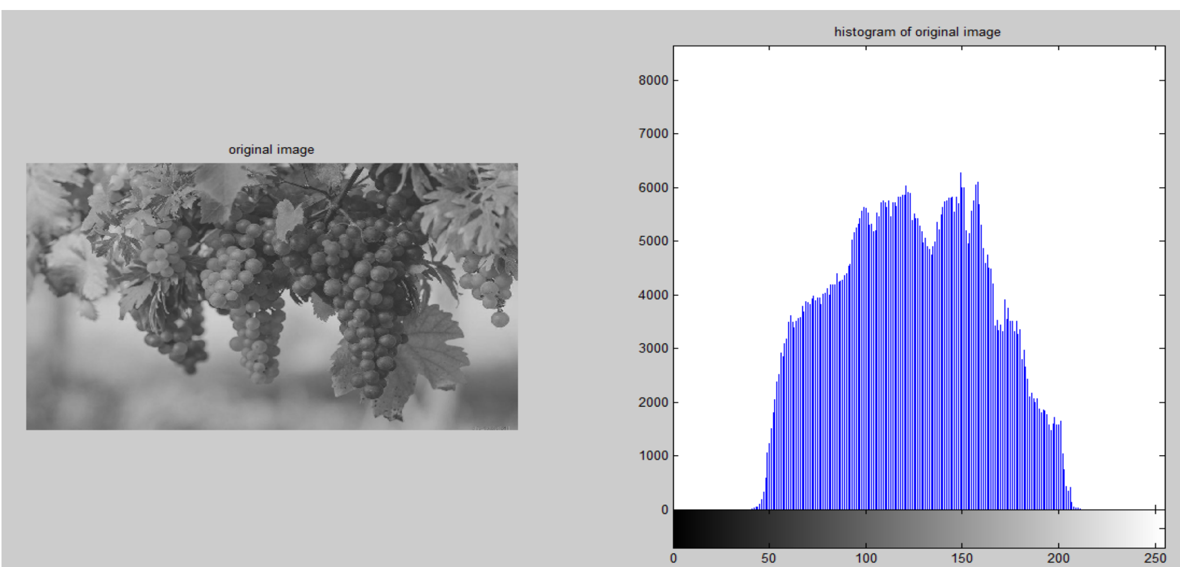

Figure 5.1: Original Low Contrast Grapes1.jpg and its Histogram Plot

Graph in Figure 5.1 is covering 256 values in the X- axis so there are 256 possible variations in the brightness and for each level of brightness it is showing the number of pixels that are achieving this outcome. For example: close to 50 there are more than 500 such pixels which are having the value of close to 50. It is evident from the graph that there is no pixel with most bright value and least bright value. Histogram Equalization technique evens out this difference so that it covers the complete range of brightness with almost similar amount of pixels for every brightness range. Figure 5.2 shows Histogram Equalized image and its histogram. In this, complete range of brightness value is covered and the graph is balanced.

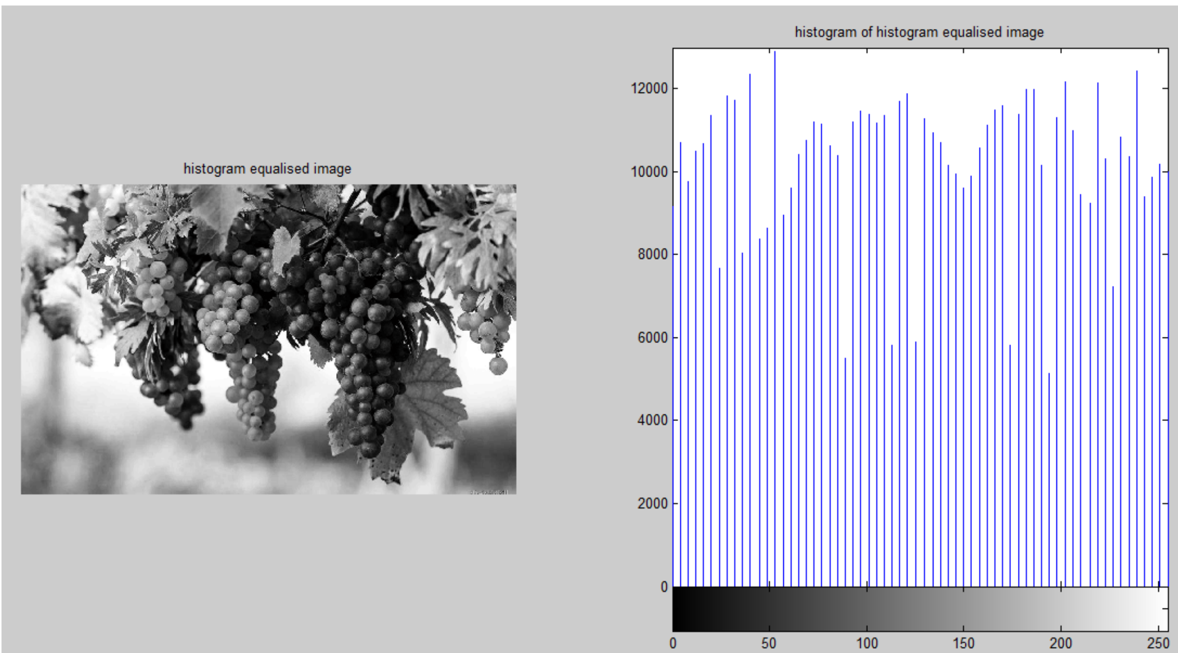

Figure 5.2: Histogram Equalized Grapes1.jpg and its Histogram Plot

5.1.2 Contrast Limited Adaptive Histogram Equalization (CLAHE)

"CLAHE" is different from the ordinary HE in respect that the adaptive technique equalizes numerous histograms, each of which correspond to a different segment of the image and redistribute the lightness values of the image by using them. Figure 5.3 shows the CLAHE improved image. The visual result shows that it prevents over amplification, over enhancement and objects are clearer than HE.

Figure 5.3: Applying CLAHE on Grapes1.jpg

5.1.3 Image Enhancement Fuzzy Algorithm (IEFA)

The Proposed work aims at improving the contrast of low contrast image by reducing the noise, without over-enhancing the contrast. The method is based on intensity level mapping onto fuzzy plane with the MF transformation that increases the contrast of the original low contrast image. Figure 5.4 to Figure 5.9 displays the visual outcomes attained after applying IEFA.

Figure 5.4: Applying IEFA on Grapes1.jpg

Figure 5.5: Applying IEFA on Beach1.jpg

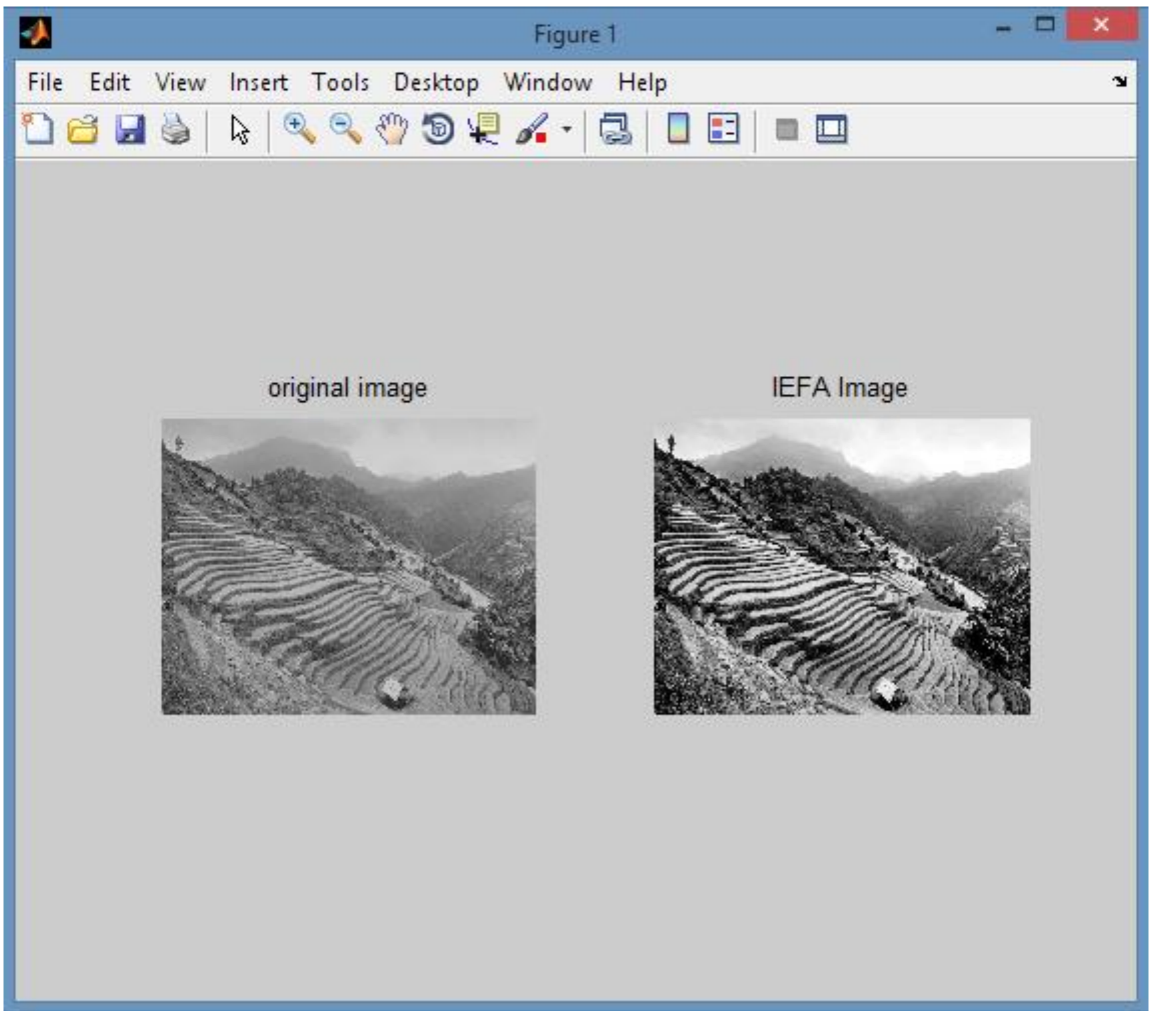

Figure 5.6: Applying IEFA on Field3.png

Figure 5.7: Applying IEFA on Medical1.jpg

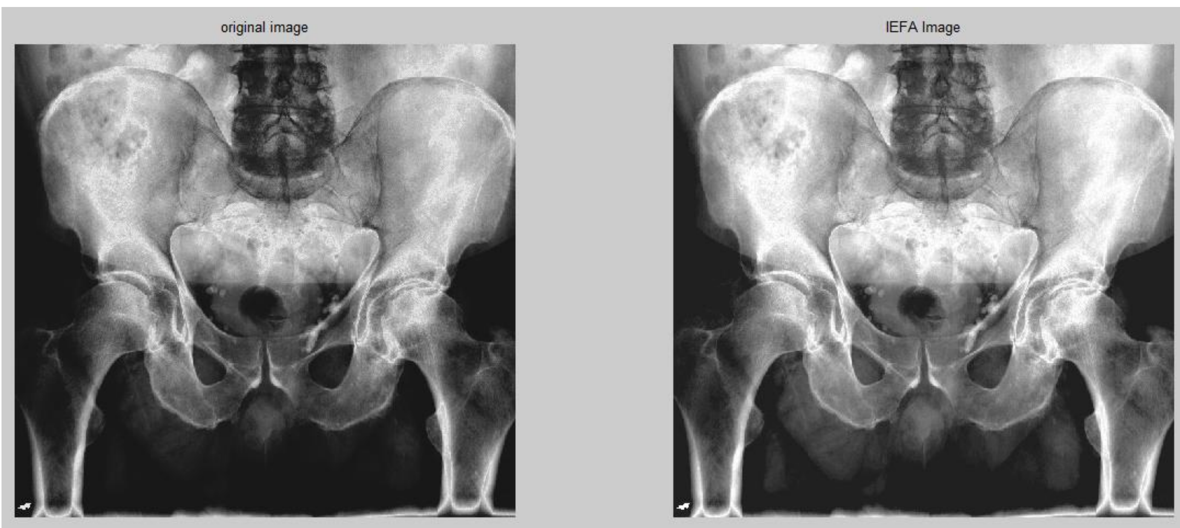

Figure 5.8: Applying IEFA on Medical2.jpg

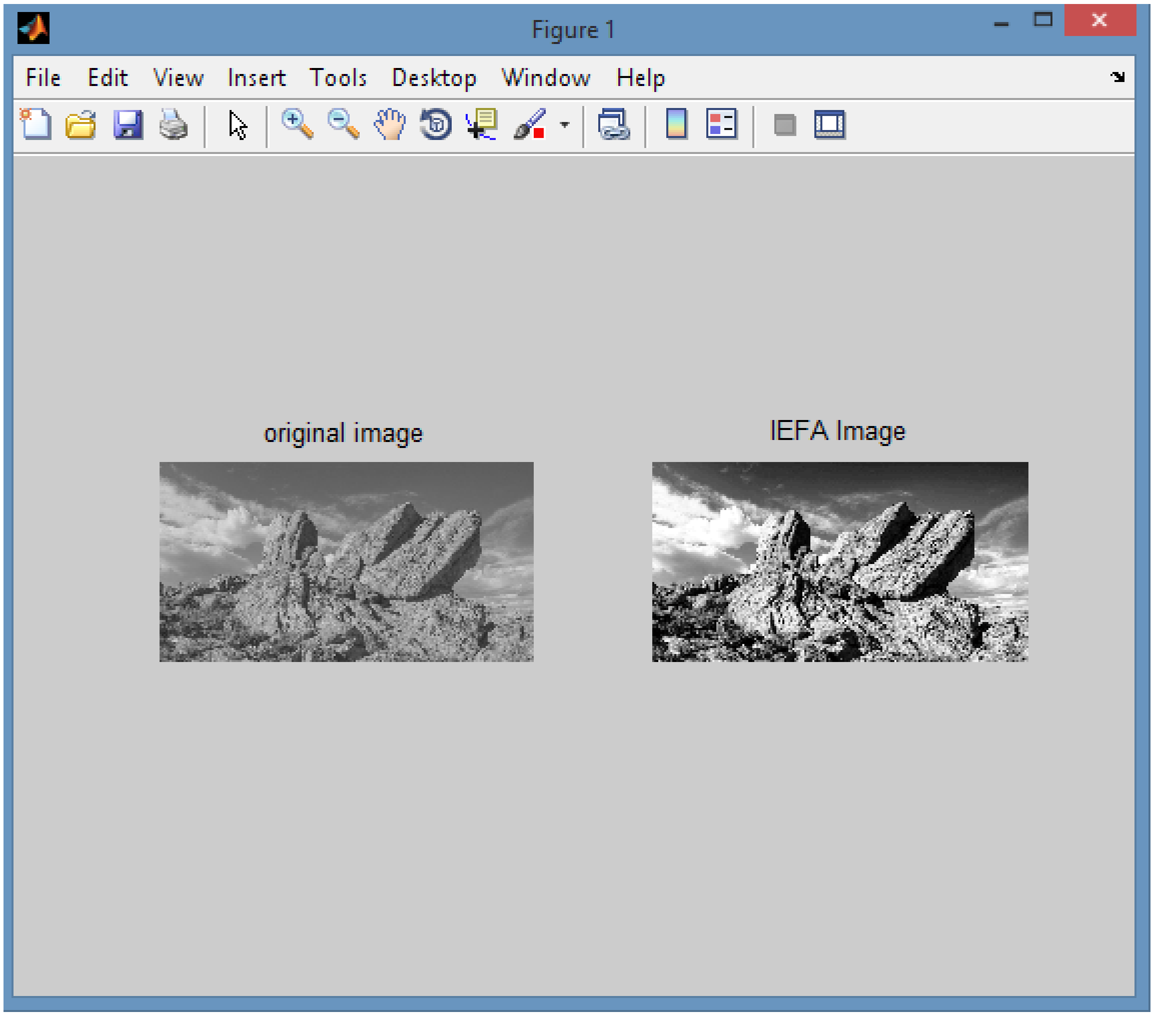

Figure 5.9: Applying IEFA on Rock1.png

5.2 PERFORMANCE EVALUATION

After applying the above mentioned image enhancement techniques on low contrast images, the results have been obtained. The performance analysis of various techniques has been done using different parameters that is "PSNR (Peak signal To Noise Ratio)"and "CII (Contrast Improvement Index)".

MSE

"Mean Square Error" is the measure of average squares of errors.

$$MSE= \frac{1}{RC}\sum_{i=1}^{R} \sum_{j=1}^{C}(f(y,z) - f'(y,z))^2 \qquad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots[15]$$

Where, R is rows in original image and C columns in original image at index y and z. f(y, z) is the original image and f´(y, z) is the degraded image.

PSNR

"PSNR is the division of the maximum possible power of a signal to the power of corrupting noise affecting image quality". For reconstruction to be of higher quality, the value of PSNR should be high. Table 5.1 shows comparison of PSNR of enhancement techniques.

$$PSNR = 10.log_{10}\left(\frac{MAX_i}{MSE}\right) = 20.log_{10}\left(\frac{MAX_i}{MSE}\right) = 20.log_{10}(MAX_i) - 10.log(MSE)$$

......[15]

Table 5.1: Comparison of PSNR of various Enhancement Techniques

Image Name	PSNR of the Original Image	PSNR of Histogram Equalized Image	PSNR of CLAHE Image	PSNR of IEFA
Grapes1.jpg	25.25	25.56	25.34	25.56
Grapes2.png	25.26	25.57	25.41	25.55
Beach1.jpg	25.27	25.54	25.34	25.56
Rock1.png	25.25	25.55	25.41	25.55
Field1.png	25.27	25.54	25.35	25.58
Field2.jpg	25.25	25.55	25.33	25.55
Field3.png	25.27	25.54	25.37	25.57

Field4.jpg	25.25	25.54	25.39	25.54
Medical1.jpg	25.30	25.56	25.28	25.43
Medical2.jpg	25.34	25.52	25.45	25.41

CII

Contrast improvement index is the division of $C_{enhanced}$ to $C_{original}$ [23]; where, $C_{enhanced}$ is average contrast of new image and $C_{original}$ is the average contrast of input image. A higher value of CII is always favored. Figure 5.11 displays a Bar representation of CII achieved by applying the techniques on low contrast images. From this Figure, it is inferred that proposed IEFA yield the highest value of CII.

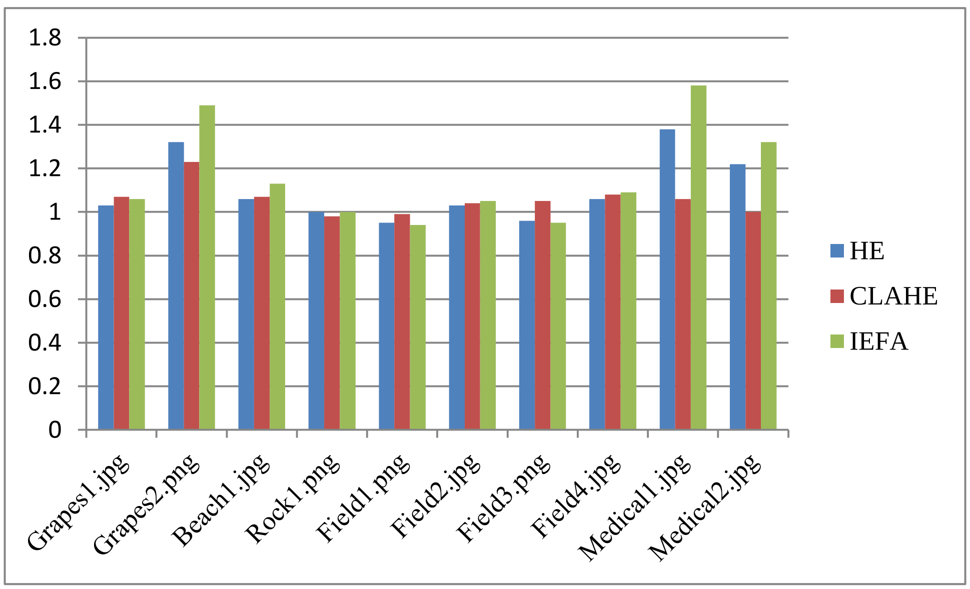

Figure 5.10: CII Evaluation of HE, CLAHE, and IEFA

Table 5.2: CII Analysis

Image Name	HE	CLAHE	IEFA
Grapes1.jpg	1.03	1.07	1.06
Grapes2.png	1.32	1.23	1.49
Beach1.jpg	1.06	1.07	1.13
Rock1.png	1.00	0.98	1.00
Field1.png	0.95	0.99	0.94
Field2.jpg	1.03	1.04	1.05
Field3.png	0.96	1.05	0.95
Field4.jpg	1.06	1.08	1.09
Medical1.jpg	1.38	1.06	1.58
Medical2.jpg	1.22	1.00	1.32

Chapter 6

Conclusion and Future Work

6.1 Conclusion

The foremost focus of the thesis is on image enhancement of low contrast images using fuzzy technique. For implementation, three MF are defined for each input and output, and rules are designed in FIS. The IEFA has been implemented in MATLAB 9.0. Experiment has been performed on low contrast images and the outcome of the proposed IEFA is compared to outcome of HE, and CLAHE. To contrast these algorithms, “Contrast Improvement Index (CII)”, and “Peak Signal To Noise Ratio (PSNR)” have been used as the performance metrics. From CII analysis it is contingent that “Histogram Equalization (HE)” and “Contrast Limited Adaptive Histogram Equalization (CLAHE)” yield less values of CII. This is because the focus of HE is only on the global contrast of image. This also leads to the loss of the local details. In CLAHE, because of non-uniform lightning, ambiguity is introduced in image which appears as imprecise boundaries during digitization. IEFA results in better CII values as compared to CLAHE, and HE; by solving the problem of vagueness and imprecise boundaries through fuzzy sets and linguistic variables.

6.2 Future Scope

In future, the work can be extended to colored images that offer more real life implementations. The algorithm can be modified to give better results for medical images. The improvised outcome for image enrichment is also used in real time augmentation of neuro evolution.

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List of Publications

[1] Ankita Sheoran and Harkiran Kaur, **"Comparative Analysis of Image Enhancement Techniques"**, IEEE International Conference on Advanced Computational and Communication Paradigms – 2017 (ICACCP- 2017). [Communicated]

[2] Ankita Sheoran and Harkiran Kaur, **"IEFA- A Fuzzy Framework for Image Enrichment**", 3rd International Conference on Next Generation Computing Technologies (NGCT-2017). [Communicated]