Image Enhancement Using MamdaniFuzzy Inference System

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Abstract—**Image enhancement means to improve the quality of the images for better human perception. The impulsive noise can be reduced and also by using different image enhancement techniques edges of the images can be sharpened. The quality of the original image is increased for better analysis by a human or a machine by using image enhancement technique. One of the image enhancement techniques is fuzzy image enhancement.**

Fuzzy logic deals with studying of possibiliticlogic or several valued logic, it uses approximation rather than fixed and exact reasoning. It handles partial truth, where the truth values may either be in between of completely true values or completely false value. Fuzzy image processing is considered important application areas of fuzzy domain. The purpose here is to increase the contrast of the original image using triangular membership function and fuzzy rules from Mamdani fuzzy inference system. Edge detection of the original image is done and by using triangular membership function image is converted to fuzzy plane from pixel plane. Fuzzy rules are applied on the original image and defuzzification is done on the same to get the enhanced image. For enhanced image Mean Square Error (MSE) and Peak Signal to Noise Ratio (PSNR) has been calculated.

The implementation work will be done using MATLAB 7.5 image processing tool box.

IndexTerms—**Fuzzy set, Mamdani fuzzy inference system, Membership function, Fuzzy if then rules.**

I. INTRODUCTION

Image enhancement process has many techniques that are sought to improve the visual appearance of a image or to convert the image so has to be better suited for analysis by a human or a machine. Image enhancement is used for improving the quality and contrast of the image.The fuzzy image enhancement includes membership functions which convert the image into fuzzy membership plane from pixel plane and linguistic variables which include fuzzy based rules in the form of sentences for image processing. Membership function for both input and output is selected and their range has been set for both respectively [1].

Fuzzy is a system of knowledge representation, it processes human knowledge in the form of fuzzy rules. Fuzzy image processing enhances image contrast very efficiently. Fuzzy technique can manage the ambiguity and vagueness of the image effectively [2].

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Fuzzy entropy, measuring the amount of blur in an image is a function which increases when the sharpness of its image decreases.

Three parameters are considered such as intensification parameter, fuzzifier and crossover point.

The degraded image representing light objects in dark background is enhanced by contrast minimization technique. A cross over point is considered, which is associated to stop fluctuation. Histogram is used to covert Shannon entropy to fuzzy entropy. Parameters of the images are calculated. After selecting cross over point, membership function is modified with respect to cross over point. Gaussian membership function is for used membership value modification [5].

Initially the minimum intensity pixel value of the input image will be assigned to 0 and maximum intensity pixels values to 1. The intensity mapping functions maps the fuzziness or uncertainty regarding low contrast from intensity plane to fuzzy plane by using membership function. The pixels are grouped with respect to their intensities. Finally image is converted from membership plane to fuzzy plane which is known as defuzzification [6].The different ranges of "salt" and "pepper" noise in the image is removed by using different filters. For comparative study purpose different filters are applied. The filter removes salt and pepper noise efficiently. Boundary detection is also made. The filter with different threshold values is applied on the noisy image.For different range of noise levels in a noisy image initially the filters are applied. The applied filters are of different window sizes. To keep away from severe blurring of image details at large noise levels, the most size of the window is limited. The filter removes every pixels which is having same values or equal to the minimum or maximum values in a window used, and then it calculates the mean value of the pixels which are remaining or the neighboring four pixels. If the pixel detected is a noise one, then it is replaced by average pixel value of the filter or median value is used to replace the corrupted pixels [7].The noise present in the image is decreased and useful information of the image is improved by improving its contrast. The color image is transformed to gray scale image and after that edge detection of the image is found using zero crossing algorithms. Further Membership functions are used to convert image from pixel plane to transform plane. Fuzzy logic is used to process knowledge in the form of fuzzy "if then" rules. It includes fuzzification, defuzzification and fuzzy rules. After enhancing the quality of the image different parameters such as PSNR and MSE of enhanced images are calculated [1]

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II. METHODOLOGY

The figure 1 shows the block diagram of the system.The color image is input for the system. The acquired image is in the jpeg or png format, which is further processed for edge detection.
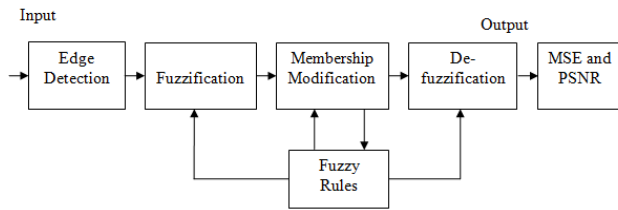

Figure.1.Block Diagram of system

A.EDGE DETECTION

The points where image intensity changes rapidly or discontinuities in the intensity level of the pixels is detected, and are organized in a collection of curved line segments called edges of the image. This is a collection of mathematical models which identifies points in the digital image.

Detecting the edges of the image helps to get the set of connected points that notify the borders of the objects in the image. The amount of data to be processed will be reduced and removal of the information that may be irrelevant, at the same time protecting the important characteristics of an image. Implementing algorithm for edge detection to an image will preserve the features of an image.

The Mamdani fuzzy inference system is used over Sugeno fuzzy inference system as system need to be carried out with three different ranges of pixel intensity namely bright, gray and dark. On Sugeno fuzzy inference system it is not possible to combine rules applied for the system as it use single spikes for each rules applied.

B. FUZZIFICATION

Fuzzification is a concept of assigning required membership function on an image, which transforms image from pixel plane to fuzzy plane. Fuzzy collections are having membership functions which are unique scenarios called characteristic function in crisp collections. The characteristic function of crisp collections is unique scenarios of the membership functions of the fuzzy sets. The acquired degraded color image is transformed to membership plane by using membership function where its values vary from the interval 0 to 1. The membership function can take infinite values between the intervals 0 to 1. Here triangular membership function is used to convert image from pixel plane to membership plane. Three membership functions for both input and output are selected at three intensity levels of the image respectively, the ranges for the each membership functions are adjusted by using membership function editor tool box. While defining fuzzy rules for the system the ranges of the both output and input membership functions are mainly considered. By dragging the selected membership function in the tool box can vary the ranges of membership function for both input and output.

C. TRIANGULAR MEMBERSHIP FUNCTION

As shown in the figure.2 three triangular membership functions are used for both input and the output namely mf1,

mf2 and mf3. Dark region is represented by mf1, mf2 represents the gray region and mf3 represents the white region of the image respectively. As shown in the figure the range of the mf1 is 0 to 100, mf2 is having the range from 25 to 225 and mf3 is having the range from 150 to 250 respectively. Fuzzy rules are added in the rule editor tool box by considering parameters of these three membership functions. X axis indicates the pixel intensity values and Y axis indicates the degree of membership assigned to the pixels with respect to their intensity variation.
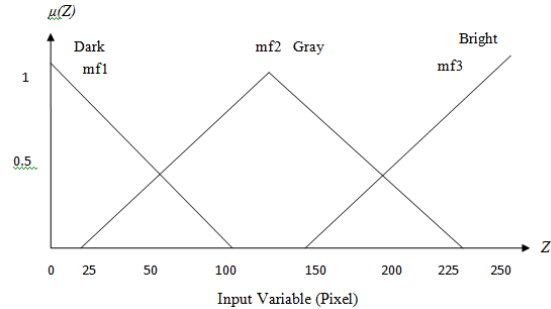

Figure 2: Triangular Membership Function for the system

D. MEMBERSHIP MODIFICATION

The membership values are modified using fuzzy inference system (FIS) tool box. Fuzzy inference system is categorized into types.

- Mamdani type FIS.
- Sugeno type FIS

FIS is a tool box of MATLAB consists of FIS editor, surface viewer, rule editor, membership function editor and rule viewer. For both input and output variables FIS consists in built membership functions. Setting a membership value for gray level of the image where maximum gray level, minimum gray level and variance between the gray levels are defined. The new membership values are defined for the pixels with respect to their gray level intensity values and membership values are assigned to the pixels based on variation in their intensity level.

E. FUZZY RULES

Fuzzy rules are expressed using linguistic variables. These are variables whose values are sentences or words. Variables usually take numerical values in mathematics, the non-numeric which may be a compound or atomic sentence generally used to express the rules and facts linguistic variables can be modified.

It consists of fuzzy if then rules. Fuzzy rules for the modified membership values with respect to the pixel intensity are defined. Fuzzy operators are used while defining the rules. The fuzzy rules are added using fuzzy rule editor tool box, where rules can be added or deleted with respect to the membership functions selected and to their range of mapping.

F.DEFUZZIFICATION

It is the inverse procedure of fuzzification. The main purpose of the defuzzification process is to locate one single crisp value which summaries the fuzzy set which enters it from the inference system. The images are transformed back to the pixel plane from fuzzy plane. New membership values are

set for the system while doing defuzzification. Defuzzification method is initially chosen in the fuzzy inference system tool box while doing the fuzzification. Centroid defuzzification method is used for the system.

G.MSE AND PSNR

Images with different sizes are taken initially for the system once the images are enhanced the peak signal to ratio (PSNR) and mean square error (MSE)of the enhanced images are calculated, Low MSE and high PSNR values indicates efficient contrast enhancement of the image. Calculated values are tabulated for different images.
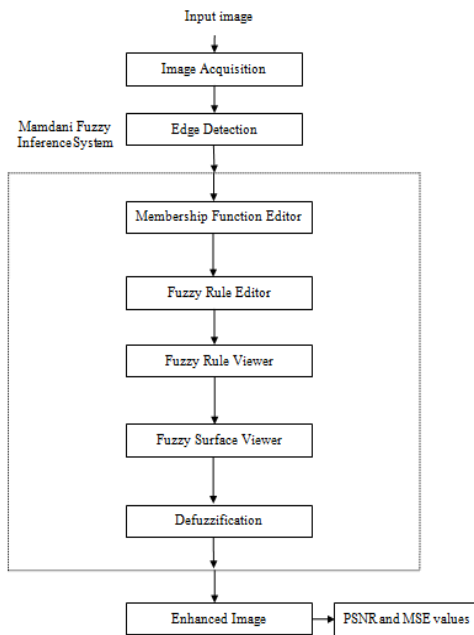
III. IMPLEMENTATION

Figure 3: Flow Chart of the System

A.IMAGE ACQUISITION

Image is acquired by data base JPEG or PNG format color image is taken for system. Images with different sizes have been considered.

B.EDGE DETECTION

By using edge detection the required intensity levels of the image is obtained for applying membership function.
The Laplace gradient filter for the image is shown in following equation (1).

Figure 4: Laplace Gradient Filter for Zero Crossing Edge Detection.

$$\nabla^2 t = -4t(u,v) + t(u,v+1) + t(u,v-1) + t(u+1,v) + t(u-1,v)$$

(1)Where $t(u,v)$ is current pixel, u indicates the row number and v indicates column number. As in the equation row number and column number is varied. This shows the neighboring pixels of the current pixel on which filter is applied.

C. MAMDANI FUZZY INFERENCE SYSTEM

It processes the image from different fuzzy inference tool boxes. By using fuzzy logic the process of mapping from given input to output can be done, which becomes basic foundation for decisions to be made or patterns discerned. Mamdani fuzzy inference system consists of following parameters:

- Fuzzifying the input variables
- Applying the fuzzy operator
- Aggregating the rule outputs
- Defuzzifying

The fuzzy inference system editor displays information about Mamdani FIS. The FIS Editor tool allows editing the utmost level characteristics of the fuzzy inference system, likewise the number of output and input variables. It consists of other various editors to operate on the fuzzy inference system. The FIS editor allows easy access to all other editors by providing more importance on maximum flexibility for communication with fuzzy system.

D. FIS EDITOR

The important features of fuzzy inference system are modified using FIS editor tool, which is the number of output and input variables required, type of membership function, ranges of the membership function and the defuzzification method used. The FIS Editor provides high level display for any fuzzy logic inference system, Due to which other different editors are made to operate on FIS. Fuzzy operators, ranges are set in this tool box.

E. MEMBERSHIP FUNCTION EDITOR

For all membership functions changes are done to the type, the name and to the other variables. Built-in membership functions are provided in the tool box. Display range and membership functions are chosen in this tool box. For both input and output membership functions and their parameters are selected in the tool box. The image is transformed to fuzzy plane from pixel plane with x axis indicating pixel range and for y axis indicating degree of membership for respective pixel.

F. FUZZIFYING THE INPUT VARIABLES

It consists of the process of converting crisp values into degree of membership intended for linguistic variables of fuzzy sets. Degree of membership values are found out for the intensity variation of the each pixels and membership functions are defined using fuzzy inference system tool box [5].Membership function is set by following equations

$$^{(2)}P(i,j) = (1 + (X_{max} - x_{11}(i,j) / Fe))^\wedge Fd)$$

Where $P(i,j)$= Resulting image pixel with i rows and j columns

$x_{11}(i,j)$ = Image pixel with $i$rows and j columns

X_{max} =Maximum gray level

Fe= Exponential Fuzzifier
Fd= Denomination Fuzzifier
New membership function value is set by equations (3) and (4)

$$P(i, j) = 2 \times P(i, j)^\wedge 2 \text{ if } P(i, j) \leq 0.5 \quad (3)$$

$$P(i, j) = 1 - 2 \times (1 - P(i, j))^\wedge 2 \quad \text{if } 0.5 \leq P(i, j) \leq 1$$
(4)

G. RULE EDITOR

The fuzzy rules are modified using rule editor in FIS editor. The applied rules are checked and edited by using fuzzy inference system. By using rule editor it is possible to add rules for all the input and output variables. The fuzzy rules can be created, changed and deleted by using this tool box [5].
The process of image enhancing the contrast of a gray scale image the fuzzy rules:

* IF a pixel is gray, THEN make it gray
* IF a pixel is bright, THEN make it brighter
* IF a pixel is dark, THEN make it darker

The fuzzy inputs are processed to the antecedents of the fuzzy rules. If fuzzy rule obtained is having multiple antecedents then fuzzy operator (AND or OR) is used to gain a single number which indicates the result after the evaluation of antecedent [8]
To calculate the disjunction of the rule antecedents OR fuzzy operator is used.

$$\mu_A(Z) \cup \mu_B(Z) = \max[\ \mu_A(Z), \mu_B(Z)] \quad (5)$$

Where $\mu_A(Z) \cup \mu_B(Z)$ is union of two fuzzy sets *A* and *B*
$\mu_A(Z)$ is degree of membership of subset *A*
$\mu_B(Z)$ is degree of membership of subset *B*
To evaluate the conjunction of the rule antecedents AND fuzzy operators are used.

$$\mu_A(Z) \cap \mu_B(Z) = \min[\ \mu_A(Z), \mu_B(Z)] \quad (6)$$

is intersection of fuzzy sets A and B
$\mu_A(Z)$ is degree of membership of subset A
$\mu_B(Z)$ is degree of membership of subset B
Aggregation of Rule Outputsdescribes about obtaining the union of the outputs of every rule by taking the membership functions of all rule results and combines them into a one fuzzy set. The list of membership functions is the input for the aggregation process. The input of the aggregation process and the output is one unique fuzzy set for all output variables.

H. RULE VIEWER

The rule viewer describes the fuzzy inference diagram for a FIS. From beginning to the end entire implementation process is viewed using rule viewer. By moving around the line indices that correspond to the inputs and then watch the system readjust and compute the new output.
The Surface viewer is a tool which is used to verify the output surface of a FIS for every number of inputs. It is a read only editor because of this it will not alter the fuzzy system or its related FIS structure at any cost. With the help of drop-down menus, the selection of two input variables given to the two input axes (*X* and *Y*), similarly output variable is assigned to the output (or *Z*) axis. For creation of smoother plot, membership functions are evaluated by input and output range for using the plot points identity.

I.DEFUZZIFYING

It is the final step involved in Mamdani type fuzzy inference system. Fuzziness is used to evaluation of the rules used, always the fuzzy system output is crisp number. To do defuzzification process aggregated output fuzzy collection and the output is a single crisp number [10].Centroid Defuzzification Methodpoint representing the centre of gravity of the fuzzy set is found. Mathematically, Center of gravity is represented as follows

$$COG = \frac{\int_a^b \mu_A(Z) Zdz}{\int_a^b \mu_A(Z) dz} \quad (7)$$

Where COG is Centre of gravity
Z is a fuzzy set
A is a subset of *Z*
$\mu_A(Z)$ is degree of membership of subset A

J. ENHANCED IMAGE

Contrast of the degraded input image is enhanced using fuzzy system. It is a process of where characteristics of an image are changed which made possible to get new image with more suitability for any particular application [9].Enhanced image can be obtained by using the equation (8)

$$I(i, j) = X_{max} - Fe * ((1 / P(i, j))^\wedge (1 / Fd) - 1)$$
(8)

Where,
$X_{max=}$maximum gray level
Fe= Exponential Fuzzifier
Fd= Denomination Fuzzifier

K. MSE AND PSNR

MSE measures the mean of the "errors", i.e., Comparison between the estimator and what is estimated is done.

$$MSE = \frac{1}{mn} \sum_{i=0}^{m-1} \sum_{j=0}^{n-1} [I(i,j) - k(i,j)]^2 \quad (9)$$

Where *m, n* indicates number of row size and column size.*i ,j* indicates current pixels row and column number.
PSNR is a difference between the maximum intensity level of the image and the capacity of distorting noisewhich affecting the accuracy of the image. PSNR is always expressed in terms of the logarithmic decibel scale. Thus large PSNR usually shows that the reconstructed image is having better quality,

$$PSNR = 10 log_{10} \frac{MAX_i}{MSE} \quad (10)$$

Where the maximum achievable pixel intensity value of the image is *MAX_i*. Here the pixelsare represented using 8 bits, then *MAX_i* is 255.

III.RESULTS

Zero crossing edgedetection has been done using Laplace gradient filter for the input image shown in figure5(a) and the output is shown in Figure5(b).

(a)   (b)

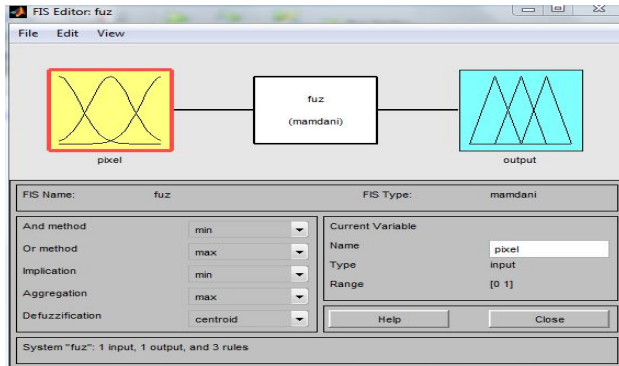**Figure 5:(a) Input image(b) Edge detection.**

Figure 6. FIS editor tool box

The figure 6 shows the basic knowledge about a FIS. As shown in the above figure, input variables are at the left side of the FIS editor and output variable are on the right side of the FIS. The boxes showing membership functions are just icons and they do not represent any type of membership functions. Fuzzy operators namely AND and OR are selected, range and defuzzification method for the system is also selected in this editor. By double clicking on to the pixel icon, membership function editor for output and input variable of the system can be obtained respectively. Mamdani inference system is selected for the system.
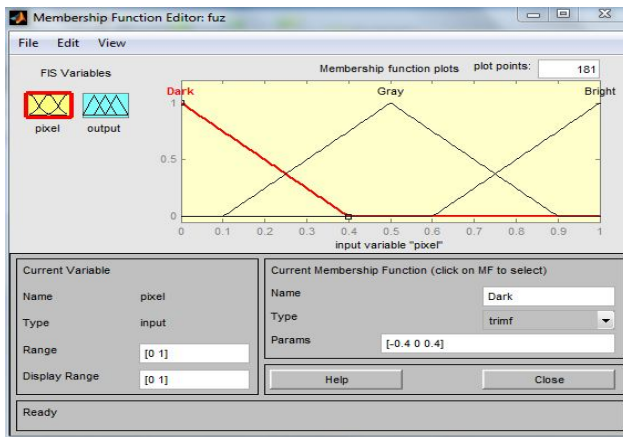

Figure 7.Membership Function Editor

The above figure 7 is the tool that used to edit the membership functions for the input variable as well as for the output variables for used in entire fuzzy inference system. The membership function editor andFIS Editor have some similar features. There are built in membership functions are

available in the membership function editor tool box. Membership functions are defined in this tool box. The type and range of the membership function for both output and input is selected in this tool box. X axis representing the pixel range and Y axis representing the degree of membership for the corresponding pixel. Triangular membership function is selected for the system.
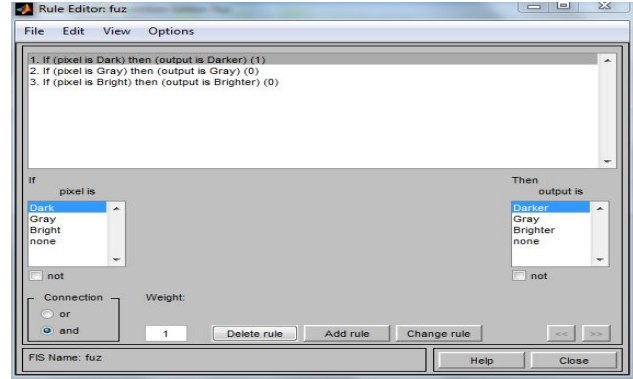

Figure 8. Rule Editor

The above figure 8 shows the tool where modification of the rules of a FIS structure can be done. The rules used by FIS for the system are inspected by using this tool box. The fuzzyrules for the system are added, changed and deleted in this editor by range and the type of membership functions is used. Rules are added considering both input and output with respect to each other.
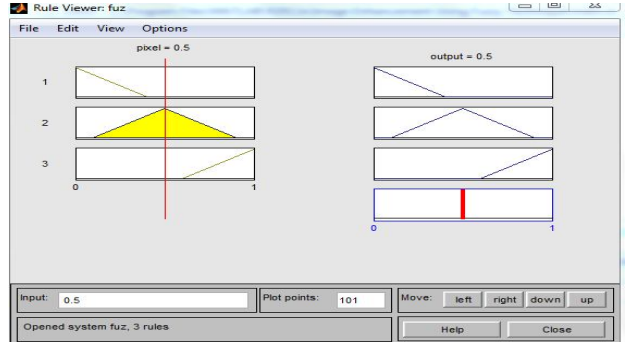

Figure 9:Rule Viewer

The above figure 9 shows the rule viewer describes the fuzzy inference diagram for a FIS. The figure 10 shows surface viewer is a tool which is used to verify the output surface of a FIS for every number of inputs. It is a read only editor because of this it will not alter the fuzzy system or its related FIS structure at any cost. With the help of drop-down menus, the selection of two input variables given to the two input axes (X and Y), similarly output variable is assigned to the output (or Z) axis.
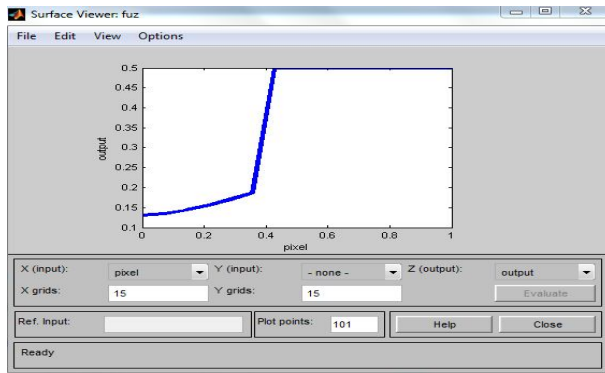
Figure10.Surface Viewer

(a)   (b)

Figure 11: Comparison between input and enhanced image (a) input image (b) enhanced image

The figure 11(b) shows the image in which contrast is high compared to the input image 11(a) which is more suitable for human perception and machine analysis
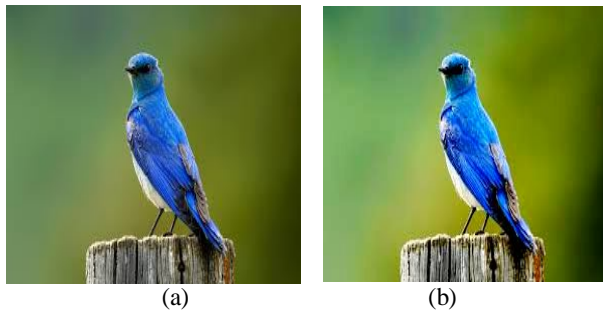

(a)   (b)

Figure 12:Comparison between input and enhanced image (a) input image (b) enhanced image

(a)   (b)

Figure 13:Comparison between input and enhanced image (a) input image (b) enhanced image

(a)   (b)

Figure 14:Comparison between input and enhanced image (a) input image (b) enhanced image

(a)   (b)

Figure 15:Comparison between input and enhanced image (a) input image (b) enhanced image

Table 1: MSE and PSNR calculation:

Image Name	MSE	PSNR
Image 11(b)	18.5874	35.4386
Image 12(b)	45.9344	31.5094
Image 13(b)	102.4726	28.0247
Image 14(b)	91.0516	28.5379
Image 15(b)	70.0942	29.6740

IV.CONCLUSION

The main focus of the paper is to enhance the contrast of the image using fuzzy image enhancement technique. Images with different sizes and variation in the contrast are taken for the system. Fuzzy membership functions and fuzzy rules are applied for the same which is a knowledge based system. Triangular membership function is used to convert image from pixel plane to fuzzy plane and fuzzy rules are applied after the modification of membership values by using Mamdani fuzzy inference system. Which results in increases of the contrast of the image and it is able to get over the drawbacks of methods like spatial domain, thresholding, histogram equalization and frequency domain methods. The low contrast image is efficiently enhanced using fuzzy technique.

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