An Optimized Multiple Fuzzy Membership Functions based Image Contrast Enhancement Technique

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Abstract

Image enhancement is an emerging method for analyzing the images clearer for interpretation and analysis in the spatial domain. The goal of image enhancement is to serve an input image so that the resultant image is more suited to the particular application. In this paper, a novel method is proposed based on Mamdani fuzzy inference system (FIS) using multiple fuzzy membership functions. It is observed that the shape of membership function while converting the input image into the fuzzy domain is the essential important selection. Then, a set of fuzzy If-Then rule base in fuzzy domain gives the best result in image contrast enhancement. Based on a different combination of membership function shapes, a best predictive solution can be determined which can be suitable for different types of the input image as per application requirements. Our result analysis shows that the quality attributes such as PSNR, Index of Fuzziness (IOF) parameters give different performances with a selection of numbers and different sized membership function in the fuzzy domain. To get more insight, an optimization algorithm is proposed to identify the best combination of the fuzzy membership function for best image contrast enhancement.

Keywords: Image enhancement, fuzzy logic, fuzzy optimization, fuzzy inference system, membership function.

1. Introduction

Fuzzy enhancement techniques have proven a powerful tool for presenting the image in a better way so that it can be used for a large number of applications in the area of contrast enhancement [1]-[4]. Nowadays, image-capturing devices are in many ranges from high resolutions to lower resolution in terms of pixels value. In this digital world, the technologies have been grown rapidly for many applications such as internet of thing (IoT) applications; Image enhancement techniques play an important role while processing the data from one device to another, an image enhancement technique could be used to forward the improved image data. Various methods of enhancement are available as first derivation technique like Sobel mask, a second derivative technique like Laplace mask and much more [1]. Different devices could require different qualities of improved images for processing the data or applications. In different qualities of an image, a device may fail to capture the better image quality and hence a good enhancement technique may be the need to achieve the required quality in the image. Qualities of images are affected due to the availability of various kinds of noises in the images like salt and pepper noise, Gaussian noise, and impulse noise.

In this paper, it is shown that how can we get a range of better quality enhanced image outputs for given image. Different fuzzy membership functions and their combinations are utilized with rule-base in fuzzy inference system for getting a range of improved contrast images. To the best of our knowledge, the use of the fuzzy rule-based procedure in image enhancement was primarily suggested by Tizhoosh et al. [8]. Based on same fuzzy inference system, recently, paper in [11] show the potential of membership function modification to improve the image brightness. Hasikin et al. [11] have used the two membership functions as the triangular and the sigmoid function to get conversion between spatial and fuzzy domain. An algorithm for optimization was used to determine the best attribute using a mathematical model for image enhancement. In this scheme, adaptive fuzzy contrast factor enhancement technique was proposed that uses the single membership function as a sigmoid function at both input and inverse of sigmoid membership function at the step of defuzzification for low contrast-uniform illumination images. In a fuzzy domain, there are various parameters such as intensification, fuzzifier, and crossover point. These are important for the desired appearance of images [12]. Similarly, a Gaussian membership function used along with histogram equalization for fuzzy image enhancement in a recent paper by Devi and Rabbani [10]. Gopalan and Arathy [12] have proposed an optimal fuzzy system where they have shown that the membership function separation from some reference point or crossover point is directly related to the fuzzy image quality.

As per observations from recent works on fuzzy image enhancement, the use of the different shape of membership functions and their impacts on fuzzy IF-THEN rules are not explored further. In this paper, we extend the work of Tizhoosh et al. [8] and Hasikin et al. [11] by considering the potential use of the different shaped membership function to be used in fuzzy inference system for image contrast enhancement. This paper proposes a new algorithm for generating the fuzzy IF-THEN rules automatically when many memberships functions are combined together for a resultant membership function. The rule base is according to intuitions drown based on location information and human observations. A set of different membership functions and their modified membership

functions by the Mamdani FIS is the basis for the transformation of the input image into an enhanced image with good quality. First, we design different combinations of membership functions for Mamdani FIS. In our study, triangular, Gaussian, and bell-shaped membership functions are utilized and their impact on image enhancement are studied. We show based on results analysis that by using optimization in the fuzzy domain, the best membership function can be selected to produce the better-enhanced image after defuzzification. With the motivation on image quality on different membership functions, the algorithm of fuzzy optimization using fuzzy quality is also proposed to determine the best membership function and its combinations. Simulation results that show the effectiveness of optimization is given in details.

The rest of the paper is organized as follows. Section 2 presents the highlights of related literature of the work. The basic structure of Mamdani FIS used in our work is explained in the Section 3 with terminology and definitions used throughout the paper. How our model would use If-then rule base and different membership function (MFs), is also explained this section. The working of proposed design is described in Section 4 along with fuzzy optimization technique. The results and discussions using the proposed and the existing techniques are given in the section 5. Finally, the paper conclusion and future work can be found in the Section 6.

2. Related Work

Assume that an image is given with M × N pixels each with different intensities having fuzzy membership grade values in the range of 0 to 1. There are many works in literature employing fuzzy logics based image enhancement viz., edge detection, noise removal, etc. (see [1, 7, 8]). In this paper, we restrict ourselves only works related to contrast stretching techniques or transformation functions in gray-level improvements. PAL and KING [7] was first to propose a contrast enhancement technique using a Contrast Intensification (CI) operator. The CT operator reduces the fuzziness and thus improves the image contrast. CT operator determines modified membership values. This operator stretches the contrast between the membership values. To obtain the good contrast, it transforms the MF values to much higher values for those MF values, which are above 0.5. The MF values which are lower than 0.5 are transformed into much lower values in non-linear manner. Thus, a good contrast is obtained using nonlinear stretching function. This CI operator (also known as INT operator) relies solely on membership function. In addition, this operator must be applied continuously on given image for attaining the proper enhancement. To overcome this limitation, NINT operator [9] is proposed which uses a Gaussian type fuzzification function containing a fuzzifier and a new intensification operator. Tizoosh [8] proposed the concept of fuzzy histogram hyperbolization. The method modifies the input membership function into logarithmic function through nonlinear human brightness perception. Initially, MF and its shape are selected according to user's requirement. The MF values are calculated using this MF and a fuzzifier beta is set in order to modify the membership function for getting good contrast image. In this method, fuzzifier beta is a linguistic hedge which can be made selection such that manner is very bright, very very bright, medium bright, very medium bright, low bright, and so on. These selections can be made on the basis image quality. If input image quality is low, then fuzzifier beta will produce slightly bright image after operation. Russo [13, 15] proposes rule-based operators based on human knowledge. Image quality can be improved by human

observation and fuzzy rule-based are according to human intuitions, which are nonlinear. The conditions for fuzzy rule are designed based on pixel gray level and neighborhood pixel values. The fuzzy rule-based systems based on soft decisions are proposed in [13] and rule-based operators for image sharpening and smoothing are suggested in [15]. Fuzzy rule-based filters for image enhancement are proposed in [16]. A comparative study on mammogram images is given in [17] to explore the features of the image using different mechanisms such as contrast intensification, IF-THEN rules, and hyperbolization. The fashion is as follows: (i) If image is dark then black, (ii) If image is gray then gray, (iii) If image is bright then white. Schneider and Craig [20, 21] have suggested the use of Fuzzy expected value (FEV) for image enhancement. In FEV, mean and median fuzzy set values are replaced to modify the more representative value in the grade of membership function. A weighted FEV was also proposed by the same authors to improve more the image contrast [21]. Although various techniques of image enhancement can extract important features of image in improving the image contrast several deficiencies in these techniques are still present. Thus, the optimization techniques have been proposed in [22, 23, 24, 25]. The enhanced images are produced by optimizing the gray-level information of the image. Other optimizations on image are based on entropy, index of fuzziness or combination of [24, 25, 26]. However, the optimizations using above measures need iterative procedure, which may be applied repeatedly to transform better image quality. To overcome these limitations, authors in [26, 27, 28, 29] have suggested the methods of locally enhancing the image without additional optimization.

Based on the selection of membership function in order to modify the membership function or convert during the fuzzy process, Hasikin et al. [11] utilized two-membership functions such as the triangular and the sigmoid function to get conversion between spatial and fuzzy domain. Recently, Devi and Rabbani [10] used a Gaussian membership function used along with histogram equalization for fuzzy image enhancement. Gopalan and Arathy [12] have shown that how the membership function separation from some reference point or crossover point is directly related to the fuzzy image quality in the design of the optimal fuzzy system. Deng et al. [14] used intuitionistic fuzzy sets for image enhancement where the restricted membership function and hyperbolisation function are used during fuzzy enhancement process. Based on classical histogram equalization (HE), Brightness Preserving and Non-parametric modified Bi-histogram Equalization (BPNMBHE) is proposed by Yao et al. [18]. In this approach, the input image is divided into two sub-images using the average intensity value and then both the sub-images are enhanced by HE. The final output image can be obtained by merging both the enhanced sub-images. HE based optimization problem is formulated by Shin and Hong [19] to the contrast enhancement for preserving localities of the histogram as an improvement in HE.

3. Mamdani FIS Model Structure

Based on fuzzy set theory, the fuzzy method introduced two kinds of fuzzy inference model, in which the first kind of fuzzy inference model is introduced by Mamdani [27], and second fuzzy inference TSK model is introduced by Sugeno [28]. These models are useful to handle the uncertainty in an image to improve the contrast of an image. Improvements of contrast in the input image are also possible with the combination of fuzzy set theory and fuzzy entropy [29]. In MATLAB, Mamdani FIS is a GUI based fuzzy

inference system where fuzzy-domain would be a conversion from MFs setting as both input and output side. In fuzzy inference system (FIS), input membership function (MFs) and output membership function (MFs) are mapped together by using rule- base design. Fuzzy Inference System (FISs) is divided into three types, Mamdani FIS, Sugeno FIS and Tsukamoto FIS for various applications [27, 28]. The basic differences between these FIS model are that the procedures for their fuzzy rules, aggregation, and defuzzification differ mostly to each other. We restrict ourselves to consider the Mamdani FIS for image enhancement. A given input image is then converted into fuzzy domain by using input MFs. In a fuzzy domain, rule-base is then applied to obtain a resultant modified fuzzy output (called output MFs). Finally, output image would be generated using centroid defuzzification method from output MFs. A plot between input MFs and output MFs is referred as transformation graph for given rule-base design. FIS design consists of input membership function rule base and output membership function blocks as shown in **Fig. 1**. There are many approaches based on human reasoning applied on image enhancement. These also deal with 'IF-THEN-ELSE' fuzzy rule-based system [3-6]. The neighboring pixel values are antecedent part of the rule in these methods. The enhanced pixel values could be based on a decision by the consequent part of the rule base design. So, a soft decision based on human intuition plays important role in enhancement of the image. But, they suffer from high cost in computations for generating fuzzy rule base. Image enhancement using fuzzy logics involves usually three stages that are also used by Mamdani FIS (see **Fig. 1**). These are image fuzzification, membership function modification, and image defuzzification. This model takes input in discrete form of the image as crisp input. If then feeds to fuzzifier which uses membership function (MF) for converting into fuzzy variable. MFs maps the crisp variables to fuzzy variables and the degree of membership of these variables are calculated. The degree of membership is normalized in the range of 0 to 1. These are image fuzzification, membership function modification and image defuzzification. This model takes input in discrete form of the image as crisp input. If then feeds to fuzzifier which uses membership function (MF) for converting into fuzzy variable. MFs maps the crisp variables to fuzzy variables and the degree of membership of these variables are calculated. The degree of membership is normalized in the range of 0 to 1. The fuzzy variables converted using MFs are then fed into the IF-THEN rule base. Using the fuzzy IF-THEN rule base, fuzzy input variables are mapped to fuzzy output variables. This mapping of fuzzy variables can be partial or overlapped and according to output MFs taken at output side in Mamdani FIS.

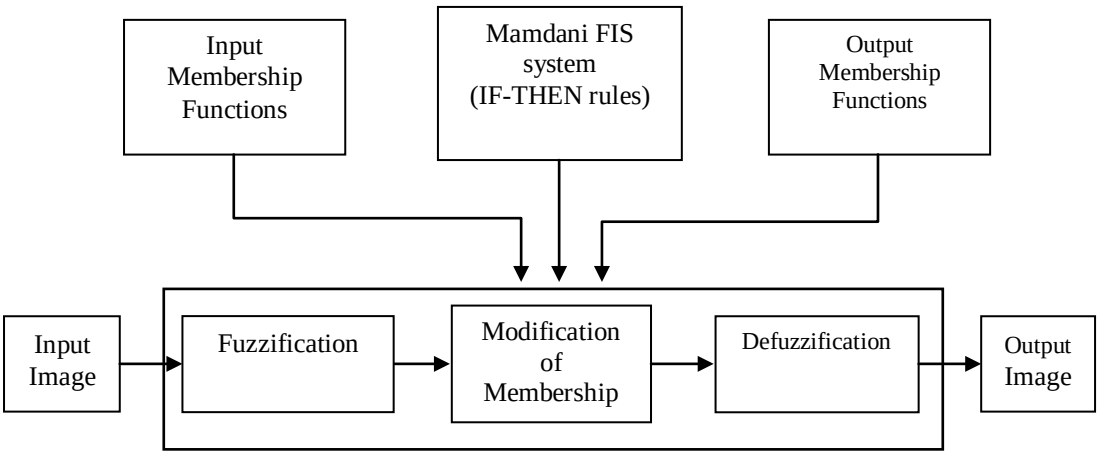


Fig. 1. Block Representation of Mamdani FIS model and Image Enhancement steps

Finally, defuzzifier then converts the fuzzy output into the crisp output. In Mamdani FIS model, different defuzzification techniques can be used to get crisp output using output MFs. Their techniques can be centroid, the centre of sums (COS) and mean of maximum defuzzification. In this paper, we used centroid method of defuzzification.

There are 12 types of MFs according to fuzzy logic theory. Fig 2 shows the triangular (T), Gaussian (G), bell-shaped (B) and sigmoid (S) membership function. As shown in figures, the x-axis range is defined from 0 to Z variable while the y-axis is set to 1. The variable Z varies from application to application. For 8-bit images, the range of x-axis could be between zero and 255 (it is known as pixel or gray level value). The range of y-axis would be always from 0 to 1. It is called grade of membership. There are many membership functions used for fuzzy image enhancement.

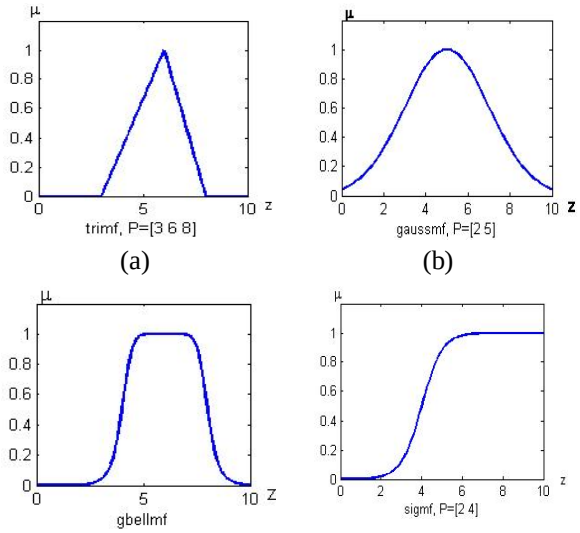


Fig. 2. Types of Membership Functions (MFs)
(a) Triangular (b) Gaussian (c) Bell-shaped (d) Sigmoid

3.1 Definitions and terminology used

We firstly define the following terms and definition, which is necessary to explain the proposed methods and procedure. Domain range of gray scale image is from 0 to 255. This range is partitioned into equidistant and identically shaped membership functions (MFs). A major advantage of this partitioning is that the fuzzy rules obtained from the fixed MFs are always interpretable according to human perception. In this paper, we used same fashion in fuzzy rules for different numbers and different types of MFs. The types of MFs for input variables and output variables used in Mamdani FIS are considered using three membership functions (MFs) such as Triangular, Gaussian and Bell shaped membership function for image contrast enhancement. Their combinations of input variables and output variables used in Mamdani FIS are studied for evaluation of image contrast enhancement. For example, Triangular MFs at input variables and Gaussian MFs at output variables for Mamdani FIS can be used for evaluation of image contrast enhancement. Studies include their combinations and the selection number to partition the gray-scale range for the analysis of contrast image enhancement using Mamdani FIS. Followings are the terms and definitions used in this paper. Assume symbol ‘T’ denotes

the use of Triangular MF, symbol ‘G’ denotes Gaussian MF and ‘B’ denotes Bell-shaped MF. We can make following combinations with Mamdani FIS.

- ‘T-T’ denotes the use of Triangular MFs and Triangular MFs at input and output variables.
- ‘T-G’ denotes the use of Triangular MFs and Gaussian MFs at input and output variables.
- ‘T-B’ denotes the use of Triangular MFs and Bell MFs at input and output variables.
- ‘G-T’ denotes the use of Gaussian MFs and Triangular MFs at input and output variables.
- ‘G-G’ denotes the use of Gaussian MFs and Gaussian MFs at input and output variables.
- ‘G-B’ denotes the use of Gaussian MFs and Bell MFs at input and output variables.
- ‘B-T’ denotes the use of Gaussian MFs and Triangular MFs at input and output variables.
- ‘B-G’ denotes the use of Bell MFs and Gaussian MFs at input and output variables.
- ‘B-B’ denotes the use of Bell MFs and Bell MFs at input and output variables.

The number of MFs considered for input and output variables in Mamdani FIS are 15 20 25 and 30. For example, ‘15 G-G’ denotes the 15 partitioning the gray-scale range (0 to 255) using Gaussian MFs at the both input and output variable in Mamdani FIS. Similarly, ‘20 B-T’ denotes the 20 partitioning the gray-scale range (0 to 255) using Bell MFs at the input and Triangular MFs at output variables in Mamdani FIS respectively. For simplicity, we restrict ourselves to study the combinations as ‘15 T-T’, ‘15 T-G’, ‘15 T-B’, ‘15 G-T’, ‘15 G-G’, ‘15 G-B’, ‘15 B-T’, ‘15 B-G’, ‘15 B-B’ for 15 partitions. Similarly, for 20 partitions, we have ‘20 T-T’, ‘20 T-G’, ‘20 T-B’, ‘20 G-T’, ‘20 G-G’, ‘20 G-B’, ‘20 B-T’, ‘20 B-G’, ‘20 B-B’. For 25 partitions, we get ‘25 T-T’, ‘25 T-G’, ‘25 T-B’, ‘25 G-T’, ‘25 G-G’, ‘25 G-B’, ‘25 B-T’, ‘25 B-G’, ‘25 B-B’. Finally, for 30 partitions, we have ‘30 T-T’, ‘30 T-G’, ‘30 T-B’, ‘30 G-T’, ‘30 G-G’, ‘30 G-B’, ‘30 B-T’, ‘30 B-G’, ‘30 B-B’. By considering above possible combinations, the evaluations have been done into cases according to the same MFs selection and different MFs selection in Mamdani FIS. The same MFs selection includes ‘T-T’, ‘G-G’ and ‘B-B’ with 15, 20, 25, 30 numbers of MFs. Followings are the cases with combinations used with Mamdani FIS.

Case-1: Same MFs Selection in FIS

Case-1A: ‘15 T-T’, ‘15 G-G’, ‘15 B-B’ for 15 partitions.

Case-1B: ‘20 T-T’, ‘20 G-G’, ‘20 B-B’ for 20 partitions.

Case-1C: ‘25 T-T’, ‘25 G-G’, ‘25 B-B’ for 25 partitions.

Case-1D: ‘30 T-T’, ‘30 G-G’, and ‘30 B-B’ for 30 partitions.

Case-2: different MFs Selection in FIS

Case-2A: ‘15 T-G’, ‘15 T-B’, ‘15 G-T’, ‘15 G-B’, ‘15 B-T’, ‘15 B-G’ for 1 partitions.

Case-2B: ‘20 T-G’, ‘20 T-B’, ‘20 G-T’, ‘20 G-B’, ‘20 B-T’, ‘20 B-G’ for 20 partitions.

Case-2C: ‘25 T-G’, ‘25 T-B’, ‘25 G-T’, ‘25 G-B’, ‘25 B-T’, ‘25 B-G’ for 25 partitions..

Case-2D: ‘30 T-G’, ‘30 T-B’, ‘30 G-T’, ‘30 G-B’, ‘30 B-T’, ‘30 B-G’ for 30 partitions.

The graphical representation of combinations for same MFs and different MFs is derived from graphical of ‘15 T-T’, ‘15 G-G’, ‘15 B-B’ as shown in **Fig. 3**. As shown in **Fig. 4** that Triangular, Gaussian, and Bell shaped MFs are partitioned over the range of 0 to 255 for an 8-bit image. Similarly, Case 1B, 1C, and Case 1D can be designed by increasing number of corresponding MFs. Using different MFs on same pixel range (0 to 255), we can have designed for Case-2 in a similar way as shown in **Fig. 4**.

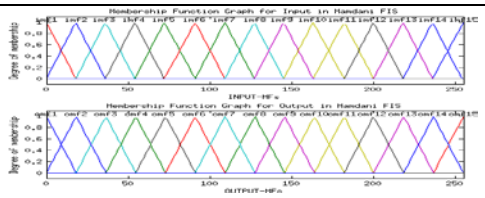
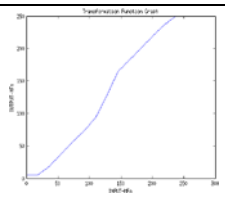
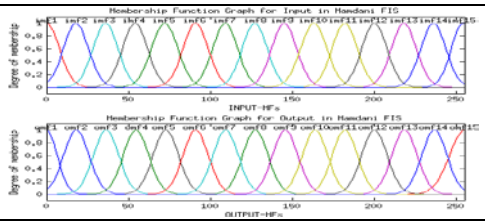
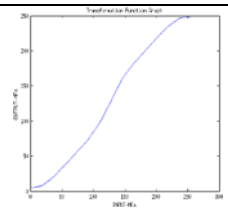
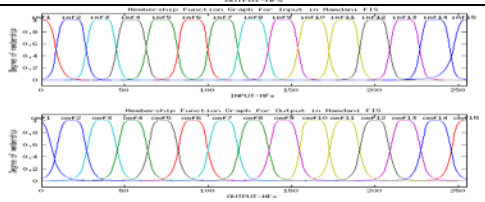
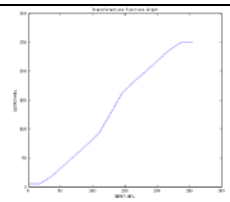
	Membership graph	Transformation graph
1 5 T-T		
15 G-G		
15 B-B		

Fig. 3. Same MFs with 15 partitions

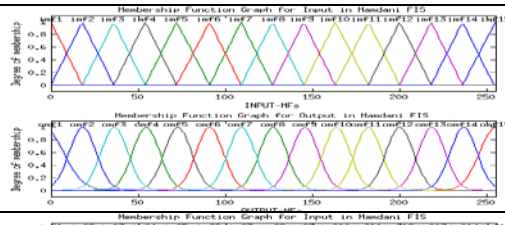
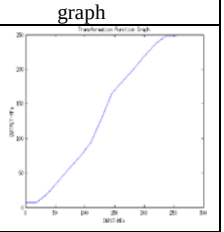
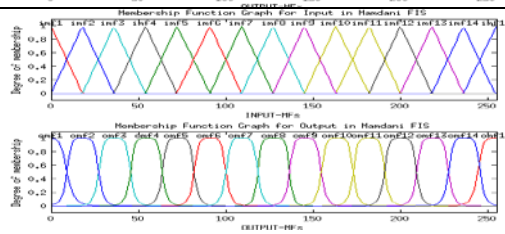
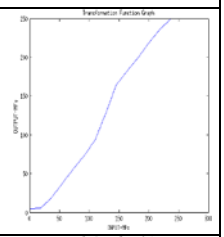
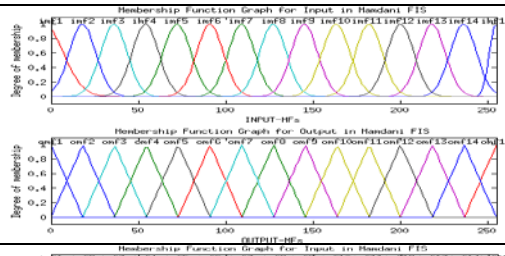
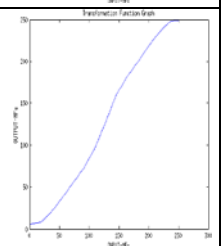
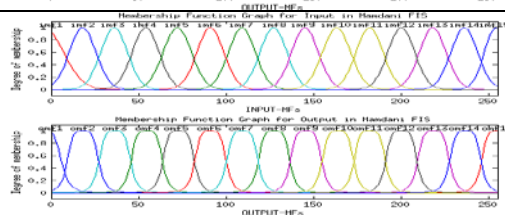
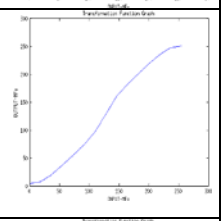
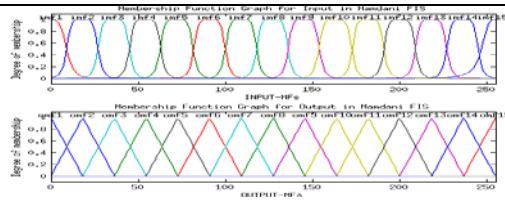
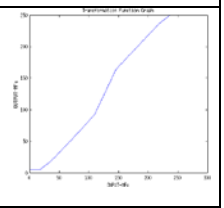
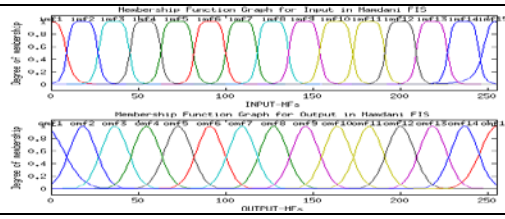
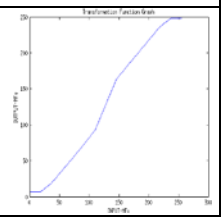
	Membership graph	Transformation graph
15 T-G		
15 T-B		
15 G-T		
15 G-B		
15 B-T		
15 B-G		

Fig. 4. Different MFs with 15 partitions

3.2 Rules base design for Mamdani FIS

Fuzzy IF-Then rules are needed to map the input and output MFs for getting the resultant better fuzzy logic so that when input MFs may apply on a given image, it can convert into fuzzy logic according to input MFs. The IF-THEN rules could be able to take

a decision based on human perception. A modified member function is obtained by applying IF-THEN rules that are equivalent to the output MFs. The obtained fuzzy logic is then reconverted back using centroid defuzzification into an enhanced version of the image. For same IF-THEN rules, input MFs and output MFs selection in Mamdani FIS is important to get improved results. Because the modified membership function would be different using same IF-THEN rule base. According to literature, different fuzzy memberships play an important role to remove uncertainty in the image. Hence, the resultant image could preserve the contrast brightness than the input given image. Using the different combination of MFs using Mamdani FIS, contrast enhancement analysis has been done in this paper for understanding the role of fuzzy logics in fuzzy image enhancements. We show that how powerful is the fuzzy logic tool for contrast enhancement of gray-scale images. A comparison with a classical methods such as histogram equalization and its variants has been done to show the improvements in terms of contrast preservation histogram equalization.

Let us assume that input and output fuzzy sets in FIS are defined by A(X) and A(Y) respectively. An input ($x \in X$) is given to Mamdani FIS. The corresponding output ($y \in Y$) is determined with the help of fuzzy If-Then rule base and logic operation. In Mamdani FIS, we use different MFs partitioning the A(X) and A(Y) fuzzy domains. Let us assume $F_i(x)$ and $F_i(y)$are partitioning fuzzy sets of A(X) and A(Y) respectively. We have n number of IF-Then rules depending on the selection of MFs in inference system. There are single-input, single-output fuzzy rules in the form of such that: R_i : if x is $F_i(x)$ then y is $F_i(y)$.

Let us be given the k number of MFs for A(X) and A(Y), where $k = 1, 2, 3, \ldots, n$. Let $F_k(x)$ and $F_k(y)$ are input MFs partitioning A(X) and output MFs portioning the A(Y) respectively. The algorithm for calculating rule base in Mamdani FIS is shown in **Fig. 5**.

$INPUT$: $F_n(x)$, $F_n(y)$ $x, y, n, C = n/2$
$OUTPUT$: $A\ set\ of\ n\ Single - Input\ Single - Output\ fuzzy\ rule\ base$
$BEGIN$
  R_1: $if\ x\ is\ F_1(x), then\ y\ is\ F_1(y)$
  $FOR\ k = 2\ to\ (n-1)\ do$
    $IF\ k \geq C\ then$
    R_k: $if\ x\ is\ F_k(x), then\ y\ is\ F_{(k-1)}(y)$
    $ELSE$
    $IF\ k \leq C\ then$
    R_k: $if\ x\ is\ F_k(x), then\ y\ is\ F_{(k+1)}(y)$
    $ENDIF$
    $ENDIF$
  $ENDFOR$
  R_n: $if\ x\ is\ F_n(x), then\ y\ is\ F_n(y)$
$RETURN$: $RULES = \{R_1, R_2, R_3, \ldots\ldots, R_n\}$
END

Fig. 5. Algorithm for calculating Fuzzy IF-THEN Rule base

4. PROPOSED APPROACH OF CONTRAST ENHANCEMENT

4.1. A Novel Mamdani FIS

Assume X be the given input image having intensities at pixels as x, where $x \in X$ and appropriate output be the Y having y intensities at pixels, where $y \in Y$. In Mamdani FIS, the followings are the procedure:

Step 1: Calculate the degree of input membership values $F_i(x)$ using given fuzzy membership functions (called input MFs), where $i = 1, 2, 3, \ldots, n$.

Step 2: Calculate the degree of output membership values $F_i(y)$ using given fuzzy membership functions (called output MFs), where $i = 1, 2, 3, \ldots, n$.

Step 3: Obtain the set of n IF-THEN rules for given input and output fuzzy sets obtained in step-1and step-2 above (see our algorithm).

Step 4: Obtain the overall modified output fuzzy set when n IF-THEN rules are applied.

Step 5: Defuzzify the resultant output fuzzy set using centroid method of defuzzification given by

$$Y = \frac{\sum y . F(y)}{\sum F(y)} \tag{1}$$

Where

$Y -$ Represents the crisp output value

$y -$ Represents the centroid of fuzzy values calculated from membership function.

$F(y) -$ Represents the area from membership function bounded by degree of membership and abscissa

4.2 Fuzzy Optimization using fuzzy image quality function

The fuzzy contrast of an image depends on how far an operator would stretch the membership function with respect to the reference point [12]. In this work, the multiple numbers and different membership functions are used. Thus, fuzzy optimization using fuzzy quality proposed in [12] can be applied for getting best membership function combinations from a set of MFs as described in section 3.1. The average value of fuzzy contrast gives the overall intensity of image while the only fuzzy contrast value indicates the spread of the gradient with respect to the reference point. The ratio of fuzzy average contrast to fuzzy contrast is the quality of the image in the fuzzy domain. Following is the algorithm of optimization using fuzzy quality.

Step 1: Input the given image and convert it into the fuzzy domain.

Step 2: In a fuzzy domain, apply one selected multiple membership functions from given set of multiple MFs in section 3.1.

Step 3: Calculate the initial value of fuzzy contrast for given selected MFs and determine fuzzy quality of the image.

Step 4: Find out the change in fuzzy quality of image between selected MFs and previous MFs

Step 5: Repeat the step 2, 3 and 4, until the minimum change in fuzzy quality is obtained.

Step 6: Defuzzify the input image for optimized MFs.

5. Results and Discussions

In this section, the detailed result analysis is presented with our proposed scheme and the existing technique. All the algorithms proposed in this paper are implemented and simulated in MATLAB 7.14 installed in window 7 PC. Followings are the qualitative attributes used for results and analysis.

(i) Peak Signal-To-Noise Ratio (PSNR) [30]:

It is a ratio of the maximum power of a signal and the power of distorting noise.

$$\text{PSNR} = 10\text{Log}_{10}\left(\frac{255}{\sqrt{\text{MSE}}}\right) \tag{2}$$

$$\text{Where, } MSE = \frac{1}{mn}\sum_{i=0}^{(m-1)}\sum_{j=0}^{(n-1)}[f(i,j) - g(i,j)]^2 \tag{3}$$

Here, f represents the original or input image and g represents the enhanced image.

(ii) Index of fuzziness (IOF) [31]

It represents equivocalness present in the image by evaluating the space between its fuzzy attribute levels to nearest ordinary level. Index of fuzziness (IOF) defined as:

$$I(A) = (2/n^k).\ d(A, \tilde{A}) \tag{4}$$

Where the distance, d(A, Ã) denotes between fuzzy set A and its nearest ordinary set Ã.

5.1 Result analysis using fuzzy optimization

In this subsection, simulation results by taking the best case using fuzzy optimization in Mamdani FIS are presented using four different types of input (IMAGE-1, IMAGE-2, IMAGE-3 and IMAGE-4) are as show in Fig. 6. These results are produced based on the selection of best MFs combinations obtained for the fuzzy quality parameter in the optimization algorithm. It indicates that the cases 1D, 2A and 2C are found to be best MFs

in Mamdani FIS for image contrast enhancement. The cases are shown with incremental enhanced of contrast enhancement. It is observed using different cases that as per application requirement, the best-optimized MFs can be selected using our fuzzy optimization algorithm. **Tables 1** and **2** show the PSNR and IOF parameters for obtained results using cases 1D, 2A, and 2C.

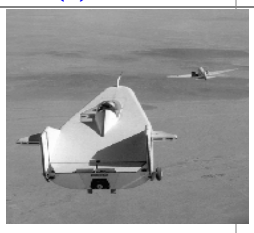
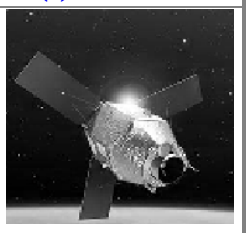
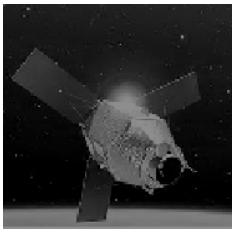
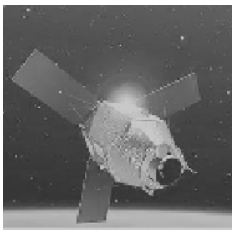
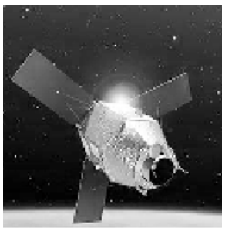
	(a) *IMAGE-1*	(b) *IMAGE-2*	(c) *IMAGE-3*	(d) *IMAGE-4*
Input images				
CASE –ID (25 G-G) Guassian -Guassian MFs				
	PSNR = 37.371 **IOF = 0.01470**	**PSNR = 36.972** **IOF = 0.01523**	**PSNR =36.154** **IOF = 0.1986**	**PSNR =37.103** **IOF = 0.1721**
CASE–2A (15 G-T) Guassian -Trangular MFs				
.	**PSNR = 36.4933** **IOF = 0.01509**	**PSNR = 35.9225** **IOF = 0.01526**	**PSNR = 37.5135** **IOF = 0.2185**	**PSNR = 36.1615** **IOF = 0.1538**
CASE–2C (25 G-T) Gaussian-Bell Shape MFs				
	PSNR = 36.884 **IOF = 0.01797**	**PSNR = 35.982** **IOF = 0.01263**	**PSNR = 37.572** **IOF = 0.2176**	**PSNR = 36.186** **IOF = 0.1483**

Fig. 6. Results using Different Membership Functions(MFs) for (a) IMAGE-1,(b) IMAGE-2, (c) MAGE-3, (d) IMAGE-4.

Table 1. Results for PSNR calculations in increase order for different Cases by optimization algorithm

Input Image types	Gaussian -Gaussian MFs (1D Case: 25G-G)	Gaussian –Triangular (2A Case: 15G-T)	Gaussian -Bell Shape (2C Case: 25G-T)
IMAGE 1	37.371	36.4933	36.884
IMAGE 2	36.972	35.9225	35.982
IMAGE 3	36.154	37.5135	37.572
IMAGE 4	37.103	36.1615	36.186

Table 2. Results for IOF calculations in increase order for different Cases by optimization algorithm

Input Image types	Gaussian -Gaussian MFs (1D Case: 25G-G)	Gaussian –Triangular (2A Case: 15G-T)	Gaussian -Bell Shape (2C Case: 25G-T)
IMAGE 1	0.01470	0.01509	0.01797
IMAGE 2	0.01523	0.01526	0.01263
IMAGE 3	0.1986	0.2185	0.2176
IMAGE 4	0.1721	0.1538	0.1483

5.2 Result analysis with existing techniques

In this subsection, based on results obtained using fuzzy quality-based optimization in the selection of best membership function in the fuzzy domain, case 2C- 25G-T is identified as best possible MFs in Mamdani FIS as shown in the previous section. Here, a comparative analysis is presented with existing fuzzy based techniques for image contrast enhancement. Followings are the algorithms used for comparations: (i) Simple If-Then Fuzzy Rule-based [4], (ii) Fuzzy Distribution based [7], (iii) Fuzzy Hyperbolization based [8], (iv) Brightness Preserving and Non-parametric modified Bi-histogram Equalization (BPNMBHE) [18], and (v) our approach using optimization of MFs.

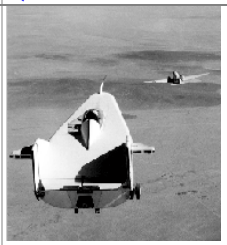
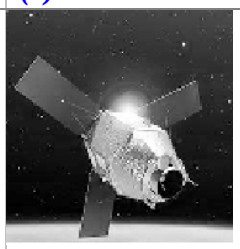
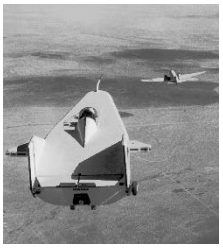
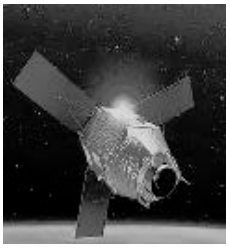
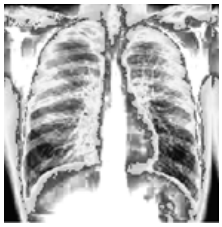
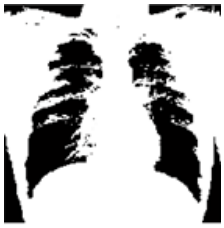
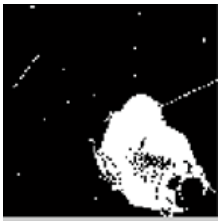
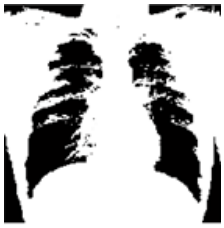
	(a)IMAGE-1	*(bIMAGE-2*	*(c) IMAGE-3*	*(d) IMAGE-4*
Proposed method				
	PSNR = 36.884 **IOF = 0.01797**	**PSNR = 35.982** **IOF = 0.01263**	**PSNR = 37.572** **IOF = 0.2176**	**PSNR = 36.186** **IOF = 0.1483**
BPNMBHE [18]				
	PSNR = 38.3051 **IOF = 0.0117**	**PSNR = 33.996** **IOF = 0.0089**	**PSNR = 35.052** **IOF = 0.0963**	**PSNR = 34.248** **IOF = 0.0483**
Fuzzy IF-THEN Rule-based [4]				
	PSNR = 31.9351 **IOF = 0.12293**	**PSNR = 30.7308** **IOF = 0.184505**	**PSNR = 30.8043** **IOF = 0.14138**	**PSNR = 30.8043** **IOF = 0.14138**
Fuzzy Distributio n based [7]				
.	**PSNR = 29.2057** **IOF =0.13184**	**PSNR = 27.0389** **IOF = 0.0961**	**PSNR = 29.4361** **IOF = 0.031084**	**PSNR = 27.5133** **IOF = 0.188**
Fuzzy Hyperboliz ation based[8]				
	PSNR = 28.0798 **IOF =0.21201**	**PSNR = 24.1215** **IOF = 0.21201**	**PSNR = 27.2927** **IOF = 0.21201**	**PSNR = 25.5671** **IOF = 0.21061**

Fig. 7. Results analysis with proposed method and existing techniques for given images

Table 3. Results for PSNR calculations with Existing Fuzzy based Techniques

Input Image types	Our approach	BPNMBHE [18]	Fuzzy IF-THEN rule-based [4]	Fuzzy Distribution based [7]	Fuzzy Hyperbolization based [8]
IMAGE 1	36.884	38.3051	31.9351	29.2057	28.0798
IMAGE 2	35.982	33.996	30.7308	27.0389	24.1215
IMAGE 3	37.572	35.052	30.8043	29.4361	27.2927
IMAGE 4	36.186	34.248	30.8043	27.5133	25.5671

Table 4. Results for IOF calculations with Existing Fuzzy based Techniques

Input Image types	Our approach	BPNMBHE [18]	Fuzzy IF-THEN rule-based [4]	Fuzzy Distribution based [7]	Fuzzy Hyperbolization based [8]
IMAGE 1	0.01797	0.0117	0.12293	0.13184	0.21201
IMAGE 2	0.01263	0.0089	0.184505	0.0961	0.21201
IMAGE 3	0.2176	0.0963	0.14138	0.031084	0.21201
IMAGE 4	0.1483	0.0483	0.14138	0.188	0.21061

6 Conclusion

This paper proposes new optimization method using multiple membership functions such as 15, 20, 25, and 30 in Mamdani FIS system. It is found that the selection of membership functions in the fuzzy domain while converting and modifying the intensity levels in the image is important as per types of the input image. In this paper, a fuzzy quality parameter is used to obtain the best-fitted MFs that give best-enhanced results of the input images. As per value of PSNR and IOF, it is observed that increment of membership function in FIS gives better contrast enhancement as calculated using fuzzy quality optimization. It is also shown that the Gaussian and Gaussian combination indicates better results. Based on a comparative study of existing fuzzy based techniques, results obtained are more improved and shown to be best visual enhanced images in terms of contrast and clarity. The PSNR and IOF results using our MFs in FIS show the out of performance than that of existing algorithms such as Simple If-then fuzzy Rule-based [4], Fuzzy Distribution based [7], Fuzzy Hyperbolization based [8], Brightness Preserving and Non-parametric modified Bi-histogram Equalization (BPNMBHE) [18]. As a resultant, the motivation is to design a weight based fuzzy neural model, which can take into account of all the combinations of various MFs to capture the best-optimized MFs for Mamdani FIS system.

References

[1] R. C. Gonzalez and R. E. Woods. "Digital Image Processing," 3rd *ed. Prentice Hall*, 2009. Article (CrossRef Link)

[2] Jang, J.-S. R., C. T. Sun, and E. Mizutani, "Neuro-fuzzy and Soft Computing: A Computational Approach to Learning and Machine Intelligence," *Prentice-Hall, Upper Saddle River, NJ,* 1997. Article (CrossRef Link)

[3] Bhutani, K.R., Battou, A., "An application of fuzzy relations to image enhancement," *Pattern Recogn. Lett.* 16(9), 901–909, 1995. Article (CrossRef Link)

[4] Choi, Y., Krishnapuram, R., "A fuzzy-rule-based image enhancement method for medical Applications In Computer-Based Medical Systems," *1995, Proceedings of the Eighth IEEE Symposium on*, 9–10 Jun 1995, pp. 75–80, 1995. Article (CrossRef Link)

[5] Young, S.C., Krishnapuram, R., "A robust approach to image enhancement based on Fuzzy Logic," *In IEEE Trans.* 6(6), 808–825, 1997. Article (CrossRef Link)

[6] Friedman, M., Schneider, M., Kandel, A., "The use of weighted fuzzy expected value (WFEV) in fuzzy expert systems," *Fuzzy Sets Syst.* 31(1), 37–45, 1989. Article (CrossRef Link)

[7] Pal S.K., King R.A., "Image enhancement using smoothing with fuzzy sets," IEEE *Trans. On Syst. Man and Cybern.*, 11(7): 494–501, 1981. Article (CrossRef Link)

[8] Tizhoosh, H.R. and Fochem, M., "Fuzzy histogram hyperbolization for image Enhancement," in *Proceedings of EUFIT 95*, vol.3, Aachen, 1995. Article (CrossRef Link)

[9] Hanmandlu, M., Jha, D., Sharma, R., "Color image enhancement by fuzzy Intensification," *Pattern Recogn. Lett.* 24(1–3), 81–87, 2003. Article (CrossRef Link)

[10] G. Shree Devi and M. Munir Ahamed Rabbani, "Image Contrast Enhancement Using Histogram Equalization with Fuzzy approach on the Neighborhood metrics (FANMHE)," in *Proc. of IEEE WiSPNET 2016*, 2016. Article (CrossRef Link)

[11] Hasikin Khairunnisa, Mat Isa N Ashidi, "Adaptive fuzzy contrast factor Enhancement technique for low contrast and nonuniform illumination Images," *journal of Signa Image and Video Processing*, pp. 1591-1603, vol. 8, 2014. Article (CrossRef Link)

[12] Sasi Gopalan, S. Arathy, "A New Mathematical Model in Image Enhancement Problem," *Procedia Computer Science*, pp. 1786-1793, vol-46, 2015. Article (CrossRef Link)

[13] Russo, F. and Ramponi, G., "Combined FIRE filters for image enhancement," in *Proc. of the Third International IEEE Conference on Fuzzy Systems, Orlando, FL*, pp. 264–267, 1994. Article (CrossRef Link)

[14] H. Deng, X. Sun, M. Liu, C. Ye and X. Zhou, "Image enhancement based on intuitionistic fuzzy sets theory," *IET Image Processing*, vol. 10, no. 10, pp. 701-709, 10 2016. Article (CrossRef Link)

[15] Russo, F., "Fire operators in image processing," *Fuzzy Sets and Systems*, 103, 265–275, 1999. Article (CrossRef Link)

[16] Choi, Y. and Krishnapuram, R., "A robust approach to image enhancement on fuzzy Logic," *IEEE Transaction on Image Processing, 6(6),* 808–825, 1997. Article (CrossRef Link)

[17] Hassanien, A.E. and Amr, B., A, "comparative study on digital mammography enhancement algorithm based on fuzzy set theory," *Studies in Information and Control*, 12(1), 21–31, 2003. Article (CrossRef Link)

[18] Z. Yao, Z. Lai and C. Wang, "Brightness preserving and non-parametric modified bi-histogram equalization for image enhancement," in *Proc. of 2016 12th International Conference on Natural Computation, Fuzzy Systems and Knowledge Discovery (ICNC-FSKD), Changsha, 2016*, pp. 1872-1876, 2016. Article (CrossRef Link)

[19] Jayong Shin, and Rae-Hong, "Histogram-Based Locality-Preserving Contrast Enhancement," *IEEE Signal Processing Letters*, vol. 22, No. 9, Sept. 2015. Article (CrossRef Link)

[20] Schneider, M. and Kandel, A., "Properties of fuzzy expected value and fuzzy expected interval in fuzzy environment," *Fuzzy Sets and Systems, 28*, 1988. Article (CrossRef Link)

[21] Schneider, M. and Craig, M., "On the use of fuzzy sets in histogram equalization," *Fuzzy Sets, and Systems*, 45, 271–278, 1992. Article (CrossRef Link)

[22] Vlachos, I.K., Sergiadis, G.D., "Intuitionistic fuzzy information-applications to pattern Recognition," *Pattern Recogn. Lett.* 28(2), 197–206, 2007. Article (CrossRef Link)

[23] Cheng, H.D.,Chen, J.R., "Automatically determine the membership function based on the maximum entropy principle," *Inf. Sci*. 96(3- 4), 163–182, 1997. Article (CrossRef Link)

[24] Pal, S.K., "A note on the quantitative measure of image enhancement through Fuzziness," *PatternAnal.Mach. Intell. In: IEEE Trans.PAMI* 4(2), 204–208, 1982. Article (CrossRef Link)

[25] Nieradka, G., Butkiewicz, B., "A method for automatic membership function estimation based on fuzzy measures foundations of fuzzy logic and soft computing," *Lecture Notes in computer science*, vol. 4529, pp. 451–460. Springer, Berlin, 2007. Article (CrossRef Link)

[26] Cheng,H.D., Xu,H., "A novel fuzzy logic approach to mammogram contrast enhancement," I*nf. Sci.*, 148(1–4), 167–184, 2002. Article (CrossRef Link)

[27] Vorobel, R., Berehulyak, O., "Gray image contrast enhancement by optimal fuzzy Transformation," *Lecture Notes in Computer Science*, ICAISC 2006, vol. 4029, pp. 860–869, 2006. Article (CrossRef Link)

[28] Li, G., Tong, Y., Xiao, X., "Adaptive fuzzy enhancement algorithm of surface image based on local discrimination via grey entropy," *Procedia Eng.* 15, 1590–1594, 2011. Article (CrossRef Link)

[29] D.H. Rao, P.P.Panduranga, "A Survey on Image Enhancement Techniques: Classical Spatial Filter, Neural Network, Cellular Neural Network, and Fuzzy," in *Proc of Industrial Technology, 2006. ICIT 2006. IEEE International Conference on*, IEEE, 2006. Article (CrossRef Link)

[30] Mamdani, E. H., & Assilian, S., "An experiment in linguistic synthesis with a fuzzy logic Controller," *International Journal of Man-Machine Studies*, 7(1), 1–13, 1975. Article (CrossRef Link)

[31] Takagi, T., & Sugeno, M. "Fuzzy identification of systems and its applications to modeling and control," *IEEE Transactions on Systems, Man and Cybernetics*, 15, 116–132, 1985. Article (CrossRef Link)

[32] Huynh-Thu, Q.; Ghanbari, M., "Scope of validity of PSNR in image/video qulity assessment," *Electronics Letters*, 2008. Article (CrossRef Link)

[33] S. K. Pal, "A Note on the Quantitative Measure of Image Enhancement Through Fuzziness," *IEEE Transactions on Pattern Analysis and Machine Intelligence*. Pami-4, no. 2, March 1982. Article (CrossRef Link)

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