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PERFORMANCE DEPENDENCY ANALYSIS OF FUZZY LOGIC BASED EDGE DETECTION ON MEMBERSHIP FUNCTION

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ABSTRACT

Edge detection aims to mark sharp intensity changes in an image and is a basis for a large number of image analysis and machine vision applications. We implement an edge detection algorithm that uses fuzzy logic. We use three membership functions namely Gaussian, Triangular and Trapezoidal as the separate cases in the fuzzification step of fuzzy logic based Edge Detection Approach. Finally we show the impact of membership function on the final edge detected image based on the number of correct edge pixels detected and number of false edge pixels detected. Finally do the comparison of the results obtained using different membership functions to conclude which membership function is better, based on the efficient edge representation obtained.

Keywords—*Fuzzification, Membership Function, Fuzzy Logic.*

I. INTRODUCTION

Edge is an important feature in an image and carries important information about the objects present in the image. Extraction of edges is known as edge detection. Edge detection aims to localize the boundaries of objects in an image and significantly reduces the amount of data to be processed [9]. Edge detection aims to mark sharp intensity changes in an image and is a basis for a large number of image analysis and machine vision applications.

Fuzzy logic provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information.

There are two types of fuzzy inference system Mamdani type FIS and Sugeno type FIS. Mamdani method is widely accepted for capturing expert knowledge. It allows us to describe the expertise in more intuitive, more human-like manner. However, Mamdani-type FIS entails a substantial computational burden. On the other hand, Sugeno method is computationally efficient and works well with optimization and adaptive techniques, which makes it very attractive in control problems, particularly for dynamic non linear systems.

The membership function is a graphical representation of the magnitude of participation of each input. It associates a weighting with each of the inputs that are processed, define functional overlap between inputs, and ultimately determines an output response. Once the functions are inferred, scaled, and combined, they are defuzzified into a crisp output which drives the system. There are different shapes of membership functions; triangular, trapezoidal, piecewise-linear, Gaussian, bell-shaped, etc.

II. RELATED WORKS

In order to recognize objects, in computer vision, a digital image is divided into multiple segments (sets of pixels). Image segmentation is generally used to locate objects and boundaries in images[7]. ErKiranpreet Kaur, Er Vikram Mutenja and ErInderjeet Singh Gill have proposed a Fuzzy Inference System (FIS) for edge detection [3]. However, they have used threshold value and 16 number of fuzzy rules for detecting edginess.

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Aborisade, D.O proposed the Novel Fuzzy logic Based Edge Detection Technique in which the proposed technique used three linear spatial filters to generate three edge strength values at each pixel of a digital image through spatial convolution process. Decision on whether pixels in focus belong to an edge or non-edge is made in the proposed technique based on the Gaussian membership functions and fuzzy rules. Mamdanidefuzzifier method is employed to produce the final output pixel classification of a given image.

The edge detection method using fuzzy logic proposed by Bhagbhati and Chumidas [5] uses 10 fuzzy rules using 2*2 mask and triangular fuzzification method is applied.Image Edge Detection Using Ant Colony Optimization by Anna Veronica Baterina and Carlos Oppus [6] proposed the method establishes a pheromone matrix that represents the edge information at each pixel based on the routes formed by the ants dispatched on the image.In a Hybrid Approach to Edge Detection using Ant Colony Optimization and Fuzzy Logic [1] uses 3*3 mask and only 6 fuzzy rules are applied and Gaussian method is used for fuzzification. The heuristics information for ants movement is decided by fuzzy logic with simple rules. In this approach Gaussian method is used for the fuzzification of input image.

Our work considers two more membership functions other than Gaussian method, namely triangular and trapezoidal and implemented separately in the fuzzy logic. Finally, we compare the experimental results obtained using different membership functions in fuzzy logic to decide which membership function is better to for edge detection.

III. SYSTEM DESIGN

A. *Design considerations*

For the proper working of this method of finding total correct edge pixels, total edge pixels, and total false pixels it must satisfy following conditions:

1) The input image (colour image) must be converted to gray image then converted to binary image.

This is because when we use the direct conversion of colour image to binary, it may consider any one plane among three planes as input image and then it results in incorrect count of actual edge pixels present in input image. This is tested with small image 12*13 containing red colour background over which small black line which has to be detected. Even though the above condition fails in giving the correct values for required parameters (total number of edge pixels detected, total number of correct edge pixels and total number of false pixels detected), it finally gives the edge detected image based on the membership function used. It is shown in the snapshot 10. [4] discussed about Improved Particle Swarm Optimization. The fuzzy filter based on particle swarm optimization is used to remove the high density image impulse noise, which occur during the transmission, data acquisition and processing. The proposed system has a fuzzy filter which has the parallel fuzzy inference mechanism, fuzzy mean process, and a fuzzy composition process. In particular, by using no-reference Q metric, the particle swarm optimization learning is sufficient to optimize the parameter necessitated by the particle swarm optimization based fuzzy filter, therefore the proposed fuzzy filter can cope with particle situation where the assumption of existence of "ground-truth" reference does not hold. The merging of the particle swarm optimization with the fuzzy filter helps to build an auto tuning mechanism for the fuzzy filter without any prior knowledge regarding the noise and the true image. Thus the reference measures are not need for removing the noise and in restoring the image. The final output image (Restored image) confirm that the fuzzy filter based on particle swarm optimization attain the excellent quality of restored images in term of peak signal-to-noise ratio, mean absolute error and mean square error even when the noise rate is above 0.5 and without having any reference measures.

2) The image must have only the white back ground with the shape outline of one pixel thickness only.

Even though the first condition is satisfied by the image the colour of image background must be white because any other colour background image converted to gray image, the background pixels also considered as edge pixels when converted to binary image. This is tested with small image 12*13 containing red colour background over which small black line which has to be detected. Even though the above condition fails in giving the correct values for required parameters (total number of edge pixels detected, total number of correct edge pixels and total number of false pixels detected), it finally gives the edge detected image based on the membership function used. It is shown in the snapshot 11.

Fuzzy image processing has three main stages: image fuzzification, modification of membership values, and, if necessary, image defuzzification as shown in Fig. 1. The fuzzification and defuzzification steps are due to the fact that we do not possess fuzzy hardware. Therefore, the coding of image data (fuzzification) and decoding of the results (defuzzification) are steps that make possible to process images with fuzzy techniques.

The new fuzzy rule based edge detection system is used by designing a Fuzzy Inference System (FIS) of Mamdani type using MATLAB toolbox. The algorithm detects edges of an input image

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by using a window mask of 2x2 size that slides over the whole image horizontally pixel by pixel. The FIS is implemented by considering four inputs which correspond to four pixels P1, P2, P3 and P4 of the 2*2 mask in Fig-3 and one output variable.

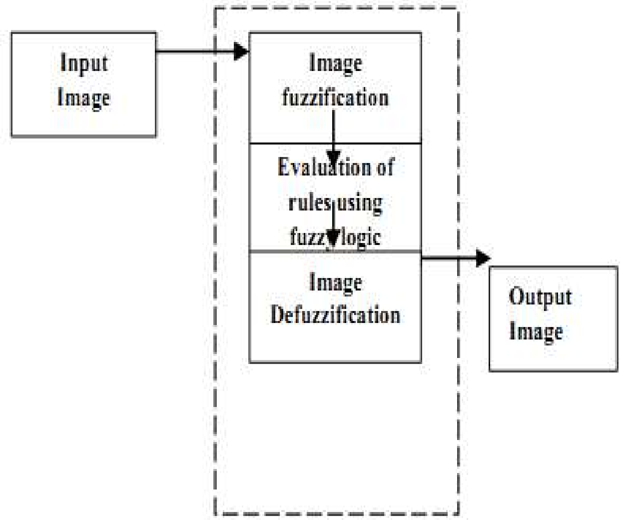

Fig.1. Structure of Fuzzy Image Processing

IV. IMPLEMENTATION

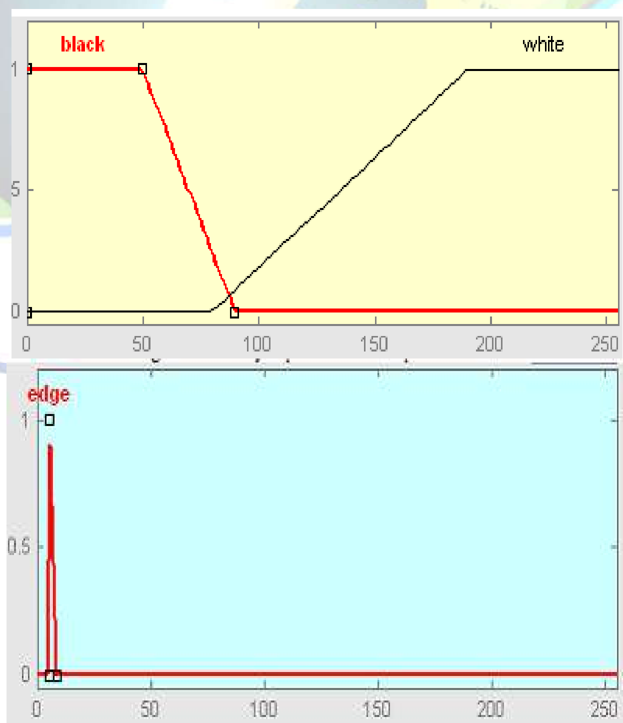

Fig 2: Sample of trapezoidal MF based input with triangular MF based output

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P1 **x(i-1,j-1)**	**P2** **x(i-1,j)**
P3 **x(i,j-1)**	**P4** **x(i,j)**

Fig 3: 2*2 mask

In the first phase of the FIS, the fuzzification of input is performed by defining trapezoidalmembership functions called Black and white separately for each membership function.On evaluation of these two functions, all the image pixels (crisp set) are classified into Black or White fuzzy sets. Once the pixels are fuzzified, in the second phase of the FIS, a rule base is evaluated to get the output. A triangular membership function for the output is defined called as Edge In the rule base of the FIS, 10 numbers of rules have been defined to apply implication on the inputs [1].

The inference rules depend on the weights of 3 neighbors i.e. P1, P2 and P3 and P4 itself, if the weights are degree of Black or degree of White. These weights are combined using AND operator as defined in the rule base. The output of applying implication is again fuzzy. These fuzzy output of all rules are combined into a single fuzzy set by aggregating them with the OR (max) operation. In the final phase of the FIS, the output fuzzy set. Edge is defuzzified to get a crisp set and the desired final output. Herethe defuzzification operation is performed by calculating the centroid. In order to resolve a single crisp value from the aggregated fuzzy output set we calculate the center of the area under the curve. The block diagram of the FIS designed here is depicted in the Figure 1.

1. The rule base used in the FIS comprises the following 10 fuzzy rules for considering the weights of the 3 neighbors P1, P2 and P3 with P4.
2. If P1 is Black and P2 is Black and P3 is Black and P4 is White then P4 is Edge.
3. If P1 is Black and P2 is Black and P3 is White and P4 is White then P4 is Edge
4. If P1 is Black and P2 is White and P3 is Black and P4 is White then P4 is Edge
5. If P1 is White and P2 is Black and P3 is Black and P4 is White then P4 is Edge
6. If P1 is White and P2 is White and P3 is White and P4 is Black then P4 is Edge
7. If P1 is White and P2 is White and P3 is Black and P4 is Black then P4 is Edge
8. If P1 is Black and P2 is White and P3 is White and P4 is Black then P4 is Edge.
9. If P1 is White and P2 is Black and P3 is White and P4 is Black then P4 is Edge
10. If P1 is Black and P2 is Black and P3 is White and P4 is Black then P4 is Edge
11. If P1 is Black and P2 is White and P3 is Black and P4 is Black then P4 is Edge.

V. RESULTS AND DISCUSSION

To make the comparison easier we are considering the images which are having object shape circle in it which of thickness 1 pixel. The results are tabulated as shown in Table form for 5 trials. Fig 4 shows the input image. Results are compared graphically in the fig 5 and 6.

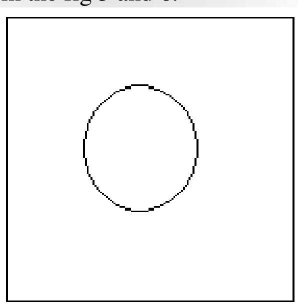

Fig 4: Image containing circle shaped object.

The three membership functions are compared based on the number of edge pixels detected, number of correct edge pixels detected and number of false pixels detected, the method used to find these values must be tested for correctness. We do testing of this method by taking a small image of size 11*12 and displayed the contents or pixels values of the image and manually verified for total edge pixels, correct edge pixels and total false pixels obtained.

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Trial 1			
Input image having circle shaped object of thickness 1 pixel 166 edge pixels	**Membership function**	**Number of correct edge pixels detected**	**Number of false edge pixels detected**
	Triangular	151	26
	Trapezoidal	146	34
	Gaussian	159	18

Trial 2			
Input image having circle shaped object of thickness 1 pixel 166 edge pixels	**Membership function**	**Number of correct edge pixels detected**	**Number of false edge pixels detected**
	Triangular	153	16
	Trapezoidal	147	21
	Gaussian	156	18

Trial 3			
Input image having circle shaped object of thickness 1 pixel 166 edge pixels	**Membership function**	**Number of correct edge pixels detected**	**Number of false edge pixels detected**
	Triangular	156	25
	Trapezoidal	151	33
	Gaussian	153	14

Trial 4			
Input image having circle shaped object of thickness 1 pixel 166 edge pixels	**Membership function**	**Number of correct edge pixels detected**	**Number of false edge pixels detected**
	Triangular	155	19
	Trapezoidal	148	25
	Gaussian	161	16

Trial 5			
Input image having circle shaped object of thickness 1 pixel 166 edge pixels	**Membership function**	**Number of correct edge pixels detected**	**Number of false edge pixels detected**
	Triangular	153	23
	Trapezoidal	151	28
	Gaussian	158	17

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Summary of 5 trials taking the average of results obtained		
Membership Function ↓	**Average Number of correct edge pixels**	**Average Number of false pixels detected**
Triangular MF	153	22
Trapezoidal MF	148	28
Gaussian	157	17

VI. CONCLUSION

We implemented an edge detection algorithm using fuzzy logic. We used different membership functions in fuzzification step such as Gaussian, Triangular and Trapezoidal techniques as separate cases. We compared the experimental results obtained using different membership functions to decide which method is better for better edge detection. We conclude that Gaussian membership function is better to use in edge detection approach using fuzzy logic. Triangular membership function gives better result than the results obtained with trapezoidal membership function. The number of correct edge pixels is more and number of false pixels detected is less in Gaussian membership function compared to triangular and trapezoidal membership functions.

VII. FUTURE WORKS

We conclude that Gaussian is better membership function in edge detection using fuzzy logic. This approach can be extended to decide the impact of membership functions in different applications. The impact of other membership functions other than Gaussian, trapezoidal, triangular can be studied using our approach.

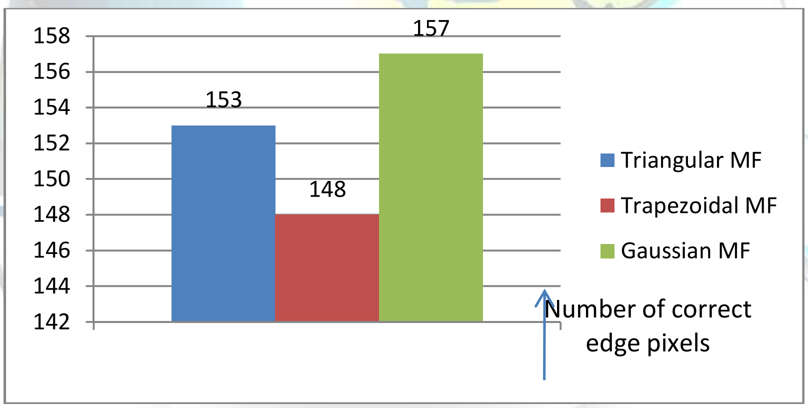

Fig 5: Comparison based on number of correct edge pixels detected

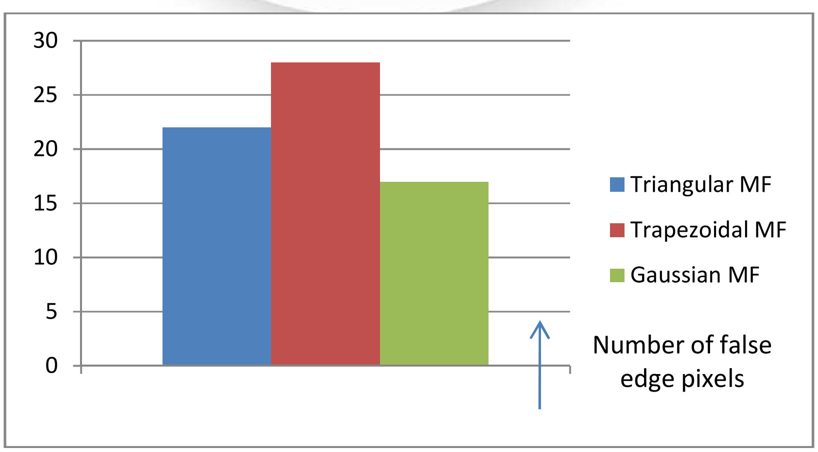

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Fig 6: Comparison based on number of false edge pixels detected

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