Fuzzy Inference System based Edge Detection using Fuzzy Membership Functions

E. Boopathi Kumar
MPhil Research scholar
Department of Information Technology
Bharathiar University
Coimbatore - 46

M. Sundaresan, Ph.D
Professor and Head
Department of Information Technology
Bharathiar University
Coimbatore - 46

ABSTRACT
An edge is the boundary between an object and the background. It indicates the boundary between overlapping objects. Edge detection is one of the most commonly used operation analysis, which is used for enhancing and detecting edges in the image. In the literature review, there are many techniques developed to achieve the edge detection task such as Canny, Sobel, Prewitt, Roberts, Laplacian, Laplacian of Gaussian, Difference of Gaussian etc. This paper presents a fuzzy rule based algorithm, which is capable of detecting edges efficiently from the grayscale images. In this paper, Trapezoidal membership function is used to detect edges. Here, 3*3 masks are proposed and this method has provided better results than the other methods such as Triangular functions 2*2 and 3*3 masks.

Keywords
Edge Detection, Fuzzy Logic, Mamdani Inference System, Membership functions, 3*3 mask and Trapezoidal Membership function.

1. INTRODUCTION
An edge in an image is defined as a boundary or a contour, where an abrupt change occurs in some physical aspect such as gray level value of a given input image [1]. In image, edges carries essential information of an object and edge detection separate dissimilar regions in an image. Edge detection is one of the most important techniques in image processing. Especially, segmentation, registration, identification and recognition are based on edge detection algorithm. Edge detection is a process that detects the presence and location of edges constituted by sharp changes in color and intensity of an image. However all the edge detection methods are categorized under the following two groups, i.e. Gradient based and Laplacian based. Gradient method such as Sobel, Prewitt and Roberts are said to be first order derivative method, which is used to detect the edges by looking maximum and minimum in first derivative of the given image. Laplacian method such as Laplacian, Laplacian of Gaussian and difference of Gaussian are said to be second order derivative methods, searches for zero crossings in second derivative of the given input image.

2. FUZZY LOGIC
Fuzzy logic is a form of knowledge representation which is suitable for notions that cannot be define precisely on their contexts [2]. Fuzzy logic helps us to highlight the edges of an image, which contains fuzzy inference system.

2.1 Fuzzy Inference System (FIS)
Fuzzy Inference System is used to frame capable of certain rules for the given process. It contains five types of editor functions such as Fuzzy Inference System Editor, Membership Function Editor, Rule Editor, Rule Viewer and Surface Viewer. Rule Viewer and Surface Viewer are read only functions. However, the number of inputs may be limited by the available memory of the machine. If the number of inputs is too large, or the number of membership functions is too big, then it may also be difficult to analyze the FIS using the other GUI tools. The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable. The Rule Editor is for editing the list of rules that defines the behavior of the system [3]. In this paper, 3*3 pixel windows are used to scan the input images and fuzzy inference system is developed for detecting edges. The rule base of 28 rules has been applied to the mask to mark the pixel as white, black or edge. The complete process of Fuzzy Inference System is demonstrated in the following figure1.

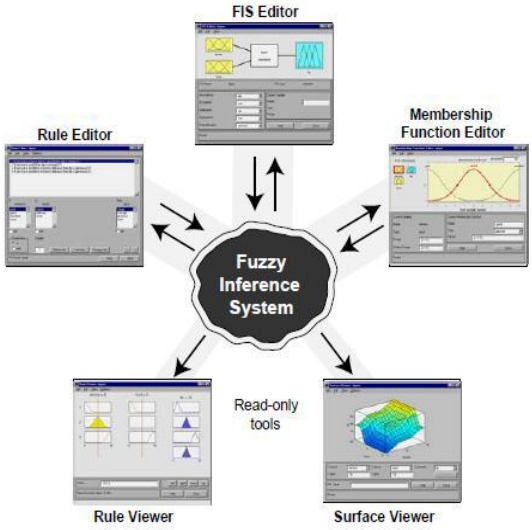


Figure 1: Fuzzy Inference System

3. FUZZY INFERENCE SYSTEM EDITOR
The FIS Editor opens and displays a diagram of the Fuzzy Inference System with the names of each input variable on the left, and those of each output variable on the right. Figure 2 shows the inputs, outputs, and a central fuzzy rule processor. Click one of the variable boxes to make the selected box as the current variable and the box are highlighted in red. Double-click on one of the variables to bring up the Membership Function Editor. Double-click the Fuzzy Rule Processor to bring up the Rule Editor. For 3*3 masks, eight input variables and one output variables are created. 28 rules are applied in Fuzzy Rule Processor [4][5][6].

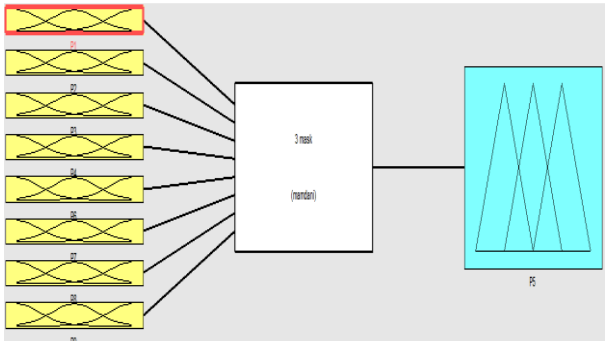


Figure 2: FIS Editor

3.1 3*3 Masks

The 3*3 window mask are framed (Shown in figure 3) with the help of 28 rules and used for scanning the given input image. The designed fuzzy inference system contains eight inputs and one output. The eight inputs are the eight pixel values named as P1, P2, P3, P4, P6, P7, P8 and P9 of the window mask which are used to scan the given image. P5 act as output pixel of the window mask [7][8]. The trapezoidal membership functions are used for both the inputs and output. Two fuzzy sets are used for the input such as Black & White and three fuzzy sets are used for the output such as Black, White and Edge. Based on the rules, the edge is found and result is kept as output. An element in a fuzzy set exposes membership values between 0 and 1. The degree to which an element belongs to given set is called Grade of Membership. Based on membership grade, input variables check the pixels of the image which is black, white or edge and output can be fetched with the base of mentioned fuzzy rules.

P1	P2	P2
P4	P5	P6
P7	P6	P9

Figure 3: 3*3 Mask for scanning

Parameters are set which is based on problem chosen [9]. In trapezoidal, degree of membership and feet parameters are taken for analysis and it can be calculated to compare the resultant and existing image. Fuzzy Rule Editor contains the function of assigning the rules to the membership function. The rules can be differing based on the input types of the membership function. Generally, 2*2 masks are worked on the basis of 16 rules. For example, Rule 1

If (P1 is Black) and (P2 is Black) and (P3 is Black) and (P4 is Black) then (output1 is Black) and 3*3 masks are worked 28 rules based. For example, Rule 1

If (P1 is White) and (P2 is White) and (P3 is White) and (P4 is White) and (P6 is White) and (P7 is Black) and (P8 is Black) and (P9 is Black) then (P5 is Edge)

Likewise, remaining 27 rules are inserted in Rule Editor. In this paper, 3*3 masks are used and 28 rules are followed [10][11].

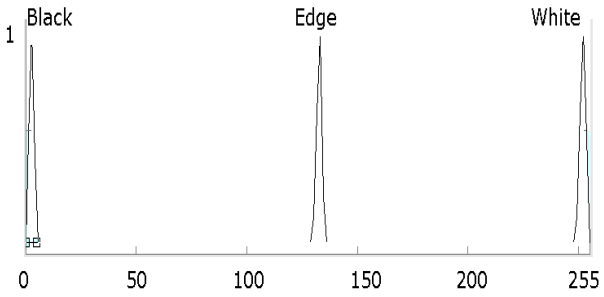


Figure 4: Membership Function Editor

4. Trapezoidal Membership Function

A membership function is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. Trapezoidal membership function is one of the types of fuzzy membership function having flat top and really is just a truncated triangle curve. It fully depends on four scalar parameters such as a, b, c and d given by following equation,

$$f(x;a,b,c,d) = \max(\min(0, x-a, b-a, 1, d-x, d-c, 0))$$

→ Equation (1)

Fuzzy Input								Fuzzy Output
P1	P2	P3	P4	P6	P7	P8	P9	P5
W	W	W	W	W	B	B	B	E
B	B	B	W	W	W	W	W	E
B	W	W	B	W	B	W	W	E
W	W	B	W	B	W	W	B	E
B	B	W	B	W	B	W	W	E
W	W	B	W	B	W	B	B	E
B	W	W	B	W	B	B	W	E
W	B	B	W	B	W	W	B	E
B	B	B	B	W	W	W	W	E
W	W	W	B	W	B	B	B	E
B	B	B	W	B	W	W	W	E
W	W	W	W	B	B	B	B	E
B	B	B	B	B	W	W	W	E
B	B	W	B	W	B	B	W	E
W	W	W	B	B	B	B	B	E
W	B	B	W	B	W	B	B	E
B	W	W	B	W	W	W	W	E
W	W	W	B	W	B	W	W	E
W	W	W	W	W	B	B	W	E
B	B	W	W	W	W	W	W	E
W	W	W	W	W	W	B	B	E
W	W	W	W	B	W	W	B	E
W	W	B	W	B	W	W	W	E
W	B	B	W	W	W	W	W	E
W	B	B	W	B	W	W	W	E
W	W	W	W	B	W	B	B	E
B	B	W	B	W	W	W	W	E
W	W	W	B	W	B	B	W	E

Figure 5: Fuzzy Rules for 3*3 mask.

In this paper, Mamdani's Fuzzy Inference method is implemented with the help of flexible Trapezoidal formula (shown in equation 1). Fuzzy Inference System Editor contains eight input variables p1, p2, p3, p4, p6, p7, p8, p9 and one output variable (p5). Two fuzzy sets are used for the input i.e. Black & White and three fuzzy sets are used for the output. It is a 3*3 mask scanning process which is done by

using eight input variables. P5 variable is chosen for output where the results are based upon fuzzy rules. In membership function editor, the value and degree of membership is denoted and the function trapmf is Chosen.

4.1 Thresholding

Segmentation involves separating an image into regions (or their contours) corresponding to objects. It usually tries to segment regions by identifying common properties. Similarly, it identifies contours by identifying differences between regions (edges). The simplest property that denotes pixels in a region can share is said to be an intensity. So, a natural way to segment such regions is through thresholding, the separation of light and dark regions. Thresholding creates binary images from gray-level ones by turning all pixels below some threshold to zero and all pixels above that threshold to one. In this work, Fuzzy Inference System produce image result by scanning the given input image with the help of 3*3 masks. After that, thresholding is included for the trapezoidal result. Here output of Fuzzy Inference System is taken as input for Thresholding process.

5. RESULTS AND DISCUSSION

Results of Trapezoidal Membership Function are successfully taken and it can be observed that the output that has been generated by the Fuzzy Inference Method has found the edges of the image more distinctly as compared to the image that have been found by triangular edge detection method. By using trapezoidal membership function formula (Refer equation 1), scanning masks are arranged with efficient input rule to detect the edges. P1, P2, P3, P4, P5, P6, P7, P8 and P9 are set as mask elements to scan the given input image and produce the resultant edge as output. Size of the scanning mask for this process is 3*3 pixels window. 3*3 masks is slid over the whole image pixel by pixel row wise and the process continues till the time whole image is scanned for unwanted edge pixels.

Thus, the Fuzzy Rule Based System provides better edge detection and has a flexible set of fuzzy conditions which helps to extract the edges with a very high efficiency. Both input and output processes are fully proposed with Trapezoidal Membership Function. Membership functions produce the result in the form of object layout which is shown in figure 5(c). After that resultant image is taken for finding gradients and it can be scanned in both vertical and horizontal directions. Resultant Trapezoidal image can be taken for edge detection by using following formula [12].

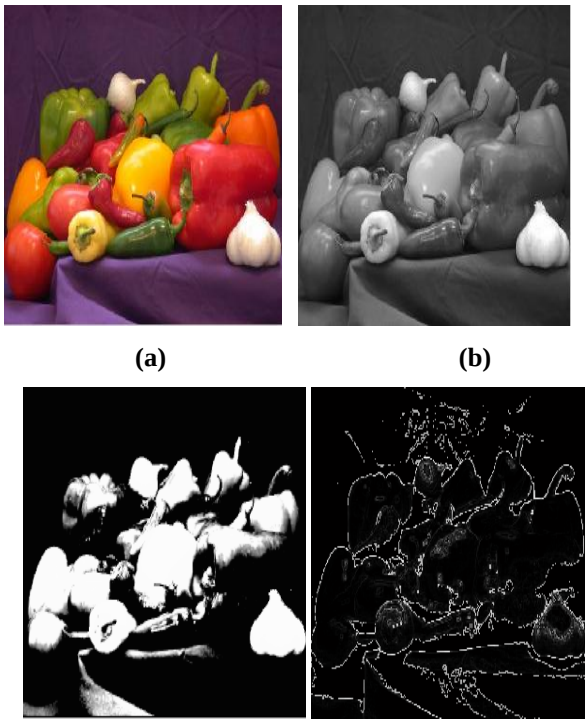
F = [x (i-1, j-1) x (i-1, j) x (i, j-1) x (i, j)] →Equation (2)

(a) **(b)**

(c) **(d)**

Figure 5. (a) Original image (b) Gray Image

(c) Trapezoidal result (d) 3*3 Mask Result



(a) **(b)**

(c) (d)

Figure 6. (a) Original image (b) Gray Image

(c) Trapezoidal result (d) 3*3 Mask Result

6. CONCLUSION

Edge detection method is one of the important techniques in image segmentation, which is used to find out the edges present in the image. The existing edge detection (Triangular Membership Function) needs much more improvement to get the exact and accurate edge result. Fuzzy Logic's Inference System is taken to implement membership function for finding edges in given input images. The proposed method of Fuzzy Inference Systems Trapezoidal Membership Function produces accurate output while compared to existing ones. Further the size of mask can be increased from 2*2 to 3*3 and accordingly more rules can be set and results can be compared with respect to mask size. Results obtained are taken and compared with the help of picture quality measures such as Average difference, Mean square error, Normalized absolute error and Structural content.

7. FUTURE ENHANCEMENT

In the present study, the images for the research work are taken in the form of grey scale which is available at MATLAB toolbox. In future, the research work can be carried out using the color images and also using the real time images by capturing sources like digital camera, web camera, etc,. Have to increase the mask size as 5*5 and applied with different set of rules.

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