An Improved Type-1 Fuzzy Logic Method for Edge Detection

Dharampal **VikramMutneja**

***Abstract*—In this paper, we describe a method for edge detection in gray scale images based on the Sobel operator and fuzzy logic. The goal is to improve a standard method for edge detection in order to obtain better results. The tests were made with an efficient type-1fuzzy inference system (T1FIS) and the results shows that the edges obtained with the fuzzy logic are better and more precise than the basic edge detection method. For defuzzification process, centroid method is used. The proposed type-1 fuzzy logic edge detection method was tested with the benchmark images and synthetic images. We used the merit of pratt measure to illustrate the performance of using type-1 fuzzy logic.**

***Index Terms* —Type-1 fuzzy logic, figure of merit (FOM), membership function, image processing, Sobel Operator, fuzzy inference system (FIS).**

I. Introduction

The principal objective of edge in an image is to define a contour or boundary where ever significant changes occur in some physical aspects such as the gray-level value of an image [1, 2]. For pattern recognition in digital images, edge detection is an intermediate step. There are many ways in digital signal processing to perform edge detection. However, most of them may be categorized as Gradient and Laplacian. The gradient method computes the first derivative of an image and then looks for the maximum and minimum values in the image. The gradient based methods such as Sobel, Prewitt and Roberts detect edges, to explore places where the intensity of first derivative value is more than a defined threshold. The Laplacian methods like Marr-Hilderth perform edge detection by computing the second derivative of the image and then searching for zero crossings to find the edges [3].

This work is an effort for the design of the pre-processing imagetechnique using FIS, which tries to obtain results from the original images. This processismore similar to the form in which the biological brain learns to recognize patterns based on its learning about past experiences.

The main objective of this paper is to improve the standard method for edge detection based on type-1 fuzzy logic and the Sobel operator with aims of finding the correct location of edges in an image.

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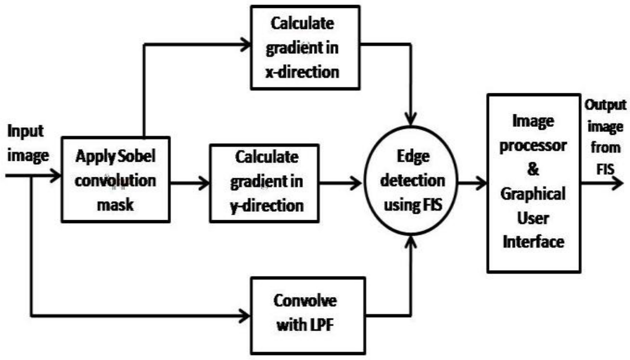

Figure 1. Example of FIS used the pre processing phase for edges detection

This paper shows the performance of the type-1 FIS for digital images are better than the standard methods, in which we used the pre-processing phase as an input to the FIS. The FIS system is used to extract the features from input and construct the input vectors to obtain the output image,highlight all the edges associated with the image, shown in Figure 1 [4].

The rest of the Paper is organized as follows. Section II describes the Sobel operator technique. Section III describes the edge detection by gradient magnitude. Section IV describes the edge detection technique using Type-1 fuzzy logic. Section V explains the technique to evaluate the quality of the detected edges. Section VI presents results with benchmark images to illustrate the achievement of the proposed technique. Finally, section VII offers conclusion of the proposed method.

II. Sobel Operator

In this paper the efficiency of the FIS for edge detection in digital images is shown. For this, it becomes mandatory to obtain the output achieved with a basic edge detector that is Sobel operator [5].

The pre-processing phase, i.e. Sobel operator used on a digital image of gray scalecalculates the gradient of brightness of each pixel in an image, giving the directionof the greater possible change in pixels (black to white). In addition, itcalculates the amount of change inthat direction [15]. The Sobel operator performs a 2D spatial gradient measurement on an image. Typically this operator is used to find the approximateabsolute gradient magnitude of each point in an input gray level image. The sobel operator uses a pair of 3×3 convolution masks, one of them is used to estimate the gradient in the x-direction (column-wise)with the mask shown in (1) and the other estimates the gradient in the y-direction (rows) as shown in (2) [15].

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A convolution mask of Sobel operator is much smaller than the actual image. As a result, the mask is slid over the whole image, manipulating the square of pixel at a time. The Sobel masks are shown below.

$$sobel_x = \begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix} (1)$$

$$sobel_y = \begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix} (2)$$

Here we define M as the source image, g_x andg_y are two images, which at each point contain the horizontal and vertical derivative approximationsof source image M and can be defined by equations (3) and (4) respectively

$$g_x = \sum_{i=1}^{i=3} \sum_{j=1}^{j=3} sobel_{x,i,j} * M_{r+i-2,c+j-2} \quad (3)$$

$$g_y = \sum_{i=1}^{i=3} \sum_{j=1}^{j=3} sobel_{y,i,j} * M_{r+i-2,c+j-2} \quad (4)$$

Sog_x and $g_y$represents the gradient along x-axis and y-axis.

The gradient magnitude g is computed with the equation (5) [6].

$$g = \sqrt{g_x^2 + g_y^2} (5)$$

III. Edge Detection using Gradient Magnitude

We used the Sobel operator to display firstlythe results obtained using only the gradient magnitude. This method has been illustrated with the cameraman image as shown in Figure 1. The gray tone value of each pixel of this image has a value between 0 and 255. Table 1show the original image and the corresponding image generated byg_x and g_y are used for further processing using the fuzzy logic system.

Figure.1.Original Image cameraman (M)

Tone	Cameraman (M)	g_x (SH)	g_y(SV)	g (Edges)
Minimum	0	-898	-936	0
Maximum	255	846	769	937

Table1 Minimum and Maximum values From Cameraman g_x, $g_y$and g.

IV. Edge Detection Approach Using Type-1 Fuzzy Logic

The designed type-1FIShas three inputs, one output and five rules [7]. Figure 2 describes a detailed description of the fuzzy logic approach for edge detection.

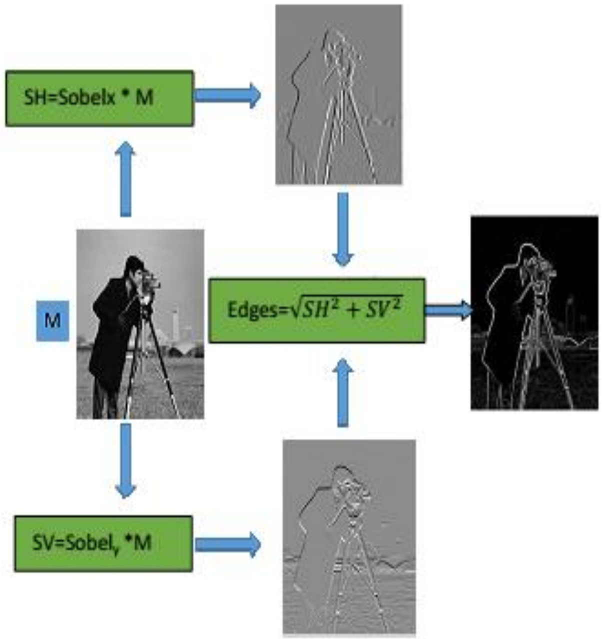

Figure 2. Edge detection approach with Sobel operators and Gradient magnitude

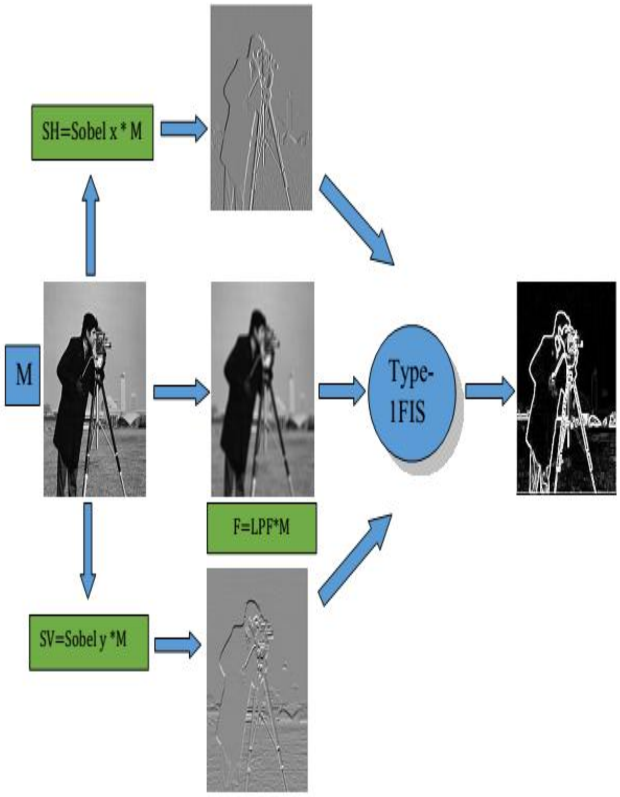

Figure 3. Edge detection approach using Tpye-1 FIS implemented using fuzzy logic tool box.

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A. Inputs for FIS

The designed Type-1 FIS has three inputs, two of them are the gradient with respect to x-axis and y-axis, calculated with equation (3) and (4) respectively which are called as SH and the subsequent, SV variable.

The thirdinput is filter that involvesapplying two masks by convolution to the original image. This is the low pass filter given by the mask ofthe equation (6) which permitsto detect image pixels belonging to regions of the input where the mean gray level is lower. These regions are proportionally more affected by noise, if it is uniformly distributed over the whole image [8].
The aim here is to design anefficient system which makes it easier to detect edges in low contrast region but ignore the edges which are affected by noise.

$$\mathrm{LPF} = \frac{1}{25} * \begin{bmatrix} 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \\ 1 & 1 & 1 & 1 & 1 \end{bmatrix} \qquad (6)$$

The inputs for type-1 Fuzzy inference system are SH=g_x, SV=g_y and the third input is F= LPF*M.

B. Fuzzy Logic Variables

The Gaussian membership functions are used for all the input and output fuzzy variables. After performing several trials with the images using different values of SH and SV,range from -800 to 800, the interval in x-axisisadjusted as shown in figures 4 and 5 for SH and SV respectively; the membership functions used are as follows

LOW: gaussmf (45, 0),
MEDIUM: gaussmf (45,128) and
HIGH: gaussmf: (45, 255).

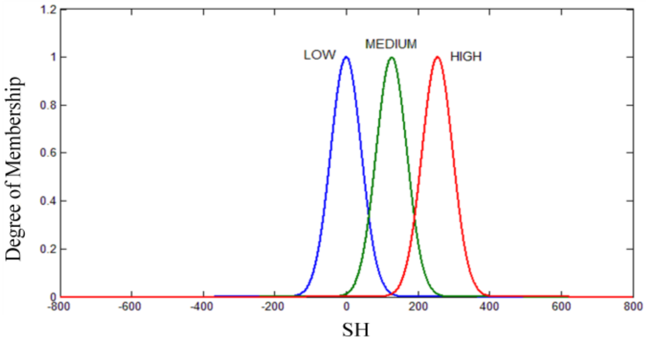

Figure 4. Fuzzy logic input variable SH

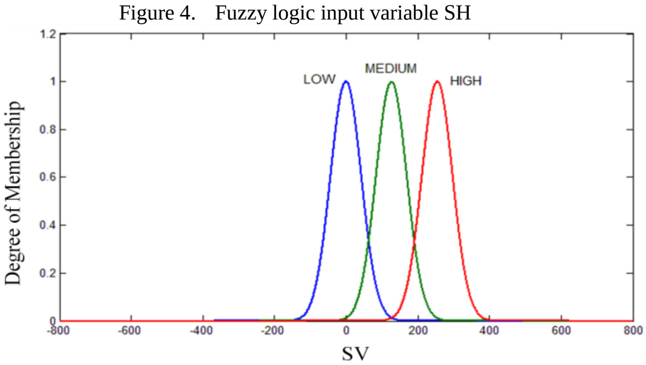

Figure 5. Fuzzy logic input variable SV

In the case of input variable F, the tests produce values in the range from 0 to 255, and thus the range in the x-axis is adjusted as it is shown in figure 6.

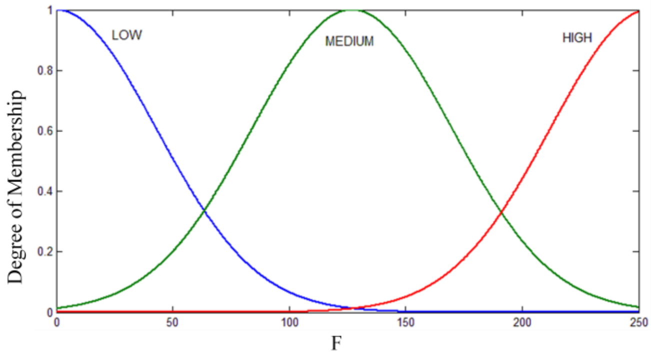

Figure 6. Fuzzy logic input variable F

In figure 7, we show the edges output variable that also adjusted the range between 0 and 255, since it is the range of values required to display the edges of an imagebecause the mean of values is near 0 and the standard deviation is near 255. [9] [10].

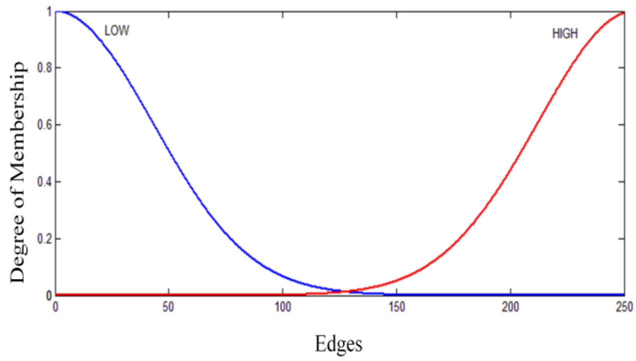

Figure 7. Fuzzy logic output variable Edges

C. The Fuzzy Rules

The FIS has five rules which were defined to estimate a value for each pixel, which allocate the assessment of the input variables and the relation with its neighbourhood so that the output image obtained with the FISdisplays the edges of the image in near black colour (low tone) and edges of the image in colour near white (high tone).

a. If (SH is Low) and (SV is Low) then (Edges is High)
b. If (SH is Medium) and (SV is Medium) then (Edges is Low)
c. If (SH is High) and (SV is High) then (Edges is Low)
d. If (SV is Medium) and (F is Low) then (Edges is High)
e. If (SH is Medium) and (F is Low) then (Edges is Low)

V. Edge Detection Performance Characteristics

In the area of image processing, there are different types of methods to evaluate the detected edges of an image. There are two common errors associated with the edge detectors (1) Failure to localize edge points and (2) Missing valid edge points. The most frequently used techniqueis the figure of merit of Pratt (Figure of Merit; FOM) that balances these two types of errors. This quantitative measure represents the deviation of actual (calculated) edge points from the ideal edge and it is defined in (7).

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$$FOM = \frac{1}{max\,(I_I,I_A)} \sum_{i=1}^{I_A} \frac{1}{1+\propto d_k^2} \qquad (7)$$

Where I_I represents the number of edge points on the ideal edge, I_A is the actual number of detected edge points on the synthetic image, d_k is the distance between the edge of the current pixel and its correct position in the ideal image. $\propto$ (Alpha) is the scaling constant (usually 1/9). To implement this metric, a test image and the ideal edge image that represents I_I is needed.

Figure.8. Images used for the simulation results

Then we apply any edge detector to obtain the value of I_A that represents the number of detected edge points. Now if the result of anequation (7) is 1 or very close to 1, this means that calculated edge I_A is the same or very close to 1, or the I_I. Otherwise, the closer value to 0, this means that there is a high difference between the detected edges and the ideal edge [11] [12].

VI. RESULT& DISCUSSION

The images for testing were obtained from the database of USC-SIPI [13] [14]. We used the standard images; some of the images used for tests can be found in figure 8. For testing the proposed edge detection method, the necessary computer programs were developed in matlab for detecting the edges in the real image. For all the images the gradient was obtained using Sobel operator as in equation (3) and (4) and also the low pass filter is applied as given in equation (6). For T1FLS the gradient and the filtered images are used as inputs. We calculate the FOM of the detected edges and compare the results with some existing techniques of edge detection. The results are shown in the Table 2.

Edge Detector	FOM
T1FLS	**0.8233**
Canny	0.7105
Roberts	0.7104
Sobel	0.7004
Prewitt	0.6996

Table 2Results with different edge detectors.

The developed type-1 fuzzy inference system has found the edges of the gray-scale image more efficiently as compared to the existing techniques. To display the results Graphical User Interface (GUI) has been designed. The sample output compares with the Sobel, Prewitt edge detection method as shown in figure 10.

Sobel	Prewitt	T1FIS

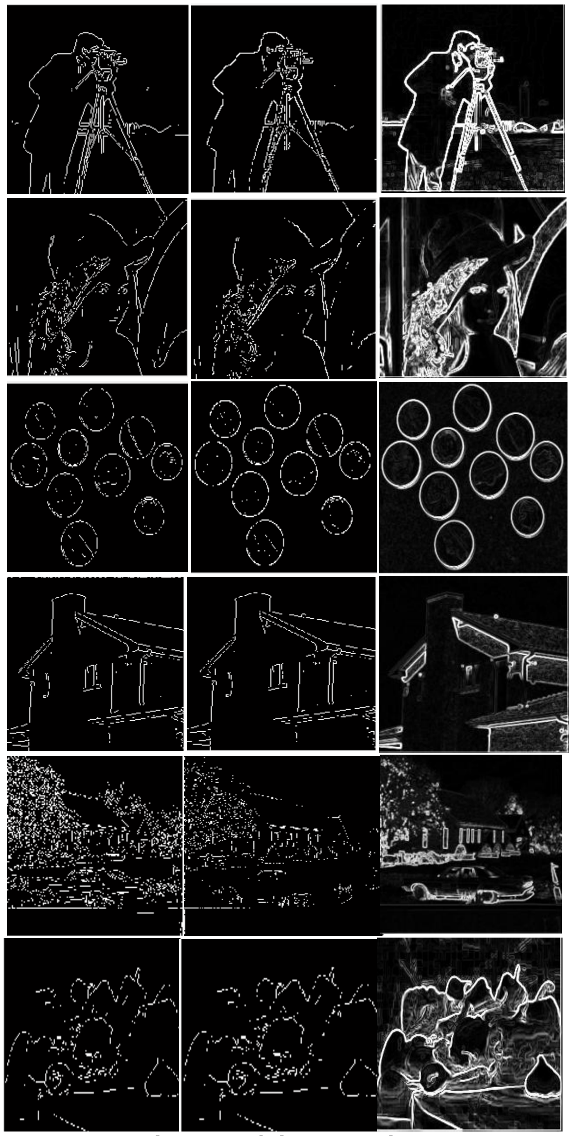

Figure.10. Results Using Sobel, Prewitt and Type-1 Fuzzy Logic System

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VII. CONCLUSION

The experiments presented in this paper shows the efficiency of the FIS system to obtain the better results. As can be noted in Table 2, when comparing the results of different edge detectors, the T1FIS achieved better results in image.In particular, the application of Sobel filters was very useful to define the input vectors for the Type-1 FIS. This method is designed to improve the quality of the standard edge detection methods. Especially the capability of T1FIS to model uncertainty in the Sobel operator and gray tone values for the edges achieved better results because it can preserve more details of the original image.

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