Comparison and Evaluation of Edge Detection using Fuzzy Membership Functions

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Abstract— Digital image processing is widely used by many research oriented fields. Edge detection method is one of the important techniques in image segmentation, which is used to find out exact position of objects in the given image. Edge detection can be achieved by various approaches such as Canny, Prewitt, Sobel, etc. Fuzzy Logic techniques have been used in image understanding applications such as detection of edges, feature extraction, classification, and clustering. Present day's membership function plays vital role in all kind of process. In this paper, edge detection can be achieved through fuzzy logic trapezoidal membership function with two different mask options such as 2x2 and 3x3 and the results are analyzed with the help of picture quality measures such as PSNR (Peak Signal to Noise Ratio) and MSE (Mean Square Error). Proposed method is compared with existing Triangular Membership Function results in the form of 2x2 and 3x3 mask and further results are tabulated based on picture quality measures.

Keywords- *Edge Detection, Fuzzy Logic, Membership functions, Trapezoidal membership function, Triangular membership function, PSNR, MSE.*

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I. INTRODUCTION

Images are produced by a variety of physical devices, including still and video cameras, x-ray devices, electron microscopes, radar, ultrasound. It is used for a variety of purposes that including entertainment, medical, business, industrial, military, civil, security and scientific. The goal in each case is for an observer, human or machine, which is used to extract useful information about the scene being imaged. Digital image processing is a subset of the electronic domain where in the image is converted to an array of small integers, called pixels, representing a physical quantity such as scene radiance, stored in a digital memory and processed by computer or other digital hardware. Digital image processing, either as enhancement for human observers or performing autonomous analysis, offers advantages in cost, speed and flexibility with the rapidly falling price and rising performance of personal computers it has become the dominant method in use. Digital image processing allows one to enhance image features of interest while attenuating detail irrelevant to a given application and then extract useful information about the scene from the enhanced image.

Edge Detection

Edge detection is the name for a set of mathematical methods which aim at identifying points in a digital image at which the image brightness changes sharply or, more formally, has discontinuities. The points at which image brightness changes sharply are typically organized into a set of curved line segments termed edges. The same problem of finding discontinuities in 1D signal is known as step detection and the problem of finding signal discontinuities over time is known as change detection.

Fuzzy Logic

Fuzzy logic starts with and builds on a set of user-supplied human language rules. The fuzzy systems convert these rules to their mathematical equivalents. This simplifies the job of the system designer and the computer, and results in much more accurate representations of the way systems behave in the real world. Additional benefits of fuzzy logic include its simplicity and its flexibility. Fuzzy logic can handle problems with imprecise and incomplete data, and it can model nonlinear functions of arbitrary complexity.

Fuzzy logic models, called fuzzy inference systems consist of a number of conditional "if-then" rules. For the designer who understands the system, these rules are easy to write, and as many rules as necessary can be supplied to describe the system adequately. Fuzzy logic is a form of many-valued logic or probabilistic logic, it deals with reasoning that is approximate rather than fixed and exact. Compared to traditional binary sets fuzzy logic variables may have a truth value that ranges in degree between 0 and 1. Fuzzy logic has been extended to handle the concept of partial truth, where the truth value may range between completely true and completely false.

Fuzzy Inference Systems

There are two types of fuzzy inference systems present in the MATLAB toolbox. Mamdani inference system is taken fore research with the help of Membership functions.

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- Mamdani
- Sugeno

These two types of inference systems vary somewhat in the way outputs are determined. Mamdani's fuzzy inference method is the most commonly seen fuzzy methodology. Mamdani's method was among the first control systems built using fuzzy set theory. It was proposed in 1975 by Ebrahim Mamdani as an attempt to control a steam engine and boiler combination by synthesizing a set of linguistic control rules obtained from experienced human operators. Mamdani's effort was based on Lotfi Zadeh's 1973 paper on fuzzy algorithms for complex systems and decision processes. Although the inference process described in the next few sections differs somewhat from the methods described in the original paper, the basic idea is much the same. Mamdani-type inference, as defined for the toolbox, expects the output membership functions to be fuzzy sets. After the aggregation process, there is a fuzzy set for each output variable that needs defuzzification.

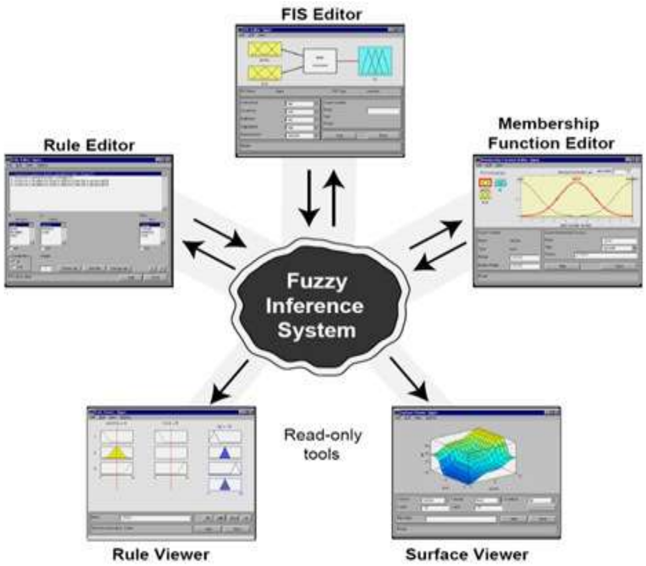

Figure 1: Fuzzy Inference Systems

Membership Functions

A Membership Function (MF) 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. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept. One of the most commonly used examples of a fuzzy set is the set of tall people.

The paper is organized into four sections as follows: Section 2 discuss about the related works carried out in the field of color image segmentation. Section 3 discuss about the modules to be proposed based on Fuzzy logic Trapezoidal Membership Functions. Section 4 highlights discussion on the experiments to be done through Trapezoidal Membership Function by 2x2 masks. Section 5 finally concludes the paper with future enhancement.

II. Related Eorks

Janvi Shah et al presented the fuzzy filter based canny Edge detection technique depends on fuzzy rule based system using 2 X 2 window mask which comprises sixteen fuzzy rules which are used to modify membership value of the image in three fuzzy sets, black, white or edge and this filtered image is given as input to canny edge detection technique. Their approach gives improved results than traditional canny edge detection technique based on Gaussian filter for noisy images. Result of their technique is compared with various standard techniques like Sobel, Prewitt and Canny edge detection.

Abdallah A. Alshennawy, and Ayman A. Aly proposed a novel method based on fuzzy logic reasoning strategy for edge detection in digital images without determining the threshold value. Their proposed approach begins by segmenting the images into regions using floating 3x3 binary matrixes. The edge pixels are mapped to a range of values distinct from each other. The robustness of the proposed method results for different captured images is compared to those obtained with the linear Sobel operator. It gave a permanent effect in the lines smoothness and straightness for the straight lines and good roundness for the curved lines. In the same time the corners get sharper and can be defined easily.

Aijaz Ur Rahman khan, Dr. Kavita Thakur presented an efficient fuzzy inference system for edge detection. Comparison of Sobel, Prewitt and proposed algorithm concludes that the more efficient edge detection is possible with the proposed algorithm. The computational complexity is also reduced. They used 2x2 masks for scanning the image with the help of 16 rules that are framed through Rule editor. Further they stated same method can be applied using 3 x 3 windows or the higher dimension window.

Suryakant, Neetu Kushwaha proposed the implementation of a very simple but efficient fuzzy logic based algorithm to detect the edges of an image without determining the threshold value. Their proposed approach begins by scanning the images using floating 3x3 pixel window. Fuzzy inference system is designed with 8 inputs, which corresponds to 8 pixels of instantaneous scanning matrix, one output that tells whether the pixel under consideration is "black", "white" or "edge" pixel. Rule base comprises of twenty eight rules, which classify the target pixel. The proposed method results for different captured images are compared to those obtained with the linear Sobel operator.

Er. Manpreet Kaur*1, Ms. Sumeet Kaur represented a modified rule based fuzzy logic technique, because fuzzy logic is desirable to convert the uncertainties that exist in many aspects of image processing. Firstly the gradient and standard deviation is calculated and used as input for fuzzy system. The standard deviation and gradient values are used as input for fuzzy system using membership function .Fuzzy if-then else rules are applied to modify the membership to one of Low, medium and high classes. Finally defuzzification is performed.

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The three edge strength values used as fuzzy system inputs were fuzzified using Gaussian membership functions. Fuzzy if then rules are applied to modify the membership to one of low, medium, or high classes. The traditional algorithm like Sobel, Prewitt, LoG are implemented and then the results are compared with modified algorithm and concluded that the proposed technique is to find the more fine edges and reduce the pixels that are not belonging to the edge.

III. METHODOLOGY

Masking is one of the important concepts which are used to scan the input image by pixel by pixel. It is an array based technique contains variables for each array attribute. In this work, 2*2 and 3*3 masks are used by following different rules format. 2*2 masks are in the form of 2 by 2 matrixes contains four input variables (P1, P2, P3 and P4) which form a mask to scan the input image. For 2*2 masks, 16 rules are followed and P4 act as output variable. 3*3 masks are in the form of 3 by 3 matrices having eight input variables (P1, P2, P3, P4, P6, P7, P8 and P9) and one output variable (P5). For 3*3 masks, 28 rules were followed to scan the input image. Here, P5 act as output variable in the masks. 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. 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.

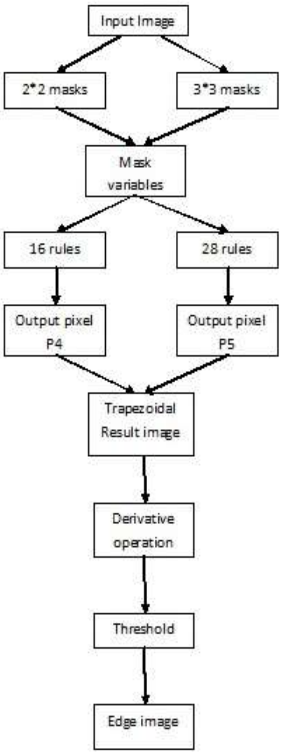

Figure 2: Flowchart of the proposed Fuzzy Edge Detection method

Above figure describes the work flow of proposed system with two different masks (2x2, 3x3) to scan and two different set of rules (16 & 28) to perform mask operation for scanning the given image.

IV. RESULTS & DISCUSSION

The results of membership functions such as trapezoidal and triangular methods are compared in this section. Picture quality measures such as PSNR and MSE are used to compare the results of both membership functions. Results of triangular membership functions 2*2 and 3*3 masks are shown in the following figure 2. Results of trapezoidal membership functions 2*2 and 3*3 masks are shown in the figure 3.

Figure 3: Triangular Membership Functions Results

Here two different trapezoidal masks are used separately and their performances are measured. Among them Trapezoidal 3*3 masks produces low error rate and high percentage of accuracy when compared to the methods using 3*3 and 2*2 of Triangular membership function. In existing work, edge detection have been done by fuzzy's inference system's triangular membership functions. In that, 2*2 and 3*3 mask are examined with the help of various fuzzy inference rules. Different input and output fuzzy sets are declared. In present works, fuzzy's trapezoidal membership function is used and 2*2 and 3*3 masks are generated. The result of both masks are compared to previous works and find that proposed work works well by finding exact edges in the given input image. The analysis can be done through finding edge plot percentage. For calculating the error rate in the proposed work, Mean Square Error and PSNR values are calculated using their formulas.

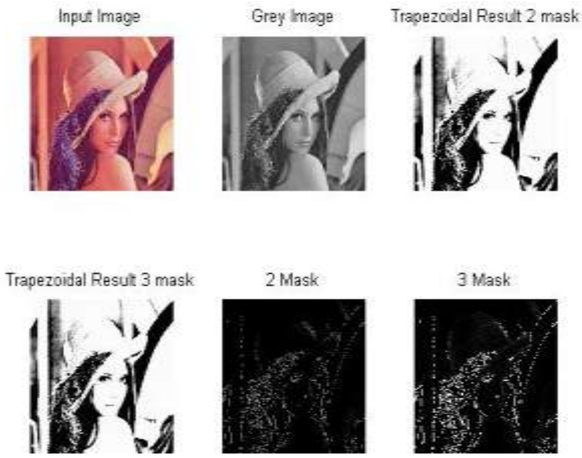

Figure 4: Trapezoidal Membership Functions Results

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Mean Square Error

Mean squared error (MSE) of an estimator measures the average of the squares of the "errors", that is, the difference between the estimator and what is estimated. MSE is a risk function, corresponding to the expected value of the squared error loss or quadratic loss.

Table 1: Mean Square Error

MSE	LENA	VEG	FLAG	PAINT	FLOWER
TRAP 2 M	*505.38*	261.74	363.94	964.14	453.20
TRI 2 M	*527.13*	305.71	347.13	902.23	402.63
TRAP 3 M	*777.56*	619.28	769.13	716.59	646.10
TRI 3 M	*794.37*	689.76	810.97	835.28	787.96

Table 1 show the analysis of Mean square error, one of the best picture quality measures which is applied for both Trapezoidal and Triangle membership functions results by means of two different set of masks 2x2 and 3x3. Membership functions are tested with five different image sets and it shows that Trapezoidal 3*3 masks results produce low error rate while compared to other three different mask results. Graph for table 1 values are plotted in figure 5. It states that 2x2 mask MSE results are differ from 3x3 mask MSE results for both membership functions.

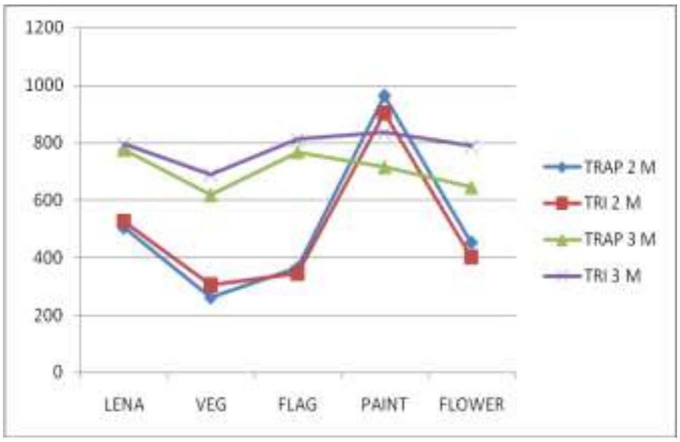

Figure 5: Mean Square Error

Peak Signal to Noise Ratio

Peak signal-to-noise ratio, often abbreviated PSNR, is an engineering term for the ratio between the maximum possible power of a signal and the power of corrupting noise that affects the fidelity of its representation. Because many signals have a very wide dynamic range, PSNR is usually expressed in terms of the logarithmic decibel scale which gives effective results.

Table 2: Peak Signal to Noise Ratio

PSNR	LENA	VEG	FLAG	PAINT	FLOWER
TRAP 2 M	21.09	23.95	30.07	18.28	21.56
TRI 2 M	20.91	23.27	22.72	16.94	16.63
TRAP 3 M	29.23	27.36	25.84	27.46	22.73
TRI 3 M	19.13	19.74	19.04	18.91	19.16

The resultant values of Peak Signal to Noise Ratio of different set of images tested are tabulated in table 2. Graph for tabulated values are shown in figure 5. Graph values represents that the result values produced by 2x2 mask of both membership functions have equal ratios and 3x3 mask of both membership functions have totally different set of ratios. Finally, Trapezoidal membership functions results of 2x2 and 3x3 masks have much clarity values while compared to existing method.

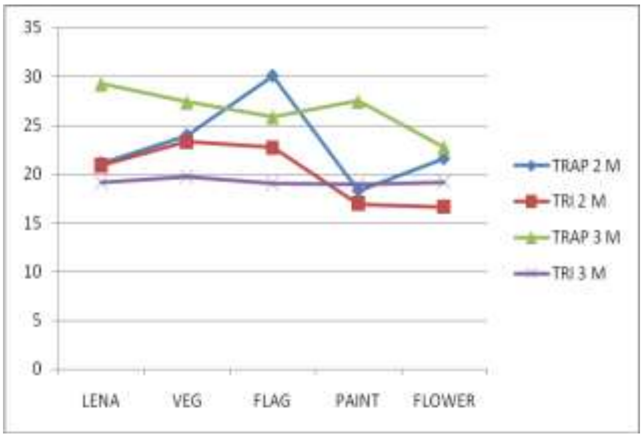

Figure 6: Peak Signal to Noise Ratio

V. CONCLUSION

The main objective of this work is to perform Edge detection using Fuzzy logic Trapezoidal membership function and to obtain the better result when compared with other methods such as Triangular membership functions 2*2 and 3*3 masks. Two different masks such as 2*2 and 3*3 are proposed in trapezoidal membership function and the results are compared with existing triangular membership function method. The scanned results from trapezoidal masks are carried out to further process such as derivative and thresholding. The final edge results of Trapezoidal 2*2 and 3*3 masks are compared with Triangular 2*2 and 3*3 masks and the results using Trapezoidal membership function produce better clarity results on variety of input images taken.

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