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An Optimum Fuzzy Logic Approach For Edge Detection In Digital Images

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Abstract—**Various kinds of images and pictures are required as sources of information for analysis and interpretation. In this paper an efficient edge detection algorithm has been proposed using fuzzy if-then rules. Fuzzy logic is an efficient operator used to deal with uncertain data. The proposed method works by segmenting the edge pixels and background pixels. The algorithm uses 3x3 window to process the image and depending upon the neighborhood information decides whether the input pixel is an edge pixel or not. The membership functions black & white are used to calculate the degree to what extent an input pixel is black & white respectively and the output membership function 'edge' is used to restore the edge pixels.**

Keywords- Edge detection, fuzzy logic, image processing, membership functions.

I. INTRODUCTION

Images processing algorithms are designed to handle different problem domains. Image-based instrumentation is widely used in industrial applications, especially, in quality control and automation. Edge detection is a very important and fundamental task in image-processing.

Edge detection is a terminology in electronic vision, particularly in the areas of feature extraction, to refer to algorithms which aim at identifying points in a digital image at which the image brightness changes sharply or more formally has discontinuities. The goal of edge detection is to locate the pixels in the image that correspond to the edges of the objects seen in the image. This is usually done with a first and/or second derivative measurement following by a comparison with threshold which marks the pixel as either belonging to an edge or not. The result is a binary image which contains only the detected edge pixels. The purpose of detecting sharp changes in image brightness is to capture important events and changes in properties of the world. Discontinuities in image brightness are likely to correspond to discontinuities in depth, discontinuities in surface orientation, and changes in material properties or variations in scene illumination.

Image edge is the boundaries among backgrounds and target objects. Some disadvantageous factors usually lead to speckle noise and the fuzziness of boundaries in images acquired by CCD camera, so it makes edge detection complicated. Therefore accurate edge detection is required for the blurry and noisy images.

So far, a variety of edge detection techniques have been presented. However, most edge detectors are sensitive to noise, including the conventional methods such as Sobel, Prewitt and so on. About this issue, many approaches of edge detection based on neural network [2], genetic algorithm

[3], and wavelet theory [4] have been presented. In addition, due to the fuzziness of noise image edge, many authors adopt fuzzy reasoning in order to extract edge. For example, Fabrizio Russo presented method on edge detection based on fuzzy reasoning in noisy images [5]. Some improved edge detection algorithms on fuzzy enhancement [6]-[8] are based on the fuzzy edge detection algorithm [9] presented by Pal and King.

This paper presents an efficient edge detection algorithm based on fuzzy theory. The paper is organized as follows: Section II describes the proposed algorithm, section III shows the experimental results using various standard images, and section IV reports conclusion.

II. PROPOSED ALGORITHM

In this paper, a fuzzy logic based reasoning strategy is proposed for detecting edges in an image without finding the threshold value. Fuzzy logic represents a good mathematical framework to deal with uncertainty of information. Fuzzy image processing is the collection of all approaches that understand, represent and process the images, their segments and features as fuzzy sets. The representation and processing depend on the selected fuzzy technique and on the problem to be solved.

Fuzzy image processing is a three step process viz. fuzzification, membership function modification and defuzzification. The fuzzification step transforms the gray level pixel values from the original image into fuzzy values. The membership functions are then modified to get the best results. The fuzzy values are then again transformed into output gray level values to display the output image.

A. MEMBERSHIP FUNCTIONS

In the proposed technique, a 3x3 window is slided over the entire image. The pixel values within the window are applied as input variables to the fuzzy inference system. The membership functions for the input pixels are defined as ‘black’ and ‘white’. The membership functions adopted for input variables associated to the linguistic variables black and white are shaped as trapezoidal functions as shown below:

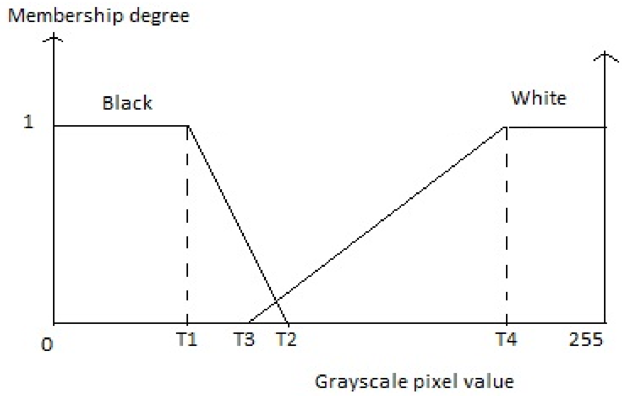


Fig 1. Membership functions black & white

The membership function black & white are given by the equations belo:

$$F(black) \quad \begin{cases} = 1; \text{ if } D < T1 \\ = 0 ; \text{ if } D > T2 \\ = (D - T1)/(T2 - T1); \text{ otherwise} \end{cases}$$

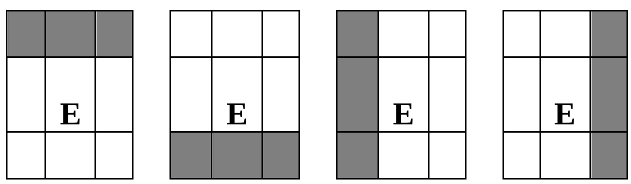
$$F(white) \quad \begin{cases} = 1; \text{ if } D < T1 \\ = 0 ; \text{ if } D > T2 \\ = (D - T3)/(T4 - T3); \text{ otherwise} \end{cases}$$

The fuzzy if-then rules are then applied to check whether the center pixel is an edge pixel or a background pixel. The fuzzy if-then rules are implemented using min operator.

The Sugeno method is used as the defuzzification process. So the output linguistic variable ‘black’, ‘edge’ and ‘white’ are assigned the constant values as 5, 135 and 250 respectively.

B. THE FUZZY IF-THEN RULES

The fuzzy inference rules depend on the weight of the eight neighbor pixels in 3x3 square window. The purpose of the rules is to calculate the degree up to which a given pixel is black or white. The fuzzy rules when fired are capable of detecting edges in various directions.
A total of twelve fuzzy rules are implemented in order to detect the edges in various directions.



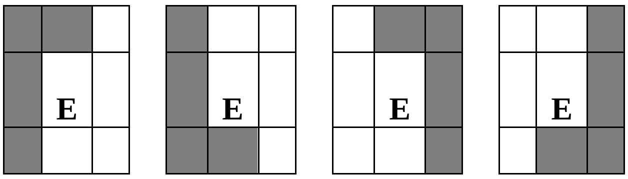
Rule 1 Rule 2 Rule 3 Rule 4

Rule 1: If {(i-1, j-1) & (i-1, j) & (i-1, j+1)} are blacks
If {(i, j-1) & (i, j) & (i, j+1)} are whites
If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are whites
Then checked pixel is edge.

Rule 2: If {(i-1, j-1) & (i-1, j) & (i-1, j+1)} are whites
If {(i, j-1) & (i, j) & (i, j+1)} are whites
If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are blacks
Then checked pixel is edge.

Rule 3: If {(i-1, j-1) & (i, j-1) & (i+1, j-1)} are blacks
If {(i-1, j) & (i, j) & (i+1, j)} are whites
If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are whites
Then checked pixel is edge.

Rule 4: If {(i-1, j-1) & (i, j-1) & (i+1, j-1)} are whites
If {(i-1, j) & (i, j) & (i+1, j)} are whites
If {(i-1, j+1) & (i, j+1) & (i+1, j+1)} are blacks
Then checked pixel is edge.



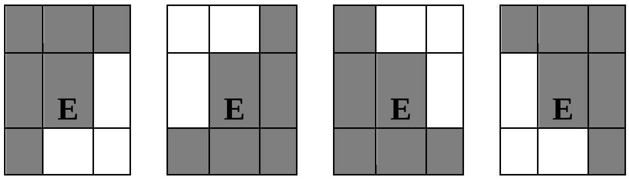
Rule 5 Rule 6 Rule 7 Rules 8

Rule 5: If {(i-1, j) & (i-1, j-1) & (i, j-1) & (i+1, j-1)} are blacks
If {(i-1, j+1) & (i, j+1) & (i+1, j+1) &(i+1, j)} are whites
If (i, j) is white
Then checked pixel is edge.

Rule 6: If {(i-1, j-1)&(i, j-1) & (i+1, j-1) & (i+1, j)} are blacks
If {(i-1, j) & (i-1, j+1) & (i, j+1) & (i+1, j+1)} whites
If (i, j) is white
Then checked pixel is edge.

Rule 7: If {(i-1, j)&(i-1, j+1)&(i, j+1)&(i+1, j+1)} are blacks
If {(i-1, j-1) & (i, j-1) & (i+1, j-1) & (i+1, j)} are whites
If (i, j) is white
Then checked pixel is edge.

Rule 8: If {(i-1, j)&(i-1, j-1)&(i, j-1) & (i+1, j-1)} are whites
If {(i-1, j+1) & [i, j+1] & (i+1, j+1) & (i+1, j)} are blacks
If (i, j) is white
Then checked pixel is edge.



Rule 9 Rule 10 Rule 11 Rules 12

Rule 9: If {(i-1, j-1) & (i-1, j) & (i-1, j+1)} are blacks
If {(i, j-1) & (i, j) & (i+1, j-1)} are blacks
If { (i, j+1) & (i+1, j) & (i+1, j+1)} are whites
Then checked pixel is edge

Rule 10: If {(i-1, j-1) & (i-1, j) & (i, j-1)} are whites
If {(i-1, j+1) & (i, j) & (i, j+1)} are blacks
If {(i+1, j-1) & (i+1, j) & (i+1, j+1)} are blacks
Then checked pixel is edge

Rule 11: If {(i-1, j-1) & (i, j-1) & (i+1, j-1)} are blacks
If {(i, j) & (i+1, j) & (i+1, j+1)} are blacks
If {(i-1, j) & (i-1, j+1) & (i, j+1)} are whites
Then checked pixel is edge

Rule 12: If {(i-1, j-1) & (i-1, j) & (i-1, j+1)} are blacks

If {(i, j-1) & (i+1, j-1) & (i+1, j)} are whites
If {(i, j) & (i, j+1) & (i+1, j+1)} are blacks
Then checked pixel is edge

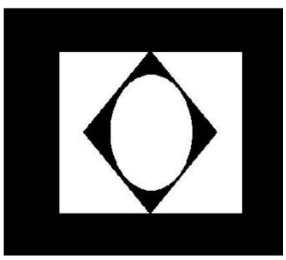
The following steps are performed while executing fuzzy edge detection:

Step 1: Input for all the pixels in 3x3 window are fuzzified into various FS with membership functions black & white.
Step 2: Firing strength is calculated using fuzzy MIN operator.
Step 3: Fuzzy rules are fired for each crisp input.
Step 4: Aggregate resultant output for all the rules is achieved using MAX operator.
Step 5: Defuzzification is performed using centroid method.

III. EXPERIMENTAL RESULTS

The proposed algorithm is tested for various standard images in MATLAB environment. It is found that the fuzzy inference based technique is able to detect very fine edges. The modified version of edge map has less noise and less edge corruption. We observe that the Sobel operator with threshold automatically estimated from image's binary value does not allow edges to be detected in the regions of low contrast which results in two edges being detected (double edges). The FIS system, in turn, allows edges to be detected even in the low contrast regions. This is due to the different treatment given by the fuzzy rules to the regions with different contrast levels, and to the rule established to avoid including in the output image pixels not belonging to continuous lines.

When Sobel operator is applied to an image, a disconnected edge appeared on the left side. The adoption of fuzzy rules specifically established to avoid double edges results in obtaining an image with single edges when the FIS system is applied to the same image. It is gave a permanent effect in the lines smoothness and straightness.



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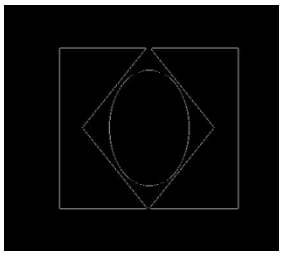
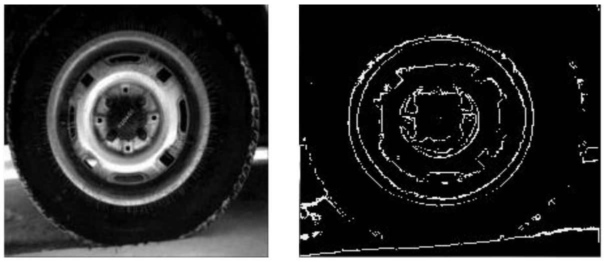


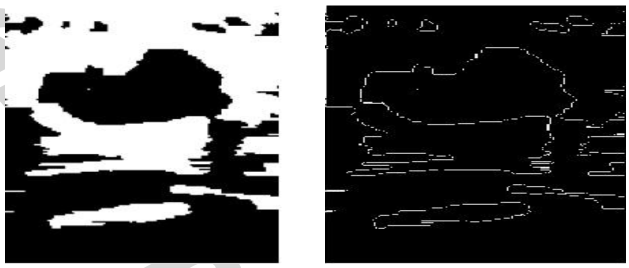
(a) (b)

Fig 2 (a) Original binary pattern (b) Edge pattern



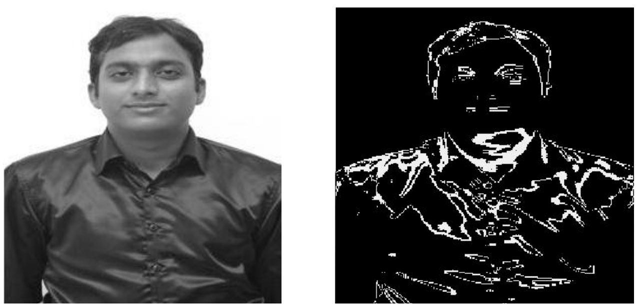
(a) (b)

Fig 3 (a) Captured Wheel image (b) Edge detected image



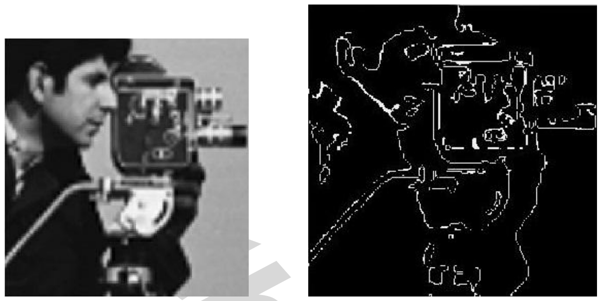
(a) (b)

Fig 4 (a) Breast tumor ultrasound image (b) Edge detected image



(a) (b)

Fig 5. (a) Original captured my image
(b) Edge detected image



(a) (b)

Fig 6. (a) Cameraman image
(b) Edge detected image

IV. CONCLUSION

This paper presents a very simple and efficient fuzzy logic based edge detector. Fuzzy logic is an optimum approach to deal with uncertainties in an image. Most of the edge detection techniques are not able to detect the edges perfectly. Because of the uncertainties that exist in many aspects of image processing, fuzzy processing is desirable. These uncertainties include additive and non-additive noise in low level image processing, imprecision in the assumptions underlying the algorithms, and ambiguities in interpretation during high level image processing. For the common process of edge detection usually models edges as intensity ridges. Nevertheless, in practice this assumption only holds approximately, leading to some of the deficiencies of these algorithms. Fuzzy image processing is a powerful tool form formulation of expert knowledge edge and the combination of imprecise information from different sources.

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