FUZZY LOGIC BASED EDGE DETECTION FOR INFRARED LANDMINE IMAGES

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Abstract

In this paper, we discuss a simple but an efficient fuzzy reasoning based edge detection as a feature extraction technique for an automated landmine detection application. Edges form the boundaries of the various regions in an image. Features such as corners, lines and curves can be extracted from the detected edges which characterize the structure of various objects present in the image. The image is scanned using a 2X2 windowing mask. The four inputs of the designed fuzzy inference system are represented by the 4 pixels in the windowing mask. The rules are applied on the mask and the output is mapped to the defined Sugeno singleton set and the processed pixel in the input image is checked for the occurrence of an edge pixel. The proposed algorithm is tested on the acquired infrared landmine images and the performance is compared with some of the standard edge detection methods. The proposed algorithm shows improved results.

Key words: edge, feature, fuzzy, landmine, mask

I.INTRODUCTION

There is an increased need for automatic processing of digital images [1] in many computer vision applications ranging from commercial to defense in order to recognize an object. The most important aspect in such pattern recognition problems is to extract the relevant features of the various objects of interest present in the scene. Instead of processing the entire image which contains a lot of redundant data, the essential features are extracted from the input image by filtering out the less relevant data and are used in pattern recognition applications, for example: road extraction.

Features could be based on certain boundaries, contour, color, intensity or texture pattern, geometric shape or any other pattern. They provide an easier way to analyze and represent an image. Edge is an important feature defining the contour of an object present in a scene. Therefore, edge detection is an essential operation in image processing and it also offers the advantage of dimensionality reduction thus saving processing time. However, it is not always possible to obtain ideal edges from real life images of moderate complexity. Application of the existing standard edge detection methods result in a degraded performance for blurred or nosiy images and they are ineffective in controlling noise [2]. As there is no availability of a specific method suitable to detect edges of all images, different methods are used for detecting the edges from different kinds of images on a heuristic approach. Hence it remains an active research area and new approaches are continually evolving. In this paper, fuzzy logic based approach for edge detection is proposed to identify the edges in the infrared landmine images acquired from a clutter rich environment. The pixel values of the image are fuzzified based on the defined membership functions. A 2X2 sliding window mask is defined. Fuzzy rule matrix is framed based on expert's knowledge and the rules are applied on the fuzzy sets in such a way that the fuzzy system's output is high only for the edge pixels in the image. Zero-order Takagi-Sugeno output function is used and the output is a singleton value.

The paper is organized as follows. Smoothing operation is discussed in section II. Section III reviews some of the standard edge detection techniques. Section III explains the proposed fuzzy based edge detection. Section IV deals with experimental results and discussion. Section V concludes the work.

II. SMOOTHING

The acquired infrared images are highly subjected to degradation due to several factors such as noise due to various types of soil contents, low sensor resolution and low contrast due to sensor's limited dynamic range [3]. The irrelevant maxima present in the gradient of a noisy image must be eliminated before the application of any edge detection algorithm [4].Gaussian filter is used for smoothing the input image. It modifies the frequency components of the image in a smooth manner. The transfer function of a two dimensional Gaussian low pass filter used is given by

$$G(x,y) = \frac{1}{\sqrt{2\pi}\sigma} e^{\frac{-(x^2+y^2)}{2\sigma^2}} \qquad [1]$$

Where σ is the standard deviation of the distribution.

The Gaussian filter used has a large peak to signal ratio (PSNR) and negligible mean square error (MSE). The following equations are used for calculating PSNR and MSE.

$$\text{PSNR} = 10log_{10}\left(\frac{255^2}{\text{MSE}}\right) \qquad [2]$$

$$\text{MSE} = \frac{1}{\text{MN}}\sum_{i=1}^{M}\sum_{j=1}^{N}[g(i,j) - f(i,j)]^2 \qquad [3]$$

Where, M and N are the total number of pixels in the horizontal and the vertical dimensions of image. *g* denotes the input noise image and *f* denotes the filtered image[5].

II. OVERVIEW OF EXISTING EDGE DETECTION METHODS

Most of the existing edge detection methods may be grouped into two categories, gradient based and Laplacian based. The gradient method detects the edges by looking for the maximum and minimum in the first derivative of the image whereas zero crossings in the second derivative of the image are found in the Laplacian method of edge detection. The pictorial representation of these two methods is shown in figure 1.

Based on these two types, the most common methods used for edge detection in digital images are Prewitt, Roberts, Sobel, Laplacian and Canny. These operators have the advantage of high detecting speed [6]. Their operators are kernels of 3x3 windows (2x2 windows in the Roberts algorithm) which are convolved with the input image to assign each pixel a value of 0 or 255.The edge detector masks used in the above methods [7] are shown in figure 2.

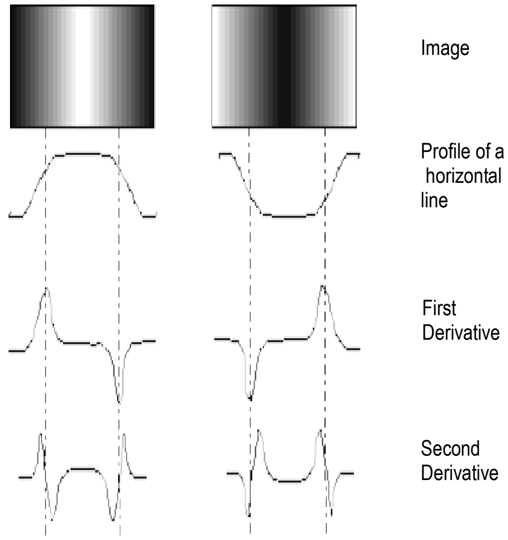

Fig. 1. Schematic of gradient based edge detection

-1	0	+1
-2	0	+2
-1	0	+1

-1	0	+1
-2	0	+2
-1	0	+1

a)Masks used by Sobel operator

-1	-1	-1
0	0	0
+1	+1	+1

-1	0	+1
-1	0	+1
-1	0	+1

b)Masks used by Prewitt operator

-1	0
0	+1

0	-1
+1	0

c)Masks used by Roberts operator

0	1	0
1	−4	1
0	1	0

1	1	1
1	−8	1
1	1	1

−1	2	−1
2	−4	2
−1	2	−1

d)Masks used by Laplacian operator

+1	+1	+1
+1	-8	+1
+1	+1	+1

Fig. 2. Edge detector masks

III. FUZZY BASED EDGE DETECTION

The proposed fuzzy inference system used for edge detection has four inputs and one output. The four pixels P1, P2, P3 and P4 of the masking window constitute the four inputs as shown in fig 3. A fuzzy set is framed for the white and black pixels as shown in the membership function in fig 4 and the inputs are fuzzified. Tiangular membership function is used for fuzzifying the inputs.

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P1	P2
P3	P4

Fig. 3. Floating 2X2 pixel window mask

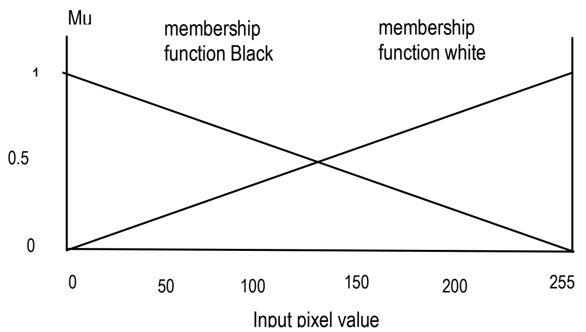


Fig. 4. Membership functions of the fuzzy sets associated to the input

Table 1. The Fuzzy rule matrix for edge detection

Fuzzy inputs				Fuzzy output
P1	**P2**	**P3**	**P4**	**P4_out**
B	B	B	B	B
B	B	B	W	E
B	B	W	B	E
B	B	W	W	E
B	W	B	B	E
B	W	B	W	E
B	W	W	B	E
B	W	W	W	W
W	B	B	B	E
W	B	B	W	E
W	B	W	B	E
W	B	W	W	E
W	W	B	B	E
W	W	B	W	E
W	W	W	B	E
W	W	W	W	W

Three outputs are defined as B for black, W for white and E for edge in this application. The Fuzzy rule matrix using 'if-then' is framed on the basis of expert's knowledge for detecting edges as shown in table 1. All the rules are implemented using AND operation.

For example, rule 2 in table 1 would read:

IF P1 is B(black) and P2 is B(black) and
P3 is B(black) and P4 is W(white),
THEN P4_out is E(edge).

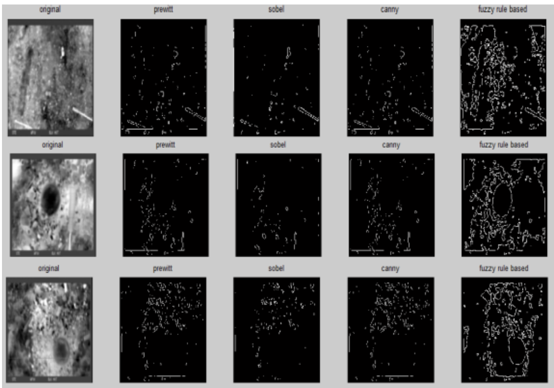
Algorithm for the proposed fuzzy based edge detection:

Step 1: Read the input image
Step2: Convert the image from rgb to gray and resize the image
Step 3: Smooth the image using Gaussian low pass filter
Step4: Frame the fuzzy sets for white and black pixels as per the defined membership function and fuzzify the input pixels
Step 5: Define the output pixels as black, white and edge.
Step 6: Define a 2X2 mask
Step 7: Frame the fuzzy rule matrix

Step 8: Use the mask in step 6 and apply the rules in step7 and map the output to the defined Sugeno Singleton Set.

IV. SIMULATION RESULTS AND DISCUSSION

The application of the proposed algorithm on some of the preprocessed infrared landmine images that contain the signature associated with a buried landmine is shown in figure 5.



(a) (b) (c) (d) (e)

Fig. 5 (a) Original images (b) Prewitt results c) Sobel results (d) Canny results (e) Proposed fuzzy edge detection algorithm results

Results obtained with the proposed method are qualitatively compared with the results of some of the existing standard edge detection algorithms such as Prewitt, Sobel and Canny. From the visual inspection of figure 5, it is perceived that the results of the proposed algorithm are better compared to that of the standard algorithms considered in this work. The edges of the object of interest (buried landmine) are not at all detected by the standard algorithms whereas the fuzzy rule based algorithm detects the edges of the landmine. Nevertheless the false edges due to the presence of a lot of clutter and also the discontinuity in the detected true edges in fuzzy rule based results are undesirable. But this can be overcome by applying some of the morphological operations as a post processing step. MATLAB was the tool used for implementing the algorithm.

IV. CONCLUSION

Gradient based algorithms are sensitive to noise and hence are not suitable for detecting the edges of objects in images with high clutter. We have presented a simple fuzzy reasoning based edge detection algorithm which shows some promising results for cases where the standard algorithms fail. It is also adaptable as we can modify the rules in the rule matrix. The computational complexity is also reduced. The results obtained can be improved by implementing some of the morphological operations such as edge linking as a post processing step.

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