Edge Detection in MRI of Head Scans Using Fuzzy Logic

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***Abstract*— In this paper we propose a method for Edge Detection in MRI of human head scans. Edge detection is one of the pre-segmentation processes of MRI head scans. MRI head scans are used to visualize the internal structure of human head in 3-Dimension. The brain segmentation from MRI head scan is a major work in head scan analysis. In the proposed method we make use of 32 fuzzy logic for edge detection. It is less in computational complexity in searching for edges when compared to Sobel and Canny edge detectors. Application of the proposed method on several MRI scans show that it produces sharp and clear edges that can be used for segmenting brain portions in MRI of human head scans.**

Keywords- edge detection, brain segmentation, Magnetic Resonance Images.

I. INTRODUCTION

Medical imaging helps the medical field to diagnose, plan to surgery, plan for treatment diseases, to know the depth of infection and so on. The medical images are taken in different modalities such as X-rays, Computed Tomography, Ultra Sound, Magnetic Resonance Image (MRI) and few others. Each of them have distinct feature and are used for diagnosing various diseases. MRI is a non-invasive, non destructive and non-ionizing method. MRI gives a high resolution images and is commonly used in imaging brain. MRI is taken, using three techniques which are T1- weighted, T2-weighted and Proton Density (PD) images. MRI of human head scan is taken in three orientations, axial (top to bottom of the head), sagittal (left to right of the head), and coronal (back to front of the head).

Segmenting and analyzing the brain structure is the most significant process in identifying deformities in brain tissues. Edge detection plays an important role in segmenting objects and background in an image. It is a step between low level and high level image processing. This helps us to separate object from the image as a pre-segmentation process. In image processing, edge detection can be employed to filter out less relevant information while preserving the basic structural properties of an image [1]. An edge is the boundary between an object and the background. This means that if the edges in an image can be identified accurately, then all the objects within it can be located and basic properties such as area, perimeter and shape can be measured. Since computer vision involves the identification and classification of objects in an image, edge detection is an essential process. Many methods are used to detect edges; some of them are Fuzzy logic, Sobel, Canny, Robert Cross edge detector.

Fuzzy Logic (FL) is an effective method to solve the problems with some definite logic. FL provides a simple way to arrive at definite conclusion based upon vague ambiguous, imprecise, noisy or missing input information. The FL can be implemented in hardware, software and both [2]. A number of research works are going on in edge detections. some of them are [3], [4], and [5]. Abdallah etl. [7] have proposed an edge detection using fuzzy logic for digital image. But this method does not work effectively for MRI head scans. In our earlier work [8] we have employed FL for edge detection in MRI. In this paper, we propose another FL based technique to detect edges in MRI of human head scans. The method remarkably reduces the searching time and increases the speed of processing.

The remaining part of the paper is organized as follows. In section 2, the proposed method is given. In section 3, the results and discussion are given and in the section 4, we conclude the article.

II. PROPOSED METHOD

In the proposed method we first find the intensity threshold for an image. Then a set of rules are framed using Fuzzy Logic that are used to detect the edges of MRI of head scans. The Riddler's method [9] is used to find the intensity threshold (T). Using the threshold T, a binary image is generated. Then a set of 32 FL are applied on the binary image to detect the edge.

A. *Riddler's Method.*

For continuity, we briefly outline the Riddler's method. In the initial step, the average (T_1) of intensity values of all the pixels in the input image I is computed as:

$$\mathbf{T_1} = \frac{\sum_{i=0}^{N-1} x_i}{N} \qquad (1)$$

where, x_i is the intensity of the pixel, N is the total number of pixels. The computed average value T_1 is used to separate the pixels in the image I into two groups G_1 and G_2.

$$f(x_i) \in \begin{cases} G_1 & \text{if}(x_i > T_1) \\ G_2 & \text{otherwise} \end{cases} \qquad (2)$$

Then the mean value (T) of the means of G1 and G2 is computed as:

$$T = \frac{\frac{\sum_{i=0}^{n} G_1}{n(G_1)} + \frac{\sum_{i=0}^{n} G_2}{n(G_2)}}{2} \qquad (3)$$

where, $n(G_i)$ is the total number of pixels in G_i, i=1,2.The above steps (2) and (3) are repeated until $T \approx T_1$. Then the binary image I_B is obtained by computing the final threshold value (T).

$$I_B(x) = \begin{cases} 1 & \text{if}(I(x) \geq T) \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

B. *Fuzzy System*

Fuzzy System is a knowledge based method for solving the problem. Now we frame, a set of fuzzy rules based on knowledge of the MRI image characterization. These rules are based on the basis of IF THEN ELSE condition. Every rule is applied sequentially. The Fuzzy system contains four components such as fuzzifier, fuzzy interface, fuzzy knowledge base, and defuzzifier. The fuzzifier component is used to change the input into linguistic format. After the fuzzfication, the fuzzy interface machine applies the fuzzy rules taken from fuzzy knowledge base, in sequential order. In the defuzzification process, the fuzzy data is converted into a crisp data. The fuzzy system is shown in Figure 1.

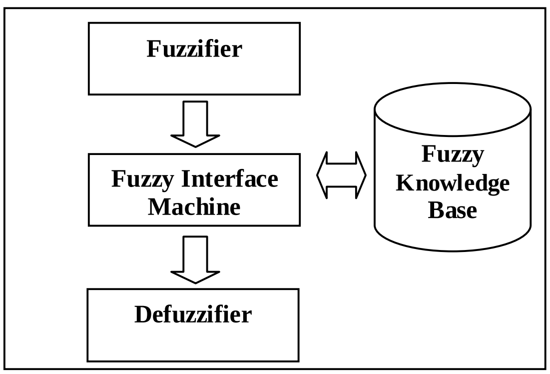


Fig.1 Fuzzy System.

C. *Fuzzy Rules*

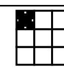
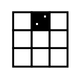
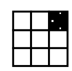
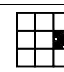
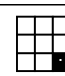
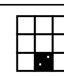
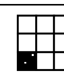
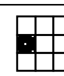
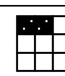
In our previous work [8], 32 rules were framed and applied sequentially. It takes more time to detect the edges in MRI human head scans. We have changed its searching methodology to reduce the searching time and increase speed of processing. The fuzzy interface machine(FIM) is modified for reducing the searching time. For that initially a mask of size 3x3 is designed and moved over the input image I_B which is shown in Figure 2. In this mask, x is the current pixel and its eight neighbors are N_1, N_2, N_3, N_4, N_5, N_6, N_7 and N_8.

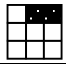
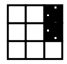
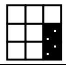
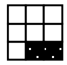
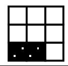
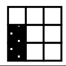
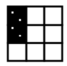
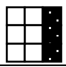
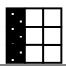
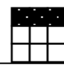
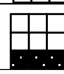
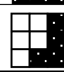
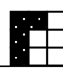
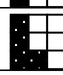
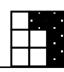
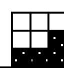
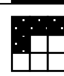
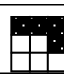
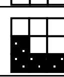
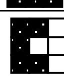
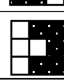
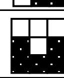
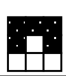
N_1	**N_2**	**N_3**
N_8	**x**	**N_4**
N_7	**N_6**	**N_5**

Fig. 2 Mask

The Fuzzy rules are framed on the basis of current pixel and its neighbors. The task of the fuzzifier is to select the zero element and its eight neighbors, when the mask is moved over the image I_B. The edge pixels should be dark and at least one of its neighbors should be bright, with this condition we have framed the 32 rules for detecting the edge points. In [7] only eight rules were used to detect the edge point of digital images. But this method is not sufficient to detect the edges in MRI of head scans. Therefore, we have framed 32 FL rules to detect the edges. These rules are sufficient to detect the true edges. The 32 fuzzy rules that we have framed are given in Table I.

TABLE I. 32 FUZZY RULES

S.No.	Rule	Diagram
1.	N_1=1 N_2& N_3&N_4&N_5&N_6&N_7&N_8=0	
2.	N_2=1 N_1&N_3&N_4&N_5&N_6&N_7&N_8=0	
3.	N_3=1 N_1&N_2&N_4&N_5&N_6&N_7&N_8=0	
4.	N_4=1 N_1&N_2&N_3&N_5&N_6&N_7&N_8=0	
5.	N_5=1 N_1&N_2&N_3&N_4&N_6&N_7&N_8=0	
6.	N_6=1 N_1&N_2&N_3&N_4&N_5&N_7&N_8=0	
7.	N_8=1 N_1&N_2&N_3&N_4&N_5&N_6&N_7=0	
8.	N_8=1 N_1&N_2&N_3&N_4&N_5&N_6&N_7=0	
9.	N_1&N_2=1 N_3&N_4 &N_5&N_6&N_7&N_8=0	

10.	$N_2\&N_3=1$ $N_1\&N_4\&N_5\&N_6\&N_7\&N_8=0$	
11.	$N_3\&N_4=1$ $N_1\&N_2\&N_5\&N_6\&N_7\&N_8=0$	
12.	$N_4\&N_5=1$ $N_1\&N_2\&N_3\&N_6\&N_7\&N_8=0$	
13.	$N_5\&N_6=1$ $N_1\&N_2\&N_3\&N_4\&N_7\&N_8=0$	
14.	$N_6\&N_7=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_8=0$	
15.	$N_7\&N_8=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_6=0$	
16.	$N_1\&N_8=1$ $N_2\&N_3\&N_4\&N_5\&N_6\&N_7=0$	
17.	$N_3 \& N_4 \& N_5 = 1$ $N_1 \& N_2 \& N_6 \& N_7 \& N_8 = 0$	
18.	$N_1 \& N_8 \& N_7 = 1$ $N_2 \& N_3 \& N_4 \& N_5 \& N_6 = 0$	
19.	$N_1 \& N_2 \& N_3 = 1$ $N_4 \& N_5 \& N_6 \& N_7 \& N_8 = 0$	
20.	$N_5 \& N_6 \& N_7 = 1$ $N_1 \& N_2 \& N_3 \& N_4 \& N_8 = 0$	
21.	$N_3 \& N_4 \& N_5 \& N_6 = 1$ $N_1 \& N_2 \& N_7 \& N_8 = 0$	
22.	$N_1 \& N_2 \& N_7 \& N_8 = 1$ $N_3 \& N_4 \& N_5 \& N_6 = 0$	
23.	$N_1 \& N_6 \& N_7 \& N_8 = 1$ $N_2 \& N_3 \& N_4 \& N_5 = 0$	
24.	$N_2 \& N_3 \& N_4 \& N_5 = 1$ $N_1 \& N_6 \& N_7 \& N_8 = 0$	
25.	$N_4 \& N_5 \& N_6 \& N_7 = 1$ $N_1 \& N_2 \& N_3 \& N_8 = 0$	
26.	$N_1 \& N_2 \& N_3 \& N_8 = 1$ $N_4 \& N_5 \& N_6 \& N_7 = 0$	
27.	$N_1 \& N_2 \& N_3 \& N_4 = 1$ $N_5 \& N_6 \& N_7 \& N_8 = 0$	
28.	$N_5 \& N_6 \& N_7 \& N_8 = 1$ $N_1 \& N_2 \& N_3 \& N_4 = 0$	
29.	$N_1 \& N_2 \& N_6 \& N_7 \& N_8 = 1$ $N_3 \& N_4 \& N_5 = 0$	
30.	$N_2 \& N_3 \& N_4 \& N_5 \& N_6 = 1$ $N_1 \& N_8 \& N_7 = 0$	
31.	$N_4 \& N_5 \& N_6 \& N_7 \& N_8 = 1$ $N_1 \& N_2 \& N_3 = 0$	
32.	$N_1 \& N_2 \& N_3 \& N_4 \& N_8 = 1$ $N_5 \& N_6 \& N_7 = 0$	

The mask shown in Figure 2 is moved pixel by pixel over the image I_B. Whenever x is zero, then all the pixels under the mask are sent to FIM. The FIM counts the non-zero elements at eight neighbors of x. If the count is greater than zero, then the fuzzy rules are applied otherwise, the mask is moved to next pixel for checking the zero element. In this manner we classify the 32 fuzzy rules into 5 groups and form a fuzzy knowledge base (FKB) as given in Table II.

TABLE II. FUZZY KNOWLEDGE BASE

Index	Rules
1	$N_1=1$ $N_2\&N_3\&N_4\&N_5\&N_6\&N_7\&N_8=0$
	$N_2=1$ $N_1\&N_3\&N_4\&N_5\&N_6\&N_7\&N_8=0$
	$N_3=1$ $N_1\&N_2\&N_4\&N_5\&N_6\&N_7\&N_8=0$
	$N_4=1$ $N_1\&N_2\&N_3\&N_5\&N_6\&N_7\&N_8=0$
	$N_5=1$ $N_1\&N_2\&N_3\&N_4\&N_6\&N_7\&N_8=0$
	$N_6=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_7\&N_8=0$
	$N_8=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_6\&N_7=0$
	$N_8=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_6\&N_7=0$
2	$N_1\&N_2=1$ $N_3\&N_4\&N_5\&N_6\&N_7\&N_8=0$
	$N_2\&N_3=1$ $N_1\&N_4\&N_5\&N_6\&N_7\&N_8=0$
	$N_3\&N_4=1$ $N_1\&N_2\&N_5\&N_6\&N_7\&N_8=0$
	$N_4\&N_5=1$ $N_1\&N_2\&N_3\&N_6\&N_7\&N_8=0$
	$N_5\&N_6=1$ $N_1\&N_2\&N_3\&N_4\&N_7\&N_8=0$
	$N_6\&N_7=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_8=0$
	$N_7\&N_8=1$ $N_1\&N_2\&N_3\&N_4\&N_5\&N_6=0$
	$N_1\&N_8=1$ $N_2\&N_3\&N_4\&N_5\&N_6\&N_7=0$
3	$N_3 \& N_4 \& N_5 = 1$ $N_1 \& N_2 \& N_6 \& N_7 \& N_8 = 0$
	$N_1 \& N_8 \& N_7 = 1$ $N_2 \& N_3 \& N_4 \& N_5 \& N_6 = 0$
	$N_1 \& N_2 \& N_3 = 1$ $N_4 \& N_5 \& N_6 \& N_7 \& N_8 = 0$
	$N_5 \& N_6 \& N_7 = 1$ $N_1 \& N_2 \& N_3 \& N_4 \& N_8 = 0$
4	$N_3 \& N_4 \& N_5 \& N_6 = 1$ $N_1 \& N_2 \& N_7 \& N_8 = 0$
	$N_1 \& N_2 \& N_7 \& N_8 = 1$ $N_3 \& N_4 \& N_5 \& N_6 = 0$

	$N_1 \& N_6 \& N_7 \& N_8 = 1$ $N_2 \& N_3 \& N_4 \& N_5 = 0$
	$N_2 \& N_3 \& N_4 \& N_5 = 1$ $N_1 \& N_6 \& N_7 \& N_8 = 0$
	$N_4 \& N_5 \& N_6 \& N_7 = 1$ $N_1 \& N_2 \& N_3 \& N_8 = 0$
	$N_1 \& N_2 \& N_3 \& N_8 = 1$ $N_4 \& N_5 \& N_6 \& N_7 = 0$
	$N_1 \& N_2 \& N_3 \& N_4 = 1$ $N_5 \& N_6 \& N_7 \& N_8 = 0$
	$N_5 \& N_6 \& N_7 \& N_8 = 1$ $N_1 \& N_2 \& N_3 \& N_4 = 0$
5	$N_1 \& N_2 \& N_6 \& N_7 \& N_8 = 1$ $N_3 \& N_4 \& N_5 = 0$
	$N_2 \& N_3 \& N_4 \& N_5 \& N_6 = 1$ $N_1 \& N_8 \& N_7 = 0$
	$N_4 \& N_5 \& N_6 \& N_7 \& N_8 = 1$ $N_1 \& N_2 \& N_3 = 0$
	$N_1 \& N_2 \& N_3 \& N_4 \& N_8 = 1$ $N_5 \& N_6 \& N_7 = 0$

This FKB helps reduces the number of searching. We also analyzed the searching time for the conventional edge detection methods Sobel, Canny and the proposed method. The relative searching time is given in Table III.

III. RESULT AND DISCUSSION

We carried out the experiment by applying our method on 130 images and thus detected the edges. Among the results of 130 images, we presented the output of 9 images in Figure 3. Column 1 shows the original images. The results obtained by Sobel operator are given in column 2. In column 3, the edges detected by Canny are given. Column 4 shows, the results obtained by our proposed method.

TABLE III. SEARCHING TIME FOR THE CANNY AND SOBEL METHODS

Items	Sobel Operator	Canny Method	Proposed Method
Data Structure	Four Arrays, 3072 additions/ subtraction 1024multiplication/division	Nine Arrays, 3584 additions/ subtraction 6157Multiplication/division	Three arrays, 2816 additions/ subtraction 31 multiplication/ division
Processing Time	High	High	Low
Applications	General Image	General Image	Medical Image

Figure 3 shows that our proposed method prominently detect the edges from MRI head scans when compare to other two methods. The average time taken for detecting edges by our method for a single slice is 16ms. But Sobel and Canny takes 26ms and 223ms respectively.

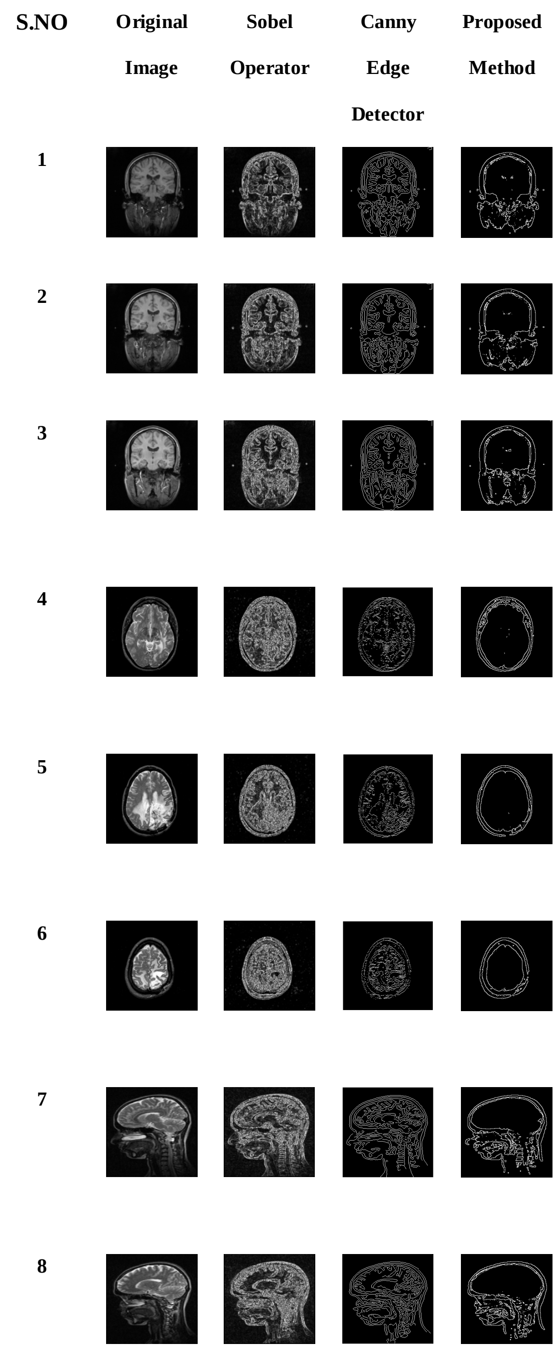


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Fig. 3 Comparative results of Edge detection methods

We have collected materials for our experiments from IBSR and Devaki Scans and Diagnostics Pvt. Ltd, Madurai.

IV. CONCLUSION

In this paper we have proposed a novel edge detection method based on 32 fuzzy rules. Application of the proposed method on MRI of human head scans show that it detects edges in a better way than the traditional Canny edge detector and Sobel edge detection operator. Further the proposed method is less computational complexity than the Canny and Sobel methods and thus takes less time for edge detections. This method can be used effectively in segmenting objects from different image types, particularly MRI.

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