Fuzzy Rule based Multimodal Medical Image Edge Detection

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ABSTRACT
During past few decades, medical Image Processing brought a great contribution in visualization of human anatomy and radically enhanced the Computer-aided diagnostic systems. It assists medical practitioners for detection and localization of pathological deformations. In which, the advanced Digital Image Processing techniques are used to analyze the various internal structures of body of the patients.Image segmentation is one of the significant step in any Digital Image Processing application, it aims to simplify and change the representation of an image into something that is more meaningful and easier to analyze.To get the appropriate image segmentation, Edge detection is considered as one of the eminent and promising techniques. Simply the Edges are characterize boundaries which help to extract the suitable features.

In present research work four fuzzy rule based edge detection techniques are applied and their results are comparatively analyzed. It has been found that the segmentation accuracy of 2x2 mask scanning 10 rule based system is more precise than other tested methods. The output image consists of edges and it is a gray type of image.

Keywords
MRI (Magnetic Resonance Imaging), CT (Computed Tomography), US (Ultrasound Sonography), X-Ray, FIS (Fuzzy Inference System)

1. INTRODUCTION
In Digital image processing the image is converted to an array of integers, called pixels, representing a physical quantity such as scene radiance, stored in a digital memory, and processed by computer and other digital hardware. Edge detection is the part of segmentation in image processing. The goal of segmentation is to simplify and change the representation of an image into something that is more meaningful and easier to analyze. Edge detection is a problem of fundamental importance in image processing. Edges in images are areas with strong intensity contrasts and a jump in intensity from one pixel to the next can create major variation in the picture quality. Edge detection of an image significantly reduces the amount of data and filters out useless information, while preserving the important structural properties in an image [1] [2] [3]. An edge is defined by a discontinuity in gray level values. In other words, an edge is the boundary between an object and the background. The shape of edges in images depends on many parameters: The geometrical and optical properties of the object, the illumination conditions, and the noise level in the images [4].Recent developments in medical imaging techniques have brought a new research field in image processing which comprises medical image enhancement and visualization, and edge detection. The principal aim is to improve medical diagnosis to obtain image-based information, such as the detection and localization of pathological deformations [3].Medical scans such as Magnetic Resonance (MR) and computed tomography (CT) are currently common diagnostic tools in surgical applications. The intensity value at a given voxel of a medical scan is primarily a function of the tissue properties at the corresponding point in space. Typically, various anatomical structures appear more clearly in different types of internal scans. Soft tissue, for example, is imaged well in MR scans, while bone is more easily discernible in CT scans. Some anatomical structures appear with more contrast in one image than in the others. Anatomical structures in these various modalities can be segmented and displayed separately. However, it is most convenient for the surgeon to have information about all the structures fused into one coherent dataset [5].The current paper focus on Multimodal medical image edge detection. Multimodal medical image edge detection found to be difficult because of nonlinear intensity biases and highly textured structures. The efficiency of existing edge detection techniques is better on other digital images than medical images. The aim of this work is to propose a novel edge detection technique using fuzzy rule based system for medical images.

The current work organized in four main sections. Section 1 describes the need of proposed system and Fuzzy rule based system. Related work on digital image edge detection systems explained in Section 2.Next Section 3 contains the proposed methodology. Results obtained from proposed system and standard edge detection system and their performance comparison is presented in section 4.

1.1 Fuzzy Rule Based System
Fuzzy image processing is the collection of all approaches that understand, represent, and process the images, their segment and features as fuzzy sets. The representations and processing depend on the selected fuzzy technique and on the problem to be solved [1]. The general structure of fuzzy image processing is shown in Fig. 1.Fuzzy image processing is important to represent uncertainty in data. Benefits of Fuzzy image processing systems are

- Fuzzy techniques are powerful tools for knowledge representation and process human knowledge in form of fuzzy if then rules.
- Fuzzy techniques can manage the vagueness and ambiguity efficiently.
- Fuzzy logic is tolerant of imprecise data.
- Helpful for very complex or lightly nonlinear processes.
- Help avoid discontinuities in behavior.

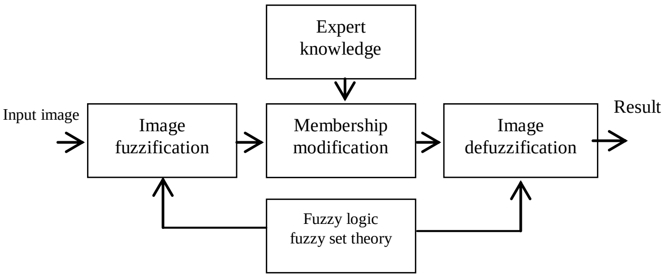


Figure 1. Fuzzy Inference System

P1(i-1,j-1)	P2 (i-1,j)	P3 (i-1,j+1)
P4 (i,j-1)	P5 (i ,j)	P6 (i,j+1)
P7 (i+1,j-1)	P8 (i+1,j)	P9 (i+1,j+1)

P1 (i-1,j-1)	P2 (i-1,j)
P3 (I,j-1)	P4 (i,j)

a) 3x3 floating mask b) 2x2 floating mask

Figure 2. Scanning Mask

2. LITERATURE REVIEW

In literature a range of methodologies are proposed by various researchers. In this section few of these methods has been explained discuss here. ShahanaBanoet. al. proposed a Fuzzy rule based edge detection system for digital images. The Fuzzy system detect edges by applying 3x3 scanning mask and then converted into binary image using first order derivative. The results are compared with Sobel edge detection method. The method increased the possibility of curved and corner edges [1]. Cristiano Jacques Miosso et al. evaluate FIS. Input image preprocessed using three linear filters Sobel operators, a low pass filter, a high pass filter. Output depends on some neighbor pixels [6].Fuzzy–based approach proposed involving two phases Global contrast intensification and local fuzzy edge detection. In First phase a modified Gaussian membership function chosen to represent each pixel in fuzzy plane. The underlying ideas of most edge detection techniques are the computation of a local first or second derivative operator, followed by some regularization technique to reduce the effects of noise [7]. 3x3 masksemployed to process each pixel. In this mask, each pixel is considered an input image processing values between 0 to 255. 32 rules are used to detect the edge [8]. Fuzzy rule based another approach is designed with 3x3 scanning mask with 8 inputs and one output that tells weather the pixel is black, white or edge pixel.28 rules are used for pixel classification. Noise removal is performed at different intermediate levels of processing [9].

Fuzzy logic based algorithm to detect the edges of an input image by scanning it throughout using 2x2 pixel windows is proposed by Er. Kiranpreet Kaur et al.Rule base comprises of 16 rules with 4 inputs and one output.First and Second order derivative used to trace the edges of resultant image[10][11].For noise removal the 3x3 window scan over the output image for removal of unwanted pixel. Falsely marked pixel is changed to white by the noise removal algorithm [8-11].BijuphukanBhagabatiet. al. developed FIS in MATLAB using 10 fuzzy rules. The smallest possible mask 2x2 is slides over the whole image for identification of edge pixel [12].

3. METHODOLOGY

In proposed method the 4 FIS has been implemented as described in [8-12], similarly two FIS i.e. S1 and S2 has been implemented using 3X3 scanning mask. Likewise the scanning mask of 2X2 has been used to implement S3 and S4. The detail algorithm and steps are mentioned in next section.

3.1 Algorithm for edge detection using FIS

[1] Read the Image (CT/MRI/Ultrasound/X-ray).
[2] Convert image into grayscale.
[3] For noise removal preprocess the image using median filter.

Table 1.Rule Base for S1

32 Rule Base									
Fuzzy Input									O/P
P1	P2	P3	P4	P5	P6	P7	P8	P9	P_ out
W	W	W	W	W	W	B	B	B	E
B	B	B	W	W	W	W	W	W	E
B	W	W	B	W	W	B	W	W	E
W	W	B	W	W	B	W	W	B	E
B	B	W	B	W	W	B	W	W	E
W	W	B	W	W	B	W	B	B	E
B	W	W	B	W	W	B	B	W	E
W	B	B	W	W	B	W	W	B	E
B	B	B	B	W	W	W	W	W	E
W	W	W	B	W	W	B	B	B	E
B	B	B	W	W	B	W	W	W	E
W	W	W	W	W	B	B	B	B	E
W	B	B	W	W	B	W	W	W	E
W	W	W	W	W	B	W	B	B	E
B	B	W	B	W	W	W	W	W	E
W	W	W	B	W	W	B	B	W	E
B	W	W	B	W	W	W	W	W	E
W	W	W	B	W	W	B	W	W	E
W	W	W	W	W	W	B	B	W	E
B	B	W	W	W	W	W	W	W	E
W	W	W	W	W	W	W	B	B	E
W	W	W	W	W	B	W	W	B	E
W	W	B	W	W	B	W	W	W	E
W	B	B	W	W	W	W	W	W	E
B	B	B	B	W	B	W	W	W	E
B	B	W	B	W	W	B	B	W	E
W	W	W	B	W	B	B	B	B	E
W	B	B	W	W	B	W	B	B	E
B	W	W	W	W	W	W	W	W	E
W	W	W	W	W	W	B	W	W	E
W	W	W	W	W	W	W	W	B	E
W	W	B	W	W	W	W	W	W	E

[4] Set the initial mask as 2x2 or 3x3(as shown in Figure2)
[5] Map the input pixels to fuzzy set using membership functions white and black.
[6] Firing strength of rule is calculated using AND operator.
[7] Determine shape of the output membership functions on the basis of the firing strength of the rule using MIN method.
[8] The output fuzzy sets returned by the above step for each rule are combined using MAX operator.
[9] Difuzzify the output fuzzy values using centroid.
[10] Slide the mask window to the next pixel and repeat step 5 to step 7 until last pixel is checked row wise.

[11] Calculate the first order derivative of fuzzy output image for obtaining edge image.

Table 2. Rule matrix for S2

28 rule base								
Fuzzy Inputs								**O/P**
P1	**P2**	**P3**	**P4**	**P6**	**P7**	**P8**	**P9**	**P_out**
W	W	W	W	W	B	B	B	E
B	B	B	W	W	W	W	W	E
B	W	W	B	W	B	W	W	E
W	W	B	W	B	W	W	B	E
B	B	W	B	W	B	W	W	E
W	W	B	W	B	W	B	B	E
B	W	W	B	W	B	B	W	E
W	B	B	W	B	W	W	B	E
B	B	B	B	W	W	W	W	E
W	W	W	B	W	B	B	B	E
B	B	B	W	B	W	W	W	E
B	B	B	B	B	W	W	W	E
B	B	W	B	W	B	B	W	E
W	W	W	B	B	B	B	B	E
W	B	B	W	B	W	B	B	E
B	W	W	B	W	W	W	W	E
W	W	W	B	W	B	W	W	E
W	W	W	W	W	B	B	W	E
W	W	W	W	W	B	B	W	E
B	B	W	W	W	W	W	W	E
W	W	W	W	W	W	B	B	E
W	W	W	W	B	W	W	B	E
W	W	B	W	B	W	W	W	E
W	B	B	W	W	W	W	W	E
W	B	B	W	B	W	W	W	E
W	W	W	W	B	W	B	B	E
B	B	W	B	W	W	W	W	E
W	W	W	B	W	B	B	W	E

Table 3. Rule Base for S3

10 rule base				
Fuzzy Inputs				**Fuzzy Output**
P1	**P2**	**P3**	**P4**	**P_out**
B	B	B	W	E
B	B	W	W	E
B	W	B	W	E
W	B	B	W	E
W	W	W	B	E
W	W	B	B	E
B	W	W	B	E
W	B	W	B	E
B	B	W	B	E
B	W	B	B	E

The information about systems like input membership function output function and types of membership functions is Table 4.

4. RESULTS& DISCUSSION

In current research work all the medical images are preprocessed using median filter. The median filter is used for multimodal image filtering purpose after comparing its performance with order filter. It is observed that the accuracy of median filter is much better in multimodal medical image preprocessing which is graphicallyillustratedin Figure 3. Each FIS has been applied and tested on all four types of medical images i.e. MRI, CT, X-ray, Ultrasound images. It is also found that all fuzzy systems accuracy is better than other methods.

Table 4. Rule Base for S4

16 rule base				
Fuzzy Inputs				**O/P**
P1	**P2**	**P3**	**P4**	**P_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

The Four FIS are compared with each other by calculating PSNR of the resultant image. The graphical representation of these four FIS comparison is shown in figure 5. In which it can be observe that the overall performance of S3 is improved than remaining techniques. The performances of the present system is compared with three standardedge detection techniques i.e. Sobel, Canny, Prewitt. Figure 4 shows the comparative output images of these three standard techniques with proposed method i.e. fuzzy edge detection using s3. In this figure Original image and output images through Sobel, Canny, Prewitt and fuzzy edge detection using s3 are shown from right to left respectively.

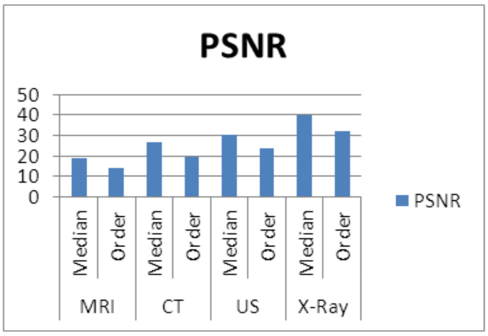
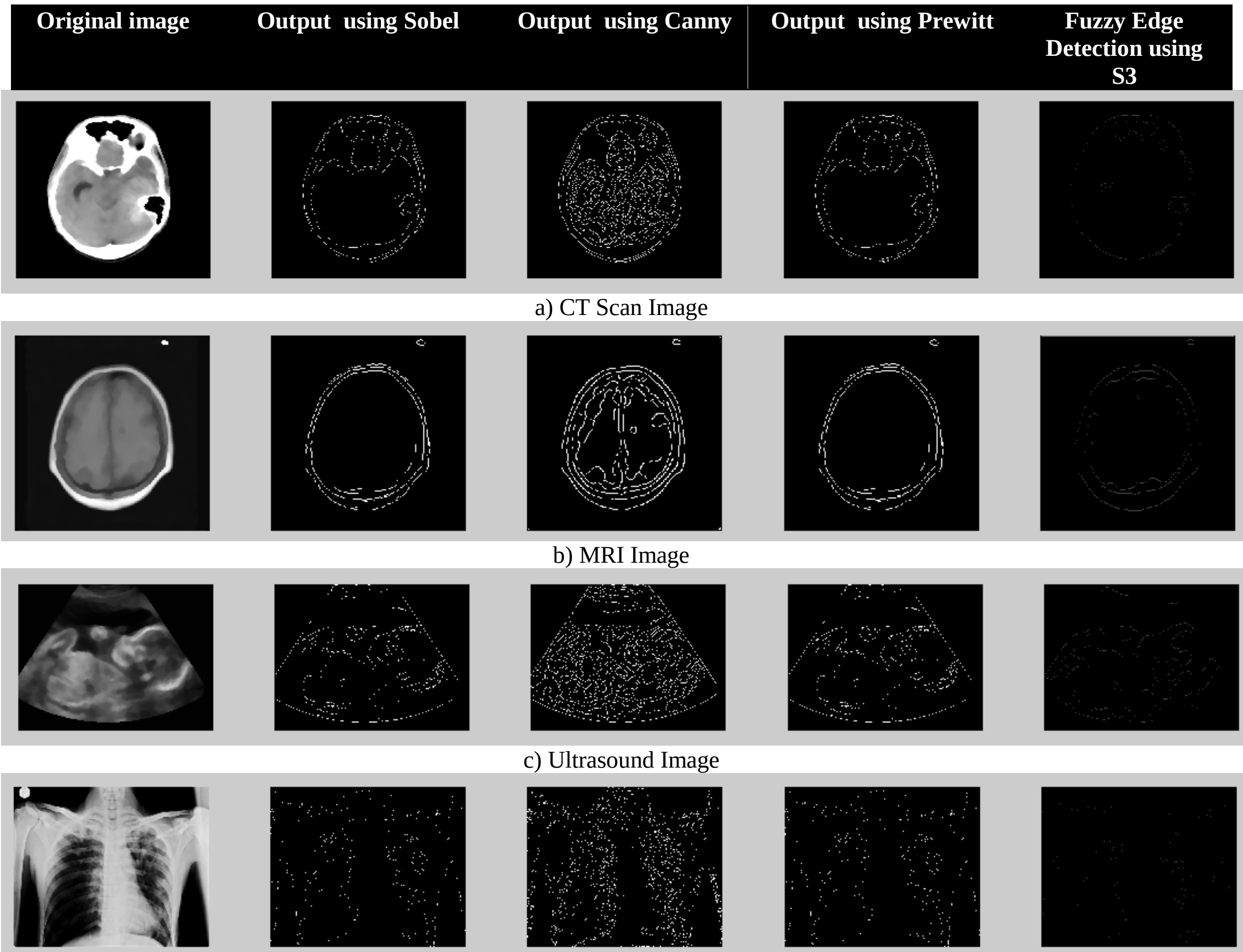


Figure 3. Comparison of Filters

Table 5 Comparison of Rule Based System

FIS		3x3 mask		2x2 mask	
		S1	**S2**	**S3**	**S4**
Pixel	**Input**	*9*	*8*	*4*	*4*
	Output	1	1	1	1
Input functions	**black**	Trapmf (0 0 60 80)	Trapmf (0 0 60 90)	Trapmf (0 0 50 80)	Trimf (0 0 255)
	white	Trapmf (80 200 255 255)	Trapmf (70 170 255 255)	Trapmf (60 200 255 255)	Trimf (0 0 255)
Output functions	**black**	-	-	-	Trimf (0 3 5)
	edge	Trimf (170 175 180)	Trimf (25 30 35)	Trimf (190 195 200)	Trimf (116 120 123)
	white	-	-	-	Trimf (250 252 255)
Rule base		32	28	10	16
PSNR	**CT**	0.7193	0.7229	0.7159	0.9749
	MRI	4.5965	4.6142	4.5861	4.0585
	Ultrasound	5.8057	5.8232	5.8099	0.6189
	X-ray	1.9848	-0.6292	3.0696	2.5778



d) X-Ray Image

Figure 4. Edge detection: Original image, output image using Sobel, Canny, Prewitt andFuzzy Edge Detection using S3, from left to right respectively

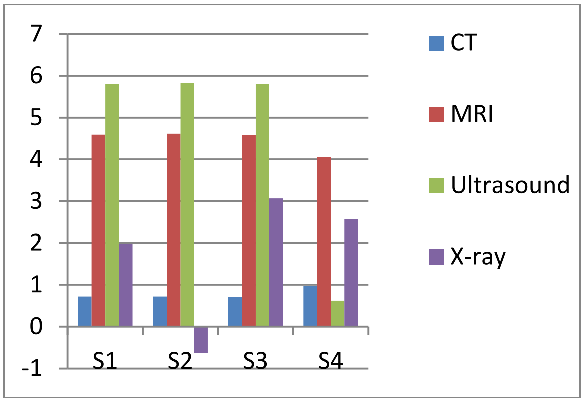


Figure 5. Comparison of four FIS

5. CONCLUSION

In current research work an attempt is made to apply and test fuzzy rule based edge detection techniques on four types of medical images i.e. MRI, CT, X-ray, Ultrasound images. Furthermore the comparative analysis of its results is performed with three standard edge detection techniques i.e. Sobel, Canny, Prewitt. It has been observed that the accuracy of 2x2 mask scanning 10 rule based system is more accurate than other tested methods. As an outcome of this work the results can be more beneficial for general medical practitioners for easy analysis, it will also saves the processing time. Where, MATLAB 2011 has been used for implementation of proposed system. In future the efforts will be continue to achieve the enhancement in performance of the system and to reduce the required processing time.

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