MRI video edge detection based on Fuzzy inference technique

Shaima Ibraheem Jabbar
Lecturer in Al Frurat Al Awsat Technical University, *Babylon technical Institute*
Babylon, Iraq
shaima.jabbar18@gmail.com

Abathar Qahtan Aladi
Stroke specielist (UK)
Babylon Health Directory
Mirjan Teaching Hospital
Babylon,Iraq
abatharomran@gmail.com

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***Abstract*— Objects recognition of the Magnetic Resonance Imaging (MRI) is a powerful tool in the detection of the geometric parameters such as area and perimeter. When outlining the border of an object, it is hard to calculate the area when it has irrelevant details inside the outline. Therefore, in this work we presented and applied a new technique based on fuzzy inference technique which helps to identify objects across MRI video with more accurate way. Fuzzy video edge detection technique was compared with Canny operator technique based on two assessment metrics (FOM and Pinho). Fuzzy video edge detection technique is superior than Canny operator with 14.5% and 7.5% based on the mean values of quantitative assessments (FOM and Pinho) respectively. The results are promising and it is possible to implement this technique and apply it on other medical imaging videos.**

Keywords— Magnetic Resonance Imaging (MRI), Video processing, Fuzzy inference system, Edge detection image, Image segmentation.

I. Introduction

Magnetic Resonance Imaging (MRI) is dominant medical imaging modality which used by the radiologists to create images of the anatomy and physiological processes of the human body. The scanner provides the clinicians more details about soft tissue as it used a strong magnetic field, magnetic gradient, and radio wave to produce soft tissue imaging [1]. Brain MRI still a challenging procedure as the brain slices differ from each other in regard to the depth of the slices and degree of complexity [2].

Image edge detection is a procedure that has been used to outlines the details of the soft tissue [3]. Clinicians and researchers need more information about the geometrical properties of the soft tissue to achieve a successful clinical evaluation and diagnosis. Particularly, this could h beneficial in the diagnosis of the diseases such as cancer diseases.

Although the resolution of the MRI images patterns is better than other medical images (ultrasound imaging), but MRI imaging still presents some ambiguity in the interpretation of the details of the image due to some of the grey level intensities have common characteristics. Therefore, fuzzy logic techniques were involved successfully to solve this technical issue [4]. Fuzzy logic techniques have ability to analysis a complex structure of MRI imaging that are often typified by vagueness and uncertainty. Recent examples of using an Edge detection of Brain MRI image using fuzzy c-means method [5], [6], [7], The idea of the researches focused on the classification of brain tumours depending on the location of the tumour; therefore, *fuzzy c-means* was a powerful tool to achieve this objective. Furthermore, characteristics of the Convolutional Neural Network CNN allow to extract local features from MRI [8]. There is the possibility of training artificial neural networks such as training convolutional neural network on these patterns for the detection of various details of the MRI imaging

However, from above techniques, it is difficult to identify important details due to presence of irrelevant details which in turn may hinder the correct analysis of the image information. Though, the presence of unnecessary pixels in the edge detection images have a negative impact on the quality of the final output images. In this work, a new technique of fuzzy edge detection was performed on the ultrasound images previously [9]. We modified this method and applied it on the MRI video using Fuzzy Video Edge Detection (FVED) Technique. Additionally, there is other limitation of the MRI imaging (image and video), it is low image contrast. Recently, a new technique was published which focused on using fuzzy membership modification to improve the low contrast of the panoramic ultrasound images [10] and MRI videos [11]. Therefore, this technique was exploited in this paper and applied it as a pre-processing step to improve image appearance and get a good MRI video quality.

The remainder of this paper is organized as follows: fuzzy video edge detection (FVED) is presented in detail in the next section and measurement metrics were presented briefly in the same section. FVED method was applied in section III, followed by discussion in section IV. The final section contains conclusions and future work.

II. methodology

This section explains the structure of the fuzzy video edge detection technique, it is consisting of three main steps. Firstly, the input MRI video are disintegrated into a set of frames, each frame represents an MRI image. Furthermore, Contrast Enhancement method are applied on these image frames as pre-processing before carrying out the main steps of the fuzzy edge detection technique. Finally, edge detection frames are combined again to get the output video of the MRI.

A. fuzzy Video edge detection (FVED)

Before performing fuzzy video edge detection Technique on the MRI video, this video dissembled into a set of frames. Three steps represent the main structure of fuzzy video edge detection technique. The first step is fuzzification using three membership functions to extract three levels of edge detection for each frame. The parameters of these membership functions are evaluated using standard deviation method in [9]. Figure (1), summarized this method to extract the main parameters of membership functions. In addition, figure (2) shows three membership functions.\

↓

thresholed image → deviation for each thresholed image SDk, k=0,1,....maximum grey

↓

k h max 1 1

parameter,h =1, 2, ...10 m_1=0.1, m_2=0.2... m_{10}=1 and SD_{max} is maximum standard deviation. This is equation helps in the extraction fuzzy membership parameters.

↓

1

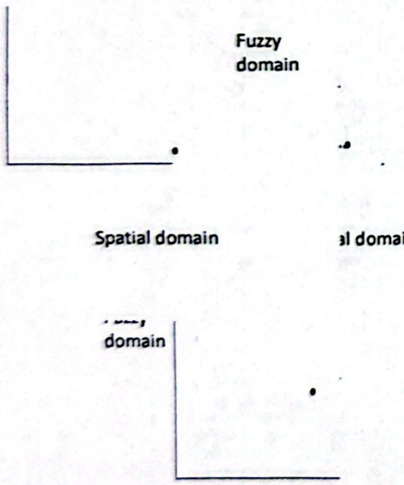
represent the standard deviation of the first thresholed image (used first cut off point (minimum grey level intensity)). Furthermore, detect the maximum standard deviation value (SD_{max}).

↓

Save *SD* values which is a difference between SD_k and S values, then assign the minimum value of this array and which cut- off points belong to differences. Decode these cut-off points to the grey level intensities.

↓

Fig.1 shows extraction parameters of membership functior



'ig.2 shows three membership functions in different colours, black for first membership function in the case of level 1, red for level 2 and green colour for representation of the membership function of level 3. Where, (a_0, a_1, a_2, and a_3) are parameters of these membership functions.

Before preforming the second step, we need to illustrate organization the structure of the central pixel and its neighbourhoods, see figure (3).

N_1	N_2	N_3
N_4	N_5	N_6
N_7	N_8	N_9

Therefore, applying fuzzy rules as follows:

Rule 1: If neighbour pixels to the central pixel of the mask (N_2, N_4, N_6, N_7, N_8, & N_9) are low & (N_1, N_3, & N_5) are high then central pixel (N_5) is edge.

Rule2: If neighbour pixels to the central pixel of the mask (N_1,N_2,N_3,N_4, N_6, &N_8) are low & (N_5, N_7,&N_9) are high & then central pixel (N_5) is edge.

...

Rule12: If neighbour pixels to the central pixel of the mask (N_2,N_3,N_4,N_6,N_7,& N_8) are low &(N_1,N_5,&N_9) are high then central pixel (N_5) is edge.

Defuzzification is the last step using Takagi- Sugeno aggregation [12]

$$Final\ output = \sum_{f=1}^{H} A_f C_f \Big/ \sum_{f=1}^{H} A_f \qquad (7)$$

where, A_f is rule weight (antecedent), the part of the sentence after IF in the rule, while C_f represents output level (consequent or conclusion in the rule) and f=1...*H*, *H* is number of rules and equal 12. All steps of Fuzzy Video Edge Detection (FVED) are summarized in the figure (4). This figure illustrates steps of extraction one level of edge detection image.

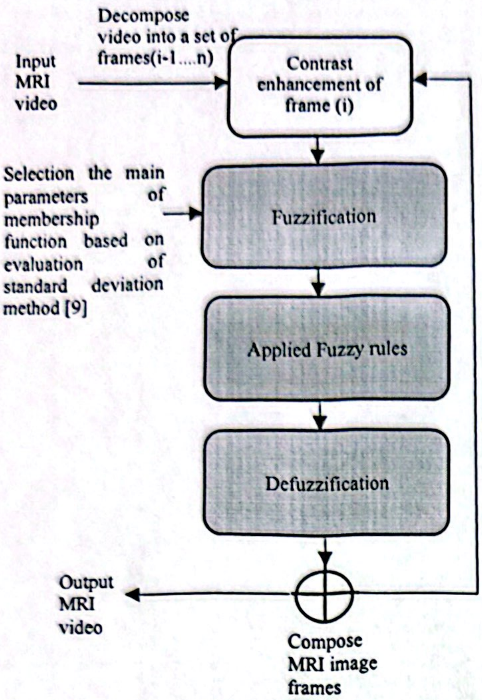


Fig. (4), illustrates steps of performing fuzzy video edge detection of MRI video.

B. Performance Measurement

In this work, two assessment metrics are utilized to assess the efficiently of the fuzzy video edge detection technique. These metrics depend on the analysis of edge characteristics such as distance between actual edge and ideal edge pixel. The first tool is called Pratt's Figure of Merit (FOM) method; it is shown in equation (2).

$$FOM_{Pratt} = \frac{1}{max\{M_r, M_T\}} \sum_{k=1}^{M_T} \frac{1}{1 + \propto C^2} \quad (2)$$

where M_r is number of edge pixel in ground truth image, M_T is number of actual edge pixel, C is distance between actual edge pixel and the nearest ideal edge pixel and α equals 1/9 (at this value, a reasonable edge position is detected, suggested by Pratt) [13]. Furthermore, the updated version of this method was achieved by Pinho for giving more effective accounting of false edges, as shown in equation (3).

$$Pinho = \left[\frac{1}{M_r}\sum_{k=0}^{M_r}\frac{1}{1+\propto C^2}\right]\left[\frac{1}{1+\beta\frac{M_{FP}}{M_r}}\right] \quad (3)$$

where M_{FP} is number of false positive pixels and the value of β is 1, but in the case of $M_{FP}=M_r$, the value of this parameter will be 0.5 [14].

III. Experimental results

MRI video samples which involved in this work are obtained from [11]. MRI video is cardiac videos that were gathered from 10 male healthy volunteers between the ages of (24-54) years old. Additionally, informed consent was signed by participants in accordance with institutional ethics guidelines was (Ref 1543C). Decomposing cardiac MRI video into a pattern of images is the first step then low image contrast of MRI video was addressed using Fuzzy Video Contrast Enhancement (FVCE) method [11], see figure (5) below:

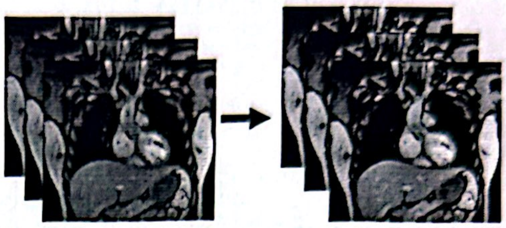


Fig (5) pre-processing step (contrast enhancement) for a set of cardiac MRI video frames (22-88-65-234) before edge detection of each frame.

The next step is applying proposed method (fuzzy video edge detection) technique on the MRI video. The main core of this method depends on three steps: fuzzification, building and applying fuzzy rules and then defuzzification. In the fuzzification step, the parameters of the membership function were extracted based on the standard deviation method in [9], see the standard deviation curve in the figure (6) which was illustrated below:

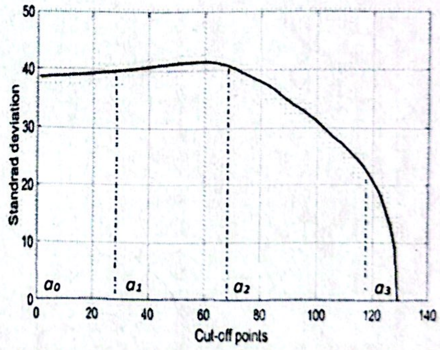


Fig.6, illustrated standard deviation curve which calculated from a set of SD values. By this curve, parameters of membership function (a_0, a_1, a_2, a_3) are extracted based on this curve.

Obtaining parameters of the fuzzy membership parameters based on the standard deviation curve in the figure (6) is the essential step in the preparing fuzzy membership function in the figure (2). This step is fuzzification, then 12 fuzzy rules in the section II-A was applied. Defuzzification using equation (1) is the last step. Figure (7) demonstrates carrying out fuzzy video edge detection technique on one frame of the MRI video. From this figure, three different levels of information can be obtained

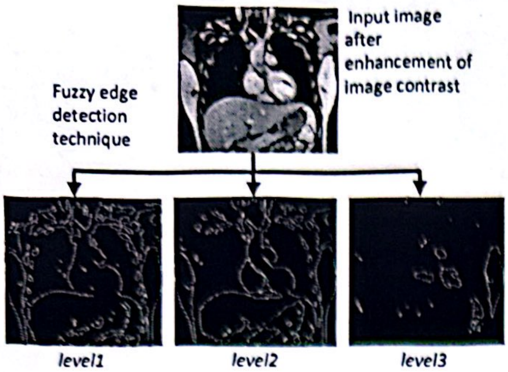


Fig (7), Fuzzy Video Edge detection method was applied on each frame of MRI video, this frame 22 was selected randomly. Three levels of image information are illustrating in this figure.

Comparison between fuzzy video edge detection (FVED) technique and image edge detection by Canny operator [15] are illustrated in the figure (8*a*,*b*). Figure (8*b*) is more unblemished than figure (8*a*) because FVED technique presents necessary information of the image.

Fig (8), *a* presents edge detection image using Canny operator while *b* illustrates edge detection image by proposed method.

The same steps of fuzzy video edge detection on the other frames of sample 1 were implemented also on the rest of other 9th MRI video samples. Table I illustrates evaluation assessment metrics (FOM and Pinho) for tenth MRI video samples

Table I shows mean values evaluation of (FOM and Pinho) for 10 MRI videos

Samples	Metrics	FVED	Canny
Sample1	FOM	0.368	0.342
	Pinho	0.832	0.70
Sample2	FOM	0.453	0.302
	Pinho	0.817	0.69
Sample3	FOM	0.391	0.325
	Pinho	0.78	0.71
Sample4	FOM	0.58	0.442
	Pinho	0.88	0.76
Sample5	FOM	0.29	0.22
	Pinho	0.67	0.63
Sample6	FOM	0.429	0.332
	Pinho	0.765	0.663
Sample7	FOM	0.522	0.438
	Pinho	0.932	0.911
Sample8	FOM	0.298	0.222
	Pinho	0.673	0.532
Sample9	FOM	0.543	0.587
	Pinho	0.911	0.95
Sample10	FOM	0.456	0.543
	Pinho	0.832	0.884
Mean of FOM		0.433	0.37
Mean of Pinho		0.800	0.74

IV. Discussion

MRI imaging (images and videos) is a powerful tool for displaying and examining what is inside the human body. Delineation the important details of the MRI imaging helps in the evaluation of the morphological description and analysis of objects, organs and tissue inside body. In this work, we introduced and implemented a new method Fuzzy Video Edge Detection (FVED) that mainly focuses on extracting important details based on the fuzzy inference system instead of showing all the details in the same image.

Fuzzy Video Edge Detection (FVED) was applied on the real time cardiac MRI video and extracted three levels of information for each frame of MRI video. Level 2 helps in the defining most important information briefly, see figure (7). Proposed method was compared with another edge detection method (Canny operator). Figure (8) illustrates example of output image frame of MRI video after applying FVED and Canny operator method, the difference between two images is clear. Our method depicts useful identification details, FVED outperforms in the performance than other method, so FVED is greater than Canny operator with 14.5% and 7.5% based on the mean values of quantitative assessments (FOM and Pinho) are demonstrated in the table I

V.Conclusions and Future work

Detection and analysis of MRI video is a promising step in many applications of medical imaging, as the use of this technique in clinical field can support the radiologist towards more accurate diagnosis. Therefore, in this research an innovative technique (fuzzy video edge detection) was applied and performed to highlight significant details of MRI video which is necessary for clinicians and researchers. This technique surpasses in the performance than Canny operator technique. Fuzzy video edge detection technique is potential method to support clinicians and researchers also it is possible to apply it on other medical imaging data.

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