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Extraction of Bood vessels in X-Ray Angiography Image using Fuzzy Logic

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Abstract: The accurate and automated analysis of vessel is a valuable tool in medical imaging since it is applicable to many medical applications involving diagnosis of atherosclerosis, surgical or treatment planning, monitoring disease progress or remission, and comparing efficacies of treatment. In this paper an automatic vessel edge detection algorithm is proposed based on Fuzzy logic. Our proposed method follows the steps firstly pre processing step to remove varying background, which is the combination of wiener filtering and morphological operators and secondly detection of vessel edges by fuzzy inference system. Experiments on Angiograms show promising detection results.

Keywords: Edge detection, Background removing, Fuzzy inference system, vessel, Angiography

I. INTRODUCTION

Coronary artery disease (CAD), is the most common type of heart disease. CAD is a condition in which plaque (plak) builds up inside the coronary arteries These arteries supply heart muscle with oxygen-rich blood. So this can cause angina or a heart attack . Coronary angiography is a test for showing the inside of coronary arteries. Since X-ray angiogram is the projection of the 3D reality into a 2D representation, after injection of the patient with a radio- opaque dye before imaging, the consistency of the dye within the vessel, the depth of the vessel, and existence of noise during the imaging process result in image that is a challenge. There are many machine vision methods addressing the problem of vessel segmentation in 2D-projection images. Some of these methods employ region growing techniques to extract vessels [2]. Tracking methods were also presented to extract vessels in images [3] some model-based approaches uses deformable spline or the snake to minimize energy functions and extract vessel structures [4]. The main disadvantage of these approaches is that they often require user interaction to initialize the algorithm, which causes the algorithm to be semi automatic. Some approaches use threshold schemes for vessel segmentation [5], but computation of threshold value is not satisfactory for all the qualities of images. Artificial Intelligence approaches [6] utilize knowledge to guide the segmentation process and to delineate vessel structures. They are so robust in accuracy, but mostly need complex computation. Pattern matching [7], neural network [8], skeleton based approaches [9] are other techniques introduced for vessel segmentation. A survey on various vessel segmentation methods can be found in [10]

In this paper we presented a new technique for extracting vessels in angiography images, The core of the algorithm is edge detection by Fuzzy Inference system, because of natural properties of angiograms, such as low SNR due to poor X-Ray penetration, low qualities of imaging tools, accurate detection of vessel edges is corrupted. To come over this problem we first employed preprocessing step in order to eliminate varying background and noise removal. This has important effect on performance of FIS in next step. The derived image will be given to Fuzzy system for extracting vessel edges. The experimental results show that we can extract the blood vessel edges with high accuracy. The remaining parts of this paper are organized as follows: In section 1 background removing is explained as a Pre processing step. IN section2 Fuzzy edge detector is introduced and applied to the results of section 1. In section 3 results on real angiograms have been shown.

II. BACKGROUND REMOVING

Background removing is a common step in the medical image processing. As mentioned before all angiograms suffer from varying background, which harden accurate detection of vessel edges. Motivated by obtaining background-free image, we applied mathematical morphology to raw image.

Mathematical Morphology (MM), created to characterize the physical and structural properties of diverse materials, relies on geometric, algebraic and topologic concepts as well as on the theory of sets. The basic operations of MM are erosion and dilation. The remaining morphological operators are defined based on the combination of these two. In this step we first calculate negative of image and then applied wiener filter of size5*5 in order to noise suppressing. Wiener filter is an adaptive low pass filter which estimates the output pixel using mean and variance of a local neighborhood of a pixel.

$$\mu = 1/MN \sum_{n1,n2\in\eta} \alpha(n1,n2) \tag{1}$$

$$\sigma^2 = \frac{1}{MN} \sum_{n1,n2\in\eta} \alpha^2(n1,n2) - \mu^2 \tag{2}$$

M and σ^2 are mean and variance the neighborhoods of size m-by-n around each pixel [1].

Then we applied morphological erosion to the filtered image, in this way we have an estimation of background. By applying dilation to the filtered image and subtracting these two images we get the binary image including vessels and less fat and less tissue. Figure (2) shows block diagram of pre processing step.

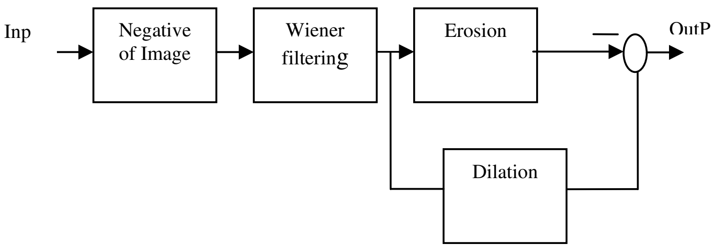


Figure1.block diagram of preprocessing step .

Results of pre processing step on 3 angiograms have been shown in figure 2.

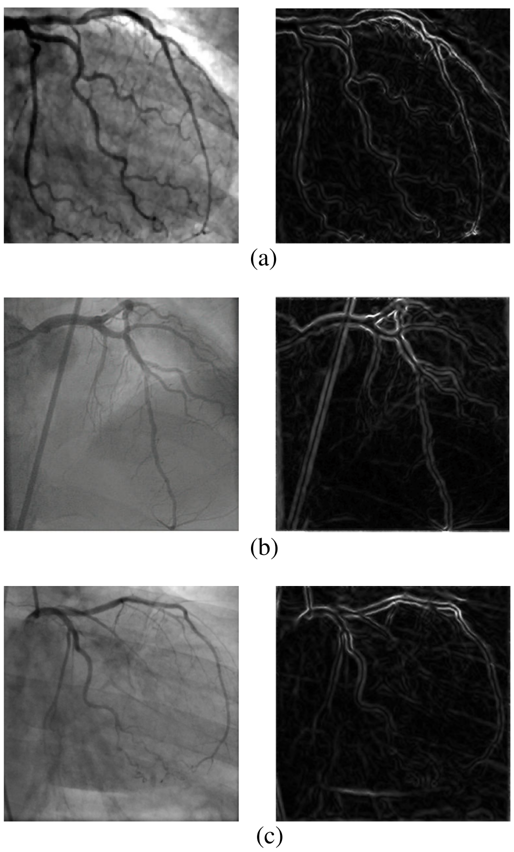


Figure 2.Results of pre processing step

a) Sample1; right: Original Image; left: pre processing result

b) Sample2; right: Original Image; left: pre processing result

c) Sample3; right: Original Image; left: pre processing result

III. VESSEL EDGE DETECTION

A. Pre Processing

The image derived in previous section needs more processing steps before being fed to the Fuzzy system , thus we used four linear filters to the resultant image .These filters are :

1- Sobel horizental edge detector

$$h_{DH}=\begin{bmatrix} 1 & 2 & 1 \\ 0 & 0 & 0 \\ -1 & -2 & -1 \end{bmatrix}$$

Sobel vertical edge detector

$$H_{dv}=\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

2- High pass filter

$$H_{hp}=\begin{bmatrix} -1/16 & -1/8 & -1/16 \\ -1/8 & 3/4 & -1/8 \\ -1/16 & -1/8 & -1/16 \end{bmatrix}$$

3- Gaussian filter

$$h(x,y,\sigma) = e^{-(x^2+y^2)/2\sigma^2}$$

These four filters are applied to the image of previous step in a parallel way. Each filter response will be fed to the FIS separately, that is :

DH = hDH * I

DV = hDV * I

HP = hHP * I

G = h * I

B. Fuzzy inference system

Fuzzy based rules method in most of fuzzy based edge detection algorithms are used in this section we introduce our fuzzy system. Goal of employing fuzzy Inference system in this section is to determine each pixel belongs to vessel edge or not Implementation of fuzzy inference system was carried out by introducing three membership functions for each FIS input. Each Membership function is related to one linguistic function (Low, medium and high). Membership functions for Input G and output are Gaussian functions as shown in Figure 3. For other inputs, membership functions corresponding to linguistic variables low and medium are also Gaussian functions and sigmoid function for variable high.

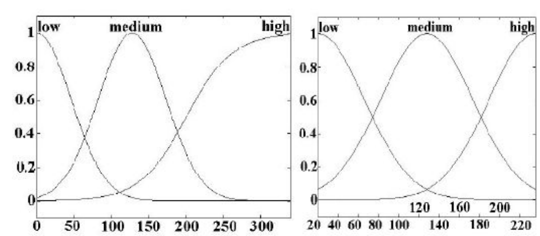


Figure 3: membership functions of input of inputs DH, DV, and HP (Left) G and output (Right)

The operating functions to implement “and” and “or” are max and min and mamdani defuzzification method was used for defuzzifiying the data. Applied fuzzy rules to define edge intensities are as follows:

1) (DH low) and (DV low) ("Edge low")

2) (DH medium) and (DV medium) ("Edges" high).

3) (DH high) or (DV high) ("Edges" high).

4) (DH Medium) and (HP low) ("Edges" high).

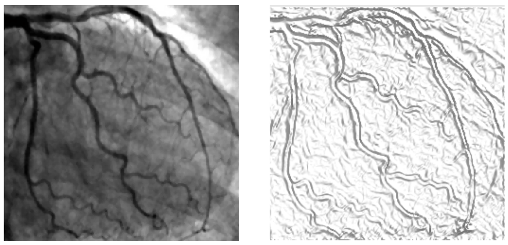
6. (DV Medium) and (G low) ("Edges" low).

7. (DH Medium) and (G low) ("Edges" low).

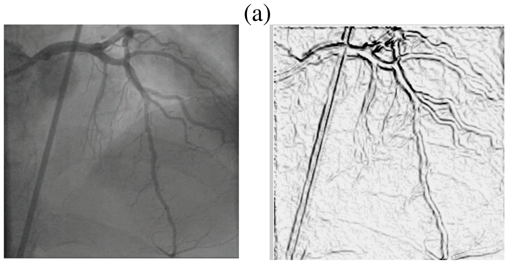
The outputs of fuzzy interference system generally determined the edge of vessels.

IV. RESULTS

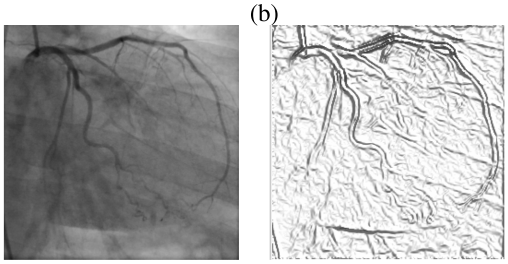
Figure 4 shows result of our fuzzy edge detector on 3 angiograms.



(a)



(b)



(c)

Figure 4.Final Results

a) Sample1; right: Original Image; left: Edge detection result

b) Sample2; right: Original Image; left: Edge detection result

c) Sample3; right: Original Image; left: Edge detection result

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