Blood Vessels Detection Using Fuzzy Inference System

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Abstract - The accurate analysis of Coronary angiographic images plays an important role in diagnosing arterial diseases. All angiograms suffer from varying background, consisting of heart tissues, which harden accurate detection of vessels. Therefore removing background is one of the important steps which have essential effect on improving performance of subsequent steps of vessel detection algorithm, especially in the presence of noise. In this paper a new method for automatic precise detection of blood vessels in angiograms is proposed. Our method follows the steps firstly background removing, Secondly enhancement of vessel edges using fuzzy inference system and finally post processing the derived image for better visualization. Experiments on Angiograms show promising detection results.

Keywords: vessel detection, Background removing, Fuzzy inference system, Angiography, Hilbert Matrix

1 Introduction

Coronary artery disease (CAD) is the leading cause of death in most industrial and semi industrial countries. Thank to Various medical imaging methods, accurate analysis of coronary arteries has been provided. Among them, angiography is a standard method for anatomical and physiological assessment of blood vessels. Precise automatic detection of vessel structures is an essential step in the analysis and interpretation of medical images. One of Major problems in extraction of vessels in angiograms results from low SNR due to poor X-Ray penetration, conventional vessel segmentation methods that rely on image intensity alone fail to detect vessel structures accurately [2].

Existing methods for vessel segmentation can be categorized into pattern recognition techniques [3], model-based approaches [4,7], tracking-based approaches [8], and classified-based approaches [5,6]. A survey on various vessel segmentation methods can be found in [9].

In this paper a new method of vessel detection is proposed which is combination of morphological operators and wiener filtering followed by fuzzy edge detection algorithm. Our fuzzy algorithm is inspired by the algorithm proposed in [10].

The remaining parts are organized as follows:

In section 1 background removing is explained as a preprocessing step. In section 2 Fuzzy edge detector is introduced and applied to the results of section 1. In section 3 the visualization of the image has been enhanced by applying an additional post processing step. Figure 1 shows the proposed algorithm.

![Figure 1: Block Diagram of Proposed method](image)

In the first step varying background has been removed using wiener filter, for noise suppressing, and morphological operator erosion. In the second step FIS is introduced and finally post processing step will be explained. Goal of using final step is vessel enhancement for better vision.

2 Background Removing

Preprocessing an image consists of all conversions on image data so as to make them more effective for consequent steps. In this step we firstly used morphological operator to remove the varying background. For this aim, negative image is calculated and then processed by wiener filter using the neighborhood of size (5*5). Wiener filter is an adaptive low pass filter which estimates the output pixel using mean and variance of a local neighborhood of a pixel

\[
\mu = \frac{1}{MN} \sum_{m,n} \alpha(m,n)
\]

\[
\sigma^2 = \frac{1}{MN} \sum_{m,n} \alpha^2(m,n) - \mu^2
\]

\(\mu\) and \(\sigma^2\) are mean and variance in the neighborhoods of size m-by-n around each pixel [1]. Applying Wiener filtering results in more distinction between vessel and background. It causes background to be blurred but not sensible degradation in edges. This helps better elimination of vessel in next step.

Negative of filtered image is computed and then processed by morphological operator erosion which is one of
the basic operators in the area of mathematical morphology. Subtracting eroded image form the negative one, we will have vessel structures more clearly, that is:

```
H3 = [1 1/2 1/3
     1/2 1/2 1/4
     1/3 1/4 1/3]
```

This step is helpful for better visualization of final image. Result of preprocessing step is shown in figure (2).

![Figure (2): Original image (Left) and result of preprocessing step (Right)](image)

### 3 Vessel Edge detection

#### 3.1 Pre Processing

The image derived in previous section needs more processing steps so as to provide stronger edges. For this aim we used fuzzy edge detection algorithm proposed by [10]. According to their algorithm 4 linear filter applied to the image as a preprocessing step. These four filters are as follows:

1. Sobel horizontal edge detector given by:
   
   \[
   h_{DH} = \begin{bmatrix}
   1 & 2 & 1 \\
   0 & 0 & 0 \\
   -1 & -2 & -1
   \end{bmatrix}
   \]

2. Sobel vertical edge detector given by:
   
   \[
   h_{DV} = \begin{bmatrix}
   -1 & 0 & 1 \\
   -2 & 0 & 2 \\
   -1 & 0 & 1
   \end{bmatrix}
   \]

3. High pass filter given by:
   
   \[
   h_{HP} = \begin{bmatrix}
   -1/16 & -1/8 & -1/16 \\
   -1/8 & 3/4 & -1/8 \\
   -1/16 & -1/8 & -1/16
   \end{bmatrix}
   \]

4. Gaussian filter given by:
   
   \[
   h(x, y) = e^{-\frac{x^2 + y^2}{2\sigma^2}}
   \]

These filters will apply to the image separately, that is:

- \(DH = h_{DH} * I\)
- \(DV = h_{DV} * I\)
- \(HP = h_{HP} * I\)
- \(G = h * I\)

Each of these variables considered as an input for fuzzy inference system which will be described in next section.

#### 3.2 Fuzzy Inference System

Goal of employing fuzzy Inference system in this section is to strengthen visualization of vessel edges, that 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) [10]. The applied membership functions for Input G and output are Gaussian functions as shown in figure (3).

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

For other inputs, membership functions corresponding to linguistic variables low and medium are also Gaussian functions and sigmoid function for variable high. The operating functions to implement “and” and “or” are max and min and mamdani defuzzification method was used for defuzzifying the data. Some of fuzzy rules to define edge intensities are as follows:

1. (DH low) and (DV low) then (“Edge low”)
2. (DH medium) and (DV medium) then ("Edges" high).

3. (DV high) and (DV (i + 1, j) high) then ("Edges" medium).

4. (DH high) and (DH (i, j+ 1) high) then ("Edges" medium).

Complete list of all fuzzy rules can be found in [10].

Figure (4) shows image processed by Fuzzy Inference System.

Figure (4): Output image of Fuzzy Inference System

4 Post Processing

The image derived by FIS needs to be processed for better visualization. So we apply an additional step as post processing to detect vessels more vividly. After contrast adjustment we applied an additional filtering step by Hilbert matrix. As mentioned before, it smoothes the image and helps better visualization [11].

Post processing step includes 4 steps:

1. filtering image with Hilbert matrix of order 3
   This filtering results in having smoother image because of noise reduction

2. Applying inverse Hilbert transform of order 2.
   Using Inverse Hilbert transform causes image being embossed

3. Subtracting image in step 2 from the image in step1.

4. Applying additional Hilbert matrix of order 2 for contrast enhancement.

Final image has been shown in figure (5).

5 Conclusion

In this paper we proposed an algorithm for accurate segmentation of blood vessels in angiograms. Our algorithm is an improved version of algorithm proposed by [11]. Results show adding a preprocessing step can improve FIS performance. Our preprocessing step consists of removing background using morphological operations and wiener filter. In addition we employed a post processing step by using Hilbert matrix and its inverse. This helps image being more embossed. Experiments on Angiograms show promising detection results.

6 References


