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Angio Vessels Detection Based on Eigen Values of the Hessian Matrix

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Abstract

The Blood vessels of the human body can be visualized using many medical imaging methods such as X-ray, Computed Tomography (CT), and Magnetic Resonance (MR). In medical image processing, blood vessels need to be extracted clearly and properly from a noisy background, drift image intensity, and low contrast pose. Angiography is a procedure widely used for the observation of the blood vessels in medical research, where the angiogram area covered by vessels and/or the vessel length is required. For this purpose we need vessel enhancement and segmentation. Segmentation is a process of partitioning a given image into several non-overlapping regions. Edge detection is an important task and in the literature, complex algorithms have been modeled for the detection of the edges of the blood vessels. The edges of the vessels in the angiogram image are detected using the proposed algorithm which is done using the classical image processing techniques. This involves the Preprocessing step, where the noise is removed using a simple wavelet denoising and Histogram equalization technique; instead of the Canny edge Detector. The proposed algorithm is not complicated but accurate and involves very simple steps.

1. Introduction

Angiography is the study of blood vessels. The function of blood vessels is to supply blood to the body for providing oxygen and nutrients to the human body. Angiography is done in catheterization laboratory where a thin tube called catheter is inserted into the blood vessels up to the heart to detect the blockage in blood vessels. If there is blockage in blood vessels then it results in less supply of blood to the heart which results in heart failure. So the main use of angiography is in blockage detection. Segmentation is one of the major steps in the analysis of medical images, as it outputs the attributes extracted from the input images. The need for automated width detection lies in analyzing the presence or absence of specific anomalies. The paper presents the segmentation of the Coronary artery tree from the angiographic images. This is done by extracting or segmenting the vessels and thereby detecting its width. The proposed algorithm consists of two main steps, namely the pre-processing and the segmentation. In the pre-processing step, the Hessian matrix analysis is done to track the coronary vessel structures from the original image and the Histogram equalization is used to enhance the angiogram image. In the second step, the segmentation is done by using Hessian matrix and finally the width of the segmented blood vessel in the coronary angiogram image is determined.

2. Methodology

The method consists of three main steps, namely (a) Pre-processing,(b)Segmentation and (c) Width detection. First the input image is preprocessed using the Wavelet Denoising and Histogram Equalization is used to get the enhanced image. Then the Hessian Matrix operations are done to segment the detected angio vessels from the background image. Finally the width of the segmented angio vessel is detected at random points along the segmented vessel automatically.

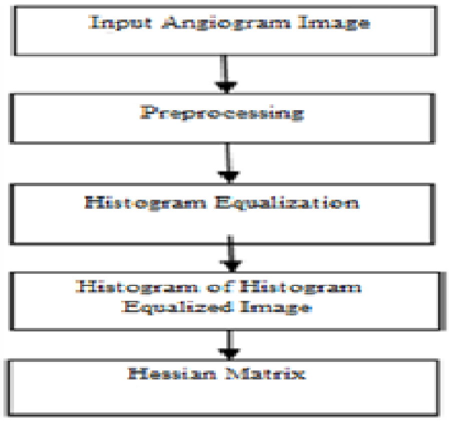

Fig 1 Flow Diagram of Algorithm

Thus mentioned method is used to detect the width of the angiogram vessel from the given angiographic image automatically.

2.1. Pre-processing

This step is done to remove the noise using the Harr wavelet and the Hessian matrix is used to provide the enhancement of the input angiogram image. Image enhancement process consists of a collection of techniques that seek to improve the visual appearance of an image. Thus the basic aim of this step is to make the image look better. The objective of the enhancement technique is to process an image so that the result is more suitable than the original image for a particular application. The Hessian matrix analysis is done to track the Coronary vessel structures from the original image. The Eigen values of the Hessian are the principal curvatures and their product is the Gaussian curvature, which is the determinant of the Hessian. Thus, for the Hessian matrix, the Eigen vectors form an orthogonal basis showing the direction of curve, which is the gradient of the image.

(i) If both the Eigen values are positive, then it is a local minimum,

(ii) If both the Eigen values are negative, then it is a local maximum,

(iii) If the Eigen values have mixed sign, then it is a saddle point.

So, if the product of the Eigen values are positive, then they are either either positive or both negative, which means that they are at the local extremes. Further the major features are detected by applying a threshold to the obtained determinant values. The tree or results of the Hessian analysis is stored for future reference. This is finally applied to obtain the vessel feature map and the vessel direction map. The Hessian matrix used is a simple second order Gaussian derivative. Hessian matrix is composed from the image 2nd order partial derivative.

$$H = \begin{bmatrix} \frac{\partial^2 I}{\partial x^2} & \frac{\partial^2 I}{\partial x \partial y} & \frac{\partial^2 I}{\partial x \partial z} \\ \frac{\partial^2 I}{\partial y \partial x} & \frac{\partial^2 I}{\partial y^2} & \frac{\partial^2 I}{\partial y \partial z} \\ \frac{\partial^2 I}{\partial z \partial x} & \frac{\partial^2 I}{\partial z \partial y} & \frac{\partial^2 I}{\partial z^2} \end{bmatrix}$$

Where H- Hessian matrix, I- Input image, X, Y, Z- co ordinates within I.

Thus, the above mentioned algorithm is used to detect the edges of the vessel from the given angiogram image. The Hessian matrix analysis is done to track the Coronary vessel structures from the original image. The Eigen values of the Hessian are the principal curvatures and their product is the Gaussian curvature, which is the determinant of the Hessian. Following eigenvalues are sorted so that | 1|≤| 2|≤| 3|. Table.2.1 summarizes the relations between i and orientation of a structure in the images

Eigen Value 1	**Eigen Value 2**	**Eigen Value 3**	**Structure Orientation**
L	L	L	Noise(no preferred structure)
L	L	H-	Bright sheet like structure
L	L	H+	Dark sheet like structure
L	H-	H-	Bright tubular structure
L	H+	H+	Dark tubular structure
H-	H-	H-	Bright blob like structure
H+	H+	H+	Dark blob like structure

Table 2.1 Eigen Values of the Hessian Matrix and Image Structure Orientation

2.2 Histogram Equalization

An image histogram is type of histogram which acts as a graphical representation of the tonal distribution in a digital image. Image histograms are present on many modern digital cameras.

2.2.1 What Is A Histogram?

A Histogram is a vertical bar chart that depicts the distribution of a set of data. Unlike run Charts or Control Chart. A Histogram does not reflect process performance over time. It's helpful to think of a

Histogram as being like a snapshot, while a Run Chart or Control Chart is more like a movie.

2.2.2 When should we use a Histogram?

When you are unsure what to do with a large set of measurements presented in a table, you can use a Histogram to organize and display the data in a more user friendly format. A Histogram will make it easy to see where the majority of values fall in a measurement scale, and how much variation there is.

2.3. Segmentation

Segmentation refers to another step in image processing methods where input is images and outputs are attributes It subdivides an image into its constituent regions or objects. Segmentation accuracy determines the eventual success or failure computerized analysis procedures. Segmentation algorithms are based on 1 of 2 basic properties of intensity values: discontinuity & similarity. Discontinuity approach is to partition image based on abrupt changes. Similarity approach is to partition the image intensities (edges) based on similar regions according to predefined criteria.It is defined to be a process of partitioning a given image into several non-overlapping regions. This feature of segmentation is used to detect tumors, regions of interest, edges of blood vessels, and a lot more from the given image. Angiogram is performed to detect, if there is any block in the flow of blood within the blood vessels. Hence the detection or extraction of the blood vessels is very important and must be very accurate. The output image is created voxel wise using the calculated vesselness values. The eigenvalues (in magnitude and sign) of the local Hessian matrix, ordered by magnitude (jl1 < jl2 < jl3) are given as follows:

$$\mathcal{R}_{\mathcal{B}} = \frac{\text{Volume}/(4\pi/3)}{(\text{Largest Cross Section Area}/\pi)^{3/2}} = \frac{|\lambda_1|}{\sqrt{|\lambda_2\lambda_3|}}$$

Equation 2.1

$$\mathcal{R}_{\mathcal{A}} = \frac{(\text{Largest Cross Section Area})/\pi}{(\text{Largest Axis Semi-length})^2} = \frac{|\lambda_2|}{|\lambda_3|}$$

Equation 2.2

Based on these values the vesselness function is given by-

$$\mathcal{V}_o(s) = \begin{cases} 0 & \text{if } \lambda_2 > 0 \text{ or } \lambda_3 > 0, \\ \left(1 - \exp\left(-\frac{\mathcal{R}_A^2}{2\alpha^2}\right)\right)\exp\left(-\frac{\mathcal{R}_B^2}{2\beta^2}\right)\left(1 - \exp\left(-\frac{s^2}{2c^2}\right)\right) & \end{cases}$$

Equation 2.3

Where α, β, c are threshold constant.

2.4 Adaptive Thresholding

Thresholding is the simplest way to segment objects from a background. If that background is relatively uniform, then you can use a global threshold value to binarize the image by pixel-intensity. If there's large variation in the background intensity, however, adaptive thresholding (local or dynamic thresholding) may produce better results. In order to overcome the ill influence of noise and shading, there is a need to take them into consideration when selecting the threshold being used.

3. Result

The method was tested on the real images acquired from 22 patients. Each image had a size of 256x256 pixels. All the algorithms were implemented in MATLAB 10.00 on a Pentium IV Personal Computer (with Central Processing Unit 2.8G and 512M memory). A Graphical User Interface is created with three push buttons, one to select the input image, next to segment the image and the last to detect the width of the angio vessel at random points. The performance of the method was evaluated in two stages. The first stage evaluation is done by comparing the proposed algorithm which involves Harr wavelet and Histogram Equalization for segmentation. The second stage evaluation is done by deriving the various performance measures in order to improve the efficiency of the method.

3.1 Simulated Outputs

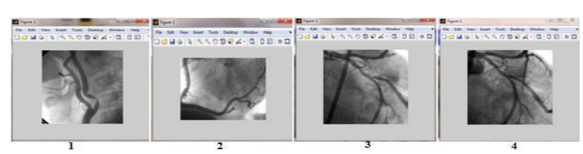

Fig 3.1: Input Angiogram Images

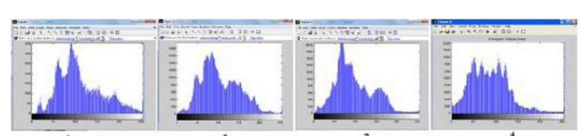

Fig 3.2 Histogram of the input images

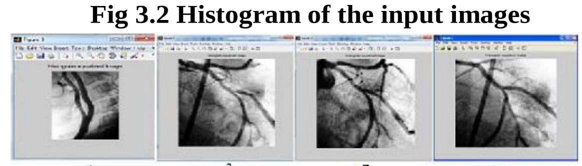

Fig 3.3 Histogram equalized images

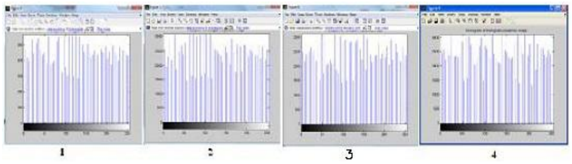

Fig 3.4 Histogram of Histogram equalized Images

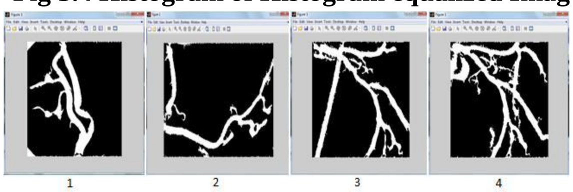

Fig 3.5: Segmented images

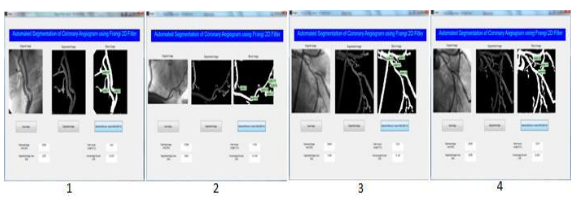

Fig 3.6: Width detected Angiogram image along with the various parameters

4. Conclusion

In this paper, the method segments the blood vessels automatically from the given Coronary angiogram image and detects the blocks and the width of the segmented angiogram image. The performance results show that the method is unique in nature and gives better results in terms of accurate segmentation with increased TVL, SIA, TIIA and VIP, and a highly reduced computational time.

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