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Research on automatic coronary artery extraction algorithm based on CTA image and model guidance

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ABSTRACT. *When doctors diagnose coronary artery by CTA data, they need to look at each section layer by layer, which consumes a lot of diagnostic time. Introducing artificial intelligence technology, using CTA image computer-aided technology to extract coronary artery automatically or semi-automatically, and assisting analysis of coronary artery, can improve the efficiency of doctors, quickly make diagnosis of patients. A priori model of coronary artery centerline based on image registration is studied. A single priori model is formed by fusing multiple cardiac CTA data, which increases the generalization ability of the model and provides more accurate priori position information of main branches for unknown CTA data. According to the composition of the model, it will be divided into two parts: the cardiac cavity model and the centerline model. The implementation of the model establishment, DMP centerline extraction and coronary analysis is introduced. The methods of central line tracing were discussed, and the clinical application of central line extraction was divided into 1) radius extraction 2) calcification and stenosis analysis. Coronary CTA (Computed Tomography Angiography) technology can not only obtain the image of coronary artery, but also image the wall of coronary artery, assisting doctors in the analysis of vascular calcification and stenosis. Coronary CTA technology adds a diagnostic approach to cardiovascular disease and makes it more acceptable to patients because of the use of non-interventional techniques.*

KEY WORDS: *CTA image , Coronary, Centerline , Image algorithm*

1. Introduction

Development trends at home and abroad: Trend of development at home and abroad: In clinic, when doctors diagnose coronary artery by CTA data, they need to look at each section layer by layer, which consumes a lot of diagnostic time. Introducing artificial intelligence technology, using CTA image computer-aided technology to extract coronary artery automatically or semi-automatically, and assisting analysis of coronary artery, can improve the efficiency of doctors, quickly make diagnosis of patients. At present, a large number of researchers are studying the automatic extraction of coronary artery, and aiming at the complex structure of coronary artery, the extraction accuracy and recognition accuracy of coronary artery are studied.

Research purpose and significance: Cardiovascular disease has become one of the major diseases in developed countries, and the number of people suffering from cardiovascular disease in China also shows a rapid growth trend. According to the China Cardiovascular Disease Report 2012 compiled by the National Cardiovascular Disease Center, about 3.5 million people die of cardiovascular diseases every year, accounting for 41% of the total causes of death. In the early diagnosis and treatment of cardiovascular diseases, the most commonly used method is catheter intervention, but this method needs to invade the human body, will bring some surgical pain to patients. At the same time, catheter intervention itself also has certain defects, such as difficult to detect changes in vascular wall thickness, which makes some early or even chronic coronary atherosclerosis can not be reliably diagnosed.

Research status: At present, the extraction of cardiac coronary artery is mainly divided into two directions: direct extraction and indirect extraction. Directly based on traditional image segmentation algorithms, such methods are difficult to achieve global optimization, and are prone to under- or over-segmentation. The indirect method first extracts the coronary centerline and then divides the coronary artery along the extracted centerline according to the demand. This method has been widely concerned and has become the mainstream of current coronary segmentation research.

2. Research Content

2.1 Study on the establishment method of coronary centerline prior model based on image registration

It will be fused by multiple cardiac CTA data to form a single prior model, which will increase the generalization ability of the model and provide more accurate main branch prior position information for unknown CTA data. According to the composition of the model, it will be divided into two parts: the heart cavity model and the centerline model:

1) Register multiple cardiac CTA data including coronary centerline into the same coordinate space, and select the fusion method to complete the establishment of the cardiac model.

2) By image registration, the main branch center line of multiple cardiac CTA data is mapped onto the heart model to form a center line cluster, and a method of merging the center line cluster into a single center line is studied.

2.2 Study of coronary artery centerline extraction algorithm based on model guidance and inertia drive

1) Model-guided and inertially driven DMP (Directional Minimal Path) method to achieve a fully automatic coronary main branch centerline extraction algorithm to extract right coronary artery (RCA), left anterior descending artery (LAD) and The three main branches of the left circumflex artery (LCX).

2) The region growing algorithm automatically recognizes the sub-branch bifurcation point on the main branch, and extracts the sub-branch on the main branch from the bifurcation point to establish the center line of the entire coronary tree.

3. Key Technologies

This project is aimed at the extraction of automatic coronary centerline and its clinical application, as shown in Fig 1. The main research steps are: pretreatment, centerline tracking and clinical application research. The specific implementation of model establishment, DMP centerline extraction and coronary analysis will be elaborated below.

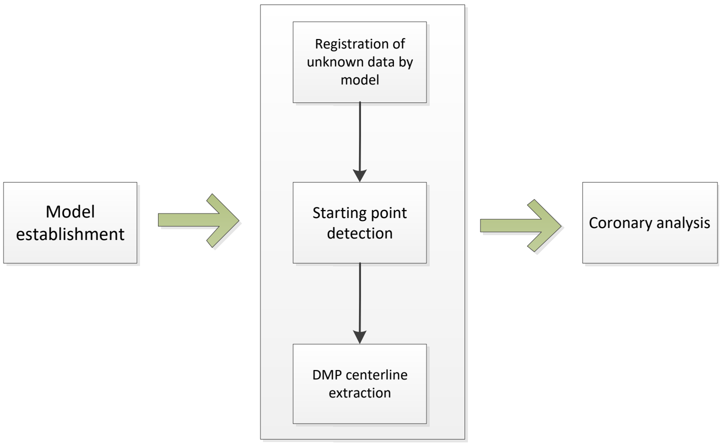

Fig 1. Automated coronary centerline extraction and clinical application framework.

3.1 CTA model establishment

The a priori model consists of two parts, the heart cavity and the centerline of the main branch. After the model is registered to the unknown CTA data to be detected, the a priori position information of the main branch of the unknown data can be obtained. In order to enhance the generalization ability of the model, multiple CTA data are selected for fusion in the model establishment stage to form a single model.

Before the model is built, eight CTA data containing the manual extraction results of the main branch centerline will be prepared. At the same time, a cardiac CTA data is selected to manually segment the cardiac cavity, and the map data indicating the segmentation result of each cavity is obtained.

3.2 Establishment of a cardiac cavity model

1) The CTA data including the segmentation map is subjected to non-rigid registration for the eight CTA data, and the segmentation maps are respectively mapped to the eight CTA data by the registration result, and the segmentation result flag maps of the eight CTA data are obtained.

2) Using the linear rigid body registration method, in which 7 segmentation marker maps are registered to another segmentation marker map, so that 8 segmentation marker maps are in the same coordinate space, and then shape-based Averaging is used. The average of the eight segmentation markers is averaged to obtain an initial mean marker map.

3) Using the non-rigid registration method, register the eight segmentation markers onto the mean marker map, and then average the eight marker images after registration using the shape averaging method to obtain the mean marker map.

4) Calculate the difference between the current mean marker map and the previous mean marker map. If the difference exceeds the threshold, return to step 3 until convergence, and finally obtain the cardiac cavity model.

3.3 Establishment of the main branch centerline model

1) Using the non-rigid registration method to register the eight marker maps to the heart cavity model established in the previous section, the main branch centerlines contained on the corresponding eight marker maps are simultaneously mapped to the same coordinate space to form The center line cluster, as shown in Figure 2.

2) Selecting a reference center line from the 8 mapped main branches requires the reference center line to have the smallest average distance from the other 7 center lines, close to the center line cluster center position.

3) Starting from the starting position of the reference center line, calculate the slice surface of each point of the reference center line one by one, and obtain the intersection of the other 7 center lines and the tangent plane, average the 8 points on the same tangent plane, and finally obtain the center line. model.

After obtaining the centerline model, look for the centerline from the centerline family that is longer than the centerline model and translate the length excess to the

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end of the centerline model. Through this processing, the centerline model is moderately extended to increase the adaptability of the model to different unknown CTA data to be detected.

In order to verify this method, we selected a CTA data substitution model, registered 8 CTA data to this CTA data, and obtained the main branch RCA centerline cluster, and calculated the center line model of RCA using the above method. , as shown in Fig 2. Intuitive results show that the merged model centerline avoids individual differences and increases the generalization ability of the model.

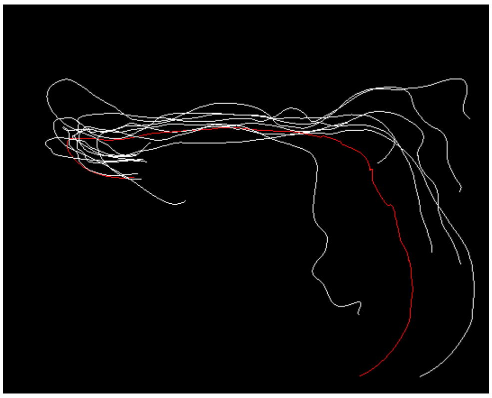

Fig. 2. The effect of center line model establishment is shown. The white is the RCA center line cluster, and the red is the RCA center line model.

4. Centerline tracking

The central line tracking of the main branch of the coronary artery consists of three main steps, namely model registration, starting point detection and DMP centerline extraction. Model registration and starting point detection provide two important sources of driving information for the DMP algorithm: centerline prior information and DMP starting position. Since the DMP centerline extraction is the core step of the project, the research methods and implementation routes will be highlighted.

4.1 Model registration and starting point detection

The purpose of model registration is to establish a transformation relationship between a priori information and unknown CTA data to be detected, so that the unknown CTA data can obtain the reference position of the center line of the coronary main branch, and provide direction guidance for the DMP algorithm. In this project, the non-rigid registration method will be selected to register the model to unknown CTA data.

The model registration also obtained the reference position of the coronary origin (aortic inflow, Ostium), which narrowed the range of the starting point detection. In the neighborhood of the reference location, we will use the three-dimensional Haar-like feature and the Probabilistic Boosting Tree (PBT) framework to detect the origin of the coronary centerline. Since the aortic inflow port is small in size relative to the entire cardiac CTA data, it would be difficult to reliably detect the aortic inflow port if using the traditional image-based gray-based Haar feature. As shown in Figure 3-c, multiple clusters are detected as aortic inflow. The same problem also occurs on the Haar feature based on Vesselness, as shown in Figure 3-d. But because the two clusters show different styles, we combine two different probability tree detection results based on image grayscale and Vesselness to detect more accurate results. As shown in Figure 3-f, the final test results can obtain fewer families and accurately locate the aortic flow inlet.

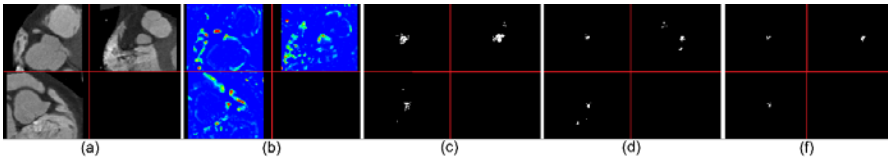

Fig 3. Haar feature PBT training detection method combining image gray scale and Vesselness: (a) three-view profile of CTA heart data; (b) corresponding Vesselness; (c) training using gray level information, probability greater than 0.99 Results; (e) using Vesselness test results (probability greater than 0.99); (f) combining the results of the two methods (probability greater than 0.99).

4.2 Centerline extraction in clinical applications

The main clinical applications of the coronary centerline are the analysis of vessel radius extraction, vascular stenosis and calcification. Radius extraction is the premise of narrow analysis, and calcification analysis can further improve the accuracy of the radius.

1) Vascular radius extraction

The blood vessel is extracted mainly using a horizontal set segmentation algorithm based on the geometric active contour model, and then the radius is calculated. First, the extracted coronary center line is traversed, and the tangent plane of each point of the center line is obtained, and the neighboring image block of the point on the slice surface is taken as the center of each point, as shown in Fig. 6-a. Then use the level set function to cut the plane area for evolution, and obtain the segmentation result of Figure 6-b. Since the curve evolution is based on the global optimal process of the image slice block, the calcification part is also included in the results of the blood vessel segmentation. In order to improve the accuracy of the final segmentation of the blood vessel, the calcification portion of the result will be removed using calcification analysis.

2) Analysis of calcification and stenosis

In the CTA image, the calcification of the blood vessels appears as a very high gray value. In the preliminary analysis, we will use a fixed threshold to extract the calcified portion from the segmented results, as shown in Figure 6-c. In further research, adaptive segmentation methods will also be considered.

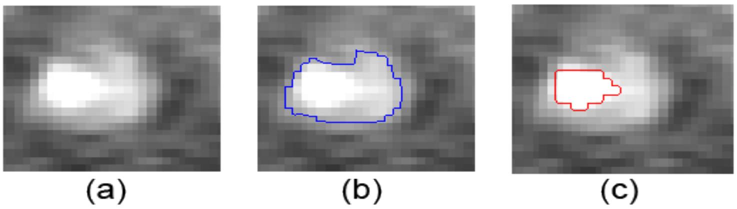

Figure 6. (a) Centerline tangent plane region; (b) Level set curve evolution vessel extraction results; (c) Calcification extraction results.

The stenosis of blood vessels is manifested by a sudden decrease in the radius of the blood vessel in a small section. After the blood vessel radius is extracted, the amount of change in the blood vessel radius is calculated, and if the amount of change largely changes, it is judged to be a narrow region. The location and stenosis of the stenosis area are calculated to provide the doctor with specific quantitative data.

5. Summary

5.1 Study on the application of coronary artery centerline in clinic

1) Using the position information of the center line and the image gradation information, the level set image segmentation technique is studied, and the layer-by-layer extraction is performed in the two-dimensional slice facing the coronary artery.

2) Using the adaptive threshold technique to extract and analyze the coronary calcification. At the same time, the coronary artery extraction results were used to analyze the radius changes and quantify the symptoms of coronary stenosis.

5.2 Advantage of coronary CTA image

Coronary CTA (Computed Tomography Angiography) technology in addition to the coronary luminal image, can also image the coronary vascular wall, assisting doctors to analyze diseases such as vascular calcification and stenosis. Coronary CTA technology increases the diagnosis of cardiovascular disease and makes it more acceptable for patients because of the use of non-invasive techniques.

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