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A Review of Left Ventricular Myocardium Analysis and Diagnosis Techniques for CT Images of Heart

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Abstract

Cardiovascular diseases associated with the left ventricle are main reason of deaths in heart diseases. Early diagnosis using advanced technologies will definitely aid in saving many lives. Cardiac computed tomography (CT) images are one of the tools for this function. Automatic segmentation of left ventricular myocardium is carried out from cardiac CT images. The system uses a iterative strategy for localization of left ventricle followed by deformation of myocardial surface to obtain refine segmentation i.e. blood pool surface of the CT image is extracted and triangulated surface is taken as an area of interest. Geometric characterization of triangulated surface gave precise localization of left ventricle. Subsequently, initialization of epicardial and endocacardial masks is done and myocardial wall is extracted. This paper gives review of different techniques used for segmentation revealed in previously reported literature along with the proposed technology. The proposed system is expected to work based on the standard rules defined by medical experts for disease diagnosis are yet to define.

Keywords: *Cardiovascular Diseases, Myocardial Wall, Left Ventricle, CT image.*

1. Introduction

With current scenario, cardiovascular diseases and heart attacks are one of the several reasons for non-accidental deaths. Cardiovascular diseases (CVD'S) are related to improper functioning of heart which is pioneer organ for blood circulation into the body. CVD's are related to myocardium of heart and blood vessels which is nothing but muscular part of heart. CVD's are one of the leading causes of death in developed countries which is around 31% deaths [1]. Therefore, there is need to understand, diagnose and give proper remedies for such disease. Over the years, different types of medical imaging techniques have been developed and used in clinical applications with each have their own abilities and limitations. Types of imaging are x-rays, molecular imaging, magnetic resonance imaging (MRI), ultrasound imaging, and computed tomography (CT). The advanced techniques used for heart diagnosis are CT scan and MRI scan, as it provides medical data about organs, tissues in 3D images for the better diagnosis. CT is a painless test that uses x-ray machine to take clear and detailed picture of heart. According to lead investigator Georg Schuetz CT is better imaging test as compared to MRI for detecting coronary artery disease as well as any muscular area of body e.g. heart, brain. The CT images are used to segment left ventricle [2]. For the diagnosis of CVD's different cardiac image models are used which mainly focused on myocardial boundaries which may be carried out manually or automatically to avoid human errors. The technique used to extract myocardial boundaries is called as segmentation. The most challenging work in extracting myocardium is to deal with large shape variability within cardiac cycles as well as weak edges between heart tissue and epicardium. Earlier clinical practices were focused on manual segmentation extract information for quantification. In this process radiologist have to draw contours manually which was very tedious and time consuming process. Also it is prone to inter and intra observer variability. That means this manual segmentation was totally dependent on observers capability to extract the information. So, doctors concluded that these visual assessments are not so accurate, therefore need to use automatic segmentation based on heart models to have accurate and robust segmentation [2].

2. Literature Review

The prognosis of CVD's commonly depending on quantitative study of anatomical wall structures for example the ventricles from cardiac images. Automatic description of those structures is robust to data variations and this is an active research field. A common strategy used is combination of global localization with local refinement sequentially. So, need to define a model of the structure to be segmented and used to guide the segmentation process. The various segmentation methods used for CT images of heart are discussed in this section.

2.1 Semi-automated Method

In Computer Aided Diagnostic (CAD) tools the geometric characteristics of the left ventricle are considered. These geometric models have fair approximations in case of healthy patients. Semi-automated methods are used to relief doctors in the segmentation process, which needs to place initial contour around left ventricle manually. It is good as compared to manual method. However, it suffers from inter and intra observer variability [2].

2.2 Traditional Methods

There are some traditional methods for segmentation like thresholding, watershed and edge detection for the evaluation of left ventricular cavity and wall. But these all methods have their own limitations like to deal with noise, requirement of large number of samples, more estimation time, gray scale variations [2].

2.3 Level Set Methods

Zeng firstly proposed theme of coupled level sets for the segmentation of the brain. This idea of coupled level sets was elaborated by Paragios for segmenting left ventricular myocardium of heart [3]. In this the prior anatomical knowledge is used to establish the constraints to improve the performance of segmentation, even in case of noisy image. But success depends on proper initialization of active contours [2]. M. Lynch and O. Ghita proposed left ventricular myocardium segmentation using a coupled level set, known as Geodesic Active Contour. It gives gradient flow with minimum energy providing to object to be segmented. Nikos Paragios presented approach for shape driven segmentation and tracking of left ventricle. In this represents the primary required information using level set distance map along with global shape consistency with rigid registration of evolving interface to prior model. The main limitation is, they cannot deal with multiple images or structures of different types [4].

2.4 Model Based Methods

In this heart model is built with the help of geometric characteristics and features of heart from cardiac images. The widely used models are Active Shape Models (ASM), Active Appearance Model (AAM). I) ASM: This model is build using primary knowledge of shape of left ventricle. They depend on training set of image data. ASM use principle component analysis (PCA), to find shape variations. The accuracy of ASM mainly depends on the amount of images as well as on variation of images from the selected training set. The disadvantage of this model is that accuracy depends upon size of training set and larger execution time [2]. II) AAM: In addition to ASM texture of shape is added to have combined shape-appearance statistical analysis. If we combine ASMs and AAMs then AAMs have problem in attaching the model with gradient information, which is addressed by Mitchell, which also need large no of training set. Model-free methods can be used to study the geometric characteristics of heart. E.g. random forests method used to study geometric characteristics and intensity features of heart [2].

2.5 Active Contour Model

It is flexible and robust in nature, used for detecting object boundaries. It is based on principle of splitting and merging object as well as simultaneous detection of boundaries of required object, also locates interior and exterior boundaries [5]. Kass worked on basic contour called as “snakes” or active contour models that are used for detection of object boundaries, based on minimizing energy functional. The energy functional is combination of two components, first component that controls smoothness of the curve and second component boundary. Proper initialization is must for good results, but snakes or active contour do not give good results for images having low contrast [2]. Vicent Caselles used geodesic active contours based on energy minimization and geometric active contours. It results in stable object boundary detection. This method is based on minimal path computations or it is geodesic. Advantage is, able to detect interior and exterior boundaries simultaneously [5]. Nuseiba M. Altarawneh concluded that Active contour model (ACM) is most successful techniques in dealing with image segmentation problems. The parametric curve is linked with an energy function. During this the curve tries to minimize its energy so that the final curve possesses a local minimum when the contour is spatially aligned with the shape or the desired image features. These models deploy statistical information inside and outside the contour in order to control its evolution [6].

2.6 Shape Segmentation

Chandrajit Bajaj [7] discussed shape segmentation while survey the Patient Heart Models for High Resolution CT images. Patients’ specific image data of heart is needed when we deal with image segmentation. Heart image contains noise and normally it is low contrast image. Therefore Yu and Bajaj [8] developed adaptive method which is better as compared to other filtering methods. Yu and Bajaj developed another method, multi-seeded fast matching method which can be used to segment multiple components and features simultaneously [8]. Malladi and Sethian proposed real time algorithm for shape recovery in

2D and 3D images. The algorithm proposed runs in real time with advantages accuracy, topological adaptivity [9].

2.7 Region Based Segmentation

A.M. Khan [10] compared various segmentation methods. Basic idea of region based segmentation is homogeneity, where discrimination of pixels is based on some predefined characteristics of neighborhood, and refined further as the region grows. This method is divided in two sub techniques as Seeded region growing and unseeded region growing. Seeded region growing, proposed by Rolf Adam [11] has characteristics like rapidness, reliable. For this method user has to define seed for region of interest, so it is semi-automatic in nature. Seed definition includes characteristics like gray level, color, texture and shape etc. Unseeded region growing is automatic in nature and flexible. Segmentation methods can be used in combination due to ill-posed nature of segmentation. For the proper segmentation prior image knowledge is very important [11]. Jean-Loic Rose proposed unification of variational approach and region growing segmentation is based on energy minimization. It is easy to implement but needs strong theoretical background. This method gives more accurate and robust results [12]. D. Muhammad Noorul Mubarak used a hybrid region growing algorithm for medical image segmentation. This technique may be used where image boundary is not prominent [13]. Liangjia Zhu worked on shape segmentation and variational region growing. Here both ventricles are extracted by automatic method from cardiac CT images. First left ventricular myocardial wall is extracted and then right ventricular myocardial wall is extracted. For this enodocardium and epicardium are segmented sequentially. For segmentation variational region growing method is used and for localization of right ventricle active contour model is used. Proposed method segments LV and RV sequentially with integration of shape segmentation and variational region growing method. Accuracy obtained in this method is far better as compared to manual. Further may extend it to extract myocardial wall at risk because of stenoses [14]. Some methods which cannot be classified are discussed subsequently. Vikram V Appia gave an approach to enhance segmentation with shape priors. This approach includes fuzzy edge or prominent edges. Allen Tannenbaum presented a technique on region based segmentation where energy is reformulated in a local way. By altering size of radius automatically it removes the added parameters, for faster execution and interaction by user [15]. Ron Kemmel worked on detection of object boundaries including contours, with simultaneous detection of internal and external boundaries. Enhancement to this work is, geometric flow can be computed by using level set representation [5]. Simon J. Crick presented his work on anatomy of pig heart which is compared with human cardiac structure. In this paper only transgeneric technology has been solved but other problems still retained [16]. L. Zhu proposed automatic method for extraction of myocardium of left ventricle which overcomes limitation of manual method [17]. D.D. Dighe and J.J.Chopde proposed susen edge detector which is efficient when we deal with low level image processing [18]. D.D.Dighe worked on edge segmentation based on susen edge detector which detects image edges, lines, corners accurately [19].

Based on above survey we are able to conclude that, global region growing method is more suitable for segmentation of myocardial wall as it performs better in presence of noise, under weak edges and improper placement of contour.

2. Proposed Work

From the survey, we have proposed a system, with the aim to achieve high accuracy in segmentation, to reduce the time of analysis and improve the diagnosis. The proposed system works in two phases. Prior to that, preprocessing is required. After that required features are extracted and two phases are implemented sequentially as shown in figure 1. Phase I (localization of left ventricle) include extract blood pool surface, detect apex point and identification of cut contour sequentially. Phase II (segmentation of myocardial wall) include endo and epicardial masks initialization, active contour evolution and extraction of myocardial wall. Combining these two phases segmentation of left ventricle is carried out for CT images. Further the standard rules can be obtained from biomedical experts and apply them for automatic disease diagnosis, are yet to define. Input to the system is 8-bit gray scale CT scan image in JPEG format. First, in pre processing filtering is used with Gaussian filter for noise removal as CT scan images are corrupted by noise which is random and spread over all frequencies. Secondly, in feature extraction, canny edge detector is used for more accurate boundary detection under blurred condition. Later phase I and II are applied sequentially. In phase I, the triangular portion of blood pool surface is localized using threshold under varying size of heart portion in sequence of images due to pumping action. Once the blood pool surface finalized, use it to select a proper image from the sequence of CT images for further processing. The refinement of blood pool surface is carried with selected image. In the second phase, endo and epicardial masks are initialized to obtain the rough result of segmentation using global region growing method. Then these results are refined from course to fine by using narrow band geometric contour algorithm iterative way. Number of iteration can be fixed by manual analysis once only. Even error minimization criteria between successive results may be utilized. As region based models are less sensitive to the position of the initial contour, they perform well in the presence of noise and with weak edges or without edges. It has a global segmentation property and can detect the interior and exterior boundaries at the same time, regardless of the position of the initial contour in the image. The processing steps for system are summarized in figure 1.

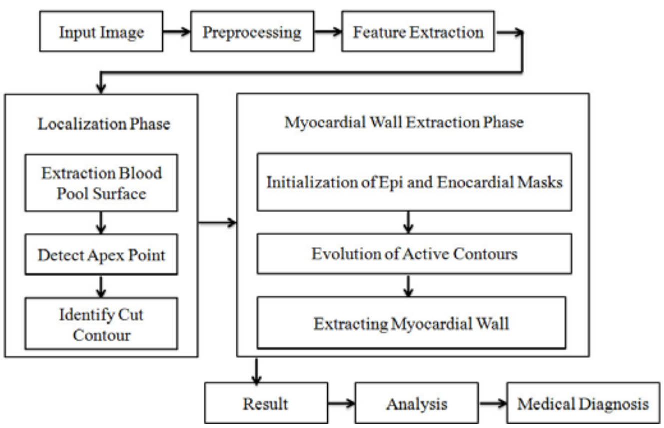

Fig.1. Proposed System

Liangjia Zhu proposed narrow band algorithm for geometric active contour. Sequential steps involved in the algorithm are:

1. Find initial cut contour C_0.
2. Next step is to refine initial cut contour C_0.
3. Initialize the level set function U with C_0
4. Construct a narrow band $\Omega_{M_{bp}}$ around the current contour on M_{tp}
5. Update U in $\Omega_{M_{bp}}$, according to
6. $U(p,t+1) = U(p,t) + dt\left(|\nabla_{M_{bp}} U|\,\nabla_{M_{bp}}\cdot\left(g\,\frac{\nabla_{M_{bp}} U}{|\nabla_{M_{bp}} U|}\right)\right)$

   Where dt is the time step in discretizing U
7. Find the new zero level set of U to update the contour C.
8. Repeat steps 2-4 until it converges or reaches the maximum number of iterations.

Where, C_0 is initial cut contour. After getting initial cut contour it is refined with the help of above algorithmic steps. In step 3 U is realized as the signed distance function from C_0 which decomposes M_{bp} in to several regions. The sign of U is positive in the region that contains the apex point. The fast matching method is used to build $\nabla_{M_{bp}}$ from C_0 with the threshold g_{max} to control the size of narrow band. Step 6 requires some numerical approximations. In step 7, a new zero level set is obtained from U. the algorithm stops either when the contour stops evolution or maximum no of iterations is reached. To reduce the noise effect that is local noise effect the contour evolution process is applied twice. The refinement of contour is done by

$$g(p) = \frac{1}{1+\left(\frac{|k(p)|}{S}\right)^2} \qquad (1)$$

Where, |k(p)| is the mean curvature at p, and S is a constant for a scaling to enhance the concave regions so that values of g(p) for such regions are not overwhelmed by those of other regions.

4. Conclusions

According to Georg Schuetz CT is better imaging test for detecting coronary artery disease as well as any muscular area of body e.g. heart, brain. So, CT images are used to segment left ventricle. Diagnosis of CVD's mainly depends on different cardiac imaging models which dominantly focused on extraction of myocardium wall considering large shape variability within cardiac cycles and weak edges between epicardium and tissues. The extraction is carried out with various segmentation methods as discussed with every method with some limitations. To obtain further accurate and robust segmentation, we have proposed global region growing method in iterative way, which is less sensitive to the position of the initial contour, it performs well in the presence of noise and with weak edges or without edges for CT images. It has a global segmentation property and can detect the interior and exterior boundaries at the same time, regardless of the position of the initial contour in the image. The proposed system implemented in two stages to eliminates limitations of existing methods. To obtain accurate results proposed algorithm is applied iteratively to refine the solution. Further the standard rules can be obtained from biomedical experts and apply them for automatic disease diagnosis, are yet to define.

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