Survey of the Heart Wall Delineation Techniques

Anjali A. Joshi[1], Vitthal J. Gond[2]

[1]PG Student, Department. Of Electronics and Telecommunication, Late G.N Sapkal College of Engineering, Nashik, Maharashtra, India

[2]Professor, Late G.N Sapkal College of Engineering, Nashik, Maharashtra, India

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Abstract: ***Cardiac diseases are very common these days. An estimated 17.5 million people died due to cardiovascular diseases in 2012, representing 31% of all global deaths. Of these deaths, an estimated 7.4 million were due to coronary heart disease. Therefore early detection of cardiovascular disease is essential. Advancement in medical imaging techniques has helped in the detection of cardiovascular diseases. Use of computed tomography for cardiovascular disease detection is prevalent. Detection of heart diseases can be done by the myocardium evaluation. Myocardium can be efficiently delineated by image processing and here we have studied some techniques for heart wall delineation. Some of the techniques have used active contours, Hough transform, PCA with local shape priors for heart wall segmentation.***

Key Words: *Cardiovascular diseases, CT scan, myocardium, active contours.*

1. INTRODUCTION

With the up gradation of standard of living, cardiovascular diseases have become the most deadly threat to humans [1].Thus, early detection and prevention of cardiac diseases has become a crucial task. Medical imaging has helped a lot in diagnosis of CVD. With increasing use of computed tomography (CT) and magnetic resonance (MR) imaging for diagnosis, treatment planning and clinical studies, it has become almost compulsory to use computers to assist radiological experts. There are three techniques for diagnosis:
• Manual method
• Interactive method
• Automatic method
The automatic method is more efficient than rest of the methods. It uses software to detect the abnormal conditions. Reliable algorithms are required for the delineation of anatomical structures and other regions of interest (ROI).
High-resolution X-ray computed tomography (CT) is the standard for cardiovascular imaging. Depending on the scanner hardware, its features are high spatial and high temporal resolution, excellent contrast resolution for the cardiac structures and surrounding anatomy, therefore CT scan is efficiently applied in examination of cardiovascular health. Some advantages of CT scan are as follows:

1. Less expense and wide availability
2. High spatial resolution with modern multi-slice scanners,
3. Short scan time,
4. Higher sensitivity than MR for sub-arachnoids hemorrhage,
5. Higher sensitivity in detecting intra-cranial calcifications[2]

Here we have gone through five techniques. Each technique is unique. Every technique does not contain all the steps mentioned in the section 1.1.

1.1 Comprehensive Block Diagram

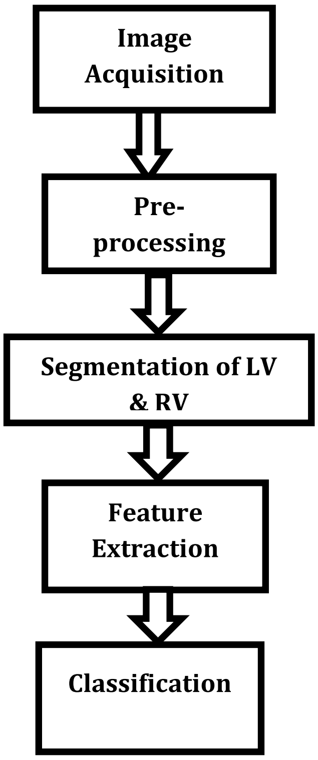

Fig1:-Block diagram of the heart wall segmentation

1.2 Components of the Block Diagram

Image Acquisition

Image acquisition is initial step of any segmentation algorithm. CT scanner is used to scan whole body within short duration of time. CT scan is noninvasive, painless technique of imaging. It uses X-ray for detection of abnormalities in the bones and soft tissues. It provides low noise and moderate spatial resolution. It also provides differentiation between soft tissues and intravenous contrast. For implementation of segmentation algorithm scan images are acquired either from online databases or from hospitals.

Image Preprocessing

Image preprocessing improves the characteristics of the image by removing noise. Filtering for removal of noise as small amount of noise is introduced due to image acquisition elements. Smoothening, and Image enhancement is done to improve contrast.

In case of chest CT scan, not only heart is captured but also the lungs. Therefore when we need to study heart, we have to do some preprocessing to remove lungs from the image. Preprocessing may include cropping to remove lungs.

Image Segmentation

Image segmentation can also be defined as partitioning of image into non overlapping regions that are homogeneous according to one or several characteristics. Accurate segmentation will lead to fruitful analysis of the image [3]. Image segmentation techniques are based on discontinuity or continuity of intensity values of the image. It is done to simplify a picture into something that is simpler to understand [4]. Segmentation divide image into group of pixels which share same characteristics.

Image segmentation can be done by two techniques, splitting the area depending on differences in its feature and merging the area depending on its similarities.

Feature Extraction

Feature Extraction is done to acquire parameters so as to collect more information, with less redundancy. Feature extraction captures the relevant data from the initial information, so volume of the information is reduced. Classification is done on the basis of these features. It beneficial when input data contains huge amount of information. Its processing becomes difficult. Therefore feature extraction play vital role in segmentation techniques.

Classification

It is the last step of Heart wall segmentation systems. Classification is dividing images into categories. These categories are defined by parameters obtained in feature extraction. Classification will provide exact results if all the steps mentioned above are performed precisely. Various classifiers are available to classify images without any error.

2. HEART WALL DELINEATION TECHNIQUES

Medical imaging has become standard in this decade. For diagnosis of any internal injury medical imaging is prescribed. It is very fast, safe and accurate. Its costs are so affordable that it has reached to the masses .Now here we are going to summarize few of the techniques for heart wall delineation

2.1 Model Based Segmentation

Olivier Ecabert et al, [5], proposed a 3-D model based approach for heart segmentation form CT image. As stated earlier, chest CT scan also contains lungs hence localization of the heart is important.

Preprocessing

Prior to training, the image is processed to enhance the heart from surrounding. Image preprocessing includes image subsampling up to 3.0x3.0x3.0mm^3.

Thresholding is done up to +50 Hounsfield Units to permit clear difference between the heart and the surrounding. Smoothing is performed to reduce staircase boundaries obtained from thresholding.

Edge detection is performed using 3x3x3 Sobel Operator. All the edges with magnitude lower than a given threshold are pruned.

Heart Localization

The heart localization is highly complex task due to interpatient and interphase shape variability, heart pose and location variability in the chest and variation in reconstructed field of view. Therefore very first step is localization of heart in the chest cavity. For localization they had implemented FAST 3-D Generalized Hough Transform. GHT writes the description of the shape into the table [6]. Entries in this table are vectors at the boundary pointing towards reference.3-D GHT exploits image properties as well as shape characteristics. For learning local shape variability, they have used method proposed by Brejl and sonka [7] to combine the R-table variability within an object class. As patient always lie on his back in the scanner, so heart is only searched around longitudinal axis (along z axis).

Parametric Adaption

1. Similarity transform is used for correction of mis-alignment in translation, rotation and scaling [8].
2. Piecewise Affine Transformation globally resizes and deforms each part of the model to the actual patient's anatomy and phase of the cardiac cycle.

This technique was applied on 150 patients, only failure was for patient with severe aortic root aneurysm. Visual inspection by surgeons stated that model is overall robust and succeeded in segmenting the heart up to minor interactive local correction.

2.2 Localized PCA Based Curve Detection Technique

V. Appia et al, [9] stated a method for curve evolution using PCA. The curves are identified locally and then combined to form global segmentation. Training data for this approach consists of training shapes and associated target masks.

Level based shape prior models are used in computer vision applications like tracking, object recognition. Use of shape priors in segmentation is introduced by Coots et al, [10].Use of average shape in geometric active contours model was proposed by Chen et al, [11].Later in [12, 13], Level set based shape prior models for image segmentation were developed. Cremer et al. [14] devised a method to improve segmentation by selectively preferring certain shape objects over others. Davatzikos et al. [15] showed that using wavelets in a Hierarchical Active Shape Model framework can capture certain local variations. Recently authors in [16] developed an explicit ASM-based scheme that generates independent partition and uses PCA strictly local to these partitions.

Segmentation

In this paper they have proposed method which uses localized shape priors for segmentation. At first the image is divided into target regions by grouping part of the global shape which has highly interconnected local variations. Then weighted PCA is performed to learn shape variation in each target area. They had applied local PCA on the level set for the shape and the mask to obtain a group of shape priors and mask priors corresponding to each target mask.

To represent local shape priors they had used signed distance function. Where zero level set depicts the shape or mask boundary. Positive distance indicates region inside the boundary and negative distance indicate region external to the borderline.

Combined Shape Evolution

Combined shape evolution is a collection of two steps first step is Initialization and next step is evolution.

In initialization step, correlated target region is defined such that local regions are isolated from each other but local variations are never completely independent. Thus the combination of local segmentation curves related to each target mask has to be done.

If the region is inside the mask then output should be 1, if the mask is shorter than desired area then output should decrease to zero and the region where mask overlaps, the hybrid level set will be the average of the overlapping level set.

In evolution step, new parameters is available thus using update equation Eigen shapes are updated. This approach focuses on local PCA for segmentation of each target region separately therefore achieves a better global segmentation.

2.3 Segmentation of CT Cardiac Images Using Graph Cuts

In this method, authors [17] have used dual source CT scan images [18]. Anisotropies spread algorithm for preprocessing of the images. Graph cuts are used for segmentation.

Preprocessing

Images either have low signal noise ratio (SNR) with good contrast, or have a low contrast with good SNR. If the SNR is minimum or the contrast is very poor then it becomes difficult to detect anatomical structures of the organs. So in medical imaging, high SNR is necessity. Therefore in this method they have used Dual source CT scan. Most of the image segmentation algorithms are highly sensitive to noise. Filtering has the ability to reduce the noise in the image. In linear spatial filtering, the content of a pixel is replaced by average brightness of its immediate neighbors. Disadvantage of this method is, it degrades sharp details of image, such as edges, lines and other fine details.

So as to preserve minute details a method proposed by Perona and Malik [18] is used. In this method they have used spread equation based on anisotropies learning towards differential method. This method strains noise and keeps details as it is .The P-M equation is

$$\frac{\partial u}{\partial t} = \mathrm{div}[c(||\nabla u||).\ \nabla u] \qquad (1)$$

$$u_q^{t+1} = u_q^t + \lambda \sum_{p \in N_4} C(\nabla u_{q.p}) \nabla u_{q.p} \qquad (2)$$

Where u is the value of grey level in the image. ∇u Represents the gradient of the image and t is the time for physical thermal diffusion. Anisotropies spread and acquire the monotonic function of the gradient in different direction. Gradient is high in the region of edge because grey levels are changing abruptly at the edges. Pulse noise is generally present in CT image. This technique can easily remove that noise. For segmentation Graph Cut based active contour algorithm is used. Let's first know what graph cuts are.

Graph Cuts

A graph consists of a pair G (V, E) with vertices $v \in V$ and edges $e \in E \subseteq V \times V$ with cardinalities $n = |V|$ and $m = |E|$. An edge, e, connecting two vertices, v_i and v_j , is denoted by e_{ij}. In image processing, each pixel is typically associated with a node and the nodes are joint via a four or eight-connected lattice the weight of the side is represented by c (a, b) or w_{ij}. Two special vertices are

there those called as the source, {s} and sink, {*t*}. Through the partitioning of all the vertices, the image can be segmented. As shown in figure2, set each pixel in the image as a node, and reset a virtual source and sink.
The image segmentation is done by finding the minimum cost about *G*. In general, each node in the graph corresponds to a pixel in an image. The weight of the edge indicates the different characteristic or similarity between the pixels. Above theory is used to build network, make capacity that network cut correspond to visual energy function.

GCBAC Algorithm
To set up an initial outline and to use this curve to get a circular neighborhood, with stationary width outline.

- Then, put this neighborhood mapped as a network. The internal border of neighborhood corresponds to the resource point of network and the externals to the sink.
- In order to reduce the amount of node and side in case of the large weight side, we transform the networks of multi-source and multi-congruence into the ones which are single-source and single-congruence.
- To use and adjust flowing and advancing the flowing/cutting algorithms excess minimally and cutting the network the most greatly of the tactics in advance, get one on new outline line with minimum energy of this hear intra-area.
- Regard line of this new outline as axis newer neighborhood finally, change, and take the place of, cut, until the fact that outlines line no longer change.

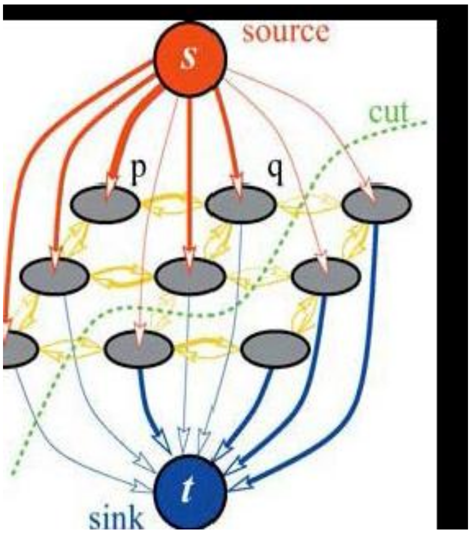

Fig2:- Segmentation of directed graph

2.4 Extraction of Myocardial Wall from CT Images

In this paper Author have proposed a combination of segmentation algorithm for CT scan images [20].

Preprocessing
In preprocessing they have used cropping, resizing and filtering techniques. For Edge detection they have used Canny's Edge detector as it is one of the finest edge detectors.

Segmentation
For segmentation for heart wall they have use region growing algorithm. In region growing algorithm seed selection is critical task as it is used for growing homogeneous region.

Active contours are also used for segmentation of left ventricle and right ventricle. For active contours mask is required here they have selected mask/window with 20 x 20. As beyond 20x 20, accuracy is sacrificed. This window is non-overlapping because overlapping window will generate redundant information [21].

Feature Extraction
GLCM features are extracted using sliding window on the input image. In this paper window selection is important task as window is going to choose its own seeds.
Myocardium is extracted after segmentation of left ventricle and right ventricle.
To classify the results they have adopted ANFIS classifier.

2.5 Automatic Heart Wall Segmentation

In this method [22], heart wall is localized as a salient component by using geometric and anatomical characteristics. Finally segmentation is achieved by applying saliency map, to find the object portion, followed by extraction of heart wall using region boundary segmentation along with expectation maximization algorithm.

Preprocessing
For image preprocessing they have used, Bicubic interpolation as it smoothens the image. Bicubic interpolation considers 16 pixels (4x4). The Image processed using bicubic interpolation has fewer artifacts and it conserves minute details better than collective algorithms. It improves the apparent sharpness of the image.

Edge Detection
Very initial contour is outlined by geometric active contour the then Neumann Boundary condition is used for boundary detection. Final outline detection is done by Active contours without edges followed by saliency mapping.

Extraction of myocardial wall is carried out by lambda-μ-sigma method. The lambda- μ-sigma method models the data, smooth the model parameters and then estimates smoothed percentiles from the model parameters. The LMS method models the entire distribution taking into account degree of skewness (L), central tendency (M) and dispersion (S). Its benefits are that, it permits calculation of *z* score as well as percentiles and allows calculation of any preferred percentile. Exact estimation of percentile from the LMS method relies on the theory that after transformation and smoothing, the variable of interest is normally distributed.
Expectation minimization algorithm is an iterative algorithm for defining maximum likelihood or maximum posteriori (MAP) estimates of parameters depending on unobserved latent variables.

Segmentation
Region based segmentation involves region growing by pixel aggregation, region merging, region splitting, split and merge. The main goal is to find homogeneous regions in the image. The major advantage is, region based techniques are generally better in noisy images. Region growing should fulfil the conditions of comprehensive segmentation and the maximum region homogeneity conditions.

3. CONCLUSION

Thus here we have summarized different CT image segmentation techniques. Model based segmentation achieves better results than any other segmentation technique reviewed. Our final conclusion is robustness of the algorithm depends on highly specific pre-processing and segmentation techniques.

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