ISSN No: 2348-4845
International Journal & Magazine of Engineering, Technology, Management and Research
A Peer Reviewed Open Access International Journal

A System for Analysis and Diagnosis for Left Ventricular Myocardium from CT Images of Heart

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Abstract:

A cardiovascular disease associated with the left ventricle of heart is main reason of deaths. Early diagnosis using advanced technologies will definitely aid in saving many lives, cardiac computed tomography (CT) images are one of the tools for this. For diagnosis and detection using digital image processing, from CT images segmentation of left ventricular myocardium is carried out. 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 obtained 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. Disease identification and its stage is calculated using area fraction of diseased area automatically. The diagnosis and detection performance of the system is verified with radiologist.

Keywords:
CT images, Cardiovascular Diseases, Left Ventricle, Myocardial Wall.

1.Introduction:

Cardiovascular diseases (CVD‟S) and heartattacks are one of the several reasons for non-accidental deaths. 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 andblood 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]. Over the years, different types of medical imaging techniques have been developed and used in clinicalapplications with each have their own abilities andlimitations.

Types of imaging are x-rays, molecular imaging, magnetic resonance imaging (MRI), ultrasound imaging, and computed tomography (CT). The advancedtechniques 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 andGeorg 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. 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 mostchallenging work in extracting myocardium is to deal with large shape variability within cardiac cycles as well as weak edges between heart tissue and pericardium. Earlier clinical practices were focused on manual segmentation to extract information for quantification. But the process need to draw contours manually which is tedious and time consuming process, also it is prone to inter and intra observer variability. So, manual segmentation was totally dependent on observer’s capability to extract the information. These visual assessments are not so accurate, therefore need to use automatic segmentation based on heart models to haveaccurate and robust segmentation [2].

2. METHODOLOGY:

In this work significant modifications have beenproposed to help radiologists in performing better andmore accurate diagnosis of left ventricular myocardium. The implementation of image processing techniques hadbeen explored, together with the analysis and validationof proposed ideas. The proposed methodology forsegmentation is:
1) Develop a system for automatically extractingthe myocardium from cardiac CT imageswithout using training images.

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2) A coarse-to-fine strategy, consisting of globallocalization and local deformations, is appliedthe myocardium segmentation. Shapesegmentation provides seed regions for regiongrowing while the latter reconstructs a heartsurface for the shape segmentation.
3) The system is mainly be divided in two majorphases as localization of left ventricle andmyocardial wall segmentation.
4) An automatic method is provided forlocalization of left ventricle. Previous methodsuses low level information from voxels butproposed method captures global geometriccharacteristics of ventricle. Hence, it is notsensitive to such issues as variability in ventricle shapes and volume coverage's.
5) After segmentation active contour model isinvolved to initialize automatically and robustly.
Also, training image is not required in proposedmethod, which is necessary in the cases wherethe number of images available is limited. This method is influenced by the opinions ofclinical collaborators. This system for extracting themyocardium from cardiac CT images will reduce manualmeasurement, improve consistency, reduce humanintervention and operator dependency, avoidcompetency factor and human errors, while it will alsoproduce reliably meaningful images and measurement,so as to support future studies in a clinical setting.

3. PROPOSED SYSTEM DESIGN:

3.1 Input Image:

Input to the system is 8-bit gray scale CT scanimage in JPEG format. As JPEG images give betterpreprocessing results.

3.2 Preprocessing:

Medical images have unevenly distributed grayvalues. So, there is need of histogram equalization.Contrast-limited adaptive histogram equalizationoperates on small regions in the image, called tiles,instead of on the entire image for better localenhancement. Contrast of each tile is enhanced, thushistogram of the output region approximately matchesthe bell shape histogram.

3.3 Filtering:

In preprocessing filtering is used with Gaussianfilter for noise removal as CT scan images are corruptedby noise which is random and spread over allfrequencies. It is implemented using weighted sum of pixels in successive windows. The weights give highersignificance to pixels near the edge i.e. they reduce edgeblurring. Weights are computed according to a Gaussianfunction as

$$g(i, j)= c.e^{\frac{i^2+j^2}{2\sigma^2}} \quad (1)$$

Where, σ is user defined. The optimal performance isobtained for σ=0.006 and c=0.5.

3.4 Thresholding:

From a grayscale image, need to separate out theregions of the image corresponding to objects in whichwe are interested, using thresholding with automaticthreshold generation using otsu"s method. The input to athresholding operation is typically a grayscale or colorimage. In the simplest implementation the output is abinary image representing the segmentation. Black pixels correspond to background and white pixelscorrespond to foreground.

3.5 Feature Extraction:

The Canny edge detector is used for edgedetection. The result of applying an edge detector to animage gives a set of connected curves that indicate theobjects boundaries, the boundaries of surface markingsas well as curves that correspond to discontinuities insurface orientation. This significantly reduce the amount of data to be processed and may therefore filter out information that may be regarded as less relevant, and bypreserving more important structural properties of animage.

3.6 Localize Left Ventricle:

The geometric features of the heart are used forlocalization. Assumption is that the orientation of a CTimage is given and there is sufficient contrast betweenblood pool and myocardium. For localization of the LVa deep concave boundary on the blood pool surface isfound as discussed in 3.7 and 3.8.

3.7 Extract Blood Pool Surface:

Since CT images have standardized gray levels, thresholding of it is done to highlight the blood poolregion.

After that, a morphological opening operator isused to remove noisy arteries and cut spines that may beresiding in the same connected component of the heart.The largest attached component is chosen andtriangulated as the blood pool surface

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3.8 Detect Apex Point:

The apex point is one salient feature which isused to locate the left ventricle. Its location isdetermined by estimating orientation of ventricles andby searching the left ventricle apex, which is the left tip point with respect to the estimated orientation. Toestimate the orientation of ventricles, the convex hull ofthe blood pool surface is first constructed. Possible apexpoint locations are given by

$$V_{ch}(\tilde{P}) = \{\tilde{P} | K(\tilde{P}) > \mu_K + \sigma_K \cap y(\tilde{P}) > t_y\} \quad (2)$$

Where K(˜p)= Gaussian curvature at each vertex ˜p ofthe convex hull, = mean and standard deviationof K ( ), = threshold i.e. it defines the region ofinterest for the ventricle.

3.9 ROI:

To find region of interest of left ventricle region,region growing method is used because it is less sensitive to position of initial contour, it performs well inthe 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. ROI is found out by applying energy functional as

$$E_{RS}(\emptyset) = \int_\Omega -p(f(x))H(\emptyset(x))dx + \lambda_{RS}\int_\Omega \delta(x)|\nabla\emptyset(x)|dx \quad (3)$$

In above equation first term measures intensity homogeneity inside the contour and secondterm controls the smoothness. Degree of smoothness iscontrolled by „sussman" method.

3.10 Active Contour Model (ACM:

The ROI obtained in previous step is refinedusing ACM which lead to energy minimization for moreaccurate result. The number of iterations is selectedmanually and its value is 250 for optimal performance.The ACM algorithm is [3]:

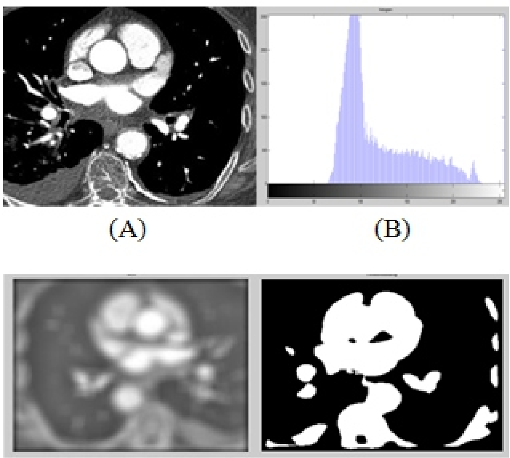
1. Find initial cut contour C_0.
2. Next step is to refine initial cut contour C_0.
3. Initialize the level set function U with C_0
4. Construct a narrow band $\Omega_{M_{bp}}$ around the current contour on M_{bp}
5. Update U in $\Omega_{M_{bp}}$,according to
6. $U(p,t+1) = U(p,t) + dt\left(|\nabla_{M_{bp}}U|\,\nabla_{M_{bp}}\cdot\left(g\frac{\nabla_{M_{bp}}U}{|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

3.11 Diseased Area Fraction:

The Area fraction is given in percentage areawith respect to segmented heart portion. From area offraction, the stage of disease can be assigned by definingstandard rules in consultation with radiologists. Stagesassigned are normal, moderate and critical.

4. EXPERIMENTAL RESULTS:

Proposed system starts with preprocessing on input CTscan image. The steps of preprocessing includeshistogram equalization, Gaussinan filter for noiseremoval purpose, thresolding for binarization of image canny edge detection for better extraction of differentboundaries. This preprocessing step enhances the imagefor further processing. Accuracy is obtained withproposed system by initialization of ROI, iterating ROIand getting area of interest. Finally system calculatediseased area fraction and based on that stage of diseaseis mentioned (i.e. normal, moderate, and critical).



(A) (B)

(C) (D)

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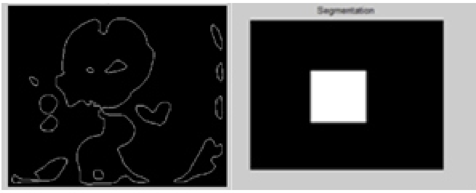
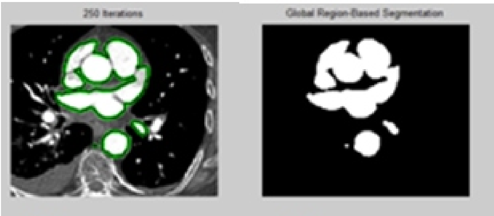


(E) (F)



(G) (H)

(I)

(J)

Figure 1
(A) Original Image (B) Histogram
(C) Filtration(D) Thresholding Image
(E) Edge Detection Discussion(F) ROI
(G) Iterations (H) Global Region BasedSegmentation
(I) Help Dialogue1(J) Help Dialogue1

4.1 Test Result of patients:

Table below shows test results of different patients. It includes area fraction, total analysis time and-state of detected disease which are verified with theresults of radiologist.

Table 1 with different datasets the results of the systemin terms of area fraction, analysis time and stagedetected.

Data Set	Area Fraction (%)	Total Time For Analysis (Sec)	Result
1	16.06	9.0493	Moderate
2	12.62	6.0479	Moderate
3	25.3	7.7651	Critical
4	11.92	3.9026	Moderate
5	11.31	3.4298	Moderate

5. CONCLUSION

Diagnosis of CVD"s mainly depends on different cardiac imaging models which dominantlyfocused on extraction of myocardium wall consideringlarge shape variability within cardiac cycles and weak edges between epicardium and tissues. The extraction iscarried out with various segmentation methods asdiscussed with every method with some limitations suchas less accuracy, more analysis time required, large noof training set is required. To obtain further accurate androbust segmentation, we have proposed global regiongrowing method in iterative way, which is less sensitiveto the position of the initial contour, it performs well inthe presence of noise and with weak edges or withoutedges for CT images. It has a global segmentationproperty and can detect the interior and exteriorboundaries at the same time, regardless of the position ofthe initial contour in the image.

The proposed systemimplemented in two stages to eliminate limitations ofexisting methods.To obtain accurate results proposed algorithm isapplied iteratively to refine the solution. Proposedmethod requires less time (9.0493 Sec for given inputimage) as compared to existing method i.e. manual method (20 min for the same image). Existing methoddo not provide diagnosis of disease. Proposed methodfirst calculates area fraction of disease and then givesstage of disease in terms of normal or moderate orcritical. With area of fraction less than 10% the stage isnormal, with area of fraction greater than 10% but lessthan 50% the stage is moderate and above 50% the stages critical. Also existing method suffers from inter andintra observer variability, which is avoided by thesystem. Proposed method is validated using availabledata set and commented by the radiologist for betterperformance verification.

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