

Left Ventricular Myocardium Analysis and Diagnosis using shape and contour for 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 endocardial 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 heart attacks 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 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]. 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.

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 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 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 have accurate and robust segmentation [2].

2. METHODOLOGY

In this work significant modifications have been proposed to help radiologists in performing better and more accurate diagnosis of left ventricular myocardium. The implementation of image processing techniques had been explored, together with the analysis and validation of proposed ideas.

The proposed methodology for segmentation is:

- 1) Develop a system for automatically extracting the myocardium from cardiac CT images without using training images.
- 2) A coarse-to-fine strategy, consisting of global localization and local deformations, is applied the myocardium segmentation. Shape segmentation provides seed regions for region growing while the latter reconstructs a heart surface for the shape segmentation.
- 3) The system is mainly be divided in two major phases as localization of left ventricle and myocardial wall segmentation.
- 4) An automatic method is provided for localization of left ventricle. Previous methods uses low level information from voxels but proposed method captures global geometric

characteristics of ventricle. Hence, it is not sensitive to such issues as variability in ventricle shapes and volume coverage's.

- 5) After segmentation active contour model is involved to initialize automatically and robustly. Also, training image is not required in proposed method, which is necessary in the cases where the number of images available is limited.

This method is influenced by the opinions of clinical collaborators. This system for extracting the myocardium from cardiac CT images will reduce manual measurement, improve consistency, reduce human intervention and operator dependency, avoid competency factor and human errors, while it will also produce 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 scan image in JPEG format. As JPEG images give better preprocessing results.

3.2 Preprocessing

Medical images have unevenly distributed gray values. So, there is need of histogram equalization. Contrast-limited adaptive histogram equalization operates on small regions in the image, called tiles, instead of on the entire image for better local enhancement. Contrast of each tile is enhanced, thus histogram of the output region approximately matches the bell shape histogram.

3.3 Filtering

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. It is implemented using weighted sum of pixels in successive windows. The weights give higher significance to pixels near the edge i.e. they reduce edge blurring. Weights are computed according to a Gaussian function as

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

Where, σ is user defined. The optimal performance is obtained for $\sigma=0.006$ and $c=0.5$.

3.4 Thresholding

From a grayscale image, need to separate out the regions of the image corresponding to objects in which we are interested, using thresholding with automatic threshold generation using otsu's method. The input to a thresholding operation is typically a grayscale or color image. In the simplest implementation the output is a binary image representing the segmentation. Black

pixels correspond to background and white pixels correspond to foreground.

3.5 Feature Extraction

The Canny edge detector is used for edge detection. The result of applying an edge detector to an image gives a set of connected curves that indicate the objects boundaries, the boundaries of surface markings as well as curves that correspond to discontinuities in surface 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 by preserving more important structural properties of an image.

3.6 Localize Left Ventricle

The geometric features of the heart are used for localization. Assumption is that the orientation of a CT image is given and there is sufficient contrast between blood pool and myocardium. For localization of the LV a deep concave boundary on the blood pool surface is found 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 pool region. After that, a morphological opening operator is used to remove noisy arteries and cut spines that may be residing in the same connected component of the heart. The largest attached component is chosen and triangulated as the blood pool surface.

3.8 Detect Apex Point

The apex point is one salient feature which is used to locate the left ventricle. Its location is determined by estimating orientation of ventricles and by searching the left ventricle apex, which is the left tip point with respect to the estimated orientation. To estimate the orientation of ventricles, the convex hull of the blood pool surface is first constructed. Possible apex point 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 $K(\tilde{p})$ = Gaussian curvature at each vertex \tilde{p} of the convex hull, μ_K = mean and σ_K = standard deviation of $K(\tilde{p})$, t_y = threshold i.e. it defines the region of interest 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 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.

ROI is found out by applying energy functional as

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

Where, ϕ = the signed distance function, H = Heaviside function, $p(f(x))$ = probability density function of a feature vector $f(x)$. In above equation first term measures intensity homogeneity inside the contour and second term controls the smoothness. Degree of smoothness is controlled by ‘sussman’ method.

3.10 Active Contour Model (ACM)

The ROI obtained in previous step is refined using ACM which lead to energy minimization for more accurate result. The number of iterations is selected manually 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

$$U(p,t+1) = U(p,t) + dt \left(\frac{|\nabla_{M_{bp}} U| \nabla_{M_{bp}} \cdot \left(\frac{\nabla_{M_{bp}} U}{|\nabla_{M_{bp}} U|} \right)}{\epsilon} \right)$$
 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 area with respect to segmented heart portion. From area of fraction, the stage of disease can be assigned by defining standard rules in consultation with radiologists. Stages assigned are normal, moderate and critical.

4. EXPERIMENTAL RESULTS

Proposed system starts with preprocessing on input CT scan image. The steps of preprocessing includes histogram equalization, Gaussian filter for noise removal purpose, thresholding for binarization of image,

canny edge detection for better extraction of different boundaries. This preprocessing step enhances the image for further processing. Accuracy is obtained with proposed system by initialization of ROI, iterating ROI and getting area of interest. Finally system calculate diseased area fraction and based on that stage of disease is mentioned (i.e. normal, moderate, and critical).

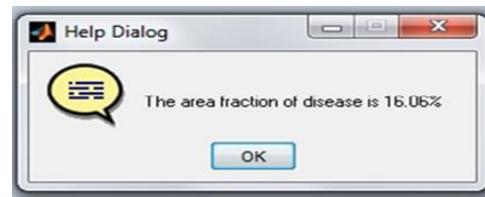
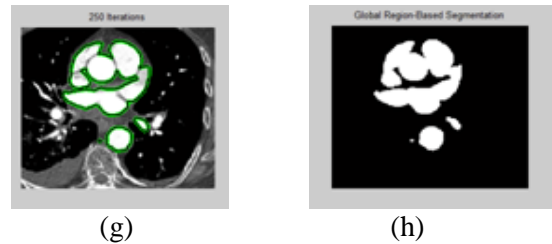
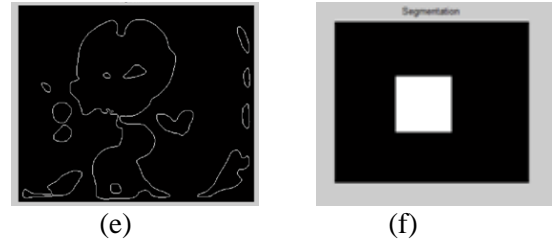
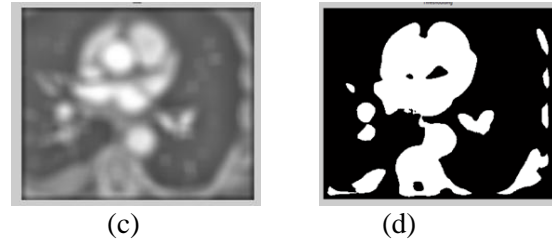
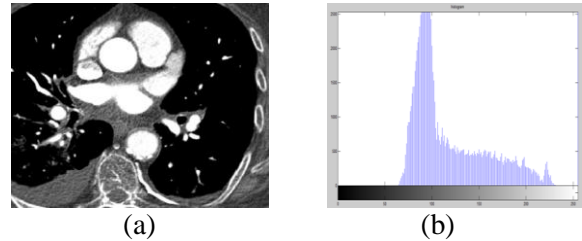


Figure 1 (a) Original Image (b) Histogram (c) Filtration (d) Thresholding Image (e) Edge Detection Discussion (f) ROI (g) Iterations (h) Global Region Based Segmentation (i) Help Dialogue1 (j) Help Dialogue1

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 the results of radiologist.

Table 1 with different datasets the results of the system in terms of area fraction, analysis time and stage detected

| 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 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 such as less accuracy, more analysis time required, large no of training set is required. 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 eliminate limitations of existing methods.

To obtain accurate results proposed algorithm is applied iteratively to refine the solution. Proposed method requires less time (9.0493 Sec for given input image) as compared to existing method i.e. manual

method (20 min for the same image). Existing method do not provide diagnosis of disease. Proposed method first calculates area fraction of disease and then gives stage of disease in terms of normal or moderate or critical. With area of fraction less than 10% the stage is normal, with area of fraction greater than 10% but less than 50% the stage is moderate and above 50% the stage is critical. Also existing method suffers from inter and intra observer variability, which is avoided by the system. Proposed method is validated using available data set and commented by the radiologist for better performance verification.

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