University of Burgundy

Project Report

Automatic segmentation of the left ventricle cavity and myocardium in MRI data

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1 Introduction

From the reports of world Health Organisation (2002) 29 percent of deaths were affected by cardiovascular disease in that 32 percent were women and 27 percent were men.These figures have made the increase in research into the diagnosis and curing the cardiovascular diseases.

In the beginning traditional methods of cardio imaging like cardiac ultrasound and angiography were used. But due to the low SNR, low contrast and some other properties these method were not up to the mark to deal with the cardiac diseases. Later 3D ultrasound and x-ray where used, these were also suffered in some areas later on some contrast agents were used by which the patient's health were affected and also the agent is effected to reach apex of the heart. Later on cardiac magnetic resonance(MRI) which is rapidly advancing in heart diseases where used. Because of its High Contrast and topographical view between the soft tissues without using a contrast agent made it very popular. In Past manual segmentation were developed later on now it is fully automated segmentation is done.

In this project the method used for segmentation of lv cavity has two phase approach which is illustrated in the fig 1.1 Here in the first phase we automatically locate and segment out the lv cavity where as in second phase we will use the thickness of the interventricular septum for segmentation remainder of epicardium using age information. According to this paper the flow off implementation goes as follows 1.The preprocessing and in short description of segmentation algorithm.
2. Automatic detection of LV cavity.
3. Segmenting the other wall of myocardium.

1.1 Objective

Here the the main Objective is to automatically segment out the left ventricle.We use short axis data, In this project the method used for segmentation of lv cavity has two phase approach which is illustrated in the fig 1.1 Here in the first phase we automatically locate and segment out the lv cavity where as in second phase we will use the thickness of the interventricular septum for segmentation remainder of epicardium using age information. According to this paper the flow off implementation goes as follows
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2. Automatic detection of LV cavity.
3. Segmenting the other wall of myocardium.

1.2 Outline

Here we implemented a novel approach for automatically segmenting the left ventricle.A diagram for the segmentation scheme is illustrated as follows

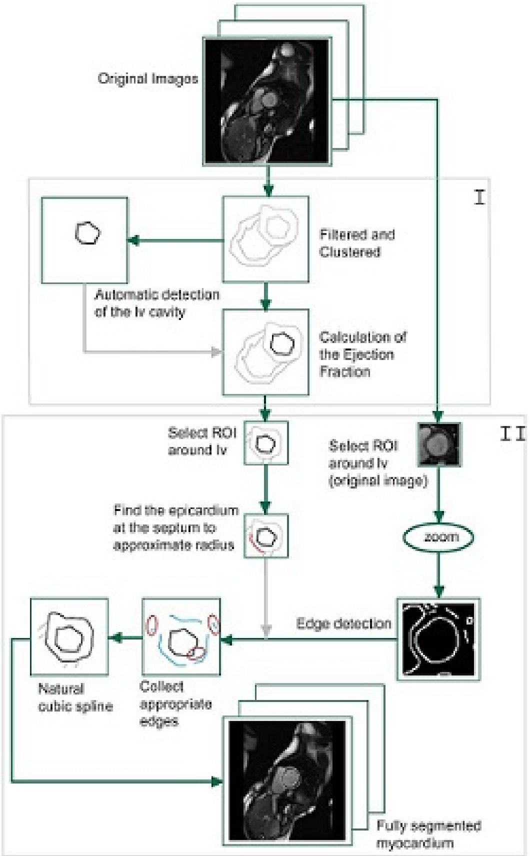

Figure 1.1: A schematic representation of the two phases involved in the segmentation of the endo- and epi-cardium border. Stage I shows the preprocessing and segmentation processes, the automatic detection of the lv cavity and the connection of the cavity through the volume. Stage II shows the method for segmenting the epi-cardium border in each image.

This paper is organised as follows:
1) Preprocessing with a short description of the segmentation algorithm.
2) Focussing on the auto detection of the lv cavity and calculate the ejection fraction.
3) Moving onto the heuristics involved in segmenting the outer wall of the myocardium.
4) The results are shown and evaluated.
5) Conclusion.

2 Concept

In this Chapter we will discuss about the whole procedure taken place for Automatically detecting the left ventricle.

So according to the paper this approach follows three main steps to acquire the result they are:
1) Smoothing is done to remove noise.

2) The image is then clustered using an adapted k-means algorithm.

3) Automatic detection of lv cavity.

4) Segmentation of epi-cardium border.

So let's discuss indepthly about each step followed to acquire the segmentation of Left ventricle cavity.

2.1 Smoothing

First let's discuss about the smoothing. In this step each image slice is smoothed to remove the noise which occurs in MR images. The smoothed image is then clustered using it adapted k-means algorithm. Keeping in mind about the edges here edge preserving smoothing is done.

Edge-preserving smoothing

In this preprocessing step noise is filtered out by maintaining the edge information. Here diffusion based filters also used. The algorithm in this paper for adaptive smoothing is actually adapted from another paper by chen ??/

The main objective of this adaptive smoothing technique is it measures two types of discontinuities in the image they are: 1. Local. 2. Spatial.
From the above two measures less ambiguous smoothing solution is found. In short we can say that local discontinuities indicates the local structure and contextual discontinuities show important features.

So in order to measure local discontinuities is four detectors are set up as shown

$$E_{H_{xy}} = |I_{x+1,y} - I_{x-1,y}|, \tag{2.1}$$

$$E_{V_{xy}} = |I_{x,y+1} - I_{x,y-1}|, \tag{2.2}$$

$$E_{D_{xy}} = |I_{x+1,y+1} - I_{x-1,y-1}|, \tag{2.3}$$

$$E_{C_{xy}} = |I_{x+1,y-1} - I_{x-1,y+1}|, \tag{2.4}$$

where $I_{x,y}$ is the intensity of the pixel at the position x, y. We can then define a local discontinuity measure E_{xy} as

$$E_{xy} = \frac{E_{Hxy} + E_{Vxy} + E_{Dxy} + E_{Cxy}}{4} \tag{2.5}$$

In order to measure the contextual discontinuities, a spatial variance is employed. First, a square kernel is set up around the pixel of interest, N_{xy} (R). The mean intensity value of all the members of this kernel is calculated for each pixel as follows:

$$\mu_{xy}(R) = \frac{\sum(i,j)\varepsilon N_{xy}(R) I_{i,j}}{|Nxy(R)|} \tag{2.6}$$

From the mean the spatial variance is then calculated to be

$$\alpha^2_{xy}(R) = \frac{\sum(i,j)\varepsilon N_{xy}(R)(I_{i,j} - \mu_{xy}(R))^2}{|Nxy(R)} \tag{2.7}$$

. This value of sigma is then normalised to $\sigma^{\ 2}_{xy}$ between 0 and 1 in the entire image.A transformation is then added into $\sigma^{\ 2}_{xy}$ to alleviate the influence of noise and trivial features. It is given a threshold value of $\theta_\sigma = (0 \leq \theta_\sigma \leq 1)$ to limit the degree of contextual discontinuities. Finally, the actual smoothing algorithm runs through the entire image updating each pixels intensity value I^t_{xy} where t is the iteration value.

$$I^{t+1}_{xy} = I^t_{xy} + \eta_{xy} \frac{\sum(i,j)\varepsilon N_{xy}(1)}{(x,y)\eta_{ij}\gamma^t_{i,j}(I^t_{i,j} - I^t_{x,y})} \sum(i,j)\varepsilon N_{xy}(1) \tag{2.8}$$

The variables S and σ determine to what extent the local and contextual disontinuities should be preserved during smoothing. If there are a lot of contextual discontinuities in the image then the value of η_{ij} will have a large influence on the updated intensity value. On the other hand, if there are a lot of local discontinuities then both γ_{ij} and η_{ij} will contribute, as η_{ij} is used for gain control of the adaption.

2.2 Clustering

The smoothed images are then clustered using an adaptation of the k-means algorithm proposed by Duda and Hart. This algorithm has four steps to find the image clusters.
(i) Initialise the position of the means $m_1 \rightarrow$ m$_k$.
(ii) Assign each of the k-items to the cluster whose mean is nearest.
(iii) Recalculate the mean for the cluster gaining the new item and the mean for the cluster loosing the same item. Recalculation is made using the variance.
(iv) Loop through steps (ii) and (iii) until there are no movements of items.

The image is clustered using an initial guess of 20 to 30 independent cluster centres which is sufficient to capture all the relevant features. The pixels are clustered together using the strategy explained before. The number of clusters is then optimised by merging clusters with similar attributes. This is repeated until there are no more clusters to be merged.

2.3 Automatic detection of lv cavity

The image has now been segmented into separate clustered regions. The next step is to automatically detect which of these clusters represents the lv cavity on the first slice. To allow for different imaging parameters the lv cavity is located using shape descriptors only and not using the grey scale values.

The images are short axis, therefore we assume that the lv cavity approximates a circular shape and that the lv feature is continuous in successive slices.Approximation to a circle is calculated as the error between the shape and the least squares approximation to the circle. It is also assumed that the lv is not located on the peripheral of the image. The volume of the left ventricle is then extracted using two criteria:
(i) Overlapping area of the regions contained in successive slices.
(ii) Grey scale value of the regions under investigation. The regions cannot be connected using just grey scale values due to the variation in the intensity values through the volume caused, to some extent, by coil intensity falloff. The lv regions are then connected in 3D and the volumes are then rendered. The ejection fraction is calculated using the volumes. The ejection fraction is defined as âthe proportion, or fraction, of blood pumped out of your heart with each beatâ and can be represented by

$$EF = \frac{V_{endo}(t_D) - V_{endo}(t_S)}{V_{endo}(t_D)} \tag{2.9}$$

where V endo is the volume of the inner walls of the heart, $V_{endo}(t_D) = max_t[V_{endo}(t)]$ is the end-diastolic volume and $V_{endo}(t_S) = min_t[V_{endo}(t)]$ is the end-systolic volume.

2.4 Segmentation of epi-cardium border

The procedure for segmenting the epi-cardium is illustrated in Fig.1.1 3. The position of the lv cavity is already known for each slice as explained in the previous section. In order to determine the epi-cardium border a region of interest is defined around the lv cavity. Two copies of this region of interest are taken. The first image Image 1 is used to find a value for the approximate radius of the myocardium and the second image Image 2 is used to find real borders around the myocardium. The two are combined to find the true value of the epi-cardium around the lv.

Image 1 is later on clustered using a predefined low number of clusters around the ROI. A low number of clusters is chosen because of the scarcity of important features around the lv cavity. Anatomically,the closest blood pocket to the lvcavity is the right ventricle cavity,it is also known that the hickness of the myocardium will not change drastically over the entire circumference. The thickness of the interventricular septum between the two blood pockets can give a reliable estimate for the thickness of the rest of the myocardium.

Image 2 is then zoomed using an area averaging technique around the area of interest.The zooming operation is applied to increase the edge separation. The image is then segmented using a thresholded edge-based algorithm. The largest connected segments within certain bounds of the estimated thickness found from Image 1 are taken as potential border segments.There is an angular restraint placed on the transition of these segments around the epi-cardium to eliminate stepping into the endo-cardium border or stepping out to other organs. A closed natural cubic spline is fitted around the points on the epi-cardium [57] (see Appendix A). The spline is used to close the epi-cardium contour by connecting all the points on the curve in a smooth way. Splines are piecewise polynomials of degree n (n = 3 in the case of cubic splines) with the pieces smoothly joined together. The joining points of the polynomial pieces are called control points which need not be evenly spaced.

3 Implementation

As far as the implementation part we had not done completely .As this is two phase approach we had accomplished only th first phase.

3.1 Environment

The following software, respectively operating systems, were used for the implementation:

- Windows 10
- Matlab 2015a

3.2 Project Structure

The implementation is done as follows:
step 1 :Adaptive smoothing.
step 2: K-means clustering.
step 3: Combining all the related clusters.
step 4: Localization of lv cavity.

3.3 Graphical User Interface

A user friendly Graphical user interface is made.To load the dicom data just press load button later that select your appropriate option then process buttons thats it.Output can be observed.The Outlook of Gui is as follows

4 Results

As I said we had done only the first phase so first phase includes following steps.
1. Adaptive smoothing whose results can be shown below
2. K-means clustering whose results can be shown below
3. Combining the clustering whose results can be shown below
4. Localization of lv cavity whose results can be shown below

4.1 Outputs

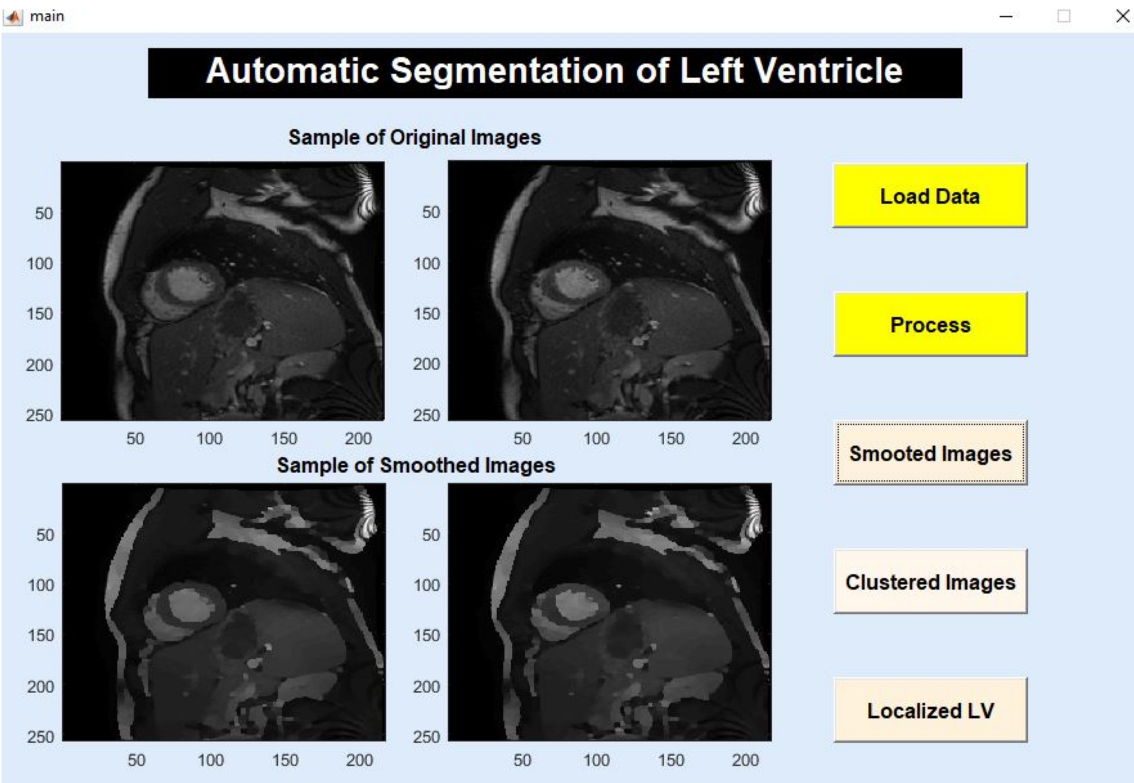

Figure 4.1: Smoothed Image Output

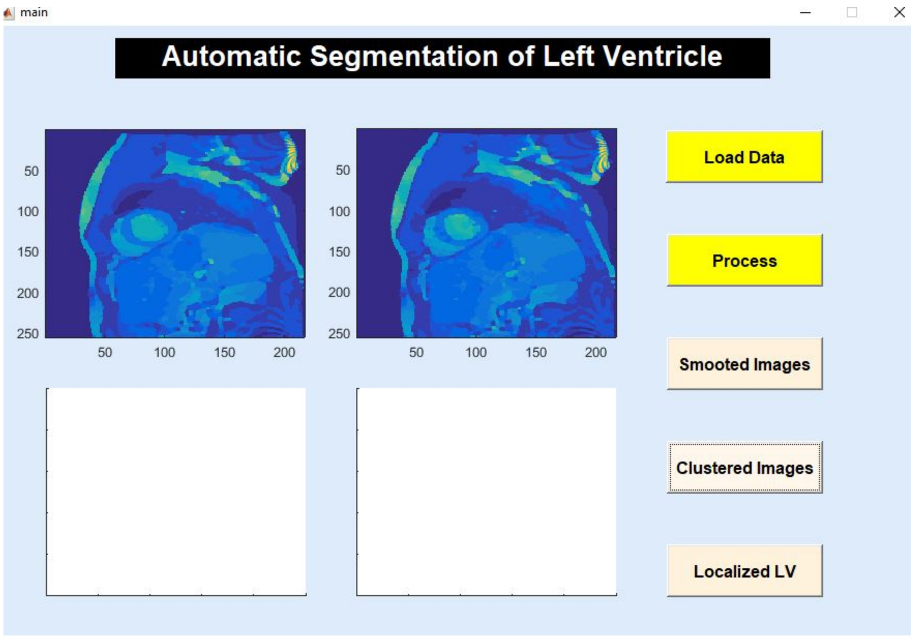

Figure 4.2: K-means Clustered Image Output

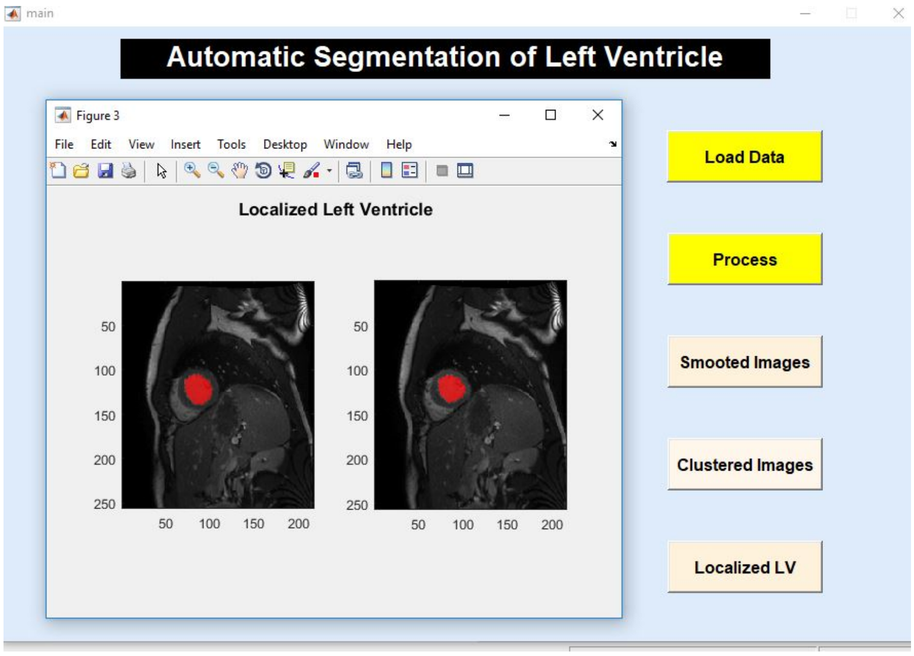

Figure 4.3: Output of Localization of left Ventricle by Overlaying

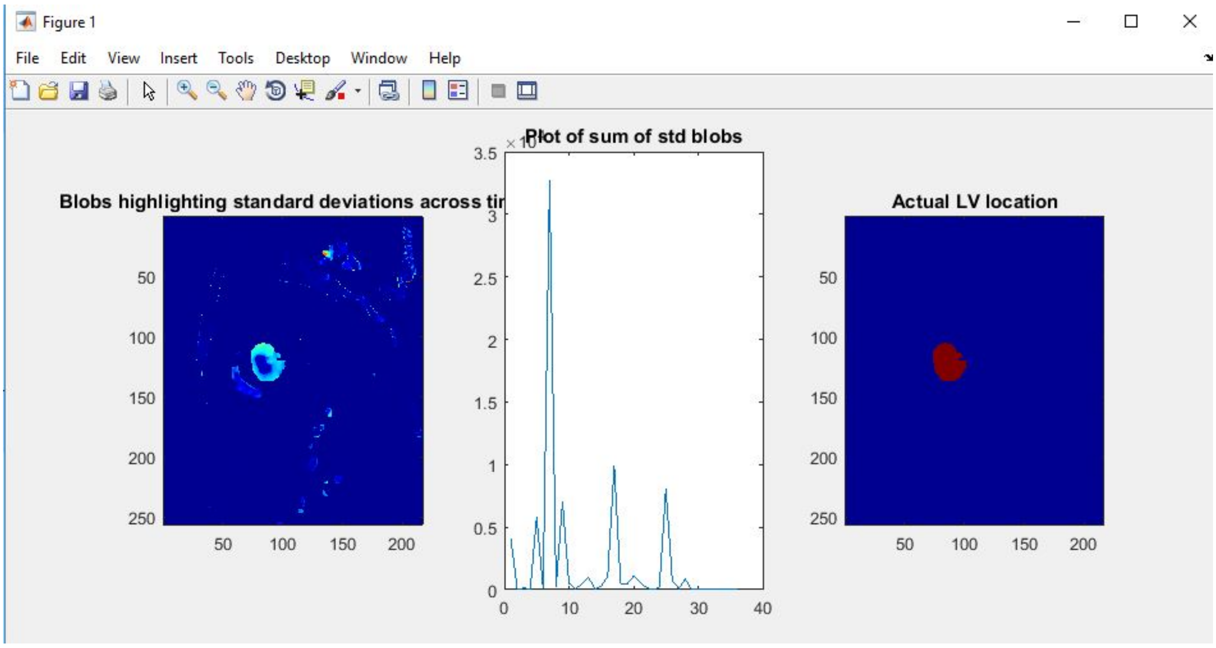

Figure 4.4: Output of Localization of left Ventricle by Highlighting blob

5 Conclusion

The objective of this project was to automatically localize the left ventricle cavity.The flow of the concept goes as follows

Firstly the input dicom images as smoothed with edge preserving filters namely adaptive filter later those smoothed images are fed to k-means clustering to form clusters later on combing of clusters are done followed by localization of lv cavity is done.As we have the clusters we need to find the the lv cavity.As we had done the localization previously we now extract the volume of lv cavity by overlapping and followed by segmentation of epicardium border by assigning region of interest.Later on pplying edge detection on ROI followed by collecting appropriate edges and lastly knowing the cubic spline.

5.1 Problems Encountered

The problems were occured on specific sequence in clustering part so we tried to use different sequences even though in final combinig of clusters we faced some errors.

5.2 Outlook

We tried our best to do as much as possible.I sincerely thank Prof.Alain lalande for assigning this project.In future we will try to completely implement the whole paper.

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