Project on Segmentation of the endocardial border of the left ventricle in diastole and systole

Alexandra Albu, Raneim Nabil Hossni Mohamed, Sheikh Adilina
Sensors and Digitization Course
Joint Master Degree in Medical Imaging and Applications (MAIA)
Université de Bourgogne, Le Creusot, France

Abstract

The purpose of this paper is to detect the left ventricle (LV) endocardium in short axis MRI images. Our algorithm is based on the method presented in [1]. However, since the imaging technique used in that paper is echocardiography, we modified the algorithm to be compatible with our imaging technique which is MRI. Our developed algorithm consisted of two stages: preprocessing and segmentation. The preprocessing stage includes reading the images, determining the region of interest (ROI), smoothing and thresholding the images. On the other hand, segmentation includes erosion filtering, edge detection , euclidean distance, and watershed algorithms. Taking into consideration that our method is adopted from the method developed for echocardiography in [1], our results were satisfying for some images and for others, some parameters needed to be adjusted in order to get a better performance.

1 Introduction

Currently, in literature there exists substantial research regarding the segmentation of the left ventricular wall of the heart especially in the latest years taking into account the bloom of usage of deep learning algorithms. We studies several research papers and their models and finally chose this paper owing to the pragmatic improvement they describe, the interesting approach, the clear explanations and the time that can be saved by using a non deep learning algorithm.

2 Tools Used

Apriori to describing our implementation of the previously mentioned paper, this section presents the tools used in creating the practical project. We have used various libraries of Python programming language to implement our model.

In order to increase the productivity to write the code and test different parts of the algorithm individually, while also having GPU and an online organised overview, we have chosen to use Google Colab in parallel with developing code on our own machines. Furthermore, another advantage of using this approach is to allow us to solve issues in each other's code with easy access in the notebooks. This not only facilitates the coding process, but serves as a useful tool for working remotely too.

3 Methodology and Results

Our methods are modified from the ones presented in [1] to fit our dataset. For example, fusion is removed as it was used to reduce motion artifacts and increase wall contrast in echocardiography, but cardiac MRI already has superior contrast to noise ratio and endocardial contours are accurately drawn so fusion will not have an influence on its images. The whole algorithm is divided in two main parts for better analysis: preprocessing and segmentation as shown in figure 1.

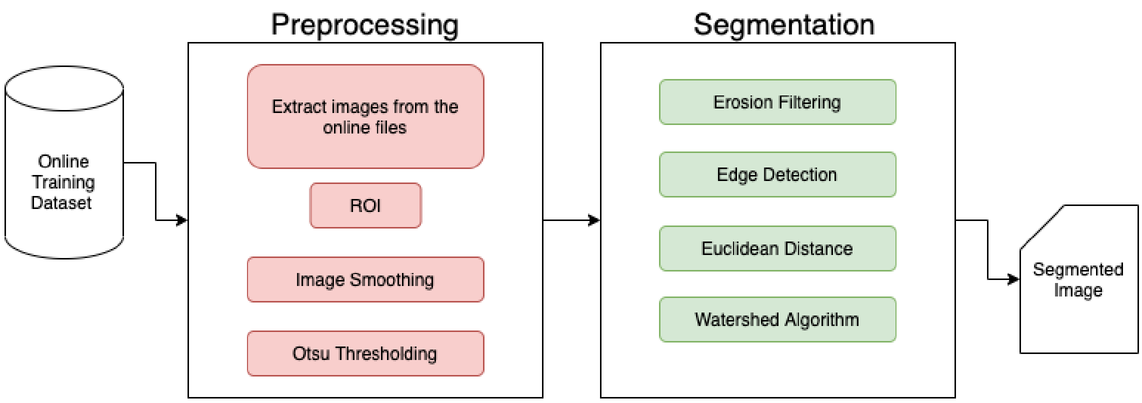

Figure 1: Overview of methodology used in this paper.

3.1 Preprocessing

The preprocessing techniques serve as an important step to enhance the regions in the image that are of interest to be analysed.

3.1.1 Loading the dataset

In the original paper, they have used DICOM format while we have used the NIfTI (Neuroimaging Informations Technology Initiative). For our project, we were asked to use the dataset from the Automated Cardiac Diagnosis Chanllenge (ACDC). Given that the images are in NifTI format, they also have an affine that relates the voxel coordinates to world coordinates in RAS+ (Right, Anterior, Superior) space. The training set consists of predicted and ground truth MRI images of 100 patients at different frames. We wrote a code to extract the images from Frame 1 of all the 100 patients.

3.1.2 Region of Interest

The next step in prepossessing is determining the ROI which is the left ventricle in our case as shown in Figure 3. This improves the results of our segmentation because the algorithm will not be influenced by other regions of the heart in the MRI image. Determining the ROI (Region of Interest) can be done in different ways, but we decided on manually selecting and cropping the region.

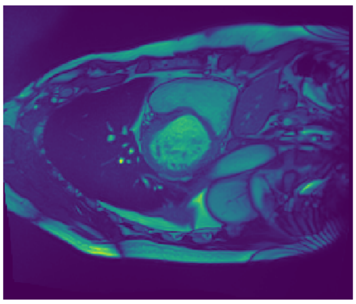

Figure 2: Training Image

Figure 3: ROI of Image

3.1.3 Image Smoothing

Smoothing is applied on the dataset to remove high spatial frequency noise and keep the details which will help for a better detection of the LV endocardium. In our experiment we used a low pass filter, Gaussian filter, to perform smoothing of the MRI images and the result of this step is shown in Figure 4.

3.1.4 Otsu Thresholding

Otsu Thresholding is an important intermediate step in our algorithm consisting of an automatic thresholding that is applied to a smoothed greyscale cropped image, ROI, to separate the image into foreground and background using a returned single intensity value. This method uses Otsu binarization which automatically calculates a threshold value from image histogram for an image whose histogram has two peaks. Figure 5 shows the blurred image after applying Otsu Thresholding.

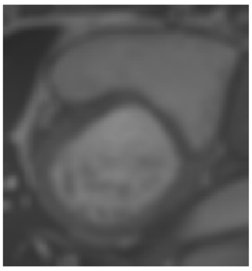

Figure 4: Gaussian blur

Figure 5: Otsu Thresholding

3.2 Segmentation

3.2.1 Erosion Filtering

The first step in segmentation is erosion which is a morphology operation that is applied to the ROI to reduce noise and distortion. Figure 6 illustrates the effect of applying erosion to the ROI.

3.2.2 Edge Detection

The next segmentation step is to detect the edges of the eroded image. we decided to use canny edge detector over laplacian because it gave better results as shown in Figure 7.

Figure 6: Image after applying Erosion

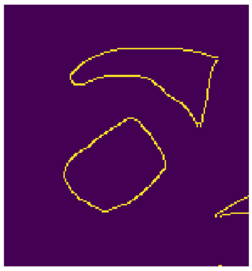

Figure 7: Canny Edge Detection

3.2.3 Euclidean Distance Transform

The Euclidean distance d(x,S) from every binary pixel to the nearest zero pixel, namely the shortest distance from x (a pixel in S) to the boundary of S is calculated and then we found peaks in this distance map.

3.2.4 Watershed Algorithm

The algorithm uses resulted peaks from the Euclidean Transform by performing a connected component analysis on the local peaks using 8-connectivity and then proceeds with the Watershed. Depending on the heart cycle, the detection of the LV might face overlapping of objects. Thus, simple thresholding and contour methods might be insufficient as a solution, watershed is used. After feeding the markers output of the 8-connectivity to the watershed, the later yielded a NumPy array with the same width and height as our input image consisting of a matrix of labels.

3.3 Results

At this point, our watershed algorithm has identified various segments in the ROI and has give them label numbers. The LV endocardium is one of the many segments. To highlight the edges of the LV endocardium, we looped through the atershed regions and selected the label number of the desired segmentation and superimposed the outline of the edge on the ROI image like shown in Figure 8.

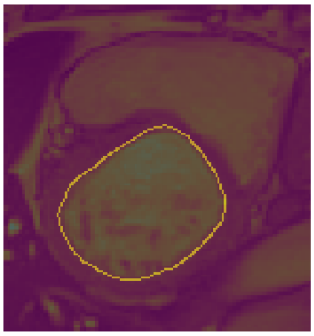

Figure 8: Highlighting the left ventricle endocardium on the cropped (ROI) image

4 Discussion and Conclusion

The results showed that the algorithm worked well on some images and the LV endocardium was correctly determined. Having said that, in most cases the model is not able to correctly segment the LV endocardium. However, with a bit of manual tweaking of parameters the model works well. One reason could be that we have manually selected the label number of segment based on the output of the first patient data. It is not necessary that the LV endocardium would always have the same label number for all the images hence the model is not displaying the correct output in case of other images. Another reason could be that all the images in a dataset cannot possibly require the same amount of blurring and erosion therefore the same hyperparameter will not work on all of them. In coclusion, we were able to develop a semi-automatic solution to detect the LV endocardium.

References

[1] J. C. Amorim, M. do Carmo dos Reis, J. L. A. de Carvalho, A. F. da Rocha, and J. F. Camapum. Improved segmentation of echocardiographic images using fusion of images from different cardiac cycles. In *2009 Annual International Conference of the IEEE Engineering in Medicine and Biology Society*, pages 511–514, 2009.