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MIA - Automatic epicardial and endocardial segmentation of the left ventricle

Contents

1 Project Overview

The main purpose of this project is to be able to perform epicardial and endocardial left ventricle segmentation. This project is divided in three main part. The first part contains the context of the project, the second part discuss about the implementation in Matlab and the last part the implementation in Cpp. All required libraries will be listed in the read me files as well as all the papers that has been followed to build these programs. To avoid compatibility issues the Cpp program has been issued in two version: Linux and Windows and code using Qt Creator 4.9.0 (Community).

2 Introduction

Cardiac MRI is one of the technologies used for assessing the condition of patients which suffer or might suffer from a heart disease like cardiac masses and thrombi, pericardial abnormalities, cardiomyopathy, arrhythmia and coronary, aortic and/or different kinds of congenital cardiac diseases. Cardiac MRI is minimally invasive, does not involve radiation and it generally delivers excellent images for diagnostics. However, some examinations can take time and/or appear to be difficult to be interpreted. The last few decades saw the development of improved and advanced image processing techniques, which have been soon applied to medical imaging as complementary tool to ease and improve expert diagnosis. Since the early 2010s, algorithms used to discriminate features in the human body started to focuses on convolutional network approach (deep learning), leaving more traditional processing methods behind. In this report, we will attempt to implement a left ventricle segmentation on short axis for both epicardial and endocardial boundaries.

To do so, this document will be divided into three parts. The first part will discuss about the context of the project, the given rules, the research and papers used to build our implementation. In a second part, we will discuss and detail the matlab implementation of the algorithm, itself divided in heart detection and segmentation subsections. Eventually, we will discuss about a second implementation, using C++, its obtained results and a comparison of the two methods.

3 Context, frame and references of the project

3.1 Context and frame of the project

The project has been inspired by the MICCAI challenge consisting of the segmentation of the left ventricle on both epicardium and endocardium boundaries, while performing a disease classification. Our project is focusing on the first part of the challenge. To build our algorithm and verify the progress, we were given access to a dataset contaning the data of 100 different subjects, in *.nii* format.

The main assigned frame of the project here is to implement a fully automatic method to perform left ventricle myocardium segmentation. The main objective here being to create a simple of use graphical user interface. Ideally, the program would be run as an executable application.

3.2 References used to conduct the project

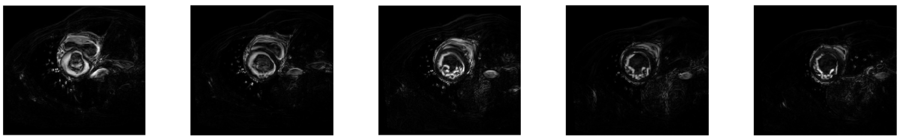
Originally, we were given two state of the art publications which could be used as starting points to search and select a method to implement [1],[2]. For the project, we have chosen an article from the first publication by *M. P. Jolly et. al*[3] as our starting point for the project. According to the author, the main basis for ventricle detection and heart segmentation is the use and manipulation of Fourier Transform on temporal domain over the set of images. From this operation, one can detect the heart, as discussed in the next section.

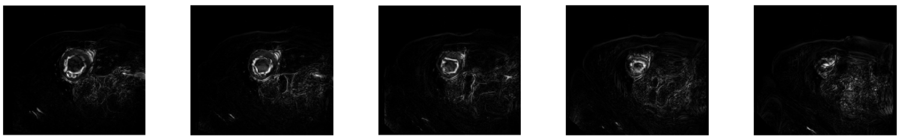
The main paper led us to other useful publications such as [4] and [5]. At this point, we had a good basis to attempt an implementation of a left ventricle segmentation program. During the project, we differed from the paper algorithm, however, we used a similar beginning to implement segmentation.

4 Matlab Program

4.1 Main Steps

To perform the project, we used MATLAB R2018a version, as it can read nifti files through in-built function, which eased program implementation in our case. After reading the file, we extracted its dimension values to perform temporal Fourier Transform. To do so, we processed the input slice by slice, each time applying a multi-dimensional Fourier transform on temporal column of 2D images. Such a procedure allows us to extract two important features, when doing the absolute inverse Fourier transform. From this point we can extract the average image on the first 10 images, for each slice, followed then by the first harmonic component on the 10 following ones. The use of harmonic component is at the core of our algorithm since it puts in evidence changes between slices as bright areas, which is the case for moving regions such as the heart. From there, after light processing to enhance our data using median filtering, we applied recursively weighted centroids, from which ROI mask have been applied.





The whole process can be summarized as follow :

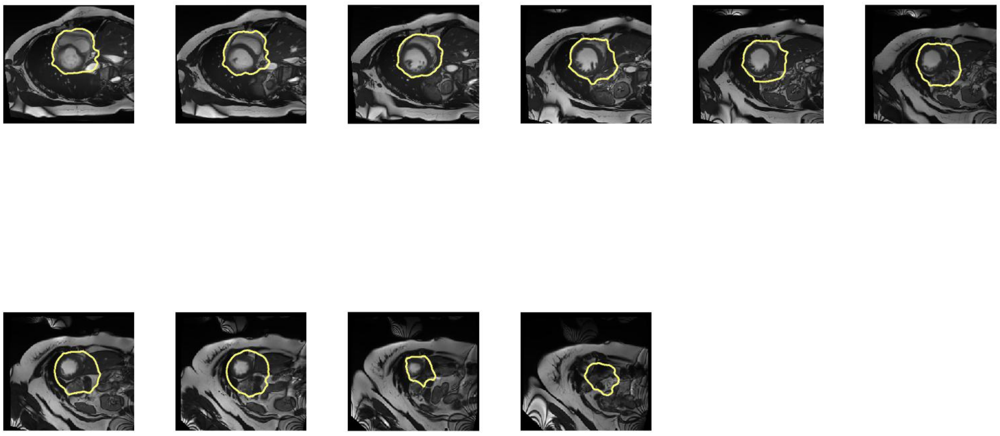
1. Read Files
2. First Fourier Harmonic for movement
3. Apply Medium Filter to reduce noise
4. Centroids shifting
5. Compute distance histogram
6. Apply mask and set the gray Level
7. Apply limit with the mask which is apply on precedent image . Loop it 5 times
8. Apply Active contour on the ROI

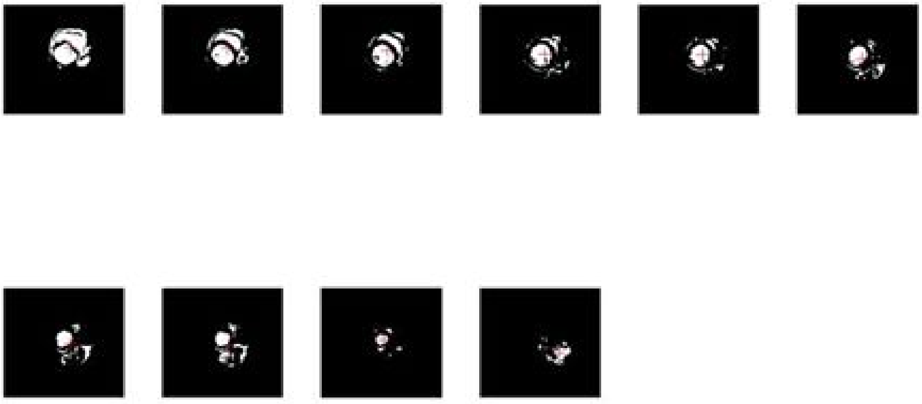
4.2 Output

From there we have been able to sucessfully target the heart region as shown in the second set of images.The main drawback we encountered was due to the disturbed weighted centroids by moving blood vessels.

4.2.1 Interpretation

The program interprets moving regions as our region of interest (the heart). From there we attempted to use again centroids with the binarized ROI to extract endocardium boundary (third set of images).





5 CPP Program

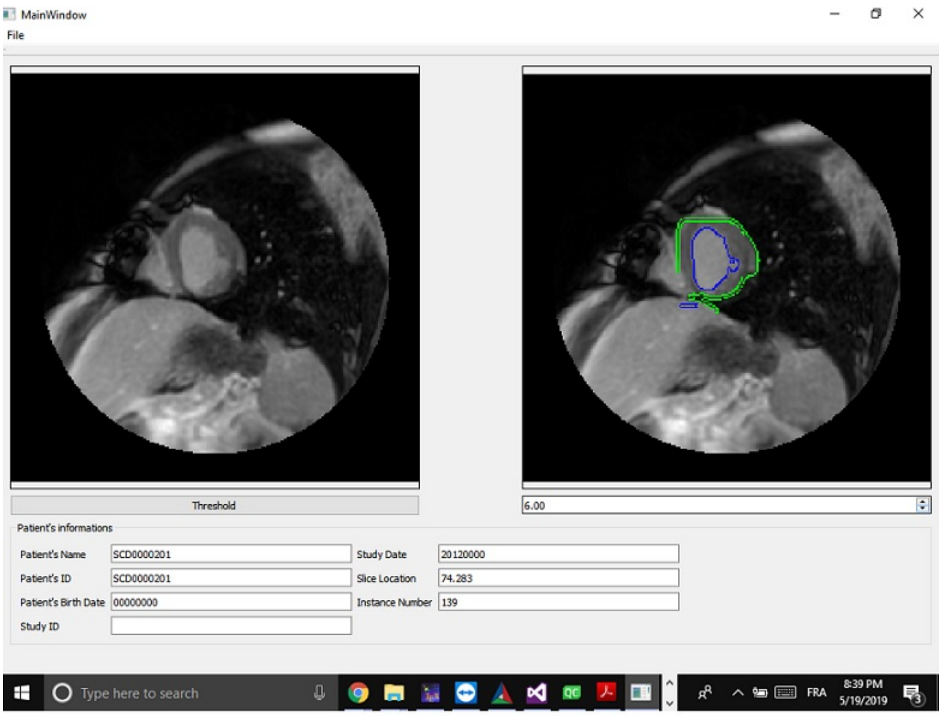
5.1 Main Steps

Here we used a similar process as in the matlab implementation, the main divergence being the use of Hough transform to detect circular shapes within the ROI. The following steps summarize such a process:

1. Load the dialog to open the specific DICOM file
2. Convert Dicom Image to Mat from OpenCV
3. Convert Mat OpenCV image to QImage from Qt
4. Get patient Information
5. Apply morphological operations
6. power-law transformation is applied on the image.
7. Select ROI

8. Threshold image to select heart cavity ROI
9. Canny Edge detection is apply via a convex-hull method to exclude papillary muscles

5.2 Output



5.2.1 Interpretation

Here, the algorithm successfully targeted the myocardium,segmenting properly left ventricle boundaries. The program is alo more flexible as settings can be parametirzied to have more or less sensitive hough segmentation.

6 Conclusion

During this project; we had the opportunity to learn and use some very useful tools for image processing. Here we have implemented recursive weighted centroids in a first program, as well as hough transform to detect ciurcular or ovoid region in a second one. One major advantage of our methods is the possibility to reuse them for object detection, or even movement detection for the former one.

References

[1] Caroline Petitjean, Jean-Nicolas Dacher *A review of segmentation methods in short axis cardiac MR images* www.elsevier.com/locate/media Medical Image Analysis 15 (2011) 169?184

[2] Olivier Bernard, Alain Lalande, Clement Zotti, Xin Yang *Deep Learning Techniques for Automatic MRI Cardiac Multi-Structures Segmentation and Diagnosis: Is the Problem Solved?* DOI: 10.1109/TMI.2018.2837502 IEEE TRANSACTIONS ON MEDICAL IMAGING, VOL. 37, NO. 11, NOVEMBER 2018

[3] Marie-Pierre Jolly, Hui Xue, Leo Grady, and Jens Guehring *Combining Registration and Minimum Surfaces for the Segmentation of the Left Ventricle in Cardiac Cine MR Images* Siemens Corporate Research, Imaging and Visualization Department Princeton, NJ

[4] Marie-Pierre Jolly *Automatic Recovery of the Left Ventricular Blood Pool in Cardiac Cine MR Images* Siemens Corporate Research, Imaging and Visualization Department Princeton, NJ

[5] Xiang Lin, Brett R. Cowan, and Alistair A. Young *Automated Detection of Left Ventricle in 4D MR Images: Experience from a Large Study* Bioengineering Institute, University of Auckland, New Zealand Center for Advanced MRI, University of Auckland, New Zealand