Medical Sensor and Digitalization Project

Manuel Ojeda Osorio

Tareke Tewele Weletnsea

Université de Bourgogne

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Abstract

The work's basis is to develop a general and versatile framework for semi-automatic segmentation of a single structure of interest. The objective of image segmentation is to give a practical representation of object shapes. So, we present semi-automatic endocardial boundary extraction in left ventricular using fast and adaptive B-spline snake algorithm applied to magnetic resonance images. Designing an interface on Matlab's App Designer tool version R2019a so the user can use the algorithm without worrying about code lines, but obtaining the proper results once the processing is done.

I. Introduction

Image segmentation is an important step for large-scale image analysis and object recognition into multiple segments (sets of pixels), there are many algorithms for processing MRI images. B-Spline Snake approach is one of the well-known methods used by researchers in different international Medicine Institutions. This project is a B-Spline snake algorithm implemented on the left ventricle endocardial boundary's segmentation, since the algorithm is well accepted in computer vision, also highly used for shape recognition, edge detection, object tracking, and segmentation.[1] The basic snake model is a B- Spline which is continually controlled under the impact of forces that include image forces and external constraint forces. The internal spline forces perform by imposing a piecewise smoothness constraint, while the image forces exert pressure on the snake towards the keys control points of the image such as lines, edges, and subjective contours. Active contours, also called "Snakes", are best suited to combine both efficient and well controlled image segmentation with extensive and easy user interaction. Statistical internal and external energy are used to push the outlining counter to its perfect position during the segmentation of images.

II. Background

In order to accomplish the endocardial boundary detection, many algorithms and methods has been published, such as Markovian random fields[2], active appearance models. Among several available approaches, the active contours, introduced by Kass et al.[3], have shown remarkable performance and reasonable computational time. Since its publication, it has became a popular method for segmentation, so much that a number of researchers have made improvements on the proposed algorithm.
Currently, B-Spline snake algorithm is described either implicitly (e.g., level sets) or explicitly with point-based and parametric snakes or, more recently, by subdivision

[1] Badoual:2019

[2] Mignotte:2001

[3] Tauber:2004

snakes. For the energy term, the most common approaches are based on edge or intensity information aggregated from either inside or on the curve.[4]
In fact, active contours, as a boundary-based approach, have found widespread applications in medical image segmentation.[5] The basic idea is to define an energy minimizing curve that is constrained by its own internal forces of continuity and curvature and external forces that drives it towards desired image features. Most of the times, low-pass filtering and morphological operations are used to define an initial estimate of the contour and also statistical internal and external energy are used to push the outlining counter to its correct position during the segmentation of echocardiographic images. Conventional active contour methods typically suffer from slow convergence speed due to large number of coefficients to be optimized. An alternative approach is expressing the curve as a parametric B-spline, which has built-in smoothness requirement, and hence requires remarkably fewer number of controlling parameters and provides faster convergence as well as local control.[6]
Instead of pursuing a computationally expensive optimization-based approach for calculating the curve evolution, a geometrical point of view is used to address this problem, which proves to be fast and reliable in our experiments.

The different kind of images acquired from different medical equipments represent a big challenge for the image processing. Because each equipment work in a special way and the results achieved are based on different purposes.[7] [8]
The difference between MRI images and Ultrasound images are notable, and those big or small differences are also who give different results with the same algorithm applied. The first difference is the price on acquiring a study, the Ultrasound test is cheaper than the MRI study. Other difference is the purpose of the study and the patient's area which is going to be applied. So for each one of the studies mentioned, it has to be defined what is the purpose and if the algorithm applied is the best fit.

III. Methodology

In the current work, a fast and adaptive method for extraction of left ventricular endocardial boundary in MRI images is presented, which builds upon conventional B-spline snake algorithm. Instead of pursuing a computationally expensive optimization-based approach for calculating the curve evolution, a geometrical point of view is used here to address this problem. In addition, an innovative combination of gradient vector flow and balloon force is employed to drive the contour towards the boundaries. More specifically, these are the basic steps to accomplish the task.

- The user only has to load the MRI image and select an initial area, the control point iterates by image force to cover the all contour outline.
- Default value for number of contour and iteration is 300 and algorithms rely on the notion of control points of the Spline curve.
- The algorithm makes the internal force matrix, which constrains the moving points to a smooth contour.
- The balloon force provides the drive for the contour in the homogeneous regions far from the boundaries.
- As the contour approaches the desired boundaries, balloon force is gradually replaced with the vector field produced by few iterations of gradient vector flow (GVF). GVF force then accurately fits the contour into the desired boundaries. The combination of external forces significantly speeds up the convergence.

[4] Badoual:2019
[5] Kass:1988
[6] Brigger:2000
[7] Levine:2012
[8] MRI/Ultrasound:2020

- Weighted external forces associated with adjacent curve segments to their common node point to determine the displacement of the corresponding node.
- Initially, only balloon force provides the drive for the contour. As the contour approaches the image features, e.g., boundaries, balloon force gradually disappears. Then, the vector field produced by few iterations of GVF algorithm dominates and deforms the contour to fit into the desired boundaries.

The NII files are associated with NIfTI-1 Data Format by Neuroimaging Informatics Technology Initiative, adapted from the widely used ANALYZE 7.5 file format. This kind of files give several benefits over other kind of files in the medical area, such as the data control and storage of information.[9]
Because of the early mention, a converter from NII files to PNG files was added to the program, with the purpose of giving the user a way to manage the NII files, because the initial points have to be selected from an image. The converter works in Matlab too, it was written by Alexander Laurence, the converter allows the user to select the nii file to convert and also gives the option to the user to rotate the files. In the case the user do not want to rotate the file, the conversion is made with the same planes as the NII File has. If the user want a rotation, the options provided are 90°, 180°, or 270°; and save the results at the folder which the user select at the beginning of the conversion process.

IV. Experiments and results

The data base used for the project was recovered from the Automated Cardiac Diagnosis Challenge (ACDC). It was created from a real clinical exams, fully anonymized and handled within the regulations , the dataset is composed of 150 exams (all from different patients) divided into 5 evenly distributed subgroups (4 pathological plus 1 healthy subject groups).[10]

The initial interface gives the option to either convert the NII files to PNG files or to initiate the segmentation process of an image the user already have. The interface has a green light which is going to be on depending on which section is active. It also has a screen at the bottom where all the vital information will appear so the user know if the process needs information or if it is done.

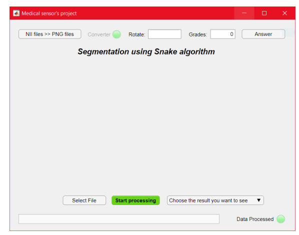

Figure 1: *Initial interface of the program realized.*

For the purpose of giving the user more tools in order to manage the data, the interface shows not only the result from the image processing, but the initial image selected at the left side and at the right side the user select between four displays:

- The image with initial contour
- The external energy
- The external force field
- Snake movement

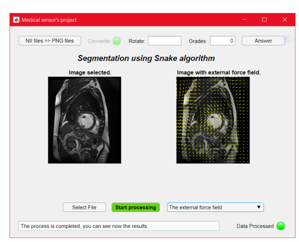

Figure 2: *Interface with the image selected and processing done.*

When working with Matlab, the software allows to manage the images displayed and

[9] NIfTI:2020

[10] Bernard:2018

they can be exported so the user can save the results of the processing for further processing.

The results shown in the use of this algorithm are satisfactory, all the NII files were converted to PNG with or without any rotation, and saved at the folder of our selection. So at the moment of begin the processing we know where the necessary files were at.

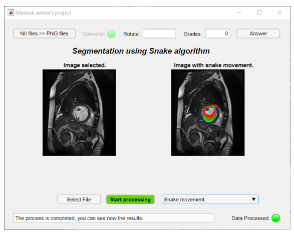

Figure 3: *Interface with segmentation process done.*

The segmentation realized to the images used showed to have a big influence from the GVF and the edges detected by the field forces, both the internal and external. The option to visualize and export the contour selected by the user and the results once the algorithm is applied gives the user more possibilities to manage the information acquired, so it can be applied a post-processing step.

V. Discussion and conclusion

The project present an algorithm used for segmentation implemented in an interface which allows more accessibility for the users who are not used to code lines and which algorithm works for segmentation based on B-spline snake's algorithm.

In the future, the project can be improved by giving more selection power to the user on changing values which allow to have different results, but at the same time it may presents better results depending of the image used. Because as we have seen, the results between ultra sound and MRI images can be different, not because they are wrong, but because each kind of image gives different kind of details and we have to be able to identify which details are needed.

To finish, it has been very obvious that for this kind of project, it is needed an expert, such as cardiologist of related to this end. Because this project, is a project which needs multidisciplinary participation in order to achieve the best results possibles, from the acquiring images step until the post-processing data step. Where the end has to be the improvement of the tests realized with reliable data after the processing is done, but also to get manageable information so the medical experts can correctly interpret the information and from there, take the best possible decision.

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