THE ANNALS OF “DUNĂREA DE JOS” UNIVERSITY OF GALAȚI
FASCICLE V, TECHNOLOGIES IN MACHINE BUILDING,
ISSN 1221- 4566, 2012

LEFT VENTRICLE SEGMENTATION USING ACTIVE CONTOUR MODEL

Simona Moldovanu, Luminita Moraru, Dorin Bibicu

Physics Department, University of Galati, 47 Domneasca St.,800008 Galati, Romania
Simona.Moldovanu@ugal.ro; Luminita.Moraru@ugal.ro; Dorin.Bibicu@ugal.ro

ABSTRACT

This study is based on the tracing of the left-ventricular endocardial borders of echocardiographic images. The algorithms used for border detection are the Active Contour Models (ACM) and also the one developed in the EchoPAC software. The mentioned algorithms were applied on apical two chamber view (A2C) in end-systole and end-diastole frames. The overlapping between borders detected using both algorithms is the goal of this work. The number of iterations and their parameters of the ACM were also taken into account.

KEYWORDS: Active Contour Models, EchoPAC software, apical two chamber view

1. INTRODUCTION

Echocardiography as an imagistic tool is widely used in observing the clinical manifestations and features of the heart and it provides efficacious and lucrative information on the heart health and function. The endocardium is the innermost layer of tissue that lines the chambers of the heart. Viewing the left-ventricular epicardial and endocardial borders is essential for quantification of the cardiac function [1].

The Active Contour Models that are also called snakes are used to delineate an object into 2D/3D image. In medical imaging the ACMs are widely used. Moreover, the ACMs were successfully applied in the segmentation of the echocardiography images. The papers [3, 4] attempt to give an overview of these methods within a structured framework. The papers [5, 6] apply the ACM in order to detect the border of the endocardium.

In this paper we propose a local segmentation of the left ventricle of the heart by using the ACM. The segmentation is accomplished on an A2C view of the heart. We automatically followed up the border detected by the EchoPAC software. EchoPAC software streamlines the work-flow and allows users to maximize the productivity.

The analysis of the overlapping on the border detected by Strain Rate Imaging (SRI) is made by using the ACM. The performance of the ACM was verified by detecting the overlapping of the border detected by both the SRI and ACM.

In the experimental section, the values of the coefficients of the ACM and the number of iterations are provided considering the borders overlapping.

2. ACTIVE CONTOUR MODELS

Kass [7] has introduced the snake as an elastic curve which tries to adjust itself to the boundaries of a biological object using the most significant features of the scene, starting from its initial state. It is deformed due to external forces that attract it towards salient features of the image, and due to internal forces which try to preserve the condition of smoothness in the shape of the curve. A final solution is given by the minimum value of the snake’s total energy, which is the result of the following equation:

$$E = \int_0^1 \left[E_{\text{int}}(S(u)) + E_{img}(S(u)) + E_{con}(S(u))\right] du, \quad (1)$$

where $E_{\text{int}}(S(u))$ is the internal energy of the spline (or curve) and $E_{img}(S(u))$ gives rise to the image energy, $E_{con}(S(u))$ gives rise to the external constraint forces [8]. The internal energy is represented by:

$$E_{\text{int}} = \underbrace{\frac{\alpha}{2}\left|\frac{\partial}{\partial u}S(u)\right|^2}_{Elastic\ energy} + \underbrace{\frac{\beta}{2}\left|\frac{\partial^2}{\partial u^2}S(u)\right|^2}_{Bending\ energy} \quad (2)$$

The first-order derivative drives the contour stretching and the second-order derivative controls the contour bending using the weighing parameters, the snake's tension and the snake's rigidity, respectively. Image energy is used to drive the contour towards the desired image features, such as boundaries. In traditional ACMs, the image energy is usually estimated as the result of the edge detection and is calculated as [9]:

$$E_{edge} = -\left|\nabla I(x, y)\right|^2 \tag{3}$$

$$E_{img} = -\left|\nabla G_\sigma(x, y) * I(x, y)\right|^2 \tag{4}$$

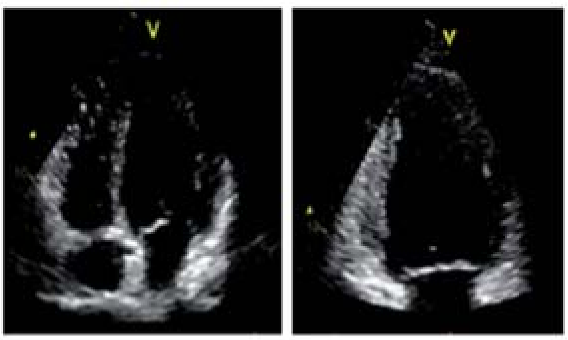
where $G_\sigma(x, y)$ is the 2D Gaussian kernel with the standard deviation σ. ∇ and $*$ represent the gradient and the convolution operator, respectively. In Eq. (4), in order to reduce the noise effect on the image, a Gaussian filtering is applied [10].

3. EXPERIMENTS AND RESULTS

The hardware experiment environment was Intel (R) Core (TM) 2 Duo CPU T 5900, 2.20 with 3G RAM, and the programming environment is the MATLAB R2009a (The Mathworks Inc., Natick, MA). Echocardiography was performed with commercially available equipment from scanning systems, VIVID E9 and GE HORTEN MOK WAY using a curvilinear probe with transducer frequency of 3.2 MHz.

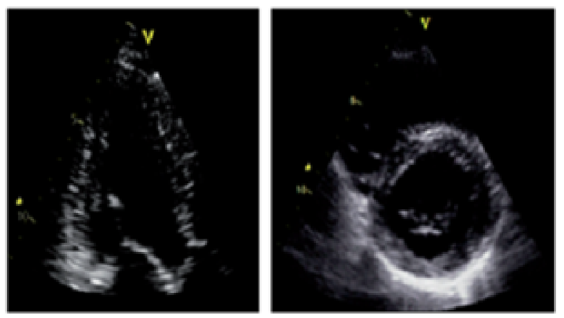
EchoPAC PC workstation includes the following modules: Tissue Velocity Imaging (TVI), Tissue Tracking, Quantitative Contrast, Strain and Strain Rate Imaging (SRI), and Tissue Synchronization Imaging (TSI). In our study, SRI is used to detect the border of the endocardium in both frames end- systole and end-diastole.

The echocardiography images of the heart used in this research were all captured from the same machine and then digitized with 512 x 524 pixels and 256 grey-level resolutions as in Figure 1.



(a) (b)

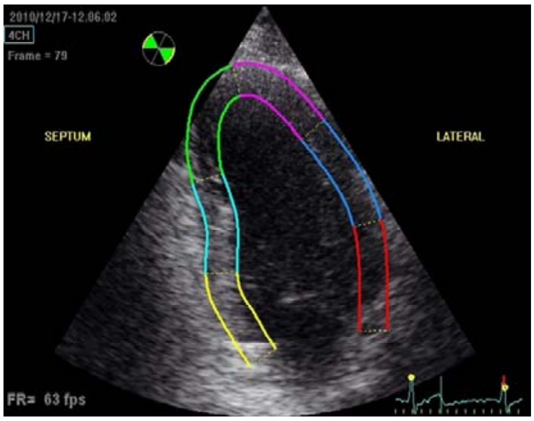
Fig. 1. *Ultrasound gray-scale images of the heart. (a) apical four-chamber view (4CH), (b) apical two-chamber view (2CH),*



(a) (b)

Fig. 2. *Ultrasound gray-scale images of the heart: (a)apical long-axis view (3CH), (b) short axis view at the basal level of the heart*

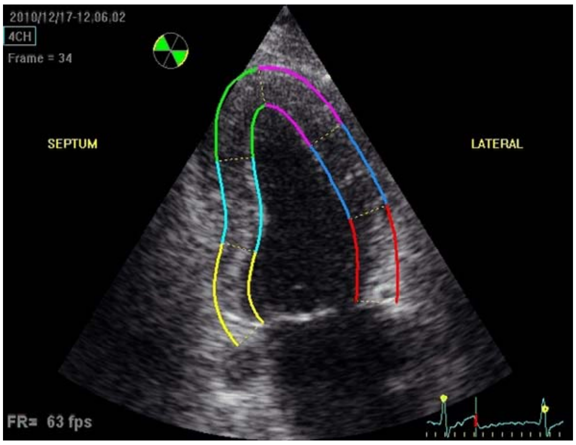
The segmentation process is performed in apical two-chamber view. In Figs.3(a) and 4(a) borders like a horseshoe were detected using the SRI option from EchoPAC software. In Fig. 3(a) the segmentation process is accomplished in the end-diastole frame and in Fig. 4(a) in the end-systole frame, respectively. This process has been repeated using the ACM algorithm and the results are shown in Fig. 3(b) in the end-diastole frame and in Fig. 4(b) in the end-systole frame.



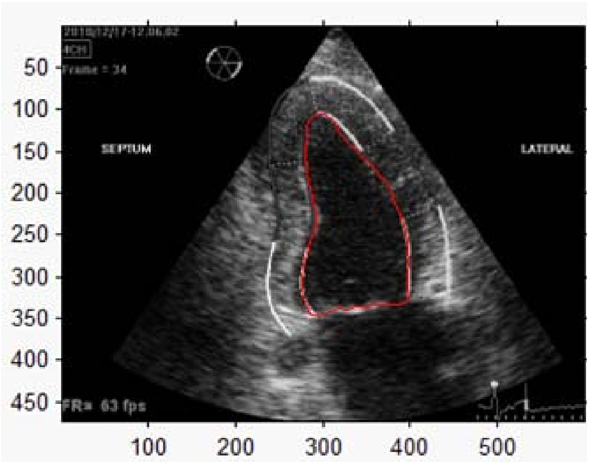
(a)

(b)

Fig. 3. *End-diastole frame of apical two chamber view. (a) borders extracted by EcoPac software; (b) borders extracted by ACM technique.*



(a)



(b)

Fig. 4. *End-systole frame of apical two chamber view. (a) borders extracted by EcoPac software; (b) borders extracted by ACM technique*

In the past years, many algorithms and models of active contours (snakes) have been developed. In comparison with algorithms such as "Greedy", the dynamic programming approach of the ACM develops a new vision based on variational calculus.

The ACM is an energy that minimizes the spline guided by external constraint forces and influenced by image forces that pull it toward the followed object. In our case, the image forces pull the snake toward endocardium border.

The complexity of ACM is O (pm^3), where p is the number of point in the contour and m is size of the neighborhood in which a point can move during a single iteration.

The performance of the ACM, for different values of different value of α and β has been tested. If the number of iteration n is in the range of $\{5,6,7,...,30\}$, then the values of α and β parameters allowing the border of ACM overlapping on the detected border by EchoPAC are:

$$(\alpha,\beta) \in \{(0.4;0.2),(0.4;0.3),...,(0.4;9.5),...,$$

$$(0.5;0.2),(0.5;0.3),(0.5;0.4),.....(0.5;9.5),....,$$

$$..........\ ....\ ....\ ....\ ....\ ....$$

$$(1.6;0.2),(1.6;0.3),(1.6;0.4)....(1.6;9.5)\}$$

We have successfully used the snakes in our interactive interpretation when α and β are ranged in the intervals $\alpha \in [0.4, 1.6]$ and $\beta \in [0.2, 9.5]$. Here, the user can impose constraint forces to guide the snake near features of interest.

4. CONCLUSIONS

A novel method that accurately detects the endocardium border of the human left ventricle in echocardiographic ultrasound images has been developed. It is based on the manipulation of both the elasticity and rigidity parameters and also it deals with the number of iterations of the ACM, so that the obtained segmentation results are acceptable. The parameters which allow the better overlapping between the borders were detected with the EchoPAC software and the borders detected with ACM were taken into account.

Acknowledgements

The authors would like to thank the Project SOP HRD-EFICIENT 61445/2009 and the Project SOP HRD -TOP ACADEMIC - 107/1.5/S id 76822 of "Dunărea de Jos" University of Galati, Romania.

REFERENCES

[1] Chalana, V., Linker, D.T., Haynor, D.R., Yongmin, K., *A multiple active contour model for cardiac boundary detection on echocardiographic sequences*, Medical Imaging IEEE Transactions, v 15, n 3, 1996, pp. 290 – 298;

[2] Morales, M.A., Positano, V., Rodriguez, O., Passera, M., Lombardi, M., Rovai, D., *Tracking of the Left Ventricle in Contrast Enhanced Echocardiography by Anisotropic Filtering and Active Contours Algorithm*, Computers in Cardiology, v 29, 2002 pp. 65−68;

[3] Loncaric, S., *A Survey of Shape Analysis Techniques*, Pattern Recognition, v 31, 1998, pp. 983–1001;

[4] McInerney, T., Terzopoulos, D., *Deformable Models in Medical Image Analysis: a survey,* Medical Image Analysis, v 1, 1996, pp. 91–108;

[5] Cheng, J., Liu, Y., Jia, R., Guo, W., *A New Active Contour Model for Medical Image Analysis,* Wavelet Vector Flow, v 36, n 2, 2006, pp. 39-44;

[6] Cho, J., Benkeser, PJ., *Cardiac segmentation by a velocity-aided active contour model.* Computer Medical Imaging Graphics, v 30, n 1, 2006, pp. 31-41;

[7] Kass, M., Witkin, A., Terzopouls, D., *Snake: active contour models*, Proceeding of International Journal of Computer Vision, v 5, 1990, pp. 321–331;

[8] Chen, D., Chang, R., Wu, W., Moon, W., Wu W., *3-D breast ultrasound segmentation using active contour model*, Ultrasound in Medicine and Biology, v 29, 2003, n 7, pp. 1017–1026;

[9] Xu, C., Prince, J. L. *Snakes, shapes, and gradient vector flow*, IEEE Transaction on Image Processing, v 7, n 3, 1998, pp. 359–369;

[10] Kim, H.C., Seol, Y.H., Choi, S.Y., Oh, J.S., Kim, M.G., Sun, K., *A study of image segmentation technique using geometric active contour model with morphological gradient edge function*. Proc Engineering Medical Biology Society, v 1, 2007, pp. 4437-4440.