DISPLACEMENT CALCULATION OF HEART WALLS IN ECHO IMAGES USING LEVEL SET AND B-SPLINE FREE FORM DEFORMATION

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ABSTRACT

Problem of displacement calculation of the heart walls ECHO ultrasound sequences is addressed. A method, which is proposed in it, consists of: 1) speckle reduction anisotrophic diffusion filtration of USG images, 2) segmentation of heart structures in consecutive denoised frames via active contour without edges method, 3) calculation of frame-to-frame deformation vectors by B-Spline FFD algorithm. Results from method testing on synthetic USG-like and real ECHO images are presented.

INTRODUCTION

Reports of the World Health Organization state that heart diseases are one of the most often and dangerous. Estimation of: 1) intima-media thickness of the common carotid artery in ultrasound B-mode examination, 2) shape and motion parameters of the left heart ventricle in ultrasound echocardiograhy are recognized as the best methods for estimation of cardiovascular risk and heart events prediction. The poster addresses the problem of displacement calculation of the walls of left heart ventricle in ECHO ultrasound sequences. A method is proposed and tested in it that consists of three steps:

- speckle reduction **anisotrophic diffusion** (SRAD) filtration of USG images,
- segmentation of heart structures in consecutive denoised frames via **active contour without edges** method,
- calculation of frame-to-frame deformation vectors by **B-Spline FFD** algorithm.

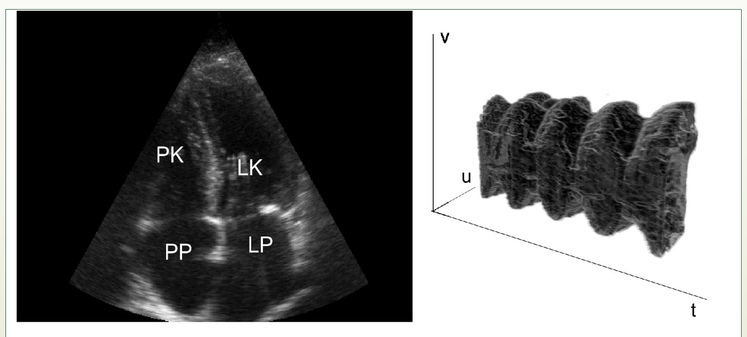

Fig. 1. *Example of ECHO image, four chamber view, PK - right ventricle, LK - left ventricle, PP - right atrium, LP - left atrium; 3D reconstruction of LK after segmentation process*

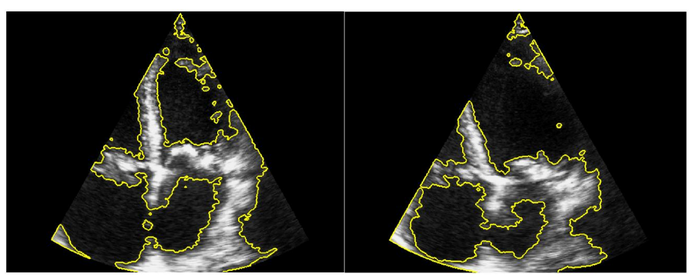

Fig. 2. *Exemplary results of walls segmentation from real Echocardiographic images*

FILTRATION

Strong disturbances (speckles, specular reections, echoes, shadows) visible in ultrasound images as multiplicative noise makes USG images segmentation a difficult task. Therefore, USG images are usually filtered before further processing. In this operation SRAD filters based on **Perona-Malik** work [1] are frequently used. In (1) the diffusivity coefficient c(·) depends on magnitude of image gradient which is also an edge estimator.

$$\frac{\partial I}{\partial t} = div\left[c\left(|\nabla I|\right)\nabla I\right] \qquad (1)$$

In our algorithm following the work [2] the control of diffusion process is based on **Kuan model** [3] instead of the image gradient:

$$\frac{\partial I}{\partial t} = div\left|\kappa \nabla I\right|,\ \kappa = 1 - \frac{1 - C_n^2 / C_I^2}{1 + C_n^2} \qquad (2)$$

where $C_n^2 = \sigma_n^2 / \bar{n},\quad C_I^2 = \sigma_I^2 / \bar{I}.$

SEGMENTATION

In Fig. 1 you can observe that walls of chambers are not well visible (as a consequence image gradient will be very small) what suggests that application of the classical active contour algorithm can lead to miss-segmentation. Therefore we propose to use for ECHO USG image segmentation an algorithm described in [4] called active contours without edges. Its main advantage is using information about intensity values inside and outside the contour.

In our approach we propose starting evolution from an ellipse which is similar to the searching shape. Its centre can be indicated by a user. If one segments a sequence of images, segmentation results from the previous frame can be treated as initial contour in the analysis of next frame.

In order to estimate the segmentation quality the following segmentation efficiency measure has been used:

$$J = \left(1 - \frac{\sum_{x=1}^{N}\sum_{y=1}^{M}\left|\mathbf{I}_{\mathbf{GT}}(x,y) - \mathbf{I}_{\mathbf{S}}(x,y)\right|}{\sum_{x=1}^{N}\sum_{y=1}^{M}\mathbf{I}_{\mathbf{GT}}(x,y)}\right)\cdot 100\% \qquad (3)$$

Exemplary visual results and calculated segmentation efficiency for artificial data are presented in Fig. 2 and Fig. 3, respectively.

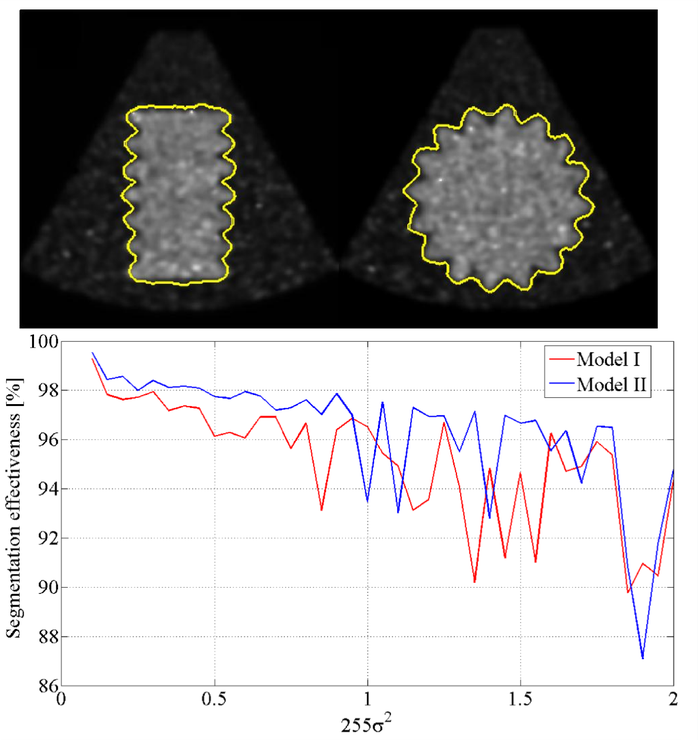

Fig. 3. *Automatic segmentation eciency for generated synthetic USG-like images presented in first row*

REGISTRATION

In order to obtain a displacement vectors for walls pixels received from segmentation of consecutive ECHO images, it is proposed to use B-spline Free Form Deformation (FFD) algorithm, described by Rueckert et al. [5] together with the Sum of Squared Differences (SSD) similarity measure function.

The method makes use of two stage deformation model. In the first step, a rigid (affine) transformation is estimated in order to establish good initial alignment of images - it allows correcting heart position in ECHO series. Then, B-spline FFD algorithm is used to model the local deformation.

Table 1. Errors of displacement calculation in pixels

	mean	std	min	max
Manual marked	2.55	1.86	0.0003	8.33
Algorithm	1.74	1.65	0.0001	6.82

SUMMARY

Method for tracking the heart left ventricle movement dynamics in ECHO videos is proposed. Obtained results for generated synthetic USG-like images and real ones are promising and encourage the authors to think about future research focused on evaluation of medical characteristics of heart functions making use of the calculated walls motion parameters. Details of proposed solution can be found in [6,7].

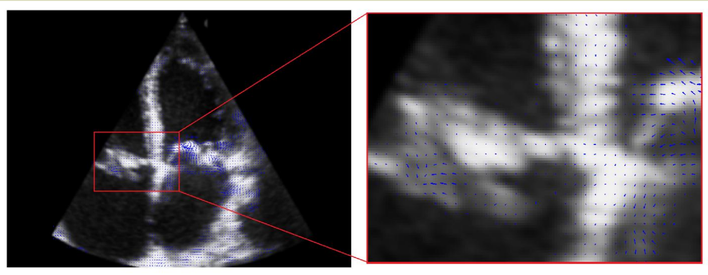

Fig. 4. *Example of calculated displacement field between two ECHO images limited to segmented area*

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