The study of features of expert signature for left ventricle on ultrasound images

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ABSTRACT

The article presents the study result of signature of left ventricle (LV) contours which are built by experts.The result is a part of a task of automatic contouring area of LV on an ultrasound frames with apical four-chamber view. Signature is LV contour curve, built in polar coordinates. The study was found the optimal point in the center of the LV base.

The resulting signature is approximated by three polynomials second and third degree: right side, left side and top. The result of such approximation has been qualitatively and quantitatively better than the whole curve.

Keywords

echocardiography, left ventricle (LV), contouring, contour signature..

1. INTRODUCTION

The ultrasound survey is a non-invasive method which does not produce ionizing radiation, relatively inexpensive and quite easy to use. For these reasons, it is widespread in different spheres of medicine, including cardiology. In this sphere it is called echocardiography. One of the most important moments in the study of the global and local left ventricle contractility is an apical four-chamber view (Fig. 1). For calculating quantitative indicators of the heart functions doctors contour the LV on echocardiographic images (Fig. 1). It is necessary to mention that at present this procedure is performed either manually or semi-automatically because fully automatic solutions do not exist.

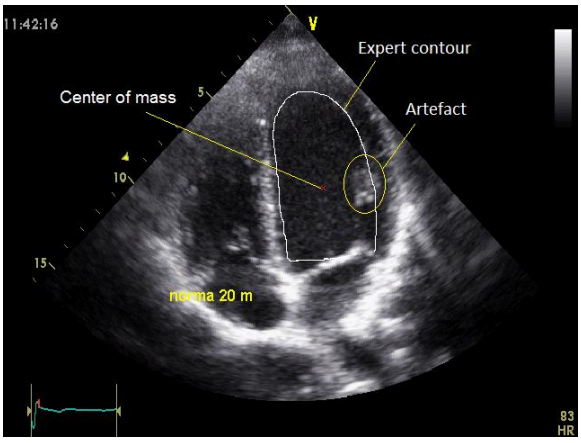

Figure 1: Example echocardiography image with an expert contour, artifact inside the area and center of mass of the LV contour**.**

One of the difficulties which appear in the development of automatic LV contouring methods is the presence of artifacts which obstruct the correct contour construction. For example, there are white color areas inside the cavity of the LV on echocardiography images of some patients. While contouring the LV manually, the expert doctor ignores these areas and draws the contour as if they did not exist (Fig. 1).

It is necessary to select the class of functions approximating the expert contour and offer a way to identify their parameters for automating the process of contouring LV. In this regard, the research topic is relevant.

2. THE CHOISE OF THE POLAR COORDINATE SYSTEM ORIGIN WHEN CONTRACTING CONTOUR

Informative parts of the circuit LV are the left wall or heart partition, the right wall and the upper part. The lower part or the base which is located in the places of fastening the valve is always a segment, the construction of which in the auto thematic mode is not a problem [1]. Approximation other parts of the circuit, in contrast, is a non-trivial. In our study were used contoured grips expert of two-dimensional binary frames ultrasound movies of 640x480 pixels. The main idea is the representation of the expert contours in the polar system coordinate for selecting a class of approximating functions. This representation called signature. An example of the signature of the expert contour present in Fig. 2. The polar coordinate origin was at the center of mass of

the contour. (Signature built relative to the center of mass of the contour called the M-shaped signature.)

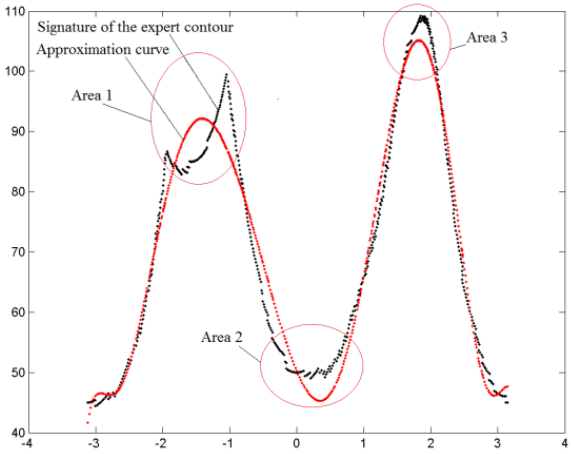

Figure 2: M-shaped signature.

Fig. 2 shows that the signature in the polar coordinate system can be approximated with a polynomial of tenth degrees. However, the quality of approximation for the following parts of the contour: area 1 (base), area 2 (middle of the right wall), area 3 (top) is not satisfactory. In addition, it turned out that the shape of the signature, and, consequently, the class of approximating functions significantly depend from the polar coordinate origin (Fig. 3)

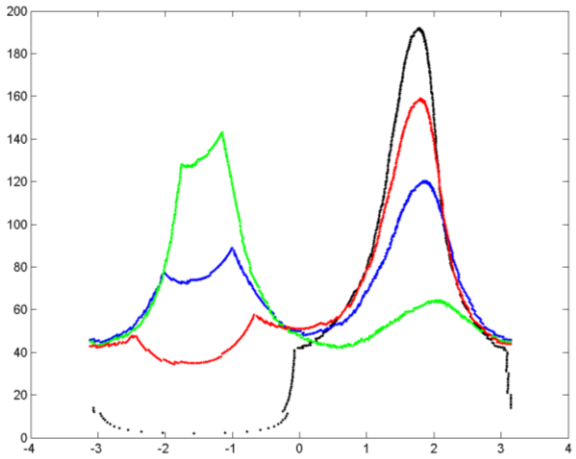

Figure 3: Multiple signatures at different position to the origin.

Fig. 3 shows that the signature with the origin of the polar system in the middle of the LV base is more convenient in terms of approximation, because the curve shape is simpler, easily stands out parts of the signature corresponding to the base of the left ventricle and the rest of the LV. (Signature built relative to the middle of the LV base called the L-shaped signature.) In addition, the procedure of finding fixed points of the left ventricle (left and right ends of the base) can be automated [1].

3. THE CHOOSE OF THE APPROXIMATING FUNCTION CLASS AND APPROXIMATION TECHNIQUE

At the first stage we have studied the possibility of approximation of L-shaped signature with a polynomial. Typical results of this approximation are presented in Fig. 4.

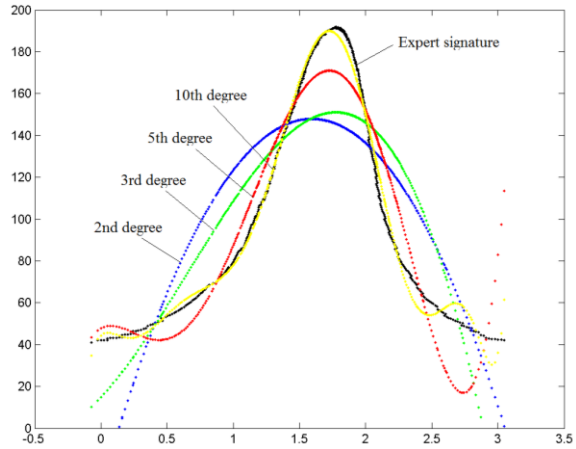

Figure 4: Approximation of L-shaped signatures of different polynomials.

Fig. 4 shows that a single polynomial for approximation L-shaped signatures cannot provide a satisfactory quality.

In this regard, the possibility of approximation of LV contour pieces was studied, in which the contour is divided into several parts and for each of them choosing the class of approximating functions and identifying their parameters. We divided L-shaped signature into three parts (Fig. 5) and approximated these parts polynomials 2nd and 3rd degrees.

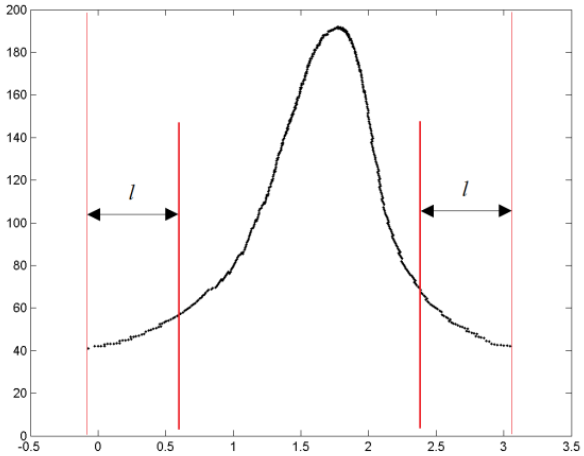

Figure 5: Division of L-shaped signature in three parts.

In connection with the fact that the quality of approximation of the selected method depend on borders position, which divide L-shaped signature on parts, total approximation error was calculated:

$$Err(\mathrm{l}) = \frac{1}{N}\sum_{i=1}^{N}(\mathrm{Y}_{sign\,i} - \mathrm{Y}_{apprx\,i})^2 \qquad (1)$$

Where $\mathrm{Y}_{sign\ i}$ – value of the expert signatures in point i, $\mathrm{Y}_{apprx\ i}$ – value approximating polynomial in point i, N – the number of points in the signature. The results of calculations for the polynomials of the 2nd and 3rd degrees at different positions of borders are presented in figures 6 and 7.

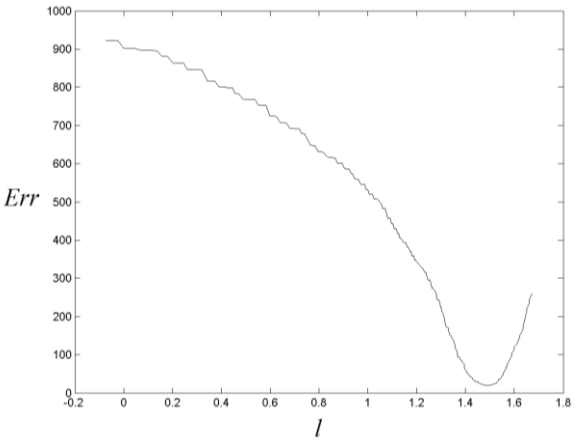

Figure 6: Total error for 2nd degree polynomial depend on borders position.

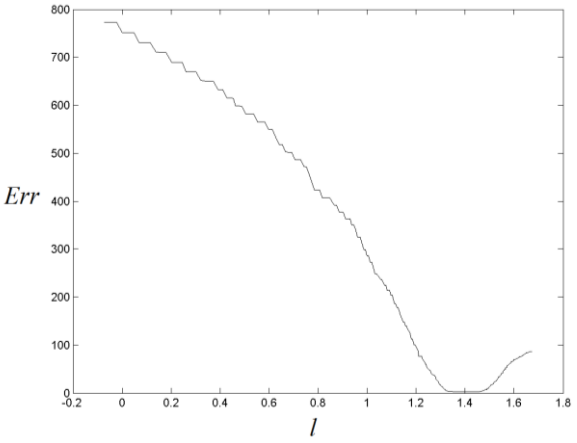

Figure 7: Total error for 3rd degree polynomial depend on borders position.

From Fig. 6 and 7 show that depending on the degree of the polynomial the best approximation is achieved when *l = 1.5* for the 2nd degree polynomial and *l = 1.4* for the 3rd degree polynomial. The results of piecewise approximation of the expert contour are presented in Fig. 8.

Fig. 8 shows that the proposed method of piecewise approximation provide acceptable quality of approximation of the expert contour. At the same time, it should be noted that at the points of conjugation of approximating polynomials can occur kinks, but can be resolved, for example, using the method of moving average. This result can be used to automate the procedure of automatic contouring LV

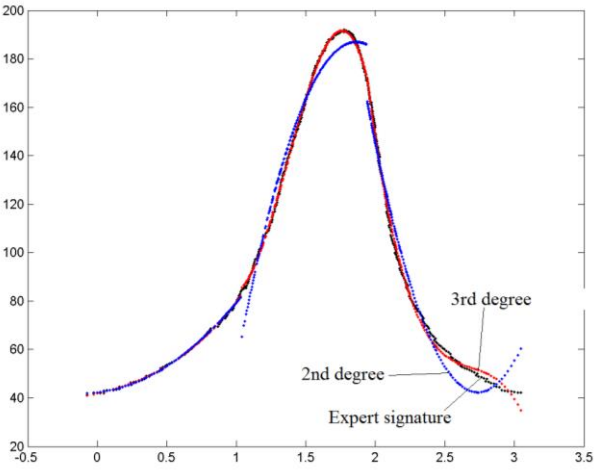

Figure 8: The result of piecewise approximation with the 2nd and 3rd degree polynomials.

on ultrasound images.

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Fig. 9 and 10 present examples of approximation expert contours with 2nd and 3rd degree polynomials. The use of 3rd degree polynomial in the proble is a better way of approximation of the contour because the curve is smoother than the curve of 2nd degree polynomial.

Note that similar results were obtained for our base ultrasound images and expert contours, which contained the ultrasound record for 30 patients. Each record has 25 frames. Total number of frames is about 750.

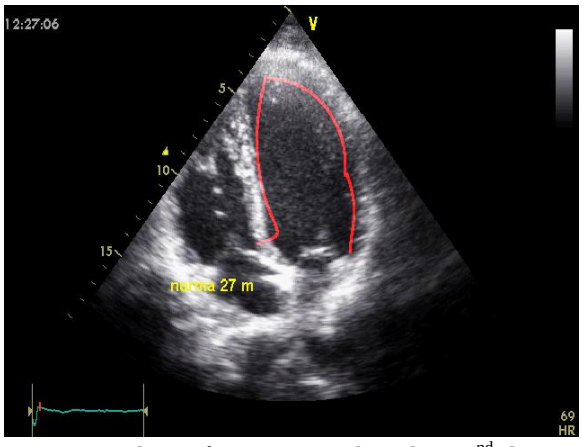

Figure 9: Edges of LV contour based on 2nd degree polynomial.

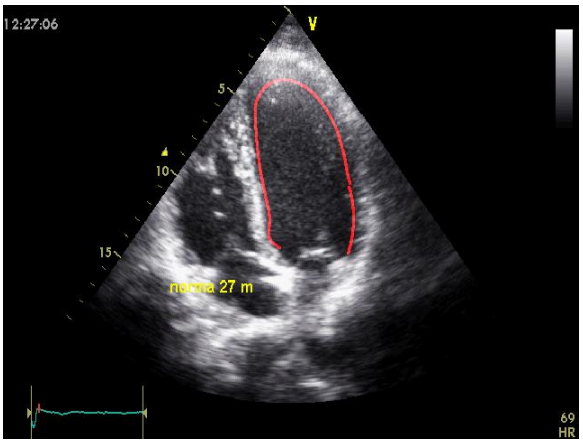

Figure 10: Edges of LV contour based on 3rd degree polynomial.

4. CONCLUSION

A comparative analysis of signatures built about the center of mass and the center-point of the base was conducted. The result of this analysis, we identified a number of advantages to the construction of a signature in relation to the central point of the base. The best approximation is achieved when $l = 1.5$ for the 2nd degree polynomial and $l = 1.4$ for the 3rd degree polynomial

Description of the automated algorithm contouring of the left ventricle and the results of its application for processing ultrasound images of patients without pathologies and patients with pathologies are subjects for further publications.

5. ACKNOWLEDGMENTS

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6. REFERENCES

[I] Zjuzin V.V., Porshnev S.V., Bobkova A.O. Opyt poiska tochek osnovanija levogo zheludochka serdca na jehograficheskih izobrazhenijah // Fizika i tehnicheskie prilozhenija volnovyh processov: Trudy XI Mezhdunarodnoj nauchno-tehnicheskoj konferencii /Pod obshh. Red. Ju.E. Mitel'mana. –Ekaterinburg: Izd-vo Ural'skogo universiteta, 2012. S. 361−363. (in Russian)