Study of the Mass Center Motion of the Left Ventricle Area in Echocardiographic Videos

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Abstract. The study of the mass center (CM) motion of the left ventricle (LV) area in echocardiographic videos is presented. CM of any phase of the cardiac cycle is inside an ellipse. An area of the ellipse is not more than 2% of the area of LV in systole. The criterion to identify correct and incorrect forms of contours are proposed for automatic contouring of LV in the frames of a video sequence.

Keywords: left ventricle, contouring, echocardiographic images (echocardiography), image processing.

1 Introduction

Echocardiography is one of the most wide spread ways of not invasive heart muscle deseases diagnosis, which most commonly uses ultrasound (US) images of the apical four-chamber heart projection. Sequence analysis of ultrasound images allows to analyze the dynamics of the heart muscle. Of particular interest to cardiologists is left ventricle (LV), since most various diseases and pathologies of the heart can change their state.

To assess the state of the LV, cardiologist puts contour on each frame of ultrasound sequence, which limits the region of the LV. As a rule, the cardiologist makes it manually or by semiautomatic modes. Using the contouring, they calculate the geometric dimensions of the LV (systolic and diastolic volumes), ejection fraction, wall contractility, etc. The obtained quantitative indicators provide reliable assessment of the heart muscle condition.

Analysis of the experience of cardiac ultrasound shows that in most cases the LV boundary is conducted subjectively and depends on the skill of the physician who performs the processing of ultrasound images. In this context, the task of developing algorithms for automated delineation of the LV on echocardiography images, that eliminate the element of subjectivity and increase the processing speed of ultrasound images of the heart, is relevant.

In this article the results of the kinematics analysis of mass center on the ultrasound images are discussed and the identification approach of inaccurate LV contour built in automatic mode are submitted.

2 Statement of the Problem

Let's consider the features of contouring procedures LV on the ultrasound image. Typical source frame of an ultrasound image is presented in figure 1. Figure 1 shows that the images are low-contrast. There is a variety of artifacts due to the presence of the papillary muscle in the heart tissue. The figure 1 also presents the expert LV contour. The expert had the right border of the LV, ignoring existing artifact in the image.

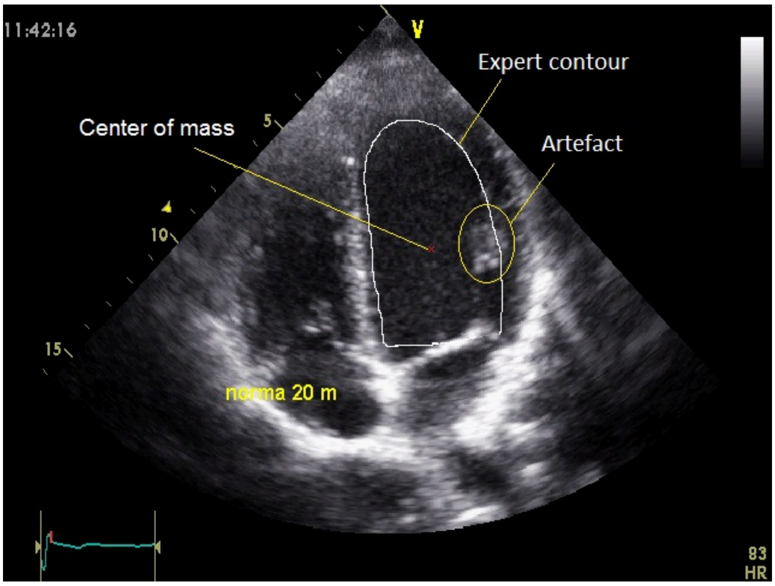

Fig. 1. The ultrasound frame with expert LV contour.

It should be noted that the presence of this artifact is critical for automatic algorithm. This problem is illustrated in figure 2, the results of the automatic delineation LV from the image are shown in figure 1.

Consequently, the automatic contouring process should have a pre-treatment procedure to remove speckle noise, artifacts and to enhance the contrast of ultrasound images. These algorithms are considered in [1], [4], [7] [8]. Analysis of the experience of their application shows that they really can improve the contrast

Fig. 2. The LV area is obtained from ultrasound image.

of the ultrasound images and in some cases remove artifacts. However, this can be done not for every patient.

Also the works [2], [3] should be particularly noted. For LV wall motion of the heart the optical flow algorithm [5] was used and analysis of LV shape changes over time. Work [9] describes the isolation area of the LV on echocardiography image. However, in these works the criteria to evaluate the correctness of contouring are not given.

Comparative analysis of the LV contour built by the expert and the contour built in automatic mode (see. Fig. 2), allows us to conclude that the CM coordinates of these contours are significantly different from each other. Thus, we can assume that the CM coordinate values are an informative parameter. This parameter allows to distinguish the contours of regular and irregular shapes (Fig. 3).

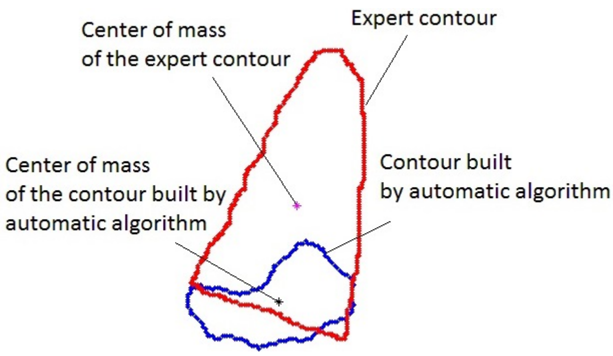

Fig. 3. Expert and contouring with the center of mass.

To test this hypothesis, the CM motion of expert contours was investigated. The results are presented in the next section.

3 The study of the CM LV motion.

In the course of the research ultrasound records of 16 patients were used, the total number of frames was 320. At each frame LV contours were built by experts. Figure 4 shows the coordinates of the CM expert LV contours of the heart. Figure 4 shows that the position of a CM is inside the minimal ellipse [6].

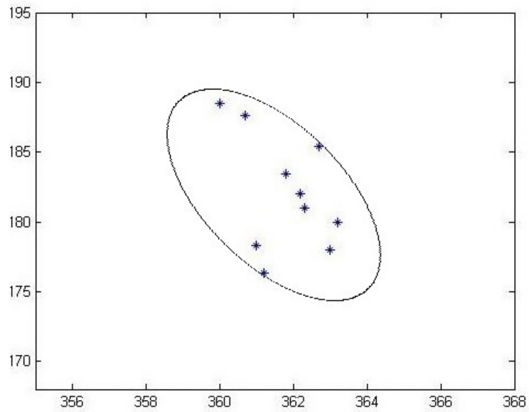

Fig. 4. CM of expert contours for one patient and ellipse constructed by CM points.

Similar calculations were performed for the remaining patients. Next, for each patient area of the respective ellipses was calculated. This area is compared with the area of LV in systole. Calculated coefficients are presented in table 1.

Table 1. The ratio of the ellipse area covering CM LV to the area of expert contour in systole.

Patient	Coefficient (expert data)	Coefficient (data obtained from automatic algorithm)	Patient	Coefficient (expert data)	Coefficient (data obtained from automatic algorithm)
B	0.0086	0.0424	K	0.0137	0.5185
C	0.0113	0.1180	L	0.0117	0.0237
D	0.0168	0.0110	N	0.0163	0.0349
E	0.0138	0.0117	O	0.0161	0.0189
F	0.0095	0.0136	R	0.0200	0.0235
G	0.0143	0.0674	T	0.0254	0.0205
H	0.0173	0.0533	V	0.0167	0.0981
I	0.0168	0.0987	X	0.0193	0.2188

Table 1 shows that the ellipse area encompassing LV CM does not exceed 2% of the left ventricular in systole. The results of similar calculations for contours constructed automatically, some of which have an irregular shape, are presented in table 1. (The automatic algorithm is considered in [10]).The maximum value of the ratio of the ellipse area, covered CM LV, to expert contour area in LV systole is 51%. Thus, the position of the CM allow to automatically identify the correct construction of the contour, using the following step:

1. Calculate the CM coordinates of the each video frame.
2. Construct a minimum ellipse which includes the CM of all contours.
3. Calculate the area of the ellipse.
4. Calculate the ratio of the areas of the ellipse to the area of LV in systole.
5. If the ratio is greater than 2% then apply the clustering procedure CM [11].
6. Identify the contours of the irregular shape which CM are assigned to a remote cluster.

Figure 5 shows the CM arrangement examples in the case, where the shape of one contour is incorrect. Figure 5 shows that CM for contours with regular shape are grouped in a certain region, while the contours of irregular shape are located at a remote distance from the grouping area.

It should be noted that the errors of second type (the contour is wrong, but CM belongs to the ellipse) were not found.

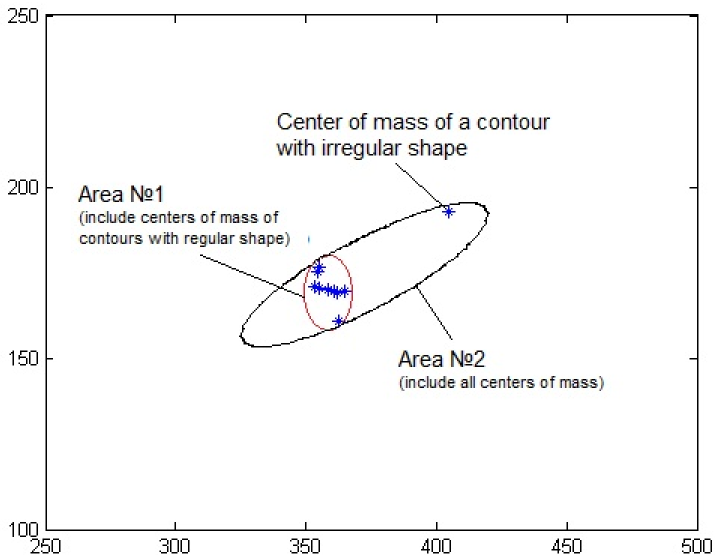

Fig. 5. Location of CM for patient X, one circuit is built wrong.

4 Conclusion

The CM for regular shape countours are grouped within the ellipse area. The CM for irregular shape countours are located out of this area. Methods of points clustering can solve this problem. An approach based on an analysis of the CM LV contours location, allowing to identify the contours of an irregular shape, is given in this work. The approach will be embeded in automatic algorithm of contouring the LV area.

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