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Mathematical model in left ventricle segmentation

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ABSTRACT

In this paper a parametric model of the left ventricle is presented. Its task is to estimate the myocardium shape on those slices, on which the segmentation algorithm has outlined the structure incorrectly. The aim of using the model on improperly segmented slices is to improve the accuracy of computing cardiac hemodynamic parameters and the heart mass. The proposed model works with any segmentation algorithm. The usefulness of the model is the largest while determining the myocardium at end-systole and calculating the heart mass. In case of the segmentation algorithm applied in this study, the error decreased from clinically unacceptable to acceptable after using the presented model.

1. Introduction

Due to the large share of heart diseases in mortality statistics the importance of cardiac condition diagnostic has increased significantly. It is usually assessed on the basis of the values of hemodynamic parameters. The most commonly performed cardiac test is MRI, which is a non-invasive, yet accurate technique [1,2].

Currently, it is a common practice to outline the contour of the left ventricle at each slice. An expert usually needs about one and a half to two hours to manually delineate 10–14 slices with a resolution of 256×256 for each phase of the cardiac cycle, which are usually recorded in the number of 16–24 [3]. Automated assessment of the heart condition would shorten the specialist's work time and therefore accelerate the diagnostic process. The beneficients of such solution are both doctors and patients and, in the long term, also institutions financing the examinations. However, fully automatic segmentation methods are often a source of errors – there occur areas that are undersegmented or incorrectly included in the wanted structure.

An important and difficult step of image diagnostics is the segmentation of anatomical structures and lesions. The segmentation quality is the most important factor determining the accuracy of the parametric description of the examined organ. A common problem in dynamic studies is blurred outlines of the structures. This phenomenon is observed inter alia in cardiac diagnostics.

Most of the currently developed cardiac MRI segmentation methods, that have practical applications, are semi-automatic methods. Intelligent scissors may serve as an example of an approach that permits a starting point to be marked by a user [4,5].

A fully automated approach implies the need of developing a methodology for determining initial conditions. However, not involving qualified specialists results in limited functionality or accuracy.

Techniques often applied in cardiac segmentation are regions of interest growing and mathematical morphology operations [6–9]. Algorithms presented in [10,11] use contours propagation. The segmentation of the left ventricle can also be based on active contours [12–14]. In [15,16] Graph Searching has been used. Examples of using Graph Cuts for segmentation can be found in [17–19]. Attempts have been also made to apply artificial neural networks for left ventricle segmentation purposes [20,21].

Popular segmentation algorithms tend to oversegment on cardiac magnetic resonance images and attempt to avoid this problem result in undersegmented areas. Methods suitable for particular data type often do not give good results in case of changing any imaging parameter. Furthermore, methods completely devoid of medical intervention (better from the user's point of view) usually segment the desired structures with less accuracy than methods initialized or even fully supervised by a specialist.

Another common approach, presented inter alia in [22–26], proposes the use of deformable models of the left ventricle. Paper [27] introduces a deformable "balloon" model. Active appearance models, which have been used in [28,29], can be found in the literature as well. An active shape model of the left ventricle has been presented in [30]. The authors of [31] have proposed the Deformable Elastic Template (DET), whereas in [32] the Optimized Nonrigid Temporal Model has been introduced. The paper [33] is an example of a combination of two processes: a global preliminary estimation of the location of the left ventricle and a local deformation of the shape.

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However, it should be noticed that most of the methods that use *a priori* models of the organ work on the basis of iterative-evolutionary algorithms. Their disadvantage is that calculations may stop at a local minimum, not achieving the global extreme. Myocardial segmentation results are therefore often burdened with significant errors [21,34], important from the diagnostic point of view [35,36].

The solution to this problem is the presented model of the left ventricle. It includes both the endocardium and the epicardium. Its task is to replace slices incorrectly segmented by an image processing algorithm, which can be arbitrarily chosen and implemented by the user. The model supports the segmentation, but does not replace it. The efficiency of the segmentation of each slice is verified using the proposed segmentation correctness coefficients. This approach combines the advantages of image processing techniques with basic knowledge about the organ shape. The presented model works with any segmentation

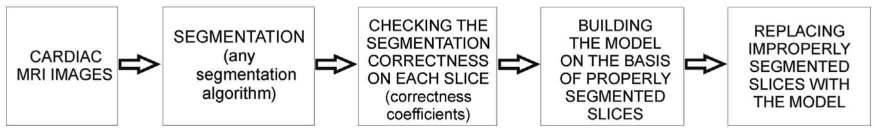

Fig. 1. Flowchart of the presented framework.

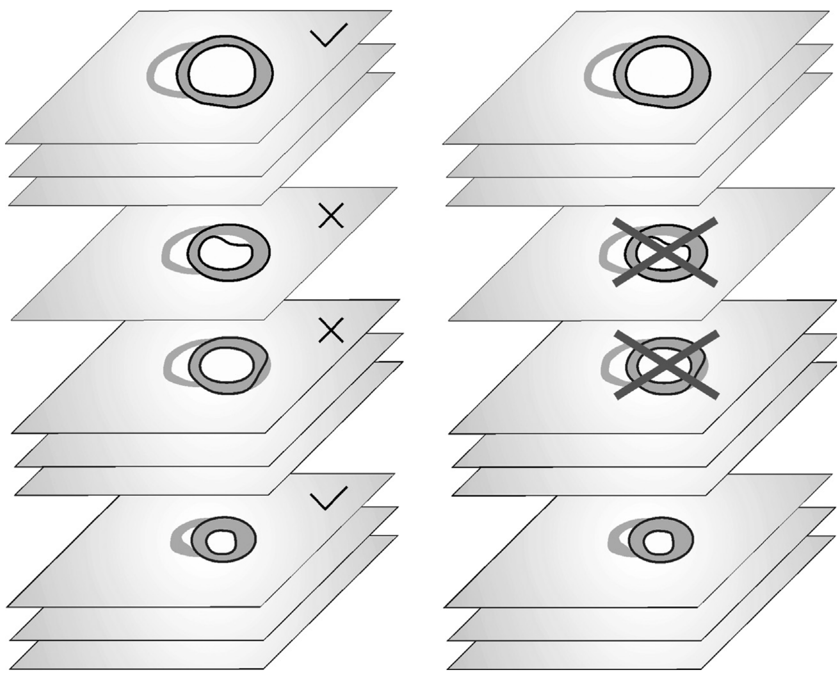

Fig. 2. Slices with incorrect segmentation are found.

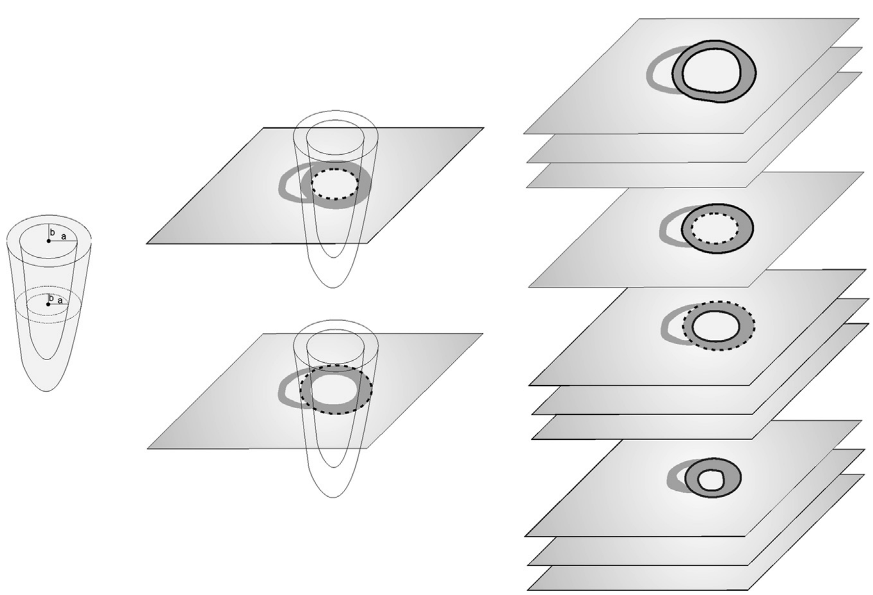

Fig. 3. Incorrect segmentation results are replaced with ellipses obtained using the model.