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Segmentation of the left ventricle in cardiac MR images

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Approach

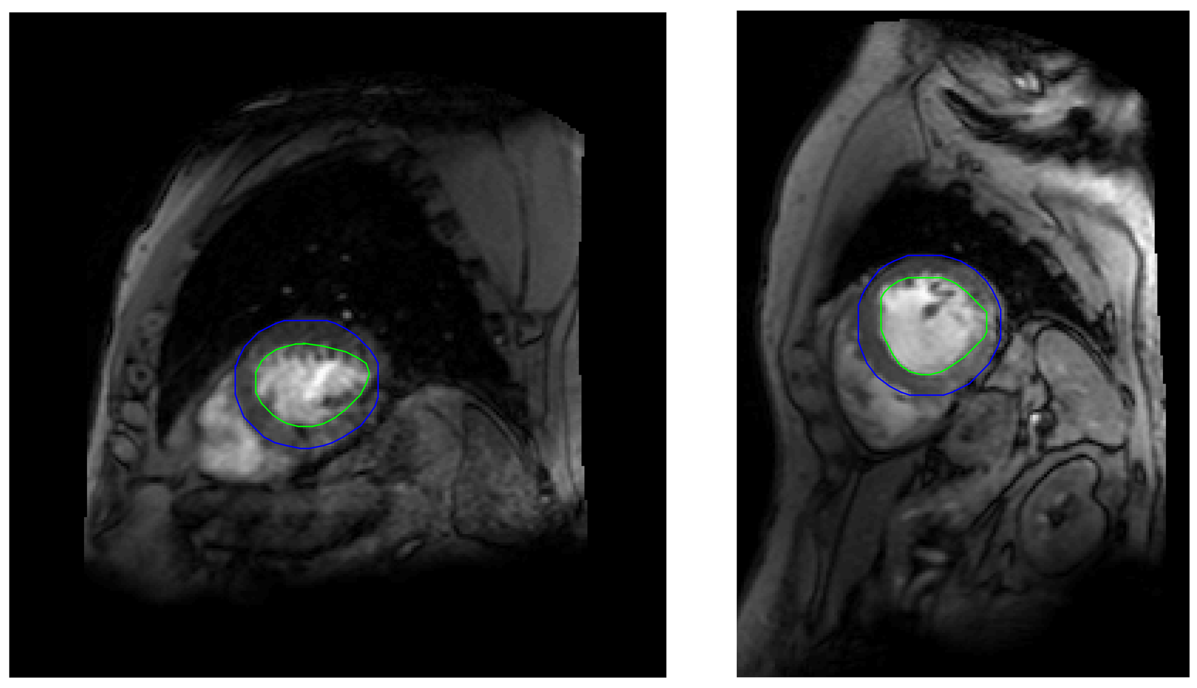
Segmentation of the left ventricle is of great clinical interest since it allows to directly measure important parameters such as end-diastolic volume, ejection fraction, and myocardial mass.

There are two main issues to consider. Segmentation of the inner contour of the left ventricle and segmentation of the outer contour. We have used two different approaches for each, and we have used information from the inner contour segmentation to use for the outer.

18 4D data sets of MRI images are given in the form Images(256, 256, number of slices, number of frames), where the frames represent a complete cardiac cycle. The middle slice through the heart is used for segmentation. Manually we have selected the center of the ventricle in each image in order to crop the image. We chose 60x60 pixels which was appropriate for all images.

Summary

The endocardial and epicardial contour of the left ventricle is identified using binary segmentation, dynamic programming, and fast Fourier smoothing. The left ventricle is identified in the end-diastolic phase in 18 patients and in one patient the left ventricle is identified in 20 frames through the cardiac cycle. The implemented method is automated and a time saver compared to manual segmentation.



Segmentation

Both frames and images have been segmented, and the same methods have been applied in both cases. The difference lies in the thresholding applied to identify the blood pool. When segmenting frames in one image the threshold value is only computed once (in the first frame), whereas it is computed for each image when segmenting images.

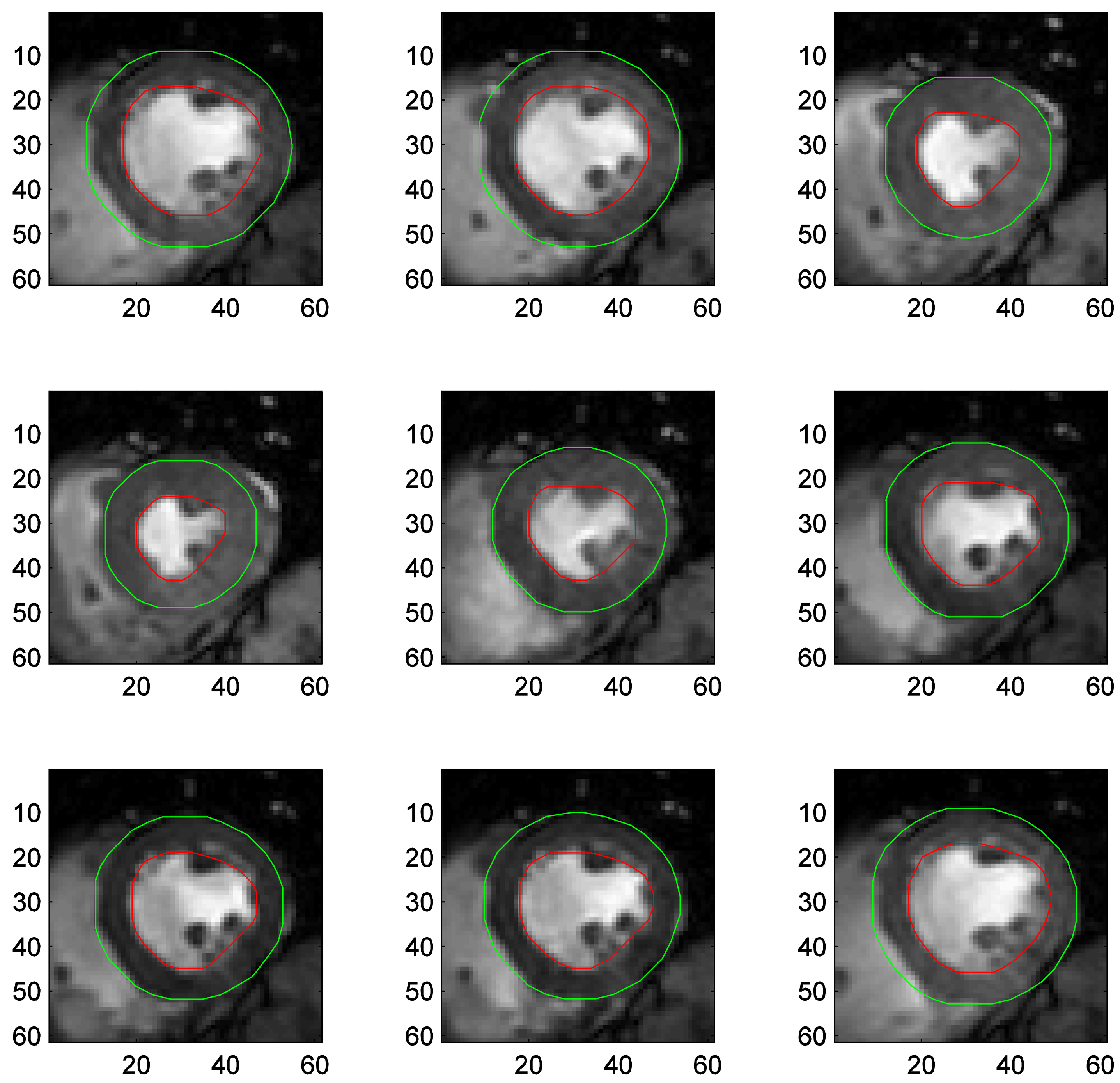


Figure 2: Segmentation of frames in one cardiac cycle of a patient. Frames shown here are [1 3 6 8 11 13 15 17 20].

Endocardial Contour

The endocardial contour is detected by identifying the blood pool by binary segmentation using thresholding and a convex hull.

1) The first step is to normalize the image.
2) Then a threshold is applied .The difficult part is to choose the appropriate value. The value chosen is the mean of the image intensities squared plus the images intensities to the power of 2.

$$\text{Threshold} = \frac{\sum_{i=1}^{n} \sqrt{val}}{n} + \frac{\sum_{i=1}^{n} val^2}{n}$$

3) The thresholding produces multiple objects but the one overlapping the center is selected.
4) The convex hull of this object is computed and the contour is found.
5) The contour is smoothed by a 1D fast Fourier transform for the x- and y-coordinates separately.

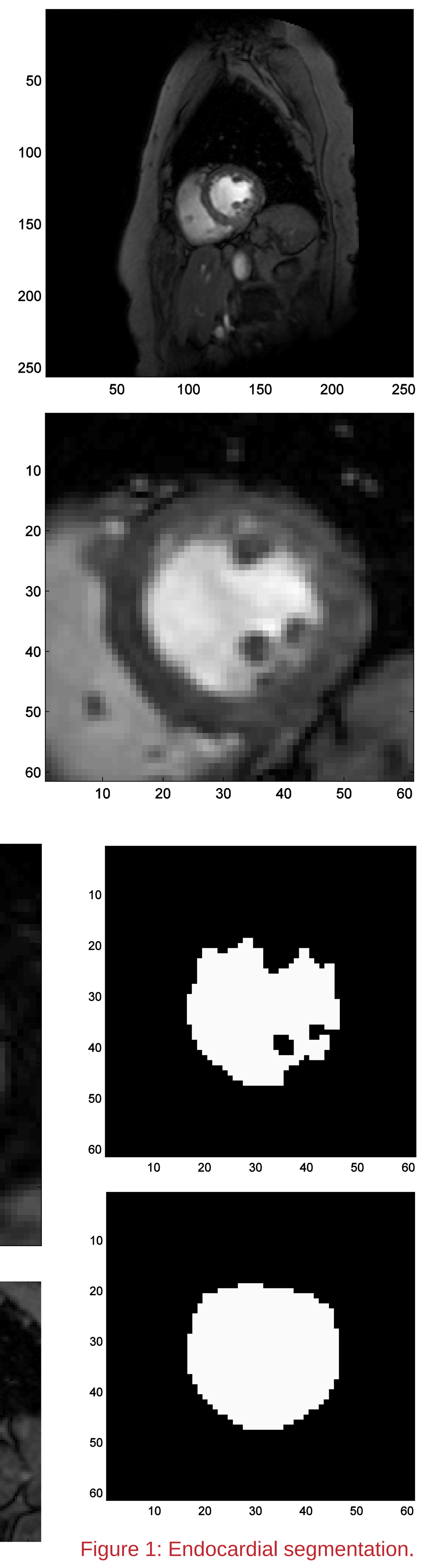


Figure 1: Endocardial segmentation.

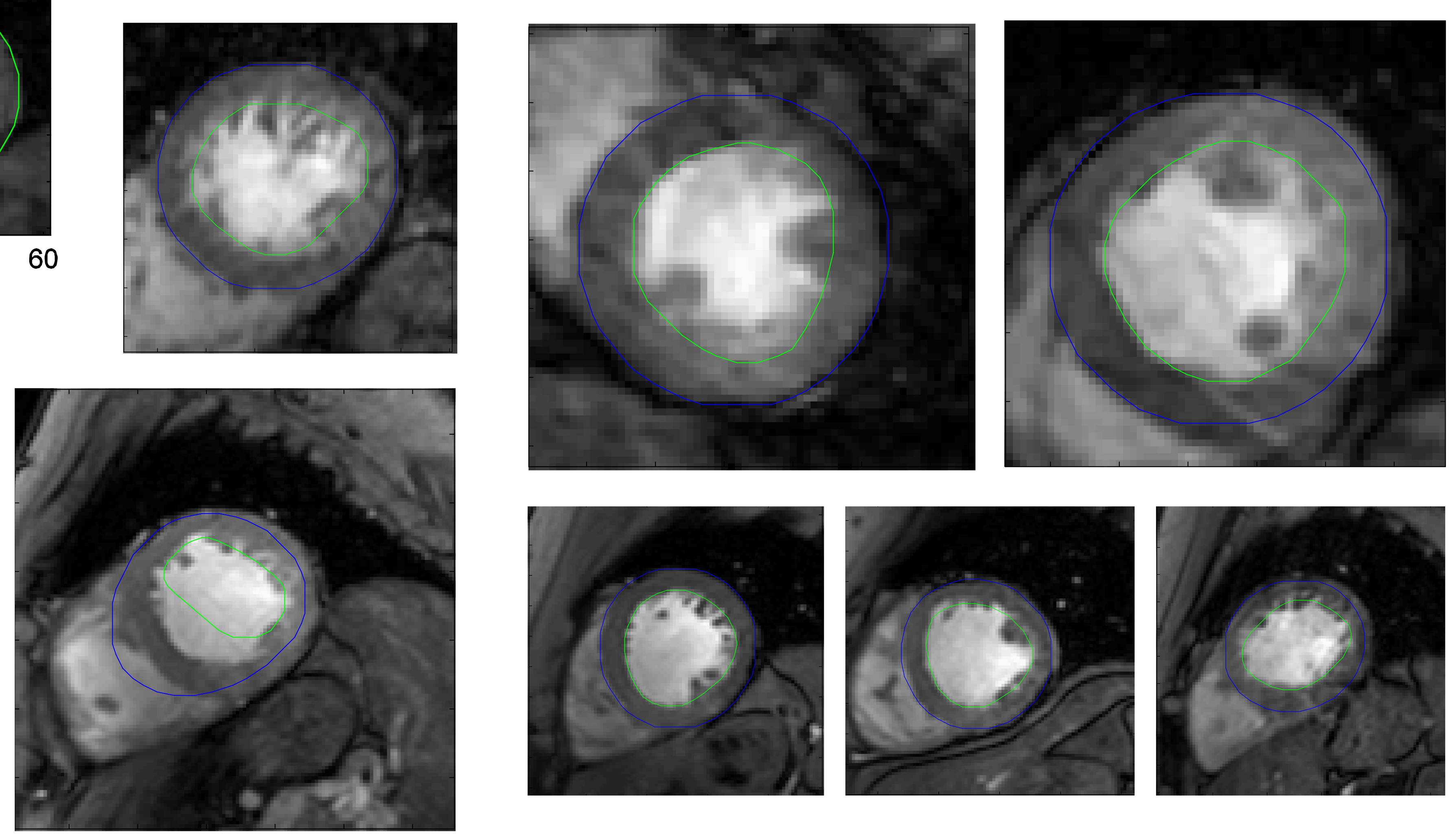


Figure 3: Segmentation of the first frame in all images. Here only 7 is shown. Some better than others but generally good. The remaining images are more or less similar.

Epicardial Contour

The epicardial contour is found using dynamic programming and binary segmentation.

1) First, the polar representation of the image is extracted.
2) Then the polar representation of the endocardial contour is extracted.
3) The polar representation of the endocardial contour is overlapped with the image. The pixels in each row is analysed by searching for pixels value that are significantly different from the previous pixel value.
4) The edge is found using dynamic programming.
5) A fast Fourier transformation is applied for smoothing.

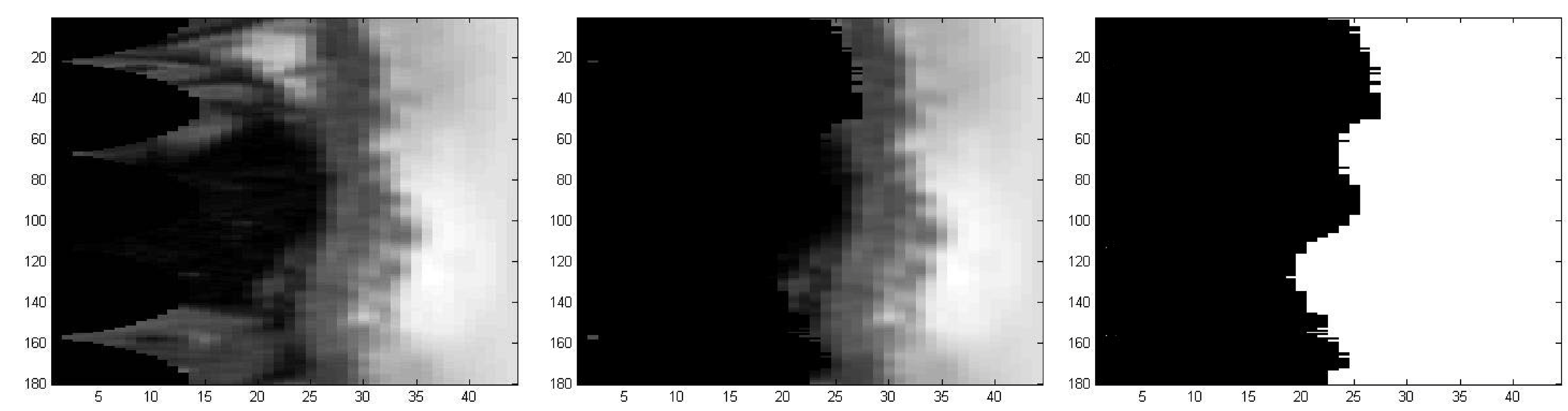


Figure 4: Epicardial segmentation with polar representation of an image and thresholding.

Conclusion

The segmentation works for both images and frames.
However, segmentation of the epicardial contour depends on the endocardial contour. In case of failure on the endocardial contour a false epicardial contour will be detected. This happens for segmentation on frames in frame number nine in one image. Here the thresholding results in a region also covering the right ventricle. It is also the thresholding which is the sensitive part of this algorithm. The endocardial segmentation works satisfactory in most cases and the epicardial contour is found satisfactory in a little over half of the cases.

Reference:
Segmentation of Left Ventricle in Cardiac Cine MRI: An Automatic Image-Driven Method
YingLi Lu, Perry Radau, Kim Connelly, Alexander Dick, and Graham A. Wright.
FIMH 2009, LNCS 5528, pp. 339–347, 2009.