A Multi-Object Machine Learning Algorithm using Fully Conventional Network for Cardiac LV and RV Segmentation

Yan Wang, Karen Ordovas, Jing Liu, David Saloner

Department of Radiology and Biomedical Imaging, University of California, San Francisco

Highlights:

1) We developed a novel deep learning-based approach to the cardiac segmentation.
2) Multi-object includes LV endo/epicardium and RV can be segmented simultaneously.
3) The results are comparable with manual segmentation.

Background: Automatic segmentation provides essential and efficient tools for accurate cardiac functional measurements, especially because manual segmentation is impractical for analysing massive and complex 3D/4D data sets. We propose a multi-object machine learning method for simultaneously segmenting left ventricle (LV) and right ventricle (RV), aiming to further improve the segmentation efficiency and accuracy.

Methods: 1) Proposed multi-object segmentation: The fully conventional network (FCN) was created based on a U-net [1] structure with following settings: kernel size = 10×10, three decomposition levels, number of convolutional layers for the first/second level = 6, no convolutional layers for the third level, number of extracted features = 32, pooling size = 2×2, ReLU activation function and “add”-merging layers. For the training of the networks, the loss function was defined as pixel wise cross entropy. The data argumentation method includes shift (< 20%), rotation and zoom (< 20%), and raw MRI images were logarithm transformed before entering into the neural networks. All the neural networks were implemented in Tensorflow software (https://www.tensorflow.org/). 2) Data & Analysis: Total 45 subjects were used (with manual segmentation as ground truth), from MICCAI 2009 LV segmentation challenge [website]. We choose 8 subjects including 2 ischemic heart failures, 2 non-ischemic heart failures, 2 LV hypertrophies and 2 normal cases as testing cases, and the rest 37 subjects as training cases. With a relatively small number of training sets, 5-fold cross validation [2], as commonly used, has been applied for assessing the accuracy of the LV and RV segmentation obtained with our proposed multi-object segmentation method.

Results:

We have successfully segmented all MRI images. Figure 1 shows the LV and RV segmentation results in short axis view along multiple slices, using our proposed Multi-Object Machine Learning method. The average Dice and CV values reached 85.79±3.50%, 87.18±2.05% and 83.08±29.08% for LV endocardium, epicardium and RV, which demonstrated that comparable and stable segmentation was achieved with the proposed method compared to manual segmentation.

Conclusion: The proposed Multi-Object Machine Learning segmentation method provides a reproducible and efficient way to define the geometrical morphology of both LV and RV.

References:

[1] Ronneberger, Olaf, Philipp Fischer, and Thomas Brox. "U-net: Convolutional networks for biomedical image segmentation." In *International Conference on Medical image computing and computer-assisted intervention*, pp. 234-241. Springer, Cham, 2015.

[2] Bengio, Yoshua, and Yves Grandvalet. "No unbiased estimator of the variance of k-fold cross-validation." *Journal of machine learning research* 5, no. Sep (2004): 1089-1105.

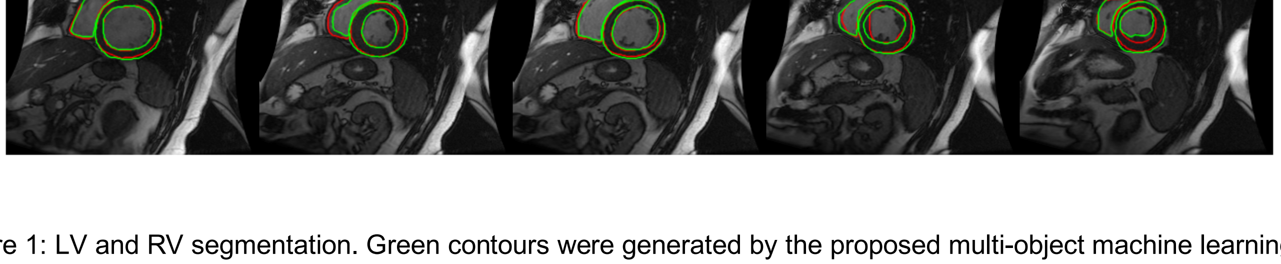

Figure 1: LV and RV segmentation. Green contours were generated by the proposed multi-object machine learning segmentation method, and red contours were obtained with manual segmentation.