Automatic Segmentation and Cardiopathy Classification in Cardiac MRI Images Based on Deep Neural Networks

ICASSP 2018

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Motivation

- Cardiac MRI offers key information for **cardiovascular diagnosis**. Clinical experts manually segment LV, RV and myocardium for cardiopathy diagnosis, but manual segmentation is time-consuming and labor-intensive.
- Due to the special characteristics of cardiac MRI, **Cardiac MRI segmentation** is a challenging task.

Dataset:

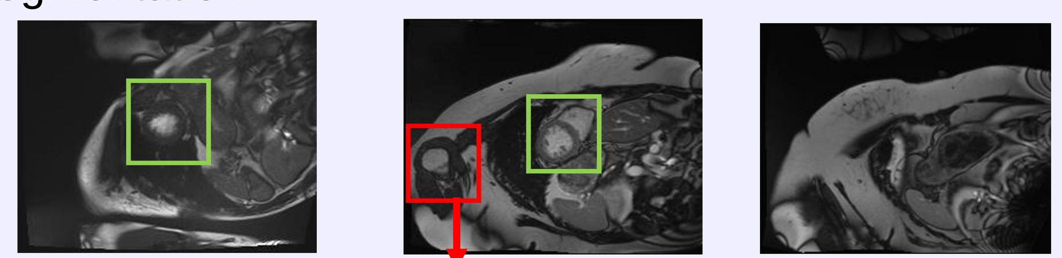
Automated Cardiac Diagnosis Challenge (ACDC) database in MICCAI challenge 2017:

- It consists of cardiac MRI images from 150 different patients, (100 for training and 50 for testing).
- It is divided into five evenly distributed groups: normal subjects (NOR), previous myocardial infarction (MINF), dilated cardiomyopathy (DCM), hypertrophic cardiomyopathy (HCM), abnormal right ventricle (ARV).

Framework

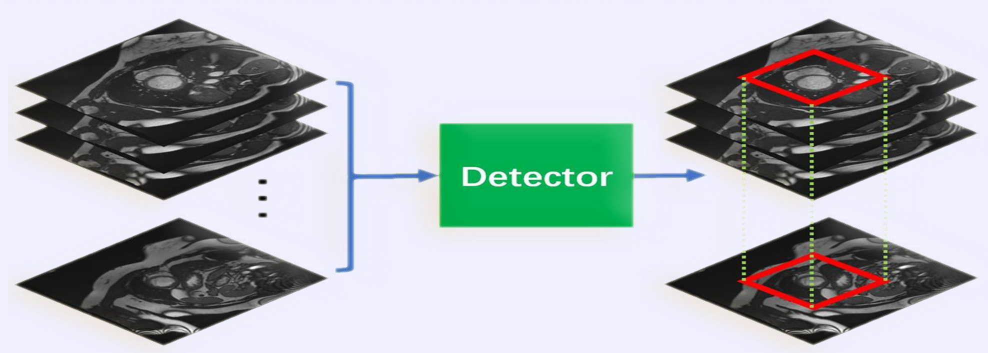
Detection and Localization

Short axis cardiac MRI database:
Wide range of observation that covers the heart and other surrounding organs.
Similar signals from other organs would interfere segmentation.



Similar signal **Without object**

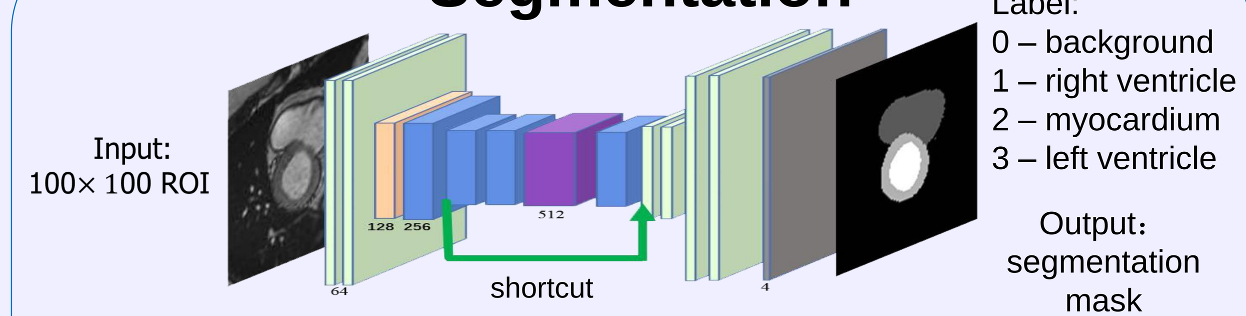
To automatically detect an object and identify its location, we construct a small network based on YOLO.



Accurate prediction:

$$\begin{cases} (x_i, y_i) \leftarrow (x_i, \quad y_i); if \, |x_i - \overline{x}| \le 10, |y_i - \overline{y}| \le 10 \\ (x_i, y_i) \leftarrow (\overline{x}, \quad \overline{y}); otherwise \end{cases}$$

Segmentation



Denote an input image as I, the collection of all pixels of I as X : $[x_1, x_2, \ldots, x_i, \ldots, x_M]$, the collection of labels as C: $[c_1, c_2, \ldots, c_j, \ldots, c_N]$, and one hot label of the pixel x_i as y_i.

For x_i, the corresponding location at the channel j is obtained as follows:

Probability of c_j : $$p(x_i = c_j) = \frac{1}{Z} \times \exp[v(c_j)]$$

The prediction of pixel x_i is performed as follows:

$$\hat{y}_i = \operatorname{argmax}[p(x_i = c_j)]$$

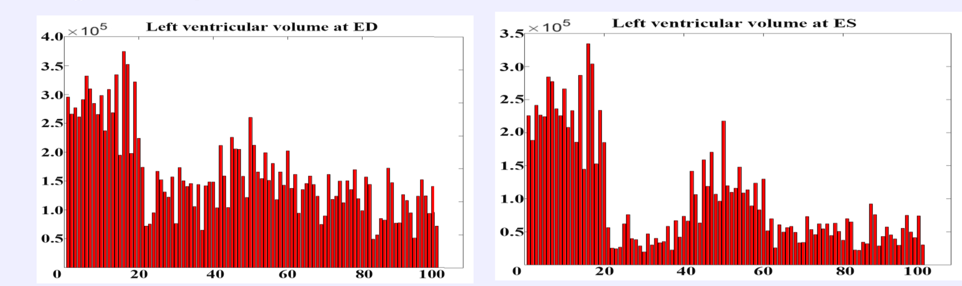
Loss function:

$$Loss = -\frac{1}{MN} \sum_i \sum_j y_{ij} \ln[p(x_i = c_j)]$$

Cardiopathy Classification

The data is evenly divided into five groups: normal subjects (NOR), previous myocardial infarction (MINF), dilated cardiopathy (DCM), hypertrophic cardiomyopathy (HCM), abnormal right ventricle (ARV).

We extract ten features: Volume of RV and LV at ED and ES, EF of LV and RV, the volume ratio between RV and LV at ED and ES, myocardial volume at ED and ES, the height and weight of patients.



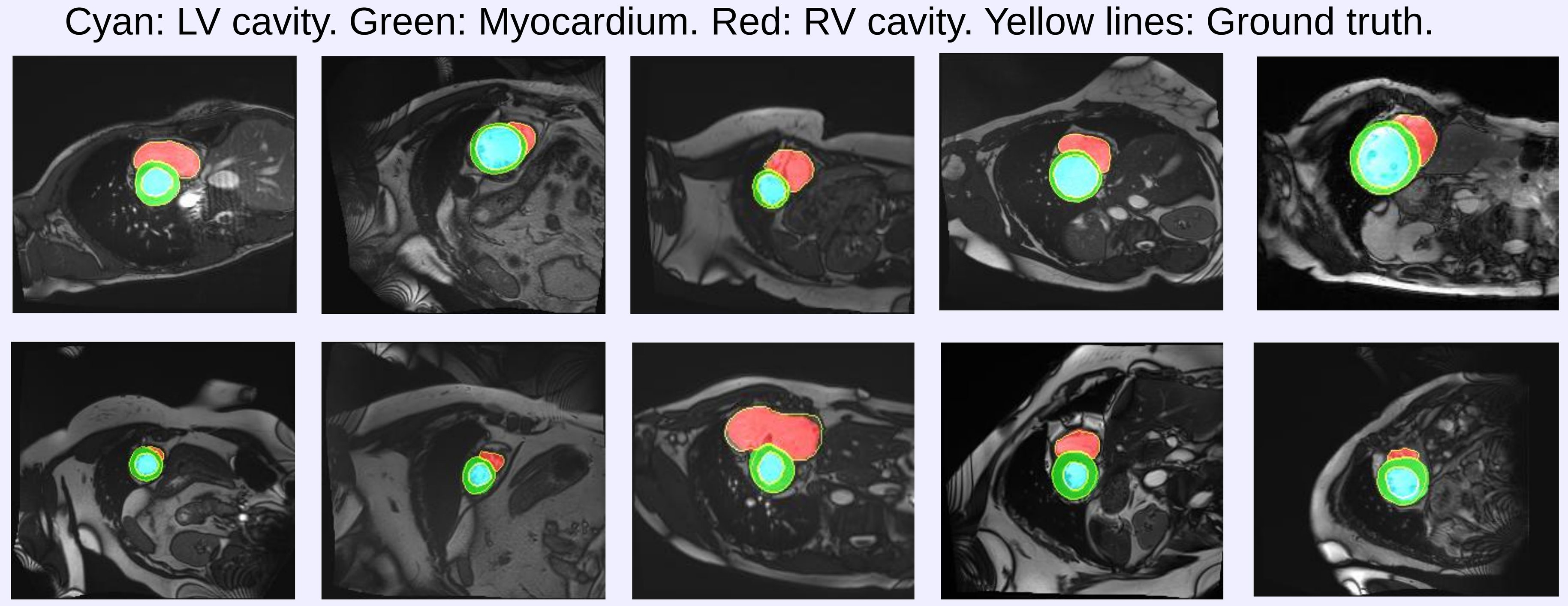
(a) (b)

Volume of LV: (a) ED, (b) ES. From left to right in (a) and (b): DCM (1-20), HCM (21-40), MINF (41-60), NOR (61-80), and ARV (81-100).

Accuracy: Fully connected network: 0.90.
Random forest: 0.88
(Testing data: 50 groups of images)

Experimental Results

Segmentation results from different patients.
Cyan: LV cavity. Green: Myocardium. Red: RV cavity. Yellow lines: Ground truth.



- It can be observed that the proposed method accurately segments LV, RV and myocardium close to the ground truth.
- Successfully distinguishes intraventricular regions and myocardium even in complex intra ventricle.
- LV is also successfully segmented in basal slice image.

Performance evaluation of LV cavity, RV cavity and myocardium in terms of Dice coefficient (Dice), Hausdorff distance (HD) and sensitivity

Measures	Dice	HD	Sensitivity
LV cavity	0.9193	10.452	0.9085
RV cavity	0.8692	10.517	0.8614
Myocardium	0.8787	9.857	0.9043

Conclusions

- We perform YOLO-based object detection to generate ROI because some slices of cardiac MRI don't contain objects.
- We simultaneously segment LV cavity, RV cavity and myocardium using a fully convolutional network.
- We perform cardiopathy classification for heart disease diagnosis with the cardiac segmentation.
- Experimental results demonstrate that the proposed method produces good segmentation results close to the ground truth and achieves 90% accuracy in cardiopathy classification.

References

[1] Liset Vazquez Romaguera, Francisco Perdig on Romero, Cicero Ferreira Fernandes Costa Filho, and Marly Guimaraes Fernandes Costa, "Left ventricle segmentation in cardiac mri images using fully convolutional neural networks," in *Proceedings of SPIE Medical Imaging*. International Society for Optics and Photonics, 2017, pp. 101342Z–101342Z.

[2] Jelmer M Wolterink, Tim Leiner, Max A Viergever, and Ivana Isgum, "Automatic segmentation and disease classification using cardiac cine mr images," *arXiv preprint arXiv:1708.01141*, 2017.

[3] M. R. Avendi, Arash Kheradvar, and Hamid Jafarkhani, "A combined deep-learning and deformable-model approach to fully automatic segmentation of the left ventricle in cardiac mri," *Medical Image Analysis*, vol. 30, pp. 108–119, 2016.

[4] Marie Pierre Jolly, Nicolae Duta, and Gareth Funkalea, "Segmentation of the left ventricle in cardiac mr images," in *Proceedings of the IEEE International Conference on Computer Vision*, 2001, pp. 501–508.

[5] M. R. Kaus, Berg J Von, J Weese, W Niessen, and V Pekar, "Automated segmentation of the left ventricle in cardiac mri," *Medical Image Analysis*, vol. 8, no. 3, pp. 245–254, 2004.

[6] Caroline Petitjean, Maria A Zuluaga, Wenjia Bai, JeanNicolas Dacher, Damien Grosgeorge, Jerome Caudron, Su Ruan, Ismail Ben Ayed, M Jorge Cardoso, HsiangChou Chen, et al., "Right ventricle segmentation from cardiac mri: a collation study," *Medical Image Analysis*, vol. 19, no. 1, pp. 187–202, 2015