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Efficient Convolutional Neural Network Model to Segment Left Ventricle from MRI Images

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Abstract : Cardiovascular diseases can be avoided from being worse through early diagnosis by automatic segmentation of the left ventricle (LV). The LV is the most important chamber among the four heart chambers to diagnose cardiovascular disease due to its capability of pumping oxygenated blood to all parts of the body. Thus, segmentation of the LV from cardiac magnetic resonance imaging (MRI) is an essential step to obtain full morphological structures of LV and quantify global and regional cardiac function. However, the segmentation of the LV remains challenging due to the complex structure of MRI and various changes in the LV shape caused by different cardiovascular diseases. To address this issue, a convolutional neural network (CNN) model was proposed to segment the LV from short-axis MRI images. The model was trained end-to-end from input images and their corresponding ground truths to classify each pixel in the images to segment the LV contours and myocardium. Training and testing phases were carried out by fine-tuning the network's hyper-parameters with a learning rate of (0.01) and stochastic gradient descent (SGD) algorithm to achieve optimal performances. The proposed model was evaluated using metrics such as global and mean accuracy, mean and weight of intersection over union (IoU), and mean boundary F1 (BF) score. Results show the robustness of the proposed model with a rigid capability to segment the LV contours which is applicable for doctors to diagnose cardiac diseases at early stages with less effort and consumed time.

Keywords: Cardiovascular Diseases, Left Ventricle Segmentation, Cnn, Mri.

1. Introduction

Cardiovascular diseases (CVDs) are considered one of the most leading cause of death worldwide, and the standard technique for assessing CVDs is cardias MRI [1]. Parameters such as left ventricle mass (LVM), left ventricle volume (LVV), wall thickness, and ejection fraction

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(EF) are obtained from short-axis MRI to analyze cardiac motion of the LV and detect cardiac diseases [2][3]. These parameters are extracted by segmentation methods to obtain the LV contours, including epi around the myocardium and the endo around the blood cavity, as shown in **figure 1**. There are several traditional proposed algorithms used for LV segmentation such as threshold-based algorithms and k-mean clustering algorithms. However, these algorithms have drawbacks, such as manual intervention which is a tedious task and time-consuming to segment large number of sequence images [4]. Thus, deep learning algorithms are used widely in cardiac MRI segmentation due to the rapid development of software and hardware performance [5][6]. In this work, a CNN-based architecture model was proposed for LV and myocardium segmentation from short-axis MRI images.

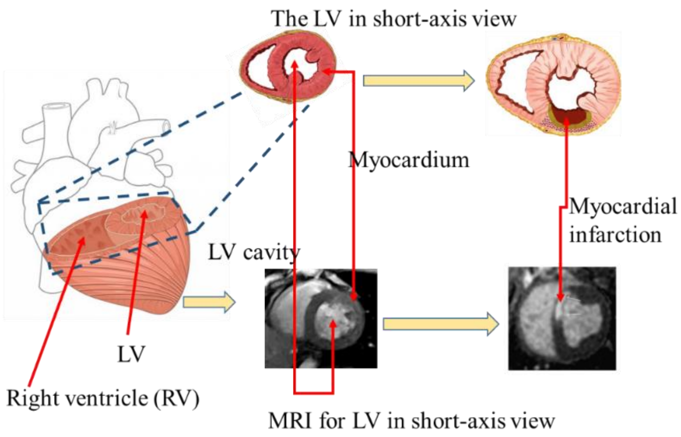

Figure 1: Anatomy of the LV

2. Materials and Methods

The main purpose of this study is to build a CNN model for the LV segmentation from short-axis MR images. The dataset used in this study is sequence of MR images from MICCAI 2020 [7], images for 20 patients were used in the training phase and 4 patients' images were used in the testing phase. **Figure 2** depitcs the main procedures of the model design, the input data for this network are grayscale images with pixels' size of 256 × 192 for both images and their corresponding labels. **Figure 3** shows the proposed architecture of the network layers like convolutional layer, rectified linear unit (ReLU) activation function, max-pooling layers, soft-max layer, and pixel classification layer. The experiments were run in MATLAB software to train the model and fine-tune the hyper-parameters like optimization algorithm, learning rate, mini-batch size, and number of epochs for the iterations.

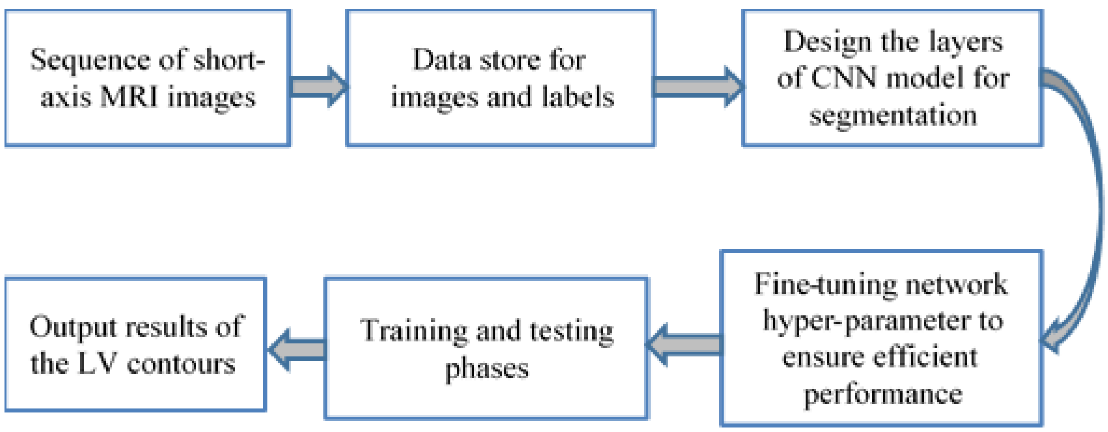

Figure 2: Main procedures to design CNN model for LV segmentation

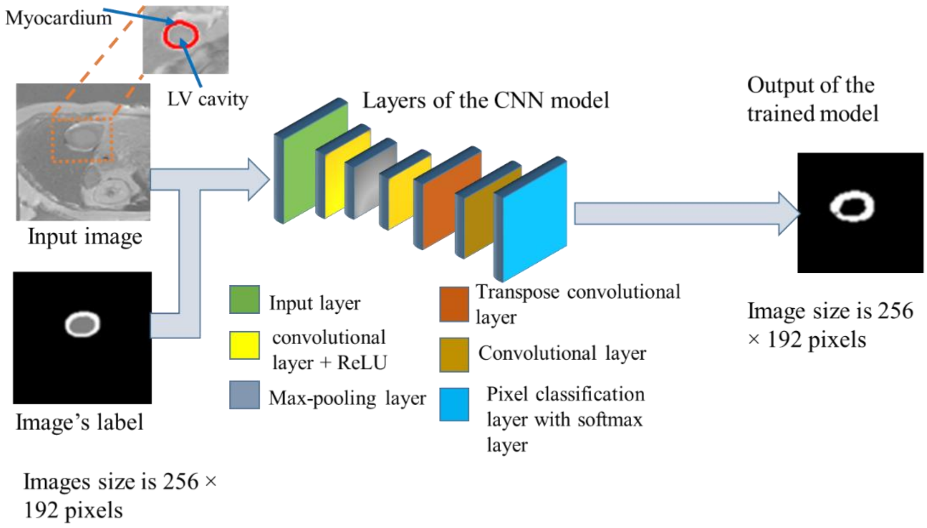

Figure 3: Architecture layers of the proposed model

3. Results and Discussion

After multiple training of the CNN model, testing phase was applied to evaluate the model performance in the segmentation of the LV and myocardium. **Figure 4** illustrates the input images and labels that used in training phase and the results of the CNN model in the testing phase. Compared with traditional methods, this trained CNN network can segment many images automatically in testing phase and lessen the load of intensive labor by analysts. The segmentation quality evaluation metrics of the network like global accuracy, mean accuracy, mean of intersection over union (IoU), weight IoU, and mean boundary F1 (BF) score are 88%, 88%, 79%, 79%, and 81%, respectively.

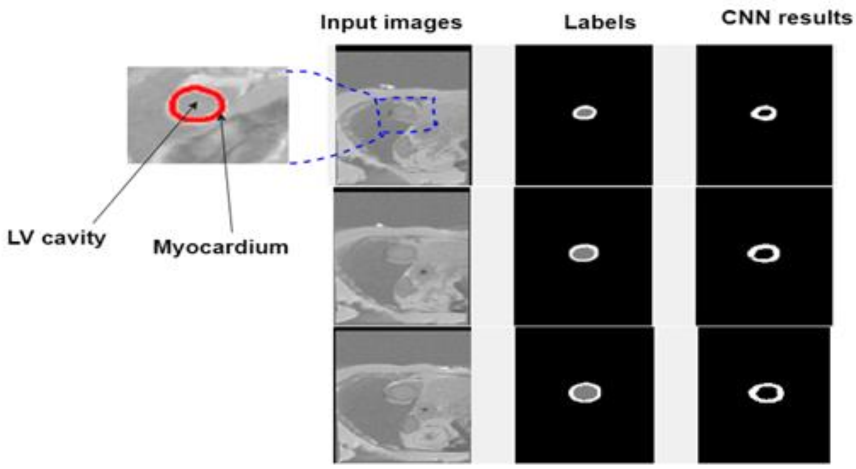

Figure 4: The input images for training phase with the CNN outcomes

4. Conclusion

In this work, a convolutional neural network (CNN) architecture for LV and myocardium segmentation from cardiac magnetic resonance images was developed. Various training sessions were conducted with optimal hyper-parameters, resulting in reliable results. Unlike the traditional network frameworks, this model was trained on an end-to-end (automatic) protocol with large number of images. Experimental results revealed that using stochastic gradient descent (SGD) optimization algorithm and learning rate of (0.01) drives the segmentation network to learn rapidly and efficiently. Based on efficient learning, the segmentation network then is capable to extract the features of the myocardium and the LV contours (endocardial and epicardial contours) to detect cardiovascular diseases. For future studies, training CNN with larger datasets and generating hybrid models with CNN to segment the LV accurately is suggested.

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References

[1] Z. Dong, X. Du, and Y. Liu, "Automatic segmentation of left ventricle using parallel end–end deep convolutional neural networks framework," *Knowledge-Based Syst.*, vol. 204, p. 106210, Sep. 2020, doi: 10.1016/j.knosys.2020.106210.

[2] Z. Zhang, X. Yang, C. Tan, W. Guo, and G. Chen, "Surface structure feature matching algorithm for cardiac motion estimation," *BMC Med. Inform. Decis. Mak.*, vol. 17, no. S3, p. 172, Dec. 2017, doi: 10.1186/s12911-017-0560-z.

[3] F. M. Parages, T. S. Denney, H. Gupta, S. G. Lloyd, L. J. Dell'Italia, and J. G. Brankov, "Estimation of Left Ventricular Motion from Cardiac Gated Tagged MRI Using an Image-Matching Deformable Mesh Model," *IEEE Trans. Radiat. Plasma Med. Sci.*, vol. 1, no. 2, pp. 147–157, Mar. 2017, doi: 10.1109/TNS.2017.2670619.

[4] B. Wu, Y. Fang, and X. Lai, "Left ventricle automatic segmentation in cardiac MRI using a combined CNN and U-net approach," *Comput. Med. Imaging Graph.*, vol. 82, p. 101719, Jun. 2020, doi: 10.1016/j.compmedimag.2020.101719.

[5] J. Wu, Z. Gan, W. Guo, X. Yang, and A. Lin, "A fully convolutional network feature descriptor: Application to left ventricle motion estimation based on graph matching in short-axis MRI," *Neurocomputing*, vol. 392, pp. 196–208, Jun. 2020, doi: 10.1016/j.neucom.2018.10.101.

[6] H. Hu, N. Pan, J. Wang, T. Yin, and R. Ye, "Automatic segmentation of left ventricle from cardiac MRI via deep learning and region constrained dynamic programming," *Neurocomputing*, vol. 347, pp. 139–148, Jun. 2019, doi: 10.1016/j.neucom.2019.02.008.

[7] A. Lalande *et al.*, "Emidec: A Database Usable for the Automatic Evaluation of Myocardial Infarction from Delayed-Enhancement Cardiac MRI," *Data*, vol. 5, no. 4, p. 89, Sep. 2020, doi: 10.3390/data5040089.