Robust White Matter Hyperintensities Segmentation by Deep Stack Networks and Ensemble Learning

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1 Data Preparation

Three datasets named *Utrecht Singapore and AmsterdamGE3T* are used as the training set. Each of them contain 20 subjects. Data preparation includes the following three steps, following the same procedure in [1].

Masking and slices selection To reduce the noise from background, we remove the background information by masking the brain. A brain mask is obtained by simple thresholding and filling the holes inside the initial brain. We remove the first and last several slices of each brain since there is little information in such slices. For example, for *Utrecht* the first 5 slices and 5 last ones are removed during the training process.

Data normalization A patient-wise normalization of the image intensities was performed both during training and testing. For the scan of each patient, the mean value and standard deviation were calculated based on intensities of all voxels. Then each image volume was normalized to zero mean and unit standard deviation.

Data augmentation Rotation, shearing, scaling along horizontal direction (x-scaling), and scaling along vertical direction (y-scaling) were employed for data augmentation on the 7 cases with full annotations. After data augmentation, a four times larger training dataset was obtained.

2 Methodology

2.1 2-D Stacked U-Net

We employed the U-Net architecture from [2] as the basic segmentation network, to capture the local information of small lesions.

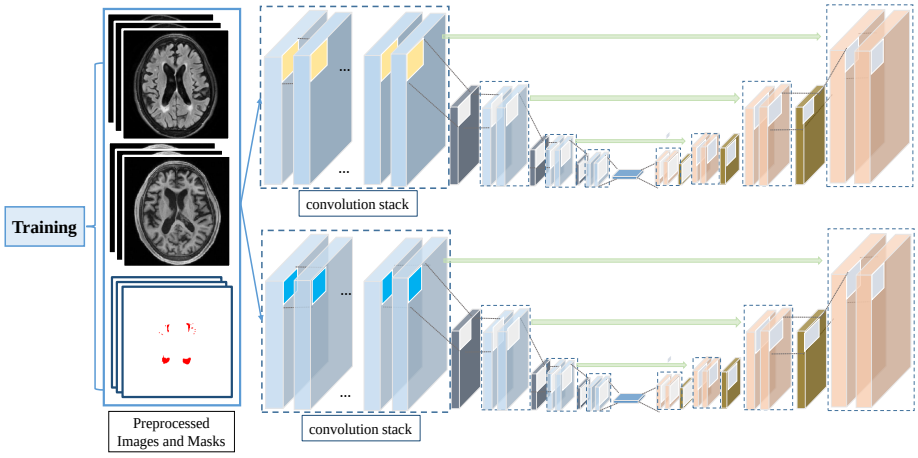

Fig. 1: Overview of the multi-scale convolutional-stack aggregation model. We replaced the traditional single convolutional-layer with convolutional-stack to extract and preserve local information of small lesions. The depth of the convolution-stack was flexible and set to 5 in our experiments. Two convolutional kernels i.e., 3×3 and 5×5 were used in two *Stack-Nets* to learning multi-scale context information. The detailed parameters setting/architecture was presented in [1].

2.2 Ensemble Learning

To improve the segmentation on small lesions, an ensemble method was employed for the final segmentation. Four stack U-Net models with the same architecture were trained with shuffled batches. Then when given a new testing subject, each subject will be segmented based on the averaged probability maps generated by the four U-Nets.

References

1. Li, H., Jiang, G., Wang, R., Zhang, J., Wang, Z., Zheng, W.S., Menze, B.: Fully convolutional network ensembles for white matter hyperintensities segmentation in mr images. arXiv preprint arXiv:1802.05203 (2018)
2. Li, H., Zhang, J., Muehlau, M., Kirschke, J., Menze, B.: Multi-scale convolutional-stack aggregation for robust white matter hyperintensities segmentation. arXiv preprint arXiv:1807.05153 (2018)