Title: Domain-Robust White Matter Hyperintensity Segmentation on T2-FLAIR MRI via Foundation Model Integration

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Purpose

To develop a robust framework for white matter hyperintensity (WMH) segmentation on T2 fluid-attenuated inversion recovery (FLAIR) MRI across heterogeneous scanner domains by integrating a foundation model with a U-Net-based architecture.

Methods and Materials

A total of 170 subjects from the 2017 MICCAI WMH Segmentation Challenge dataset were used in this study. The original challenge data split was adopted, with 60 subjects for training and 110 for testing. The test set includes data acquired from five different scanners, two of which were not present in the training set, enabling evaluation of generalization to unseen acquisition domains. The proposed framework combines nnUNet and the Segment Anything Model (SAM), a widely used segmentation foundation model. FLAIR scans are first processed by nnUNet to generate coarse WMH predictions, which are then used as prompts for SAM together with the original FLAIR images. By incorporating coarse structural priors, SAM is guided to focus on relevant WMH regions and refine the initial predictions, while its parameters are further fine-tuned during training. This approach leverages the complementary strengths of nnUNet and SAM, improving boundary delineation as well as overall segmentation accuracy and robustness.

Results

We assessed segmentation performance using the Dice similarity coefficient (DSC) and absolute volume difference (AVD). Across all test data and acquisition domains, the proposed method consistently outperformed the baseline (nnUNet-only), increasing the mean DSC from 74.94 to 81.12 and reducing the mean AVD from 23.37 to 16.95. Notably, performance gains were observed not only in seen domains but also in unseen domains acquired from scanners not included in the training set. In particular, the 3T PET/MR dataset, which represents an unseen domain, showed an approximate 10% improvement in DSC. These results demonstrate the robustness of the proposed framework, particularly in handling domain shifts across different acquisition settings.

Conclusion

The integration of a foundation model with a U-Net-based framework significantly improves WMH segmentation performance. By leveraging coarse structural priors and refinement, the proposed approach enhances boundary delineation and reduces volumetric error. This framework offers a robust and efficient solution for WMH segmentation under heterogeneous and unseen conditions.

		Baseline		Proposed	
		DSC ↑ (%)	AVD ↓ (%)	DSC ↑ (%)	AVD ↓ (%)
3T Philips	**Seen**	73.60	24.53	79.37	18.03
3T Siemens	**Seen**	76.66	21.91	83.15	15.58
3T GE	**Seen**	77.21	21.50	80.81	17.31
1.5T GE	**Unseen**	77.72	20.85	81.62	16.07
3T PET/MR	**Unseen**	70.48	26.78	80.75	17.40
Average		74.94	23.37	81.12	16.95

Table 1. Comparison of WMH segmentation performance across acquisition domains between the baseline and proposed methods.