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Automated 3D Brain Tumor Segmentation Using a Cascaded 2.5D–3D Deep Learning Framework on BraTS 2020

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Abstract: *Brain tumor segmentation from multi-modal magnetic resonance imaging (MRI) is a critical task for clinical diagnosis, treatment planning, and disease monitoring. Existing full 3D deep learning models often achieve high segmentation accuracy but impose substantial GPU memory requirements, limiting applicability on standard clinical hardware. To address this challenge, this paper presents a two-stage cascaded deep learning framework for accurate and memory-efficient 3D brain tumor segmentation.*

The proposed method combines a coarse 2.5D U-Net for global tumor localization with an attention-based 3D U-Net for fine-grained volumetric refinement. The first stage processes multi-view 2.5D contextual slices (5 adjacent slices × 4 MRI modalities = 20 input channels) to efficiently capture global tumor structure. The second stage refines boundaries using overlapping 96×96×96 voxel 3D patches, guided by probability maps from the first stage. A novel learnable residual mixing mechanism (LearnableResidualMix) adaptively balances coarse and refined predictions via a trainable scalar α.

The framework is trained and evaluated on the BraTS 2020 dataset using four MRI modalities (T1, T1ce, T2, FLAIR) across 369 patients. The final model (32 base filters, depth 5) achieves a mean Dice Similarity Coefficient of 0.865 on the validation set, with Dice scores of 0.932, 0.937, and 0.888 for Whole Tumor (WT), Tumor Core (TC), and Enhancing Tumor (ET) respectively — outperforming nnU-Net (single model) and standard Attention U-Net baselines.. .

Keywords: Brain tumor segmentation, deep learning, cascaded neural networks, 2.5D U-Net, 3D U-Net, attention gates, BraTS 2020, medical image analysis, MRI, learnable residual mixing