Reliable Brain Tumor Segmentation Based on Spiking Neural Networks with Efficient Training

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Accurate and reliable brain tumor segmentation is crucial for clinical diagnosis, treatment planning, and prognosis [1]. Deep neural networks (DNNs) have shown strong performance in this task, but their high computational and energy demands limit their deployment in resource-constrained clinical settings [2]. Moreover, clinical segmentation models must not only achieve high accuracy, but also quantify predictive uncertainty to enable the safe and trustworthy deployment of AI systems in clinical practice [3]. To address these challenges, we propose a reliable and energy-efficient framework based on spiking neural networks (SNNs) for 3D brain tumor segmentation (Fig. 1). A multi-view ensemble of sagittal, coronal, and axial SNN models provides voxel-wise uncertainty estimation and enhances segmentation robustness. To improve SNN training efficiency for semantic image segmentation, we employ Forward Propagation Through Time (FPTT) [4], which maintains effective temporal learning while reducing the computational and memory burdens associated with Backpropagation Through Time (BPTT) [5]. Experiments on the Multimodal Brain Tumor Segmentation Challenges (BraTS 2017 [6] and BraTS 2023 [1]) demonstrate competitive segmentation performance, well-calibrated uncertainty, and an 87% reduction in FLOPs, underscoring the potential of SNNs for reliable, low-power medical Internet of Things (IoT) and point-of-care systems.

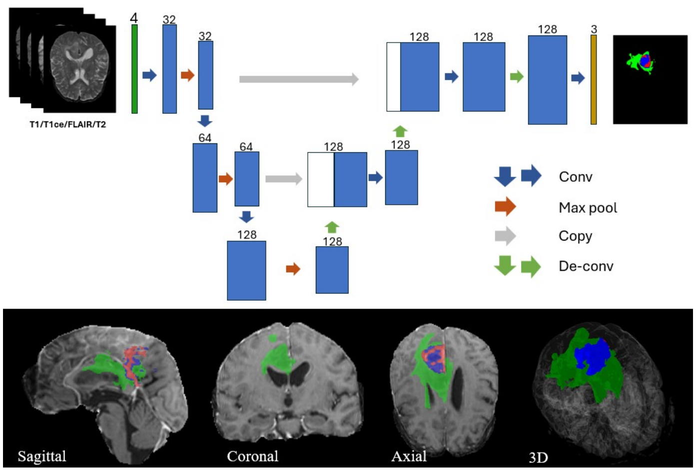

Figure 1: (Top) Architecture of proposed Spiking U-Seg-Net; (Bottom) Tumor segmentation results across three views—sagittal, coronal, and axial—with enhancing tumor in red, necrotic/non-enhancing tumor in blue, and peritumoral edema in green

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