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Scalable Framework for Region-Specific Brain Network Models: Integrating Multimodal Data for Deep Brain Activity Simulation

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We present a scalable computational framework for simulating brain dynamics within structurally complex regions such as the hippocampus, integrating high-resolution multimodal data—including BigBrain-derived surface meshes and diffusion MRI tractography—into The Virtual Brain simulator. This Region Brain Network Model (RBNM) framework enables vertex-level placement of neural mass models (NMMs) informed by region-specific connectivity, anatomical subfields, and morphological descriptors. Our layered architecture supports biologically grounded simulations of EEG, MEG, and BOLD signals, validated against empirical recordings across frequency bands. Compared to standard whole-brain simulators, RBNM enhances anatomical precision, simulation fidelity, and regional interpretability. We benchmark the framework using hippocampal data and achieve high spectral correlation with intracranial EEG (iEEG). The code and data pipelines are openly available to support reproducibility and adoption in the neuroscience community.

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