EEG Simulation through Integration of Structural Connectivity Data and High-Density Surface Meshes in Brain Region-Specific Network Models

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Abstract

This project presents a novel Region-Specific Brain Network Model (RSBNM) framework that integrates high-resolution multimodal data, exemplified through a case study focusing on the hippocampus. The core elements include leveraging the high-density surface mesh of the hippocampus from BigBrain [1, 2] to simulate EEGs within The Virtual Brain (TVB) environment, employing MRI-derived structural connectivity data [3] exported from EBRAINS, and generating regional mapping information.

A significant challenge in model development is balancing practical feasibility with biological authenticity. While high-resolution surfaces are ideal for accurately depicting intracortical connectivity, the computational demands are substantial. To address this challenge, we developed the BigBrain Network Model (BBNM) framework, designed to integrate the high-resolution brain atlas of BigBrain with TVB's simulation capabilities.

Structural connectivity maps from 200 HCP subjects were averaged. The HCP structural connectome dataset is derived from 20 state-of-the-art brain parcellations to reconstruct region-based empirical structural connectivity from diffusion-weighted MRI data. The following brain parcellation schemes, along with their respective number of parcels and associated publications, were utilized:

- MIST: 31, 56, 103, 167 parcels [Urchs et al., 2019]
- Craddock: 38, 56, 108, 160 parcels [Craddock et al., 2012]
- Shen 2013: 79, 156 parcels [Shen et al., 2013]
- Harvard-Oxford: 48, 96 parcels [Desikan et al., 2006; Frazier et al., 2005; Goldstein et al., 2007; Makris et al., 2006]
- Desikan-Killiany: 70 parcels [Desikan et al., 2006]
- von Economo-Koskinas: 86 parcels [Scholtens et al., 2018; von Economo & Koskinas, 1925]
- AAL (version 2): 92 parcels [Rolls et al., 2015; Tzourio-Mazoyer et al., 2002]
- Destrieux: 150 parcels [Destrieux et al., 2010]
- Brainnetome: 210 parcels [Fan et al., 2016]
- Schaefer: 100, 200 parcels [Schaefer et al., 2018]
- Julich-Brain (version 2.9)**: 294 parcels [Amunts et al., 2020; Amunts et al., 2021]

This comprehensive approach enables detailed simulations of EEG activity, providing valuable insights into the structural-functional relationships within the human brain and demonstrating the practical applicability of the region-specific BBNM framework.

[1] Katrin Amunts *et al.* BigBrain: An Ultrahigh-Resolution 3D Human Brain Model.*Science***340**,1472-1475(2013).DOI:10.1126/science.1235381

[2] Jordan DeKraker, Roy AM Haast, et al. (2022) Automated hippocampal unfolding for morphometry and subfield segmentation with HippUnfold eLife 11:e77945

[3] Domhof, J. W. M., Jung, K., Eickhoff, S. B., & Popovych, O. V. (2022). Parcellation-based structural and resting-state functional brain connectomes of a healthy cohort (v1.1) [Data set]. EBRAINS. https://doi.org/10.25493/NVS8-XS5