Towards Multiscale Brain Simulations for Personalised Medicine: Extending Neuron–Astroglia–Vasculature in The Virtual Brain

The Virtual Brain (TVB) is an open-source platform for large-scale brain network simulations, widely used to integrate multimodal neuroscientific data and explore whole-brain activity. We implemented a biophysically grounded Neuron–Astroglia–Vasculature (NAV) model into TVB to investigate how cellular signaling processes, including neuronal glutamate release and astrocytic calcium dynamics, shape blood-oxygen-level-dependent (BOLD) responses.

Our implementation captures the cascade from neuronal glutamate release to astrocytic IP_3-calcium signaling, prostaglandin-mediated vascular modulation, and the resulting BOLD responses, all driven by excitatory firing rates from the mean-field neuronal model. The framework captures how the balance of excitatory and inhibitory drives modulates the amplitude and duration of the BOLD response, including the post-stimulus undershoot.

Ongoing work will explore different numerical integration methods to better characterize the intrinsic dynamics of the NAV system. The next stage will scale the implementation to the mesoscopic level, enabling simulations of local brain regions and bridging cell-level signaling with macroscopic fMRI signals in whole-brain models.

Extending the NAV model into TVB contributes an additional tool within the platform's ecosystem, enabling the study of brain dynamics seamlessly across spatial scales, i.e. micro, meso, and macro. This multiscale perspective can be viewed as a crucial pillar for advancing personalized treatment, where TVB's ability to run subject-specific simulations creates new opportunities to connect cellular mechanisms with individual clinical outcomes.