Contribution ID: **12** Contribution code: **P-6** Type: **Poster & advertisement flash talk**

Elucidating the spatial complexity of brain circuits with the NEST::multiscale toolchain

Tuesday 18 June 2024 14:28 (3 minutes)

Synaptic transmission plays a crucial role in neuron-to-neuron communication, while internal voltage dynamics, driven by dendritic currents and the spatial arrangement of synapses, influence the responses of neurons within networks. The extent to which these dynamics affect computations at different spatial scales is not fully understood. Current simulation tools focus either on detailed neuron models (e.g. NEURON, Arbor) or on abstract large-scale network dynamics (e.g. NEST), leading to a divide where models such as those from the Blue Brain Project (BBP) include dendritic details in NEURON, but lack these specifics in abstract models in NEST.

Addressing this gap requires a comprehensive approach, including detailed neuronal model databases, a systematic method for simplifying these models, and a simulation tool that supports both detailed and abstract models in network simulations. By integrating the BBP models into the NEural Analysis Toolkit (NEAT)[1], we enable simplification to varying degrees of coarse-grained descriptions. In addition, a compartmental modelling framework has been introduced within NEST using NESTML, which allows the simulation of both full and reduced models seamlessly, referred to as the NEST::multiscale toolchain.

This toolchain has been used to develop a network model of layer 5 of the visual cortex, using recent connectomics data[2] to investigate the spatial resolution required for accurate modelling of brain circuits. The results reveal the appropriate level of spatial complexity required in neural models to reproduce the computational functions of cortical neurons, and provide insights into the design of minimal yet functionally representative neuron models for efficient and effective simulation.

Acknowledgements

References

[1] W. Wybo et al., eLife, 10, e60936, 2021
[2] X. Jiang et al., Science, Vol. 350, No. 6264, 2015

Preferred form of presentation

Poster & advertising flash talk

Keywords

neural circuits, morphology

Topic area

Models and applications

Speaker time zone

UTC+2

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Session Classification: Poster teasers