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Modeling Calcium-Mediated Spike-Timing Dependent Plasticity in Spiking Neural Networks

Wednesday 18 June 2025 12:10 (20 minutes)

This study translates the model of Chindemi et al. on calcium-dependent neocortical plasticity into a spiking neural network framework. Building on their work, we implemented a computationally efficient model comprising a point neuron and synapse model, using NESTML. Our approach combines the Hill-Tononi (HT) neuron, which features detailed NMDA and AMPA conductance dynamics, with the Tsodyks-Markram (TM) stochastic synapse, which controls vesicle release probability. We extended these components to create a comprehensive framework that captures the relationship between calcium dynamics and spike-timing dependent plasticity while maintaining computational efficiency for large-scale network simulations. Both our model and Chindemi's rely on the assumption that calcium-dependent processes following paired pre- and post-synaptic activity influence synaptic efficacy on both sides of the synapse: by modifying the maximum AMPA conductance (GAMPA) at the post-synaptic site and the release probability (USE) at the synapse. We validated our implementation through a series of experiments: first confirming the functionality of the TM synapse model paired with HT neuron modifications to account for calcium currents, then testing isolated pre- and post-synaptic activations, generating NMDA and VDCC calcium currents respectively. Finally, we examined paired pre-post stimulation at varying time intervals. Our results successfully replicate Chindemi's findings obtained with more complex multicompartmental models, also assessing plasticity outcomes according to the distance of the synaptic input to the soma, as experimental evidence shown by P. J. Sjöström and M. Haüsser. This work bridges neuronal activity patterns and synaptic modifications underlying learning and memory.

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Preferred form of presentation

Talk (& optional poster)

Topic area

Models and applications

Keywords

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Speaker time zone

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