FROM SINGLE NEURON TO NETWORK MODELS: REALISTIC LARGE-SCALE SIMULATIONS OF A CENTRAL NETWORK

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Understanding neuronal network functions is one of the greatest challenges of Science. The intricate connectivity, the neuronal properties, and the communication mechanisms endow neural networks with more complex dynamics than what can be achieved increasing the network size. It follows that networks can generate intrinsic population dynamics while maintaining a critical role for any individual single neuron, can generate predictive behaviors despite stochastic processes can influence their activity, and can transiently or persistently change their functions through plastic mechanisms although homeostasis keeps them in balance. This complex scenario requires new investigation tools involving advanced experimental recording techniques and large-scale realistic network modeling.

By exploiting the PARALLEL-NEURON-PYTHON platform, we have modeled the cerebellar circuit exploiting the outstanding level of physiological knowledge about its neurons and synapses. We have built realistic models of the cerebellar granule cells, Golgi cells and Purkinje cells (D'Angelo et al., 2001; Nieus et al., 2006; Solinas et al., 2007a, b; Diwakar et al., 2011; Arleo et al., 2011; Masoli, solinas and D'Angelo, in preparation) and of the chemical and electrical synapses in between (Solinas et al., 2010; Solinas and D'Angelo, in preparation) generating a full model of the granular and molecular layer. The functionality of this cortical cerebellar network model was validated using input patterns of known impact on the network dynamics. Low frequency random mossy fiber (MF) inputs, simulating background resting activity, induced low frequency oscillations in the granular layer. High frequency bursts delivered to specific MF bundles activated multiple activity spots within the granular layer, with a center-surround configuration. We are now able to analyze the impact of neuronal and synaptic mechanisms, stochastic release, resonance, oscillations, timing and plasticity in this cortical network and to determine the relationship between single neuron and population responses. These results indicate that computational modeling will become fundamental to further investigate the mechanisms of central brain network functioning.

Keywords: Computational Modeling, Cerebellum, Synaptic Plasticity, Homeostasis.