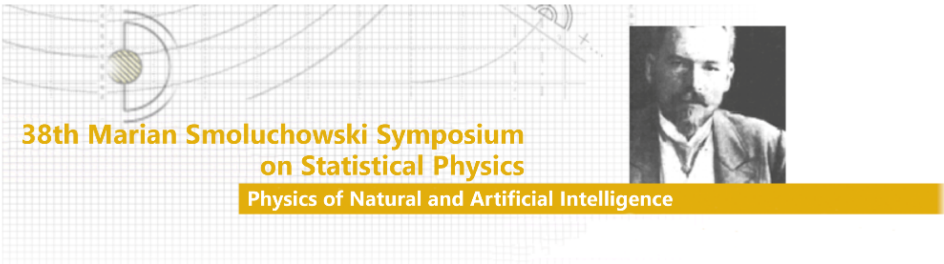

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Dynamics of neural motifs realized with a minimal memristive neuro-synaptic unit

Sunday, 14 September 2025 16:00 (30 minutes)

The use of electronic circuits to model neural systems goes back to C. Mead and is present in models, from leaky-integrate-and-fire to Hodking-Huxley. Simulating neural networks with analog hardware is attractive: it allows to implement neurocomputations in real time without discretization approximations, it has perfect simulation-time scaling with system size, and it provides ready-to-deploy neuromorphic circuits for applications. There are implementations in CMOS technology, however, they are complex, require sophisticated fabrication facilities and, most importantly, suffer from significant device mismatch. In a radically different approach, based on the concept of memristors, we introduce a neuro-synaptic circuit of unprecedented simplicity, with readily available cheap off-the-shelf electronic components, that can quantitatively reproduce textbook theoretical neuron and synaptic current models. Our neuron circuits can avoid the mismatch problem and are easily tunable at bio-compatible time-scales. We first introduce a voltage-gated conductance bursting neuron model that produces spike traces that bear striking similarity to experimental recordings. We then introduce synaptic current circuits and show the modularity of our method implementing neurocomputing primitives of basic network motifs, including CPGs. With this "theoretical hardware" approach we show: (i) that neuron adaptation and self-excitation can be viewed as a self-consistent dynamical problem; (ii) that a dynamical memory can be minimally implemented with a single recursive spiking neuron; (iii) that an adaptive membrane current reveals a connection between bursting and the driven harmonic oscillator, perhaps pointing to a neural correlate of the pendular limb motion. Finally we discuss the limitation of the approach to mid-size networks of mid-size and its potential application for brain-machine-interfaces, robotics and AI.

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