

SPIKE BASED COMPUTING ON SELF ASSEMBLED LIPID MONOLAYERS

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ABSTRACT

A new physical platform inspired by the physics of biological neurons is presented, which will allow testing and implementing thermodynamically optimized computing schemes at the hardware level. While the remarkable energy efficiency of neuronal processes is inspiring the next generation hardware, the physical basis of this efficiency within neuroscience is surprisingly a matter of debate. The electrical spikes in neurons, also known as action potentials, are believed to be purely electrical phenomenon. The standard model of the phenomenon assumes that the information, in the form of a spike, travels via directed mass transfer or diffusion as it irreversibly depletes an electrical gradient across the outer membrane of a neuron. However, recent research strongly suggests that information can also travel in such systems, i.e. the outer membrane of a neuron, via momentum transfer, a reversible process similar to the propagation of sound.

Such spikes have now been realized experimentally as two-dimensional nonlinear sound waves that propagate within single molecule thin films of lipids, which provide the physical basis for the new computational platform [1]. These waves can mimic all the computationally relevant properties of spikes in neuron, such as a threshold for excitation, solitary wave propagation, its dependence on environmental variables like pressure and temperature, and annihilation of spikes upon collision. The lipid monolayers that support the phenomenon are extremely robust and quickly self-assemble at the air/water interface and provide a practical platform to develop brain-like computing. The device operates at energy and timescales comparable to real neurons, and is also highly scalable as the platform employs nonlinear wave mechanics in a planar continuous medium, which allow for massively parallel computing. Furthermore, as the phenomenon occurs at a material phase transition in the lipids, the platform provides unique capabilities to implement self-organized criticality (SOC) and momentum based optimization, as well as dissipation based learning at the hardware level.

Keywords: self-organized criticality, SNN hardware, 2D materials, shock waves, avalanches

Reference

- [1] Shrivastava, Shamit, and Matthias F. Schneider. "Evidence for two-dimensional solitary sound waves in a lipid controlled interface and its implications for biological signalling." *Journal of the Royal Society Interface* 11, no. 97 (2014): 20140098.