Liquid state computing in neuronal cultures: effects of noise and connectivity modularity on response separation and generalisation in numerical simulations

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Abstract

Networks of biological neurons are being used to create artificial learning and processing machines. However, biological neurons and networks differ significantly from the abstract ideations used to develop artificial neural networks. Biological networks are intrinsically noisy and have non-trivial physical embeddings. It is thus unclear to what extend biological neurons are usable for artificial intelligence applications. Intuitively, a basic requirement for a system to be a good (artificial) learning machine is the potential to respond distinctly to different inputs, yet reproduce similar activity when presented with similar stimuli.

In this study we show, in a numerical model of neuronal cultures, that network activity patterns change in response to different inputs, whereas activity patterns for similar inputs coalesce, as expected within the liquid state computing framework. Moreover, we investigate the influence of additive noise and connectivity modularity on the stimulus-responses. We find that moderate levels of additive noise help to increase the separability of the responses, akin to stochastic resonance phenomena, and that modularity increases the repertoire of responses, leading to enhanced separation-capabilities of the network.

Lastly, we explore these results *in-vitro* using primary neuronal cultures on high-density micro-electrode arrays, showing the possibility to use *in-vitro* neuronal cultures for liquid state computation.

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