Coarse-grained analysis of patterned activity in a discrete-time neural network

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Abstract

At the single cell level, neurons typically exhibit all-or-nothing responses, dependent on the input currents they receive from the rest of the network. Due to far reaching processes, neurons can form connections with distant parts of the network, allowing for rapid communication across long distances.

Certain neural systems show computation through patterned activity; persistent localised activity, in the form of bumps has been linked to working memory whilst the propagation of activity in the form of waves has been associated with binocular rivalry tasks. The assumption of sufficiently slow synapses allows for the replacement of firing patterns with firing rates, resulting in a neural field model that is amenable to perturbative analysis. This description averages out fluctuations in both space and time ignoring these small scale effects. Our aim is to analyse a network that retains these small scale effects, but whose large scale effects can be predicted in an analogous way to neural field models.

We present analysis of a network of minimal three-state neurons whose transitions are probabilistic. By taking appropriate limits, we demonstrate the existence and compute stability of spatiotemporally patterned activity across the network. We then show how coarse-grained analysis can be used to construct bifurcation diagrams for the network when these limits are relaxed and illustrate how these can be used to reduce the complexity of the dynamics.

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