Dynamical Behaviour of a Population-Based Neuron Model with Adaptation Current

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Mathematical modelling of neuronal networks plays an important role in understanding how human brain and memory work. One of the most widely used types of neuron models is the rate model, where the state variable represents the firing rate of a neuronal population in the system of differential equations. These models can be treated as dynamical systems enabling us to use bifurcation theory to investigate the changes in the states of neurons.

We study the behaviour of a deterministic rate model which describes the dynamics of an excitatory and inhibitory neuron population. Adaptation current is also added to the excitatory cells as a negative feedback. Our goal is to reproduce the behaviour of neurons that neurobiologists observe in their experiments, including different types of oscillations. We focus on the effect of adaptation and the self weight of the excitatory population. We detect the saddle-node bifurcation curve in the system which shows where the number of steady states changes. Stability of equilibria and appearance of periodic solutions are also studied by determining Andronov-Hopf bifurcation in the rate model. Both of these bifurcations are local bifurcations where the phase portrait changes in a neighbourhood of an equilibrium and they can be investigated analytically. Applying ReLU activation function allows us to give explicit formulas for the bifurcation curves. We show a few examples for the more interesting phase portraits. We identify the detected periodic orbits with different types of oscillations observed in the brain.

[1] A. Ecker, et al. Hippocampal sharp wave-ripples and the associated sequence replay emerge from structured synaptic interactions in a network model of area CA3. *Elife* **11** (2022) e71850.

[2] D. Levenstein, et al., NREM sleep in the rodent neocortex and hippocampus reflects excitable dynamics. *Nat communications* **10**(1) (2019), 1-12.