Analysis of a group of Hindmarsh-Rose neurons with directional connections

Noah Marko Mesić | University of Zagreb

Authors: Noah Marko Mesić (University of Zagreb, Faculty of Electrical Engineering and Computing)

Abstract

The Hindmarsh-Rose model is widely used to simulate neuronal dynamics and replicate diverse patterns of activity observed in biological neurons. Leveraging dynamical systems theory, this study investigates bifurcations and chaotic behavior in a system of two bidirectionally coupled Hindmarsh-Rose neurons, with input current serving as the bifurcation parameter. The analysis was conducted using the MatCont toolbox in MATLAB. The study identifies Andronov-Hopf bifurcations associated with a fixed point and explores Neimark-Sacker and saddle-node bifurcations of the resulting periodic orbits. Three-dimensional phase-space trajectories were examined to characterize synchronous and asynchronous neuronal activity. Furthermore, Lyapunov exponents were computed to detect chaotic behavior, which is characteristic of the Hindmarsh-Rose neuron. The findings validate the occurrence of Andronov-Hopf bifurcations leading to synchronized limit cycles and reveal previously unreported bifurcations that result in asynchronous cycles. Additionally, the emergence of chaos via the Afraimovich-Shilnikov scenario was visualized, with Lyapunov exponents providing further verification.