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Geometric Analysis of Synchronization in Neuronal Networks with Global Inhibition and Coupling Delays

Hwayeon Ryu
University of Hartford, hryu@hartford.edu

Sue Ann Campbell
University of Waterloo, sacampbell@uwaterloo.ca

Geometric Analysis of Synchronization in Neuronal Networks with Global Inhibition and Coupling Delays

Hwayeon Ryu*

Department of Mathematics
University of Hartford, West Hartford, CT 06117, USA

Sue Ann Campbell

Department of Applied Mathematics and Centre for Theoretical Neuroscience
University of Waterloo, Waterloo, Ontario, N2L 3G1, Canada

Abstract

We study synaptically coupled neuronal networks to identify the role of coupling delays in network's synchronized behaviors. We consider a network of excitable, relaxation oscillator neurons where two distinct populations, one excitatory and one inhibitory, are coupled and interact with each other. The excitatory population is uncoupled, while the inhibitory population is tightly coupled. A geometric singular perturbation analysis yields existence and stability conditions for synchronization states under different firing patterns between the two populations, along with formulas for the periods of such synchronous solutions. Our results demonstrate that the presence of coupling delays in the network promotes synchronization. Numerical simulations are conducted to supplement and validate analytical results. We show the results carry over to a model for spindle sleep rhythms in thalamocortical networks, one of the biological systems which motivated our study. The analysis helps to explain how coupling delays in either excitatory or inhibitory synapses contribute to producing synchronized rhythms.

Keywords: Neural Networks, Synchronization, Delays, Geometric singular perturbation

*Corresponding author
Email addresses: `hryu@hartford` (Hwayeon Ryu), `sacampbell@uwaterloo.ca` (Sue Ann Campbell)