Mathematical Methods and Models in Biosciences
June 15–20, 2025, Sofia, Bulgaria
https://biomath.math.bas.bg/biomath/index.php/bmcs

Controlling populations of neural oscillators

Jeff Moehlis

Department of Mechanical Engineering,
University of California, Santa Barbara, USA
moehlis@ucsb.edu

Many challenging problems that consider the analysis and control of neural brain rhythms have been motivated by the advent of deep brain stimulation as a therapeutic treatment for a wide variety of neurological disorders. Control of such rhythms comes with a long list of challenges: the underlying dynamics are nonnegligibly nonlinear, high dimensional, and subject to noise; hardware and biological limitations place restrictive constraints on allowable inputs; direct measurement of system observables is generally limited; and the resulting systems are typically highly underactuated.

In this talk, I highlight a collection of recent analysis techniques and control frameworks that have been developed to contend with these difficulties [1]. Particular emphasis is placed on the problem of desynchronization for a population of pathologically synchronized neural oscillators, a problem that is motivated by applications to Parkinson's disease where pathological synchronization is thought to contribute to the associated motor control symptoms.

The first control strategy to be covered will be optimal chaotic desynchronization for finding an energy-optimal stimulus which exponentially desynchronizes a population of neurons, based only on a neuron's phase response curve, and will include recent results on the effect of constraints on stimulus magnitude on the control efficacy. The second control strategy to be covered will be optimal phase resetting which brings the neurons' states near a phaseless set, so that background noise perturbs the neurons onto random isochrons which randomizes their asymptotic phases, and will include recent results on how accounting for stochasticity in the control design can improve performance [2]. These algorithms hold great promise for controlling neural oscillator populations with a variety of control objectives.

Our hope is that these successes will motivate more research on how to implement them in experimental and clinical studies, opening the door to more effective and more efficient treatments for Parkinson's disease and other neurological disorders.

References

[1] D. Wilson, J. Moehlis, Recent advances in the analysis and control of large populations of neural oscillators, *Annual Reviews in Control*, 54:327–351, 2022.

[2] F. Rajabi, F. Gibou, J. Moehlis, Optimal control for stochastic neural oscillators, *Biological Cybernetics*, 119:9, 2025.