SYNCHRONY AND CHAOS IN COUPLED OSCILLATORS AND NEURAL NETWORKS

Abstract

by

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This dissertation studies the dynamics of ensembles of coupled, dynamical elements with discrete and continuous time dynamics. Specific problems include the appearance of synchronous behavior in an ensemble of dynamical elements.

We show that the dynamics of coupled map lattices with connectivity that scales with inter-site distance exhibit a transition from spatial disorder to spatially uniform temporal chaos as the scaling varies. We investigate the eigenvalue spectrum of the stochastic matrix characterizing fluctuations from the uniform state numerically and show that the spectrum is bounded, real and the largest eigenvalue (corresponding to the uniform solution) has a gap separating it from the remaining N-1 eigenvalues which correspond to non-uniform solutions. The width of this gap depends on the scaling exponent. We relate the stability of the uniform state to this gap and show that the state is globally stable even in a strongly chaotic region of the uncoupled map.

Bursting is a prototypical pattern of voltage oscillations of membrane potentials of biological cells, where the membrane potential alternates between fast oscillations and a slow drift. These complex oscillations arise as a result of interactions between the kinetics of fast and slow ion channels. While bursting in isolated cells is well understood, the study of populations of interacting bursters is less developed. We

study a one-dimensional continuum model of bursting and show that a spatial wave of bursting separating active and quiescent cells extinguishes synchronous bursting when the coupling is weak. This result places bounds on the measured values of coupling strength between secretory cells in the pancreas.

The interactions of cellular and synaptic mechanisms acting on several timescales control rhythmic behavior in animals, such as locomotion, digestion and respiration. We explore a simple rhythmic circuit model with two cells reciprocally inhibiting each other with fast and slow timescale inhibition. The interaction between the fast oscillations of the cells and the slow inhibition results in a complex pattern of bursting, while isolated cells can only oscillate but not burst. This result clarifies understanding the design of central pattern generators in invertebrates where multiple timescale inhibition is common.