Symposium
Synchronization patterns in networks of nonlinear oscillators

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Controlling Chimeras

Coupled phase oscillators model a variety of dynamical phenomena in nature and technological applications. Nonlocal coupling gives rise to chimera states which are characterized by a distinct part of phase synchronized oscillators while the remaining ones move incoherently. Here, we apply the idea of control to chimera states on continuous media: using gradient dynamics to exploit drift of a chimera, it will attain any desired target position. Through control, chimera states become functionally relevant. For example, their localized nature becomes accessible to develop novel applications, such as using the position of localized synchrony to encode information and perform computations. Since functional aspects are crucial in (neuro-)biology and technology, the localized synchronization of a chimera state becomes accessible to develop novel applications. Based on gradient dynamics, our control strategy applies to any suitable observable and can be generalized to arbitrary dimensions. Thus, the applicability of chimera control goes beyond chimera states in non-locally coupled systems.

[1] C. Bick and E. A. Martens, „Controlling Chimeras“, New Journal of Physics, 17, 33030 (2015).
[2] E. A. Martens, C. R. Laing, and S. H. Strogatz, „Solvable Model of Spiral Wave Chimeras“, Physical Review Letters, 104, 44101 (2010).

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Death and rebirth of neural activity in sparse inhibitory networks

Inhibition is a key aspect of neural dynamics playing a fundamental role for the emergence of neural rhythms and the implementation of various information coding strategies. Inhibitory populations are present in several brain structures and the comprehension of their dynamics is strategical for the understanding of neural processing. In this paper, we clarify the mechanisms underlying a general phenomenon present in pulse-coupled heterogeneous inhibitory networks: inhibition can induce not only suppression of the neural activity, as expected, but it can also promote neural reactivation. In particular, for globally coupled systems, the number of firing neurons monotonically reduces upon increasing the strength of inhibition (neurons' death). However, the random pruning of the connections is able to reverse the action of inhibition, i.e., in a random sparse network a sufficiently strong synaptic strength can surprisingly promote, rather than depress, the activity of the neurons (neurons' rebirth). Thus, the number of firing neurons reveals a minimum at some intermediate synaptic strength. We show that these minimum signals a transition from a regime dominated by the neurons with higher firing activity to a phase where all neurons are effectively sub-threshold and their irregular firing is driven by current fluctuations. We explain the origin of the transition by deriving a mean field formulation of the problem able to provide the fraction of active neurons as well as the first two moments of their firing statistics. The introduction of a synaptic time scale does not modify the main aspects of the reported phenomenon. However, for sufficiently slow synapses the transition becomes dramatic, the system passes from a perfectly regular evolution to an irregular bursting dynamics. In this latter regime the model provides predictions consistent with experimental findings for a specific class of neurons, namely the medium spiny neurons in the striatum.

[1] D. Angulo-Garcia, S. Luccioli, S. Olmi, A. Torcini, "Death and rebirth of neural activity in sparse inhibitory networks", New Journal of Physics 7, 1577 (2017).

[2] S. Olmi, D. Angulo-Garcia, A. Imparato, A. Torcini, "Exact firing time statistics of neurons driven by discrete inhibitory noise", Scientific reports 19, 053011 (2017).