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Partial synchronization in diluted neural networks

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Partial synchronization (PS) is a collective dynamics discovered in fully coupled networks of leaky integrate-and-fire (LIF) neurons [1,2]. This dynamical state is quite peculiar, since the mean-field is characterized by a periodic dynamics, while the single neurons do not show any synchronization and behaves quasi-periodically in time. PS arises from the destabilization of a regime characterized by a constant mean field and by periodic motion of the single neurons. This regime, termed "Splay State," as been widely studied in several context, including computational neuroscience [3].

Our aim is to investigate the role of network dilution on the stability properties of PS and splay states and the influence of dilution on the transition scenario leading from the splay state to partial synchronization. In particular, we have examined a pulse-coupled excitatory network of LIF neurons with 20% of randomly broken links in two different configurations: quenched, where the network topology is fixed, and annealed, where the links to break are chosen at each spike emission. For both configurations, we have been able to rewrite the dynamics of the network (described by a set of differential equations) as an exact event driven map by extending the approach developed in [4].

We observe that the splay state and the PS state, as well as the transition scenario, are quite robust with respect to dilution, both for the quenched and annealed configurations. Moreover the dynamics for finite number of neurons is chaotic at variance with the fully coupled case. The dependence of the degree of chaotic behavior (characterized in terms of the maximum Lyapunov exponent) on the number of neurons N is analyzed, as a first results we notice that finite-N effects are more relevant in the quenched configuration with respect to the annealed one.

Finally, the possibility to reproduce the deterministic dynamics of the diluted network for finite N, by introducing an additive colored noise term in the equations describing the fully coupled case, is investigated. The noise term amplitude and correlation are determined by the analysis of the mean field properties associated with finite diluted networks.

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