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Chaos and Synchronization in Stochastic Neural Networks on Random Graphs

Abstract

Networks of interacting neurons have been observed to exhibit a rich range of synchronized behaviours. In some regimes they behave chaotically, like gas particles, and in other regimes they can exhibit linear and / or spiral travelling waves, as well as resonances at various spatio-temporal frequencies. There is currently a huge effort underway to simulate neural networks on an inhomogeneous architecture (often derived directly from experiments). In fact many of the phenomena observed in simulations can be explained using statistical mechanics / stochastic analysis techniques. I therefore develop a model of N stochastic interacting particles on a random graph to investigate some of these phenomena. In my first application, I take the connections to be random, Gaussian and correlated, with variance scaled by $N^{-1/2}$. In the large N limit, the limiting probability law becomes non-Markovian (the dynamics is affected by the entire past). Indeed these results are a generalization of a classical result on the large deviations of spin glasses by Ben Arous and Guionnet to include correlated connections. In my second application, I take an Erdos-Renyi random graph, with the probability law of the connection probabilities and correlations motivated by the experimental literature. I use the theory of Large Deviations to determine which spatial Fourier modes are most likely to be excited, in the large network size limit. I find bifurcation conditions governing the onset of synchronization over particular modes. In my final application, I study the effect of spatio-temporal white noise on travelling waves in neural field equations (with a convolution operator modeling the interactions).