Title : Reservoir computing and edge of chaos

Abstract :

Today, artificial neural networks serve as an essential basis of modern machine learning theory. These systems, especially recurrent random network models, are known to exhibit rich dynamical properties, including collective chaotic dynamics, common-signal-induced synchronization, and noise-induced suppression of chaos [1]. It is particularly remarkable that common-signal-induced synchronization, where any trajectory of the network state converges under the same input regardless of the previous history, brings a new informational perspective to the network dynamics. Combined with the rich dynamical patterns of the networks, this phenomenon enables them to serve as a resource for real-time information processing, such as time-series prediction, observer problem, reinforcement learning, and speech recognition. Such a framework is referred to as *reservoir computing* (RC) (for reviews, see Ref. [2]) and they have attracted a great deal of interest in the last decade.

In this work, we give a comprehensive study of the dependence of reservoir computer's performance on the network structures, especially the distribution function of the random coupling constants. First, based on the MSRDJ path integral formalism [3], we clarify the universal behavior of the random network dynamics in the thermodynamic limit, which depends only on the asymptotic behavior of the second cumulant generating functions of the network coupling constants. Thereby we can classify the random networks into several universality classes, according to the distribution function of coupling constants chosen for the networks. Subsequently, the relation between the computational power of the reservoir computer and the network parameters is investigated by numerically evaluating the phase diagrams in the steady network states, common signal-induced synchronization, and the computational power in the chaotic time-series predictions, for several types of universality classes.

[1] H. Sompolinsky, A. Crisanti, and H. J. Sommers, PRL **61**, 259 (1988).

[2] M. Lukosevicius and H. Jaeger, Computer Science Review **3**, 127 (2009).

[3] J. Schuecker, S. Goedeke, and M. Helias, PRX **8**, 041029 (2018).