Tracking Dynamics of Neural Networks with Continuous Attractors

Si Wu
Department of Informatics
Sussex University
Brighton
BN1 9QH, UK.

Abstract

Understanding how the dynamics of a neural network is shaped by the network structure, and consequently facilitates the functions implemented by the neural system, is at the core of using mathematic models to elucidate brain functions. The present study investigates the tracking dynamics of continuous attractor neural networks (CANNs). Due to the translational-invariance of neuronal recurrent interactions, CANNs can hold a continuous family of stationary states. They form a continuous manifold in which the neural system is neutrally stable. We systematically explore how this property facilitates the tracking performance of a CANN, which is believed to have wide applications in brain functions. By using the wave functions of the quantum harmonic oscillator as the basis, we demonstrate how the dynamics of a CANN is decomposed into different motion modes, corresponding to, respectively, the changes in amplitude, position, width or skewness of the network state. We then develop a perturbative approach that utilizes the dominating movement of the network stationary states in the state space. This method allows us to approximate the network dynamics up to an arbitrary accuracy depending on the order of perturbation used. We obtain results on the maximum speed for a moving stimulus to be trackable, and the reaction time for the network to catch up an abrupt change in stimulus.