Analysis of "Integrate and Fire" models for neural networks

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Abstract

Neurons exchange informations via discharges, propagated by membrane potential, which trigger firing of the many connected neurons. How to describe large networks of such neurons? How can such a network generate a spontaneous activity? We tackled using nonlinear integro-differential equations. These are now classically used to describe neuronal networks or neural assemblies. Among them, the Wilson-Cowan equations are the best known and describe spiking rates in different brain locations.
Another classical model is the integrate-and-fire equation that describes neurons through their voltage using a particular type of Fokker-Planck equations. Several mathematical results will be presented concerning existence, blow-up, convergence to steady state, for the excitatory and inhibitory neurons, with or without refractory states. Conditions for the transition to spontaneous activity (periodic solutions) will be discussed.
One can also describe directly the spike time distribution which seems to encode more directly the neuronal information. This leads to a structured population equation that describes at time t the probability to find a neuron with time s
elapsed since its last discharge. Here, we can show that small or large connectivity leads to desynchronization. For intermediate regimes, sustained periodic activity occurs. A common mathematical tool is the use of the relative entropy method.

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