Neuronal excitability, oscillations and coincidence detection

Gemma Huguet

Gemma Huguet (gemma.huguet@upc.edu)
Universitat Politècnica de Catalunya

Abstract. A fundamental property of neurons is excitability: in response to a brief, strong enough stimulus they may undergo a characteristic large amplitude, transient excursion from rest (the action potential or spike). Such spikes are the main means of communication between neurons. In some neuronal systems this transient spike response can be turned into a sustained one when a steady input is applied, i.e. the state of such neurons has a limit cycle.

In 1948, Hodgkin proposed three classes of excitability based on experimental observations from responses of various axon types to steady inputs. Two of them, Classes I and II could show repetitive firing for sustained inputs; but not Class III, for which only one spike or a few are generated at the onset of a step current.

In this talk, I will first review the mathematical framework for understanding generic transitions from resting to repetitive firing activity in single neuron models, as developed by Rinzel and Ermentrout (1989), and their relationship with Hodgkin's classification. I will then discuss methods to study properties of periodically spiking neurons using the concepts of isochrons and phase response curves. In particular, I will present fast algorithms to compute these objects up to high order. Finally, I will focus on some features of Class III-excitable systems and contrast their potential for exquisite temporal precision with that of systems that can fire repetitively. Exemplars are found in the auditory brain stem where precise timing is important for sound localization.