Probabilistic Models in Neuroscience

Sanjoy Mitter
(MIT)

Abstract:

In a remarkable book "Computer and the Brain," John Von Neumann's unfinished work, which was to have been the Silliman lectures at Yale , he writes: "Thus the nervous system appears to be using a radically different system of notation from the ones we are familiar with in ordinary arithmetic and mathematics: instead of the precise systems of markers where the position – and presence or absence – of every marker counts decisively in determining the meaning of the message, we have here a system of notations in which the meaning is conveyed by the statistical properties of the message." Von Neumann goes on to describe how the lack of precision is compensated by logical reliability and how the language that the brain uses is different from the language of mathematics as we understand it today. Von Neumann's ideas may be interpreted as suggesting that a new kind of mathematics will ultimately have to be developed (some version of Grothendieck's ideas?) to understand the structure and organization of the brain. The goal of these lectures is much more modest. It is to model probabilistically spike trains and ensemble of spike trains and how "information" might be coded in neural signals by viewing it as inference problems on probabilistic models (modulated point processes) of ensemble of spike trains.

The broader goal is to see how ideas from information, control and theory of computation might be used to illuminate questions in Neuroscience. It needs to be done with care and one needs to be faithful to Neuroscience. We need a much better understanding of what properties are preserved under interconnections of stochastic systems. I suggest that the theory of stochastic dissipative systems and their interconnections to be a subject which may well be important for Neuroscience. I do not in any sense claim to be knowledgeable in Neuroscience. However the work that I have done in this area has been in collaboration with neuroscientists.