

# Copulae and network modeling

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Mathematical models for neuron activity are an important tool to increase our comprehension of neural code. Between single neuron models Leaky Integrate and Fire ones are particularly popular. This fact is due to two main features: they can fit a variety of experimental data and they are mathematically simple enough to allow analytical and numerical studies. The use of these models hints on various neuron features. Typical examples are the role of noise in neural transmission or the study of the response of the neuron to periodic stimuli. Furthermore their use has allowed the application of information theory to the neuron code.

The possibility to record simultaneously from groups of neurons suggests to switch from the single neuron to the network description. Because of the important role of mathematical models in the study of single units, suitable models for networks are needed. Unfortunately the major complexity determined by the large number of interconnected units discourages analytical approaches making object oriented networks or simulation techniques the most popular methods. Alternatively multiparticle models have also been proposed. The main lack of all these studies is their inability to relate single units and network features. Indeed they often oversimplify the description of the units of the network focusing on the links between them.

Here we discuss the possibility to get advantage from our knowledge on single neuron models to determine neural network models. Copulae are the mathematical object allowing to join marginal distributions to get the joint one. The use of copulae has recently been proposed for the statistical description of counts of spikes in network; however their use for modeling purposes has not yet been sufficiently investigated. Here we propose new models using copulae. It should be however noticed that we are presenting preliminary results limited to only two neurons. We limit ourselves to study the coupling between the spike times of two neurons due to the difficulty of the description of the coupling of the point processes describing the spike trains. We describe the two neurons by means of LIF models and we couple the noise terms in the equations describing the membrane potential dynamics. Then we study the spike times of the modeled neurons and we focus on the copula joining these times. Various properties of these times are discussed and some open problems are listed.

In the talk we also describe some open mathematical problems that should be solved to allow the switching to a larger number of units in the network.