UNIFYING PROPAGATORS AND COVARIANCES OF NETWORK MODELS BY ORNSTEIN-UHLENBECK-PROCESSES

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Different models are used for the investigation of neuronal recurrent networks and their corvariance structures. Currently it is unclear which features of correlations are generic properties of recurrent networks and which are peculiarities of the often abstracted models. In this work we present a unified theoretical view on pairwise correlations in recurrent random networks, show how different neuron models relate to each other and how results obtained with one model carry over to another. We consider binary neuron models, leaky integrate-and-fire models, and linear point process models. We follow a novel approach and show the equivalence of each of these explicit or effective non-linear models after linear approximation to the Ornstein-Uhlenbeck (OU) process [1]. The considered models split in two groups, differing in the location of the effective noise on either the output or the input side. The closed solution for the correlation structure of OU processes [1] holds for both classes. We identify different contributions to correlations in recurrent networks: the solution for output noise is split into several terms corresponding to the delta-peak in the autocovariance, the covariance caused by shared input, and the direct synaptic influence of stochastic fluctuations of one neuron on the other – these echo terms are equal to propagators acting with delays [4]. Our approach enables us to transfer results between models, e.g. to extend all considered models with delays and to present simpler ways to obtain solutions for systems considered earlier [3]. Finally we show that the presence of synaptic delays known to evoke an oscillatory instability in networks of integrate-and-fire models [2,4] is a model-invariant feature of any of the studied dynamics. We relate this instability to the pole structure of Fourier transformed covariance functions, which determine the power spectra in different models and we explain the class dependent differences in the shape of covariance functions. Our results are also suitable to estimate the dependence of covariance functions on Manhattan distance between neurons in random recurrent networks and to determine the connectivity for a given covariance structure. The obtained equations describing the relation between connectivity and correlation can be used to investigate the evolution of synaptic amplitudes in a system with spike-timing dependent plasticity.
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