A tractable method for describing complex couplings between neurons and population rate

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Abstract

Recent studies (Okun) show that each cell in a population is influenced by the population rate. Here, the authors build a model of population activity that reproduces the firing rates, the population rate distribution, and the linear coupling between them. The model is tractable, and easy to train even on a normal laptop. Some cells had a preffered population rate, at which they were most likely to fire. The linear model could not account for these features, so the authors developed a more general, but still tractable, model that could account for these non-linear dependencies.

Introduction

The model is derived using the maximum entropy principle. Re-iterates the finding that some neurons are tuned to a certain population rate.

Materials and Methods

Three models are defined. The *minimal model*, which reproduces the firing rates and the population rate distribution, the *linear-coupling model*, which reproduces the same as the minimal model and the linear correlation between the population rate and the firing rate for each neuron, the *complete-coupling model*, which reproduces the joint probability between the individual responses and the population rate, i.e. $P(\sigma_i, K)$, for $i = 1, \ldots, N$.

Model Solutions

The solution parameters to each model can take the form h_{iK} for $i = 1, \ldots, 0$ and $K = 0, \ldots, N$. For the minimal model, the h_{iK} are constrained to take the form $h_{iK} = \alpha_i + \beta_K$. For the linear-coupling model, $h_{iK} = \alpha_i + \beta_K + \gamma_i K$. For the complete-coupling model, there are no constraints on h_{iK}.

Regularization

$P(K)$ and $P(\sigma_i|K)$ were regularized using pseudocounts equal to their average values under an independent distribution.

Quality of the model

The quality of the model was tested using a goodness of fit index quantifying the amount of correlations predicted by the model, the improvement in mean log likelihood in comparison to the minimal model, and the multi-information.

Results

The goodness of fit index for the linear coupling model and the complete-coupling model were very similar. The improvement in log-likelihood was more significant. According to the multi-information the linear coupling model could account for 65% and 53% of correlations in populations of 10 and 20 neurons respectively. The complete-coupling model could account for 68% and 56%. (Not as good as the pairwise maximum entropy model in Schneidman 2006, 90%!)