A simple mechanism for higher-order correlations in integrate-and-fire neurons

David Leen† and Eric Shea-Brown†‡

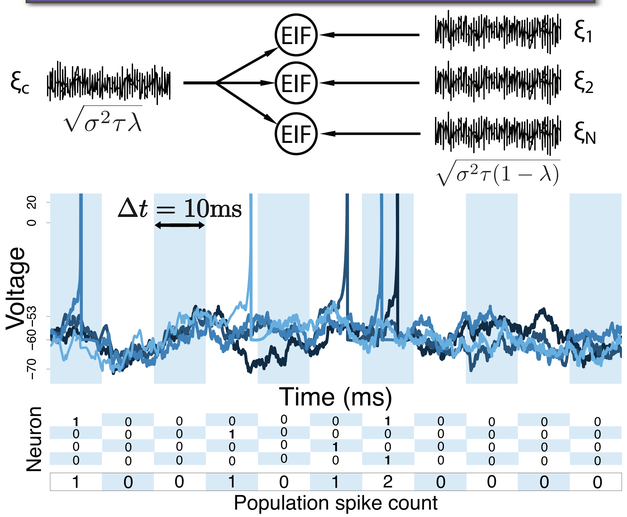
dleen@uw.edu etsb@uw.edu

APPLIED MATHEMATICS
UNIVERSITY of WASHINGTON

Introduction

- This study asks whether common input to integrate-and-fire neurons gives rise to higher-order correlations.
- A tractable reduction of the EIF model - the linear-nonlinear cascade is used to provide an analytic description of our results.
- The Dichotomized Gaussian model provides an excellent description of the EIF setup.
- Finally we compare the LNL cascade to the Dichotomized Gaussian model.

EIF neurons receiving common input



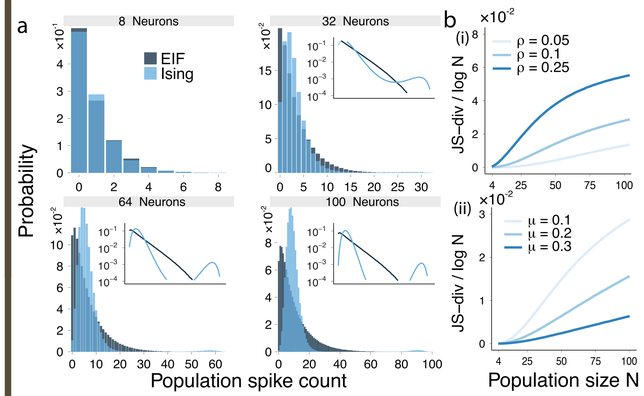
The voltage of the EIF neurons evolves according to the equation: $\tau_m V_i' = -V_i + \psi(V_i) + I(t)$

where $\psi(V_i) = \Delta_T \exp\left((V_i - V_S)/\Delta_T\right)$ defines the EIF neuron and the input current is:

$$I(t) = \gamma + \sqrt{\sigma^2 \tau}\left[\sqrt{1-\lambda}\xi_i(t) + \sqrt{\lambda}\xi_c(t)\right]$$

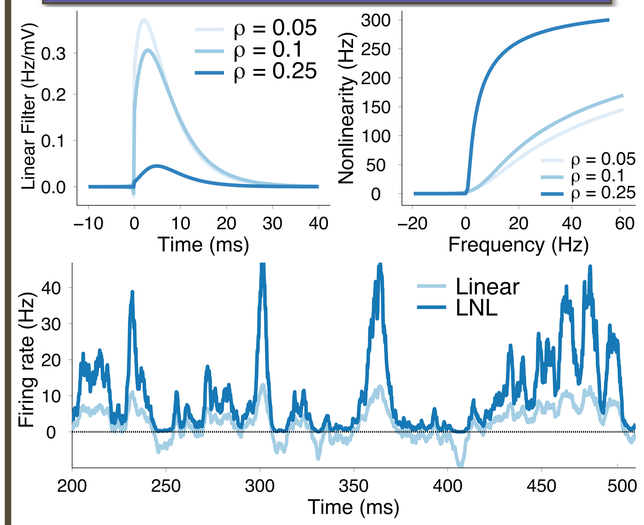
Time is divided into bins of 10ms. A spike occurs when the voltage reaches a threshold of 20mV. The voltage is reset to the rest potential of -60mV and the neuron remains silent for the refractory period of 3ms.

Mean firing rate is measured as the mean number of spikes per bin: $\mu = 0.1$
Correlation coefficient is: $\rho = 0.1$



Exponential integrate-and-fire neurons receiving common input give rise to higher-order correlations i.e. not well described by pairwise maximum entropy model.

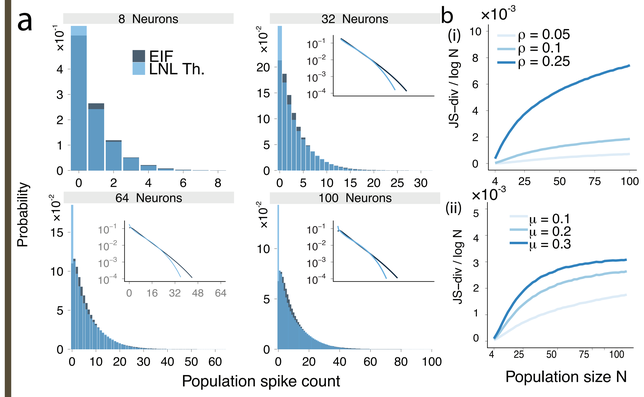
Linear-nonlinear cascade approximation



The firing rate is estimated as:

$$r(t) = F\left(r_0 + A * c(t)\right)$$

where $A(t)$ is the linear filter and F is the static non-linearity.



Dichotomized Gaussian model

Comparison of LNL and DG

Conclusions

[1] J. Macke, et. al. Common Input Explains Higher-Order Correlations and Entropy in a Simple Model of Neural Population Activity. **PRL 106 May 2011**
[2] S. Yu, et. al. Higher-Order Interactions Characterized in Cortical Activity **J. Neuroscience 31(48): 17514 Nov 2011**
[3] S. Ostojic, N. Brunel. From Spiking Neuron Models to Linear-Nonlinear Models **PLoS Comput Biol 7(1) 2011**
[4] M. Richardson. Firing-rate response of linear and nonlinear integrate-and-fire neurons... **PRE 76 (2007)**

†Department of Applied Mathematics ‡Department of Neurobiology and Behavior