Dimensionality Reduction in spatio-temporal MaxEnt models and analysis of Retinal Ganglion Cell Spiking Activity in experiments
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Retinal spike response to stimulus is constrained on one hand by short range correlations (receptive field overlap) and on the other hand by lateral connectivity (cells connectivity). This last effect is difficult to handle from statistics because it requires to consider spatio-temporal correlations with a time delay long enough to take account of the time propagation along synapses. Although MaxEnt model are useful to fit optimal model (maximizing entropy) under the constraints of reproducing observed correlations, they do address spatio-temporal correlations in their classical form (Ising or higher order interactions but without time delay). In such models somewhat integrates propagation effects, but in an implicit form, decision is not based on severity bias data [1]. To resolve this issue we have considered spatio-temporal MaxEnt model formerly developed e.g. by Vasquez et al. [2]. The price to pay, however is a huge set of parameters that must be fitted to experimental data to explain the observed spiking patterns statistics. There is no a priori knowledge of which parameters are relevant and which ones are contributing to overfitting. We propose here a method of dimension reduction, i.e. a projection on a relevant subset of parameters, relying on the so-called Susceptibility matrix closely related to the Fisher information. In contrast to standard methods in information geometry through, this matrix handle space and time correlations.

We have applied this method for retina data obtained in a diurnal rod (Octodon degus, hemisphere of cones photoreceptrs) and a 252-MEA system. Three types of stimuli were used: spatio-temporal uniform light, white noise and a natural movie. We show the role played by time-delayed pairwise interactions in the neural response to stimuli both for close and distant cells. Our conclusion is that, to explain the population spiking statistics we need both short-distance interactions as well as long-distance interactions, meaning that the relevant functional correlations are mediated not only by common input (i.e receptive field overlap, electrical coupling, apoptosis) but also by long range connections.

### Introduction

**Methods**

**Recordings:** Extracellular recording of the electrical activity of retinal ganglion cells (GCs) from Octodon degus were performed in vivo using a Multitelectrode Array (UMBEA656 from Multichannel Systems, MCS GmbH).

**Stimuli:** (i) Photopic spontaneous activity (PSA): A uniform spatio-temporal invarient field (15 ms), (ii) White noise (WN): Bi-

**Analysis:** A binary raster \( w = 50 \) with a bin size of 5ms was used when \( c = 1 \) and \( \epsilon = 1 \). The goal is to fit the empirical distribution of \( w \) with a MaxEnt model (eq. 1) and compute its Susceptibility matrix (eq. 2):

\[
N(c,\epsilon) = \sum_{k=1}^{N} n_{k} \sigma_{k}(c,\epsilon)
\]

where \( n_{k} \) are the observables, \( \sigma_{k} \) the free parameters to fit, \( l \) is a parameter label: 1 range from 0 to \(-1\), the integer \( l \) is called the range (in example the potential \( Y_{l} \)), in this case, \( l = 2 \).

The Susceptibility matrix (eq. 2) tells us how much a change on one parameter \( \sigma_{i} \) changes the estimation of the observables probabilities \( n_{k} \) depends on stimulus, increasing its entries as the stimulus complexity increases.

**Observables:**

- \( k \) is purely combinatoric:
- \( \log \sum_{k} \sigma_{k}(c,\epsilon) \) characterizes the effect of precision (\( s \)) and finite sampling. Minimizing eq. 1 [1] yields the optimal set of parameters given a finite sample size (eq 3) with accuracy \( s \).

\[
\log \left( \sum_{k} \sigma_{k}(c,\epsilon) \right) = \log \left( \sum_{i=1}^{N} \lambda_{i} \right) = \log \left( \frac{\left( N + N - c - \epsilon \right)}{\left( N - c - 2 \right)} \right)
\]

- \( \lambda_{i} \) are decreasing \( \chi^{2} \) eigenvalues; \( \log \left( \sum_{k} \sigma_{k}(c,\epsilon) \right) \) is purely combinatoric;
- \( \log \sum_{k} \sigma_{k}(c,\epsilon) \) characterizes the effect of precision (\( s \)) and finite sampling. Minimizing eq. 1 [1] yields the optimal set of parameters given a finite sample size (eq 3) with accuracy \( s \).

\[
\log \left( \sum_{k} \sigma_{k}(c,\epsilon) \right) = \sum_{i=1}^{N} \lambda_{i} = \sum_{i=1}^{N} \log \lambda_{i}
\]

- \( \lambda_{i} \) are decreasing \( \chi^{2} \) eigenvalues; \( \log \left( \sum_{k} \sigma_{k}(c,\epsilon) \right) \) is purely combinatoric;
- \( \log \sum_{k} \sigma_{k}(c,\epsilon) \) characterizes the effect of precision (\( s \)) and finite sampling. Minimizing eq. 1 [1] yields the optimal set of parameters given a finite sample size (eq 3) with accuracy \( s \).

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\]

\[
\lambda_{i} \text{ are decreasing } \chi^{2} \text{ eigenvalues; } \log \left( \sum_{k} \sigma_{k}(c,\epsilon) \right) = \sum_{i=1}^{N} \log \lambda_{i}
\]

**Conclusion:**

One of the key functions of \( \chi^{2} \) spectrum is to summarize information about individual neurons firing rates, while the second cut-off contains information about spatio-temporal correlations. If \( k_{\chi} = N \), there is no relevant information about spatio-temporal correlations on the data and it can be optionally explained by a model which takes into account only neuron firing rates.

All tested stimuli require spatio-temporal interactions to optimally fit the observed retinal population activity. So, as other works have shown on different species (salamander [2,3,5]; monkey [4]; guinea pig[3]), retinal population activity presents significant spatio-temporal interactions. Moreover, the stimulus high-order correlations increase the information about spatio-temporal interactions on the network.

The first \( N \) dimensions contains mainly information about firing rates, while the next \( k_{\chi} - N \) concentrates information about spatio-temporal correlations.

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**References**


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**Conclusions**

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