A simple population code in a fast-changing world

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Introduction

**Exact inference**

We find the posterior distribution over the stimulus at time T given all spikes observed so far as

\[
p(x_T | s_T) \propto \int \delta(s_T - s_t) p(x_T | s_T) p(s_T)
\]

**Assumption:** Independent, identical Poisson neurons

**Result:** Posterior distribution is a simple Gaussian

**OU prior**

\[
\mu_T = \sum_i \lambda_i \eta_i(T) \\
\Sigma_T = \sum_i \lambda_i \eta_i(T) \Sigma_i \eta_i(T)
\]

**Smooth prior**

\[
\mu_T = \sum_i \lambda_i \eta_i(T)
\]

**Exact kernels k**

**Static case:** Simply count how many spikes i(t) each neuron / has emitted up to time T

\[
\mu_i(T) = \sum_j \lambda_j \eta_j(0)
\]

**Dynamic case:** spikes are not just counted but are weighted by kernel k

\[
\mu_i(T) = \sum_j \lambda_j \sum_k k(t) \xi_k(t)
\]

**Structure of the code**

**Complex decoder**

There is no such formulation for the smooth process.

**With a smooth prior, decoding is NONLOCAL in TIME and across NEURONS**

**Natural temporal priors combined with a simple encoder lead to a code which is very hard to decode.**

**A powerful, simple code**

Decide each spike independently. Posterior is product over spikes.

\[
p(x_T | s_T) \propto \exp \left( \sum_i a_i \xi_i(t) \xi_i(t+\tau) \right)
\]

**This is a computationally very powerful code that allows straightforward combination of information across modalities.**

Neglecting correlation structure is bad, but maybe there is a good independent interpretation of spikes?

**Best independent interpretation of spikes is similar for extremely different priors.**

**Conclusions**

Decoding in time necessitates an informative prior.

Natural priors combined with a simple encoder engender a computationally inflexible code. This is due to the stimulus-induced correlations which need to be taken into account.

The structure of a decoder tells us where the information is, in what format it is available. In our case, the information was not in an accessible format to downstream neurons.

We propose a recording. Recording engenders a computationally and representationally powerful and flexible code. The resulting spike trains seem to have "adapted" to the temporal statistics of the stimulus.

**Related work**

Previous work has mainly used uncorrelated, uninformative priors, so priors have been introduced (Britten et al. 1995, Deneve et al. 2001, Dayan, 2000). Some work has used informative priors to decode movement-related activity and found it to be strongly semantically consistent. 

Kemere et al. (2004) have used informative priors to decode movement-related activity and found it to be strongly semantically consistent.

Neiterberg et al. (2001) show that retinal Ganglion cells are independently decodable.

**Statistics efficient coding in time**

**Recoding**

Reencoding eliminates the temporal redundancies in the neural activities – the grey curve shows flat correlations across neurons after recoding.

This is the temporal analogue of adaptation to visual scene statistics (eg. Srinivasan et al. 1982).

**Nonlocal in time and across neurons**

**Osculating**

For OU process, it can be decomposed into a product of the spike duplets. This decomposition allows us to write a new set of equations to compute the posterior distribution.

The OU code generates a temporally compact decoder.

**Thus the same information can be represented by simply decodable spikes that are readily used in computations.**

**Statistically efficient coding in time**

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