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Reconstruction and classification of stimuli encoded with neural circuits with feedback

Aurel A Lazar* and Eftychios A Pnevmatikakis

Address: Department of Electrical Engineering, Columbia University, New York, NY 10027, USA

Email: Aurel A Lazar* - aurel@ee.columbia.edu

* Corresponding author

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Overview

Recent theoretical work has addressed the problem of finding spike kernels ([1,2] and the references therein) for predicting parameters that characterize neural activity or for the reconstruction of sensory stimuli. In [1], the authors define a spike kernel for predicting velocities embedded in cortical recordings. The spike kernel is string-based and acts on binned spike trains. In contrast, we used the exact time occurrence of spikes and assumed that the stimuli of interest are bandlimited and showed bandlimited stimuli can be perfectly recovered from the spike data provided that the number of neurons is sufficiently large [2].

Methods

We present a general approach to the reconstruction and classification of sensory stimuli encoded with networks of leaky integrate-and-fire neurons with feedback. The stimuli are modeled as elements of a Reproducing Kernel Hilbert Space. Both constraint [3] as well as regularized [4] optimality criteria are investigated. The reconstruction and classification is based on finding a stimulus that minimizes a quadratic error and a hinge loss optimality criterion, respectively. We discuss in detail the reconstruction and classification of sensory stimuli modeled as absolutely continuous functions as well as stimuli with absolutely continuous first order derivates. Reconstruction and classification results are presented in analytic form for stimuli encoded with single as well as a population of neurons. Examples are given that demonstrate the performance of the reconstruction and classification algorithms as a function of model parameters.

Conclusion

The approach to reconstruction and classification of sensory stimuli adopted here is very general. We hope that practicing systems neuroscientists will find our detailed methodology easy to apply or will readily adapt it to other models of sensory stimuli of interest.

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