BMC Neuroscience

BioMed Central

Oral presentation

Multi input multi output neural population encoding

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from Sixteenth Annual Computational Neuroscience Meeting: CNS*2007
Toronto, Canada. 7–12 July 2007

Published: 6 July 2007

BMC Neuroscience 2007, **8**(Suppl 2):S5 doi:10.1186/1471-2202-8-S2-S5

A formal mathematical model for representing neural stimuli is presented. The model enables the investigation of stimulus representation by spiking neurons, and provides algorithms that under certain conditions can recover the stimuli with no error, by knowing only the time of the spike trains.

In our model, we assume that N bandlimited input stimuli approach the dendritic trees of M spiking neurons. Each stimulus comes to a different branch of each dendritic tree, and each dendritic tree is modeled as a linear time invariant (LTI) filter. The outputs of all dendritic branches are summed together with a background current (bias), and this sum enters the soma of each neuron, which is modeled as an Integrate-and-Fire neuron.

We prove that under certain conditions, it is possible to recover all N input spike trains, by knowing only the M spike trains, and provide an algorithm for that purpose. The proof comes from the mathematical theory of frames and the conditions require a minimum average spike density from the neurons and some mild conditions in the impulse responses of the dendritic branches/filters.

We illustrate this algorithm with an example that recovers the stimuli when the dendritic branches perform arbitrary but known time-shifts to the signal. This particular example is important as it illustrates how information from sensory neurons that respond with different latencies, can be combined together.

Finally, the model points to the significance of neural population codes, as it shows that data from a single neuron can be misleading in terms of what the input stimulus is. We illustrate this significant observation with an example.