MASTER'S THESIS

Impact of synaptic properties, background activities and conductance effects on neural computation of correlated inputs

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Impact of Synaptic Properties, Background Activities and Conductance Effects on Neural Computation of Correlated Inputs

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DECLARATION

I hereby declare that this thesis represents my own work which has been done after registration for the degree of MPhil at Hong Kong Baptist University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications.

Signature: ________________

Date : May 2015

Abstract

Neurons transmit information through spikes in neural networks through synaptic couplings. Given the prevalence of correlation among neural spike trains experimentally observed in different brain areas, it is of interest to study how neurons compute correlated input. Yet how it depends on the synaptic properties and conductance kinetics in neuronal interaction is very little known. Through simulation of leaky integrate-and-fire (LIF) neurons, we have studied the effects of excitatory and inhibitory synaptic decay times, level of background activities and higher-order conductance effects on the output correlation of different time scales for neurons receiving correlated excitatory input. We also provided important understanding on the mechanism of how these factors influence neural computation of such correlated input.

We showed that when the conductance effects are totally ignored, increasing excitatory synaptic decay time jitters output spike time and shapes the output correlation of short to medium time scale, while the output correlation of very long time scale is determined by the membrane time constant. When conductance effects are considered, this is no longer the case as the effective membrane time constant becomes comparable to the excitatory decay time. We found that the ratio of long-term correlation to short-term correlation (synchrony) increases with excitatory synaptic decay time and decreases with the level of input activities due to the combined effects of jittered spike time. This observation can be associated with the time window and magnitude of the effects of a single input spike on membrane potential, and burst firing. In particular, it is possible for neurons with small excitatory synaptic decay time in high conductance state to respond to correlated input by solely giving extra precisely timed synchronous spikes without exhibiting correlation of longer time scale. In addition, we found that inhibitory synaptic decay time shapes correlation by controlling the relative contribution of excitatory and inhibitory input to output firing. As a result, both output correlation and synchrony increase with it. These results are qualitatively true for a wide range of input correlation and synaptic efficacies. Finally, we showed that fluctuations of conductance and membrane potential reduce output correlation, which can be explained by the reduced prevalence of burst firing.

These results suggest that spike initiation dynamics of neurons can be well characterized by their synaptic decay times and the level of input activities. These properties are therefore expected to influence neurons' ability to code temporal information. These results also hint that correlation, in particular that of long time scale, would be lower if more realistic biophysical features like neural adaptations and network circuitry with feed-forward or recurrent inhibition are considered. It suggests that studies using single LIF neurons tend to overestimate output correlation and underestimate the ability of neurons in producing precisely timed output.

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