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Poster presentation

Storage capacity of a superposition of synfire chains using conductance-based integrate-and-fire neurons

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Background

It has been proposed that the cortex could be a random superposition of synfire chains, in which waves propagating on the synfire chains account for the majority of the 5 Hz background activity observed in cortex [1]. This proposal is an alternative to other recent models that treat background activity as the stochastic firing of neurons in response to recurrent and external input in a sparse random network [2]. Here we study the synfire superposition model using a leaky integrate-and-fire spiking neuron with conductance-based synapses, along with the incorporation of inhibitory neurons into the chains, to establish whether the model is feasible and consistent with observed neurophysiology.

Methods

Storage capacity is analysed in terms of two constraints: spurious spiking rate stability and synfire wave propagation stability. An expression for the (spurious) spiking rate in response to excitatory and inhibitory background input has been obtained using a diffusion approximation [3]. A low spiking rate is achievable with high rates of background input in the regime where the mean of the fluctuating membrane potential is positioned sufficiently below the firing threshold. In this regime, a linear relationship between background input and spurious spiking rate is found. We use this to obtain a limit on the amount of connectivity available to store synfire links such that the network state of low spurious spiking rate remains stable and below the spiking rate due to synfire waves. For a given level of background activity (5 Hz) this equates to a limit on background input. Next, the minimum pool size for stable wave propagation is obtained for a given level of background input, via single-neuron simulations that determine the probability of firing in response to synfire wave input. This is done for plausible settings of three independent background input parameters (excitatory synaptic conductance, ratio of excitatory to inhibitory input connectivity per neuron, and number of standard deviations of mean potential below threshold). Simulations of wave propagation on synfire chains of varying pool size in the presence of varying levels of background input are used to verify the validity of the minimum pool size calculation. The optimal storage capacity is then found by minimising pool size and maximising connectivity subject to the two constraints.

Results

The minimum pool size for wave transmission as a function of background input as obtained by single-neuron simulations was in close agreement with the corresponding synfire chain simulations. High storage capacities in which the number of synfire pools exceeds the number of neurons in the network were found for plausible parameter choices. Cortically realistic levels of reinforced connectivity (2×10^3—2×10^4 excitatory inputs per neuron) were also found. Storage was found to be optimised by a mean membrane potential positioned about 3.5–3.8 standard deviations below threshold.

Discussion

The optimal position of the mean membrane potential is due to a trade-off between stability of wave propagation and stability of spurious firing, and is located only a few millivolts below threshold, in accordance with *in vivo* observations [4]. This implies an advantage for conductance-based over current-based synapses in the synfire superposition model: in the latter a much larger standard deviation is found for the same background input level [2] implying a much less favourable trade-off for synfire chain storage.

References

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