BMC Neuroscience

Poster presentation

Constraining neural microcircuits with surrogate physiological data and genetic algorithms

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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):P16 doi:10.1186/1471-2202-8-S2-P16

Background

Biophysically detailed bottom-up approaches to modelling neural networks have previously used simulated annealing, gradient-decent or ad-hoc algorithms to constrain the many free parameters [1]. This study explores the use of genetic algorithms to automatically search for a known configuration using extracellular spike recordings or intracellular voltage data. Surrogate data on neural responses is generated and the ability of the algorithms to find the (known) neural parameters is assessed.

Materials and methods

Four cell subtypes, in a known microcircuit of the mammalian cochlear nucleus [2], are simulated in a network with 60 frequency channels of auditory input. Each cell received a 'tonotopic' projection of auditory nerve fibres, simulated using a phenomenological auditory nerve model response to a 60 dB SPL notch noise stimuli. Single compartment Hodgkin-Huxley neurons and conductance synapses were implemented in NEURON. Detailed equations for the active voltage-dependant currents I_{Na}, I_{KHT}, I_{KLT}, I_{KA} and I_h, were derived from *in vitro* studies of cochlear nucleus cells [3]. Using genetic algorithm optimisation, four cost functions using identical input stimuli were investigated. The cost functions calculated error in either: (i) absolute spike times, (ii) peri-stimulus time histograms, (iii) cumulative spike counts, or (iv) average intracellular voltages for each cell in the network. Network parameters controlling the number, weight and distribution of the synaptic connections were used in the optimisation, but these could easily be extended to incorporate other cell properties. In all, 30 parameters controlling 10 synaptic connections were converted to a GA binary string.

Results

Each cost function was allowed to run for 2 × 200 generations of the GA, after which a best solution was determined. Normalisation of the results was difficult due to the different scale of scores produced by the cost functions and the different binary resolutions of the parameters. Table 1 shows the performance of the cost function as judged by the best solutions. The average intracellular voltage obtained the best solution as determined by the parametric mean error relative to the target parameters, although each of the cost functions were able to converge successfully to a solution that was within 30% of the target values. Cost function parameter sensitivity was a key factor, since some parameters were visibly under constrained. Sensitivity analysis was also performed for each parameter in the search space around the target.

Table 1: Genetic Algorithm Cost Function Performance

% Diff	[1]Best GA Score	Mean Top 100 [2]
Spike Times	31.08	32.8 (5.5)
PSTH	30.13	31.3 (7.1)
CSC	29.41	32.2 (12.3)
IV	23.17	28.2 (14.7)

[1] Percentage difference between target values and best GA solution, normalised for each parameter. [2] Mean (stdev) of each the top 100 GA scores (per parameter).

Conclusion

Success of the GA optimization was affected by intrinsic noise in the neural model and depended on the sensitivity of the cost function to changes in each parameter. The results have shown the potential of genetic algorithms to constrain the underlying synaptic parameters of BNNs from any of the chosen sources of physiological data. More work is needed to assess the impact of reducing the amount of information available to the cost function and setting confidence limits for each parameter.

References

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