

Using Evolutionary Algorithms and the Efficient Coding Hypothesis to Tune Spiking Neural Networks

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Although significant progress has been made towards the specification and simulation of large-scale brain networks on a variety of hardware platforms, many challenges remain before these neurobiologically inspired algorithms can be used in practical applications. Foremost is the problem of tuning and stabilization of these large-scale dynamical systems, which are characterized by a large number of state variables and open parameters. Complex neural simulations often find many combinations of parameters that yield neural networks which match experimental data with low error rates. In such cases one can introduce an additional objective function based on the notion of parsimony. For spiking neural networks (SNNs) one possible approach is to follow the *efficient coding hypothesis*. The fundamental idea of the efficient coding hypothesis is that sensory systems adapt their responses to the regularities of their input, and employ knowledge about these regularities to increase the amount of transmitted information at any given time. At the level of single neurons, efficient coding requires that the input-output function be adjusted so that the entire response range is employed to represent the stimulus distribution. When the group activity of multiple neurons is considered, the efficient encoding hypothesis requires that the joint encoding of a stimulus reflect both optimal responses in individual neurons and efficiency across the set of neurons. Following the efficient coding hypothesis may not only provide a metric for tuning networks of simulated spiking neurons, it may also be instructive as to how real brain networks process information and achieve homeostasis. Here we present a computational framework that uses neural heterogeneity to characterize STDP and homeostasis parameters for a population of spiking neural networks (SNNs) capable of forming self-organizing receptive fields (SORFs) similar to those found in cortical area V1 when presented with visual stimuli. We used an evolutionary algorithm (EA) to evolve parameters that produced SNNs with SORFs in a manner consistent with the efficient coding hypothesis. The EA/SNN framework simulated multiple spiking neural networks, each with different parameter sets, in parallel on a graphics processing unit (GPU). We observed a 60x speedup with the GPU implementation of this EA/SNN framework over an equivalent CPU implementation. The study showed that the efficient coding hypothesis is sufficient for the evolution of self-organizing maps and that the EA/SNN framework presented here is an efficient tool for constructing large-scale spiking neural networks.