An Unbiased Method for Evolutionary Optimization of Neuronal Morphologies

B. Torben-Nielsen, K. Tuyls and E.O. Postma
IKAT, University of Maastricht

Dendritic morphology plays a key role in the information processing capabilities of neurons [3]. Despite its proven importance, biological data on neuronal morphology is scarce due to the difficulty of measuring dendritic morphology. Virtual neurons offer an alternative for studying the relation between neural morphology and function. Virtual neurons are digital models of neurons which emphasize their morphological properties. These properties can be obtained by methods, such as tracing, reconstruction, or generation from scratch [1]. The main disadvantage of these methods is that they impose a priori constraints on neural morphology obtained from potentially unreliable morphometric data from the literature. We propose a new virtual neuron generation methodology that combines L-Systems with Evolutionary Computation (EC) and that does not suffer from a priori limitations on possible morphologies. L-Systems is a mathematical formalism for describing branched structures such as neuronal morphologies. EC is a technique from Artificial Intelligence that incrementally tunes parameters in a way similar to Darwinian evolution. Our method consists of two phases: the generation phase and the validation phase. In the generation phase, random neuronal morphologies are generated. In the validation phase, these morphologies are assigned a fitness which is a quantitative measurement of the biological accuracy of the generated neuronal morphology. By invocation of EC, the neuronal morphologies incrementally get more accurate until they meet a predefined fitness yielding a biologically accurate morphology. The advantage of our method is that, in contrast to existing methods, it does not impose any a priori limitations on the virtual dendritic morphology. Instead, it selects morphologies a posteriori by assigning a fitness value. Therefore, any morphology that meets a predefined fitness can be obtained. We performed experiments, in which we successfully generated different virtual motor neurons by defining a fitness obeying Hillman's fundamental parameters of motor neuron morphology [2]. We can conclude that we succeeded in the construction of a new, unbiased method for the generation of virtual neurons.

References

[1] Giorgio A. Ascoli, Jeffrey L. Krichmar, Ruggero Scorcioni, Slawomir J. Nasuto, and Stephen L. Senft. Computer generation and quantitative morphometric analysis of virtual neurons. *Anat. Embryol.*, 204:283–301, 2001.

[2] D.E. Hillman. *Neuronal shape parameters and substructures as a basis of neuronal form*, volume The neurosciences, Fourth Study Program. The MIT Press, Cambridge, MA, 1979.

[3] Idan Segev and Michael London. Untangling dendrites with quantitative models. *Science*, 290:744–749, 2000.