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Systematic mapping of neural function to morphology

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The dendrites of neurons in animal brains display a wide variety of shapes and branching patterns both across different animal species as well across different brain structures and cell types within each species. This diversity of dendritic shapes presumably parallels the diversity of dendritic computational functions. Although some function – structure relationships are understood, there is no general insight in how dendritic functions, such as the integration of synaptic signals, are fulfilled differently by different dendritic morphologies. We have previously developed two methods for finding dendritic structures optimized for a given computational function ([1] and [2]). Both methods implement a recursive algorithm that represents dendritic morphology in a compact manner, by an L-System as in [3]. Then, Genetic Algortihms (GAs) are used to find L-Systems [2] or its parameters [1] so that the resulting dendritic morphology fulfills a certain computational function chosen by the user. Dendritic function was assessed using multi-compartmental models using NEURON [4].

We have previously shown that this method can reliably find dendrites that sum synaptic potentials linearly [1,2] or react preferentially to one temporal order of synaptic inputs [1]. Here, we first improved this method in order to generate more realistic neural morphologies. Then we used it to systematically explore the mapping of dendritic function to structure. In particular, we investigated the trends in dendritic shapes when neurons were optimized to react preferentially to the temporal order of synaptic inputs, with a range of interval times (Δt = 2, 4, 8, 16, 32, 64 ms). As previously observed, the optimized neurons had two sets of dendrites carrying the synapses activated 1st and 2nd in the preferred temporal order. A systematic, but non-linear, trend emerged in the properties of the two sets of dendrites in the electrotonic length, number of synapses and differential filter properties when Δt was varied. We have thus established a mapping from one axis of function space onto the space of dendritic morphologies.

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