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Modelling and Simulation of the Growth of Neuronal Dendrites in 3-Dimensional Space

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Abstract

The Morphological development of neurons is a very complex process involving both cellular and molecular mechanisms. Computational modelling and numerical simulation of neuronal morphology are invaluable tools for understanding evolvement procedures and structurefunction relationships. The aim of this project is to apply and develop methods of stochastic modelling, Markov chains, for simulating the dendritic morphology of brain neurons in 3-dimensional domains. We examine how dendritic elongation, branching and termination tips in pyramidal neurons are controlled by the birth and death process, with the number of growing dendrites as its state and the appropriate growth, birth, bifurcatioand termination rates. Pyramidal neurons consist of three different kinds of dendrites in terms of their arborisation; namely: 1) basal dendrites, 2) apical and oblique dendrites and 3) tuft dendrites. We present the approach based on the continuous time birth and death process for the basal and tuft dendrites, whereas this method is replaced by a discrete time model for the simulation of apical and oblique dendrites. Simulations are performed to validate each models performance by comparing with the real neuronal cells. It is shown that the models are able to simulate the dendritic arborisation of different parts of pyramidal neuron with respect to the methods described above. These three models are joined after considering the location measurements and a single picture of a pyramidal neuron is created.
Key words: Pyramidal Neurons, Dendritic Arborisation, Markov Chains, Discrete and Continuous Time Birth and Death Process.

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