Title: Statistical modeling of neuron dendrites: stochastic model and simulation algorithm

Speaker: Iana Bondarenko, Valery Turchyn, Dnipropetrovsk National University, Ukraine

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13:15–14:15 and 14:15~ Coffee/Tea

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Abstract:

The problem of creation a neural network is a perspective problem of the present time. It includes the study of biological neurons, the development of a mathematical model of the neuron dendrites and neural network concepts. Neuron (nervous cell) is the basic functional and structural element of the nervous system. It receives signals coming from the receptors and other neurons, processes and sends them in the form of impulses to neural ends that control the activities of executive organs. Information is accepted with branching structures (these structures are called dendrites). Information is transferred with long branch (this structure is called axon). Axon branches approaching to other nerve cells and forms numerous ends on the soma and dendrites of these cells (these ends are called synapses). A nerve cell receives signals from other neurons with synapses.

A lot of works have been published recently on various aspects of the study of neurons and, in particular, its modeling. The main results in this area associates with the names D. Hillman (USA), H.B.M. Uylings, J. van Pelt, M. van Veen, R. Verwer (Netherlands), A. Dityatev (Switzerland), R. Nowakowski, A. Carriquiry, W. Kliemann, R. Burke, G. Ascoli, J. Krichmar, S. Nasuto, S. Senft, R. Scorcioni (USA) and other.

In present work the stochastic model and the simulation algorithm of dendrite are offered. We used both the generally accepted terminology and new concepts in order to describe the structure of dendrite. Dendrites are considered as ordered sets of segments, each segment ends with a bifurcation point or an endpoint of the dendrite. Dendrites are characterized by numerical characteristics: length of segments, angles between segments, angles between links, the distance between subtrees and others. All these characteristics are random variables.

A stochastic model of the dendrite is given by distribution of the angle between the parent and daughter segments, distribution of intermediate angle, distribution of the angle between the

Fig. 1. Dendrites of Purkinje cells from guinea pig cerebellar cortex
root and parent segments, distribution of the link length, bifurcation probability, probability of continuation of segment’s growth without subtrees, probability of continuation of segment’s growth with subtrees, probability of occurrence of subtree on the segment, probability of forming segment as segment without subtrees, probability of forming segment as segment with subtrees, probability of the intersection of the segment’s "corridor", distribution of dendrite radius.

The general simulation algorithm of dendrite consists of the simulation algorithm of segment’s link, the simulation algorithm of segment without subtrees, the simulation algorithm of segment with subtrees, the simulation algorithm of subtree. The segment of the dendrite is simulated as polygon with a random link length and a random number of links. The concepts of probability of continuation of segment’s growth (with subtrees, without subtrees) and an intermediate angle allowed us to simulate segments with real geometric form "step by step".

The influence of the basic numerical characteristics of probability model on the dendritic form and on the values of the emergent characteristics of dendrite is investigated. The influence of the basic characteristics illustrated by numerous implementations of the dendrite. The series of implementations begins with realisations obtained using a model with almost all deterministic characteristics and ends with realisations obtained using a model with all stochastic characteristics.

The work of algorithm and the adequacy of probability model of dendritic tree are verified on the example of Purkinje cells from guinea pig cerebellar cortex. The adequacy of the description of real dendrite by model is established by check of statistical hypotheses about concurrence of distributions and parameters of distributions of the basic and emergent numerical characteristics of model and real dendrite.

References


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