New System of Parallel and Biologically Realistic Neural Simulation

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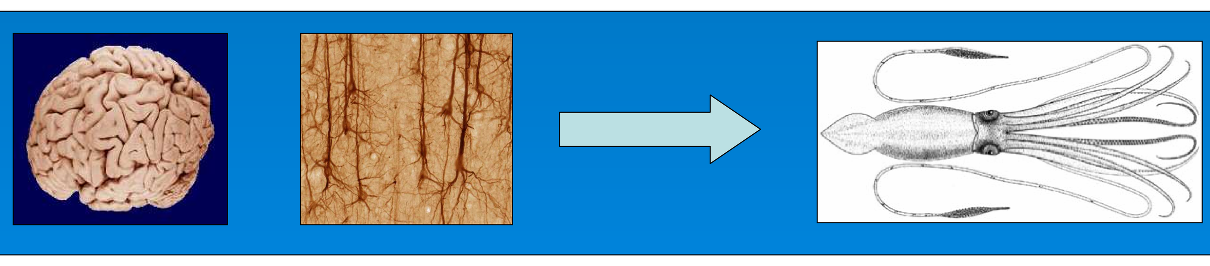
Mammalian brains are one of the most complicated complex systems in the known Universe. Human brain consisting of 1011 neural cells (neurons) has 1014 degree of complexity and it is responsible for the origin of consciousness, mind, intelligence and other higher psychical functions. Even partial understanding of the brain functionality would allow for treatment of many diseases, creation of new generation of neural prothesis and explaining a wide range of cognitive phenomena lasting for centuries in mankind interest.



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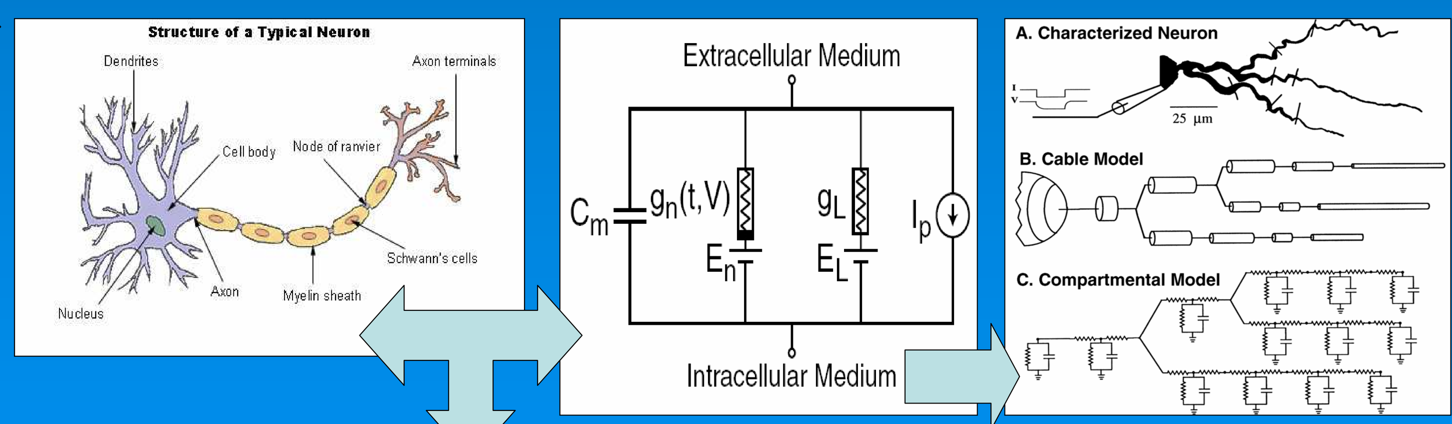
From the physics point of view each neuron is a complicated computational unit and can be simulated in computers. However, in the biologically realistic Hodgkin-Huxley (HH) model each neural cell is represented by set of several (sometimes several thousands) non-linear differential equations describing the behaviour of so-called neuron-equivalent electrical circuit. These equations can be solved only in numerical way. Simulations of neural networks consisting of thousands of biologically realistic HH neurons is always power consuming and good parallelisation of algorithms is required. Nevertheless we are still unable to simulate the whole brain in satisfactory detail.



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There are several neural simulators (i.e., GENESIS, NEURON) using parallelisation techniques for modelling, however, their effectiveness is relatively low. They use script language that creates the model during the simulation and often the process of model creation takes longer than the simulation itself. Models implemented in this way cannot be used for solving other problems that they were originally dedicated to, their modification is relatively difficult. Simulators have been developed by many people for several years, mainly in C or C++, which also must have had some influence on their stability and efficiency.

3

$$C_m \frac{dV_m}{dt} = \frac{(E_m - V_m)}{R_m} + \sum_k [(E_k - V_m) G_k] + \frac{(V_m' - V_m)}{R_a'} + \frac{(V_m'' - V_m)}{R_a} + I_{inject.}$$

$$G_{Na} = \bar{g}_{Na} m^3 h \qquad G_K = \bar{g}_K n^4 \qquad \frac{dm}{dt} = \alpha_m(V)(1-m) - \beta_m(V) m$$

$$\frac{dh}{dt} = \alpha_h(V)(1-h) - \beta_h(V) h \qquad \frac{dn}{dt} = \alpha_n(V)(1-n) - \beta_n(V) n$$

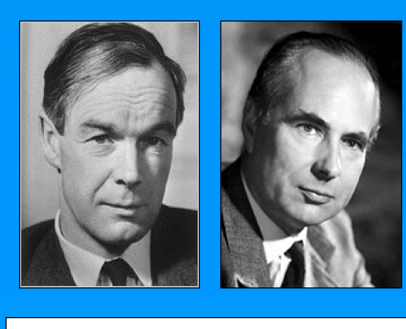
5

We present the idea of new system for neural simulation. The main task of the project was to design the software making possible elastic development of large models by different groups of researchers. As natural consequence of high computational requirements, the system is optimised for parallelisation with use of cluster and heterogeneous grids. Using **Java**TM, software engineering techniques and parallelisation optimisation we created the system consisting of two main and **separate** modules: the **model constructor** and the **simulator**.

GENESIS NEURON Java

DEVELOPED IN LUBLIN

SNNML
Simple Neural Network Modelling Language



Hodgkin–Huxley Model

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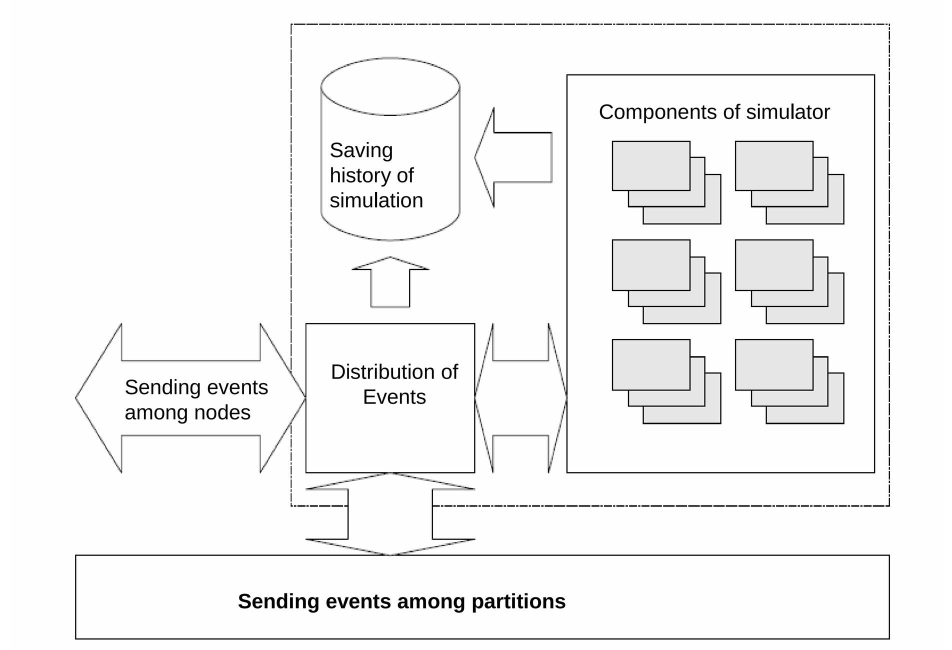
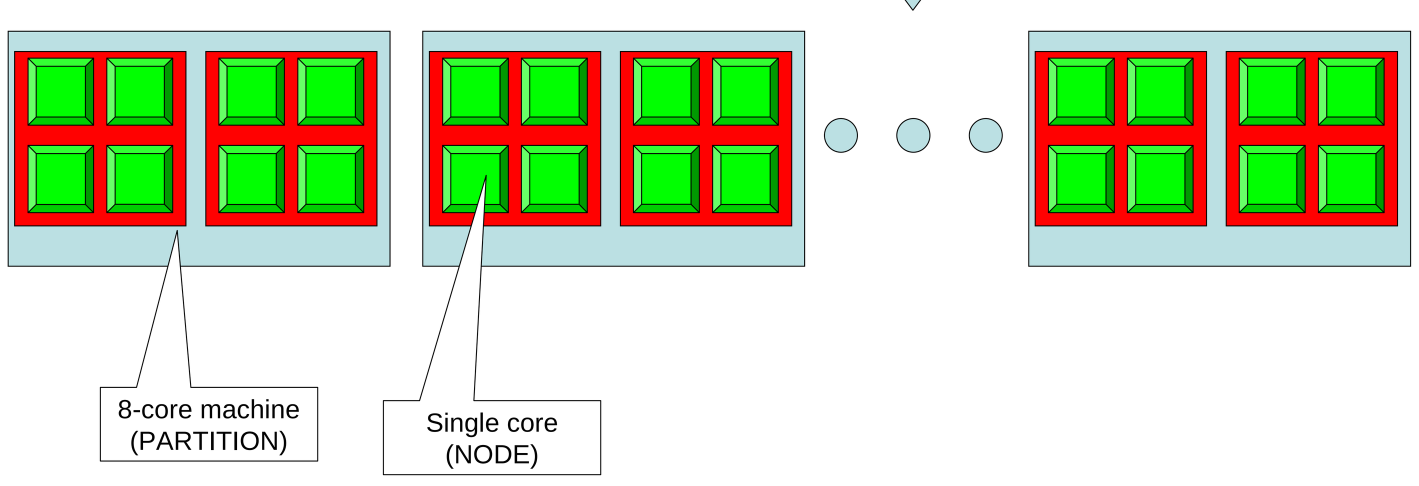
Components of simulator are compiled before the simulation. Each neuron can be a typical component. Thanks to the early compilation we achieve high computational efficiency in solving HH equations. The generated code is specialised for particular types of cells and ionic channels.

Then the simulation is split to many nodes (processors in one machine) and then into partitions (other multiprocessor machines).





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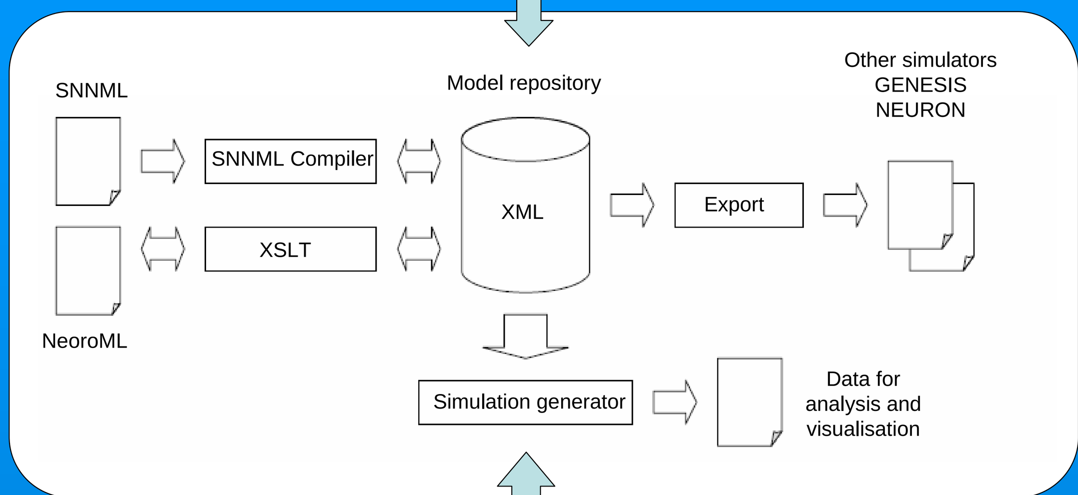
The application works on models kept in XML Universal Repository. Models can be written in newly developed language SNNML or in NeuroML with a possibility of exporting them to commonly used GENESIS and NEURON simulators.



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The model (network itself, architecture of connections, morphology of cells) is compiled before the simulation starts, such an approach shortens the simulation time.

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To remember: In old declarative simulators (GENESIS, NEURON) models are constructed during the simulation. Quite often, constructing the model takes much longer then the simulation itself. Our Java-based object oriented approach is easier to parallelise, more intuitive from the modeller's point of view, compatible with existing software (possibility of script generation) and much faster. What's more, thanks to the separation of model creator and simulator, the script is clearer and except the imagination there are no limits for designing completely new computational experiments.

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[3] Neuron website: http://www.neuron.yale.edu/neuron/

[4] and… www.wikipedia.org ;-)

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