Software tool for modelling coding and processing of information in auditory cortex of mice

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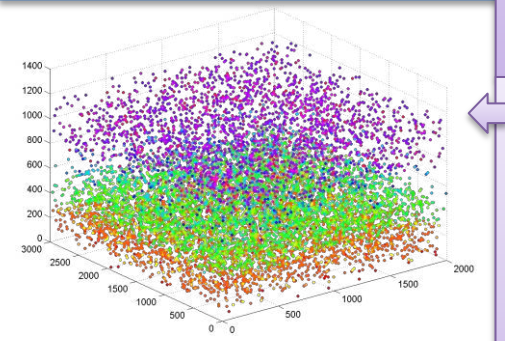
Motivation

- Coding and processing of information in the Auditory Cortex (AC) is still poorly understood.
- A computer model could help to understand these processes.
- The few existing AC models are very limited (in size, plausibility, neuron types, connectome, and duration of experiments).



Main Goals

- To develop a **simulator** suitable for AC modelling.
- To design and create a **model** of the AC in the developed simulator.
- To design and run **experiments** in order to test and describe basic features of the model.

Results: Simulator

- Allows to create, run and analyse neural network models with spiking neurons. It supports neural networks with any structure, neuron distribution and connectome, i.e., not only AC models.
- Supports features required by our AC model (Izhikevich neuron model, STDP).
- Is implemented in a modular hierarchical architecture suitable for easy designing and adding new models.
- Contains many performance optimizations and built-in parallelization.
- Is suitable for large networks (we tested up to **10^5 neurons** and nearly 21 millions of synapses; 1 s of simulation time lasted 34 s of real time).
- Allows batch processing of more experiments.
- Contains a simulation part and comprehensive additional tools for analysis of the results.

Results: Model of the Auditory Cortex

- Corresponds to the primary auditory cortex (A1) of mouse with layers L1-L6.
- Uses a state-of-the-art model of neuron by E. Izhikevich and long-term synaptic plasticity STDP.
- Features diverse neuronal types (17 types). Their distribution, the network structure and the connectome is based on real data.
- Comprises a model of spontaneous synaptic release based on published observations from the real AC.

Results: Experiments

- Dozens of testing and 50 final experiments, up to 5 h of simulation time each.
- Validation and exploration purposes.
- General measured features: development of firing rate, global and local oscillations (waves), excitatory synaptic weights, spike-time raster plot.
- Features related to tonotopy (auditory specific phenomenon): receptive fields, best and characteristic frequencies, degree of local heterogeneity.

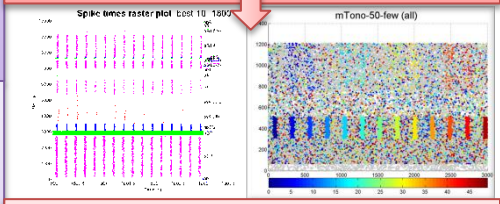
Experimental Findings

Validation experiments:

- Measured features and their development corresponded to data from in vivo, in vitro and in silico experiments.

Exploration experiments:

- New interesting observations (alternating synchronous and asynchronous states; emergence of tonotopy).



Contribution

The thesis presents, to our knowledge:

- The **first sizeable model** of AC.
- The **first simulator specialized** in AC modelling.
- **New explanation** of emergence of different degrees of tonotopy.

The results of the thesis initiated a follow-up study and a preparation of a journal publication, on which we are working in cooperation with AS CR.