Spatio-Temporal Membrane Potential and Resistive Current Reconstruction from Parallel Multielectrode Array and Intracellular Measurements in Single Neurons

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Here we show that we have developed a novel mathematical data analysis method to determine spatio-temporal distribution of neuronal membrane potentials and the distribution of membrane current components during brain activity. My interdisciplinary presentation will incorporate a unique mathematical model, a software programming solution, and an innovative measurement procedure as well. Our model is based on the inverse solution of Poisson equation, via calculating the spatio-temporal solution of partial differential equations from one-dimensional voltage dataset. Based on parallel multichannel extracellular and single-channel intracellular potential recordings, it is possible to reconstruct the spatio-temporal distribution of membrane potential with the spatial resolution of the extracellular recordings in a single neuron. Moreover, we show, that reconstruction of intracellular membrane potential made possible the distinction between two components of the current source density (CSD): the resistive and the capacitive currents. This distinction would provide a clue to the proper interpretation of the CSD distribution, as the resistive component corresponds to the active channel currents, both synaptic and voltage-sensitive channel membrane currents, while capacitive current corresponds to the passive counter currents. The importance of this distinction is further emphasized by different features of the resistive membrane current distribution compared to the CSD. As the CSD is a net membrane current, the sum of the CSD along a whole intact cell should be zero at each time moment, according to the charge conservation law. In contrast to this, the sum of the resistive current should not be necessarily zero since it governs the membrane potential dynamics. Thus, estimation of the spatial distribution of the resistive membrane current makes possible the distinction between active and passive sinks and sources of the CSD map and localization of the synaptic input currents, which makes the neuron fire. I am going to validate our reconstruction approach on simulations and demonstrate its application on simultaneous and co-localized rat brain slice recordings. I am going to show our results of the digital spatio-temporal reconstruction. The algorithm has more dynamic purposes as well.

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