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Poster presentation

Robust short-term memory in the neuronal field model involving nonlinear dendritic integration

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Several studies has suggested that a single dendritic branch can be a computational subunit which locally integrate the synaptic inputs to produce dendritic action potential (dAP) [1]. In the present study, we investigate the influence of dAPs on the network dynamics by using a neuronal two-field model incorporating the dendrite nonlinearly. We discuss functional significance of the unique dynamics present in our model.

Our network model consists of two fields (Figure 1): (1) somatic field representing a squarely arrayed soma of neurons whose dynamics are described by the Izhikevich model [2], (2) dendritic field representing a squarely arrayed dendritic branches whose long-lasting Ca^{2+} action potentials are described by the Morris-Lecar model. The dynamical variables actually sit on lattice points placed in the two fields. Each soma on the somatic field innervates to a disk-shaped area in the dendritic field according to the observed axonic arborization and a disk-shaped area on the dedritic field in turn delivers dendritic currents to each soma on the dendritic field according to the observed dendritic arborization. Actual innervation to the dendritic field from a given soma and current injection from the dentric field to the soma are determined probabilistically according to Gaussian distributions with different widths. The soma-to-dendrite signaling happens only when the somatic action potential (sAP) occurs. The dendrite-to-soma signaling happens continually. A particularly strong signal is sent from the dendritic field when dAP occurs. We test long and short durations of dAP since a wide ranges (up to a few hundreds of msec) of dAP duration have been reported [3].

First, we studied the network dynamics of the model in response to constant external currents with short-lasting or long-lasting dAP. In both cases, we observed the spatially clustered patterns of sAPs, which were gradually deformed. The deformation was slower in case of the long-lasting dAP than in the case of the short-lasting dAP. However, the difference did not simply reflect the difference in the time constants of the two dynamics. Next, we applied the external strong noise to somatic field. As expected, noise destroyed patterns rapidly in the case of the short-lasting dAP. Surprisingly however, in the case of long-lasting dAP, the pattern was more robustly preserved than in the noiseless case. We expect that this robustness has advantage for information storage, thus may lead to novel mechanism for short-term memory. Figure 2.

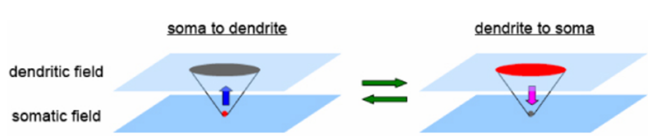

Figure 1
Two-field model. The blue and magenta arrow expresses the synaptic inputs to and the dendritic currents from the subpopulation of dendritic field, respectively.

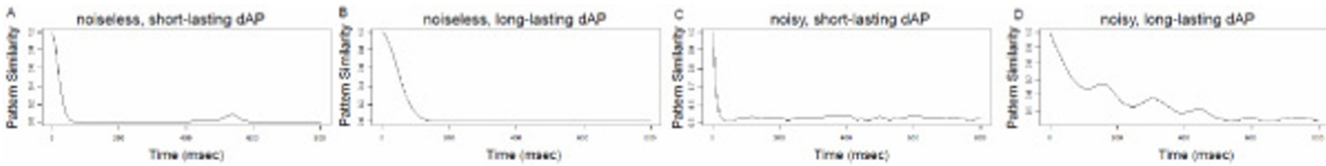

Figure 2
Measuring the persistence of spatial patterns based on the similarity between the patterns at different points in time.

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