Topic: 2 oral

The Neural Code in Developing Cultured Networks: Experiments and Advanced Simulation Models

W.L.C. Rutten, T.A. Gritsun, I. Stoyanova and J. leFeber

Neural Engineering Dept., University of Twente, Enschede, The Netherlands

Background

Understanding the neural code of cultured neuronal networks may help to forward our understanding of human brain processes.The most striking property of spontaneously firing cultures is their regular bursting activity, a burst being defined as synchronized firing of groups of neurons spread throughout the entire network. The regularity of bursting may change gradually with time, typically being stable over hours (Stegenga et al. 2008). Cultured cortical networks composed of many thousands of neurons show bursting behavior starting from the end of the first week in vitro. Bursts can be characterized by both intraburst parameters (burst shape, maximum firing rate, leading and trailing edge steepness, etc.) and interburst parameters (statistics, stability of burst rates) (Van Pelt et al. 2004; Wagenaar et al. 2006). Not only the temporal burst characteristics develop with time. Also, spatial burst propagation patterns, socalled ''burst waves'', change with age of the network.

Methods

In (Gritsun et al. 2010) we modeled the intraburst phenomena, whereas in (Gritsun et al. 2011) we focused on the interburst intervals (IBIs). The spiking activity model used basically consists out of the ''Izhikevich neuron" model for individual neurons and a connectivity matrix of randomly positioned neurons. Recently, by adding a biologically realistic neuronal growth model (with and without field-guided axonal bundling) we structured the position and outgrowth of neurons. By integrating the growth-spatial model with the spiking activity model, we modeled the development of bursting behavior, both in time and space, for networks with 50000 neurons or more.

Results

The integrated model yielded realistic activity patterns, such as bursting patterns. Bursting activity (their spread, as well as their development in time) was validated against experimental recordings obtained from cortical neuronal cultures. This integrated network model enabled us also to visualize the 'wave-like' spatial propagation of bursts. Depending on network size, wave reverberation mechanisms were seen along the network boundaries. These reverberations may explain the generation of phases of elevated firing before and after the main phase of the burst shape and they may explain the occurrence of very short inter-burst intervals.

References

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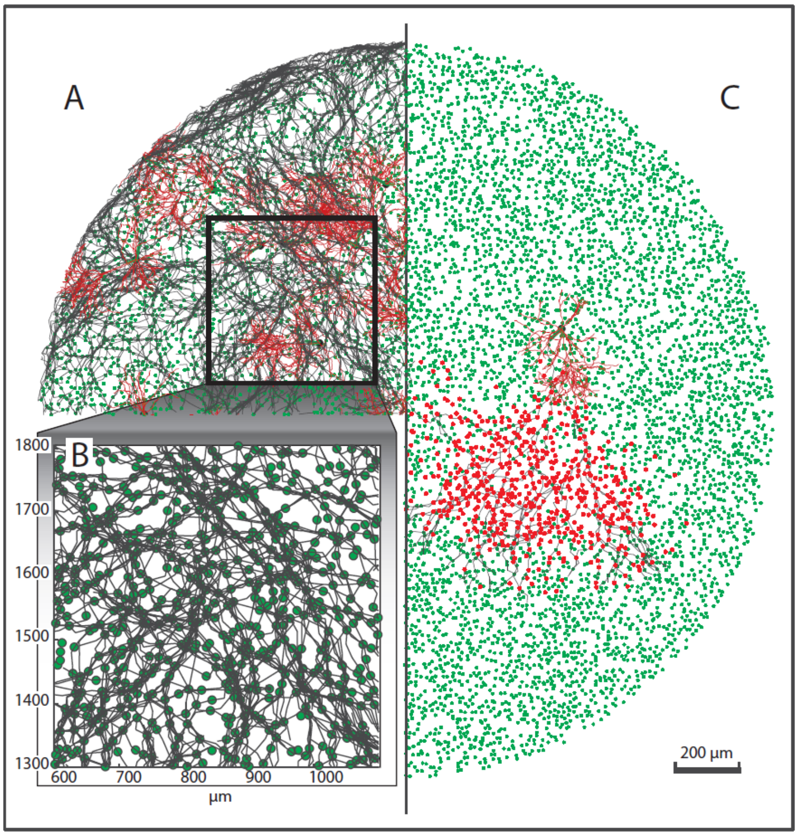

Figure 1. Simulation of neurite morphology in the field guided network of 10,000 neurons. A: The neuronal somas are indicated in green. For 0.5% of these neurons, marked with a large black dot, the neurite structures are shown: axons (black) and dendrites (red). B: Close-up of A, showing bundles of axons that occur in field guided growth models. C: Axon (black line) and dendritic tree (red lines) of a pyramidal neuron (large black dot). Neurons that receive input from this pyramidal neuron are indicated by blue dots.

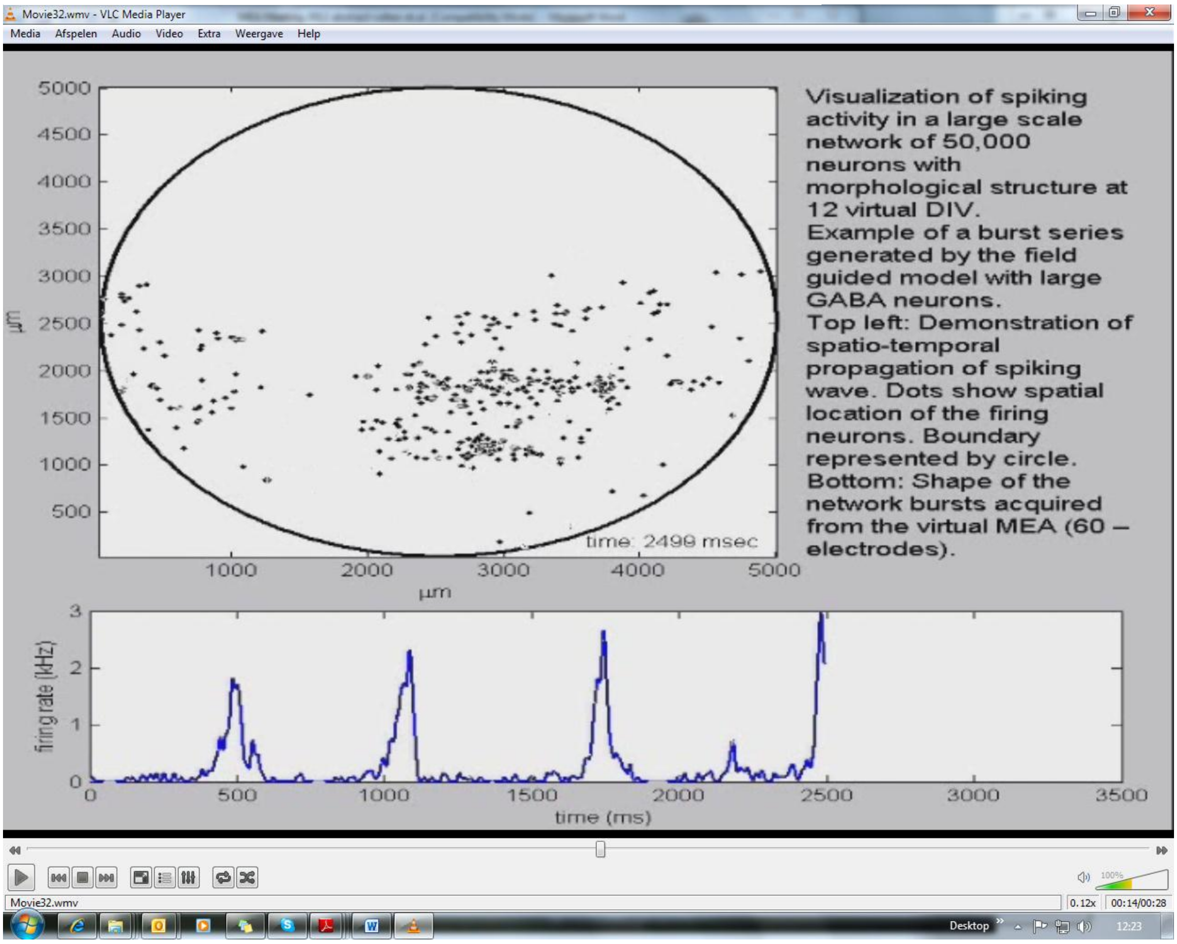

Figure 2. The integrated model at work: snapshot at time 2500 ms of a visualization movie of a burst wave.