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Title

Construction and simulation of an open cortical multi-area model at cellular resolution

Abstract

The mammalian brain exhibits universality. In evolution the cortex has increased in volume from mouse to man by three orders of magnitude, while the architecture at the local scale of a cubic millimeter has been largely conserved in terms of the multi-layered structure and the density of synapses. Furthermore, local cortical networks are similar independently of whether an area processes visual, auditory, or tactile information. At the brain scale, the areas again form a hierarchical recurrent network, and the area-specific cellular and laminar composition of the network is related to the connectivity between areas. This gives us hope that fundamental mechanisms of cortical computation can be discovered. So far an integrated view of the construction principles is, however, missing. Our recent modeling study [1] integrates architectural and axonal tracing data into a multi-scale framework describing one hemisphere of macaque vision-related cortex at cellular resolution. This brain structure contains about 1 billion neurons, the limit of what supercomputers can simulate today but too costly for routine work. Therefore, our model represents each of the 32 areas by just one microcircuit of about 100,000 neurons. Simulations [2] confirm that brain activity is compatible with in-vivo resting-state data on multiple levels from spiking activity to fMRI. Further increasing model size requires progress in simulation technology. Code [3] developed in collaboration with the post-K computer project makes the memory consumption of the individual compute nodes of a supercomputer fully independent of total network size, as needed for

exascale systems. Still, the microscopically parallel brain challenges supercomputers. Achieving real-time or accelerated speeds as desirable for studies of plasticity and learning is difficult. Neuromorphic computing promises an alternative as we recently indicated by porting a full-scale microcircuit model to SpiNNaker [4]. Brain-scale models require the collaboration of researchers because of the amount and heterogeneity of the data that need to be aggregated. Furthermore, the executable model description is not sufficient for the publication of findings. Researchers can only add data to the model or modify assumptions if they have access to the process of model construction. Borrowing techniques from computer science and systems biology [5] we present a digitized workflow of model construction reproducing all figures of our respective publications. We are confident that the open digital availability of brain-scale models serves the development of neuromorphic hardware by providing science cases and platforms for the integration of ideas on particular brain functions. The repository of the model is https://inm-6.github.io/multi-area-model and a tutorial video is located at https://youtu.be/YsH3BcyZBcU.

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Biography

Prof. Dr. Markus Diesmann is director of the Institute of Neuroscience and Medicine (INM-6, Computational and Systems Neuroscience), director of the Institute for Advanced Simulation (IAS-6, Theoretical Neuroscience) and director of the JARAInstitute Brain structure-function relationships (INM-10) at Jülich Research Centre, Germany. He is also full professor in Computational Neuroscience at the School of Medicine, RWTH University Aachen, Germany and affiliated with the Department of Physics at the same university. Prof. Diesmann studied physics at Ruhr University Bochum with a year of Cognitive Science at University of Sussex, UK. He carried out his PhD studies at Weizmann Institute of Science, Rehovot, Israel, and Albert-Ludwigs-University Freiburg. In 2002 he received his PhD degree from the Faculty of Physics, Ruhr-University Bochum, Germany. From 1999 Prof. Markus Diesmann worked as senior staff at Department of Nonlinear Dynamics, Max-Planck-Institute for Dynamics and Self-Organization, Göttingen, Germany. In 2003 he became assistant professor of Computational Neurophysics at Albert-Ludwigs-University, Freiburg, Germany before in 2006 joining the RIKEN Brain Science Institute, Wako City, Japan as a unit leader and later team leader. In 2011 Markus Diesmann moved to Jülich. His main scientific interests include the correlation structure of neuronal networks, models of cortical networks, simulation technology and supercomputing. He is one of the original authors of the NEST simulation code and a member of the steering committee of the NEST Initiative.