Usage Report for Fiscal Year 2019

Project Title:
Development of cortico-thalamic circuits
Name:

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1. Background and purpose of the project, relationship of the project with other projects

In mammals' brain, cortico-thalamic circuit is a crucial part that performs information processing in cognitive function including decision making, sensory processing, and motor control. In the exploratory challenge 4 on Post-K Computer project (Understanding the neural mechanisms of thoughts and its applications to AI), we have been developing a large-scale brain simulation model of cortico-thalamic circuit. In HOKUSAI system, we investigated information processing mechanism in primary somatosensory cortex model and primary motor cortex model.

2. Specific usage status of the system and calculation method

We implemented a cortical-thalamic circuit model using NEST simulator on HOKUSAI supercomputer. NEST simulator 2.14, 2.16, 2.18. and 3.0 versions were used in HOKUSAI Big Water Fall system. Cortical-thalamic circuit consisted of primary somatosensory cortex, primary motor cortex and the thalamus. We used leaky integrate-and-fire neuron model for describing the state of a neuron in terms of its membrane potential and conductance-based synapse model with alpha-function for synaptic conductance, and the step size for numerical integration was set to 0.1 ms. We used 2D Gaussian function for describing the connection probability functions.

3. Result

For primary somatosensory cortex model (S1 model), we investigated the mechanism for generating surround suppression in the superficial layer of the model. We found wider spatial extents of connections pyramidal neurons (Pyr neurons) to somatostatin neurons (SST neurons) resulted in activation of SST due to spatial summation. The activation of SST caused suppression of Pyr and PV as in real physiological experiments (Figure).

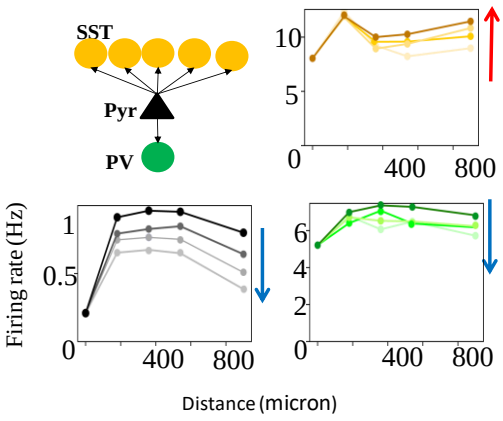

Figure Spatial summation and surround suppression through SST.

4. Conclusion

We investigated surrounding suppression phenomenon in S1 model. The simulation results suggest that the wider spatial extents of connections Pyr to SST than that of connections Pyr to PV may work for spatial summation and surround suppression in selection of signals.

Weak scaling performance of S1 model was also tested on HOKUSAI supercomputer with NEST simulator.

5. Schedule and prospect for the future

The secondary somatosensory cortex and the secondary motor cortex will be implemented in our next fiscal year's research. We will also test integrated cortical model includes primary somatosensory cortex and primary motor cortex model to investigate

Fiscal Year 2019 List of Publications Resulting from the Use of the supercomputer

[Paper accepted by a journal]

Igarashi J., Yamaura H., & Yamazaki T. (2019) Large-Scale Simulation of a Layered Cortical Sheet of Spiking Network Model Using a Tile Partitioning Method, Front. Neuroinform., 29.

[Conference Proceedings]

Igarashi J., Yamaura H., & Yamazaki T., Parallel computing of a cortio-thalamo-cerebellar circuit using tile partitioning parallelization method by MONET simulator. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Gutierrez C., Gutierrez C., Sun Z., Yamaura H., Heidarinejad M., Igarashi J., et al. A whole-brain spiking neural network model linking basal ganglia, cerebellum, cortex and thalamus. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Hedarinejado M., Sun Z, & Igarashi J. Hierarchy of inhibitory circuit acts as a switch key for network function in a model of the primary motor cortex. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Sun Z., Hedarinejado M., & Igarashi J. Spatially organized connectivity for signal processing in a model of the rodent primary somatosensory cortex. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Yamaura H., Igarashi J., & Yamazaki T. Building a spiking network model of the cerebellum on K computer using NEST and MONET simulators. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Gutierrez C., Gutierrez C., Sun Z., Yamaura H., Heidarinejad M., Igarashi J., et al., A spiking neural network model of the whole-brain circuit linking basal ganglia, cerebellum and cortex, Annual Meeting of the Japan Neuroscience Society (Neuro*2019), July 25-28, 2019, Niigata, Japan.

Sun Z., Hedarinejado M., & Igarashi J., Spatial summation of excitatory and inhibitory signals in a model of the rodent primary somatosensory cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

Igarashi J., Yamaura H., & Yamazaki T., Parallelization of building spiking neural networks in MONET simulator, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

Sun Z., Hedarinejado M., & Igarashi J., Spatial summation of excitatory and inhibitory signals in a model of the rodent primary somatosensory cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

Hedarinejado M., Sun Z, & Igarashi J., Switches of activation in hierarchical inhibitory circuitry in simulated primary motor cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

[Oral presentation]

Jun Igarashi. Parallelization method of cortico-thalamo-cerebellar circuits toward exascale computing. Neuromodulator of neural microcircutis NM2, 2019, Champery, Switzerl.

Gutierrez C., Sun Z., Yamaura H., Heidarinejad M., Igarashi J., et al., Large-scale simulation of a spiking neural network model consisting of cortex, thalamus, cerebellum and basal ganglia on K computer, NEST conference 2019, June 24-25, 2019 , Ås, Norway.

Sun Z., Hedarinejado M., & Igarashi J., Spatial summation of excitatory and inhibitory signals in a model of the rodent primary somatosensory cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

[Poster presentation]

Igarashi J., Yamaura H., & Yamazaki T., Parallel computing of a cortio-thalamo-cerebellar circuit using tile partitioning parallelization method by MONET simulator. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Gutierrez C., Gutierrez C., Sun Z., Yamaura H., Heidarinejad M., Igarashi J., et al. A whole-brain spiking neural network model linking basal ganglia, cerebellum, cortex and thalamus. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Hedarinejado M., Sun Z, & Igarashi J. Hierarchy of inhibitory circuit acts as a switch key for network function in a model of the primary motor cortex. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

Sun Z., Hedarinejado M., & Igarashi J. Spatially organized connectivity for signal processing in a model of the rodent primary somatosensory cortex. Computational Neuroscience (CNS*2019), July 13-17, 2019, Barcelona, Spain.

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Sun Z., Hedarinejado M., & Igarashi J., Spatial summation of excitatory and inhibitory signals in a model of the rodent primary somatosensory cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.

Hedarinejado M., Sun Z, & Igarashi J., Switches of activation in hierarchical inhibitory circuitry in simulated primary motor cortex, Annual Conference of Japanese Neural Network Society (JNNS*2019), September 4-6, 2019, Tokyo, Japan.