Usage Report for Fiscal Year 2018

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 tested the scaling performance of the cortico-thalamic model implemented on NEST simulator.

２． Specific usage status of the system and calculation method

We implemented a cortical-thalamic circuit model using NEST simulator on HOKUSAI supercomputer. Both of NEST 2.14 and 2.16 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

Firstly, we tested the minimal size (1 mm^2 with 164986 neurons) of cortical-thalamic neural network simulation. The simulation run successfully in HOKUSAI system on one compute node with 40 CPU cores. Then, we carried out weak scaling performance test for 1~ 5 mm^2 of the cortical-thalamic circuit using 1 ~30 nodes. We were able to scale up to the model with 4119700 neurons using 32 compute nodes. However, the computational time lineally increased with increase in compute nodes although compute time is expected to be constant in ideal case of weak scaling test. This result suggests that there is still a room for improvement in terms of computational time.

Next, in order to investigate spatial properties of excitatory and inhibitory signals in somatosensory cortex, we developed a slice model of somatosensory cortex and compared the response in simulation with the real experimental results. The result suggested that spatial extents of different connections may cause spatially coupled excitation and inhibition, which may lead to cooperative information processing by excitation and inhibition.

４． Conclusion

We tested computational performance of simulation of cortico-thalamo circuits on HOKUSAI and confirmed scaling-up of the network using 32 compute nodes. We also investigated spatial properties of excitatory and inhibitory signals in somatosensory cortex.

５． Schedule and prospect for the future

The subcortical regions and secondary somatosensory cortex will be implemented in our next year's research. We will investigate mechanism of information processing by interaction among the brain regions and test the scaling performance using thousands of compute nodes in the next fiscal year.

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Fiscal Year 2018 List of Publications Resulting from the Use of the supercomputer

[Conference Proceedings]

1. Zhe Sun and Jun Igarashi, A Virtual Laser Scanning Photostimulation Experiment of the Primary Somatosensory Cortex, proceeding of 28th Annual Conference of the Japanese Neural Network Society, 2018.

[Oral presentation]

1. Zhe Sun, Jun Igarashi, Research of human-scale cortical simulations for supercomputer, the 1st International Forum on Psychological Science and Human Factors, invited talk, 2018.

[Poster presentation]

1. Morteza Heidarinejad, Zhe Sun and Jun Igarashi, Development of simulation platform for multiple cortico-thalamic circuits using pyNEST, Advances in Neuroinformatics, 2018.
2. Zhe Sun and Jun Igarashi, Spatial property of excitation and inhibition in a spatial neural network of the rodent primary somatosensory cortex, Advances in Neuroinformatics, 2018.