Usage Report for Fiscal Year 2020

Project Title:

Development of a neural network model of cortico-thalamic circuit.

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

The cortico-basal ganglia-thalamic circuit is one of fundamental network in the brain. It performs information processing in cognitive function including decision making, sensory processing, and motor control. In this fiscal year, we introduced more physiological experiments data for the primary somatosensory cortex model (S1) construction. Then, we investigated sensory information process mechanism with the updated S1 model. In addition, we investigated a whole brain loop circuit which included cerebral cortex, basal ganglia, cerebellum, and thalamus (CBCT model) collaborating with teams headed by Prof. Doya (OIST) and Prof. Yamazaki (UEC).

２. Specific usage status of the system and calculation method

We implemented the cortical-thalamic circuit model using NEST simulator on HOKUSAI supercomputer. All of neuron model, synapse model and distance-dependent connection models were implemented by NEST simulator. NEST 2 and 3 versions were tested in HOKUSAI Big Water Fall system. Both of thread-parallel simulation (OpenMP based) and distributed simulation (MPI based) were used for parallelization in the system. For the cortical-thalamic model, leaky integrate-and-fire (LIF) neuron model was used for all neuron types with conductance-based synapses. Spatial extents, probabilities, and connectivity from the reports of laser-scanning photo-stimulation experiments and patch clamp recordings were used to build the connectives in the cortical simulation.

3. Result

3.1 Simulation of primary somatosensory cortex

For the new version of S1 model, we realized resting state activity using Poisson noise generators. The reasonable firing rates of different neurons was introduced according to results of electrophysiological experiments. Then we implement a virtual LSPS experiment in S1 model. The model showed similar response shown in the real LSPS experiments of S1. The results also gave LSPS map for inhibitory input to inhibitory interneurons that has not been measured in real experiments and can be compared with experiments in future. We investigated relation of excitation and inhibition balance at superficial and deep layers by mimicking laser stimulations. The result exhibited similar decays of excitatory and inhibitory signals with increase in distance between stimulation site and neuron positions as measured in experiment.

3.2 Simulation of CBCT circuit

To examine interactions between brain regions, such as cerebral cortex, basal ganglia, cerebellum, and thalamus, we have developed CBCT models using Hokusai. In this fiscal year, we adjusted the inter-reginal connections and the levels of Poisson noise in CBCT model to reproduce the resting state neural activities. We confirmed signal propagation from cerebral cortex to basal ganglia and cerebellum. The signal propagation accompanied propagation of oscillatory components as observed in the experiment.

3.3 Porting of CBCT model to NEST3

Next-generation of NEST 3 has new features to perform an efficient calculation and further scaling-up of spiking neural network simulation. In order to utilize the features to CBCT model, we ported the NEST 2 version of CBCT code to

NEST3 and checked the operation and performance on HOKUSAI BW system. NEST3 improved the elapsed time of simulation and building time of the network. However, the memory consumption slightly increased.

３． Conclusion

We made a new version of S1 model. Several virtual experiments were implemented with the S1 model to investigate how the S1 processes information. We developed CBCT model by connecting S1 model with basal ganglia model, cerebellum model and thalamus model. We reproduced resting-state neural activity of all of the regions and examined interaction among them. We ported to NEST3 and tested performance on Hokusai.

４． Schedule and prospect for the future

In the future we will investigate

In the next step, we will investigate how the inhibitory cells contribute to sensory responses in awake cortex using our S1 model. And we will also corroborate with NEST team and improve the current NEST 3 based CBCT model. The difference of performance between NEST 2 and 3 will be investigated.

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Fiscal Year 2020 List of Publications Resulting from the Use of the supercomputer

[Conference Proceedings]

Carlos C, Sun Z, Hiroshi Y, Morteza H, Jun I, Tadashi Y, Kenji D, Simulation of resting-state neural activity in a loop circuit of the cerebral cortex, basal ganglia, cerebellum, and thalamus using NEST simulator, Annual Conference of Japanese Neural Network Society (JNNS*2020), December 2-5, 2020, Japan.

[Oral presentation]

Carlos C, Sun Z, Hiroshi Y, Morteza H, Jun I, Tadashi Y, Kenji D, Simulation of resting-state neural activity in a loop circuit of the cerebral cortex, basal ganglia, cerebellum, and thalamus using NEST simulator, Annual Conference of Japanese Neural Network Society (JNNS*2020), December 2-5, 2020, Japan.