Usage Report for Fiscal Year 2017

Project Title:

Analyzing computational mechanisms in the brain by recurrent neural networks

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Description of the project

1. Background and purpose of the project

Recurrent neural networks (RNNs) are increasingly popular machine learning tools which have been proposed as theoretical models to capture principles of cortical computation. In addition to being able to account for several properties of neural responses observed in biological circuits, RNNs and their dynamics can be reverse-engineered to address important questions about the underlying computational mechanism at play in neuronal populations (Mante et al., 2013). In addition, the predictions of RNN models can be validated experimentally using modern neuroscience tools such as optogenetic perturbations. Unfortunately, the considerable computational cost of artificial neural network optimization is a well-known bottleneck in performing this type of research, particularly when the training of many models on large-scale neurophysiological data is necessary, leading to the need for suitable computational resources.

2. Specific usage status of the system and calculation method

We used the system to train fully-connected RNN models (Figure 1) on the Application Computing Server. We optimized the parameters of our network (~40,000 connection weights) by minimizing an average least-squares error function, using a customized MATLAB toolbox based on a Hessian-free optimization solver (Martens and Sutskever, 2011).

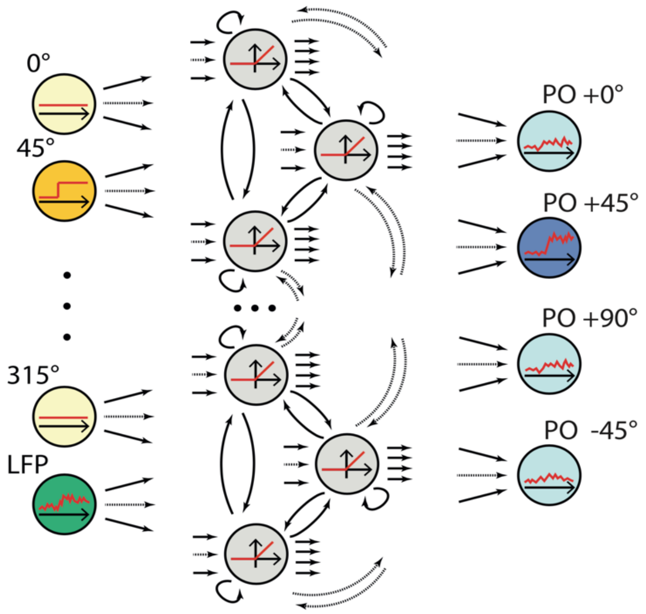

Figure 1: architecture of the RNN model

3. Result

By fitting data recorded from the primary visual cortex (V1) of adult awake mice presented with oriented grating stimuli, we were able to train, under minimal constraints, artificial network models whose response properties were similar, in terms of selectivity to features of visual stimuli (orientation), to those experimentally observed in biological circuits (Figure 2). We expect to be able to improve on these results by using more biologically plausible variants of the RNN models (which will be accomplished by implementing suitable optimization constraints on the model parameters). The results of our research were presented at the 3rd Area Meeting of the "Brain-AI" research initiative, and we expect the project to ultimately lead to the publication of a full journal paper.

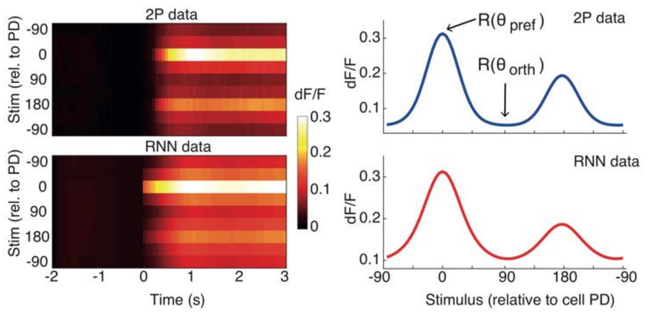

Figure 2: orientation-tuned responses from real data and from the RNN model

4. Conclusion

Although preliminary in nature, our results have been encouraging and suggest the feasibility of using recurrently connected neural networks as credible models to: (1) capture complex properties of visual cortex responses, such as orientation tuning and overall balance between excitatory and inhibitory currents, (2) make testable predictions on the effect of perturbations on the dynamics of neural circuits.

5. Schedule and prospect for the future

During the upcoming Fiscal Year, we plan to continue working on the same topics. We do expect to make significantly more use the system as the amount of data we need to process (and thus the number of models we need to train and their complexity) increases, leading to higher running times and making it difficult to rely on local resources only.

Finally, although the person currently in charge of the ACCC account for this project (EF) will conclude his employment at RIKEN at the end of the current FY, plans have already been made for a new laboratory member to take ownership of this project, which, importantly, will be carried on as described with the same goals.

Fiscal Year 2017 List of Publications Resulting from the Use of the supercomputer

[Others (Press release, Science lecture for the public)]

E. Frandi, T. Tsubota, A. Benucci, "Modeling responses to visual stimuli in the mouse cortex with recurrent neural networks" (poster), Correspondence and Fusion of Artificial Intelligence and Brain Science (Brain-AI), 3rd Area Meeting, December 19, 2017, Hitotsubashi Hall, Tokyo.