A conversation with Professor Dong Song, September 19, 2019

Participants

- Prof. Dong Song - Research Associate Professor, Department of Biomedical Engineering, University of Southern California
- Joseph Carlsmith - Research Analyst, Open Philanthropy

Note: These notes were compiled by Open Philanthropy and give an overview of major points made by Prof. Song.

Summary

Open Philanthropy spoke with Prof. Dong Song of the University of Southern California as part of its investigation of what we can learn from the brain about the computational power ("compute") sufficient to match human-level task performance. The conversation focused on Prof. Song's experience building hippocampal prostheses, and on his views about the level of modeling complexity necessary to reproduce the brain's intelligence.

Hippocampal prostheses

Dr. Song and his collaborators have been working on hippocampal prostheses intended to improve memory. These prostheses are based on a multi-input/multi-output (MIMO) computational model, trained on neural input/output data. These models have had some success in improving performance on memory tasks in rats, monkeys, and humans.

Necessary levels of detail in brain modeling

Some people think that the minimum representation of human intelligence requires highly detailed modeling of the brain's biophysical mechanisms. On some versions of this view, even modeling at the level of single ionic channels is not sufficient. Rather, you need to rely on quantum phenomena to explain how the brain works.

Prof. Song does not believe this. In his view, to replicate intelligence at a level similar to humans (as opposed to some more detailed level of simulation accuracy), you don't need to model quantum phenomena, or ionic channels, or even Hodgkin-Huxley-level dynamics. Rather, a spiking neuron model, with a rich array of input-output behavior, is sufficient.

That said, certain simplified spiking neuron models are probably not sufficient. These included linear integrate-and-fire neurons, the Izhikevich model (a simplified version of the Hodgkin-Huxley model), and the models used in Prof. Song's MIMO model.

You also need a detailed connectivity scheme, both local and global.

Detailed biophysical modeling is still very important. For example, it is valuable for understanding how spikes are generated, for scientific curiosity, and for understanding how to cure neurological diseases.

It would be hard for Prof. Song to prove his view.

Centrality of neuron signaling to brain function

Prof. Song thinks that everyone should agree that neurons are the fundamental computational unit of the brain. If you can replicate all the neuron activity, you'll probably be able to replicate brain function.

Neurons communicate with each other via spikes. Variables internal to a neuron are important to determining the neuron's spiking behavior in response to inputs, but the other neurons do not know or care about these internal variables. So as long as you can replicate the input-output mapping at the level of spiking, you are basically replicating the relevant function of a single neuron. So if you have a good spiking neuron model, and you connect your neurons correctly, you should be able to replicate brain function.

Redundancy of ion channel dynamics

The functional impact of ion channel dynamics in the context of a Hodgkin-Huxley model is highly redundant. This makes Prof. Song think that Hodgkin-Huxley models can be simplified -- e.g. you can replicate the input-output behavior of the Hodgkin-Huxley model, with fewer equations. Indeed, this almost has to be the case.

There are also studies that show that many different combinations of ionic channels can generate the same overall behavior, both for a single neuron and a small neuronal circuit.

Views in the field

A lot of people implicitly believe Prof. Song's view that replicating spiking-level behavior is sufficient for replicating human intelligence, but they never articulate it.

Neuroscientists are also careful about what they say, and their responses will depend on how you frame the question. If you ask: "is replicating neuron spiking behavior enough to replicate brain function, yes or no," most people will hesitate. But if you ask them to vote on the level of detail most relevant to replicating at least the majority of brain function, Prof. Song guesses that most of them would vote on the spiking neuron level.

Alternative signaling mechanisms

There are phenomena in the brain that cannot be explained by spiking activity alone -- for example, field effects. These mechanisms cannot be ruled out as importantly involved in brain function. However, Prof. Song strongly believes that at least the large majority of brain function can be recovered at the spiking neuron level.

Other people to talk to

- Dr. Randal Koene -- Dr. Koene helped launch the company Kernel.

All Open Philanthropy conversations are available at
http://www.openphilanthropy.org/research/conversations