December 10, 2018

Neurobiology

One step closer to brain-like computing

by Sacha van Albada [1] | Group Leader; Markus Diesmann [1] | Director

[1]: Institute of Neuroscience and Medicine, Computational and Systems Neuroscience (INM-6) & Institute for Advanced Simulation, Theoretical Neuroscience (IAS-6) & JARA Institute Brain Structure-Function Relationships (INM-10), Jülich Research Centre, Jülich, Germany

This Break was edited by Reinier Prosee, *Scientific Editor* - TheScienceBreaker

ABSTRACT

Neuromorphic computers take inspiration from the brain to achieve enhanced efficiency. We describe the first full-scale simulation of a patch of cerebral cortex on the neuromorphic system SpiNNaker. This work provides a building block for brain-scale simulations.

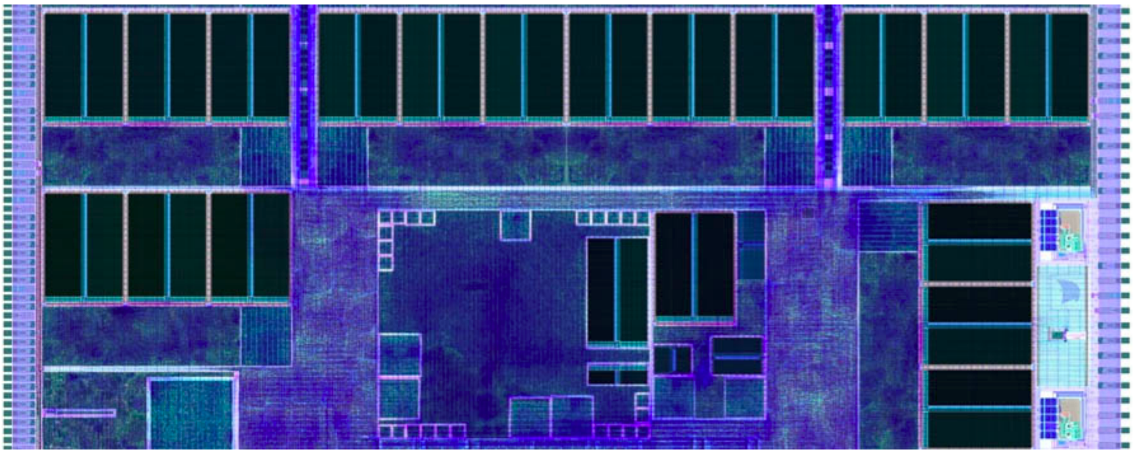

Image credits: Sacha van Albada ©

In many ways, we do not know how the brain processes information. However, we do know that the brain is mighty efficient at what it does. For instance, the human brain consumes only about 20 W, less than a standard light bulb. How does the brain achieve this great efficiency? One feature setting it apart from conventional computers is that it is microscopically parallel and `noisy': A conventional computer carries out operations one by one, whereas nerve cells (`neurons') process whatever comes in at any given time and do not wait for each other. The signal transmissions between neurons can fluctuate in strength and even fail. These aspects of brain processing have inspired novel, so-called `neuromorphic' computing systems, which already enter our lives for instance via vision processors in modern smartphones.

Neuromorphic computers are designed to simulate networks of neurons. Such simulations take the single-neuron properties, the network structure, and the input to the network, and calculate the resulting activity of the neurons. An ultimate challenge is to simulate all of the human brain's billions of neurons and the trillions of connections between them. However, until recently, only small networks and large, but highly simplified networks had been simulated on neuromorphic hardware. In our study, we set out to run a large biologically realistic neuronal network on a neuromorphic computer. The aim was twofold: first, to technically enable the simulations, laying a basis for even larger-scale neuronal network simulations; and second, to characterize the hardware performance in comparison with a conventional computer, to guide further development of the specialized hardware.

For this purpose we used a neuromorphic system called SpiNNaker, which is developed at the University of Manchester in the context of the European Human Brain Project (HBP). One brain-like aspect of SpiNNaker is how it routes signals between neurons. Neurons in the brain convey electrical pulses to other neurons via extensions called axons, which propagate the signals along a `highway' from which smaller `country roads' branch off to the target cells. The signals on SpiNNaker similarly follow a straight path in the general direction of the target cell, until they are told to change direction to head directly to the target. SpiNNaker further mimics the brain by processing signals as they come in and using noisy signal transmission where the signals between neurons can be lost. Like the brain, SpiNNaker thereby trades precision for efficiency. The system has recently been built up to a size of a million processors.

The particular network we implemented represents a patch of mammalian cerebral cortex---the thin layer of cells on the surface of the brain, which is responsible for most complex behaviors. To stay true to biology, we included all neurons and their connections within the patch. What is special about this choice of network is that it forms a kind of `module' or building block for larger cortical networks, since the majority of all connections onto the neurons come from within the patch, making it largely self-contained.

Our colleagues in Manchester successfully implemented the model using less than one hundredth of the complete SpiNNaker system. To evaluate the performance of the neuromorphic system, we programmed the same network also using the software NEST, a well-tested simulator that runs on conventional computing systems ranging from laptops to supercomputers. For the network at hand, a standard compute cluster sufficed to run the model. Directly comparing the different systems has the added advantage that it promotes an exchange between neuroscientists and neuromorphic hardware developers, so that technical advances and knowledge of the brain flow equally into the hardware and software design.

While the two systems currently consume a similar amount of energy, the comparison revealed that SpiNNaker can accurately simulate the activity of the neurons in the given type of network, despite its built-in imprecisions. This is a breakthrough because larger networks, all the way up to the brain scale, can now be simulated. Technical improvements to the processors promise to make SpiNNaker faster and more energy-efficient in the near future. Together with the neuromorphic hardware's ability to handle the processing of massive networks, our successful simulation of a brain `building block' means that future generations of SpiNNaker are well positioned to enable efficient simulations of large portions of the human brain.