Major Milestone in Brain Science: Scientists Digitize and Simulate Neural Tissue, Reveal Diverse Brain States

Hebrew University scientist is a senior author of paper, major contributor to ?Blue Brain Project?

SUMMARY: An international team led by École Polytechnique Fédérale de Lausanne (EPFL) scientists and featuring major contributions from a Hebrew University of Jerusalem brain scientist has completed a first draft computer reconstruction of a piece of the neocortex, the most recently developed part of the mammalian brain. The electrical behavior of the virtual brain tissue was simulated on supercomputers and found to match the behavior observed in a number of previous brain experiments. Further simulations revealed novel insights into the functioning of the neocortex. This first step towards the digital reconstruction and simulation of the brain is published in the prestigious journal Cell.

The Blue Brain Project, a key part of the European Union?s 10-year Human Brain Project, released today a detailed computer representation of microcircuitry of the rat brain. The paper presents a first draft digital reconstruction of the neural microcircuitry of a small area in the somatosensory cortex of the brain of young rats, the part of the brain responsible for the sense of touch.

Marking a major milestone in brain science, the digital reconstruction is a comprehensive computer model representing the shapes and electrical behaviors of approximately 30,000 nerve cells (neurons) in the reconstructed tissue, and approximately 40 million synapses (the sites of connection and communication between neurons) that they form.

Published by the renowned journal Cell, the paper is the result of a massive effort by 82 scientists and engineers at EPFL and at institutions in Israel, Spain, Hungary, USA, China, Sweden, and the UK. It represents the culmination of 20 years of biological experimentation that generated the core dataset, and 10 years of computational science work that developed the algorithms and built the software ecosystem required to digitally reconstruct and simulate the tissue.

The Hebrew University of Jerusalem?s Prof. Idan Segev, a senior author of the research paper, said: ?With the Blue Brain Project, we are creating a digital reconstruction of the brain and using supercomputer simulations of its electrical behavior to reveal a variety of brain states. This allows us to examine brain phenomena within a purely digital environment and conduct experiments previously only possible using biological tissue. The insights we gather from these experiments will help us to understand normal and abnormal brain states, and in the future may have the potential to help us develop new avenues for treating brain disorders.?
Segev, a member of the Hebrew University’s Edmond and Lily Safra Center for Brain Sciences and director of the Department of Neurobiology, sees the paper as building on the pioneering work of the Spanish anatomist Ramon y Cajal from more than 100 years ago: ‘Ramon y Cajal began drawing every type of neuron in the brain by hand. He even drew in arrows to describe how he thought the information was flowing from one neuron to the next. Today, we are doing what Cajal would be doing with the tools of the day: building a digital representation of the neurons and synapses, and simulating the flow of information between neurons on supercomputers. Furthermore, the digitization of the tissue is open to the community and allows the data and the models to be preserved and reused for future generations.’

A video abstract from Cell Press

While a long way from digitizing the whole brain, the study demonstrates that it is feasible to digitally reconstruct and simulate brain tissue, and most importantly, to reveal novel insights into the brain’s functioning. Simulating the emergent electrical behavior of this virtual tissue on supercomputers reproduced a range of previous observations made in experiments on the brain, validating its biological accuracy and providing new insights into the functioning of the neocortex. This is a first step and a significant contribution to Europe’s Human Brain Project, which Henry Markram founded, and where EPFL is the coordinating partner.

The reconstruction is a first draft, it is not complete and it is not yet a perfect digital replica of the biological tissue, says Markram. In fact, the current version explicitly leaves out many important aspects of the brain, such as glia, blood vessels, gap-junctions, plasticity, and neuromodulation. According to Sean Hill, a senior author: ‘The job of reconstructing and simulating the brain is a large-scale collaborative one, and the work has only just begun. The Human Brain Project represents the kind of collaboration that is required.’

The project has published the full set of experimental data and the digital reconstruction, in a public web portal, allowing researchers around the world to use them; see https://bbp.epfl.ch/nmc-portal.

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