Unlocking the secrets of the brain's intelligence to develop smarter technologies

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Of all the fast and powerful computers in the world, our brain remains by far the most impressive. Now an interdisciplinary team of scientists, led by Baylor College of Medicine, aims to reveal the computational building blocks of our brain and use them to create smarter learning machines.

To enable this ambitious project, the U.S. government's Intelligence Advanced Research Projects Activity(IARPA) has awarded a $21 million contract to an interdisciplinary team of neuroscientists, computer scientists, physicists and mathematicians, led by principal investigator Dr. Andreas Tolias, associate professor of neuroscience at Baylor. The research team includes scientists from Baylor, the California Institute of Technology, Columbia University, Cornell University, Rice University, the University of Toronto and the University of Tuebingen.

The program supporting this research is known as Machine Intelligence from Cortical Networks (MICrONS) and was envisioned and organized by Jacob Vogelstein, a neuromorphic engineer and program manager with IARPA. It is part of the broader BRAIN Initiative, launched in 2013 by President Obama with the goal of understanding devastating brain diseases and developing new technology, treatments and cures.

"Our goal is to discover the algorithms and learning rules that the brain implements and use these discoveries to create fundamentally smarter artificial neural networks" said Tolias.

Artificial Intelligence

Artificial Intelligence (AI) has been a dream for a long time, but an elusive one. People have consistently underestimated how hard it is to construct intelligent systems, Tolias said. Famously, in 1955, cognitive scientists proposed to solve AI as a summer project for several Dartmouth undergraduates. It didn't turn out to be that easy.

But in the past few years, AI has been booming, and applications have blossomed everywhere. Handheld devices now use machine learning algorithms to recognize faces and speech, the first self-driving cars already are on the roads, and computer systems regularly wade through Big Data to find new medicines and anticipate geopolitical and financial trends.

Despite their new successes, "these artificial neural networks are still incredibly primitive compared to biological neural networks, and don't learn the way real brains do," said Dr. Xaq Pitkow, co-principal investigator of the MICrONS project, and an assistant professor of neuroscience and McNair Scholar at Baylor as well as an assistant professor of electrical and computer engineering at Rice University. "By modeling the brain's computations and extracting their key features, we think we can give computers the ability to do much better."

Bigger Data

Researchers have been trying to develop brain-like intelligence for years, so what has changed that makes this more achievable today? Tolias's answer: bigger and better data.

Jacob Reimer, assistant professor of neuroscience at Baylor and one of the lead scientists and project manager of the team, agrees.

"Technologies in both physics and molecular biology have advanced so much that we can now record from many hundreds of neurons at a time, with even more extensive recordings on the horizon," he said. "This lets us analyze neural circuits in ways that we couldn't dream of just a few years ago."

In order to accomplish their ambitious goals, the team musters an impressive range of experts, each directing a research group in different aspects of the project. Chris Xu, a physicist at Cornell University, has pioneered 3-photon imaging, a novel method to monitor neural activity non-invasively and more deeply in the brain than ever before. Thanos Siapas of Caltech will focus his team's efforts on unraveling the learning rules in the brain. On the theoretical and mathematical modeling side, Mathias Bethge of the University of Tuebingen and Liam Paninski of Columbia, will develop mathematical models and statistical methods to help interpret the complex data collected by the team's experimentalists.

Even with the massive trove of data they will collect by recording neural activity, it can be hard to tell which neurons are connected to each other, directly exchanging information. That type of wiring information is critical to understanding the brain's algorithms that are embodied in its biological wetware.

Accordingly, the Baylor-led team also is partnering with two other groups to reconstruct the complete wiring diagram for a cube of brain whose activity they measure.

Clay Reid and Nuno da Costa from the Allen Institute for Brain Science will use electron microscopy to image biological structures down to scales reaching just billionths of a meter. They will then hand off about 1,000 large hard disks full of these massive images to Sebastian Seung from Princeton University, who will extract the three-dimensional structure of the neurons, including their shapes and connections. All together, the team will create one of the most exhaustive neuroscience data set in history.

Creating Networks

The ultimate key to succeeding in the goals of the MICrONS project is to implement neuroscience principles in computer algorithms. Working closely with the neuroscientists, team members Ankit Patel, assistant professor of neuroscience at Baylor College of Medicine and Rice University, Richard Baraniuk from Rice University, and Raquel Urtasun and Richard Zemel from the University of Toronto, are machine learning experts, tasked with integrating the computational building blocks the neuroscientists discover into new kinds of artificial neural networks.

This endeavor represents a monumental challenge and opportunity for both neuroscience and computer science. There is no better test of neuroscience principles than to see whether machines built from those principles actually solve real-world problems, Tolias said.

"The project demonstrates what is possible when we bring together world-class interdisciplinary researchers to solve fundamental problems. This bold endeavor could provide enormous benefits to society, including new computer technologies, new understanding of the brain, and new medical breakthroughs," said Dr. Paul Klotman, Baylor College of Medicine president, CEO and executive dean.

The team's grand aims are to understand one cubic millimeter of a mouse brain, and if they are successful their new algorithms will revolutionize machine learning. But it will still be the product of human ingenuity and creativity, and it will take more understanding than we can squeeze from a tiny cube of mouse brain to match that feat.

Provided by Baylor University