Technology PUBLISHED BY MIT Review

Wednesday, November 28, 2007

A Working Brain Model

A computer simulation could eventually allow neuroscience to be carried out in silico.

By Duncan Graham-Rowe

An ambitious project to create an accurate computer model of the brain has reached an impressive milestone. Scientists in Switzerland working with IBM researchers have shown that their computer simulation of the neocortical column, arguably the most complex part of a mammal's brain, appears to behave like its biological counterpart. By demonstrating that their simulation is realistic, the researchers say, these results suggest that an entire mammal brain could be completely modeled within three years, and a human brain within the next decade.

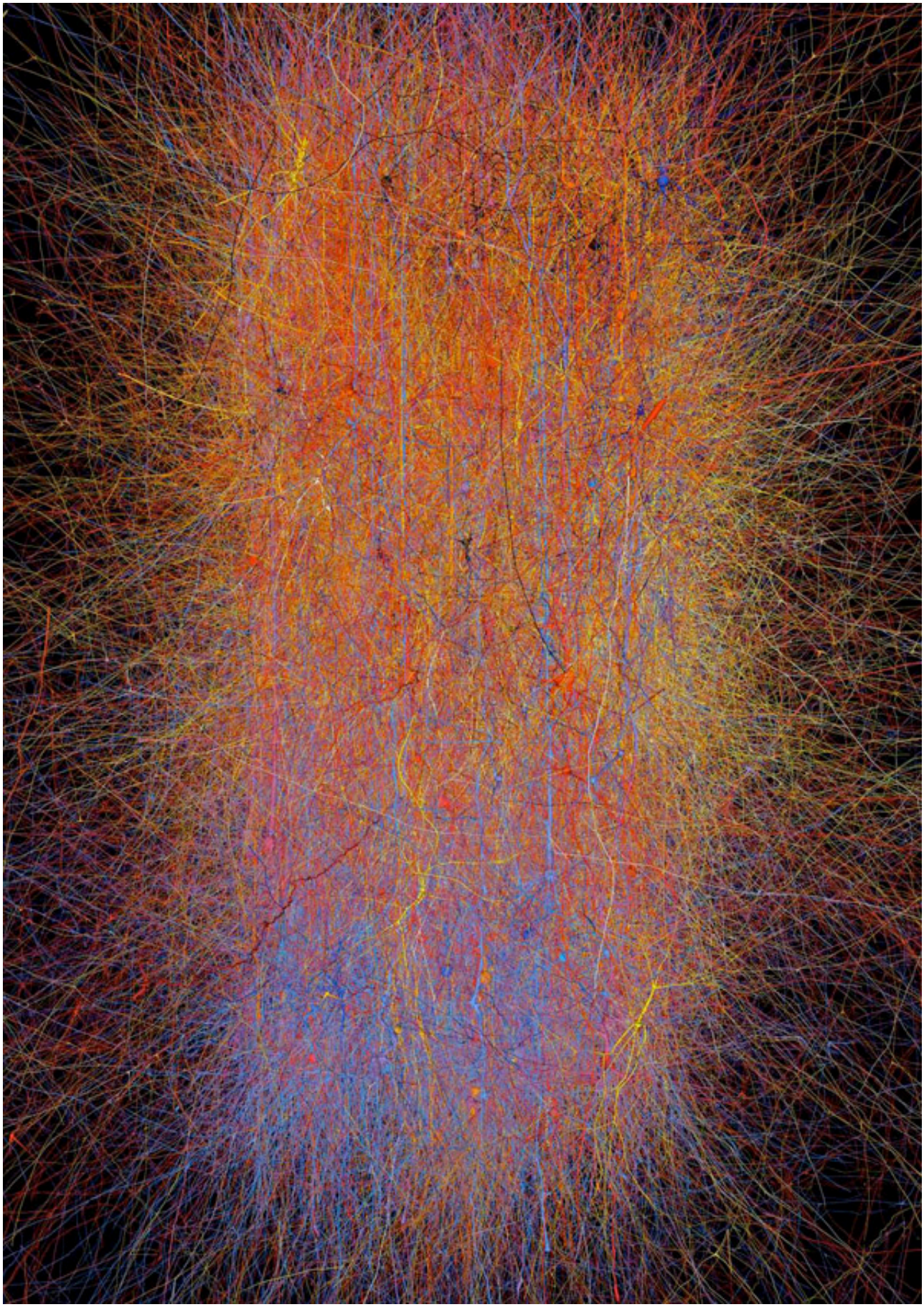
"What we're doing is reverse-engineering the brain," says Henry Markram (http://bmi.epfl.ch/page61216.html) , codirector of the Brain Mind Institute at the Ecole Polytechnique Fédérale de Lausanne, in Switzerland, who led the work, called the Blue Brain (http://bluebrain.epfl.ch/) project, which began in 2005. (See "IBM: The Computer Brain (http://www.technologyreview.com/Biztech/14743/page2/) .") By mimicking the behavior of the brain down to the individual neuron, the researchers aim to create a modeling tool that can be used by neuroscientists to run experiments, test hypotheses, and analyze the effects of drugs more efficiently than they could using real brain tissue.

The model of part of the brain was completed last year, says Markram. But now, after extensive testing comparing its behavior with results from biological experiments, he is satisfied that the simulation is accurate enough that the researchers can proceed with the rest of the brain.

"It's amazing work," says Thomas Serre (http://web.mit.edu/serre/www/) , a computational-neuroscience researcher at MIT. "This is likely to have a tremendous impact on neuroscience."

The project began with the initial goal of modeling the 10,000 neurons and 30 million synaptic connections that make up a rat's neocortical column, the main building block of a mammal's cortex. The neocortical column was chosen as a starting point because it is widely recognized as being particularly complex, with a heterogeneous structure consisting of many different types of synapse and ion channels. "There's no point in dreaming about modeling the brain if you can't model a small part of it," says Markram.

The model itself is based on 15 years' worth of experimental data on neuronal morphology, gene expression, ion channels, synaptic connectivity, and electrophysiological recordings of the neocortical columns of rats. Software tools were then developed to process this information and automatically reconstruct physiologically accurate 3-D models of neurons and their interconnections.



Connect the dots: *A representation of a mammalian neocortical column, the basic building block of the cortex. The representation shows the complexity of this part of the brain, which has now been modeled using a supercomputer. Credit: BBP/EPFL*

The neuronal circuits were tested by simulating specific input stimuli and seeing how the circuits behaved, compared with those in biological experiments. Where gaps in knowledge appeared about how certain parts of the model were supposed to behave, the scientists went back to the lab and performed experiments to identify the kinds of behavior that needed to be reproduced. In fact, about a third of the team of 35 researchers was devoted to carrying out such experiments, says Markram.

Through an iterative process of testing, the simulation has gradually been refined to the point where Markram is confident that it behaves like a real neocortical column.

However, none of these results have so far been published in the peer-reviewed literature, says Christof Koch (http://www.klab.caltech.edu/~koch/) , a professor of biology and engineering at Caltech. And this is by no means the first computer model of the brain, he points out. "This is an evolutionary process rather than a revolutionary one," he says. As long ago as 1989, Koch created a 10,000-neuron simulation, albeit in a far simpler model.

Furthermore, Koch is skeptical about how quickly the brain model can progress. Any claims that the human brain can be modeled within 10 years are so "ridiculous" that they are not worth discussing, he says.

Rat brains have about 200 million neurons, while human brains have in the region of 50 to 100 billion neurons. "That is a big scale-up," admits Markram.

But he is confident that his model is robust enough to be expanded indefinitely. What's more, he believes that the level of detail of the model can also be taken further. "It's at quite a high resolution," he says. "It's still at a cellular level, but we want to look at the molecular level." Doing so would enable simulation-based drug testing to be carried out by showing how specific molecules affect proteins, receptors, and enzymes.

"I wouldn't be surprised if they could do it," says Serre. "However, it's not clear what they could get out of it," he says. If you want this model to be useful, you have to be able to understand how the behavior relates to specific brain functions. So far, it is not clear that the Blue Brain project has done this, he says.
