Eyeing robots whose brains would work just like ours

Numenta is just one of the many companies looking to recreate the human brain's processing power virtually.

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It starts with a guessing game. On a laptop, Subutai Ahmad draws a square virtual blackboard, attaches an "L" on its back to it and puts a "T" on top. "What's that?" asks the vice-president of the startup company Numenta. A milk pot? A car trailer? No. The computer indicates that the most likely object depicted is a ... helicopter.

Even though this may appear like a game from the computer stone age, the demonstration gives us a glimpse of the future of data processing. High-performance computers may play chess perfectly or help meteorologists predict the weather. But the task of differentiating a cat from a dog is still tricky for machines.

Human brains work in parallel, in contrast to serially calculating computer processors. "We believe," Ahmad says, "that computers can get close to the processing power of our brains if the software architecture is based on our cerebral cortex." And this is what the program demonstrates - at least in principle. Even if so-called "neural networks" in the 90s may have been able to achieve similar feats, the selling point is the hidden design of the software. "In Numenta's opinion," says Ahmad, "this marks a new beginning for the computer industry, just like the revolution of the microchip 50 years ago."

Rebuilding the brain
Big announcements like these are a dime a dozen in Silicon Valley. But the ambitions of Numenta are shared by scientists and engineers around the world working on artificially rebuilding our neuronal HQ with software and microprocessors. Not only do they develop neuronally inspired software, they resurrect our thinking tissue in detailed simulations and even built hardware versions of the neocortex. The goals are powerful computers, insights into the structure of our brain and the hope of revealing secrets of our consciousness.

At the end of the 80s a graduate student at the University of California, Berkeley, was refused permission to build a software model of the brain for his dissertation. The student, Jeff Hawkins, was not amused and headed for Silicon Valley instead, where he invented the Palm Pilot and a few years later the Treo. Numenta is the latest enterprise of the wealthy 50-year-old maverick. Its selling pitch: Numenta is developing an algorithm similar to the one governing our cognitive abilities.

Hawkins' project builds on an assumption by Vernon Mountcastle, a neurobiologist who in the 70s pointed out that in the neocortex all the neurons are organised in the same way, even though different areas of the cortex perform different functions. Horizontally they are divided into layers, and vertically in columns. Mountcastle concluded that they are governed by the same algorithm. The only difference is the kind of information they process.

Based on this idea, Hawkins suggests neural processing in the neocortex works as follows. Our thinking - and Numenta's software - is based on forecasts, which follow from memories. Memories that help us make predictions are created over time by analysing incoming sensory information level by level, until a pattern is filtered from the initial data chaos. These concepts help to make predictions in the future, when similar perceptions occur.

But not everyone is convinced. Bob Knight, a neuroscientist at Berkeley University, says that Hawkins' theory is compatible with our current knowledge of how the brain works. But he points out that the theory lacks details and experimental proofs. For Numenta's software, which is designed to make predictions based on prior experiences, this criticism is irrelevant. What matters, says Ahmad, is that the programs work, not that they give a wholly accurate picture of the brain.

He also points to early successes. EDSA Micro, based in San Diego, uses an early version of the software to monitor electric grids; and Lockheed Martin applies it to satellite image analysis for mundane objects such as mailboxes, traffic lights or trash cans. The purpose: to gain insights about enemy activities.

Other brain engineers actually want to copy the brain. The neuroscientist Henry Markram and his colleagues of the Blue Brain Project at the Swiss Federal Institute of Technology Lausanne want to create a complete digital version of the brain, based on the latest scientific data. That is, they do not want to reconstruct the whole brain, just one basic element, a column consisting of layers of the neocortex. And for the sake of simplicity they do not simulate a human brain's column, but one of a rat's brain (tinyurl.com/388lps).

Only two millimetres long and half a millimetre thick, this area still contains 10,000 neurons with extensions that lead to thousands of brain cells. Recently, Markram's group completed a crucial step - a model of the cortical column that accurately allows to simulate experimental gained from a rat's brain. The scientists now hope to simulate larger brain structures step by step. First, how the columns are embedded into the supporting structure of glial cells; after that, they want to tackle the complete rat brain. By 2015, says Markram, "we even want to model the whole human brain". The benefit? Better understanding of what happens in the brains of autistic people or epileptics.

But even recreating the brain virtually is not enough for some; they literally hope to pour it into silicon. Now, certainly, computers consist of microprocessors, not of nerve cells; they use specialised parts, a central clocking device and so far cannot keep up with the parallel data processing of the neurons. But there are ways for a microchip to emulate a brain.

In the 80s, the microelectronics engineer Carver Mead found that electrical pulses of nerves could be simulated with transistor circuits. This paved the way for the development of silicon retinas, which may one day help those with vision loss. Like nerve cells, these neuromorphic chips are analogue, with continuously growing and falling electric signals. Still, they have one disadvantage: they are hardwired and cannot mimic the brain's ability to form new connections.

Adding memory to the mix
Kwabena Boahen, a former graduate student of Mead from Ghana and now a professor at Stanford University, wants to avoid this problem. Sitting in a stylish office, the scientist holds a transparent plastic box with a chip, made to his own specifications. "Since the 80s I have worked on creating artificial nerve cells - back then I could only dream of having a chip like this."

The microelectronic wonder simulates the inside and outside of neurons. The analogue circuits simulate the ion channels in a cell's membrane, which allow the passage of a signal's charged particles into and out of the cell body. Soldered to a circuit board, its digital signals run to neighbouring cells and also to a memory location, a RAM chip, which redirects the signal to other cells. Since this rerouting is variable, it functions like the plastic brain, changing connections whenever needed.

These chips may not be as detailed as the cell model Markram's at Lausanne creates, but it functions in real time. "You flip the switch and see how the signal runs through the network - that's how simple it is," jokes Boahen. Now the brain mechanic is working on "Neurogrid", a silicon model consisting of 16 microchips, which will mimic up to a million neurons with 6bn connections. Today this can only be done with a few thousand.

The pocket-sized board will have a computing power of 300 teraflops - more than 10 times as much as the Blue Brain supercomputer. Once completed, it will allow the testing of various theories about the brain - and, hopefully, find some solid answers.