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Simulated brain scores top test marks

First computer model to produce complex behaviour performs almost as well as humans at simple number tasks.

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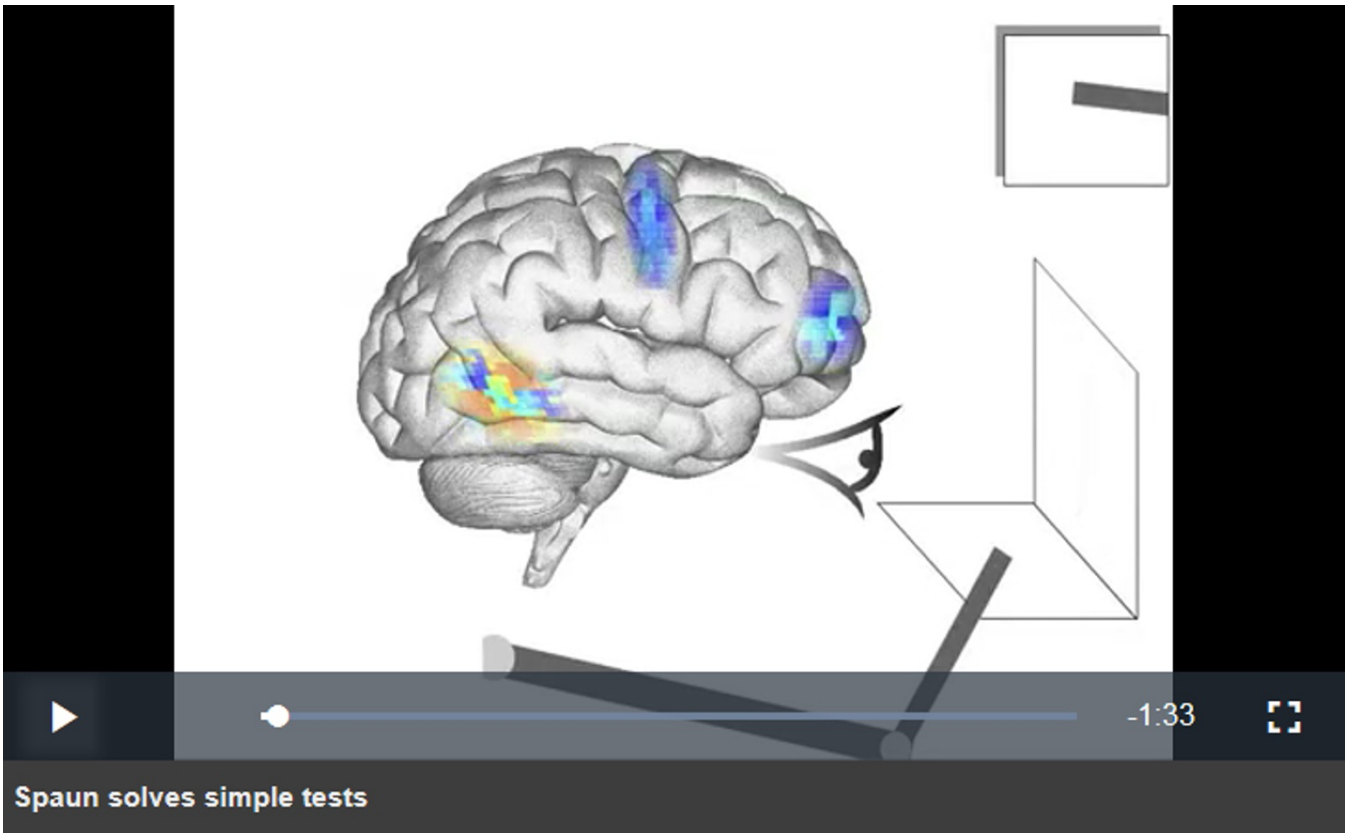
29 November 2012



Spaun sees a series of digits: 1 2 3; 5 6 7; 3 4 ?. Its neurons fire, and it calculates the next logical number in the sequence. It scrawls out a 5, in legible if messy writing.

This is an unremarkable feat for a human, but Spaun is actually a simulated brain. It contains 2.5 million virtual neurons — many fewer than the 86 billion in the average human head, but enough to recognize lists of numbers, do simple arithmetic and solve reasoning problems.

Described for the first time in *Science*[1], Spaun — the Semantic Pointer Architecture Unified Network — is the brainchild of Chris Eliasmith, a theoretical neuroscientist at the University of Waterloo in Canada, and his colleagues. It stands apart from other attempts to simulate a brain, such as the ambitious Blue Brain Project (see 'Brain in a box'), because it produces complex behaviours with fewer neurons. “Throwing a lot of neurons together and hoping something interesting emerges doesn’t seem like a plausible way of understanding something as sophisticated as the brain,” says Eliasmith.

“Until now, the race was who could get a human-sized brain simulation running, regardless of what behaviours and functions such simulation exhibits,” says Eugene Izhikevich, chairman of the Brain Corporation in San Diego, California, who helped to develop some of the first large-scale neuronal models — including one with 100 billion neurons. “From now on, the race is more [about] who can get the most biological functions and animal-like behaviours. So far, Spaun is the winner.”

Mind machine

A pure computer simulation, Spaun simulates the physiology of each of its neurons, from spikes of electricity that flow through them to neurotransmitters that cross between them. The computing cells are divided into groups, corresponding to specific parts of the brain that process images, control movements and store short-term memories. These regions are wired together in a realistic way, and even respond to inputs that mimic the action of neurotransmitters.

As Spaun sees a stream of numbers, it extracts visual features so that it can recognize the digits. It can then perform at least eight different tasks, from simple ones like copying an image, to more complex ones similar to those found on IQ tests, such as finding the next number in a series. When finished, it writes out its answer with a physically modelled arm.

Spaun is almost as accurate at such simple tasks as the average human, and reproduces many quirks of human behaviour, such as the tendency to remember items at the start and end of a list better than those in the middle. “We weren’t surprised that it could do tasks,” says Eliasmith, ”but we were often surprised that subtle features like the time it took or the errors it made were the same as for humans”.

Behavioural switchboard

Spaun could provide a powerful platform for testing hypotheses about how the brain works. For example, it includes a virtual version of the basal ganglia, a region thought to act as a switchboard to allow the brain to toggle between different behaviours. “This was an untested suggestion,” says Eliasmith. “We showed that the basal ganglia can perform that role in a way that allows Spaun to match human performance for different tasks.”

He adds, “If we destroy parts of this model, we can see what behaviours might fail. Or we could change how neurotransmitters function and see how that relates to behaviour.” The researchers have already submitted a paper in which they killed off Spaun's virtual neurons at the same rate as those in an ageing brain, and saw the same cognitive decline.

Spaun has its limits. It simulates only a small fraction of the full brain, and cannot learn completely new tasks or deal with inputs beyond the ten numerals and a few symbols. It is also slow in computing terms, taking hours to simulate one second of neural behaviour. Eliasmith wants to improve the model so that Spaun works in real time and can learn on its own. “Instead of us giving it strategies for performing these tasks, it would be able to discover strategies based on experience, just like humans do,” he says.

Nature | doi:10.1038/nature.2012.11914

References

1. Eliasmith, C. *et al*. *Science.* **338**, 1202–1205 (2012).