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Brain-like chips are boosting computers and battling cybercrime

The human brain is more powerful and energy-efficient than any computer. Scientists are imitating the way it works to produce better computer chips and help deal with the growing amounts of data generated every day.

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To prevent smart household devices from being hacked, researchers are developing ultra-fast, energy-efficient brain-like chips that can detect threats in real time, right on our devices.

From smart fridges and TVs to internet-connected toothbrushes, more and more household gadgets are now part of the Internet of Things. That makes it easier to analyse usage data or install remote updates. But it is also a security risk.

These smart devices are frequently targeted by hackers to create so-called botnets – networks of compromised devices that can be used to launch large-scale cyber-attacks.

Computing on the edge

To address this, we can, for example, collect all the data that passes through a device and send it to a data centre where AI algorithms are used to spot suspicious activity in millions of connected devices. But that takes time and requires transferring enormous amounts of data.

This is why scientists want to be able to do these calculations locally – on the fridge or the toothbrush itself.

But this concept of edge computing, where calculations happen locally, on the edge of the network, also has its challenges. A number of complex calculations must be quickly done on small chips that do not use much electricity.

“If you’re generating these quantities of data, then processing it on the fly is very demanding,” said Dr Matěj Hejda, a research scientist specialising in advanced computing and photonics. Hejda is part of an EU-funded

initiative called NEUROPULS, which is tackling this problem head-on.

Hejda and other researchers on the NEUROPULS team are developing a small chip, or processor, which can make very fast AI calculations while consuming hardly any energy.

“If a cyber-attack occurs, you can’t afford delays. We rely on AI to make rapid decisions based on very large amounts of data. That’s what our chip is designed to do,” he said.

Brain power

Their innovation is inspired by the human brain, which can perform complex tasks with far less energy than today’s conventional computers. By basing their work on the key features of neural processing, the team hopes to deliver smart, low-power computing for a range of real-world applications.

“The circuits mimic the behaviour of the brain,” said Dr Fabio Pavanello, a lead French National Centre for Scientific Research researcher at the Centre for Radiofrequencies, Optic and Micro-nanoelectronics in the Alps. Pavanello is responsible for coordinating the NEUROPULS research.

This new blend of neuroscience and high tech is called neuromorphic computing, and it is quickly gaining relevance.

“There are a lot of ways to do this. We chose photonics, which means that we use light beams instead of electrical signals to make the computations,” said Pavanello.

Merging memory and processing

Some of the research is being done at the Hewlett Packard Enterprise labs in Belgium, where Hejda works. The researchers there are working to resolve one of the bottlenecks in modern AI computing: memory.

“We have a way to bypass that barrier,” said Pavanello. On conventional computers, the memory is separated from the central processing unit where the calculations happen. The processor calculates things, while the data used in that calculation is stored in the memory unit.

That data needs to be constantly shifted from the memory to the processor and back, generally through some electrical circuit. That creates a bottleneck for AI because the connection between the processor and the memory cannot handle such massive data flows.

This bottleneck leads to slower calculations and higher energy use. But the researchers may have found a workaround.

“We aim to place the memory and the calculations in the same place,” said Hejda. “This is also how it’s done in our brain, by the way. In nature, memories and thinking appear to be co-located.”

Light waves

Another innovation the NEUROPULS chip proposes is ultra-low-power photonic computing. Instead of doing calculations with electrical signals, it uses special chips where light passes through microscopic pathways called waveguides.

Using light provides several advantages, such as minimal signal loss, ultra-low latencies or delays between sending and receiving data, and large data rates.

“It’s also easier to do many parallel calculations with it by using different colours of light,” Pavanello said.

“Using these systems, you can have more sensors and gather more data. That means we can make better informed decisions with lower costs in energy.”

Another advantage of using photonic technology is the potential for building more secure shields for such chips to better protect their operation and the data they handle. “This is a key requirement for their safe use in systems and networks,” Pavanello added.

Boost for self-driving cars

The NEUROPULS research team plans to test the new chip in practical applications such as detecting intrusions on computer networks. But they also want to use it in other real-world situations.

For example, it could be used to speed up the reaction times of self-driving cars. When a vehicle needs to brake or swerve suddenly in traffic, it cannot wait for a remote data centre to process information and respond – everything must happen instantly and reliably.

The photonic architectures used in NEUROPULS will provide high bandwidth and low latency, allowing the cars’ software to make real-time decisions and improving road safety.

The chips can also be used in traffic cameras and sensors, helping to optimise urban mobility, or in wearable health devices that monitor vital signs and send out real-time alerts if something is wrong.

Fast progress ahead

Partners in the project include the French Alternative Energies and Atomic Energy Commission, the Barcelona Supercomputing Center, and leading universities from Italy, Belgium, Portugal, Germany and Greece.

The researchers aim to finalise and test their new chip design by 2027. Still, it might take some time before the brain chips find their way into our devices, as they need to be made ready for larger scale applications.

“It will take some years before this actually goes into widespread use, although our approach is highly scalable, thanks to the use of the same technology used for microchips,” said Pavanello.

That said, neuromorphic and photonic chips are already becoming the latest tech fashion. Large AI chip companies such as Nvidia are investing in integrated photonic technology. For Hejda, this is a sign that the technology is on the cusp of wider acceptance.

“It is becoming apparent that the biggest players in the market think photonics is a technology they need to look at,” he said. “That’s a good sign and could accelerate the path to real-world applications.”

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