Nanoprinted high-neuron-density optical linear perceptrons perform near-infrared inference on a CMOS chip

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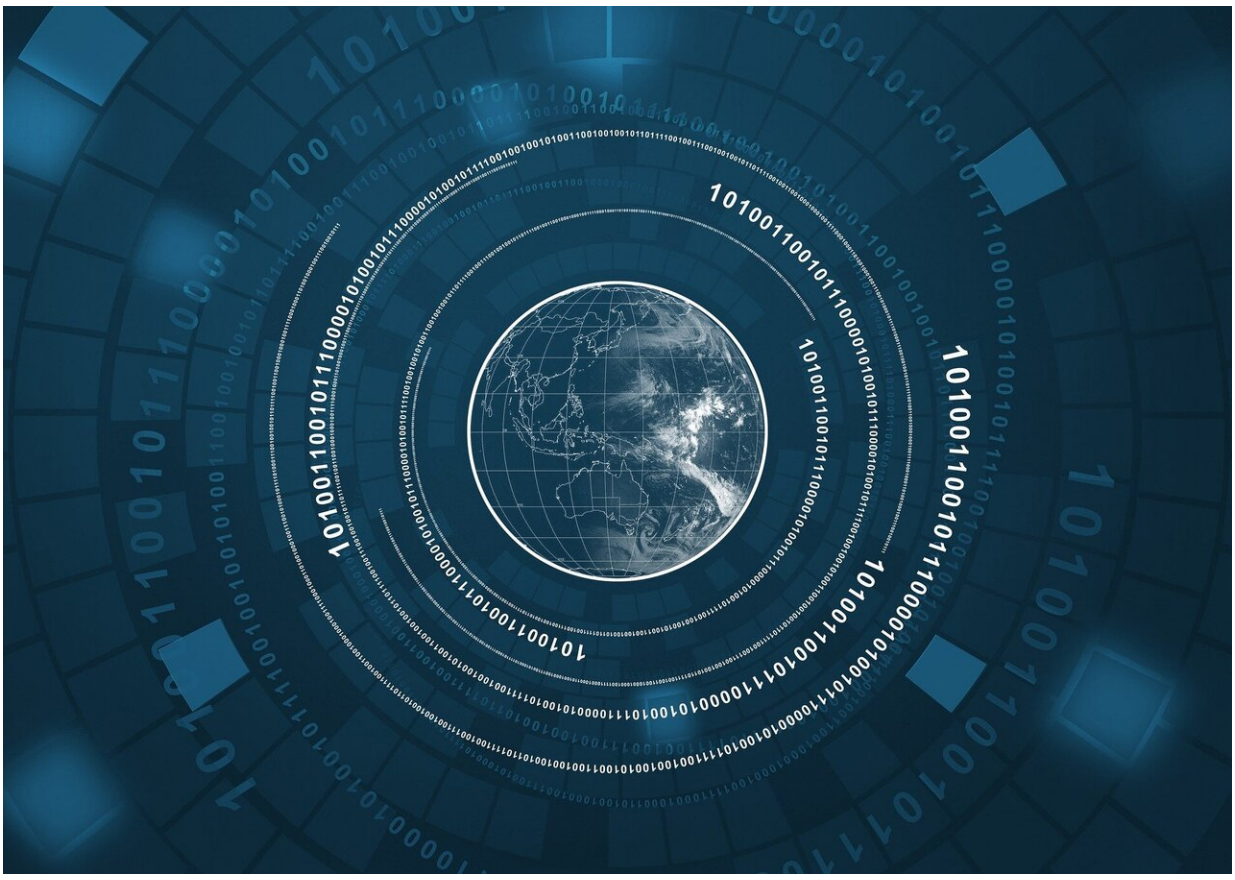

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Today, machine learning permeates everyday life, with millions of users

every day unlocking their phones through facial recognition or passing through AI-enabled automated security checks at airports and train stations. These tasks are possible thanks to sensors that collect optical information and feed it to a neural network in a computer.

Scientists in China have presented a new nanoscale AI optical circuit trained to perform unpowered all-optical inference at the speed of light for enhanced authentication solutions. Combining smart optical devices with imaging sensors, the system performs complex functions easily, achieving a neural density equal to 1/400th that of the human brain and a computational power more than 10 orders of magnitude higher than electronic processors.

Imagine empowering the sensors in everyday devices to perform artificial intelligence functions without a computer—as simply as putting glasses on them. The integrated holographic perceptrons developed by the research team at University of Shanghai for Science and Technology led by Professor Min Gu, a foreign member of the Chinese Academy of Engineering, can make that a reality. In the future, its neural density is expected to be 10 times that of human brain.

How it works

Traditionally, visual information is translated into electronic information, which is then processed by energy-hungry hardware. The technology Professor Gu's team developed skips this translation step and processes the optical information directly and without using any power.

Elena Goi, the first author of the published paper and a key member of Prof Gu's team, said that the processing of optical information is enabled by state-of-the-art nanofabrication.

"By employing high-precision 3-D nanofabrication technology, we are

able to add AI optical elements to industry-standard imaging sensors. This is comparable to putting tailored, task-specific smart glasses on the imaging sensors, which process the incoming optical information before it is even detected."

Impact

Using a state-of-the-art laser 3-D-nanoprinting technology, the researchers fabricated optical perceptrons with a neuron density of over 500 million neurons per square centimeter. The nanoscale feature size of these smart optical elements pushes the upper limit for the computational power for the nanoprinted decryptors lies at 400 ExaFLOPS (10^{18} FLOPS, floating operations per second), an increase in the operations per second of five orders of magnitude compared with integrated photonic hardware.

By printing the perceptrons directly on CMOS imaging chips, Goi said, it is possible to realize AI optical circuits, which not only outperform current optical methods, but show the potential for application in a wide range of fields from security check, medical diagnostics, automatic driving, satellite image processing, etc.

According to Professor Gu, this technology will enable a whole new family of energy-efficient, AI-enabled edge devices for processing optical information. This is of particular importance for applications where energy consumption is critical or data connectivity is limited, for example, smart sensing devices in remote areas or smart sensors for long-term deployment.

More information: Elena Goi et al, Nanoprinted high-neuron-density optical linear perceptrons performing near-infrared inference on a CMOS chip, *Light: Science & Applications* (2021). DOI: 10.1038/s41377-021-00483-z