Getting an all-optical AI to handle non-linear math

The problem is that this cascading requires massive parallel computations that, when done on standard computers, take tons of energy and time. Bandyopadhyay's team feels this problem can be solved by performing the equivalent operations using photons rather than electrons. In photonic chips, information can be encoded in optical properties like polarization, phase, magnitude, frequency, and wavevector. While this would be extremely fast and energy-efficient, building such chips isn't easy.

Siphoning light

"Conveniently, photonics turned out to be particularly good at linear matrix operations," Bandyopadhyay claims. A group at MIT led by Dirk Englund, a professor who is a co-author of Bandyopadhyay's study, demonstrated a photonic chip doing matrix multiplication entirely with light in 2017. What the field struggled with, though, was implementing non-linear functions in photonics.

The usual solution, so far, relied on bypassing the problem by doing linear algebra on photonic chips and offloading non-linear operations to external electronics. This, however, increased latency, since the information had to be converted from light to electrical signals, processed on an external processor, and converted back to light. "And bringing the latency down is the primary reason why we want to build neural networks in photonics," Bandyopadhyay says.

To solve this problem, Bandyopadhyay and his colleagues

designed and built what is likely to be the world’s first chip that can compute the entire deep neural net, including both linear and non-linear operations, using photons. “The process starts with an external laser with a modulator that feeds light into the chip through an optical fiber. This way we convert electrical inputs to light,” Bandyopadhyay explains.

The light is then fanned out to six channels and fed into a layer of six neurons that perform linear matrix multiplication using an array of devices called Mach-Zehnder interferometers. “They are essentially programmable beam splitters, taking two optical fields and mixing them coherently to produce two output optical fields. By applying the voltage, you can control how much those the two inputs mix,” Bandyopadhyay says.

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