The State of Optical Computing at its Frontier

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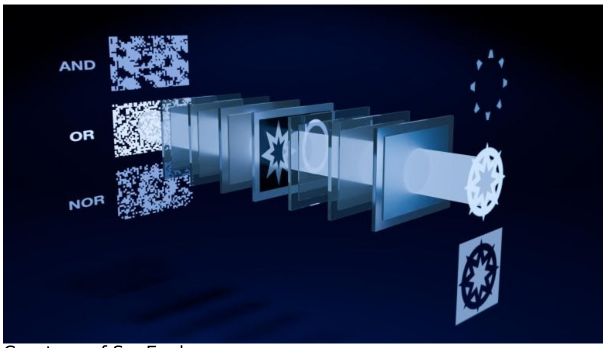

Courtesy of SynEvol
Credit:2024 Mashiko et AL.

Optical computing shows promise as a means of improving speed and power efficiency as computers become more powerful and energy-intensive due to artificial intelligence and other complicated applications. Its actual application, though, has encountered many difficulties. Diffraction casting is a revolutionary design architecture that attempts to address these problems by presenting novel ideas that may promote the use of optical computing in future technologies.

All modern computing equipment, from the laptop on your desk to the smartphone in your pocket, rely on electronic technology. However, this has certain inherent disadvantages. Specifically, when they perform better, they must inevitably produce a lot of heat. Furthermore, semiconductor fabrication processes are getting close to the outer bounds of theoretical possibilities. Consequently, academics look at other computational approaches that can address these issues and, hopefully, provide some new functionality or features as well.

One potential is optical computing, an idea that has been around for a number of decades but hasn't yet taken off and proved economically feasible. Essentially, light waves' speed and their capacity to interact intricately with various optical materials without producing heat are utilized in optical computing. In principle, this can be combined with the fact that a wide variety of light waves can flow through different materials at the same time without interfering with one another to create a massively parallel, fast, and power-efficient computer.

Researchers in Japan investigated shadow casting, an optical computing technique that could carry out a few basic logical operations, in the 1980s. On the other hand, its execution relied on quite large geometric optical forms, maybe resembling the vacuum tubes used in the first digital computers. Although they were functional in theory, Associate Professor Ryoichi Horisaki of the University of Tokyo's Information Photonics Lab stated they lacked the adaptability and simplicity of integration needed to produce something worthwhile.

We provide diffraction casting, an optical computing technique that outperforms shadow casting. Diffraction casting, on the other hand, is based on the properties of the light wave itself, resulting in more spatially efficient, functionally flexible optical elements that are extensible in ways you'd expect and require for a universal computer. Shadow casting is based on light rays interacting with different geometries. With inputs that were smaller than the icons on a smartphone screen—16 by 16 pixels in black and white—we performed numerical simulations that produced incredibly encouraging results.

Horisaki and his group suggest an all-optical system, meaning that all of the system's stages are optical up until the point at which it is converted to an electronic or digital format. The concept involves using an image as a data source, which implies that this system may be used for image processing. However, other types of data, particularly those used in machine learning systems, may also be graphically represented. Finally, the source image is combined with a number of other images that represent different stages of logic operations.

Consider it analogous to layers in an image-editing program like Adobe Photoshop: An input layer, also known as the source image, can have layers applied on top of it to communicate, modify, or disguise data from the layer below. The combination of these layers essentially processes the output, or top layer. In this instance, light passing through these layers will produce a picture on a sensor (hence the "casting" in diffraction casting), which will then be converted to digital data for user presentation or storage.

It might be best to think of diffraction casting as an addition to current systems rather than their complete replacement, similar to how graphical processing units are specialized parts for workloads related to graphics, gaming, and machine learning. Diffraction casting is just one building block in a hypothetical computer based on this principle, according to lead author Ryosuke Mashiko.

"It will take about ten years to reach the commercial market, as there is still a lot of work to be done on the physical implementation, which is still under construction even though it is based on actual work." We can currently show how effective diffraction casting is in carrying out the sixteen fundamental logic operations that form the basis of most information processing, but there is also room to expand our system into quantum computing, an emerging field of computing that goes beyond the conventional. Time will tell.