Optical Neural Network

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Neural networks are useful computational tools for an array of problems including image classification. At the industrial scale, there are massive inefficiencies such as the memory bottleneck in standard (von Neumann) computer architectures that alternative computational approaches can address. Here, we will explore an alternative approach: optical computing.

We will build an optical embodiment of a neural network. Light will be patterned with an input structure, passed through lenses and modulation devices, and land on a camera to parse the output.

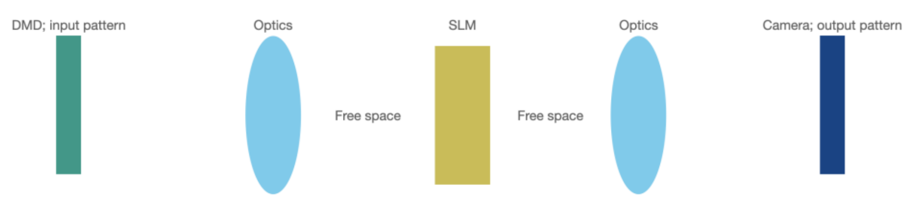
Background notes

Optical computing has a long history, but silicon computing devices have stayed ahead until recently. With the closing of Moore's Law era, there is renewed interest in these approaches, including fiber-based and integrated photonics approaches. Here we are focused on one strength of optical computing: free space fanouts. In a 3D circuit, it takes a large and complex fanout to connect one matrix to another. In freespace optics, it is trivial to such connections, and they scale well.

The company *LightOn* already has a device on the market. It performs large scale, random (but repeatable) matrix multiplications using freespace optics. Similarly, Lin, Rivenson, Yardimci, et al. developed a freespace optics multilayer network for MNIST classification (but fixed, and without any nonlinearities).

Step 1.
Select components and plan the system: a light source, a 4f system from the DMD on one side, across the SLM, to the camera on the other.

Step 2.
Build the system.



Step 3.
Use the system to classify MNIST digits. Use backpropagation to tune the SLM to maximize the discriminability of the output.

It may be good to initially use the camera output pattern as an input to a neural net on a computer, complete with nonlinearities. Then, the SLM will be acting to increase separability of the MNIST digits, somewhat like the LightOn device. It may be possible to later dispense with that component, and have the camera output itself provide the classification, as in the Lin et al. paper.

Potential extensions

A hybrid optical/CMOS nonlinear layer.

A key component of neural nets is a nonlinearity applied to the output of each unit. Nonlinearities are difficult (weak, or power hungry) in optics, but are easy in silicon. Custom silicon could provide a simple layer of nonlinearities. An array of photodiodes on one side, wired straight through to LEDs on the other side. This could be planned, designed, modeled, and perhaps fabricated and tested.

Optical modeling of the system, integrated with algorithm development.

Program an optical modeling system, validate it with the prototype, and integrate it into a learning paradigm for not only modifying the SLM command, but also altering the airgap spacings in the 4f system.

All-optical machine learning using diffractive deep neural networks
X Lin, Y Rivenson, NT Yardimci, M Veli, Y Luo… - Science, 2018

https://lighton.ai