

Optical Neural Network for All-Optical Logic Gates Solution

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With the escalating demand for speed and computational power to meet the ever-growing requirements of AI algorithms, coupled with the limitations of von Neumann computing, there is an increasing necessity for alternatives to silicon-based computers. Photonic computers emerge as a promising solution to this challenge, leveraging the low latency and parallelism of light to deliver unrivaled capabilities for neuromorphic computing. Notably, they offer significant reductions in energy consumption and substantial speed enhancements, allowing for matrix multiplications at the speed of light. These operations are particularly crucial as they constitute approximately 80% of computer usage in convolutional neural networks.

In this work, we present an optical system capable of performing logic operations, such as AND, OR, NOT, and XOR, in an all-optical manner. This is made possible by utilizing a spatial light modulator (SLM), which receives and adjusts the input light according to the desired logic operation and input binary values. These values are encoded using a metal mask that segments a collimated light beam from a He-Ne laser. To incorporate not only the binary value of each bit but also the desired logic operation simultaneously, specific regions within a CCD sensor that receive the input beam after passing through the mask are defined. In a simplified approach, we designate the two lower quadrants of the CCD image to represent individual bits (lower left = bit 1; lower right = bit 2) and by detecting light intensity above a defined threshold, a logic value of '1' is assigned; otherwise, '0' is interpreted. Similarly, the same intuitive method can be applied to the upper quadrants to determine the logic operation (upper left = AND; upper right = OR). Further divisions of the CCD image can be implemented to accommodate additional operations or to create a bias beam, which is crucial for solving more complex problems.

The analogy between this optical neural network and traditional networks can be drawn as follows: incident light on each SLM pixel forms the input vector, multiplied by a weight matrix via programmable phase delays. The resulting light, reflected by the SLM, is focused by a lens and captured by a CCD camera, effectively summing up the results to produce an output or new layer. The presented approach is particularly interesting for establishing a basis for future improvements and characterizations of optical non-linear activation functions.

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