Optical Low-Power Image Recognition with Effective Two Layer Neural Network

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Machine vision has made tremendous advances in classification accuracy and flexibility, but most solutions remain power-hungry, sensor-demanding, and latency-limited due to their reliance on electronic computation. As energy constraints tighten for edge and wearable systems, optical computing has emerged as a promising alternative. Thanks to the natural linearity and parallelism of light, optical systems can natively perform matrix-vector multiplications – the core operation of neural networks – at extremely low energy levels, approaching or even surpassing sub-photon per multiply-accumulate benchmarks. However, the energy benefits of such optical processing can diminish when light modulators are reconfigured at high speeds or large scales, as dynamic modulation remains a bottleneck.

In this work, we demonstrate an energy-efficient hybrid system for optical image recognition that combines pre-trained, fixed-weight matrix projections with ambient light processing. By encoding weight matrices on a low-power LCD-based spatial light modulator (SLM) and focusing the modulated image onto a single photodiode, we implement an neuron optical neuron. By applying multiple fixed masks and aggregating the photodiode responses through a digital bagging model, we simulate a two-layer neural network. Our approach is energy efficient because it avoids high-speed optical modulation.

We validated our system on a binary classification task from the Quick Draw dataset, detecting the presence of the "smile" class against various hand-drawn shapes. Our optical neural network achieves a classification accuracy of 92%, illustrating the feasibility of low-power, low-latency machine vision at the edge using ambient light and passive optical computation. The architecture can be further extended to multi-detector systems with fixed masks and lens arrays, supporting real-time applications. This technology can be scaled for resolving energy related limitations in always-on sensing, robotics and other.