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DEEP PHYSICAL NEURAL NETWORKS TRAINED WITH IN-SITU BACKPROPAGATION

ABSTRACT

Deep learning excels in complex tasks like natural language processing and machine vision due to its ability to learn hierarchical representations from data. However, escalating energy consumption increasingly limits its scalability, which has motivated the development of specialized hardware for energy-efficient deep learning. Traditionally, this revolved around computing matrix-vector computations, but this approach limits the array of physical systems that can be deployed to solve deep learning's energy problem.

The talk will center around our recent work on deep physical neural networks, which leverage controllable physical systems for deep learning. These networks utilize the inherent transformations of their physical components to effectively learn hierarchical representations of input data, akin to traditional deep neural networks. For efficient training, we introduce a novel hybrid in situ - in silico backpropagation algorithm.

We demonstrate the generality of our proposed framework by experimentally constructing physical neural networks from multimode mechanical oscillators, analog electronic circuits, and ultrafast nonlinear optical systems, to perform image classification tasks. Beyond these proof-of-concept experiments, we have also probed the potential of scaled-up physical neural networks through simulations. Finally, I will discuss our recent work on constructing a physical neural network with a large number of parameters that is based on integrated photonics.

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