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Efficient Analog Backpropagation Training Architecture for Photonic Neural Networks

Stanford researchers design and demonstrate a novel in situ backpropagation training algorithm for photonic implementations of neural networks. Backpropagation is a standard algorithm for training neural networks, but its implementation in optical devices was previously not established, although photonic accelerate hybrid neural networks address increasing energy demands to support ML-related inference tasks. The inventors develop an optical setup and experimental platform to test gradients in a 6x6 bidirectional network of photonic Mach-Zehnder interferometer that can measure power at all intermediate points in the photonic circuit via an IR camera. They demonstrate proof of concept of the setup in a computationally intensive linear portion of the photonic neural net, such that a computer performed all other computationally inexpensive differentiation.

Stage of Development
Prototype, where authors demonstrate the protocol on a foundry-manufactured photonic integrated circuit using a single-layer photonic network

Applications

- Photonic matrix multiply accelerator devices for machine learning/AI-based data centers
- Adaptive optics and photonics for LIDAR and sensing
- Photonic circuit sensitivity analysis
- Error correction of photonic circuits

Advantages

- Analog gradient updates improve energy efficiency by avoiding analog-to-digital conversion in training neural networks
- Only linear optical devices require analog gradient measurement
- Can be flexibly incorporated in popular differentiation packages

Publications

- Pai S, Hughes TW, Hughes TW, Park T, Bartlett B, Williamson I, Williamson I, Minkov M, Minkov M, Milanizadeh M, Abebe N, Morichetti F, Melloni A, Solgaard O, Fan S, Miller DAB. Inference and Gradient Measurement for Backpropagation in Photonic Neural Networks. Conference on Lasers and Electro-Optics (2022).

Patents

- Published Application: 20250356192

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