Multimode Fiber Based Optical Computing Unit for Large Scale Neural Networks

Master Project

Background

In our recent study, we demonstrated that light propagation inside multimode optical fibers can be utilized as nonlinear, high-dimensional data transform units and thanks to their rich physical dynamics, machine learning tasks could be performed with a much smaller dependence on digital electrical hardware (such as GPUs)[1]. This phenomenon holds promise to alleviate the consequences of overparameterization, which allowed neural networks to perform extraordinarily complicated tasks but has downsides such as high energy consumption and an exponential increase in the need for digital computation resources.

For achieving competitive performance levels with the proposed optical computation approach, the reconfiguration of the system for the planned task is crucial. In another study, we have shown that with wavefront shaping and by optimizing a few tens of parameters, the reconfiguration of the system could improve the performance of the optical computer significantly[2]. Figure 1 illustrates the improvement in the performance of the optical neural network with surrogate model optimization. After the programming procedure, the optical neural network could achieve the same performance as a digital convolutional neural network which has 50 times more model parameters and possibly an order of magnitude smaller energy consumption.

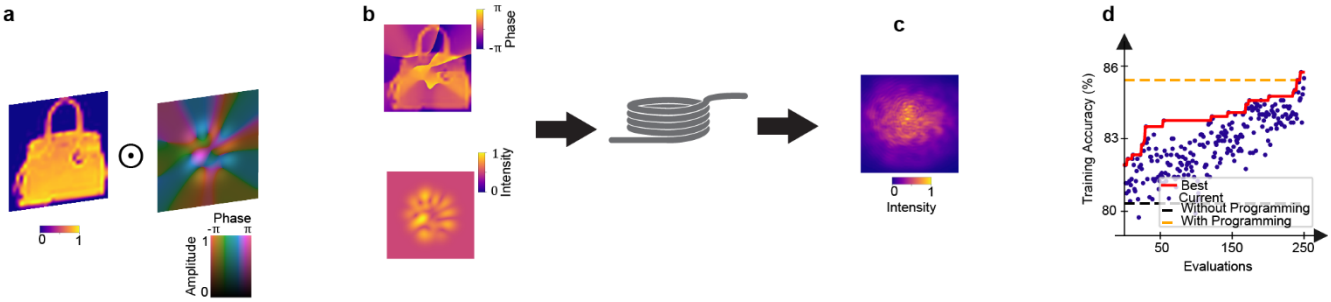

Figure 1. Programming the optical transform by combining data with a fixed pattern(**a**). **b** shows an example of programmed patterns on the SLM, **c** shows recorded intensity patterns after the propagation inside the optical fiber for the given input pattern. **d** depicts the progression of training accuracies during programming iterations.

Project Description

The main goal of this project, which will be in collaboration with Google Research, is to benefit from the excellent efficiency of this novel optical neural network architecture for improving the environmental footprint of current state-of-the-art neural networks. For this purpose, the optical device will be used as a computing block inside neural networks and a digital model of the optical approach will be used to enable error backpropagation based training. During the project, the student will explore different neural network architectures and training strategies. Therefore, introductory experience with neural networks is a sufficient background for the project.

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References

1. Teğin, U., Yıldırım, M., Oğuz, İ., Moser, C. & Psaltis, D. Scalable optical learning operator. *Nat. Comput. Sci. 2021 18* **1**, 542–549 (2021).
2. Oguz, I. *et al.* Programming Nonlinear Propagation for Efficient Optical Learning Machines. Preprint at https://doi.org/10.48550/arXiv.2208.04951 (2022).