Internship Master 2, LAAS-CNRS, PHOTO group, 2024/25: "Multi-head optimized optical neural networks – MOONN"

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BACKGROUND – OPTICAL INFORMATION PROCESSING

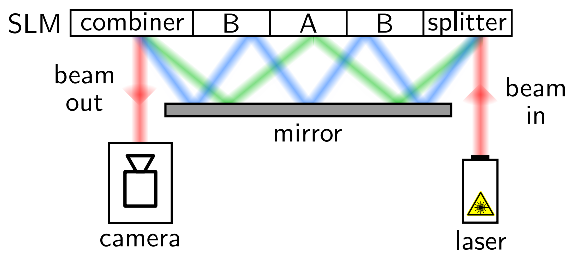

FIG. 1. Sketch of the experiment to be developed. A laser beam (red) is directed on a spatial light modulator (SLM). The SLM is configured with a superposed grating to split the beam at two distinct angles (green and blue beams). Note that the laser wavelength does not change, the colors are only meant to indicate the different paths. The SLM pixels in zones A and B represent the neurons of two independent pathways ("heads") of the equivalent optical neural network.

GOALS

The ultimate goal of the project is to develop an optical computation approach inspired by modern deep learning (DL) [1, 2]. The key idea is to physically implement an all-optical non-linear data processing setup based on multiple interactions of a coherent laser beam with a spatial light modulator (SLM).

The work will be two-fold: both experimental developments and numerical studies will be caried out.

On the experimental side, based on existing hardware, the intern will setup a dedicated optical bench to physically implement a multi-head neural network using multiple diffraction from an SLM. The work will include setting up, designing and testing several approaches to implement a variable number of layers and variable number of heads. This work will rely on linear superposition of diffraction phase-gratings to implement beam-splitters, beam-recombiners and various information encoding layers (labelled A and B in figure 1). A key experimental study will be to determine the maximum number of layers and heads that can be implemented given the below unity efficiency of the diffraction by the SLM, in order to feed numerical studies on neural network architectures to investigate.

On the numerical modelling side, the work consists in using an in-house optical neural network framework implemented in pytorch, to investigate multi-head optical neural networks on simple toy problems like digit-classification. The goal is to assess the impact of optical losses at each reflection on the performance, as well as to study so-called "structural non-linearities" [3] in a multi-head configuration.

WORK CONTEXT

The internship will take place within a dynamic collaboration of researchers working in optics and deep learning in the Photonics group (PHOTO) at LAAS-CNRS in Toulouse, for a duration of 5-6 months. All required experimental equipment is available. Numerical tools for the modelling of the optics and training of optical neural networks are already developed and tested and several hardware (dedicated workstation with GPU, LAAS cluster, etc ...) will be available. For the experimental work the intern will have access to the LAAS Fablab and will receive a laser safety training.

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CANDIDATE

The candidate should have a background in physics and a strong interest in optics and electrodynamics. The candidate should be enthusiastic about programming, as the numerical models as well as the control of the experiment require coding. A good level of English is required. Some experience in experimental optics would be a plus.

CONTACT / WORKPLACE / REMUNERATION & DURATION

Interested candidates should contact Antoine Monmayrant (antoine.monmayrant@laas.fr) or Peter Wiecha (pwiecha@laas.fr) with a short CV, a brief statement of motivation and ideally a reference contact (e.g. former intership supervisor).

Remuneration is around 590€ per month for a period of 5-6 months.

REFERENCES

[1] M. A. Nielsen, *Neural Networks and Deep Learning* (2015) `http://neuralnetworksanddeeplearning.com/`.
[2] X. Lin, Y. Rivenson, N. T. Yardimci, M. Veli, Y. Luo, M. Jarrahi, and A. Ozcan, Science **361**, 1004 (2018).
[3] M. Yildirim, N. U. Dinc, I. Oguz, D. Psaltis, and C. Moser, Nature Photonics **18**, 1076 (2024), arXiv:2307.08533 [physics].