Hellenic Foundation for Research & Innovation

Description of the funded research project

1st Call for H.F.R.I. Research Projects to Support Faculty Members & Researchers and Procure High-Value Research Equipment

Please insert a photo related to the funded research project

DeepLight

Title of the research project: Photonic Neuromorphic Hardware for Deep Learning Applications over Light-enabled Integrated Systems

Principal Investigator: Nikos Pleros

Reader-friendly title: Neuromorphic Photonic Hardware for Deep Learning

Scientific Area: Engineering Science and Technology

Institution and Country: Aristotle University of Thessaloniki, Greece

Host Institution: Aristotle University of Thessaloniki

Collaborating Institution(s): Centre National de la Recherche Scientifique (CNRS)

Project webpage (if applicable): http://deeplight.eu/

Please insert a photo of the PI and/or the Research Team

Budget: 189,905.76 Euros

Duration: 36 months

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Research Project Synopsis

DeepLight aims to invest in photonics towards offering a radically new DL-enabling platform! DeepLight aims to transform the state-of-the-art and highly energy-efficient optical interconnect technology into a powerful Deep Learning technology, deploying the necessary hardware photonic infrastructure and DL models and following from the beginning a tight hardware-software co-design approach. In this effort, DeepLight aims to outperform current electronic and photonic Deep Learning hardware prototypes by offering:

a) New linear algebra optical architectures suitable for matrix-vector multiplication engines

b) New coherent photonic technology blocks for realizing linear optical neurons and nonlinear activation functions

c) New DL training algorithms adapted over the characteristics of the underlying analog photonic hardware platform

These research targets are expected to introduce unique perspectives towards reducing energy consumption, maximizing computational performance and allowing DL platforms to perform at speeds currently experienced in the field of optical communications!

Project originality

DeepLight aims to demonstrate experimentally photonic neurons operating at higher than 10Gb/s with sub-pJ/bit energy efficiency, designing, deploying and demonstrating photonic activation elements based on optical memory configurations and offering both the integration and firing functionalities through a single optical circuit. At the same time, it will design linear algebra matrix implementations through CMOS plasmonics co-integrated with silicon photonics, investigating two possible options for negative number representations: i) the use of carrier phase, and ii) the use of wavelengths. DeepLight will start with InP-based optical memory devices prior transferring the optimal integrate-and-fire layout in the InP-on-Silicon photonic crystal nanostructures, to be fabricated and demonstrated experimentally as ultra-compact (um^2 footprint) and ultra-low power (few fJ/bit) activation elements. It also intends to establish the theoretical foundations for Deep Learning algorithms and models executed over light-enabled technologies, deploying and applying innovative algorithms that can optimally exploit the idiosyncrasy of the photons. DeepLight will conclude with innovative WDM-enabled photonic neural network designs capable to be integrated as on-chip compact modules with significant performance improvement and energy gains over state-of-the-art Deep Learning machines.

Expected results & Research Project Impact

DeepLight extends along a number of groundbreaking concepts that, in case of success, have the potential to highly impact science, economy and society. More specifically:

a) Lead to higher computational speed and more energy efficient NN hardware: DeepLight intends to release a neuromorphic photonic platform that can yield 2 orders of magnitude improved efficiency and 5 orders of magnitude higher computational speeds.

b) Shape a new theoretical framework and set new performance boundaries for DNNs: DeepLight will set the ground for a new theoretical neural network framework over photonic hardware, combining neural network techniques with physical principles and devices stemming from the world of photons.

c) Set the scene for reduced NN hardware cost and facilitate access to NN platforms:. DeepLight can trigger significant cost reductions by i) introducing plasmonics and a number of optical multiplexing techniques ii) investing in CMOS-compatible plasmonics and photonic circuitry making inroad towards lower cost NN hardware allowing access of smaller organizations and SMEs to large computational power resources.

d) Reduce DNN training time: Current state-of-the-art models will require several months or years to train without the use of multiple GPUs/TPUs. Providing a faster and more efficient alternative to these traditional neural network accelerators will provide an enormous boost, allowing for developing more complex and more accurate DL models.

The importance of this funding

The H.F.R.I. funding has provided significant help in strengthening the collaboration between the photonics and the Deep Learning research teams and shaping a clear research path, which in turn served as the precursor of subsequent H2020 projects in the field.
It also helped to secure funding for PhD and Post-doctoral students, allowing to grow our group and devote certain human resources to a new and exciting research field.

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