HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

RESEARCH PROJECT #: HPCMP-HIP-24-015

Investigating the Computing Capacity of Deep Diffractive Neural Networks

About AFRL:

Air Force Research Laboratory (AFRL) is a scientific research organization operated by the United States Air Force Materiel Command. AFRL is dedicated to leading the discovery, development, and integration of aerospace warfighting technologies, planning, and executing the Air Force science and technology program, and providing warfighting capabilities to United States air, space, and cyberspace forces.

RESEARCH LOCATION: Wright-Patterson AFB, OH

PROJECT DESCRIPTION:

This project will be carried out as a joint effort between subgroups of the Structured Optical Materials Processing Research Team and Polymers and Responsive Materials Research Team at AFRL's Materials and Manufacturing Directorate. This project will focus on the design of optical metasurfaces to perform in materio computing operations.

Information processing is the backbone of the DoD decision chain and necessitates continued innovations in computing concepts and hardware to maintain superiority. Optical metasurfaces present a novel class of computing materials that can simultaneously detect and process light-based information, offering both efficiency and C-SWAP advantages. The goal of this internship is to expand the library of metasurface elements (meta-atoms) that can be used to design optical metasurfaces that emulate neural network functionality and characterize their computing performance.

The AFRL team has an initial database of refractive properties for metasurface geometries (meta-atoms) consisting of cylinders, squares and cross elements. In addition, the team has an established design optimization workflow to predict the spatial arrangement of these meta-atoms to achieve targeted input-output mappings. The internship will consist of 1) broadening the library of meta-atoms and 2) characterizing the complexity of input-output mappings achievable with distinct sets of meta-atoms. This two-part strategy will enable the intern to investigate metasurface computing performance questions with the current toolset, while they build up their understanding of how to expand the meta-atom library through modeling additional meta-atom shapes. Research tasks will include setting up optimization routines, executing parameter studies to create the refractive index library for new meta-atom geometries, training NN surrogates to interpolate between library data points, and developing metrics to compare the information processing capacity between metasurfaces designs.

Deep neural networks are gaining broad adoption throughout a range of technical disciplines, including engineering, materials science, bioinformatics, and more. The intern will gain familiarity with the fundamental functionality of deep neural networks, as well as experience with explaining their behavior. Transferable skills will be gained by working with our code workflow on a local cluster, on the Google Cloud Platform, and on the HPC. The intern will also gain experience with Python packages that are popular across disciplines, including TensorFlow, NumPy, Matplotlib, and Scikit-learn.

We have structured the internship to provide a balance of concrete tasks and open-ended research questions to best ensure an experience that is both productive and challenging.

In addition to these project-specific activities, the AFRL Materials and Manufacturing Directorate (AFRL/RX) provides several opportunities for students to learn about STEM research areas and career pathways. For example, the directorate organizes the weekly RX101 technical seminar series where the mission and technical overview of each research team is presented. RX also has a machine learning working group and seminar series, called “Miracle”, that the intern will be encouraged to attend. The AFRL/RX summer student poster session also provides an opportunity for the students to interact with AFRL researchers and showcase their summer research activities.

Week 1-2: Introduction to DSRC, Python, and (DNA)2

Weeks 3-5: Exploration of meta-atoms and DDNNs design

Weeks 6-8: Generate new library elements and benchmark

Weeks 9-10: Prepare final report, RX poster, HIP presentation, and archive code

ANTICIPATED START DATE:

May 2024 – Exact start dates will be determined at the time of selection and in coordination with the selected candidate.

QUALIFICATIONS:

The ideal candidate will be currently pursuing a degree in a field such as physics, engineering, computer science, or statistics. Previous coding experience (any language) is highly encouraged, with Python experience preferred.

ACADEMIC LEVEL:

Degree received within the last 60 months or currently pursuing:

- Bachelor’s
- Master’s
- Doctoral

DISCIPLINE NEEDED:

- Computer, Information, and Data Sciences
- Engineering
- Mathematics and Statistics
- Physics
- Science & Engineering-related