HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

RESEARCH PROJECT #: HPCMP-HIP-25-030

Investigation of the Role of Network Topology on the Computing Performance of Optomechanical Reservoirs

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 in Polymers and Responsive Materials Research Team at AFRL's Materials and Manufacturing Directorate. This project will focus on the design of optomechanical reservoirs to perform in materio computing operations.

Nonlinear dynamics are a pervasive phenomena on AF systems. Physical reservoir computing as a machine learning framework for harnessing these dynamics as a means of information processing. In this study, we will investigate the role of network topology on the dynamics and computing performance of an optomechanical spring system. The work will yield insights into how to design optomechanical structures for optimal information processing capacity.

The AFRL team has developed a computational code for simulating optomechanical reservoir computers, a family of metrics for evaluating reservoir computer performance, and a computational workflow for exploring the design space via a novelty search algorithm. A handful of simple 2D network topologies have already been identified, but there is a need for more in-depth exploration of network topologies. The internship will consist of 1) identifying new ways to parameterize network topologies, and 2) conducting parametric studies to characterize the performance of various 2D optomechanical reservoirs. This two-part strategy will enable the intern to investigate reservoir computing performance questions with the current toolset, while they build up their understanding of how to represent a variety of network topologies. Research will include developing scripts to generate various network topologies, executing parametric studies of reservoir computers using the established workflow on the HPC, and leveraging statistical/machine learning techniques to identify network design features and motifs that correspond to superior reservoir performance.

The intern will gain familiarity with the fundamental functionality of physical reservoir computing, 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 research and open-ended 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 interns 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 the AFRL optomechanical solver

Weeks 3-5: Exploration of 2D network topologies on reservoir performance

Weeks 6-8: Generate new topology parameterization and compare with reservoir benchmark metrics

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

ANTICIPATED START DATE:

May 2025 – 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 mechanical engineering, computer science, or physics. Knowledge of either 1) machine learning algorithms and/or 2) nonlinear dynamics. Knowledge and coursework in finite element analysis. Knowledge of programming such as MATLAB, Python, C++, and/or Julia is 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
- Physics
- Science & Engineering-related