HIGH PERFORMANCE COMPUTING MODERNIZATION PROGRAM

RESEARCH PROJECT #: HIP-24-009

Decoding Dynamic Trends: Forecasting Stress Evolution and Crack Formation in Carbon Fiber Reinforced Polymer (CFRP) Composites using Recurrent 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 aims to engineer cutting-edge recurrent neural network architectures that will not only decipher stress evolution images of CFRPs but also unlock insights into the intricate interplay between microstructure distribution, stress evolution, and crack formation. By mastering the underlying context via attributes extracted from time-series data, this project promises to unravel the fundamental mechanisms that drive stress evolution in such microstructures and how we can optimize such microstructures to delay critical stresses that lead to their failure.

This project will leverage time-series CFRP stress-strain FEM datasets to comprehend evolving stress-fields' intricate evolution over time. The internship plan will encompass the following key phases:

- Data Generation: Employ HPC resources to produce CFRP stress evolution input data via FEM calculations
- Feature Extraction: Perform feature engineering to identify relevant features (pixels, etc.) to be input to ML model
- RNN Framework Development: Extend physics-informed differential neural network (PiNDiff) to predict stress evolution
- Model Validation: Assess model accuracy on unseen data, aiming for < 5% error in stress predictions. If time permits, test against in-house experimental datasets.

Upon successful training, verification, and validation against test datasets, this tool will rapidly predict stress evolution, crack initiation and growth in unknown CFRP microstructures and aid in addressing microstructural characteristics' (fiber distribution, fiber/matrix interface strength) impact on composite performance (damage onset) towards optimizing microstructures for enhanced structural performance.

Internship Technical Research:

- Generate stress evolution input data for CFRC using in-house code on HPC.
- Develop a physics-integrated recurrent neural network ML framework (PiNDiff) to predict CFRC's elastic and non-linear response.
- Validate the model using unseen test data.
- Utilize experimental datasets to predict failure sites once the model is validated.
- Summarize findings in a technical report and draft journal publications post-internship.
- Present findings in technical meetings and an RX-wide poster session.

Professional Development Opportunities:

- Attend RX101 seminars focusing on Materials and Manufacturing Directorate's importance in the AF mission and AFRL's materials research areas.
- Participate in guided tours of RX and, if arranged, HPC supercomputer facilities.
- Engage in weekly technical research team meetings to understand AFRL current and future research directions.
- Interact and learn from the subject matter experts from various technical fields.

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 should be knowledgeable in:

- Machine Learning and Materials Science
- Running Molecular Dynamics Simulations on High Performance Computing Resources
- Python for Pre-/Post- Processing of Data.

ACADEMIC LEVEL:

Degree received within the last 60 months or currently pursuing:

- Bachelor’s
- Master’s
- Doctoral

DISCIPLINE NEEDED:

- Chemistry and Materials Sciences
- Computer, Information, and Data Sciences
- Engineering
- Science & Engineering-related