Investigating the Application of Multi-Modal Large Language Models to Accelerate Insights from Simulation and Experimental Data

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.

The composites performance team at the Air Force Research Laboratory Materials and Manufacturing Directorate uses a combination of novel and high-impact experiments, in-house high-fidelity HPC simulation software, and machine learning to characterize and predict the performance of current and emerging materials.

RESEARCH LOCATION: Wright-Patterson AFB, OH

PROJECT DESCRIPTION:

AFRL consistently generates vast amounts of data through simulations and material characterization techniques (such as X-Ray CT, serial sectioning, and digital image correlation). To extract valuable insights from this data, AFRL currently relies heavily on the expertise of its researchers. While AI/ML has garnered significant excitement across government and industry for its potential, and AFRL is actively utilizing various ML models for scientific applications like material structure generation and surrogate modeling, little focus has been placed on how multi-modal Large Language Models (LLMs) could expedite the process of feature identification within this data. This project aims to explore how current off-the-shelf multi-modal LLMs can assist researchers in this crucial research.

The overall objective of this project is to understand how multi-modal LLMs can be leveraged to identify features of interest or important differences between datasets. To simplify the scope of this challenging problem, two-dimensional simulation and experimental data will be used, since 2D image data is more amendable to trained off-the-shelf models. Research includes the identification of geometrical features (such as corners and holes), features in the material structure (such as fibers, voids, and inclusions), stress concentrations and nearby geometrical features, and differences between experimental DIC results and a simulated digital twin of the experiment. To achieve the goals of the project, the intern will:

Week 1: Complete in-processing, obtain access to a DoD HPC system, and learn how schedule simulations on an HPC system.

Week 2: Build familiarity with off-the-shelf multi-modal LLMs.

Week 3: Establish a workflow to evaluate Google's multi-modal LLM in Google Cloud.

Weeks 4-5: Explore feature identification tasks using provided simulation data in Google Cloud.

Week 6: Establish a workflow to evaluate Meta's multi-modal LLM on the DoD HPC.

Weeks 7-8: Explore feature identification tasks using provided simulation data for Meta's model.

Weeks 9-10: Author a report summarizing the research, document all code and results, give a research presentation to research team, and present at the HIP symposium.

In addition to the activities related to the project directly, the intern will have the opportunity to attend seminars focused on computing, machine learning, and material science; attend technical meetings across a variety of disciplines; participate in tours in the computing and material labs; and network with experts across disciplines.

These activities will give the intern the opportunity to lead a research project typical to those in government labs, develop an understanding of a variety of computational tools and computing environments, and show how findings can impact a broader community of researchers in the lab. If desired, the intern can choose to pursue authoring a DoD technical report.

ANTICIPATED START DATE:

May 2025 – Exact start dates will be determined at the time of selection and in coordination with the selected candidate.

QUALIFICATIONS:

Required qualifications for the intern include:

- Be proficient in Python
- Have some experience with machine learning
- Have experience documenting code and research efforts.

Qualifications that are not required but would be helpful include:

- Familiarity with generative AI models
- Familiarity with LLMs,
- Familiarity with PyTorch
- Familiarity with job scheduling and typical workflows in HPC environments

ACADEMIC LEVEL:

Degree received within the last 60 months or currently pursuing:

- Bachelor's
- Master's
- Doctoral

DISCIPLINE NEEDED:

- Computer, Information, and Data Sciences