Project Title: Exploring Physics Informed Neural Networks (PINNs) for Modeling Electron Kinetics in Low-Temperature Plasmas

Project Reference Code: Wang-Applied Materials

Name of Project Leader: Dr. Jun-Chieh (Jerry) Wang

Host Facility: Applied Materials, Inc.

Internship Location: Center for Space Plasma and Aeronomic Research (CSPAR) at the University of Alabama in Huntsville, 320 Sparkman Dr. Huntsville, AL 35805

Host Facility Location: Huntsville, AL 35806 https://www.appliedmaterials.com/

Project Description:
The use of Artificial Intelligence (AI) and Machine Learning (ML) to speed up and increase the physical fidelity, accuracy, and reliability of computational plasma physics simulations is currently being intensively explored and investigated in the research community and could result in great leaps in the capabilities and practical value of the discipline. Artificial Neural Networks (ANNs), and more specifically, Physics-Informed Neural Networks (PINNs), are one of the most promising AI / ML techniques for solving computational physics problems. PINNs can be used to generate computational solutions of the underlying partial differential equation (PDE) system that describe the behavior of plasmas, but without requiring discretization on meshes as done with the finite-volume, particle-in-cell, and other classical PDE solution methods. PINNs can also be used to solve the Boltzmann or Fokker-Plank equations in models for electron kinetics, even within existing plasma physics solvers (such as the commercially available codes COMSOL and ACE+), and at a fraction of the computational effort and memory needed by classical computational methods. Having faster electron kinetics models will enable the electron energy distribution function (EEDF) and the transport coefficients and properties to be calculated with high fidelity and accuracy and in reasonable time, leading to substantial improvement in the state-of-the-art in plasma physics computational modeling.

In this project, the student will be guided to train PINNs for selected kinetic models, to deploy and test these PINNs, and to evaluate their computational cost and physical fidelity relative to benchmark calculations. The work will give the student a good understanding of the theory and practice of constructing and training ANNs and PINNs and will give the student experience in scientific computing. The work should be appealing for any student interested in plasma physics, computational modeling, or the use of ANNs and PINNs in novel and innovative ways that are at the forefront of AI and ML.

Importance:
Kinetic models for electrons are becoming increasingly attractive for low-temperature plasma physics simulations. This is because such models offer higher physical fidelity than classical models but without significantly increasing the computational cost. Developing and improving such models, especially within existing plasma physics solvers, will have a substantial impact on the discipline of computational plasma physics and will increase the use of modeling in the study, design, and optimization of processes and equipment that use low-temperature plasmas.

Requirements:

- **Preferred Major**
  - Engineering (including mechanical, aerospace, electrical, computer, chemical, or civil engineering)
  - Physics or chemistry, including plasma physics
  - Computer science
  - Any field closely related to the above.
- **Class work**
  - Must have completed all basic science, mathematics, and engineering courses
  - Computer programming
- **Programming knowledge**
  - Excellent programming skills in at least one language
- **Software knowledge**
  - No specific requirements

Biography:

Jun-Chieh Wang is a Senior Member of Technical Staff at Applied Materials and an Affiliate Graduate Faculty at UAH. He holds an M.S. in Physics from National Cheng Kung University and a Ph.D. in EECS from the University of Michigan. Jun-Chieh specializes in software development, plasma physics, and numerical modeling. He leads plasma module development for the CFD-ACE+ Suite and collaborates on low-temperature plasma research, with over 10+ publications, 20+ technical talks, and patents.

Is U.S. citizenship required to participate in this project? No

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The name and contact information of personnel at the host facility is provided for further assistance with questions regarding the host facility or the project.

Interns will not enter into an employee/employer relationship with the host facility. No commitment with regard to later employment is implied or should be inferred.