Offer #2023-07017

Neural Methods for Plasma

Contract type: Internship
Level of qualifications required: Graduate degree or equivalent
Fonction: Internship Engineering

Assignment

Efficient simulation of plasma dynamics remains an important challenge for achieving productive nuclear fusion. Classical simulations involve Semi-Lagrangian methods for Vlasov-type problems, and Finite Elements for Magnetohydrodynamics (MHD) models. These methods are accurate, but require a large number of degrees of freedom. This becomes prohibitively expensive when the PDE dimension increases. Classical methods such as these are based on a projection onto a finite-dimensional function vector space.

More recently, methods have been devised based on a projection onto a manifold. This is equivalent to approximating with functions living in a finite-dimensional space, which are nonlinear with respect to their degrees of freedom. Gaussian mixtures or neural networks are examples of such recent methods.

The goal of this internship is to investigate the « Neural Galerkin » method, a recently developed deep-learning-based approach. This method uses a neural network to approximate the solution in space; the weights of the neural network evolve over time to capture the dynamic. Such approaches usually are less accurate than classical ones, but they could require fewer degrees of freedom in large dimensions, are mesh-free, and are able to deal with parametric PDEs.

This internship is joint between the TONUS Inria team in Strasbourg and the Culham Centre for Fusion Energy, in the UK.

In practice, the internship is located in Strasbourg, for a period of 6 months, but travel to Culham during the internship is possible and encouraged. This internship could naturally lead to a PhD in Strasbourg, in collaboration with Culham; we are looking for candidates who are also interested in applying for this PhD.

Code developments will be realized in the in-house SciMBA library, where several some neural methods are already implemented in the PyTorch framework.

Main activities

In practice, we will consider the « Guiding center » model, which corresponds to a transport equation with a variable velocity, itself solution to a Poisson problem. The classical test case for this problem is the Diocotron instability, whose growth rate has an analytical solution.

The first step will be to propose an algorithm to couple the solution of the transport and the Poisson equations. We propose two approaches, the first using physics-informed neural networks and the second with neural operators. In both cases, obtaining a high-order scheme in time will be challenging.

The second step will be the construction of a specific neural network architecture able to approach such a problem with few degrees of freedom. This solver can be coupled with an adaptive sampling method. Time permitting, an extension to other models (Hasegawa-Wakatani 2D turbulence model or Navier-Stokes equation in toroidal geometry) will be considered, in order to prepare for MHD applications.

Main activities (5 maximum):
- state of the art of neural methods and applications to plasma
- developpement of the spatial numerical scheme
- proposition of the new time scheme for the Guiding center problem
- validation on physical test cases and problems

Skills

Technical skills and level required:
Languages:

Relational skills:

Other valued appreciated:

**Benefits package**

- Subsidized meals
- Partial reimbursement of public transport costs
- Leave: 7 weeks of annual leave + 10 extra days off due to RTT (statutory reduction in working hours) + possibility of exceptional leave (sick children, moving home, etc.)
- Possibility of teleworking (after 6 months of employment) and flexible organization of working hours
- Professional equipment available (videoconferencing, loan of computer equipment, etc.)
- Social, cultural and sports events and activities
- Access to vocational training
- Social security coverage

**Remuneration**

4.05 per hour of training

**General Information**

- Theme/Domain: Earth, Environmental and Energy Sciences
- Scientific computing (BAP E)
- Town/city: Strasbourg
- Inria Center: Centre Inria de l'Université de Lorraine
- Starting date: 2024-03-01
- Duration of contract: 6 months
- Deadline to apply: 2024-01-14

**Contacts**

- Inria Team: TONUS
- Recruiter: Franck Emmanuel / emmanuel.franck@inria.fr

**About Inria**

Inria is the French national research institute dedicated to digital science and technology. It employs 2,600 people. Its 200 agile project teams, generally run jointly with academic partners, include more than 3,500 scientists and engineers working to meet the challenges of digital technology, often at the interface with other disciplines. The Institute also employs numerous talents in over forty different professions. 900 research support staff contribute to the preparation and development of scientific and entrepreneurial projects that have a worldwide impact.

**The keys to success**

The ideal candidate for this internship will be a second-year Master's student in applied mathematics, PDE modeling and numerical analysis, looking for a Master's thesis as part of their curriculum. Basic knowledge of neural networks would be appreciated, but is not necessary. A good knowledge of the Python language is important.

**Warning:** you must enter your e-mail address in order to save your application to Inria. Applications must be submitted online on the Inria website. Processing of applications sent from other channels is not guaranteed.

**Instruction to apply**

**Defence Security:**

This position is likely to be situated in a restricted area (ZRR), as defined in Decree No. 2011-1425 relating to the protection of national scientific and technical potential (PPST). Authorisation to enter an area is granted by the director of the unit, following a favourable Ministerial decision, as defined in the decree of 3 July 2012 relating to the PPST. An unfavourable Ministerial decision in respect of a position situated in a ZRR would result in the cancellation of the appointment.

**Recruitment Policy:**

As part of its diversity policy, all Inria positions are accessible to people with disabilities.