Offre n°2022-05611

Physics-Informed Neural Network for electromagnetic wave propagation

Type de contrat : Stage

Niveau de diplôme exigé : Bac + 5 ou équivalent

Fonction : Stagiaire de la recherche

Niveau d'expérience souhaité : Jeune diplômé

A propos du centre ou de la direction fonctionnelle

The Inria Université Côte d'Azur center counts 36 research teams as well as 7 support departments. The center's staff (about 500 people including 320 Inria employees) is made up of scientists of different nationalities (250 foreigners of 50 nationalities), engineers, technicians and administrative staff. 1/3 of the staff are civil servants, the others are contractual agents. The majority of the center's research teams are located in Sophia Antipolis and Nice in the Alpes-Maritimes. Four teams are based in Montpellier and two teams are hosted in Bologna in Italy and Athens. The Center is a founding member of Université Côte d'Azur and partner of the I-site MUSE supported by the University of Montpellier.

Contexte et atouts du poste

Numerical simulations of electromagnetic wave propagation problems primarily rely on spatially and temporally discretization of the system of time-domain Maxwell equations using finite difference or finite element type methods. For complex and realistic three-dimensional situations, such a process can be computationally prohibitive, especially in view of many-query analyses (e.g., optimization design and uncertainty quantification). Therefore, developing cost-effective *surrogate models* is of great practical significance. Among the different possible approaches for building a surrogate model of a given PDE system in a non-intrusive way (i.e., with minimal modifications to an existing discretization-based simulation methodology), approaches based on neural networks and Deep Learning (DL) has recently shown new promises due to their capability of handling nonlinear or/and high dimensional problems. In the present study, we propose to focus on the particular case of Physics-Informed Neural Networks (PINNs) introduced in [1]. PINNs are neural networks trained to solve supervised learning tasks while respecting any given laws of physics described by a general (possibly nonlinear) PDE system. They seamlessly integrate the information from both the measurements and partial differential equations (PDEs) by embedding the PDEs into the loss function of a neural network using automatic differentiation. Such PINNs have for instance been studied for inverse problems in nano-optics and metamaterials in [2].

At Inria, the Atlantis project-team [3] gathers applied mathematicians and computational scientists who are undertaking research activities aiming at the design, analysis, development and application of innovative numerical methods for systems of partial differential equations (PDEs) modeling nanoscale light-matter interaction problems. In this context, the team develops the DIOGENeS (DiscOntinuous GalErkin Nano Solvers) software suite [4]. which implements several Discontinuous Galerkin (DG) type methods tailored to the systems of time- and frequency-domain Maxwell equations possibly coupled to differential equations modeling the behavior of propagation media at optical frequencies. DIOGENeS is a unique numerical framework leveraging the capabilities of DG techniques for the simulation of multiscale problems relevant to nanophotonics and nanoplasmonics.

The work carried out in this internship project will give first insights of the effectiveness of PINNs in the considered physical context, in view of a further study, which will aim at

designing and developing a new component of the DIOGENeS software package dedicated to AI-based reduced-order modeling.

[1] M. Raissi, P. Perdikaris and G.E. Karniadakis. Physics-informed neural networks: a deep learning framework for solving forward and inverse problems involving nonlinear partial differential equations. J. Comp. Phys., Vol. 378, pp. 686-707 (2019)

[2] Y. Chen, L. Lu, G.E. Karniadakis and L. Dal Negro. Physics-informed neural networks for inverse problems in nano-optics and metamaterials. Opt. Expr., Vol. 28, No. 8, pp. 11618-11633 (2020)

[3] http://www-sop.inria.fr/atlantis/

[4] https://diogenes.inria.fr/

Mission confiée

In this internship, we propose to conduct a study of the applicability of PINNs for building efficient surrogate models of the system Maxwell equations in 2D (two-dimensional case). This internship will proceed in two steps: first a detailed bibliographical review on PINNs and related physics-constrained neural networks approaches will be conducted and documented, with a focus on recent works for electromagnetic and other wave propagation models; then, PINNs will be formulated and developed for several configurations of interest to optical wave modeling. A particular attention will be given to the performance of the training phase. More precisely, we want to study in detail the influence of the network configuration (number of layers and neurons in each layer, activation function, etc.) as well as of the definition of the loss function on the behavior of the training phase. Finally, we will study possible routes for improving the performance of the training phase and the accuracy of the resulting surrogate model such as adaptive sampling of the training points, locally adaptive activation function, etc.).

Compétences

This position is intended for master students in the field of applied mathematics and scientific conmputing with a strong background in numerical computing and related subjects. to AI.

Required Skills

- Good knowledge of one or two DL frameworks (tensorflow, pytorch)
- Good knowledge of Linear Algebra and one or more libraries (Eigen, blas/lapack, xtensor, ...)
- Good knowledge of Python and associated Numpy-type libraries

Avantages

- Restauration subventionnée
- Transports publics remboursés partiellement
- Congés: 7 semaines de congés annuels + 10 jours de RTT (base temps plein) + possibilité d'autorisations d'absence exceptionnelle (ex : enfants malades, déménagement)
- Possibilité de télétravail (après 6 mois d'ancienneté) et aménagement du temps de travail
- Équipements professionnels à disposition (visioconférence, prêts de matériels informatiques, etc.)
- Prestations sociales, culturelles et sportives (Association de gestion des œuvres sociales d'Inria)
- Accès à la formation professionnelle
- Sécurité sociale

Informations générales

- **Thème/Domaine :** Optimisation, apprentissage et méthodes statistiques
  Calcul Scientifique (BAP E)
- **Ville :** Sophia Antipolis

- **Centre Inria :** Centre Inria d'Université Côte d'Azur
- **Date de prise de fonction souhaitée :** 2023-03-01
- **Durée de contrat :** 6 mois
- **Date limite pour postuler :** 2023-05-30

Contacts

- **Équipe Inria :** ATLANTIS
- **Recruteur :**
  Lanteri Stéphane / Stephane.Lanteri@inria.fr

A propos d'Inria

Inria est l'institut national de recherche dédié aux sciences et technologies du numérique. Il emploie 2600 personnes. Ses 215 équipes-projets agiles, en général communes avec des partenaires académiques, impliquent plus de 3900 scientifiques pour relever les défis du numérique, souvent à l'interface d'autres disciplines. L'institut fait appel à de nombreux talents dans plus d'une quarantaine de métiers différents. 900 personnels d'appui à la recherche et à l'innovation contribuent à faire émerger et grandir des projets scientifiques ou entrepreneuriaux qui impactent le monde. Inria travaille avec de nombreuses entreprises et a accompagné la création de plus de 200 start-up. L'institut s'e□orce ainsi de répondre aux enjeux de la transformation numérique de la science, de la société et de l'économie.

L'essentiel pour réussir

With a scientific background, you have an appetite for scientific fields and digital sciences, with a first experience in the fields of scientific computing and AI. Motivation, curiosity and the desire to learn is the main quality expected. Your ability to work in a team, to be proactive and to motivate a team will also be very important.

Attention: Les candidatures doivent être déposées en ligne sur le site Inria. Le traitement des candidatures adressées par d'autres canaux n'est pas garanti.

Consignes pour postuler

Sécurité défense :
Ce poste est susceptible d'être affecté dans une zone à régime restrictif (ZRR), telle que définie dans le décret n°2011-1425 relatif à la protection du potentiel scientifique et technique de la nation (PPST). L'autorisation d'accès à une zone est délivrée par le chef d'établissement, après avis ministériel favorable, tel que défini dans l'arrêté du 03 juillet 2012, relatif à la PPST. Un avis ministériel défavorable pour un poste affecté dans une ZRR aurait pour conséquence l'annulation du recrutement.

Politique de recrutement :
Dans le cadre de sa politique diversité, tous les postes Inria sont accessibles aux personnes en situation de handicap.