Postdoc offer in optimization:

Multilevel block coordinate methods for physics informed training in ocean flow reconstruction

Coordinators: Elisa Riccietti (**elisa.riccietti@ens-lyon.fr**), LIP ENS Lyon
Nelly Pustelnik (**nelly.pustelnik@ens-lyon.fr**), CNRS, ENS Lyon

Duration: 18 months
Place: LIP, ENS Lyon, 46 Allée d'Italie, 69364 Lyon
Working language : french or english

Scientific context: Physics-informed neural network (PINN) techniques are revolutionizing data assimilation in fluid mechanics [1]. In the context of the ocean, they offer a promising opportunity for deep flow reconstruction, an area that remains underexplored. The challenge is that, while surface ocean currents can be reconstructed with confidence due to the abundance of available data, reconstructing abyssal flow is much more uncertain due to the limited data in these deeper regions. Recently, it has been shown how surface measurements can be combined with sparse interior data to reconstruct deep flows with PINNs [2]. While this work, developed within an idealized flow model, served as a proof of concept for ocean data assimilation using PINNs, the challenge now is to scale and evaluate these methods for accurately reconstructing deep ocean flows in real-world conditions.

Subject: This postdoc subject will be concerned by the solution of the optimization problem in the PINNs training. The peculiar structure of the problem will lead to formulating the training problem as the minimization of an objective function that implies contributions from different “levels”, which have various interactions among each others. The resulting loss function is expected to be high dimensional and expensive to train. The postdoc will investigate the potential of multilevel strategies, which exploit hierarchies of neural models and/or collocation points, drawing on multigrid algorithms used for solving PDEs [3], in this context. Specifically, the aim of the postdoc is twofold:

- to propose block coordinate type algorithms, inspired by multilevel methods, capable of exploiting the structure of the problem to reduce the cost of the solution process. The methods will be tested experimentally on model problems arising from the considered application and their convergence will be theoretically studied.
- To study adaptive methods for selecting the collocation points, focusing on optimizing their distribution to solve ocean models with varying physical complexities. A key focus will be on ocean problems where interior data is sparse, but surface data is abundant.

Presequisites: The candidate is expected to have a general background in optimization, to be at ease with convergence proofs of optimization methods and with the implementation of the methods in python. A knowledge of physics informed neural networks and programming skills in PyTorch is a plus.

Working context: This postdoc will be funded by the ANR MEPHISTO, lead by Elisa Riccietti, and the research topic will be part of the research project ANR PINOT, lead by Antoine Venaille at ENS Lyon. The candidate will be part of the OCKHAM team at LIP, ENS Lyon and work in close collaboration with the SYSIPH team of the physics department.

References

[1] G. E. Karniadakis, I. G. Kevrekidis, L. Lu, et al., “Physics-informed machine learning”, Nature Reviews Physics, vol. 3, no. 6, pp. 422–440, 2021.

[2] V. Limousin, N. Pustelnik, B. Deremble, and A. Venaille, “Deep learning in the abyss: A stratified physical informed neural network for data assimilation”, arXiv 503.19160 submitted to Journal of Advances in Modeling Earth Systems, 2025. [Online]. Available: https://arxiv.org/abs/2503.19160.

[3] S. Gratton, V. Mercier, E. Riccietti, and P. L. Toint, “A block-coordinate approach of multi-level optimization with an application to physics-informed neural networks”, Computational Optimization and Applications, vol. 89, no. 2, pp. 385–417, 2024.