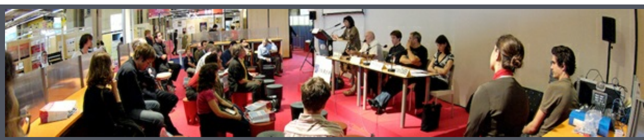
INTERNATIONAL RELATIONS



INTERNSHIP SUBJECT

2901 - Neural Network-Based Approaches for Coupled Stochastic Dynamic

Keywords: PINNS, Model Design; Stochastic Modeling, Simulation, Times series related to Environmental Processes;

Context:
As deep learning tools rapidly evolve and address various challenges, Physics-Informed Neural Networks have emerged as promising tools for approximating and learning dynamical systems such as ordinary differential equations (ODE) and partial differential equations (PDE). These networks embed physical laws within the learning framework with the idea of improving their ability to model complex systems. However, in many practical situations, particularly those where diffusivity or multiscale interactions play a role, the system under study may be subject to randomness that turns ODE and PDE to stochastic equations. This stochastic nature implies to modifies the concepts of solutions, as realizations (or trajectories) of stochastic processes.

Although some approaches for learning with neural networks in the context of stochastic differential equations (SDEs) have already emerged, this task is fundamentally challenging due to the intrinsic stochasticity of the system, specially when the involved noise structure is not just Gaussian or when the dynamics presents nonlinearities. McKean-Vlasov stochastic differential equations (McKV SDEs in short) offer a formal approach to model nonlinear stochastic dynamics. They are particularly helpful for modelling environmental processes. In the context of complex flows (coastal currents, wind near boundaries), McKV SDEs are useful to describe the transport and diffusion of scalars physical quantities like temperature or salinity. This so-called Lagrangian transport captures the intrinsic correlations between flow velocity and the studied scalar fields.

Recent literature has proposed a deep learning, particle-based method for solving McKV equations, leveraging ergodic properties of the process. This approach integrates the physical constraints of the SDE model with the capability of deep neural networks to learn smooth coefficients. Based on this principle, we want to explore an approximation/calibration procedure for a coupled model of wind velocity and scalar (temperature) continuous time series, by incorporating physical information, such as velocity-scalar correlations, into the learning framework. This method allows for partial parameterisation of the model, which may help reduce the complexities typically associated with a complete analytical formulation.

The proposed topic aligns with the aim of the **SWAM** Team (https://project.inria.fr/swam/), which specializes in the stochastic modelling of environmental systems and has established collaborations between Chile and France. It also aligns with efforts to develop methodologies for estimating and approximating complex processes that combine expert knowledge with deep learning techniques.

Internship tasks and related methodology:
The aim of the internship is threefold. Based on python libraries,

1. Understand the framework of coupled test SDEs, by simulating datasets (useful for the second phase) using a classical simulation method (applicable on this test equation, albeit with a well-chosen nonlinearity form).
2. Adapt (or re-deploy) a PINNs (Physics-informed neural networks) solver/simulator following (for example) the methodology described in [1].
3. Apply the previous methodology to time series (velocity/temperature) dataset, and analyse some qualitative comparison with the nonlinear model under development by CALISTO-SWAM, the later being designed following mainly physical considerations on complex flows.

Reference:
[1] Jingyuan Li and Wei Liu, Solving McKean-Vlasov Equation by deep learning particle method. arXiv:2501.00780, 2025. https://arxiv.org/abs/2501.00780

Required Skills

Expected profile

- The position is open to Master or PhD student, with background in machine learning techniques, while involved in one of the following disciplines : Statistics, Data Sciences, Applied Mathematics, Physics.
- Knowledge and interest in programming (in particular Python).
- Fluent in English.

General Information

- **Research Theme :** Stochastic approaches
- **Locality :** Sophia Antipolis
- **Level :** Master
- **Period :** 5th January 2026 -> 5th April 2026 (3 months)

These are approximative dates. Please contact the training supervisor to know the precise period.

- **Deadline to apply :** 1st July 2025 (midnight)

Contacts

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More information

- **Inria Team :** CALISTO
- **Inria Center :** Centre Inria d'Université Côte d'Azur