

Master's Thesis:

Machine Learning Acceleration of Fluid–Structure Coupled System Identification

System Identification (SI) seeks to determine physical or material parameters by combining experimental data with numerical simulations [1,2]. In fluid–structure interaction (FSI) problems, the high computational cost of fluid solvers poses a significant bottleneck for iterative SI processes.

This thesis investigates the use of Machine Learning (ML) models—such as Neural Networks (NN), Graph Neural Networks (GNN), Physics-Informed Neural Networks (PINN), etc—to partly or fully emulate the fluid solver within the coupled SI loop. The aim is to develop a hybrid SI framework that integrates data-driven surrogates to accelerate simulations while maintaining physical accuracy. The study focuses on **steady-state coupled FSI**, enabling controlled training, validation, and comparison between high-fidelity and ML-augmented approaches.

Work Packages

- Literature Review:** Review existing ML applications in simulation acceleration, optimization, system identification, and FSI / RANS.
- High-Fidelity SI Setup:** Understand, review, and perform steady-state coupled FSI simulations for reference results.
- ML Model Design:** Select and configure suitable surrogate model architectures (NN, GNN, or PINN).
- Training & Data Generation:** Generate simulation datasets and train ML models.
- Evaluation:** Integrate the trained surrogate into the SI workflow and compare accuracy, speed, and convergence.

The work will make use of **KratosMultiphysics** for setting up and running coupled FEM–CFD simulations, while **PyTorch** or **TensorFlow** will be employed for developing and training the machine learning models.

Applicants should have solid programming skills in **Python** and basic **C++**, a good understanding of **numerical methods**, **CSD / CFD**, **FEM**, and **optimization**, as well as a **basic familiarity with machine learning** concepts.

References:

- [1] Löhner, R., Airaud, F., Antil, H., Wüchner, R., Meister, F., & Warnakulasuriya, S. (2024). High-fidelity digital twins: Detecting and localizing weaknesses in structures. *International Journal for Numerical Methods in Engineering*.
- [2] Ansari, T. S. A., Löhner, R., Wüchner, R., Antil, H., Warnakulasuriya, S., Antonau, I., & Airaud, F. (2025). Adjoint-based recovery of thermal fields from displacement or strain measurements. *Computer Methods in Applied Mechanics and Engineering*.



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Start date: Flexible