Ph.D. in Information Technology
Thesis Defense

November 20th, 2026
At 10:30 a.m.
Sala Schiavoni - Building 20A

Alessandro COLOMBO – 38th Cycle

EXPERIMENTAL INVESTIGATION OF TRANSFORMER-BASED FOUNDATION MODELS FOR ESTIMATION AND CONTROL

Supervisor: Prof. Simone Formentin

Abstract:

Recent developments in Large Language Models have highlighted the generalization capabilities of Transformer-based Foundation Models.

Efforts have been made to transfer these properties to time-series filtering for estimation and control; however, most of the work in the literature operates only in simulated environments, without considering real-time feasibility and deployment issues. In this thesis, we aim at filling this gap by developing contextual estimators and controllers for physical applications, able to generalize across similar but different systems, with an inference time compatible with the application's sampling frequency. Furthermore, we show how, through generalization, these filters can enable a fully sim-to-real pipeline: only simulated data from Digital Twins are used for training, and the filters are deployed on real systems without retuning, outperforming model-based, fine-tuned benchmark alternatives. Specifically, this pipeline is validated on three applications. First, we explore the sensorless speed estimation of brushless DC motors, developing a contextual filter able to generalize across different inertial loads. Second, we explore the dual problem of speed control for the same platform, closing the loop in real time with our contextual controller. Third, we transpose this pipeline to a more complex system, for the estimation of the sideslip angle of racing vehicles, outperforming industrially tuned observers. Here, a sensitivity analysis is also performed, providing practical guidelines for the choice of the model hyperparameters. In all three cases, the filters are trained only on simulated trajectories and are then able to generalize across similar physical systems with different parameter configurations.

Sofia TROMBINI – 38th Cycle

TOWARDS OFFSHORE AIRBORNE WIND ENERGY: MODELLING, PRELIMINARY ANALYSIS AND CONTROL FOR FLOATING APPLICATION

Supervisor: Prof. Lorenzo Mario Fagiano

Extending Airborne Wind Energy Systems (AWESs) to floating offshore platforms represents a promising opportunity to exploit stronger and more persistent wind resources. However, placing an AWES on a floating platform fundamentally changes the dynamics of the system and raises a question that has so far received little attention: can an AWES operate effectively from a floating support and, if so, what new challenges emerge from the interaction between the airborne and floating offshore subsystems?

This thesis addresses these questions by developing a comprehensive framework for the investigation of floating offshore ground-generation AWESs. A coupled model integrating the airborne subsystem, tether, ground station, floating platform, and mooring system is developed to capture the mutual interaction between flight dynamics and platform motion. The results support the preliminary operational feasibility of the considered floating offshore AWES configuration under the investigated operating conditions. More importantly, they reveal a relevant interaction mechanism: the cyclic loads generated during the pumping cycle may excite the natural modes of the floating platform, giving rise to resonance phenomena and increased structure motions. This result shows that the dynamics of floating offshore AWESs are inherently frequency-dependent, making the spectral content of both the environmental excitation and the pumping cycle a key aspect for system operation.

Building upon these findings, the thesis investigates how the identified challenges can be mitigated through control. Two dedicated control strategies are proposed: one aimed at reshaping the frequency content of the tether loads to avoid resonance excitation of the floating platform, and a second designed to reject disturbances affecting the reel-out dynamics using an Internal Model Controller. Finally, a dedicated Hardware-in-the-Loop experimental setup is developed to reproduce the coupled interaction between a simulated AWES and a scaled floating platform. The experimental campaign validates the proposed methodology, confirms the frequency dependent nature of the identified interaction mechanisms, and demonstrates the effectiveness of the proposed anti-resonance strategy.

Overall, this work provides the first comprehensive investigations of floating offshore AWESs, showing that offshore operation is feasible while highlighting the new dynamic challenges introduced by floating supports. By establishing a framework to understand, analyse, and control these interactions, this work provides a foundation for the future development of floating offshore Airborne Wind Energy.

PhD Committee

Prof. Gian Paolo Incremona, **Politecnico di Milano**

Prof. Manuel Pusch, **Munich University of Applied Sciences**

Prof. Tom Oomen, **Technische Universiteit Eindhoven**