Ph.D. in Information Technology
Thesis Defenses

January 13th, 2025
At 14:00 p.m.
Sala Conferenze Emilio Gatti, Edificio 20

Riccardo BUSETTO – XXXVII Cycle

META-LEARNING FOR DATA-DRIVEN CONTROL SYSTEM DESIGN: THEORY AND APPLICATIONS
Supervisor: Prof. Simone Formentin

Abstract:

Learning controllers and estimators from data broadens the technology's accessibility, shifting the focus from the design of a problem-specific solution to the design of methods for solving several problems. However, collecting the necessary data for these learning methods can be costly or challenging. In such scenarios, leveraging past, similar experiences can be advantageous. Learning models suitable for similar systems and tasks go by the name of meta-learning, a rapidly growing set of machine learning tools that allow the sharing of information available in distributions that are not identical.
This thesis introduces a collection of meta-learning techniques for control and estimation, to reduce the data the algorithms require to deliver performing results. The contributions of this work are motivated by practical needs, exemplified by the data-driven design of a controller for brushless DC electric motors (BLDC), where a trade-off between performance and the amount of data available emerges. The intuition to mitigate this effect without collecting further data from the system is that when prior on solved similar problems is available, meta-learning can be used to boost the performance. In practice, we show how it can be used to initialize key hyperparameters of black-box optimization techniques like Set- Membership Global Optimization (SMGO), leading to faster convergence to the solution. Alternatively, meta-learning is suitable for improving model reference control techniques by combining previously tuned controllers for similar systems to obtain a performing controller for a new one, retaining the speed of direct methods. This approach is validated with experiments on BLDC motors and further improved by allowing for the auto-tuning of the reference model. Finally, the novel in-context learning paradigm is leveraged for designing model-free controllers and estimators. With a Transformer, an architecture powerful enough to model the complexity of an entire class of systems, we show how we can obtain a unified mathematical description suitable for controlling or filtering multiple plants. When deployed, this powerful architecture can recognize the particular instance of the class it has been trained on, to deliver improved performance.

Miao YU – XXXVI Cycle

HYBRID SYSTEM IDENTIFICATION USING A RANDOMIZED METHOD
Supervisor: Prof. Luigi Piroddi

Abstract:

Hybrid systems provide a uniform framework for handling the modeling problem of complex systems exhibiting a switching behavior among a set of local (non)-linear dynamics according to some switching mechanism. This thesis proposes several methods for the identification of hybrid systems, which involves the estimation of both the local models (modes) and the mode transition mechanism.

The primary challenge in hybrid system identification lies in the combinatorial complexity, as the number of possible switching mechanisms (represented by sample-mode assignments) grows exponentially with the size of the training dataset. Additionally, as noted in the literature, some samples are "ambiguous" and can be fitted equally well by multiple local models. Assigning these samples based solely on fitting performance may sometimes introduce outliers. While misclassifying such ambiguous samples does not significantly affect the accurate estimation of local models or their fitting performance, it can severely impact the correct estimation of the switching mechanism.

This thesis addresses these challenges by associating clusters of samples with their correct modes, rather than adopting a point-wise assignment. This reduces combinatorial complexity (since there are far fewer clusters than individual samples) and minimizes the impact of outliers (as ambiguous samples are influenced by unambiguous ones within the same cluster). Simulations verify that these methods achieve high classification accuracy, albeit with a slight reduction in fitting performance, enabling a more precise analysis of the switching mechanism.

PhD Committee

Prof. Marcello Farina, **Politecnico di Milano**

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Prof. Fabio Pasqualetti, **University of California at Riverside**