Ph.D. in Information Technology
Thesis Defense

February 27th, 2024
at 14:30
Sala Seminari Nicola Schiavoni, Building 20

Federico DETTU' – XXXVI Cycle

THE TWIN-IN-THE-LOOP APPROACH FOR VEHICLE DYNAMICS ESTIMATION AND CONTROL: METHODS AND APPLICATIONS

Supervisor: Prof. Simone Formentin

Abstract:

In vehicles, the ever increasing computing power in on-board Electronic Control units enables the use of demanding software components. Specifically, vehicle Digital Twins are full-fledged dynamic simulators, used for off-line design and testing; recent developments allow for the real-time execution of these models on on-board vehicle control units.

What would be the impact of embedding such sophisticated models in on-line estimation and control algorithms? This is the question tackled in this thesis, in which we develop, analyse and validate a framework named Twin-in-the-Loop (TiL).

On the control side, in typical design frameworks a certain controller (possibly a very sophisticated one) is finely tuned on increasingly complex vehicle models, up to a final implementation on the real vehicle, requiring a long and costly End-of-Line calibration: we change this framework by directly employing the controlled simulator on the real vehicle as an open-loop feedforward contribution, while a simple compensator – e.g. a PID – is enforced to guarantee stability of the overall system. After validating and comparing the approach against a benchmark, onto a significant case study, we tackle some practical problems of it: specifically, we address the problem of tuning the TiL compensator directly from data, while guaranteeing some robustness in the process.

On the estimation side, recent research showed as TiL observers (employing a vehicle simulator as a plant replica) are able to outperform benchmark ones: a critical aspect when considering TiL estimators also lies in the calibration of the algorithm itself.

In this work, we extend and experimentally validate the original formulation to the problem of estimating unknown parameters (such as the vehicle mass and moments of inertia). Then, we focus on the problem of calibrating the estimator closed-loop correction law. Due to the high number of parameters to be tuned, a reduction of the complexity is necessary in order to have a well posed optimization problem: this is made further complex by the fact that the Digital Twin is a black-box object, thus preventing the use of classical observer tuning approaches (e.g. the Kalman Filter theory). To solve the problem, we employ both supervised and unsupervised learning approaches; eventually, we show as the automatic complexity reduction is more performing than one carried out via physics-inspired considerations.

Andrea SASSELLA – XXXVI Cycle

EXPLICIT DATA-DRIVEN PREDICTIVE CONTROL DESIGN

Supervisor: Prof. Simone Formentin

Abstract:

This dissertation investigates Data-Driven Predictive Control (DDPC) with the aim of promoting its adoption as a viable control design technique. DDPC, which adapts the principles of Model Predictive Control (MPC) into a data-based framework, offers the combined benefits of predictive control and direct design strategies. Unlike standard MPC, DDPC does not necessitate knowledge of a parametric model of the controlled system but relies on a behavioral description derived directly from experimental data. The research objective is to address contemporary challenges in DDPC, particularly focusing on noise interference in the data used for system representation and minimizing the computational workload for calculating individual control actions.

PhD Committee

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