Ph.D. in Information Technology
Thesis Defenses

February 2nd, 2022
at 9:30
Room Alpha and online by Webex

Alex GIMONDI – XXXIV Cycle

Vehicle dynamics control for independent-all-wheel-drive full electric vehicles

Supervisor: Prof. **Sergio Savaresi**

Abstract:

Nowadays, two significant trends are driving the automotive industry: electric vehicles and autonomous cars. Besides the ecological aspect, electric powertrains offer attractive advantages: a fast response, a precise generation of requested torque, the possibility to have multiple motors on the vehicle. These peculiarities pave the way for reconsidering classical vehicle dynamics controls (ABS, TC, ESC) and improving autonomous driving performance.

This dissertation discusses different control strategies to exploit the advantages introduced by vehicle electrification; in particular, we present a control stack for autonomous full-electric vehicles with 4 electric motors (1 per wheel). Following a bottom-up approach, we start from the lowest level, i.e. wheel dynamics, for which we have designed a nonlinear longitudinal slip regulator. The novelty of the proposed approach consists in synthesising the controller using a grey-box model to include the transmission dynamics. Afterwards, we have considered lateral vehicle dynamics, firstly to improve safety and then to increase fun-to-drive. We have proposed an ESC scheme able to maintain the vehicle stable in critical situations regardless of the road conditions; it controls a convex combination of yaw rate and sideslip. We leverage the expertise gained to design a torque vectoring control that continuously enhances the vehicle dynamics.

Then, autonomous driving scenario is tackled with focus on path tracking. We propose a multi-layer controller that easily integrates the lower level control structures managing multiple actuators (steering wheel, electric motors). The controller, designed exploiting LPV/Hinf technique, includes tyre nonlinearities.

Finally, the highest level, i.e. planning, is addressed; we focus on the longitudinal dynamics, in which regenerative energy capabilities can be exploited. Specifically, we have designed a progressive iterative dynamic programming algorithm that includes both comfort and consumption aspects.

We have validated all the proposed control systems using the full-fledged software IPG CarMarker and VI-Grade. ABS/TC and the ESC have been experimentally tested utilising a full electric SUV with 4 motors in different conditions: dry asphalt, snow and ice. The TV has also been validated using a static simulator with certified pilots gathering useful insights that were otherwise impossible to capture.

Giorgio RIVA – XXXIV Cycle

Force-feedback control system design for high performance vehicles

Supervisor: Prof. **Sergio Savaresi**

Abstract:

This dissertation deals with control and estimation of forces in the Vehicle-Dynamics-Control (VDC) context. The interest in this research field is motivated by the pivotal role of forces in the whole vehicle dynamics, making their knowledge crucial in the transition towards autonomous vehicles to enhance performance and robustness at any vehicle level. The content of the work can be exemplified through a conceptual nested control scheme. The inner layer is dedicated to the novel Electro-Mechanical (EM) Brake-By-Wire (BBW) technology, where the driver is decoupled from the actuator and the clamping force exerted by the pads on the disk represents the key variable to be controlled, for which, being force sensors costly and difficult to calibrate, estimation represents a crux tool. Actual state-of-the-art estimation approaches are grounded on physical models, thus sensitive to friction modelling errors, while control schemes are typically tuned via standard model-based techniques. Given such a baseline, in this work we demonstrate the potential of novel data-driven approaches, improving both estimation performance, keeping the complexity low, and controller tuning procedures, accounting nonlinear phenomena, and uncertainties. In the external layer, we look at a broader problem, namely the control of the vehicle dynamics, where the Electro-Mechanical-Brake (EMB) is one possible actuator. Currently, state-of-the-art control schemes are based on slip variables, and they do not exploit tire-road force knowledge due to the absence of cost-effective sensors, and of reliable estimates. This work makes a step forward in this direction. Firstly, we demonstrate that current estimation techniques, based on simplified vehicle models, can be overcome through novel approaches, opening the way to the real employment of such variables. Then, given the lack of control-related literature, we show the feasibility of control schemes based on tire-force knowledge in a general vehicle dynamics context, highlighting the main benefits, like the insensitivity to uncertainties in the friction curve and the improved robustness, and the possible shortcomings.

PhD Committee

Prof. **Silvia Carla Strada**, Politecnico di Milano
Prof. **Francesco Ferrante**, Universita' di Perugia
Prof. **Radu Emil Precup**, Politehnica University of Timisoara