Ph.D. in Information Technology
Thesis Defenses

July 14th, 2025
At 9:00 a.m.
Sala Conferenze Emilio Gatti – Building 20

Chiara MARTELLOSIO – XXXVI Cycle

MODELLING, CONTROL AND HARDWARE-IN-THE-LOOP PLATFORM DEVELOPMENT FOR ADVANCED SUSPENSION SYSTEMS

Supervisor: Prof. Sergio Matteo Savaresi

Abstract:

The main objective of this work is to enhance vehicle performance in terms of vertical dynamics, attitude angle regulation, and suspension stroke management, aiming to provide the best possible experience for both passengers and driver. The study addresses the three main types of controllable suspensions, starting from the conventional semi-active systems, progressing to the highly promising multi-chamber solution, and culminating in an innovative active suspension design.

The study begins with the design and stability analysis of a Hardwarein- the-Loop (HIL) platform for suspension systems. HIL platforms allow reliable testing and validation of control algorithms by integrating physical actuators with virtual vehicle models, overcoming the limitations of traditional simulations.

Focusing on semi-active suspensions, the research develops an optimal policy for end-of-stroke (EOS) avoidance on speed bumps using a sequential learning methodology. The policy, tested on the HIL platform, ensures effective suspension travel management, with good level of comfort both on single-event obstacles and irregular profiles.

Further advancements in comfort are achieved by proposing two semiactive control laws with continuous damping modulation, improving vehicle comfort across a wide array of realistic road profiles while maintaining reduced vertical jerk. Subsequently, the benefits of combined stiffness/-damper control are explored by implementing the proposed semi-active control laws in parallel with stiffness algorithms from the literature on an experimental vehicle equipped with a multi-chamber suspension.

The study then transitions to handling-oriented control, introducing amodular damping controller designed to regulate vehicle angular rates during dynamic maneuvers such as steering, braking, and acceleration. Combined with a state-of-the-art stiffness controller, the proposed system significantly enhances vehicle attitude regulation and stability compared to decoupled control strategies.

Finally, a novel active suspension architecture, the Epicyclic Active Suspension (EAS), is analyzed. The EAS employs an innovative electromechanical design featuring two rotational motors and an epicyclic gearbox. A joint plant/controller optimization approach is applied to the EAS, considering comfort performance, active force requirements, and motor constraints. Compared to a state-of-the-art system, the EAS achieves similar handling performance while significantly improving ride comfort, demonstrating its potential as a next-generation active suspension technology.

Luca TAGLIONE – XXXVII Cycle
ANALYSIS AND DEVELOPMENT OF ALGORITHMS FOR HIGH-PERFORMANCE VEHICLES
Supervisor: Prof. Sergio Matteo Savaresi

Abstract:

The automotive industry is experiencing a significant shift, fostered by two major trends: electric or hybrid vehicles and autonomous vehicles. On one side, electric and hybrid vehicles are gaining increasing importance due to their potential environmental benefits. Indeed, transportation is the leading source of CO2 emissions in Europe, responsible for a quarter of total greenhouse gas emissions. On the other side, substantial investments are being made in the development of autonomous vehicles, which could provide various benefits, such as enhanced safety and decreased road congestion. Besides, the architecture of this new generation of cars comes with major technological innovations. The powertrain of electric vehicles enables a faster and more precise modulation of the driving torque at the wheels compared to traditional internal combustion engine-driven cars. As for autonomous vehicles, the driver has to be replaced by electronic control units communicating with *x-by-wire* actuators and a network of advanced sensors perceiving the surrounding environment. All these technological advancements offer a remarkable opportunity for enhancing vehicle control systems, such as active safety systems and advanced driver-assistance systems (ADAS).
The goal of this dissertation is to advance the development of vehicle-related control and estimation algorithms that leverage the capabilities of the aforementioned architectures. The research is structured to tackle the problem sequentially: it begins with an analysis of longitudinal and lateral dynamics-related applications, treating them as separate issues. Subsequently, the insights gained from both topics are integrated to approach the vehicle dynamics problem as a unified challenge. As for the longitudinal dynamics, a tyre-adaptive Anti-lock Braking System (ABS) for a Brake-By-Wire (BBW) architecture has been developed to show the advantages that could be attained when exploiting tyre-road contact information provided by a *smart tyre*. The same technological novelty has been employed for the lateral dynamics-related application, developing two tyre-adaptive friction predictors for pure lateral manoeuvres that provide an estimate of the available tyre-road grip before the vehicle has reached the limits of handling. Concerning the combined dynamics, this work presents the analysis and development of an advanced tyre-adaptive localization-based Electronic Stability Control system (ESC), that exploits the precise positioning of the vehicle supplied by a Global Navigation Satellite System with Real-Time-Kinematic corrections (GNSS-RTK) to enhance a commercial ESC by providing it with lane keeping assistance capabilities.

PhD Committee

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