Agenda of Planned Lectures

# **Modeling and Control techniques for automotive and mechatronics applications**

The automotive industry is facing new challenges related to the need of improvements of vehicle performance, in terms of fuel consumption reduction, limitation of pollutant emissions, component reliability, safety and driving comfort. Emerging of new technologies for sensors, electronics, micro-mechanics, and the development of innovative prototyping tools and low cost microcontrollers, enabled the application of advanced control techniques to the automotive field. In particular, the contribution of control theory consisted in providing a systematic methodology to controller design, by introducing tools such as mathematical modeling, identification, estimation, and by proposing advanced control approaches (e.g. adaptive and robust control, hierarchical and decentralized control, intelligent control, etc.). In this framework, modeling and identification plays a crucial role, enabling the application of model-based approaches for controllers design.

This short course will be focused on advanced topics, and current research directions related to modelling and control of automotive and mechatronics systems. Non-integer (fractional)-order modelling techniques and design/tuning methods of non-integer (fractional)-order controllers will be also shown and discussed.

# **Part #1** Introduction to modelling and control of automotive systems

The aim of these lectures is to introduce the main control loops in automotive systems, with particular emphasis on engine control systems. After a short introduction on the relevant control loops in automotive applications, the main modeling approaches will be described, including physical models, grey-box models, black-box models. Finally, some relevant control schemes and design approaches will be considered.

* Vehicle electronics
* (Main) Vehicle electronics and control systems
  + The electronic stability program (ESP)
  + Adaptive Cruise Control (ACC)
  + Driveline Control
  + Internal Combustion Engine Control
* Internal Combustion Engine (ICE) Control
* Models of the multivariable and nonlinear behavior of processes and components of ICE
  + Physical models, Grey-box models, Black-box models in automotive applications
* ICE Control challenges and applications
  + Basic control structures
  + Linear and nonlinear feedforward and feedback control schemes
  + Nonlinear static engine feedforward control
  + Nonlinear dynamic engine control
* ICE Control case studies

# **Part #2 Introduction to Fractional order modeling and control**

In recent years, fractional order controllers attracted the interest of many researchers thanks to their robustness to undesirable changes and uncertainties, dynamic performance, disturbance rejection, etc. The aim of these lectures is to introduce briefly fractional order systems and controllers. Firstly, Fractional order models, i.e. models described by differential equations involving fractional derivatives of the input and output, will be introduced. Then, some design approaches for fractional order controllers for mechatronic applications will be discussed, with particular emphasis on fractional-order PI (FOPI) controllers, in which the integral action of non-integer order is added to a standard proportional action. Approximation of fractional differentiation with application to control systems implementation will be addressed too.

* Many real phenomena, processes and behaviours are better modelled by differential equations in which derivatives are of non-integer order
* Fractional-Order Systems and dynamics
  + fractional-order differential equation
  + fractional-order transfer function
* Fractional-order control design and implementation
  + FOPID design
  + Implementation of fractional order controllers
* Control strategies in mechatronics, and application of fractional order design methods for practical case studies.

# **Part #3** Applications and current research directions on automotive and mechatronic control systems

The aim of these lectures is to present some current research directions on modeling and control of automotive and mechatronic systems. In particular, some specific automotive applications and case studies will be introduced and discussed. More in details, the lectures will be focused on advances on: modelling and identification of fractional order automotive systems (Diesel and CNG injection systems, variable valve timing systems, etc.); design, tuning, and implementation of fractional order controllers for automotive and mechatronic systems.

* Modelling and identification of fractional order models for automotive applications
* Research activities on CNG injection systems
  + The CNG injection system
  + Modeling and identification of the CNG injection system
  + Model predictive control of the injection system
  + Fractional order control of the injection system
* Research activities on CR Diesel engines
  + Fractional-order dynamic modelling and identification of innovative electro-injectors
  + Identification of an electro-actuated valve in a VVT system
  + Combustion noise control in Diesel engines
* Discussion of topics for MSc/PhD theses