MECHANICAL ENGINEERING

DIMEAS - Predictive and AI-based Controllers of Active Suspension Systems for Electric Vehicles with Multiple Powertrains and V2X Connectivity

Funded By	Dipartimento DIMEAS
Supervisor	SORNIOTTI ALDO - aldo.sorniotti@polito.it
Contact	
Context of the research activity	The objective of this PhD studentship is to develop novel active suspension controllers for electric vehicles with multiple powertrains and V2X connectivity. The information on the tyre-road friction level, curvature and road profile ahead will enable the implementation of innovative preview-based algorithms, which will embed elements of artificial intelligence (AI), e.g., in the form of neural network model predictive control and deep reinforcement learning.
	This PhD project is in the framework of the Horizon Europe CliMAFlux consortium, involving participants from industrial and academic backgrounds, implementing and assessing novel axial flux electric machine technologies for electric powertrains and active suspension actuation. This PhD studentship will focus on the conception, development, implementation and assessment of innovative active suspension controllers with so far unexplored preview and adaptation capabilities, and their integration with powertrain control structures. The PhD activity plan is as follows: Year 1 • Literature review on control and actuation methodologies for electro-mechanical active suspension systems with regenerative capability, including interactions with electric powertrain control • Preparation and submission of a high-quality review paper (e.g., for Annual Reviews in Control, see the following examples: Model predictive path tracking control for automated road vehicles: A review - ScienceDirect, Preview-based techniques for vehicle suspension control: a state-of-the-art review - ScienceDirect, Anti-jerk controllers for automotive applications: A review - ScienceDirect, Integrated chassis control: Classification, analysis and future trends - ScienceDirect) • Simulation model (in CarMaker by IPG) for control system assessment, based on the CliMAFlux demonstrator vehicle, targeting the baseline configuration • Experimental assessment of the baseline vehicle, in cooperation with the other consortium participants • Experimental validation of the CarMaker simulation model

Objectives	• Inclusion of the high-fidelity models of the considered electric machines/inverters and suspension actuators (for body control, ride comfort enhancement as well as vehicle dynamics control), including consideration of the coupling implications (interaction among the different actuation objectives in terms of variation of suspension elasto-kinematics), and the actuation dynamics aspects • Toolchain for the development of nonlinear model predictive controllers (ACADO toolkit / ACADOS / CasADi), neural network tools and deep reinforcement learning tools (Matlab, Python) • End of year presentation Year 2 • Set-up of the V2X interface within the vehicle simulation model (preview of road curvature, road irregularities, speed profile, steering profile, yaw rate profile, optionally tyre-road friction factor) • Digital twins based on physics-derived formulations • Digital twins based on artificial intelligence techniques (deep neural networks) • Experimental validation of the resulting digital twins • Nonlinear model predictive controller for active electro-mechanical suspension and torque-vectoring control using the physics-based digital twins • Neural network model predictive controller for active electro-mechanical suspension and torque-vectoring control based on the AI-derived digital twins • Simulation-based critical analyses on: i) potential benefits associated with the prioritisation of the of the different control objectives and actuators, in the context of integrated suspension and electric powertrain control; ii) comparison between the NMPC and NNMPC implementations • Preparation of a quartile 1 journal paper on critical analysis i) and a quartile 1 journal paper on critical analysis ii) • End of year 2 presentation Year 3 • Deep reinforcement learning (DRL) for active suspension and torque-vectoring control • Critical analysis of DRL performance including comparisons with NMPC and NNMPC • Experimental sessions for controller validation on the CliMAFlux demonstrator vehicle • Preparation and submission of a journal paper on DRL and respective critical analysis, and a paper on the experimental validation aspects • Final PhD thesis write-up During the PhD project, at least 6 months will be spent at another company or academic institution. In the CliMAFlux project framework, funding is available for attending conferences, project meetings, and testing sessions at the facilities of the other industrial and academic participants.

Skills and competencies for the development of the activity	1) Vehicle dynamics 2) Vehicle simulation 3) Automotive suspension systems 4) Matlab-Simulink simulation experience 5) Fundamentals of control theory 6) Good oral and written English language skills 7) Good presentation skills

	8) Good teamworking capabilities