MECHANICAL ENGINEERING

DIMEAS-Predictive and AI-based Controllers of Active Suspension Kinematics for Electric Vehicles with Multiple In-Wheel Powertrains & V2X Connectivity

Funded By	Dipartimento DIMEAS
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Context of the research activity	The scope of this PhD project is to develop innovative predictive and artificial intelligence (AI) based algorithms for controlling suspension kinematics, i.e., the individual toe and camber angles as well as the half track width at each vehicle corner, by using innovative actuators. V2X connectivity will be included to provide information, such as the road profile, road curvature, and tyre-road friction coefficient ahead.
	The activity will be carried out in the framework of the Horizon Europe project SmartCorners, involving industrial and academic participants, focused on the advanced implementation and control of multi-actuated corners characterised by direct drive in-wheel machines, active/semi-active suspension actuators with regenerative capability, and innovative actuators for suspension kinematics control. The expectation is that by the end of the project the researcher will have gained international leadership - based on high-quality research publications - on the topic of the control of active suspension kinematics. The PhD workplan will consist of the following steps: Year 1 • Literature review on control and actuation methodologies for active suspension kinematics • 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 VSM by AVL) for control system assessment, based on one of the SmartCorners demonstrator vehicles, targeting the baseline vehicle • Experimental assessment of the baseline vehicle, in cooperation with the other SmartCorners consortium participants

Objectives	• Experimental validation of the VSM simulation model • Inclusion of the high-fidelity models of the considered suspension actuators (for individual toe angle control, camber angle control as well as half-track width control), including consideration of the coupling implications (interaction among the different actuations 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 suspension kinematics using the physics-based digital twins • Neural network model predictive controller for active suspension kinematics using the AI-derived digital twins • Simulation-based critical analyses on: i) potential benefits of the different active kinematics actuations; 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 kinematics • Critical analysis of DRL performance including comparisons with NMPC and NNMPC • Experimental sessions for controller validation on at least one SmartCorners 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 SmartCorners 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