ELECTRICAL, ELECTRONICS AND COMMUNICATIONS ENGINEERING

DET - High-level optimization and control of complex systems with industrial applications

Funded By	Dipartimento DET

Supervisor	NOVARA CARLO - carlo.novara@polito.it

Contact	RIZZO ALESSANDRO - alessandro.rizzo@polito.it

Context of the research activity	Traditional optimization and control methods struggle to cope with strong nonlinear dynamics, combinatorial decision variables, and real-time constraints and uncertainty. At the same time, emerging hardware and algorithms in quantum optimization and advanced mixed-integer optimization offer the potential to solve large-scale decision and scheduling problems more efficiently than classical approaches alone. This project targets the high-level optimization and control layer for complex systems, with a focus on automated driving, space missions and power grids.

Objectives	Motivations and Background Modern engineering systems, like automated vehicles, spacecraft, and large-scale power grids, are increasingly complex, tightly interconnected, and subject to stringent safety and performance requirements. Traditional control and planning methods struggle to cope with strong nonlinear dynamics, combinatorial decision spaces (discrete modes, on/off devices, routing choices), and real-time constraints and uncertainty. At the same time, emerging hardware and algorithms in quantum optimization and advanced mixed-integer optimization offer the potential to solve large-scale decision and scheduling problems more efficiently than classical approaches alone. This project targets the high-level optimization and control layer for such complex systems, with a focus on automated driving (single vehicle, fleet-level routing and coordination), space missions (trajectory design, guidance navigation and control (GNC), and mission planning and scheduling), and power grids. Objectives 1) Modeling: Develop modeling frameworks for automated vehicles, spacecraft operations, and power grids that capture nonlinear dynamics, discrete decisions, and uncertainty. 2) Algorithms: Design scalable nonlinear optimization and mixed-integer optimization algorithms, and explore quantum optimization approaches (e.g., QUBO formulations) for high-level control, planning and scheduling.

	3) Integrated Control Architectures: Integrate high-level optimization with low-level controllers, particularly in GNC for space and autonomous driving, and supervisory control for power grids. Nonlinear Model Predictive Control will play a key role in this context. 4) Demonstration and Validation: Demonstrate the methods on realistic case studies in: autonomous driving fleets in mixed traffic, multi-satellite or planetary mission planning and scheduling, and real-time power grid operation with high renewable penetration. Expected Outcomes - A set of unified modeling and optimization frameworks applicable across automated driving, space missions, and power grids. - Novel algorithms combining nonlinear optimization, mixed-integer optimization, and quantum optimization for high-level control, guidance, and scheduling. - Validated guidance navigation and control architectures that leverage optimization for trajectory generation and mission safety. - Demonstrated mission planning and scheduling tools for satellite constellations and complex power grid operations.

Skills and competencies for the development of the activity	Solid background in - dynamic systems - classical automatic control - optimal/predictive control - convex and non-convex optimization - quantum optimization - data analysis. Experience on - spacecraft guidance, navigation and control - vehicle dynamics. Excellent programming skills in MatLab/Simulink, and possibly Python.