

**Ph.D. in Information Technology
Thesis Defenses**

May 25th, 2026

At 3:00 p.m.

Sala Conferenze - Building 20A

Paolo FUSCO – XXXVIII Cycle

**TRAJECTORY PLANNING AND CONTROL FOR HIGH-PERFORMANCE
AUTONOMOUS VEHICLES**

Supervisor: Prof. Sergio Matteo Savaresi

Abstract:

The problem of high-performance autonomous driving has gained significant attention in recent years, driven by advancements in vehicle technology and the increasing demand for autonomous systems. The real-world applications of high-performance autonomous vehicles are often found in racing scenarios, where vehicles are required to operate at the limits of their capabilities while maintaining safety and reliability. The ability of autonomous vehicles to behave correctly in these challenging conditions is the perfect proving ground for the development of safe and efficient autonomous driving technologies that can later be transferred to everyday driving scenarios. In this work, we focus on the trajectory planning and control aspects of high-performance autonomous driving for both four-wheeled and two-wheeled vehicles. The trajectory planning and tracking challenges are strictly related with respect to one another: the planned trajectory must be feasible and trackable by the vehicle, while the control strategy can not be expected to work properly if the planned trajectory is not suitable for the vehicle dynamics. Therefore, the theme of codesigning planning and control is addressed to assess its advantages with respect to classical decoupled approaches. Furthermore, solutions to both the planning and control problems are proposed on four-wheeled vehicles and two-wheeler vehicles, highlighting the specific challenges of each development platform.

Roberto BOFFADOSSI – XXXVII Cycle

**ROBUST AND BALANCED MULTI-OBJECTIVE OPTIMIZATION: METHODOLOGY
AND APPLICATIONS**

Supervisor: Prof. Lorenzo M. Fagiano

Abstract:

Modern production systems require decision-support tools capable of determining optimal operating conditions while accounting for multiple, conflicting factors and constraints. This is particularly critical when balancing sustainability objectives with production targets, requiring a thorough analysis of possible optimal scenarios. Cooperation between human cognitive capabilities and advanced learning and control modules is central to the Industry 5.0 paradigm, leading to the

development of frameworks such as Human–Cyber–Physical Systems (HCPS), which aim to enhance human capabilities without replacing them. The decision-maker plays a crucial role in identifying the best compromise and providing real-time feedback, based on information derived from data analysis, while adapting control modules according to their instructions. In this context, Multi-Objective Optimization (MOO) offers a rigorous framework to explore trade-offs and support reliable decisions. This thesis develops an enhanced a posteriori approach by adopting a Pareto front (PF) surrogate with robust and balanced approximation error guarantees, enabling informed choices and an efficient representation of the complete set of optimal alternatives.

The methodology introduces a linear and invertible transformation to convert the problem of identifying the PF into that of identifying a black-box function, in which the solution set computed by scalarization corresponds to the available dataset. First, an algorithm for the bi-objective case, named ROBBO (RObust and Balanced Bi-objective Optimization), is introduced. It computes a continuous approximation of the entire PF with guaranteed accuracy. Moreover, it provides necessary and sufficient theoretical guarantees on the dataset to fulfill user-defined requirements. This strategy is rigorously shown to be superior to classical methods in terms of sampling complexity, offering prior information on the worst-case number of Pareto-optimal solutions required. The approach is showcased in a constrained path-following problem for a two-axis positioning system and in a steady-state optimization problem for a Continuous-Flow Stirred Tank Reactor. Extensions are presented to handle disconnected PFs by combining a modified Pascoletti–Serafini scalarization with a systematic detection of gaps.

The approach is then generalized to the multi-objective case, RObust and Balanced Multi-Objective Optimization (ROBMO). A new transformation is introduced to convert the MOO problem into a black-box function estimation with unknown domain. New guarantees are established regarding the PF approximation error and the upper bound on the number of samples required in the worst case. The algorithm is further adapted to estimate the boundaries of the PF (i.e., the domain of the function), and its effectiveness is demonstrated through benchmarks in problems with more than two objectives.

The methodology is validated within an HCPS, deployed on an industrial large-scale manufacturing plant for Medium-Density Fiberboard production. A Multiple-Criteria Decision Support System, interconnected with a digital twin and predictive control, and based on the ROBBO algorithm, is designed to assist operators in balancing production and sustainability by suggesting optimal process parameters. The system supports what-if analyses and transmits realized operating points to the control layer. The scheme has been implemented and tested in production, representing one of the few documented examples of such systems deployed in large-scale industrial plants. Finally, the ROBBO algorithm is extended to deal with objective functions featuring parametric uncertainty, where the PF constitutes a bundle of functions, and scenario optimization is used to derive probabilistic accuracy guarantees for the approximation using only a limited number of measures of the uncertain element.

The research was conducted in the context of the European project E2COMATION, “Life cycle optimization of industrial energy efficiency by a distributed control and decision-making automation platform”, which aims to improve industrial energy efficiency by integrating data analysis with advanced optimization techniques, addressing both production and environmental perspectives.

PhD Committee

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