Research theme title:
Intelligent systems for robotic path planning in industrial processes

Description:
Robot manipulators are widely employed in industrial assembly lines and manufacturing systems. In industrial robotic applications, the trajectory planning problem has been a hot spot. With the aim of improving the manufacturing productivity and the movement stability, trajectories with short execution time or smooth profile are highly desired. Hence, in the scientific literature many studies have been conducted to address the trajectory planning for the optimization on minimum time, minimum energy, and minimum jerk [1].

The overall objective of this PhD project is firstly the study and analysis of the state-of-the-art methodologies for the trajectory planning problem in manufacturing processes and then the design of innovative industrial architectures and control methods in presence or absence of optimization for trajectory planning/re-planning and tracking problems, collision avoidance and collision detection issues. To this aim, mechanical aspects of industrial manipulators with an increasing number of degrees of freedom such as statics, kinematics, and dynamics must be considered and incorporated in constrained optimal control problems. In particular, the trajectory planner must be able to handle additional mechanical degrees of freedom (seventh axis or mobile robot) or the case of constraints or additional degrees of freedom due to the process (e.g., maintaining an optimal straight line free from collisions, exploiting the degree of freedom along the z tool in case it is independent for the process) [2].

Finally, the mathematical assumptions and the defined control architectures will be tested and validated on real robot manipulators in practical industrial applications like welding tasks since it can be seen that intelligent optimization algorithms, environment modeling, obstacle avoidance strategies, and multi-objective path optimization problems are effective for welding robot trajectory planning [3].

The research activities will be conducted in strict collaboration between the Decision and Control Laboratory (http://dclab.poliba.it/) of Polytechnic of Bari and Comau SpA (https://www.comau.com/), which is an Italian multinational company in the automation field company specialized in advanced and robotic solutions for complex manufacturing systems. Moreover, the PhD project is of absolute centrality for the Italian National PhD Program in Autonomous Systems, given that it can be considered as a step forward toward the concept of autonomous production powered by robots performing tasks intelligently, with the focus on safety, flexibility, versatility, and collaboration.

Finally, it is worthwhile mentioning that the objective of the PhD project is aligned with the national development strategies as well as the international research directions, which are undergoing radical transformations, enabled by the progressive and pervasive adoption of digital and automation technologies in the industrial sector. In particular, the project is coherent with the strategic pillars and horizontal principles of the Italian National Recovery and Resilience Plan (PNRR), being fundamental for Strategy M2C2 “Digitalization, innovation, and competitiveness in production systems”.

References:
[1] Proia et al. 2022. Control Techniques for Safe, Ergonomic, and Efficient Human-Robot Collaboration in the Digital Industry: A Survey. IEEE Transactions on Automation Science and Engineering. 19(3), 1798-1819.
[2] Bahrin et al. 2016. Industry 4.0: A review on industrial automation and robotic. Jurnal teknologi. 78, 6-13.
[3] Wang et al. 2021. A survey of welding robot intelligent path optimization. Journal of Manufacturing Processes. 63, 14–23.

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