Research theme title:
Decision and control techniques for autonomous smart systems applied to precision agriculture

Description:
Precision agriculture and autonomous vehicles are nowadays topics of increasing interest in the agricultural sector [1]. Currently, most agricultural activities involve manual material-handling tasks - e.g., harvesting, pruning, pulling, pushing, carrying heavy loads and fertilization-spreading tasks. The wide range of manual tasks involved in agriculture makes these activities physically demanding by nature. The risk of accidents is increased by fatigue, poorly designed tools, repetitive movements in awkward body positions, difficult terrain, sun exposure and poor general health. Moreover, many European countries have been facing the problem of labour shortages caused primarily by difficulties in recruiting workers.

Mobile robots operating in agricultural environments have been a significant research topic in recent years to address these problems [2]. Although remarkable progress has been made in robotic navigation and control, autonomous navigation of mobile robots in outdoor harsh environments such as agricultural fields is still an open problem [3]. The design of robust sensing and control systems for agricultural mobile robots capable of overcoming issues related to dynamic environments, unexpected obstacles, terrain conditions variations, and vegetation is still challenging.

The proposed PhD project aims at developing a prototypal autonomous ground vehicle composed of an electric mobile platform and a set of modular manipulators to perform harvesting activities in long-line field crops. The vehicle will be capable of autonomously moving through the agricultural field on arbitrary rough terrains along a pre-defined trajectory. The PhD candidate will be responsible for the analysis and implementation of techniques, algorithms, and control methods to collect and process data provided by a plethora of onboard proprioceptive and exteroceptive sensors (e.g., encoders, IMU, GNSS, 3D vision systems) for environment perception and vehicle status (position, orientation, safety) estimation, in order to guarantee the path following, obstacle avoidance, and dynamical stability control of the vehicle. The roughness of the terrain and the vehicle-terrain interaction will be properly estimated through state-of-the-art techniques in order to control the shocks and vibrations the vehicle experiences, thus assuring vehicle stability [4]. Moreover, the PhD candidate will support the product technical team on the selection and design of the transporter (e.g., wheels, half-crawler, crawler, robotic leg) and suspension system (e.g., semi-active suspension) in order to improve both the dynamical stability of the system and the performances of the onboard vision systems.

The main activity will be therefore based on the study of computational methods for features extraction and data fusion of sensor measurements to support navigation control and on the development of control algorithms to command engine and suspension actuators to control position and orientations of the platform.

The research activities will be conducted in strict collaboration between the Decision and Control Laboratory (http://dclab.poliba.it/) of Polytechnic of Bari and G-nous Srl (https://g-nous.com), which is an Italian company specialized in advanced solutions for various applications such as robotics. 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 fully automated smart factory model and agriculture 5.0 [5] in the fight against the dependence of human manpower for agricultural applications.

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 agriculture 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 “Sustainable agriculture” included in Mission 2 “Green revolution and ecological transition”.

References:
[1] Christiaensen et al. The future of work in agri-food. Food Policy 2021, 99, 101963.
[2] Roshanianfard et al. 2020. A review of autonomous agricultural vehicles. Journal of Terramechanics. 91. 155-183.
[3] Reddy et al. A critical review on agricultural robots. Int. J. Mech. Eng. Technol. 2016, 7, 183–188.
[4] Zhong et al. 2014 Motion Control and Stability Improvement of Autonomous Mobile Robots with Suspended

Wheels.
[5] Zambon et al. Revolution 4.0: Industry vs. agriculture in a future development for SMEs. Processes 2019, 7, 36.

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