Research theme title:
Platforms for optimization and control of Drone-as-a-service in logistics

Description:
State of the art
Drones, also known as unmanned air vehicles (UAVs), represent a key enabling technology of Industry 4.0, thanks to their functionality and versatility in several industrial and logistic sectors. Over the past few years, UAVs have become pivotal for several businesses and governmental organizations and have managed to pierce through areas where certain industries were either stagnant or lagging behind. From quick deliveries at rush hour to scanning an unreachable military base, drone features are proving to be extremely beneficial in places where man cannot reach or is unable to perform in a timely and efficient manner. Recently, drones also offer industrial and logistic companies several top uses – that are referred to as the paradigm of Drone-as-a-Service (DaaS) – aimed at increasing work efficiency and productivity, decreasing workload and production costs, improving accuracy, refining service and customer relations, and resolving safety issues on a vast scale.
Drones can perform both outdoor and indoor missions in very challenging environments and their applications and services cover a wide range of logistic applications. The drones' applications can be categorized in different ways. On the one hand, the categorization can be based on the type of missions (military/civil), type of the flight zones (outdoor/indoor), and type of the environments (underwater/on the water/ground/air/space). On the other hand, the categorization can be based on the drones' capabilities to "see", "sense", "move", and "transform". "See" is the capability of collecting visual data, often in the forms of images and videos. In logistics, examples are the visual inspection of equipment and the monitoring of the operators' safety and ergonomics such as during maintenance operations where fixed cameras are not economically feasible. "Sense" is the capability of collecting data and transforming them into other forms of data or structured data (i.e. information) without performing additional physical operations. Some relevant examples in logistics include thermal inspection of equipment and machines, gas detection, tracking and finding lost pallets and slots for inventory management. "Move" is the ability of a drone system to grasp and carry objects or perform physical operations. A typical example consists of intra-logistics operations, such as delivering light components, spare parts or tools. Finally, "transform" is the ability of a drone system to collect data and transform them into information while performing physical operations (e.g., carrying objects). It combines the capabilities of "see", "sense", and "move". The simultaneous implementation of these three capabilities introduces major challenges of cooperation, analytics, information processing, and optimization, all of which are control-centric in nature and require innovative tools. Indeed, current examples of "transform" in the logistic scenario are scarce and in the related literature few contributions rely on this category. Bridging this gap is exactly the objective of the present project.
Objectives and Innovativeness
Thanks to the drones' ability to fly and hover autonomously, avoid obstacles in different layouts, navigate indoor and outdoor, land precisely and potentially operate in fleets, the use of DaaS will have a great impact on several aspects of companies specialized both in internal and external logistics. In particular, this project will focus on the most promising areas of indoor drone services in warehouses 4.0, which are inventory management, intra-logistics of items, as well as inspection and surveillance and on the integration of outdoor drones services in urban areas and delivery networks. To this aim, decision and control techniques for mission and path planning, collision avoidance, synchronization, formation tasks for surveillance, tasks for coordination with ground vehicles and platforms will be implemented for drones and fleets of drones operating in complex environment. All these features constitute a challenging problem for control engineering and robotics with numerous applications.
UAVs and networks of UAVs are fruitful ground for control systems research as their dynamical nature and under-actuated configuration make it ideal to synthesize and analyze control algorithms. In fact, over the last two decades, several research studies have focused on the guidance, navigation, and control for drones and fleet of drones, resulting in various techniques and methods that are organized according to the above categories (i.e., guidance, navigation, and control). For each category, methods are grouped at the highest level based on the autonomy level they provide, and then according to the algorithmic approach implemented, which in the majority of cases is closely associated with the type of sensors used.
Therefore, in order to make drones-based services part of modern daily life, the main contribution of this project will be the development of complex control platforms within warehouse management and external logistics that integrate the control techniques studied in the related literature with innovative solutions addressing the interaction with human workers (human-drone interaction). Indeed, focusing on the improvement of operator's safety and well-being and on the increase of flexibility and productivity as well as efficiency of industrial processes, the use of drones can definitely lead to a reduction of the production downtime and of the labor turnover.
Challenges and Methodologies
With the aim of combining the drones' capabilities of see, sense and move, this project will define new decision and control techniques for the use of DaaS in warehouses and external logistics. The expected results will be focused on the development of new control architectures and frameworks for path planning and collision avoidance

("move") using on-board sensors in both structured and dynamically changing environments ("see") without relying on external infrastructure, such as GPS or motion capture systems and implementing algorithms which are able to identify any anomalies ("sense") within the warehouse and urban delivery management (e.g., loss of items). In this way, drones are able to actively navigate and collaborate with operators in both indoor and outdoor environments extracting the best knowledge from them.
Finally, emphasis will be given on real-time implementation and on extending their scope to deal with dynamic changing environments that capture the features of realistic urban spaces. The project will involve an interplay of theoretical developments and practical implementation on existing platforms.

References:

Proia, S.; Cavone, G.; Tresca, G.; Carli, R.; Dotoli, M., "Hybrid Truck-Drone System for Last-Mile Delivery", 9th International Conference on Control, Decision and Information Technologies (CODIT 2023), July 3-6, 2023, Rome, Italy.
Proia, S.; Cavone, G.; Camposeo, A.; Ceglie, F.; Carli, R.; Dotoli, M., "Safe and Ergonomic Human-Drone Interaction in Warehouses", 2022 IEEE/RSJ International Conference on Intelligent Robots and Systems (IROS 2022), October 23-27, Kyoto, Japan.

Type of scholarship:

DM 118/2023 – Project on PNRR (Italy's Recovery and Resilience Plan)

Hosting University

Polytechnic of Bari, Italy

Contacts:

Prof. Mariagrazia Dotoli (mariagrazia.dotoli@poliba.it) (*Polytechnic University of Bari*)
Prof. Raffaele Carli (raffaele.carli@poliba.it) (*Polytechnic University of Bari*)