DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE - PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING - 36TH CYCLE

Title of the research activity:	Bridging the gap between advanced artificial intelligence algorithms and nano-class Unmanned Aerial Vehicles (UAVs) for robotic applications.
State of the Art:	Nowadays, both the research community and the industries are pushing the technology advancement of autonomous flying vehicles toward rapidly decreasing form factors and increasing onboard intelligence. The latest researches have shown impressive results on Micro Aerial Vehicles (MAVs) applications. These platforms have been successfully equipped with autonomous sense-and-act capabilities, running in real-time complex and computationally intensive multi-sensor and vision-based control systems. Among the most important State-of-the-art (SotA) functionalities performed using onboard computation it is important to mention simultaneous localization and mapping (SLAM) [1, 2], path planning [3], visual odometry [4, 5], and many more. However, two important aspects still pose important challenges: the demand for UAVs with reduced size and the need for high-level artificial intelligence (AI) functionalities. UAVs with nano-size form factors open numerous issues regarding power consumption and weight constraints. To address these requirements, currently these drones are typically equipped with low-power single-core microcontroller units (MCUs) [6]. Therefore, in contrast to Micro Aerial Vehicles (MAVs) with a weight between 500g to few Kg, SotA solutions for nano-size class UAVs either rely on the implementation of only basic algorithms on board [7], or on offloading computationally-intensive functionalities to remote base-station [8]. While taking advantage of external workstations with high-tier computational resources could be tempting to bypass the onboard limitations, it entails a number of problems that span from latency and maximum communication distance to wireless channel reliability and security leaks. On the other hand, more advanced AI capabilities are required to make autonomous UAVs a game-changing technology. These include target driven-navigation, active target tracking, topological localization and planning, and semantic scene and object relation understanding [9, 10, 11, 12]. Unlocking these functionalities require to exploit deep learning and deep reinforcement learning technologies (DRL). Despite these solutions represent, in most cases, the only viable alternative to solve the aforementioned tasks, they have two important downsides: First, a large amount of training samples and episodes are needed to train the deep learning models. Simulated environments that rely on photorealistic engines are currently one of the most promising ways to overcome these problems [9]. Secondly, these algorithms are computationally intensive even during the inference phase and entail the availability of onboard power-hungry processing units (such as GPUs) and sensors, making computational issues on nano-class UAVs even more troublesome. The ISARLab research group has developed strong expertise on these topics, positioning itself as one of the reference research groups on vision-based navigation algorithms for robotic platforms that take advantage of deep learning and deep reinforcement learning techniques [3, 5, 9]. Inspired by the previous considerations, one of the most important research directions of the group in the immediate future will focus on bridging the gap between the demand for advanced AI solutions and the tight constraint of nano-class UAVs.
Short description an	The Ph.D. project is aimed at the development of innovative solutions to provide nano-class UAVs with advanced AI capabilities for different robotic tasks (e.g., navigation, localization,

d objectives of the research activity:	exploration, target tracking, and target-driven navigation), accounting for the weight and power consumption constraint of such platforms. Research activities include the implementation and testing of the proposed solutions in real applications. As a first stage, besides an accurate review of the literature, the implementation of state of the art solutions will allow for baseline schemes to be used for comparison purposes. The key project goals are: - Developing algorithms for analysis and observations across different conditions/limitations related to autonomous systems; - Developing Deep Learning and Deep Reinforcement Learning algorithms for perception, tracking, sensor fusion, localization; - Devising perception-to-action strategies based on deep reinforcement learning for global/local planning and navigation; - Exploring scalable algorithms for perception, tracking, sensor fusion, localization on nano-class UAVs; The whole set of solutions will be accurately tested in real-world applications with nano-class UAVs, in both indoor and outdoor scenarios.
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