DIPARTIMENTO DI INGEGNERIA
CORSO DI DOTTORATO IN INGEGNERIA INDUSTRIALE E DELL'INFORMAZIONE -
PHD COURSE IN INDUSTRIAL AND INFORMATION ENGINEERING -
37TH CYCLE

Title of the research activity:	Deep Learning and Deep Reinforcement Learning strategies for vision-based autonomous navigation in robotic applications.
State of the Art:	The realization of autonomous robotic platforms with high-level reasoning skills has recently become one of the most crucial elements to take a substantial step towards the technological advancement in several contexts, ranging from logistics and supply chain to industries and human assistance. Recent research solutions from the Artificial Intelligence AI and the Robotics communities have shown impressive results in a wide variety of applications. Furthermore, the number of robotic-based commercial products is exponentially growing, proving that the level of maturity and robustness of these systems has considerably improved. This has been made possible since several medium and low-level capabilities related to the navigation and localization tasks (such as depth estimation, object detection and obstacle avoidance) have reached a grade of efficiency and robustness previously unthinkable, mostly thanks to the advent of Deep Learning technologies. As an instance, Micro Aerial Vehicles (MAVs) are certainly among those that benefited the most from these advancements. These platforms have been successfully equipped with autonomous perception and planning capabilities (including Simultaneous Localization And Mapping (SLAM) [1], [2], path planning [3] and visual odometry [4], [5]), running in real-time complex and computationally intensive multi-sensor and vision-based control systems. However, the majority of those success cases have been designed for narrow and specific problems, such as navigation and exploration in structured environments or delivery systems in well-defined and controlled areas. The next generation of robots, on the other hand, should be able to fulfill more complex tasks in unstructured, unknown and dynamic contexts. To interact with humans, understand the given objective and execute it by interacting with a complex and unknown scenario, requires multiple high-level capabilities: i) to understand the task and identify the steps and the objects to interact with; ii) to recognize the entities in the environment and model their relationship; iii) to map the information acquired from sensors to actions. To this end, stand-alone deep architectures are not sufficient, since a tight interaction between different modules and capabilities is required. A step toward this direction has been recently made by relying upon the Deep Reinforcement Learning (DRL) paradigm. The DRL framework allows modeling complex perception-to-action relationships in an end-to-end manner, avoiding the need to explicitly build several disconnected modules to perform localization, detection and mapping. DRL is grounded on Reinforcement Learning (RL), which has a long history in the Artificial Intelligence research field [6]. However, it is only in recent years, with the adoption of Deep Neural Networks (DNNs) that the first great results have been achieved. The pioneering works aimed to show the potentialities of DRL were focused on gaming [7], [8], [9]. These successes in DRL have also inspired several works in the robotic field, as shown, for example, in [10], [12], [14]. 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, 11, 12, 13, 14]. Inspired by the previous considerations, one of the most important research directions of the group in the immediate future will focus on devising innovative solutions to provide robotic platforms with advanced AI capabilities.
Short description an d objectives	The Ph.D. project is aimed at the development of innovative solutions to provide robotic platforms (both ground and aerial) with advanced AI capabilities for different robotic tasks (e.g., navigation, localization, exploration, target tracking, and target-driven navigation), accounting

of the research activity:	for different platform constraints. 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 and localization. The whole set of solutions will be accurately tested in real-world applications with different robotic platforms, in both indoor and outdoor scenarios.
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