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:	Intelligent autonomous vehicles and robots: solving the whole algorithm stack from visual odometry and SLAM to target driven navigation by using deep learning methods.
State of the Art:	The robotic evolution is opening the way to a number of applications where autonomous driving will be a key component of everyday life. Among many others, driverless cars in urban environments and driverless vehicles for precision farming are promising examples. Other relevant cases are steaming from the COVID crisis, which is calling for autonomous vehicles to cope with operations in contaminated environments, such as sanitation, good transportation, routinely medical operations and monitoring. The development of smart, robust and efficient autonomous robotic systems is strongly dependent, among other, on a number of interplaying functions, such as perception, planning and navigation, localization, mapping and SLAM (Simultaneous Localization And Mapping). The development of State-of-the-Art integrated solutions for those problems heavily rely on machine learning tools. The Isarlab group has developed a strong expertise on such a field, and it is now addressing the problem of smart localization and navigation and the problem of navigation. The common framework is the use of computer vision solutions and ideas. As for smart localization and navigation, a major ingredient is that of Visual Odometry (VO) and obstacle detection based on deep learning solutions. While geometry based VO is well accepted, it still is suffers from a number of robustness issues [Cadena et alii, 2016, Bresson et alii, 2017, Gaber et alii, 2020], which can be overcame by a learned approach, i.e., by algorithms where the input-output relationship between an acquired image flow and the associated motion parameters is computed by means of a deep learning model. [T. A. Ciarfuglia at alii, 2014]. From the point of view of navigation, target-driven visual navigation is a longstanding goal of the robotics community. A robot able to navigate and reach user specified targets, by using only visual inputs, would have a great impact on many robotic applications, from people assistance to industrial automation. A naive way to approach this problem is to combine a classic navigation system with an object detection module. In view of a number of problems affecting such an approach, map-less methods (see, e.g., Kahn et alii, 2018) have proven to be much more suitable for target-driven visual navigation. A widespread approach is to combine deep Convolutional Neural Networks (CNNs) with reinforcement learning. Deep Reinforcement

	Learning (DRL), indeed, allows to manage the relationship between vision and motion in a natural way, and it has shown impressive results for mapless visual navigation and many other robotic tasks. Along the line of research based on deep reinforcement learning, the ISARLab group has proposed the approach in (Devo et alii, 2020).
Short description and objectives of the research activity:	The PhD project is aimed at the development of innovative solutions for the main problems encountered in the design and realization of a wholly autonomous mobile robot, and at the implementation and testing of the proposed solutions in real applications. As a first stage, beside 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 the development of innovative, machine learning based, approaches for visual odometry, SLAM and obstacle detection, embedding methods to also provided an estimate of the output accuracy. In addition, novel target driven navigation schemes will be studied, still based on suitable deep reinforcement learning schemes. The whole set of proposals will be accurately tested in real world applications, with specific attention to precision farming and outdoor urban environments.
Bibliography:	[Bresson, G. et alii, 2017]. Simultaneous localization and mapping: A survey of current trends in autonomous driving. *IEEE Transactions on Intelligent Vehicles*, *2*(3), 194-220. [Cadena, C. et alii, 2016, Past, present, and future of simultaneous localization and mapping: Toward the robust-perception age. *IEEE Transactions on robotics*, *32*(6), 1309-1332. [Ciarfuglia T.A. et alii, 2014], Evaluation of non-geometric methods for visual odometry. Robotics and Autonomous Systems (2014), Vol. 62, No. 12, pp. 1717-1730. [Devo A. et alii, 2020] Towards Generalization in Target-Driven Visual Navigation by Using Deep Reinforcement Learning. IEEE Transactions on Robotics. Doi: 10.1109/TRO.2020.2994002 [Gaber, H., et alii, 2020], Localization and Mapping for Indoor Navigation: Survey. In *Robotic Systems: Concepts, Methodologies, Tools, and Applications* (pp. 930-954). IGI Global. [Kahn, G. et alii, 2018]. “Self supervised deep reinforcement learning with generalized computation graphs for robot navigation,” in 2018 IEEE International Conference on Robotics and Automation (ICRA). IEEE, 2018, pp. 1–8. [Zhu, Y, et alii, 2017] “Target-driven visual navigation in indoor scenes using deep reinforcement learning,” in 2017 IEEE international conference on robotics and automation (ICRA). IEEE, 2017, pp. 3357–3364.
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