PhD in Computer and Control Engineering

Research Title: Optimization of Guidance, Navigation and Control (GNC) techniques on embedded systems for Service Robotics

GNC optimization for Service Robotics

Funded by	REPLY SpA

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Context of the research activity	Service robotics is expected to grow significantly in the next few years, fueled by the large number of innovations in the field and the decreasing trend in the cost of the hardware. However, it is not yet completely clear how to use such robots, which include drones, rovers, etc., in the most effective way to create innovative services. Furthermore, the problem may become even harder when the target scenario/environment is completely unknown. In this context, the activity proposed in this PhD proposal will address the guidance, navigation and control optimization, data processing, storage and communication issues that may arise in the service robotics scenario, when robots need to map and navigate an unknown - dynamically changing - environment avoiding obstacles and fulfilling a specific target mission (exploration, data collection, pure mapping, etc…). The unknown scenario poses many challenges in terms of robot structure and sensors typology because the main goal is to map & navigate using only what can be directly acquired by the robot itself (no external data, no anthropization) optimizing internal data-processing resources (internal layers organization and structure) and proprioceptive/exteroceptive sensors (complexity and costs).

	Research in this area is still ongoing. For instance, while many efforts have been devoted to designing optimal navigation strategies when the environment and constraints are known, optimizing strategies in real-time on board of the devices is still difficult when the environment is not well known or when any type of connection is not available. Another challenging aspect is how to automatically perform optimal adaptation of both the map and the path, in a way that it is jointly optimized, and satisfies both behavioral as well as computational requirements on state of the art embedded systems (EDGE computing). Moreover, optimal storage strategies for huge amounts of data need to be sought, since the robots are expected to collect as much information as possible with the onboard sensors; collected data can be processed to allow, for instance, extracting relevant information in a short time frame that can be then re-used for many tasks, avoiding, or reducing the need to transmit and process them in external (possibly available) much more powerful computing system.

Objectives	In this PhD proposal, among the many service robotics application fields, a few will be identified, analyzed in detail, and addressed, in coordination with the activity carried out by the PIC4SeR Interdepartmental Center. As a starting point, applications will include, but will not be limited to, the so-called Indoor Assistive Robotics, where efficient mapping and local/global navigation techniques are required. Such objectives will be achieved by using both theoretical and practical approaches. In fact, the adopted methodologies will include the development, wherever possible, of theoretical frameworks to model the whole system, in order to investigate the problem from an analytical point of view. The proposed techniques will build upon recent advances in traditional optimized algorithms and artificial intelligence, exploiting machine learning to determine optimal map&planning strategies in the presence of multiple competing constraints and under the presence of uncertainty. Artificial intelligence techniques can be employed both for sensing the environment and for planning the optimal trajectory (e.g. through reinforcement learning). The research project will leverage resources, data and know-how acquired by the PIC4SeR Centre for training the intelligent components, as well as define simulation environments in which classic techniques and artificial intelligence systems can be safely and effectively used.

	The resulting insights will then be validated in practical cases by analyzing the performance of the system with simulations and real-world experiments. In this regard, cooperation with companies will also be sought to facilitate the migration of the developed algorithms and technologies to prototypes that can then be effectively tested in real application scenarios.

Skills and competencies for the development of the activity	• Solid knowledge in Electronics and Computer Engineering • Application Layer analytical development skills • Basic knowledge about machine learning (supervised learning, reinforcement learning) • Experience with deployment on embedded systems • Strong programming skills • ROS/ROS2 skills • Team working capacities