PhD in Electrical, Electronics and Communications Engineering

Research Title: Advanced Control Strategies for lower limb exoskeletons.

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Context of the research activity	Spinal cord injury is a critical condition which often leads to permanent disability, permanent use of wheelchair and several secondary clinical complications. In most cases, repetitive and task-oriented movements of the impaired limbs can prevent complications such as muscle atrophy and osteoporosis. In this scenario, lower-limb exoskeletons can be a valid tool for rehabilitation: they can intensify the training, allowing the patient to autonomously walk over ground, for longer duration and reproduce rhythmically correct movement patterns. Motivated by this, researchers have been developing a vast range of robotics exoskeletons for spinal cord injury patients. The current leading products are ReWalk, Ekso and Indego. Traditional designs of lower-limb exoskeleton present two degrees of freedom in each leg to obtain the flexion-extension of the knee and hip joints, which are generally actuated by electric motors. Some recent lower-limb exoskeletons, as well as WalkOnSuit, Mina 2020 and Project March showed promising new design concepts to equip the new generation of exoskeletons with powered ankle joints. In the context of rehabilitation, additional degrees of freedom open new scenarios: indeed, a more articulated system can perform a wider range of movements which can be exploited to handle complex tasks and to allow therapists to design different exercises for rehabilitation purposes. Moreover, from a robotic point of view, more articulated exoskeletons leave wide margins to implement novel and advanced control strategies. These strategies can focus on several aspects related to deambulation (not only strictly connected to the walking pattern, the fluidity and reproducibility of physiological gait) but also involving walking-related features such as balancing or fall prevention. The aforementioned characteristics would enhance not only the usability and effectiveness of the device, but also its safety. In the Rehab Technologies Lab we are developing a new version of lower-limb exoskeletons. The main objective of this PhD is to develop new control strategies for multi degrees of freedom lower-limb exoskeletons aimed to the rehabilitation of

	existing system and to respond to the growing needs of clinicians. In this scenario, the PhD candidate will work in a multidisciplinary team of engineers, researchers and physiotherapists, that strongly cooperate with the aim of share and improve their know-hows on lower-limb exoskeletons and rehabilitation fields. The successful candidate will have access to our lower limb exoskeleton devices named Twin, and an exhaustive range of mechatronics equipment to facilitate the development activities. The successful candidate will have the opportunity to work in an international environment with a transfer technology mindset.

Objectives	1. *Control Strategies for rehabilitation purposes* This research work will aim at developing new software for our lower limb exoskeletons at the Rehab Technologies Lab. This research work will be grounded on advanced control strategies, based on mathematical models and methods, that will be implemented with sophisticated real-time algorithms. The Rehab Technologies INAIL-IIT Lab is creating a new generation of medical exoskeletons in close contact with physiotherapists and physiatrists. In this context, the work of this PhD will mainly consist in understanding the clinical needs, in order to identify and develop novel control strategies that enhance the rehabilitation capabilities of our exoskeletons. 2. *Innovative behaviors* The lower-limb exoskeleton capabilities to react at particular conditions (i.e. falling) or to adapt at the different environments without an intervention from external actor(s) are still open points. In the research context, one of the objectives of this PhD is to develop methods and strategies to increase the safety and security of the device and to adapt to the environment more effectively. 3. Based on the previous objectives, the final goal is hence: *"Development of advance control strategies and algorithms to enhance the capabilities of our multi degrees of freedom lower limb exoskeletons"*.

Skills and competencies for the development of the activity	• MSc in Mechatronic Engineering, Automation Engineering, Computer Engineering or related; • Programming languages: C, C++; • Robotics and Control; • Design of software architectures; • Linux; • Team working.