POLITECNICO DI MILANO

PhD in BIOINGEGNERIA / BIOENGINEERING - 39th cycle

THEMATIC Research Field: HYBR-ID: UPPER LIMB REHABILITATION SYSTEM INTEGRATING EXOSKELETON ASSISTANCE AND FUNCTIONAL ELECTRICAL STIMULATION DRIVEN BY A USER-BASED INTENTION DETECTION FRAMEWORK

Monthly net income of PhDscholarship (max 36 months)
€ 1400.0 In case of a change of the welfare rates during the three-year period, the amount could be modified.

Context of the research activity	
Motivation and objectives of the research in this field	The need to identify the best treatment options for upper limb (UL) recovery is included in the top 10 priorities relating to life after stroke. Although robotic devices and Functional Electrical Stimulation (FES) have shown to be valid training modalities per se, their combination in hybrid systems can overcome the limitations of every single approach. Training assisted by hybrid devices in lifelike scenarios, allowing the subject to freely interact with the environment, may optimize the transfer of functional gains to activities of daily living (ADL). In this context, this PhD project aims at developing **a multi-modal robotic platform to support three-dimensional (3D) UL reaching**, targeted to enhance functional arm recovery and ADL gains in stroke survivors with some residual motor capabilities. The foreseen platform will consist of a **cooperative control module**, which combines the user's residual volitional contribution, FES-induced assistance and robot assistance, and an **intention detection module**, able to identify the user's intention to move towards a set of specific targets, both integrated with a previously developed compliant-controlled arm exoskeleton (e.g. AGREE exoskeleton). The cooperative control module will include: i) a **feedforward anti-gravity robot assistance** to compensate for device and arm weight; ii) a **multi-muscle synergy-based FES controller** to guide the subject's hand towards the desired reaching target; iii) a **feedback corrective robot**

	assistance to facilitate target reaching. Both FES and robot assistance will be implemented according to an **assist-as-needed paradigm** to maximize user's involvement. The final platform will encompass different technological advances, as it will represent the first attempt to integrate voluntary contribution, FES action and robot assistance to perform 3D UL reaching tasks, directly guided by the user. From a clinical perspective, the final expectation is that training with such a platform may enhance arm functional recovery in stroke survivors, improving the capability to transfer functional gains to ADL. This project will be carried out within the project HYBR-ID: upper limb reHabilitation sYstem integrating exoskeleton assistance and functional electrical stimulation driven By a user tailoRed synergy-based Intention Detection framework (CUP: D53D23001230006), funded by the Ministry of University and Research (PRIN 2022, CUP D53D23001230006).
Methods and techniques that will be developed and used to carry out the research	To the best of our knowledge, the cooperative control system will represent the **first attempt to integrate volitional, FES-induced, and robot assistance contributions to support multi-DOF UL movements**. The PhD student will be asked to develop a control system including three modules: 1) a feedforward anti-gravity compensation, by which the exoskeleton continuously compensates for its weight and for the user's arm at the actual pose. 2) a multi-muscle synergy-based FES controller, which will guide the user's hand towards the desired reaching target; 3) a feedback corrective assistance, which will modulate a robot-assisted corrective force-field to facilitate target reaching. To avoid "slacking" effects, the variable 3D force-field will be implemented following the assist as needed paradigm. The force field amplitude could be increased when the movement exceeds a specific timeout or when the user deviates from the nominal reaching direction. Alternatively, it could be set inversely proportional to the distance from the target. The cooperative control system will be built upon the AGREE rehabilitation/assistance

	platform, which relies on a modular structure based on a re-configurable mechatronic UL exoskeleton, a modular software architecture based on impedance control, a trajectory generation routine for personalized exercises, and a sensor network for the monitoring of kinematic, dynamic, and physiological signals. As for the exoskeleton module, AGREE is equipped with 4 modular actuation units to assist the shoulder glenohumeral ball-socket joint and elbow flexion/extension. The exoskeleton structure aligns with the human joints and supports the user's arm at two interface points (i.e., upper arm and forearm). At the end-effector no handle is added, to allow grasping tasks with real objects. Each joint is provided with a load cell-based actuation unit to measure and regulate human-robot interaction, behaving compliantly to both user-generated and therapist-applied forces. Each joint is provided with mechanical end-stops to avoid exceeding the physiological range of motion for safety reasons. The exoskeleton can be controlled to operate in different modalities, including passive mobilization, weight-counterbalance and active assistive modes. The integration of FES in a robotic platform can lower the motor torque requirements, permitting the use of smaller motors, thus increasing portability, wearability of exoskeletons and overall energy sustainability. On the other hand, robot assistance can facilitate target reaching, which is difficult to achieve in FES-only supported movements. Also, robot assistance can possibly delay the onset of muscle fatigue and even support the therapy after fatigue occurrence.
Educational objectives	We provide doctoral candidates with high-level scientific training, fostering and refining research and problem-solving abilities by focusing on both theoretical and experimental skills. A PhD in Bioengineering will be able to layout, draft and carry on original research, by leading a research group or working in a team.
Job opportunities	National and international academic and non-academic institutions and organizations, engaged in innovation, research and technical development; high-tech SMEs, government departments.

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Composition of the research group	3 Full Professors 1 Associated Professors 2 Assistant Professors 8 PhD Students
Name of the research directors	PROF. EMILIA AMBROSINI

Contacts

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Additional support - Financial aid per PhD student per year (gross amount)	
Housing - Foreign Students	--
Housing - Out-of-town residents (more than 80Km out of Milano)	--

Scholarship Increase for a period abroad	
Amount monthly	700.0 €
By number of months	6

Additional information: educational activity, teaching assistantship, computer availability, desk availability, any other information

Two laboratories will be involved in this project: the Neuroengineering section of the NEARLAB, within the Department of Electronics, Information and Bioengineering of Politecnico di Milano https://nearlab.polimi.it/ and the interdepartmental laboratory WECOBOT ?Wearable and collaborative robotics laboratory? located at Polo Territoriale di Lecco of Politecnico di Milano https://www.polo-lecco.polimi.it/ricerca/laboratori-interdipartimentali/we-cobot-lab-wearable-and-collaborative-robotics-laboratory The PhD student will collaborate with the Department of Mechanical Engineeing of Politecnico di Milano (Prof. Marta Gandolla) and with the rehabilitation center Villa Beretta, Costa Masnaga, Lecco.

Educational activity: The student will be encouraged to attend to courses at POLIMI or abroad in International Schools.
Teaching assistantship: There are various forms of financial aid for activities of support to theteaching practice. The PhD student is encouraged to take part in these activities, within thelimits allowed by the regulations.
Computer and desk availability: the student will be allowed to access facilities of the DEIB.