COMPUTER AND CONTROL ENGINEERING

CNR/IEIIT - Advanced Intelligent Robotic Collaborative Assistance for Rehabilitation

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Context of the research activity	This PhD research focuses on the development of intelligent collaborative robotic systems for rehabilitation, integrating dual-arm collaborative robots, imitation learning, motion capture, and psychophysiological sensing. The goal is to design adaptive, safe, and human-like robot-assisted therapies by transferring expert therapist motor skills to robots, enabling coordinated multi-limb rehabilitation and personalized treatment based on quantitative motion analysis and bio-signal feedback.
	The proposed PhD research addresses the development of advanced intelligent robotic systems for physical rehabilitation, targeting scenarios in which patients with reduced mobility or motor impairments require repetitive, assisted movements as part of their recovery process. Traditional rehabilitation relies heavily on continuous physical intervention by healthcare professionals, leading to significant physical workload, limited scalability, and reduced continuity of care. Collaborative robotic technologies offer a promising solution to support therapists while improving the quality, personalization, and sustainability of rehabilitation treatments. The research will focus on the design, implementation, and experimental validation of an integrated rehabilitation framework based on collaborative multi-robot systems, artificial intelligence, motion capture technologies, and psychophysiological sensing. A central innovation of the project is the coordinated use of two collaborative robotic arms operating in synergy, enabling both localized and distributed rehabilitation exercises, such as simultaneous or coordinated movements of upper and lower limbs. This multi-robot paradigm extends beyond conventional single-robot rehabilitation systems, offering increased flexibility and the potential to enhance motor coordination and functional recovery. A key research direction concerns the development of intelligent control and learning architectures for coordinated multi-robot assistance. The PhD candidate will investigate control strategies that ensure safe, synchronized, and adaptive robot behavior during physical human–robot interaction.

Objectives	Particular emphasis will be placed on robustness, safety, and compliance, which are essential for rehabilitation applications involving direct contact with patients. Artificial intelligence will play a central role in enabling robots to perform movements that are natural, fluid, and biomechanically plausible. The research will explore imitation learning and supervised learning techniques to transfer expert motor skills from human therapists to robotic systems. Using high-precision marker-based motion capture, the movements performed by experienced therapists during rehabilitation exercises will be recorded and used to train learning models capable of reproducing these trajectories on collaborative robots. This approach aims to move beyond rigid, pre-programmed motions, allowing robots to replicate the sensitivity and expertise of human therapists in a digital and repeatable form. Motion capture technologies will also be used as a quantitative validation tool. The PhD work will include the development of methodologies for comparing robot-generated trajectories with human reference motions in terms of spatial accuracy, temporal coherence, smoothness, and movement quality. This quantitative evaluation will support iterative optimization of both control and learning algorithms, contributing to more ergonomic and effective robot-assisted rehabilitation protocols. Another distinctive aspect of the research is the integration of an anthropomorphic robotic hand into the rehabilitation framework. Unlike traditional end-effectors, a robotic hand allows grasping and manipulation tasks that more closely resemble therapist–patient interaction, potentially increasing comfort, realism, and effectiveness during assisted mobilization exercises. The candidate will study control and coordination strategies that integrate the hand with the robotic arms during rehabilitation tasks.

Skills and competencies for the development of the activity	- Master’s degree (Laurea Magistrale) in Biomedical Engineering or Mechatronic Engineering; - Skills in the development and validation of Machine Learning algorithms applied to biomedical data; - Experience in the processing of biomechanical and physiological signals, as well as in human motion analysis and gait analysis based on inertial sensors; - Scientific programming skills, including Python, MATLAB, C, Simulink, and Arduino, for data analysis, modeling, and algorithm development; - Scientific interest and basic competencies in neuroengineering, robotic rehabilitation, and artificial intelligence.