Editorial
Special Issue on Wearable Robotics and Assistive Technology

THIS special issue highlights some of the best work presented at the 4th International Symposium on Wearable Robotics (WeRob2018), held October 16–20, 2018, in Pisa, Italy. The papers focus on new technologies in the areas of neural interfaces, soft wearable robots, sensor and actuator technologies, and robotic exoskeletons. Based on the quality and significance of presentations at the conference, some of the presenters were invited to submit substantially expanded versions of their papers to IEEE TRANSACTIONS ON NEURAL SYSTEMS AND REHABILITATION ENGINEERING (TNSRE). The papers went through the normal journal peer-review process at that point. Eventually, six papers were ultimately selected for this special issue.

We believe that the papers in this special issue present researchers and clinicians with a timely update on the state of the field of wearable robotics. All of the papers collected here offer practical solutions to real-world challenges related to the implementation of wearable robots in rehabilitation and bioengineering. Five contributions focus primarily on technical solutions related to the design, development, and clinical validation of wearable robotics systems for assistive applications. One of the papers addresses the state of the field and the challenges associated with translating wearable robotics from the test-bench to the bedside.

"Closed-Loop Multi-Amplitude Control for Robust and Dexterous Performance of Myoelectric Prosthesis," by Marko Markovic *et al.*, published in the February 2020 issue, demonstrates that reliable dexterous control of a myoelectric hand prosthesis can be achieved using a simple, user-friendly method. Their proposed EMG-based system for hand amputees overcomes drawbacks of commercial methods for myoelectric control, which can be unintuitive and cognitively taxing, and academic machine-learning methods, which can require extensive training.

Robotic hands are also the subject of "A Novel Soft Robotic Supernumerary Hand for Severely Affected Stroke Patients" by Ciullo *et al.*, published in the May 2020 issue. Their system extends beyond the hand alone, however. The authors present a system to provide arm-hand compensational support to severely affected stroke patients for grasp activities with their paretic side. Unlike other rehabilitation devices, their system, consisting of a robotic hand, a gravity support system, and sensors to detect the user's intention, allows stroke patients to grasp objects using the residual functionality of the affected arm and hand.

The next three papers are on powered exoskeletons. "Actuation Selection for Assistive Exoskeletons: Matching Capabilities to Task Requirements" by Calanca *et al.*, in this issue, proposes a task-oriented methodology and a graphical tool to improve selection of actuator components—such as motor, reduction gear, and parallel stiffness profile—in order to match the actuator's capabilities to the purpose of the exoskeleton and ultimately to improve usability for users. The authors present a case study of the design of a back-support exoskeleton for load-lifting to walk the reader through how the proposed methodology works in practice, resulting in a more lightweight, compact, and efficient system.

"Neuromuscular Controller Embedded in a Powered Ankle Exoskeleton: Effects on Gait, Clinical Features and Subjective Perspective of Incomplete Spinal Cord Injured Subjects" by Tamburella *et al.*, published in the May 2020 issue, reports a pilot study of an autonomous wearable robot to assist the ankle during walking of patients who have experienced incomplete spinal cord injury. The study, which assessed the potential to adapt robotic assistance based on specific residual functional motor abilities, is an important contribution to the continuing work on optimizing human-robot interaction.

"Walking Perception of Time-Discrete Haptic Feedback on the Waist Is Invariant with gait events" by Cesini *et al.*, published in the July 2020 issue, presents the results of a study of a novel wearable sensory feedback apparatus made of a pair of pressure-sensitive insoles and a belt equipped with vibrotactile units. The device provides time-discrete vibrations around the waist, synchronized with biomechanically relevant gait events during walking. Controlled experiments with fifteen healthy volunteers and stimuli of different intensities at twelve locations revealed that perception of time-discrete vibrations was not affected by phase-related gating mechanisms, suggesting that the waist could be a good conduit for haptic feedback during walking.

Finally, Pinto-Fernandezy *et al.* address the exponential increase in papers focused on the evaluation of robot-assisted locomotion in their paper, "Performance Evaluation of Lower Limb Exoskeletons: A Systematic Review," published in the July 2020 issue. They scan the literature to identify the most promising performance indicators that can be converted into practical benchmarks for translation into marketable products that improve lives. They found that the evaluation of lower limb exoskeletons is still largely focused on straight walking

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on level, even terrain, with few studies addressing most of the basic motor skills that make up the activities of daily life. Their analysis also revealed a clear bias toward generic kinematics and kinetic indicators, in spite of the available metrics of human-robot interaction. They use these results to identify and discuss a number of promising research directions and benchmarks that may help the wearable robotics community advance the field.

In conclusion, we would like to thank the guest editors, Antonio Frisoli and Lorenzo Masia, and all the authors of the submitted papers, as well as the reviewers whose constructive comments ensured the quality of this special issue.

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