In recent years, rehabilitation engineering has played a crucial role in improving the quality of life for individuals with disabilities, by developing innovative devices and assistive technologies. In particular, the population aged over 75 is expected to rise considerably with a corresponding increase in long term conditions and functional and sensory impairments. In addition, people with a range of neuromuscular diseases may benefit from immediate support in order to avoid more severe or permanent damage. At the same time, robotics and mechatronics applications have rapidly expanded from the industrial environment to human assistance in rehabilitation and functional improvements. Already, there are many open challenges and opportunities to integrate engineering concepts into rehabilitation, increase population wellbeing and wealth, as well as reduce healthcare costs. This motivates researchers to study, design, and develop novel rehabilitative and assistive technologies and methods to help people to recover or improve cognitive and motor functions. Specifically, the challenge is to transfer the research results and new knowledge to stakeholders (e.g. users and their families, physicians, physiotherapists, clinics, hospitals, industry), creating a general awareness of the importance of rehabilitation engineering.

The purpose of this Special Collection is to collect high-quality research and contributions that deal with recent advances and developments in rehabilitation engineering, focusing on innovative support systems and robots, novel mechatronic devices and technologies for assistance and rehabilitation of human movements. This Special Collection presents 16 articles from Canada, China, Colombia, Germany, Iran, Italy, Poland, Romania, Spain, Turkey, and the UK, reflecting the frontier research in rehabilitation engineering.

The first paper, titled “Robotics for rehabilitation of hand movement in stroke survivors,”1 explores the research status in hand rehabilitation robotic technology. The study focuses on both mechanical design (e.g. concept), usability (e.g. setup, lightness, portability), and training paradigms (e.g. hand, hand/wrist or entire arm) since these parts are interconnected for effective hand recovery. An overview of the main advantages and drawbacks in applying robotics to hand motor impairments is provided in order to give a general view of the relationship between hand rehabilitation devices, rehabilitation theories and results.

In the paper “Design and control of a diagnosis and treatment aimed robotic platform for wrist and forearm rehabilitation: DIAGNOBOT,”2 a robotic platform for diagnosis and treatment (therapeutic exercise) is presented. The proposed solution is able to perform flexion-extension and ulnar–radial deviation movements for the wrist and pronation–supination movement for the forearm. The platform has a modular and compact structure treating two patients concurrently. A number of experiments on five healthy subjects demonstrates that the proposed robotic platform and its controller can perform therapeutic exercises.

The paper titled “Golem project: Concept and design of a trekking/hiking wheelchair”3 proposes the design of an improved model of trekking/hiking wheelchair taking into account passenger comfort and better functionality of the device. The system allows the movement of disabled people in mountain areas. The device design and modeling with the definition of dynamic parameters and the suspension system are discussed, highlighting the promising results to develop the new prototype.

In the paper “Structure design of active power-assist lower limb exoskeleton APAL robot,”4 a new exoskeleton device is investigated in order to withstand load and actively share the weight of a human body. The study illustrates the prototype and three basic functions (human movement perception, force transmission, and movement cooperation) are preliminarily verified in a
single leg swinging experiment. The effect of follow-up mode and active power-assist mode are quantitatively analyzed in marches-on-the-spot experiments. Proportional reduction of the wearer foot force and smooth man–machine coordination in field experiments demonstrate the feasibility of this structure design of active power-assist lower limb.

The paper titled “Development of a robotic device for post-stroke home tele-rehabilitation” proposes the mechanical design of the new HomeRehab robot that supports rehabilitation therapies in 3D with an adaptive controller that optimizes patient recovery. The aim is to develop a rehabilitation system for in-home use, guaranteeing similar performance of hospital systems but with reduced size, weight, and price. The system is based on a quadrilateral layout of bars that obtains maximum tip movement with minimum rotation on its base. A preliminary usability test is shown comparing HomeRehab performance with Robotherapist 2D.

In the paper “Hand exoskeleton for rehabilitation therapies with integrated optical force sensor,” the design of a hand exoskeleton is defined. The modularity is achieved by dividing the exoskeleton in separate units, each one driving a finger or pair of them. These finger modules have a single degree of freedom and may be easily attached or removed from the robot frame and human fingers by snap-in fixations. A first experimental session is performed in a clinical environment in order to check whether the hand exoskeleton can successfully move an impaired hand in a “Mirror Therapy” environment. A second study is carried with healthy subjects to check the technical feasibility of using the integrated force sensor as a human–machine interface.

In the paper “A wearable somatosensory teaching device with adjustable operating force for gait rehabilitation training robot,” a novel wearable multi-joint teaching device for lower-limb gait rehabilitation is employed in order to facilitate the adjustment of training modes in unique requirements of patients. A physiotherapist manipulates this active teaching device to plan the personalized gait trajectory and to construct the individual training mode. The adjustable operating force is experimentally demonstrated with the characteristics of good linearity and response speed. In addition, the results of master–slave control experiments preliminarily have verified the effectiveness of the control approach.

In the paper “Active rehabilitation training system for upper limb based on virtual reality,” an active rehabilitation training system based on the virtual reality technology is designed for patients with upper-limb hemiparesis. The aim is to increase the patients’ interest during the rehabilitation training. The basic functions of the virtual rehabilitation task scenes are tested and verified through the single-joint training and the multi-joint compounding training experiments.

The paper titled “Kinematics and performance analysis of a serial hip assistive mechanism” presents a serial assistive mechanism for the hip adduction/abduction and flexion/extension motion assistance. The study proposes a closed-form position solution of the assistive mechanism, employing the Jacobian matrices to map the velocity and force from the active joint space to hip joint space. A number of indices is defined to evaluate the assistive feature adequately.

The paper titled “Advanced technology for gait rehabilitation: An overview” is from a multidisciplinary multinational team and presents an analysis of the current technology for gait rehabilitation, reviewing the principles of ambulation training. The study highlights a need of new solutions to overcome existing system limitations and integrative approaches that address physical and psychological aspects of ambulation in real life situations.

In the paper “Path-planning of a hybrid parallel robot using stiffness and workspace for foot rehabilitation,” a 9 degree-of-freedom hybrid parallel robot is designed for ankle rehabilitation. The robot stiffness is investigated in both simulation and experimentation. The study highlights the capability of the proposed robot design in performing foot rehabilitation exercise with larger workspace and higher stiffness than hexapod and tripod systems.

In the paper “Automatic and manual devices for cardiopulmonary resuscitation: A review,” an analysis of the current technology of cardiopulmonary resuscitation (CPR) systems is proposed. Firstly, the devices are classified by actuation method, applied force, working space, and positioning time. Then, the discussion focuses on the device effectiveness, fast positioning, versatility, and reliability. The study highlights that most of the trials and meta-analyses have not completely demonstrated that chest compressions given with automatic devices are more effective than those given manually. However, advances in clinical research and technology are constantly improving the effectiveness of automatic devices.

The paper titled “Robotics rehabilitation of the elbow based on surface electromyography signals” proposes a control system based on the use of electromyography signals to drive the joint movement of the robotics arm in rehabilitation. The correlation between surface electromyography signal and the force exerted by the subject is studied in grasping tests. The control system is validated by an experimental campaign on healthy subjects with promising results that open the way to future research.

In the paper “Development and evaluation of two posture-tracking user interfaces for occupational healthcare,” the authors compared two interactive posture-
tracking user interfaces applied to promote proper spinal column exercise form. The first user interface is based on a wooden manikin with an integrated inertial measurement unit to provide a tangible user interaction while the second user interface presents a mobile application that provides instructions and explanations of the exercises. The usability of both interfaces are evaluated through a series of flexion and extension exercises. The results show the effectiveness of the systems; however, a combination of both may improve user engagement and motivation, providing a more accurate motion profile.

In the paper “The use of a cascaded Kinect and electromyography gesture decoding algorithm in an initial robot-aided hand neurorehabilitation,” an active-assistive control algorithm integrating electromyography bio-feedback into hand gesture recognition is defined. The initial experimental platform and the proposed algorithm are verified, proving an improvement of the tracking accuracy.

The paper titled “Automatic load-adapting passive upper limb exoskeleton” presents a passive exoskeleton with an automatic load-adapting mechanism. The system aims to assist people in rehabilitation exercise and load carrying. A gas spring is selected as the passive energy actor in order to reduce the weight of the structure. The experimental campaign proves the system capability to balance the load in the direction of the gravity, changing its load ability automatically.

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