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EDITORIAL

Trends in rehabilitation robotics

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Recent advances in rehabilitation procedures, methodologies and tools tend to include more and more the cognitive aspects of motor control. With the exploitation of new technologies for brain imaging, it is also possible to 'close the loop' from brain to action. In this multidisciplinary field, robotics gets a relevant role, which can be fruitfully employed in the rehabilitation of neuromotor functions and motor capabilities, by providing tools that are by nature flexible and programmable and that allow to set and assess procedures quantitatively.

Furthermore, rehabilitation robotic systems are:

– patient-specific, because they can easily optimize the degree of involvement of the patient by customizing the level of physical and/or cognitive assistance provided during each therapeutic session.
– self-motivating, because they can give direct quantitative feedback to the patient about her/his performance during and after the therapy, thus enhancing motivation and self-appraisal of the value of the proposed exercises.
– prone to telemedicine application, since many of them can be used at home, or in other locations outside the rehabilitation hospital, under remote supervision and/or tele-controlled by a therapist\physician.

Robotic tools also have been proposed and applied not only for motor rehabilitation but also to improve the treatment of cognitive disorders, e.g., to support the psychological enrichment of the elderly.

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This Special Issue is related to the workshop 'Future trends in Rehabilitation Robotics' organized within the framework of the IEEE International Conference on Biomedical Robotics and Biomechatronics, 2010 whose main objective was to provide an overview of the most recent advances in rehabilitation robotics and to explore new directions in the field, focusing particularly on cognitive aspects of motor control.

The articles in this special issue can be classified in three reviews and nine original papers. The reviews address some relevant topics related with the rehabilitation robotics research field: overview of upper-limb rehabilitation devices, different approaches to neurorobotic and hybrid management of lower limb motor disorders and a review about the assessment of the effectiveness of robot-facilitated neurorehabilitation for relearning motor skills. Moreover, the original papers cover a wide range of relevant topics like: virtual rehabilitation, rehabilitation robotic devices to train activities of daily living, electrical stimulation, assessment of upper-limb motor control in robot-aided rehabilitation, new assistance algorithms based on adaptative oscillators, upper-limb rehabilitation devices based on pneumatic technology, bilateral robot-mediated therapy and assistive robotic devices for elderly people and for children with special needs.

Classical devices for upper-limb rehabilitation clinical research, like ARMin [8], MIT-Manus [4] and many others are revised on Rui Loureiro et al. [15]. Tables in this work give a present update of the well-known devices. The paper overviews the current state-of-the-art on upper-limb robot-mediated therapy with a focal point on the technical requirements of robotic therapy devices leading to the development of upper-limb rehabilitation techniques that facilitate reach-to-touch, fine motor control, whole-arm movements and promote rehabilitation beyond hospital stay. Often, these devices are combined with virtual environments to integrate motivating game-like scenarios. Several studies have shown a positive effect of game-playing on therapy outcome by increasing motivation. Latest works, like Guidali [7], with those devices involve the application of virtual reality to train activities of daily living.

The same is done for lower limb devices; classical systems are reviewed on Moreno [12]. This work reviews the motor learning principles, robotic control approaches and novel developments from studies with neurorobots and hybrid systems, with a focus on rehabilitation of the lower limbs and on recovering gait ability.

In addition, one aspect that has raised attention is the evaluation of the robotic rehabilitation. Harwin et al. [3] gives us an excellent review about the requirements to assess and measure the impact of any proposed solution. It is clear that to be widely accepted a study is required to use validated clinical measures but these tend to be subjective, so mechanical assessment techniques will be required. Zollo [1] presents an interesting approach to the multi-modal analysis of patient performance, carried out by means of robotic technology and wearable sensors, and aims at providing quantitative measure of biomechanical and motion planning features of arm motor control following rehabilitation. Johnson [9] presents a novel evaluation system along with methods to evaluate bilateral coordination of arm function on activities of daily living tasks before and after robot-assisted therapy. The clinical results on the case studies on Johnson [9] showed that stroke patients compared to healthy subjects move slower and are less likely to use their arm simultaneously even when the functional task requires simultaneous movement. Pradhan [14] also presents an interesting clinical research that tries to examine the effects of medication on the attentional demands of precision and power grips in individuals with Parkinson disease.

The rest of contributions are related with particular applications or with basic research on systems interacting with patients. First, it is clear that human–robot interaction requires new developments on actuators, new techniques for controlling classical actuators or new safety designs that allow us to increase the current performance of the systems. One of these approaches is the use of pneumatic actuation for rehabilitation. Several systems have been designed using this technology. They are revised on [5]. This contribution also presents a new pneumatic rehabilitation robot for Proprioceptive Neuromuscular Facilitation therapies and for relearning daily living skills: like taking a glass, drinking and placing object on shelves is described as a case-study and compared with the current pneumatic rehabilitation devices. One fascinating field of interest on rehabilitation robotics is its application to paediatric rehabilitation. Paediatric rehabilitation focuses on maximizing the function and enhancing the lives of children with a wide range of conditions such as cerebral palsy, spina bifida, stroke, brain injury, genetic abnormalities and other developmental disabilities. Although, there are several publications about paediatric rehabilitation, few of them are about robotic rehab [6]. Schoepflin and the team of Prof Sunil Agrawal [13] present an original work with a bio-driven device for mobility of infants and toddlers. The development of child's motor skills is related with the self-generated mobility. One of the interests of the biological research on rehabilitation processes is the application to new therapies that help to increase the quality of life or the capacity to perform daily activities. Popovic et al. [2] present a multichannel electrical stimulator for the suppression of pathological tremor. This system is applied to seven patients with Parkinson's disease and Essential tremor for minimization of the wrist joint tremor. Ronsse et al. [11] also propose a new method, based on adaptative oscillators, for providing assistance during cyclical movements. This method can help on the designing processes of innovative rehabilitation and assistance protocols. Finally, Carrera et al. [10] introduces the concept design and analysis of a robotic system for the assistance and rehabilitation of disabled people. This work is focused on those robots that assist with gait, balance and standing up.

The guest editors hope that the summary of approaches to robotic rehabilitation presented in this issue will help and stimulate researchers to contribute to this field. We honestly think that it is worthwhile to spend our efforts in this satisfactory goal of helping people.

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