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Innovative Assistive and Rehabilitation Robotic Systems

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ABSTRACT

Assistive Technology and Rehabilitation Engineering consist in application of science and technology for more effective rehabilitation processes and reintegration of the disabled in family and society. This paper presents few innovative systems belonging to robotics, developed for maximizing the functional capabilities of people with different disabilities. Different types of original upper limb exercisers, exoskeleton-type wearable rehabilitation systems for upper limb, a complex system for mobility and posture are described in terms of their destination, structure and functional parameters.

KEYWORDS: *Assistive Technology, Rehabilitation Engineering, Exerciser, Mobility Aid.*

1. INTRODUCTION

National, European and worldwide statistical data reveal a process which is becoming more evident, at the same time, more pronounced, of increasing the percentage of older adults (over 65 years), as well as, the real need of the elderly for high - performance technical support in assisting them. On the other hand, there is a large number of people with special needs (impaired, disabled, handicapped) and the costs of their reintegration into society and family are less than the cost of their institutionalization.

As a result of complex rehabilitation and assistance approaches, the patients gain greater independence in all activities, improved safety conditions, which means a substantial increase in their quality of life. Among the basic attributes of rehabilitation and assistive processes, there are also performance characteristics of the equipment, so it is recognized that these processes are more effective as the equipment is more efficient. In this regard, we emphasize the great potential that mechatronic systems offer in Biomedical Engineering, especially in Rehabilitation Engineering and Assistive Technology [1], [2].

2. ASSISTIVE AND REHABILITATION ROBOTICS

With the increased demand for assistive technology for the disabled and elderly, service robotics should have a potentially major contribution to make. Generally, a service robot operates semi- or fully autonomously to perform services useful to the well-being of humans and equipment, excluding manufacturing operations. Both, professional and domestic service robotics, contain robotic systems with a wide variety of targets: cleaning, inspection, maintenance, construction, defense, rescue, security, personal transportation, domestic tasks, entertainment, medical (surgery, therapy, rehabilitation), assistance and special purposes [3].

The Rehabilitation Robots are dedicated to clinical therapy in neuro-motor rehabilitation and training, including robotic systems for gait restoration and robots for upper extremities therapy. The Assistive Robots improve the quality of life of disabled and elderly people, mainly

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by increasing personal independence. They contain prosthetic devices and artificial limbs, orthotic devices and exoskeletons, robotic mobility and manipulation aids, personal assistants and smart living spaces, [4].

In order to improve the quality of life, assistive and rehabilitation robots cooperate with a user in the user's environment. Their basic functions are: physical assistance, recovery of motor functions, safety, monitoring, social companion, communication. As a consequence, the operation workspace of these robots (domestic environment) is unstructured and variable, so a high degree of adaptability is essential for task execution. It is not recommended to adapt existing robotic solutions, designed for industrial purposes, to rehabilitation and assistive problems., thus is a real need for innovative systems.

3. THE DEVELOPED ROBOTIC SYSTEMS

Previous activities of our group have developed a strong sense of empathy with the specific needs of older people and those with disabilities, which led to a deep understanding of their functional limitations, essential to carry out research in this area. Several prosthetic and orthotic systems have been proposed, new exercisers have been developed, wearable exoskeleton-type systems have been investigated and mobility aids have been designed.

3.1. Wrist exerciser

Figure 1a presents the CAD model of an exerciser, dedicated to passive flexion-extension and abduction-adduction movements of the hand. The mechanical part of the exerciser is based on a 2 DOF mechanism, actuated by two actuators which are placed in accordance with the biomechanical axis. The geometrical characteristics of the exerciser are based on anthropometric data of the hand, wrist and forearm. The functional prototype (Fig. 1b) could be programmed by the therapist with the exact exercise each patient need. The relevant data are stored and then analyzed by the therapist [5].

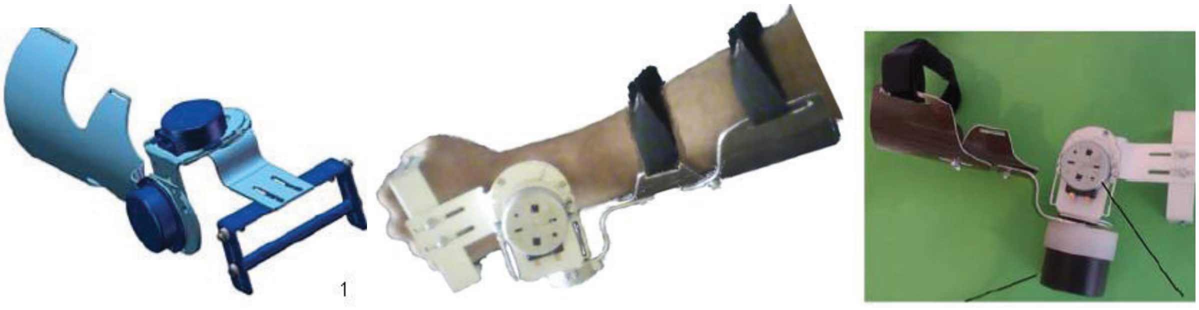

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Fig. 1. Wrist exerciser

A substantial improvement of such exerciser is represented by adding a brake for *active with resistance* movements of the hand, in the wrist joint. The property of the electrorheological fluids (ERF) to change their shear stress in respect to electric field intensity was valorified, as in Fig. 1c which shows an ERF brake mounted on the wrist exerciser, instead of the actuator. The ERF brake design is based on the principle of hydraulic clutches, which is determined by the torque transmission between two disks through a viscous fluid. After development, the brake was tested with commercial ERF and laboratory developed ERF. The maximum brake value is 177.5 [mNm] and was obtained for Reslinol 415/GE16 commercial ERF at 6.6[kV] activation voltage [6].

3.2. Wearable exercisers

The shoulder and elbow joints are addressed by the two degrees of freedom exoskeleton, given in Fig. 2. For shoulder and elbow flexion-extension movements (Fig. 2a), based on the structural scheme given in Fig. 2b, has been developed the CAD model of a semi-portable exoskeleton type system (Fig. 2c), which is fixed to the seat and is attached at the same time, to the upper limb. Its role is to recover both mentioned movements of the arm and forearm and as an upper limb trainer. The structural elements for the arm and forearm, the actuators at the shoulder and elbow joints (fitted with gearboxes) and the attachment to the seat are highlighted. The modular structure, the adjustment possibilities and ease of adaptation to the attachment are major advantages of the system.

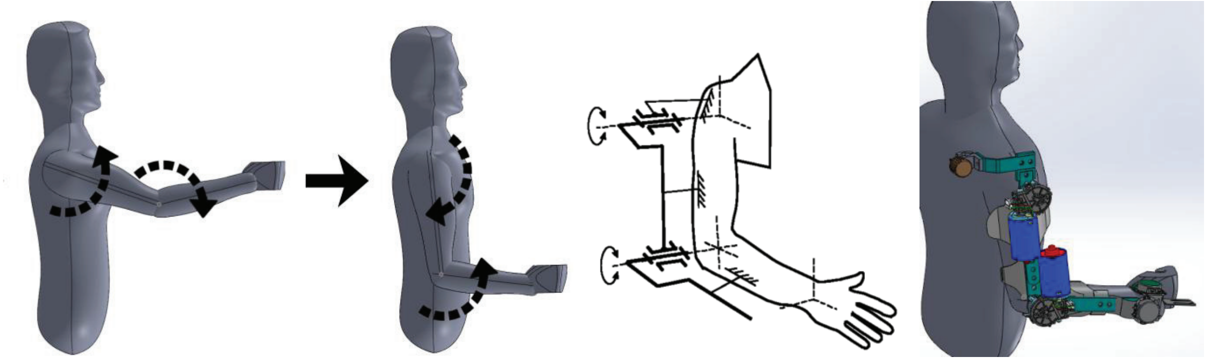
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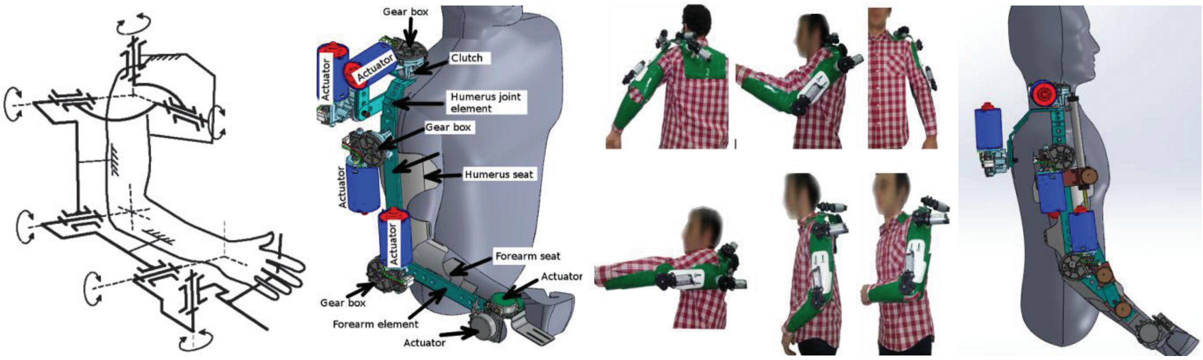
Fig. 2. Shoulder and elbow exerciser

Based on the structural scheme presented in Fig. 3a, in which the anatomical movements at shoulder, elbow and wrist are emphasized, the CAD model of the wearable exoskeleton with six degrees of freedom was developed (Fig. 3b). The experimental prototype, without wrist module, is shown in Fig. 3c [7]. The model of such an exoskeleton equipped with a linear damper based on ERF is presented in Fig. 3d. It is intended to *active with resistanc*e flexion-extension of the forearm.



a b c d

Fig. 3. Upper limb exoskeleton

3.3. Assistive and rehabilitation robotic system

The objective of our research team was to cover several functions: assisting and maintaining the biped posture, assisting the transfer from a position to another, assisting and training the gait, ensuring mobility as a wheelchair [8]. Thus, the system is designed for two operation modes: first is the mobility mode and second is gait trainer mode, both with capabilities for transfer. Figure 4 gives the sequences of work phases: positioning the system and standing up (Fig. 4a), user rotation (Fig. 4b), stand up phase (Fig. 4c) and mobility aid (Fig. 4d). The subject is seating and starts the use of the system in order to ensure the mobility (as a wheelchair) or the system starts to move to ensure the gait recovery (Fig. 4e).

An experimental prototype was developed (Fig. 4f). For vertical and horizontal positioning, linear electric actuators are implemented, while the rotation of the user around its axis is realized by rotational actuators. The control of the system was divided into two units: the command for the drive wheel system – a joystick-based module operated by the right hand, and the command for the position of the user in respect with the system – a group of switches operated by the left hand.

Fig. 4. Assistive and rehabilitation robotic system

4. CONCLUSIONS

The developed rehabilitation and assistive robotic systems are characterized by structural strength and safe operating regimes. Their low costs are achieved by modular structure. The systems have acceptable controls and user interfaces is minimal. The design of the proposed systems aimed to ensure energetic autonomy and possibility to personalize for each user's needs. Further improvements will lead to better maintenance of good health, increased safety, and encouraged independence.

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