Chapter 11
Cable-Driven Robot for Upper and Lower Limbs Rehabilitation

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ABSTRACT

The science of rehabilitation shows that repeated movements of human limbs can help the patient regain function in the injured limb. There are three types of mechanical systems used for movement rehabilitation: robots, cable-driven manipulators, and exoskeletons. Industrial robots can be used because they provide a three-dimensional workspace with a wide range of flexibility to execute different trajectories, which are useful for motion rehabilitation. The cable-driven manipulators consist of a movable platform and a base, which are connected by multiple cables that can extend or retract. The exoskeleton is fixed around the patient's limb to provide the physiotherapy movements. This chapter presents the upper and lower human limbs movements, a review of several mechanical systems used for rehabilitation of upper and lower limbs, as well as the mathematical model of cable-driven manipulators. The experimental tests of the cable-driven manipulator for upper and lower limb rehabilitation movements are presented showing the viability of the proposed structure. Finally, this chapter presents the future research directions in rehabilitation robots.

INTRODUCTION

Stroke is the most common cause of disability in the developed world and can severely degrade lower limb function. The use of robots in therapy can provide assistance to patients during training and can offers a number of advantages over other forms of therapy (Pennycott et al., 2012). Movements' recovery after stroke is related to neural plasticity, which involves developing new neuronal interconnections, acquiring new functions and compensating for impairment. Stroke rehabilitation programs should include meaningful, repetitive, intensive and task-specific movement training in an enriched environment to promote neural plasticity and movements' recovery. Robotic training can offer several potential advan-

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tages in rehabilitation, including good repeatability, precisely controllable assistance or resistance during movements and quantifiable measures of subject performance. Moreover, robot training can provide the intensive and task-oriented type of training that has proven effective for promoting movements learning (Takeuchi & Izumi, 2013; Colombo et al., 2012; Kuznetsov et al., 2013; Maciejasz et al., 2014, Dzahir & Yamamoto, 2014).

There exist two common techniques for movement rehabilitation: the first technique involves the patient staying passive throughout the therapy while the therapist (or the rehabilitation system) manipulates the injured limb to promote its movement. Motion and load limits must be well controlled in this technique to avoid new injuries of the still injured region/limb. In the second technique, the patient performs active movements. The big difference between patients and injury means different and/or multiple devices should be at the disposal of therapists (Carvalho & Gonçalves, 2012).

One can identify two important areas for the application of robots to human health: the robotic surgery and the rehabilitation robots. Both areas have advanced considerably due to the development of control systems, video cameras, micro and nano technologies, new materials, and so on.

Physical medicine and rehabilitation is intended to treat, recuperate, or alleviate the disabilities caused by chronic diseases, neurological damage, or injuries resulting from pregnancy and childbirth, car accidents, cardiovascular diseases, and work. Rehabilitation is a comprehensive and dynamic process-oriented physical and psychological recovery of the disabled person, in order to achieve social reintegration.

The rehabilitation process involves several activities, from diagnosis to prescription of treatment, where the prescribed treatment must facilitate and stimulate the recovery processes and natural regeneration. In general, the process involves stimulus and repetitive movements that must be performed several times at various speeds.

The science of rehabilitation has shown that repeated movements of human limbs can to help the patient regain function of the injured limb. Robotic systems can be more efficient in performing these exercises than humans, and they the recording of information like position, trajectory, force and velocity. All data can be archived and then compared to check the progress of patients in therapy.

Different robotic architectures have been developed and applied in the rehabilitation of upper and lower human limbs. In general, robotic structures used in rehabilitation are industrial robots or a new structure specifically designed for and/or adapted to the reproduction of human movements.

Robots are mechatronics system that can be used in all fields of modern engineering science and technologies. Mechatronics enables the creation, design, and support of new concepts for realizing intelligent human-oriented machines that coordinate and cooperate intelligently with their human users (Habib, 2007). Thus, this paper focuses on mechatronics system based in cable-driven parallel manipulators which are used in medicine to rehabilitate patients with loss of movement.

These systems should reproduce the correspondent human limb motion which will be recovered. The development of such mechanical systems is not a simple task due to the complexity of human limb motion. In order to understand the complexity of designing the mechanical structure for movement rehabilitation, initially the upper and lower human limb movements are introduced. In the following, a review of several systems used for their rehabilitation is presented. They are based on industrial robots, specific structures (serial and parallel robotic structures), structures based on articulated closed loop mechanisms, and cable-driven parallel manipulators. Finally, the mathematical model and experimental tests of cable-driven manipulators for upper and lower limb rehabilitation movements are presented showing the viability of the proposed structure.

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