Chapter 3
Cable-Driven Robots in Physical Rehabilitation:
From Theory to Practice

Rogério Sales Gonçalves
Federal University of Uberlândia, Brazil

Thiago Alves
https://orcid.org/0000-0001-5666-0831
Federal University of Uberlândia, Brazil

Giuseppe Carbone
DIMEG, Università della Calabria, Italy

Marco Ceccarelli
https://orcid.org/0000-0001-9388-4391
University of Rome Tor Vergata, Italy

ABSTRACT

This chapter deals with cable-driven robots when applied in physical rehabilitation. In general, neurorehabilitation is limited to physical therapy that is delivered by clinicians and potentially augmented by robotic tools to facilitate neurorehabilitation and to reduce the consequences of central nervous system injury. Among the robotic tools for rehabilitation can be considered the cable-driven manipulators. First, this chapter presents the upper and lower human limbs movements. The main rehabilitation robots are presented as exoskeletons and cable-driven manipulators. After, the cable-driven manipulators theory is introduced focusing on considerations for robot design in rehabilitation and control with safe human-machine interaction. Experimental examples with different cable-driven robot's structures are presented so that this chapter suggests that these structures can be used as a complement to conventional therapies and not as a substitute. Finally, this chapter presents the clinical evidence in cable-driven robots when applied in physical rehabilitation.

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INTRODUCTION

Stroke is the leading cause of disability in the world and leaves a significant number of individuals with motor and cognitive deficits (Tucan et al., 2019; Gonçalves & Krebs, 2017). It can degrade upper and lower limbs functions and rehabilitation training is the most effective way to reduce these motor impairments in stroke patients. Robots can be suitable for this purpose since they can train patients for long durations with precision (Hatem et al., 2016). The robotic therapy assists the patient during training and can offer several advantages over conventional therapy as pointed out in Pennycott et al. (2012).

After a stroke the recovery of the movements is related to neural plasticity, which involves developing new neuronal interconnections, acquiring new functions and compensating for impairment. To promote neural plasticity and consequently movement's recovery, the use of robots on rehabilitation can provide an intensive, repetitive and task-oriented training which has proven effective for the movements learning (Duret et al., 2019; Takahashi et al., 2016; Takeuchi & Izumi, 2013; Colombo et al., 2012; Kuznetsov et al., 2013; Maciejasz et al., 2014, Dzahir & Yamamoto, 2014).

Repeated movements of human limbs can help the patient to regain function of the injured limb. This process involves repetitive movements that must be performed several times at various speeds. The robots are, generally, more effective and efficient in performing these exercises than humans offering longer and more frequent therapy sessions for a patient and, consequently, they are attracting significant research interest. Additionally, a self-treatment with remote supervision of several patients by a single therapist professional can be implemented using these devices (Stein, 2012; Reinkensmeyer and Boninger, 2011).

Moreover, these systems can be coupled with virtual reality simulators, enhancing conventional physical therapy by recording patient information like position, force, time and velocity. The rehabilitation process involves other activities like diagnosis and prescription of the treatment to stimulate the recovery processes.

The recorded data by the robot can be achieved and compared through patient sessions to follow the progress (or even between different patients to aid in diagnosis), providing an objective measure of the progress and outcomes of therapy (Matin & Cazorla, 2019; Ceccarelli et al., 2010, Gonçalves et al., 2015).

These measures can offer a sensitive, accurate and time-efficient approach for the assessment of sensorimotor function after neurological impairment compared to standard clinical assessments. Besides that, motor functions of stroke patients are frequently related and evaluated using drawing/tracing tasks which are simpler with robotic systems (Takebayashi et al., 2018; Dipietro et al., 2007; Hussain et al., 2017). Additionally, the use of robotic solutions has strong potential for reducing

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