Chapter 3
Development of a Novel Parallel Structure for Gait Rehabilitation

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ABSTRACT

This chapter deals with the development of a new active body weight support, based on a parallel robotic structure with 5 degrees of freedom. Initially, a revision of the main structures applied in body weight support for gait rehabilitation is presented, along with a conceptual model of the proposed structure. Therefore, the inverse kinematics and singularity analysis are performed. A dynamic model is then built based on the obtained kinematics, and all parts of the structure are optimized using an evolutional algorithm. Finally, a CAD model of the structure is built based on the optimized dimensions and the model is applied to computational simulations of the gait rehabilitation, being thus ready for prototype construction.

INTRODUCTION

Rehabilitation is an area of medicine and physiotherapy that deals with the treatment of chronical neurological diseases and injuries, caused during birth, or by work or transit accidents. The main objectives of this science is to manage a dynamic process over patients to achieve physical recover in order to regain global functional skills (Rogério S. Gonçalves, 2010).

The rehabilitation process begins with pathology identification and its disabilities, followed by improvements projection based on the rehabilitation potential. Hereafter an appropriate treatment is prescribed, applying medical-surgical action if needed, and finally proceeding with physical stimulations to maximize residual capacities by natural recovery and regeneration processes (Barbosa, 2013).

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Recovery of physical functions that promote functional independency for patients contributes for self esteem increase, joy for life and sensation of overcoming difficulties, implying in improving life quality (Camargos et al., 2012).

Robotics has a wide area of application which includes physical rehabilitation, acting in coadjustment and support to medical-surgical actions; facilitation and stimulation of the processes of natural recovery and regeneration; and stimulation, maximization and compensation of residual capacities (Nunes, 2012).

Treatments applying robotic structures are common to victims of Stroke (Babaiasl, Mahdioun, Jaryani, & Yazdani, 2015; Louie & Eng, 2016; Lum, Reinkensmeyer, Mahoney, Rymer, & Burgar, 2002); Cerebral Palsy (CP) (Wu, Hwang, Ren, Gaebler-spira, & Zhang, 2011); and Spinal-Cord Injury (SCI) (Jezernik, Colombo, & Morari, 2004; Mekki, Delgado, Fry, Putrino, & Huang, 2018).

The rehabilitation robotic systems can be defined as an example of a new unifying interdisciplinary engineering science, as can be classified as a Human Adaptive and Friend Mechatronic (HAFM). The main goals of this new era of Mechatronics are to provide smart environments, reducing repetitive and stressful routines, enhancing productivity and contributing to a better life. HAFM are changing the concept of the machines, where their new smart features allow them to behave as a partner rather than a simple tool (M. Habib, 2007; M. K. Habib, 2008).

The application of robotic structures in treatments mentioned above has successfully benefitted medicine and physiotherapy with active labor cost reduction for movement-based procedures, and with the expansion of the range of therapy exercise, helping chronical patients to maintain mobility by continuous therapy (Lum et al., 2002).

In addition, Stroke, in most cases, causes impairment to the victims, while being the third most common cause of death in United States and Europe (Lloyd-Jones et al., 2010), and the most frequent in Brazil, causing a large social and economic impact (Brasil, 2013). These fact highlights the importance of Stroke treatment, therefore encouraging robotic research to this application.

It is estimated that for every 100,000 Brazilians, there will be 108 annual stroke cases, with fatalities up to 30 days to 18.5% of cases and up to 12 mouths to 31% of cases (Brasil, 2017). In average, a person in United States will have a stroke every 40 seconds (Lackland, 2017).

In this chapter, a novel robotic structure applied in human gait rehabilitation of Stroke, CP and SCI patients is proposed. The conceptual model of this structure is shown in Fig. 1. Along the next sections, a literature review of the robotic structures applied in gait rehabilitation and human gait kinematics provides the background of this research.

Next, the mathematical, kinematic and dynamic models of the structure are presented, followed by a singularity analysis of the obtained kinematic chain. Then, based on the obtained models, the dimensions of each part of the structure are optimized using an evolutionary algorithm. After, CAD models of the structure are built and used to generate computational simulations.

Finally, the first actuator prototype of the structure and its control system are built. Load-less experimental tests are used to tune the control parameters to velocity and position control. The obtained results are then analyzed in order to present the next steps and perspectives of the development process.

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