Chapter 12
Human-Inspired Robotic Exoskeleton for Post-Stroke Gait Rehabilitation: Design, Modelling, Control, and Experimental Testing

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ABSTRACT

Stroke is one of the leading causes of physical disability and many suffer paralysis to their limbs. The rehabilitation to recover the function of gait often takes time because the current rehabilitation technique used is labour intensive and time consuming for the therapists and difficult to perform it effectively. In order to improve the gait rehabilitation process, robot assisted gait rehabilitation has gained much interest over the past years. The contributions of this research are the development of new robotic exoskeleton device designed to be lightweight, comfortable, and safe to use for gait rehabilitation for stroke patients, which were lacking in the existing devices. Another contribution is the establishment of new manufacturing technique that allows custom exoskeleton components for each individual patient. Finally, the development of advanced model-based Feedforward (FF) controller that achieves fast and accurate tracking performance is explored in this chapter.

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INTRODUCTION

Every day, about 24 New Zealanders have a stroke ("Stroke Foundation of New Zealand," 2013). A stroke is the rapid loss of brain function due to lack of blood flow to the part of the brain caused by a blockage or a haemorrhage (Sims & Muyderman, 2010). Stroke not only affect older people but affects all ages, about 40 strokes in New Zealand are suffered by children and nearly quarter of all stokes are suffered by people under 65 ("Stroke Foundation of New Zealand," 2013). Stroke is survivable with an immediate medical assistance with estimated 60,000 stroke survivors in New Zealand ("Stroke Foundation of New Zealand," 2013). The effect of stroke to the patient can vary from the loss of speech or visual sense, but most often stroke will result in Hemiplegia, an inability to move one or more limbs on one side of the body (Belda-Lois et al., 2011; Donnan, Fisher, Macleod, & Davis). There are many other injuries and medical condition that affect human motor skills such as cerebral palsy (CP) and spinal cord injury (SCI) ("Cerebral Palsy," 2007; Hussain, 2012).

The impairments on limbs, particularly on their gait have a huge impact in the life of a patient and considerable costs for health and social services (Evers et al., 2004). In order to minimise the long term disabilities, patients undergoes rehabilitation to regain the motor skills. Although the majority of stroke patients achieve an independent gait, many do not reach a walking level that enable them to perform all their daily activities, and fewer than 50% of patients regaining their independence after 6 months (Schaechter, 2004; Wade & Hewer, 1987).

Traditional approaches to gait rehabilitation for stroke patient consist of body weight supported (BWS) manually assisted treadmill training, as shown in Figure 1 which is in practice for more than 20 years (Behrman & Harkema, 2000; Finch, Barbeau, & Arsenault, 1991). BWS treadmill training starts while the patient are not capable of moving their leg by themselves which is usually around four to six weeks after a stroke. Body weight support system consisting of weight compensation system with harnesses are attached to the patient's trunk as they are also not capable of supporting and stabilising their body. The training usually requires a team of three or more physical therapist to guide the legs and hip of patient along the correct paths. This method has proven significant improvement in the gait of patient including the step length, endurance and walking speed (da Cunha Filho et al., 2001; Hassid, Rose, Commisarow, Guttry, & Dobkin, 1997; S Hesse et al., 1995; Stefan Hesse, Konrad, & Uhlenbrock, 1999; Laufer, Dickstein, Chefez, & Marcovitz, 2001; Murray, Spurr, & Sepic, 1985; Shawnna L Patterson, Rodgers, Macko, & Forrester, 2008; Visintin, Barbeau, Korner-Bitensky, & Mayo, 1998).

BWS treadmill training may be more effective if the movement of the body especially the legs are in a reproducible, rhythmical and physiological manner (Colombo, Joerg, Schreier, & Dietz, 2000). Consequently, the quality of BWS treadmill training depends on the experience and judgement of the therapists which varies among the therapists. Additionally, fatigue on therapist limits the manual training to last only about 10 to 15 minutes as it is physically demanding and could cause back pain on therapists (Colombo et al., 2000). Moreover, the manual training does not have any proper method of recording the progress and recovery of patient.

Mechatronics have evolved since early 70s and represents a unifying interdisciplinary and intelligent engineering science paradigm which fuses, permeates, and comprehends modern engineering science and technologies (M. Habib, 2012; M. K. Habib, 2007)

In order to improve the gait rehabilitation process and quality of the outcome, robot assisted gait rehabilitation has gained much interest over the past years. Robot assisted training has many advantages over manual physical therapy. At first, robot can guide and assists the movement of legs and other part of patient's body at desired trajectory for the training. This can be done accurately and repeatable every time.

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