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A hybrid active force control of a lower limb exoskeleton for gait rehabilitation

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Abstract: Owing to the increasing demand for rehabilitation services, robotics have been engaged in addressing the drawbacks of conventional rehabilitation therapy. This paper focuses on the modelling and control of a three-link lower limb exoskeleton for gait rehabilitation that is restricted to the sagittal plane. The exoskeleton that is modelled together with a human lower limb model is subjected to a number of excitations at its joints while performing a joint space trajectory tracking, to investigate the effectiveness of the proposed controller in compensating disturbances. A particle swarm optimised active force control strategy is proposed to facilitate disturbance rejection of a conventional proportional-derivative (PD) control algorithm. The simulation study provides considerable insight into the robustness of the proposed method in attenuating the disturbance effect as compared to the conventional PD counterpart without compromising its tracking performance. The findings from the study further suggest its potential employment on a lower limb exoskeleton.

Keywords: particle swarm optimisation; rehabilitation; robust; trajectory tracking control.

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Introduction

The World Health Organization's (WHO) 2013 World health statistics reported that 8% of Malaysia's population is well over 60 years old [29, 33]. About 11% and 7.2% of children aged between 0 and 18 years were discovered with physical and cerebral palsy disabilities, respectively, as reported in the Malaysian Ministry of Health's annual report 2011 [21, 29]. The report also suggests that there is an average increase of 300% of stroke patients on top of 1.2 million new diabetic cases reported annually. It is not uncommon that gait abnormalities affect the aforesaid percentile [28]. Gait, in essence, is one's ability in maintaining balance and assume the upright position as well as one's capability in initiating and sustaining rhythmic stepping [25]. Gait disorders may originate from cerebellar disease, neuromuscular disease, cardiac disease, cognitive impairment, stroke, brain or spinal injury or even other general circumstances that may cause this condition [9, 22].

Owing to the rising number of ageing society globally as well as other contributing factors, the demand for rehabilitation services is on the rise [9, 21, 22, 29, 33]. It is evident from previous studies that through continuous locomotion activity, patient's mobility may be improved [5, 31]. Traditional rehabilitation therapy in facilitating this form of activity requires the support of at least two physical therapists [8]. However, this type of treatment is deemed too laborious to the therapist as well as cost demanding. This scenario has led the research community to address the drawbacks of conventional rehabilitation therapy as well as the increasing demand for gait rehabilitation by engaging robotics. The control strategies developed over the years with respect to rehabilitation robotics reported in the literature can be classified into four main categories, namely, position tracking control, force and impedance control, biosignal-based control and adaptive control [20].

As previously mentioned, one's mobility may be increased through regular and repetitive training on the impaired limb. This manner of exercise is of particular importance, particularly in the early stage of recovery whereby passive form is recommended, and this treatment