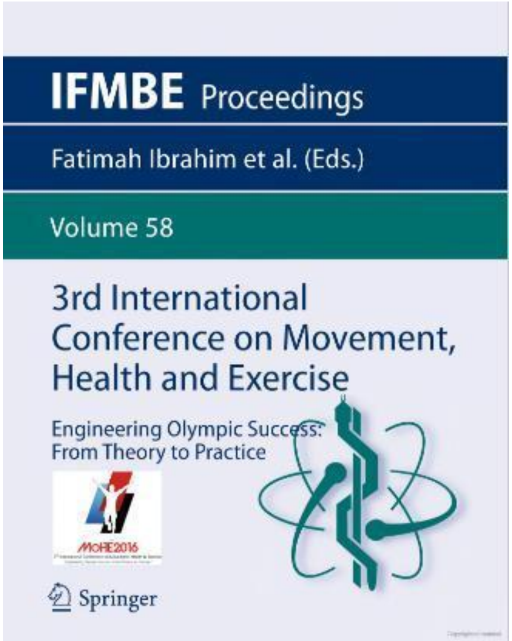

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by **Fatimah Ibrahim** (Editor), **Jadeera Phaik Geok Cheong** (Editor), **Juliana Usman** (Editor), **Mohd Yazed Ahmad** (Editor), **Rizal Razman** (Editor)

Editors
Fatimah Ibrahim
Center for Innovation in Medical Engineering (CIME)
Department of Biomedical Engineering
Faculty of Engineering
University of Malaya
Kuala Lumpur
Malaysia

Jadeera Phaik Geok Cheong
Sports Centre
University of Malaya
Kuala Lumpur
Malaysia

Juliana Usman
Centre for Applied Biomechanics (CAB)
Department of biomedical Engineering
Faculty of Engineering
University of Malaya
Kuala Lumpur
Malaysia

Mohd Yazed Ahmad
Center for Innovation in Medical Engineering (CIME)
Department of Biomedical Engineering
Faculty of Engineering
University of Malaya
Kuala Lumpur
Malaysia

Rizal Razman
Sports Centre
University of Malaya
Kuala Lumpur
Malaysia

Victor S. Selvanayagam
Sports Centre
University of Malaya
Kuala Lumpur
Malaysia

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Contents

The Control of an Upper-Limb Exoskeleton by Means of a Particle Swarm Optimized Active Force Control for Motor Recovery

A. P.P. Abdul Majeed, Z. Taha, I. Mohd Khairuddin, M. Y. Wong, M. A. Abdullah and M. A. Mohd Razman

Innovative Manufacturing, Mechatronics & Sports Laboratory (iMAMS),
Faculty of Manufacturing Engineering, Universiti Malaysia Pahang, Pahang, Malaysia

Abstract—**The modelling and control of a two degree of freedom upper extremity exoskeleton for motor recovery is presented in this paper. The dynamic modelling of the upper arm and the forearm for both the anthropometric based human upper limb as well as the exoskeleton was attained via the Euler-Lagrange formulation. A proportional-derivative (PD) architecture is employed to assess its effectiveness in performing joint-space control objectives namely the forward adduction/abduction on the shoulder joint and the flexion/extension of the elbow joint. An intelligent active force control (AFC) optimised by means of the Particle Swarm Optimisation (PSO) algorithm is also integrated into the aforesaid controller to examine its efficacy in compensating disturbances. It was established from the simulation study that the PD- PSOAFC performed notably well in catering the disturbances introduced to the system whilst maintaining its excellent tracking performance as compared to its pure classical PD counterpart.**

Keywords— **Active force control, Particle swarm optimisation, Robust, rehabilitation, Trajectory tracking control.**

I. Introduction

Over the past couple of decades, the life expectancy amongst the ageing has increased steadily around the globe [1]. Approximately 8.3% of Malaysia's population is well over 60 years old [1]-[2]. The number of stroke patients as reported in the 2013 Malaysian Ministry of Health's annual report, demonstrated an average increase of threefold annually [3]. Furthermore, it was also reported in the 2011 report, that 11% and 7.2% of Malaysians between the age of an infant to 18 years old are affected by physical and cerebral palsy disabilities [2]. It is not uncommon for people that fall into the aforesaid figures are affected by complete or partial loss of motor control of the upper-limb which essentially affects their activities of daily living [4].

It has been established from the literature that through continuous and repetitive rehabilitation activities, these individuals may regain their mobility [4]–[7]. Nonetheless, it is worth to note that conventional rehabilitation therapy is often deemed to be laborious and costly which in turn limiting the patient's rehabilitation activities [4]–[6]. Owing to the increasing demand for rehabilitation coupled by the shortcomings of conventional rehabilitation therapy has led the research community to address the aforementioned issues through the engagement of robotics [4], [5], [8], [9]. It is hypothesised that the use of exoskeletons may progressively eliminate the long hours of consultation as well as rehabilitation sessions and subsequently accommodate more patients.

The control strategies developed over the years with respect to rehabilitation robotics reported in the literature can be classified into four main classes, viz. position tracking control, bio-signal, impedance and force control based control as well as adaptive control [10]. As previously mentioned, one's mobility may well be further developed through repetitive and continuous exercise on the impaired limb. This form of training is of particular importance, especially in the early stage of rehabilitation whereby passive mode is required, and this therapy may be achieved through positional or joint based trajectory tracking control.

Hitherto, a number of control strategies have been employed with regard to positional or joint based trajectory tracking control for the upper limb exoskeleton system i.e. Proportional-derivative (PD) controller [11]-[12], nonlinear sliding mode control (SMC) [13]-[14], modified non-linear computed-torque control [15] as well as intelligent based controller such as fuzzy-based PD [16] amongst others. The objective of the study is to examine the tracking performance of a robust control scheme viz. a hybrid proportional-derivative particle swarm optimised active force control (PD-PSOAFC) that is to some extent oblivious to the presence of disturbances of a two DOF upper limb exoskeleton system. The performance of the proposed controller is then compared to a classical pure PD controller by exciting the same form of disturbance into both systems. To the best of the authors' knowledge, the study is novel as the proposed controller has yet been utilised in any upper limb exoskeleton system.