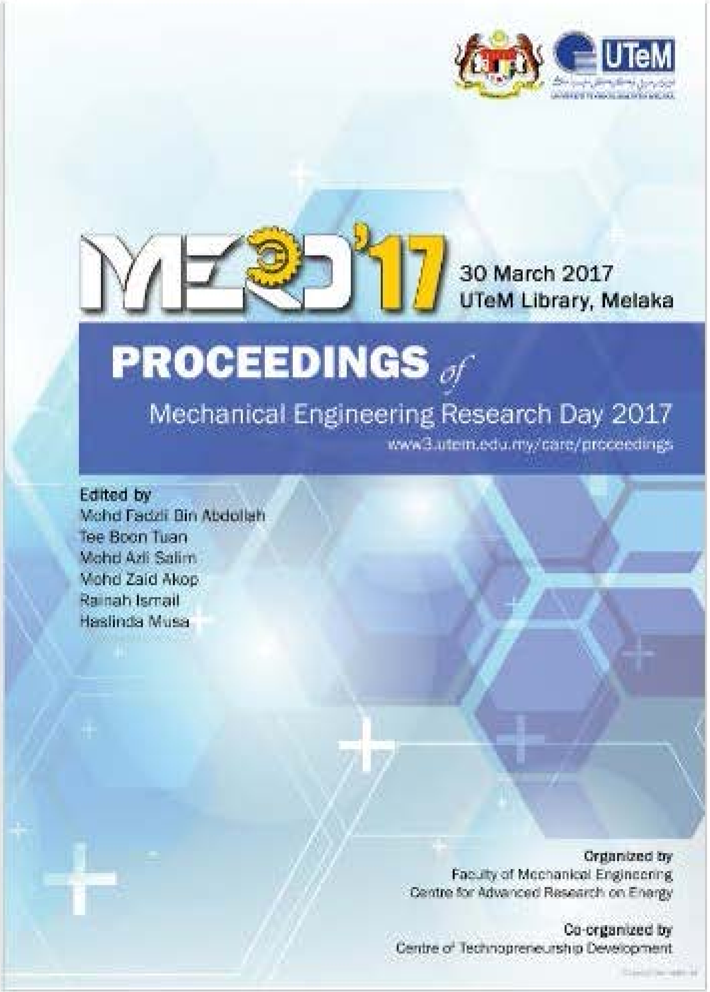

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Tel: +606 234 6891 | Fax: +606 234 6884 | E-mail: care@utem.edu.my
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The identification and control of an upper extremity exoskeleton for motor recovery

Z. Taha, A.P.P.A. Majeed*, M.A. Abdullah, I.M. Khairuddin, M.A. Zakaria, M.H.A. Hassan

Innovative Manufacturing, Mechatronics and Sports Laboratory, Universiti Malaysia Pahang, 26600 Pekan, Pahang, Malaysia

*Corresponding e-mail: anwarmajeed@imamslab.com

Keywords: Rehabilitation; system identification; control

ABSTRACT – This paper presents the model identification and control of an upper-limb exoskeleton system. The exoskeleton is intended for the rehabilitation of the elbow joint. The input-output measurement i.e. current and angular displacement of the actuator is used to identify the model via MATLAB System Identification Toolbox. The identified plant is then used to perform the Hardware in the Loop (HIL) simulation to identify appropriate Proportional-Derivative (PD) control gains prior to its employment of the actual exoskeleton system. It was established that the exoskeleton is able to track the joint trajectory prescribed with an acceptable error bounded between+/-2°.

1. INTRODUCTION

Approximately 21,000 stroke cases are reported each year in Malaysia, causing 2,000 deaths and 19,000 significant disabilities [1]. More often than not, patients who survived this acute event are left with a considerable residual disability. They, in turn, would essentially require assistance with activities of daily living (ADL). Studies have shown that continuous rehabilitation may significantly increase one's mobility and this could be achieved through the use of robotics [2].

The present study aims at identifying an appropriate model for the control of an upper-limb exoskeleton system. The exoskeleton is designed to rehabilitate the flexion and extension of the elbow joint. A HIL simulation is performed prior to assessing suitable control gains, specifically the PD gains prior to its implementation on the hardware. The performance of the system is also assessed.

2. METHODOLOGY

The exoskeleton system is shown in Figure 1(a). In this study, a sinusoidal signal with an amplitude of 90° and a frequency of 0.5 rad/s for a period of 30 seconds is supplied to the system. The angular displacement of the 12V DC motor (rated current of 15A) (Cytron) attached at the exoskeleton elbow joint is measured by means of a potentiometer (Honeywell 53C3 20k). MD 30C 30A (Cytron) motor driver is used to regulate the motion of the DC motor. The input measurement, i.e. current value is measured via a current sensor (BB-ACS756). Arduino Mega 2560 is used as the data acquisition (DAQ) device. The controller unit is shown in Figure 1(b). MATLAB Simulink Arduino Support Package was used to calibrate the sensors as well as recording the data.

Figure 1 (a) Exoskeleton unit and (b) controller unit.

MATLAB System Identification Toolbox is used to ascertain the model of the system based on the recorded input-output measurements [3]. Figure 2 depicts the measurement data. Approximately 70% of the data is used for the estimation process, whilst the remaining 30 % of the data is utilised for the validation process. A number of continuous transfer function (ctf) were estimated by varying the number of zeros and poles of the system. AzBp, where A corresponds to the number of zeros whilst B the number of poles. Furthermore, a second order state-space model was also estimated. All the estimation and validation fit of the estimated models are evaluated.

Once the appropriate model is acquired, the identified model is used to perform the HIL simulation via MATLAB Simulink, in which in this study, the appropriate PD-controller gains are heuristically tuned to provide satisfactory joint trajectory tracking. The tuned PD gains are then used on the hardware, and the performance of the system is evaluated.

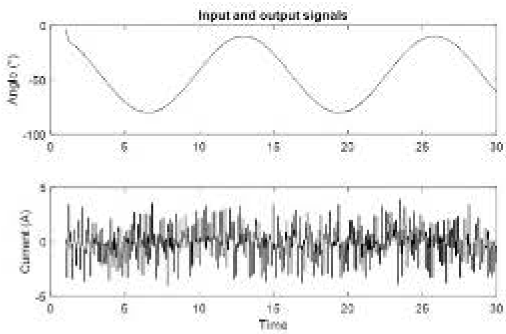

Figure 2 Measured input-output data.