SUPERVISOR'S ENDORSEMENT

"I hereby declare that I have read through this report entitle *"Identification and Parameter Estimation of Multifunctional Prosthetic Hand "* and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Electrical Engineering (Control, Instrumentaion and Automation)"

Signature :

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IDENTIFICATION AND PARAMETER ESTIMATION OF MULTIFUNCTIONAL PROSTHETIC HAND

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A report submitted in partial fulfilment of the requirements for the degree of

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DECLARATION

I declare that this thesis entitled "Identification and Parameter Estimation of Multifunctional Prosthetic Hand" is the result of my own research except as cited in the references. The thesis has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature :

Name : Ali Izzuddin Bin Bahran

Date :

DEDICATION

To my beloved mother and father,

Rohana binti Ahmad and Bahran bin Ismail

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ABSTRACT

Nowadays, number of patients with forearm amputations have been increased tremendously due to trauma, surgery coma or prolonged constriction. Many problems and challenges occurred for the patients who suffer with these issues especially in their daily life. The evolution of prosthetic hand is written in history, it happens from primitive beginning until the future. Some ideas and inventions have been worked and expanded for example the fixed-position foot became the use of iron in prosthesis. The main objective of this study is to create and develop nonlinear mathematical modelling of prosthetic hand. There are three phase of purposed methodology in order to complete this project which started with developing the model of prosthetic hand with grasping force which taking Electromyography (EMG) signal as input reference signal. Then, system identification and parameter estimation using voltage signal and position will be designed and implemented in the prosthetic hand. Lastly, validation on the real data from experimental works has been conducted by using the data obtained from mathematical modelling design. The system identification is a technique which can provides more accurate data and efficient of prosthetic hand. There are two type of mathematical model used in experimental including ARX for linear model and Hammerstein-Wiener for nonlinear model. For conclusion, the Hammerstein-Wiener mathematical model is acceptable because the Final Prediction Error (FPE) and Mean Square Error (MSE) are lower than ARX mathematical model.

ABSTRAK

Pada masa kini, jumlah pesakit yang kehilangan tangan telah meningkat dengan ketara disebabkan oleh trauma, pembedahan atau penyempitan berpanjangan. Pelbagai masalah dan cabaran telah dihadapi pesakit yang menderita dengan isu-isu ini terutamanya dalam kehidupan seharian mereka. Evolusi tangan prostetik telah ditulis dalam sejarah, ia berlaku dari awal primitif sehingga masa kini. Beberapa idea dan ciptaan telah dicetus dan berkembang sebagai contohnya; kaki palsu tanpa pergerakan tetap menjadi penggunaan besi dalam prostesis. Objektif utama kajian ini adalah untuk mewujud dan membangunkan pemodelan matematik yang tak linear terhadap tangan prostetik. Terdapat tiga fasa yang telah dirangka dalam meteologi untuk melengkapkan projek ini,dimana pada mulanya tangan protetik telah dimodel dengan mengambil isyarat Electromyography (EMG) sebagai rujukan dalam daya genggaman. Kemudian, sistem pengenalan dan anggaran parameter dengan menggunakan isyarat voltan dan kedudukan akan menjadi reka bentuk dalam pelaksanaan tangan palsu. Akhir sekali, pengesahan data sebenar dari eksperimen telah dijalankan dengan menggunakan data dari reka bentuk model matematik. Pengenalan sistem adalah teknik yang boleh menyediakan lebih banyak data yang tepat dan tangan palsu yang cekap. Terdapat dua jenis model matematik yang telah digunakan dalam eksperimen termasuklah ARX untuk model linear dan Hammerstein-Wiener untuk model tak linear.Kesimpulannya, model matematik Hammerstein-Wiener boleh diterima kerana Final Prediction Error (FPE) dan Mean Square Error (MSE) adalah lebih rendah daripada ARX model matematik.

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CHAPTER 1

INTRODUCTION

1.1 Introduction and Motivation

People with disabilities (PWDs) in Malaysia can be considered as one of minority group in Malaysia population [1]. In 2011, World Bank and Word Health Organization (WHO) estimated that are 15 % of the word population having some form disabilities. The total number of disable peoples in Malaysia are 3055640 and 106252 who encountered disable physical problem [2]. Refer to Department of Social Welfare, Malaysia statistic 2013, there are 8,289 men, and 5,465 women, registration of disabilities at the physical department.

Table 1.1 :Number of New Registration of PWDs by Category of Disabilities, Age Group and Sex, 2013

Kumpulan Umur	PENGLIHATAN		PENDENGARAN		FIZIKAL		MASALAH PEMBELAJARAN		PERTUTURAN		MENTAL		PELBAGAI		JUMLAH	
	L	P	L	P	L	P	L	P	L	P	L	P	L	P	L	P
Kurang dari 6 tahun	101	73	144	116	413	329	859	594	119	74	3	1	277	199	1,916	1,386
7 - 12 tahun	199	155	240	194	511	404	1,774	1,141	253	167	2	5	318	228	3,297	2,294
13 - 18 tahun	266	187	264	257	588	397	1,292	866	184	121	47	22	225	176	2,866	2,026
Jumlah (a)	**566**	**415**	**648**	**567**	**1,512**	**1,130**	**3,925**	**2,601**	**556**	**362**	**52**	**28**	**820**	**603**	**8,079**	**5,706**
19 - 21 tahun	154	99	128	123	455	279	795	504	103	65	99	51	114	73	1,848	1,194
22 - 35 tahun	590	388	624	535	1,520	917	1,343	1,111	193	168	883	500	463	320	5,616	3,939
36 - 45 tahun	603	350	385	366	1,447	835	831	668	135	108	934	573	293	227	4,628	3,127
46 - 59 tahun	884	604	602	499	1,877	1,307	647	610	107	95	814	613	338	247	5,269	3,975
60 tahun ke atas	732	412	516	356	1,478	997	272	212	33	18	188	189	182	102	3,401	2,286
Jumlah (b)	**2,963**	**1,853**	**2,255**	**1,879**	**6,777**	**4,335**	**3,888**	**3,105**	**571**	**454**	**2,918**	**1,926**	**1,390**	**969**	**20,762**	**14,521**
Jumlah (a + b)	**3,529**	**2,268**	**2,903**	**2,446**	**8,289**	**5,465**	**7,813**	**5,706**	**1,127**	**816**	**2,970**	**1,954**	**2,210**	**1,572**	**28,841**	**20,227**

Table 1.1 shows the age group from 46 – 59 years is highest of physical disabilities of man which is 1877. For patient that facing this problem especially handicapped have difficult to adapt daily environment. Losing all 5 fingers, it will be difficult for them to perform basic movement such as grasp the object.

Human hand is a complex system. It has large number of freedom, sensor embedded in structure, complex hierarchical control, actuator and tendon. Therefore the development of prosthetic hand is very demanding endeavour. It can become support equipment for amputated people to support daily life activities.

Identification is a powerful technique for develop accurate models of complex system from noisy data [8]. Identification is the methods to measure the data by build mathematical models of dynamic system. There are three steps to develop system identification [8]:

I. The design of an experiment
II. The construction of a model, black box or physical laws
III. The estimation of the model parameters from the measurements.

Therefore the identification technique is used for measure data which applied in Multifunction of prosthetic hand. This technique is to measure electromyogram (EMG) signal for the input, force and position for the output. The MATLAB/ Simulink software is provided application such as System Identification Toolbox, for construct mathematical models of dynamic systems from measured data. This toolbox provides detail data like hood, prediction-error minimization (PEM) and subspace system. It also represents nonlinear model system dynamic which is Hammerstein-Wiener model and nonlinear ARX models with wavelet network, sigmoid network and tree partition [9].

1.2 Problem Statement

It has been addressed in many researchers about multifunction prosthetic hand, it more focusing to develop functionality and controllability of prosthetic hand [3]. Generally the researcher use transfer function equation and combine with any controller to control the movement of prosthetics hand. A linear mathematical modelling can express a certain psychical situation without include the independent variable. However it cannot operate with the flexible and unpredictable data. For system identification, the nonlinear mathematical modelling is more suitable for mapping the unpredictable data from input or output. In order to bury present prosthesis limitation and augment the level acceptable of the artificial limb, the mathematical modelling must be developing to measure the input and output system of multifunctional prosthetic hand.

1.3 Objective

The objectives of the study included:

I. To design the prosthetic hand which capable to control degree position

II. To develop mathematical equation modelling using system identification for multifunctional prosthetic hand

III. To validate and verify the nonlinear mathematical modelling and linear mathematical modelling.

1.4 Project Scope

This project will focuses on identification and parameter estimation of multifunctional prosthetic hand. The scopes of study are follows:

I. The mechanical design of prosthetic hand focused in five fingers.

II. The input data from MATLAB applied to the system and be mapping for identification system.

III. Determine and collecting position data from one finger of prosthetic hand.

IV. MATLAB software will be implemented in collecting the data and develop identification system.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this chapter, the previous works on identification and parameter estimation for multifunction prosthetic hand will be discussed. The research more focuses in the development of nonlinear mathematical modelling and parameter estimation. The studies on the design of prosthetic hand also will be assessed in order to develop the hardware platform where the hardware model of prosthetic hand is crucial part in the analysis of mathematical modelling.

2.2 Design of Prosthetic Hand

The researcher use bio mechatronic approach in the design of an anthropomorphic artificial hand [4]. The objective of the journal is to mimic the motion of the human finger. The design of bionic hand consists of three fingers with three of freedom (DOF) for each finger and degree of freedom for ubanation. The modelling prototype which is design by Pro-Engineer is constructed by using aluminium alloy while the finger is shell of carbon fibre like Figure 2.1. The prototype has ten DOF and 4 degree of movement.

Figure 2.1: Design of Bionic hand [4]

In [5], the researcher has introduced the multi-fingered anthropomorphic robotic hands that have fourteen degree of freedom (DOF).The objective of his journal is to mimic the functionality of the biological hand, especially in handling the object. The design of robotic hand consists of five finger where each finger has three different phalanxes which is proximal, middle and distal phalanxes. The prosthetic hand is designed by using CATIA and fabricated by using In Vision XT-3D Modeller. The Acrylic Plastic material is chosen to fabricate robotic hand with the tensile modulus and 1772MPa and 34MPa of tensile strength. Figure 2.2 is the example of complete design of researcher.

Figure 2.2: Design of Robotic hand [5]

In [6], the design of prosthetic hand consists of the two degree of freedom (DOF) for each finger where it has three fingers. The objective of this paper is to develop an upper limb prosthesis that can be fielded as a part of the body by amputee [6]. This paper also represents the design and fabrication of novel prosthetic hand by used a bio mechatronics and cybernetic approach. The prototype of prosthetic hand is fabricated by using Fused Deposition Modelling (FDM) process. Meanwhile acrylonitrile/ butadiene/ styrene (ABS) plastic is used to construct the body structure. Figure 2.3 show the design of Prosthetic hand. MP joints represented metacarpo-phalangeal and PIP joints represented proximal interphalangeal joints. The distal interphalangeal joints is represented as DIP joints.

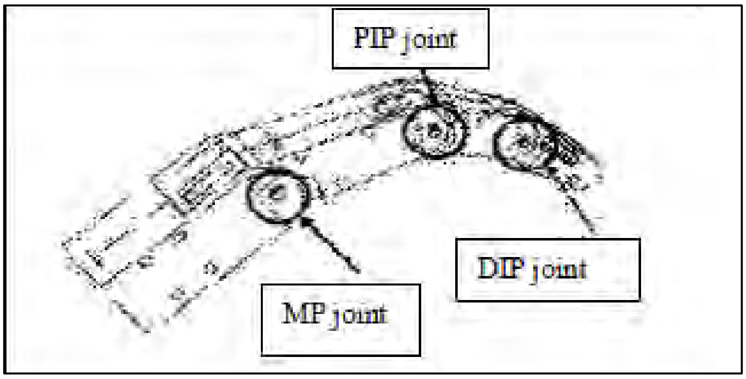

Figure 2.3: Design of Prosthetic hand [6]

Three fingered gripper can be designed and stimulate to provide both gross motion and fine motion of the finger [7]. The objective of this paper is to copy the human hand in term of dexterity and adaptive capabilities to function as either a manipulator or as prosthetic device [7]. This prosthetic hand is designed with three finger which is thump, middle, and index like Figure 2.4. It also designed seven of degree freedom. All part of prosthetic hand is assembly by using SolidWorks software.

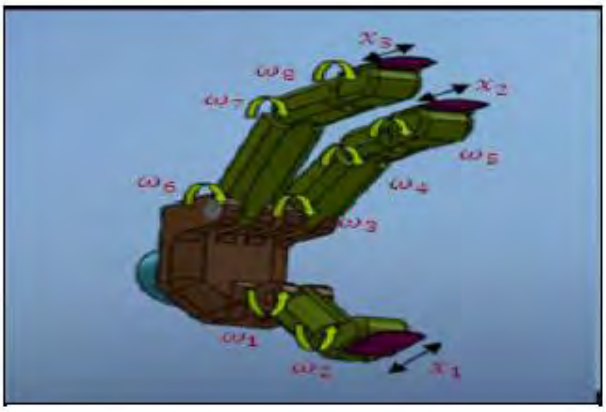

Figure 2.4: Design of Prosthetic hand [7]

In 2013, the researchers in [8] have developed of prosthetic hand which perform hand opposition and reposition action (clasp and release) base of the real EMG signal from an elbow amputee [8]. The objective of these studies is to develop human hand which can provide natural haptic functionality .The prosthetic hand is design with two freedom of degree (DOF) below elbow amputee like shows Figure 2.5.

Figure 2.5: Design of Prosthetic hand [8]

2.3 System Identification

System Identification is a method to build models of dynamical systems from measured data. It also includes the optimal design of the experiment for efficiently generate information data for fitting. There are two common model to start measurements of the behaviour of the system which is grey box model and black box model. The white box model is known as complex and impossible to obtain in reasonable time because the complexity of nature. For studies about system identification, many of researchers applied the system identification to mapping EMG signal. The concept and method the researcher can be applied to estimate parameter of force and position signal data.

2.3.1 Identification of EMG signal.

In 2015, the researchers in [11] write the journal about mapping EMG signal using System Identification technique. The aim of the journal is to develop a mathematical modelling with surface EMG (sEMG) signal from the biceps and triceps muscle as input and velocity of motion of fore arm as output [11]. The researcher uses two model identification systems which is ARX Model for linear parameter and Hammerstein-Wiener Model for nonlinear parameter. LabVIEW software is used as platform to development and comparison between two models. For starting study system identification system techniques, ARX Model as linear is used to developing EMG signal model. Then Hammerstein Wiener Model is used for more accurate sEMG signal. There are two stage in this study; data acquisition and system identification stage. For data acquisition, the EMG signal form bicep and triceps is processing meanwhile the second stage, the mathematical model relating sEMG are used.

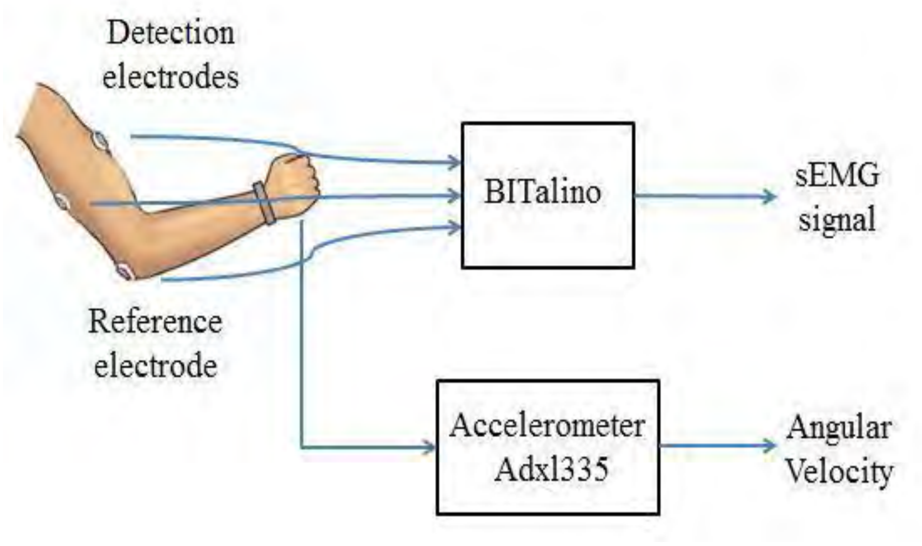

Figure 2.6: Block Diagram of Data Acquisition stage [11]

Figure 2.6 represents the data acquisition block diagram where the flexion and extension in bidirectional movement are considered for acquisition of sEMG signal [11]. There are four study conditions is considered in the experimental setup which is represented as follows:

I. Fast Flexion
II. Fast Extension
III. Slow Flexion
IV. Slow Extension

Three surface electrodes are connected at the arm, one reference electrodes on the elbow and two detection electrodes at bicep and triceps. ADXL335 is a 3 axis accelerometer and used for acquisition acceleration of fore arm angular velocity which is to measure output. BITalino is a biomedical data acquisition device which is used for acquired sEMG signal.

Table 2.1: Comparison between ARX and Hammerstein models [11]

sEMG- Angular Velocity Model		ARX Model	Hammerstein Model
Cases	RMSE		
Fast Flexion	Estimation	0.09655	0.09139
	Validation	0.152385	0.13970
Fast Extension	Estimation	0.11552	0.09505
	Validation	0.15139	0.14149
Slow Flexion	Estimation	0.117059	0.09797
	Validation	0.141825	0.11436
Slow Extension	Estimation	0.12369	0.09685
	Validation	0.2243	0.1903

Table 2.1 shows the result of comparison between performance of ARX model and Hammerstein model in different case studies.

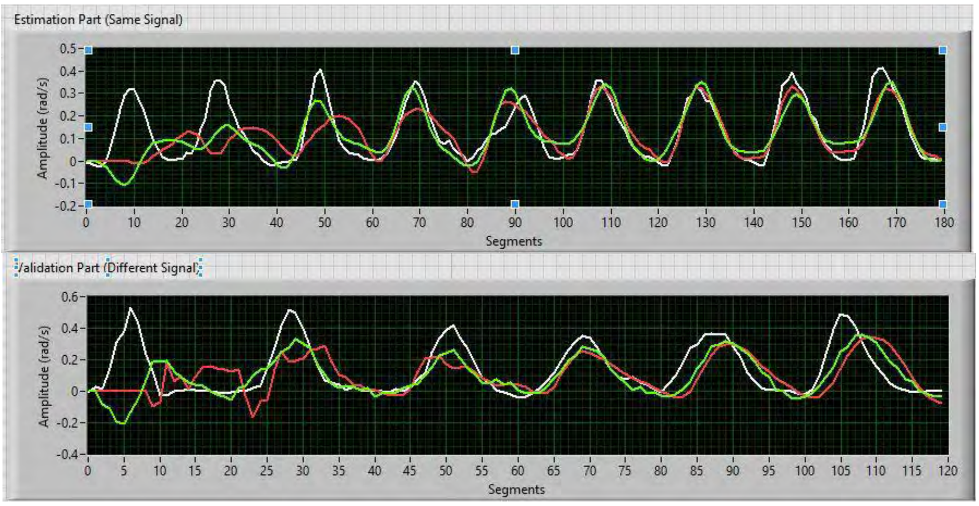

Figure 2.7: Fast flexion model response [11]

Figure 2.7 shows the result of fast flexion model response. The upper panel for the estimation input and the lower for validation input. The white signal represent actual response, red represent ARX model response and green represent Hammerstein model response. For each 10 segment, the amplitude graph for actual signal is in fast flexion modes which have a little different from 0.29 to 0.41 rad/sec. The validation of ARX input signal unpredicted for starting and after segment 35, the signal return to normal state.

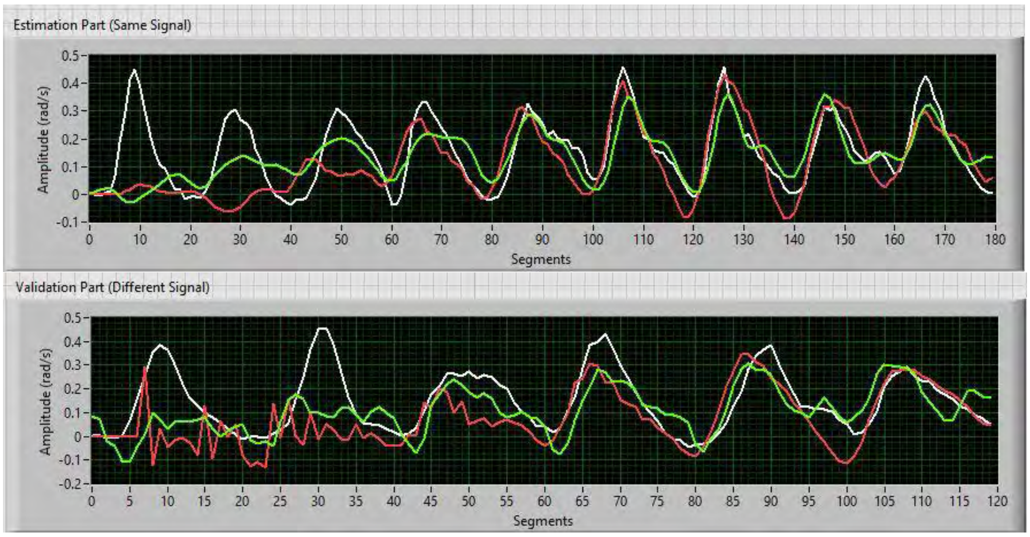

Figure 2.8: Slow flexion model response [11]

Figure 2.8 shows the slow flexion condition for ARX model and Hammerstein model. The upper panel shows an estimation input response and the lower panel shows validating input response. The white signal represent actual response, red represent ARX model and green represent Hammerstein model. It can be seen that overall response of the Hammerstein signal is an estimation response is more identical to actual signal. The estimation of ARX signals showing inaccurate response from starting and to 60. After the segment 60 the data signal can estimate identically with actual signal compare to Hammerstein model. The ARX model in slow flexion is not validating from 0 to 44 segments. After that, the signal is validate with actual signal.

The muscle is a source producing force and the basic function unit of muscle is motor unit, when applied some force the electrical signal is generated on muscle surface and it called electromyogram (EMG) [11].The objective of this research is to purpose the new mathematical model which obtained through identification system to mapping EMG to joint torque by use EMG sensor. The EMG signal has physiologic signal, real time, non-stationary, non-linear, non-Gaussian, and continuous [11]. These properties provided easier way to modelling of the EMG signal. There are traditional approaches which assume the surface of EMG can be modelled as band limited white nose modulated by the level of muscle contraction. Muscle tension can be determined by controlling length and activation level of muscle. EMG signal are used as indirect measure of force and joint torque.