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DEVELOP FUZZY LOGIC CONTROLLER FOR PROSTHETIC HAND

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This Report Is Submitted In Partial Fullfillment Of Requirements For The Bachelor Of Electrical Engineering (Control, Instrumentation, and Automation)

Fakulti of Electrical Engineering
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2016

I declare that this report entitle “Develop Robust Adaptive Controller For Prosthetic Hand” is the result of my own research except as cited in the references. The report has not been accepted for any degree and is not concurrently submitted in candidature of any other degree.

Signature : .....

Name : Muhammad Faris Bin Hamdani

Date : 30th May 2016

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ABSTRACT

Hand is one of the important part of human physical bodies that has high complex structure with highest precision, flexibility and accurate movement involve a lot of numbers nerve connected. There are having a high consequence result before regarding the manufacturing and analysing the suitable design controller to provide the prosthetic hand for amputees. Amputees are people who has difficulties when dealing with their routine or daily life activities because of physical problem such as lost all or certain part of an arm, hand or leg. Hands is one of the part that required to perform in high capabilities to control the velocity, actual displacement, positioning, force and flexibility the movement fingers. Based on the research before, there are facing a lot of problem related to the prosthetic hand when dealing in highest performance because of inadequate functionality, lack in prediction controlling fingers precision and insufficient responding variables due to lack of adaption robust controller capability depends on the disturbance or error analysis instant undergoing the operation. The main purpose for this project to focus on the designing the prosthetic hand consist of the intelligent controller based on the multiple rule that having capabilities to operate on fuzzy logic control algorithms for amputees. This project utilized fuzzy logic controller to control the positioning of prosthetic hand as feedback input to provide the membership rule in fuzzy logic control algorithm. The digital pulse will interpreted the data and classified into several rule before generate the output that control the linear actuator that embedded inside the palm of prosthetic hand. Based on the simulation result, the controller is capable to accurately control prosthetic mechanism in term of their transient response and stability which give advantages for amputee used.

ABSTRAK

Tangan adalah salah satu bahagian yang penting didalam tubuh badan fizikal manusia yang mempunyai struktur kompleks dengan ketepatan tinggi, fleksibiliti dan pergerakan tepat melibatkan saraf-saraf yang berkait. Terdapat beberapa kelemahan melibatkan proses pembuatan dan menganalisa sistem kawalan ketika penghasilan tangan palsu. Kudung adalah manusia yang mempunyai masalah dalam berurusan dengan aktiviti harian disebabkan masalah fizikal seperti kehilangan semua atau sebahagian tertentu lengan, tangan atau kaki. Tangan adalah salah satu bahagian yang diperlukan untuk mengawal halalaju, anjakan sebenar, kedudukan, daya dan fleksibiliti pergerakan jari. Berdasarkan dapatan kajian, terdapat pelbagai masalah yang dialami ketika penghasilan tangan palsu untuk mencapai prestasi tertinggi kerana fungsi yang tidak mencukupi, kurang ketepatan dalam meramal pengerakan jari dan pembolehubah bergerak balas yang tidak mencukupi disebabkan kekurangan adaptasi keupayaan sistem kawalan bergantung kepada gangguan atau analisis yang lemah. Tujuan utama projek ini ialah untuk memfokuskan reka bentuk tangan palsu yang terdiri daripada sistem kawalan pintar berdasarkan beberapa peraturan serta mempunyai keupayaan untuk beroperasi pada kawalan logik kabur dalam pembuatan tangan kudung. Projek ini mencadangkan teknik mengawal kedudukan tangan palsu yang sesuai melalui maklum balas dalam sistem kawalan serta menyediakan peraturan keahlian pada sistem kawalan pintar logik kabur. Keluaran digital akan ditafsirkan dalam bentuk data dan dikelaskan kepada beberapa peraturan sebelum menghasilkan keluaran kawalan untuk menggerakkan linear motor yang diletakan di dalam telapak tangan palsu. Berdasarkan dapatan kajian simulasi,sistem kawalan mampu mengawal ketepatan mekanism prostetik dalam bentuk tindak balas transien dan kestabilan dimana ianya memeberi kelebihan kepada pengguna tangan palsu

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CHAPTER 1

INTRODUCTION

1.1 Research Background.

Based on history, the development of the myoelectric prosthetic hand was invented by using a combination concept between electrical and mechanical forces in control system of an electrical prosthesis advanced introduce since in 1965[1]. There are having a few researchers studied present the preference of the myoelectric prostheses issues in terms of lack in designing the robust controller system. The growing of development performance design compatible controller for prosthetic hand is provided to help amputee who had failing to using the physically wrist because incidentally lost all or part. The most prosthetic hand technology are precisely not having much different in terms of quality control related to human hand. The efficiency of operational prosthetic hand can be increase using a positioning as a feedback to define and improving the system by reducing the disturbance or error [2].

The input signal will provide as reference and used to recognise the performance of dc linear motor functional. The voltage signal will put as a reference into the plant and provided the positioning angle as output to be control. The test and result output is cover for a positioning of fingers hand via simulation and will recorded to provide the improving suitable robust controller for prosthetic hand. The prosthetic hand will be designed and fabricate according the human hand by replacing a linear actuator, electrical instrument, processing control system and few instruments to replicate the flexibility in finger movement. This researches will focus only one degree of freedom (DoF) design where is fully functional by using dc motor to control the linearity movement finger.

This project are purpose to control the positioning finger at once and investigate the issues about the differences between real human finger and prosthetic hand finger precision in positioning. This prototype are concern the some technology problem obtain when applied the high numbers of DoF effected to complexity control unit with implement a lot of computational power. The best design in development cosmetic prosthetic hand that will increase the performance and efficiency must be follows the criteria such as a low energy consumption, simplicity control system, less friction, reduction of sizing actuator and simple grasping design approach by reducing the active degree of freedom (DoF) [3].

1.2 Problem Statement

The main issues on prosthetic hand are robustness and less accuracy which effected to provide the smooth operational. Robustness can be defined as an ability of algorithm which operates directly even abnormalities in input and calculation was occurred. One of robustness problem in prosthetic hand control system is dealing with a non-linearity variables. The unknown non-linearity on prosthetic hand will provide an external disturbance and effected to model inaccuracies to control the positioning of finger and under actuated mechanism.

Usually the prosthetic hand having a limitation functional in terms of grasping, slippage control, vibrations, and enabling corrective control techniques. This project will define the suitable controller based on artificial intelligence that implemented to the linear dc motor which analyse and apply the input linguistic variables fuzzy control system as a membership function. The linear dc motor positioning finger and displacement stroke linear dc motor can be control by analyse the errors parameter input variables into the plant. The conventional optimizing technique is easily arrive at locally optimal solution and usually lack of robustness. Therefore the fuzzy logic controller will determined the structure needs to be access.

1.3 Objective

The main objective for this project is to developed a fuzzy logic controller for wrist disable people or amputee, which more focusing on human finger positioning and controlling system by using a forearm or others target that suitable to give the instructions on prosthetic hand. Below are the objective that must be fully required at the end of project.

i. To develop a mathematical modelling of the prosthetic hand using system identification techniques.
ii. To design control system using artificial intelligence technique which is fuzzy logic control algorithm.
iii. To evaluate and analyse the effectiveness of controller via simulation.

1.4 Motivation

People with disabilities are present all societies and country. Malaysia already provide the community who responsible to amputee people consist rehab session, physiological advice and others facilities for disable people. Based on the statistic in 2012, the total of the numbers disable people who was facing with physical problem that already registered under the Social Welfare Department is 25115. The statistic record already cover all age group, gender and also including the paralyzed and maimed limbs.

Table 1.1:- Statistical Bulletin Social Welfare Department

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	114	70	169	153	630	467	1,390	879	56	39	-	-	306	281	2,665	1,889
7 - 12 tahun	306	214	411	356	884	729	5,799	3,057	163	94	10	6	443	315	8,016	4,771
13 - 18 tahun	317	244	513	453	925	651	5,101	2,924	79	59	39	30	382	231	7,356	4,592
Jumlah (a)	**737**	**528**	**1,093**	**962**	**2,439**	**1,847**	**12,290**	**6,860**	**298**	**192**	**49**	**36**	**1,131**	**827**	**18,037**	**11,252**
19 - 21 tahun	184	133	247	228	655	320	1,343	979	40	31	90	65	130	100	2,689	1,856
22 - 35 tahun	971	574	1,478	1,282	3,356	1,617	3,010	2,456	102	81	1,238	654	591	414	10,746	7,078
36 - 45 tahun	854	492	772	685	2,864	1,305	967	878	52	49	1,093	671	330	235	6,932	4,315
46 - 59 tahun	1,448	810	964	829	4,319	2,210	622	586	61	51	912	724	401	277	8,727	5,487
60 tahun ke atas	1,150	705	638	391	2,716	1,467	352	279	29	23	257	274	237	166	5,379	3,305
Jumlah (b)	**4,607**	**2,714**	**4,099**	**3,415**	**13,910**	**6,919**	**6,294**	**5,178**	**284**	**235**	**3,590**	**2,388**	**1,689**	**1,192**	**34,473**	**22,041**
Jumlah (a + b)	**5,344**	**3,242**	**5,192**	**4,377**	**16,349**	**8,766**	**18,584**	**12,038**	**582**	**427**	**3,639**	**2,424**	**2,820**	**2,019**	**52,510**	**33,293**

The Table 1.1 shows that the several type of the disable problem that had been registered under Malaysia Social Welfare Department. The table state that the physical problem involve at all ages. The group age that having the highest rate is 46 until 59 years old. There are consist of two group which is child age stage and the other one is adult age stage. The total adult age that suffer a disability defeat is 20829 people, meanwhile total child age is 4286 people that had been registered in Malaysia Social Welfare Department.

Table 1.2:- Statistical Physical Disable People State

NEGERI	FIZIKAL							
	M	C	I	PSM	PSB	PSW	L	J
Johor	1,757	1,201	434	5	2	11	4	**3,414**
Kedah	1,748	315	278	1	-	1	16	**2,359**
Kelantan	1,623	90	11	4	2	-	12	**1,742**
Melaka	359	207	173	2	2	11	10	**764**
Negeri Sembilan	797	311	311	6	1	1	10	**1,437**
Pahang	1,690	327	221	47	-	1	7	**2,293**
Perak	934	491	449	32	2	3	19	**1,930**
Perlis	409	44	4	-	-	-	9	**466**
Pulau Pinang	707	620	298	-	1	-	12	**1,638**
Sabah	72	175	4	6	1,203	11	243	**1,714**
Sarawak	255	222	1	-	2	595	7	**1,082**
Selangor	1,815	945	1,064	10	12	11	17	**3,874**
Terengganu	1,449	43	-	-	-	-	1	**1,493**
W.P Kuala Lumpur	402	323	163	-	1	1	4	**894**
W.P Labuan	6	3	-	-	5	1	-	**15**
JUMLAH	**14,023**	**5,317**	**3,411**	**113**	**1,233**	**647**	**371**	**25,115**

The Table 1.2 shows that every state having a similar problem with physical disable. From Table 1.2, Selangor was recorded the highest reading followed Johor and Pahang state. For patients who suffer from a disability defect to hand will effected to their routine life and difficult to adapt with a daily environment. Base on this problem, people which losing all finger will difficult to perform a basic movement such as grasp, pinch and other task related with their routine. Therefore, the bionic hand was introduce to disable people for assisting and perform their routine life better than before used.

1.5 Project Scope

This project will primarily focus on the identification system and fuzzy logic control system to control the positioning of finger base on fuzzy linguistic variables that implemented in membership function in prosthetic hand that required characteristic limitation for this project. The design prosthetic hand has only one DoF that functional to complete the task such as grasp, force and others that assign from controller to linear actuator movement. Additional to the limitation, the input signal will control the prosthetic finger to support the output by manipulate the system into several rule. The rule was assign by controlling the two variables input which is error and derivative of error into the fuzzy controller system before apply the controller to the plant. The error and derivative of error will tune by defuzzification proses after evaluates which the control rule are relevant at the current time before decide what the suitable input to the plant. The fuzzy controller provide the better response performance to controls the fingers. The design is developed using a Solidworks 3D software meanwhile LabVIEW software will use for the system identification as collected from linear to control the finger positioning. The MATLAB introduced for system identification and analyse the response of signal generate by discrete transfer function and controller by simulation.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the review of previous and related research about bionic hand was conducted. The research focuses more about design criteria for challenging task such as system identification and design fuzzy logic rule. The fuzzy logic need the two variables input to controlling the error and derivative of error. The output fuzzy controller will determine and assign a suitable the defuzzification method before apply into plant system. The aspect on this review will consider as a research to develop a better prosthetic hand followed the requirement and material. A material that being used must be durable, light and easy to operate and low cost.

2.2 Prosthetic Hand

Prostheses hand technology is having an enhancement to maintain and increase quality of life for those who has lost of limbs by accidently or birth defect. The development of prosthetic hand is having challenging task to fulfill the requirement as much as human arm because of the sensing element, design criteria classification, mechanical problem, lack controller and cosmetic issues. There having a few researchers purpose to approach design by focusing a priority criteria which consist of three parts such as mechanical actuation system, mechatronic development and artificial controller architecture [4].

Human central nervous system (CNS) or Peripheral nervous system (PNS) is structure human nervous system where the neural signal will being captured before design as an intuitive controller on prosthetic by replacing the communication between brain, sensor and actuators. The advanced mechatronic limb design capable to keep in action user intent which provide the perception functional hand action by sending the signal sensor proprioceptive and exteroceptive information[5].

The measurement tool to achieve a goals at the end of the design must be completely functionalities useful for amputee apply in activities of daily living (ADLs). There were a survey among amputee community conducted by researchers to analyse the estimation percentage according to basic utilization for grips and gestures test in ADLs [6,7].

Table 2.1:- Survey Test on Amputee Community

Test	ADLs Approximation Percentage
Power Grasps	35%
Precision Grasps	30%
Lateral Grasps	20%
Extensions Grasps	10%
Index pointing (useful for typing or pressing)	-
Basic gestures	-

Regarding the Table 2.1, the result shows the power of grasp is a priority for amputee to be consider in activities of daily living (ADLs). Meanwhile the least functionalities useful for amputee to apply the activities of daily life are Index of pointing and basic gesture. This test are giving the list of criteria that need to be implemented on prosthetic design.

Based on the Figure 2.1, the power of grips shows a highest approximation percentage that will being use as references and the highest requirements for design the prosthetic hand. This result will effected to design the robust prostheses hand based on mechanical system and type controller that will being used. There are having a few others studied related with this case to define and analyse the details what amputee needs to improve the design based on the interview with respect to new generation developments.

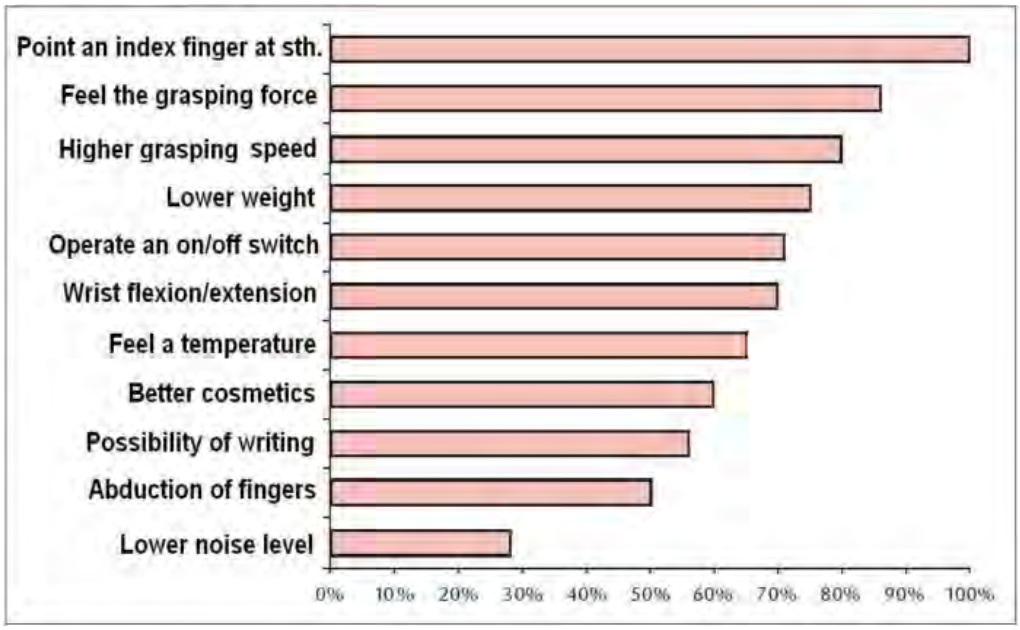

Figure 2.1:- Survey the Criteria Improvement Design on Amputee [7].

Based on the result, most amputees need a lot improvements in term of functionality prosthetic hand. The priority for designing the prosthetic hand refers to interview session is point an index finger and the feedback on grasping force. Besides that, there are also criteria need to be considering such as the speed should be increase and the weight also need to be reduces. Based on design from manufacturing company of Otto Bock, the design are completely functional with a few additional technologies where the speed was increase up to 300mm/sec. But an advantages for one user will deficiency to others part, such as when increase the speed will effected to controlling system where it's becomes more difficult and complex.

Figure 2.2:-Otto Bock Product [7]

The interview conducted by previous researchers' shows 70 percent was supported to improve the wrist extension and flexion to applied additional movement function to the prostheses hand. Meanwhile 65 percent of amputee are expressed to sense the temperature object. Only certain amputee wanted to hand writing and abduction of fingers. The lowest requirement need by amputee regarding the analysis from interview session is lower noise level. But the quiet prostheses can be a one of part requirement for cosmetic design which can implemented into single of mechanical actuation system [7].

2.3 System identification

A mathematical models are required in control system design in order to describe the overall system dynamics, and identification processes. The continuous time models is easier to understand about the relation between pole zero and time response of the models. However, as computer advances, a lot of system identification method give benefit from digital processing have been developed, and identification for discrete-time systems has been studied to facilitate the analysis and data processing [8].

Typical application encompass simulation, prediction, fault diagnostic, and control system design. A model represented as modelling transfer function with a behaviour of a process as closely as possible. The model quality is typically measured in terms of a function of the error between the process output and the model output. There are three different modelling approaches can be distinguished white box models, grey box models and black box models are solely based on measurement data and no or very little prior knowledge is exploited [9]**.** This paper deals with a black box modelling where its assign a random of signal to the input motor and taking a positioning of an angle motor. Black box is a method where the plant is totally unknown in terms of order and parameter.

2.4 Controller Design

There are having two type of control system where it's effected to reduce disturbance performance are conventional feedback control. The conventional feedback control system is purpose to elimination of the effect towards disturbance upon the controlled variables. The intelligence controller is a type of controller that can be functional to define and tuning the parameter variations by evaluates which control rules a relevant occurring in a control system in real time, in order to achieve or maintain a desired level of performance control system [10].

Based on the principal in control strategies, the coefficient of the controller can divide into two part; linear and non-linear which this principle are implemented with principle orders in design system. The system that insufficient controller will provide satisfactory performance where the system are time-varying, subject to changes in operating condition. High performance control system needed precisely in term of tuning the controller but the plant disturbance model parameter may be unknown [11].

Intelligence controller can further improve the performance of robust control system by expanding the range of uncertainty for which performance specification can be achieved or tuning the controller based on method that being used. The main issues in designing a control system is robustness for the underlying controller design implemented in system. There are various types of design system controller methods. Each method are having their structure and technique where provide a different benefits and flexibility such as PID controller, Artificial Neural Network controller, Neuro-fuzzy controller, Bayesian controller and Fuzzy logic [10,12,13]. This chapter will more focusing about the fuzzy logic controller and design the robust controller system for prosthetic hand.

2.4.1 Fuzzy Logic Concept

Fuzzy logic is a machine learning technique consist of multi valued logic allows intermediate values to be defined. This system technique provide a computing based on "degrees of truth" consist inference mechanism which interpret and execute commands. Application fuzzy logic system are suitable for uncertain or approximate reasoning. Fuzzy logic control can assign a multiple input variables and sensor output parameter will sample into time depends on designer which delay was introduce.

This system are mostly use a digital control system where the system analyse difference between two or more input refers to delay time was applied and give the desired value of output. Base on Figure 2.3, the desired value represented will proceed to next fuzzification interface which data will process and convert by fuzzy interference engine. The fuzzy data value will interpret into the interference engine where these value are compared with rule that was assign on the controller then analyse to provide the output crisp value after the rule was defuzzication. The decision making unit part will compared the between input and updated rules to give a set point of desired value on output.

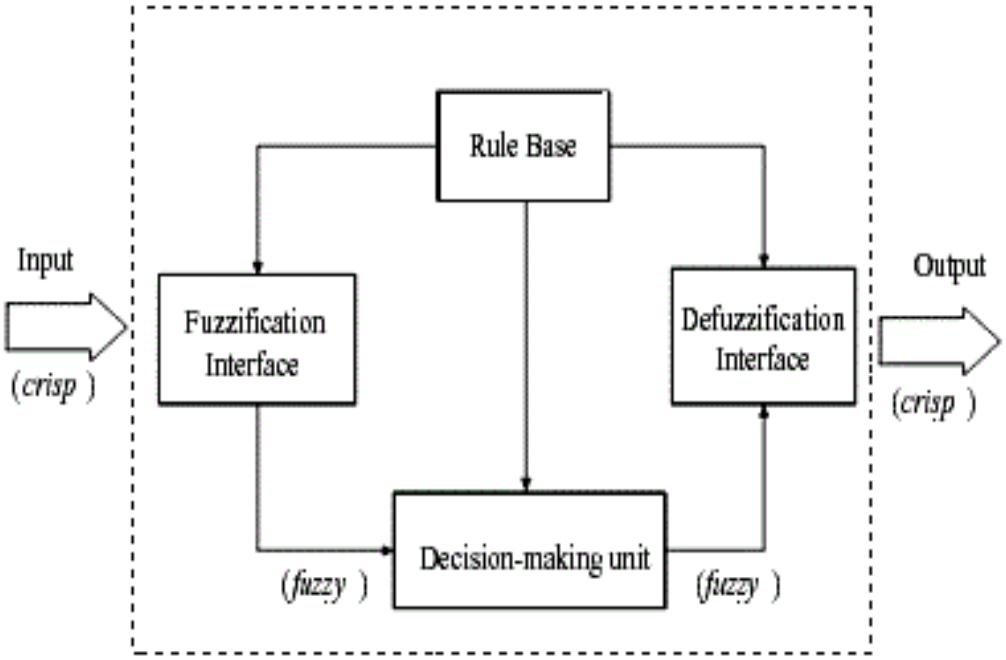

Figure 2.3:- Block diagram for fuzzy process [4]

The fuzzy rule basically use a command logical AND and logical OR operator to combination between two input variable. The command rule start with IF statement to define the variables inputs with combination another input variables and followed the result output the weight of the rule depend on design. There are having a system that have been done before by researchers where the slippage and grasp issues is priority objective. The design are divide into three scenario that achieved the operational of controller.

First rule are including “slow slip” condition which controller are determine the slow slipping object. The next scenario is “fast slip” condition where the slip value are rapidly change in controller system. The last is grasp condition where the no action will be taken when object was grasp perfectly. This design are provide the output triangular membership function are not overlap to each other [3]. The input self-tuning fuzzy controller are speed error and change-in-speed error.