SUPERVISOR'S ENDORSEMENT

"I hereby declare that I have read through this report entitle *"Design and Development of Exoskeleton Bionic Hand"* and found that it has complied the partial fulfillment for awarding the degree of Bachelor of Mechatronics Engineering"

Signature : .....

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Date : .....

DESIGN AND DEVELOPMENT OF EXOSKELETON BIONIC HAND

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A report submitted in partial fulfillment of the requirements for the degree of BACHELOR OF MECHATRONICS ENGINEERING

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DECLARATION

I declare that this report entitle *"Design and Development of Exoskeleton Bionic 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 the candidature of any other degree.

Signature : .....

Name : Mohamad Fakri Bin Juhari

Date : .....

To my beloved father and mother

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ABSTRACT

Recently, the number of patients with wrist and forearm amputations increased tremendously due to trauma, prolonged constriction, or surgery. The amputees experienced lots of problems, especially in dealings with their daily life activities. Thus, as a solution, a prototype called as bionic hand is designed. Early design of bionic hand comprises of 14 motors with 14 degree of freedom which caused the bionic hand to be costly and complex to control. In this research, design of a bionic hand that has 10 degrees of freedom with 5 motors attached to mechanical linkages is proposed. The bionic hand designs in SolidWorks that resembled the function and size of an actual human hand. It is fabricated using aluminum 6061 as it is light in weight and durable. As for the sensor, V3 muscle sensor is utilized to identify a signal generated from the human muscle and amplified it as the primary control signal to control the movement of the bionic hand. The performance of bionic hand is tested in terms of repeatability and accuracy. Repeatability accuracy test is divided into two phases, the first test is constructed to analyze the repeatability of angular movement for each finger while the second test is constructed to analyze the repeatability of wrist movement. Similarly, the accuracy test is also divided into two phases where the first test is conducted to analyze the accuracy of finger press while the second test is to analyze the accuracy of hand grasp. The results are compared with the natural human force and yielded acceptable results. Finally, the hand is tested in term of canonical hand posture and manage to emulate actual human hand.

ABSTRAK

Baru-baru ini , bilangan pesakit dengan pergelangan tangan dan lengan amputasi meningkat dengan ketara disebabkan oleh trauma , penyempitan yang berpanjangan, atau pembedahan. Pesakit akan mengalami banyak masalah terutama dalam urusan dengan aktiviti kehidupan harian mereka. Oleh itu, sebagai penyelesaian , prototaip yang dipanggil sebagai tangan bionik direka. Reka bentuk awal tangan bionik terdiri daripada 14 motor dengan 14 darjah kebebasan yang menyebabkan tangan bionik menjadi mahal dan kompleks untuk mengawal. Dalam kajian ini, reka bentuk tangan bionik yang mempunyai 10 darjah kebebasan dengan 5 motor dilampirkan kepada hubungan mekanikal adalah dicadangkan . Tangan bionik direka mengunakan Solidworks yang menyerupai fungsi dan saiz tangan manusia sebenar. Ia direka menggunakan aluminium 6061 kerana ia adalah ringan dan tahan lama. Bagi sensor, sensor V3 otot digunakan untuk mengenal pasti isyarat yang dijana daripada otot manusia dan dikuatkan ia sebagai isyarat kawalan utama untuk mengawal pergerakan tangan bionik . Prestasi tangan bionik diuji dari segi kebolehulangan dan ketepatan. Kebolehulangan ujian ketepatan dibahagikan kepada dua fasa, ujian pertama dibina untuk menganalisis kebolehulangan pergerakan sudut untuk setiap jari manakala ujian kedua dibina untuk menganalisis kebolehulangan pergerakan pergelangan tangan. Begitu juga, ujian ketepatan yang juga terbahagi kepada dua fasa di mana ujian pertama dijalankan untuk menganalisis ketepatan akhbar jari manakala ujian kedua adalah untuk menganalisis ketepatan memahami tangan. Hasilnya dibandingkan dengan daya manusia yang semula jadi dan membuahkan hasil yang boleh diterima. Akhir sekali , tangan ini diuji dari segi postur tangan berkanun dan menguruskan untuk mencontohi tangan manusia sebenar.

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CHAPTER 1

INTRODUCTION

Bionic hand is the hand that is designed similar to the human hand. It is produced in order to resemble the work and movement that can be done by humans. With the existence of bionic hand technology, it can help disabled people, especially amputees to carry out their daily activities as usual. However, this technology can be used not only in medicine, but it can also be used in industrial field. For example, Bionic hand can help reduce the risk to workers who are exposed to radiation, where all the works that related to radiation can be managed by using the Bionic hand. The research about bionic hand is started in 1963 at the Princess Margaret Rose Hospital in Edinburgh David Gow. Then, he joined the Bioengineering Center hospitals in 1986 and begun a study on the electronic hand including wrist hand and shoulder. In 1993, he manages to develop his own partial hand and in 1998 he gained recognition when he develops his first shoulder electric power installations. David Gow then join the company called Touch Bionics where in 2007 the company has launched Bionic hand named I - LIMB hand. Then the company has launched a new product are designated the I-LIMB hand extends to the research of the I-LIMB 2007. In 2010 and 2011 they launched the I-LIMB Pulse that has good characteristic compare to the previous. So, bionic hand, this is a prelude to the creation of other parts such as Bionic legs, eyes and so on.

1.1 Motivation

Refer to the *Buletin Perangkaan* 2012, the table shows 359 203 the total of the numbers disabled people registered under the Social Welfare Department and the total amount of 123 346 that which were registered under the handicapped people with physical disabilities catagories. This included the record like, paralyzed, maimed limbs.

Table 1.1: Statistical Bulletin Social Welfare Department [1]

Negeri *State*	**Penglihatan** *Visually impaired*	**Pendengaran** *Hearing*	**Fizikal** [a] *Physical*	**Masalah pembelajaran** *Learning disability*	**Pertuturan** *Speech*	**Mental**	**Lain-lain** *Others*	**Jumlah** *Total*
Malaysia	**31,924**	**43,788**	**123,346**	**134,659**	**725**	**8,927**	**15,834**	**359,203**
Johor	3,094	4,732	13,191	19,396	100	1,436	1,661	43,610
Kedah	2,823	3,070	9,395	9,449	66	623	1,403	26,829
Kelantan	3,570	4,612	10,315	8,720	124	678	3,592	31,611
Melaka	1,126	2024	6,270	7,828	37	511	529	18,325
Negeri Sembilan	1,259	1,689	6,867	7,321	30	469	537	18,172
Pahang	1,469	2,092	7,457	6,973	86	696	1,049	19,822
Perak	2,765	3,779	12,305	13,567	30	1,018	1,166	34,630
Perlis	605	564	2,041	2,003	16	143	215	5,587
Pulau Pinang	1,908	3,042	8,832	8,104	19	494	784	23,183
Sabah	2,123	2,805	6,105	7,206	26	190	1,481	19,936
Sarawak	1,950	2,459	5,699	6,883	69	542	434	18,036
Selangor	3,709	6,271	19,059	19,171	92	1,213	1,723	51,238
Terengganu	2,351	2,644	6,704	8,413	22	439	825	21,398
W. P. Kuala Lumpur [b]	3,117	3,918	8,827	9,193	3	462	420	25,940
W. P. Labuan	55	87	279	432	5	13	15	886

The Table 1.1 shows that Selangor recorded the highest reading in the category of disabled people with physical disabilities. For patients that facing this problem of maimed hands, their daily activities become stunted and difficult to adapt to the daily environment. This is because, by losing all five fingers, it will be difficult for them to perform basic movements such as grasps and hanging the object. Therefore, the prototype called bionic hand is implemented to assist and perform their daily activities.

1.2 Problem Statement

Bionic hand is the human hand modelled as a set of links connected by joints. Using the method of robotics, the motion of finger described as a serial robot. However to resemble human movement in daily activities, bionic hand shape and feature need to construct like a human hand, some of the characteristics must be considered before it can be built. Bionic hand must be able to assist the user to grasp and moving the entire finger.

One product that has been produced is the I-limb Ultra which has been designed by Touch Bionics' Company, but by using 14 Degree of Freedom (DOF) the system of this bionic hand become more complex and it's difficult to control. For the mechanical part of the bionic hand, it's hard to implement because having degrees of freedom. It is because by having a lot of degree of freedom the bionic hand will have more joint and more part that need to assemble together.

Thus, the design of new bionic hand with 10 Degree of Freedom is proposed by using five linear motors and mechanical linkages to generate the movement of the finger. By reducing the number of motor and degree of freedom, the cost of construction of bionic hand can be reduced. At the same time by reducing the total number of motors, the weight of bionic hand also can be reduced. Beside to make the Bionic Hand more durable and easy to construct this project purpose to use the aluminium seven series so it this bionic hand will lighter and better compare to previous bionic hand.

1.3 Objective

i. To design bionic hand that resembles the real human hand.
ii. To fabricate the design bionic hand.
iii. To analyze the performance of the bionic hand in term of repeatability and accuracy.

1.4 Scope

1. The bionic hand is designed by using Solid works Software.
2. The bionic hand focused to 10 Degree of Freedom (DOF).
3. Each of finger has 2 Degree of Freedom (DOF).
4. The bionic hand is actuated using a combination of five Linera DC motors and mechanical linkages.
5. Each the finger of bionic hand actuated between 0˚ to 90˚ degree.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

In this section, the research about bionic hand is conducted. The research focuses more on the mechanism, degree of freedom (DOF), actuator and as well as the material that used to develop the prototype following the K Chart that already develop referring to the Appendix A. There is some concept that must be considered before constructed the bionic hand, the first concept that must be considered, it's the type of mechanism that used to actuate each Degree of Freedom (DOF) for each finger. There are several mechanisms which are applied in the previous experiment to actuate the movement of the Proximal Phalanx (PP), Middle Phalanx (MP) and Distal Phalanx (DP). The second aspect that is considered from the previous research is the number of Degree OF Freedom (DOF). Degree of Freedom (DOF) is the number of movements that can be made by robots. A lot of Degree of Freedom (DOF) will help the robot to do the task better and easier, so if the robot has a lot of number Degree of Freedom (DOF) more work can be done by robots. Bionic hand also needs to be constructed with Degree of Freedom (DOF) where each of finger must have at least two or three Degree of Freedom (DOF) to actuate the Metacapophalangeal joint (MCP), Proxima Interphalangeal joint (PIP) and Distal Interphalangeal joint (DIP). The third aspect is selection of motor to generate the good movement and in accordance with the requirement. A Fourth aspect that is considered in this research is the selection of material. A Material that used must be durable, light, easy to find and also low cost.

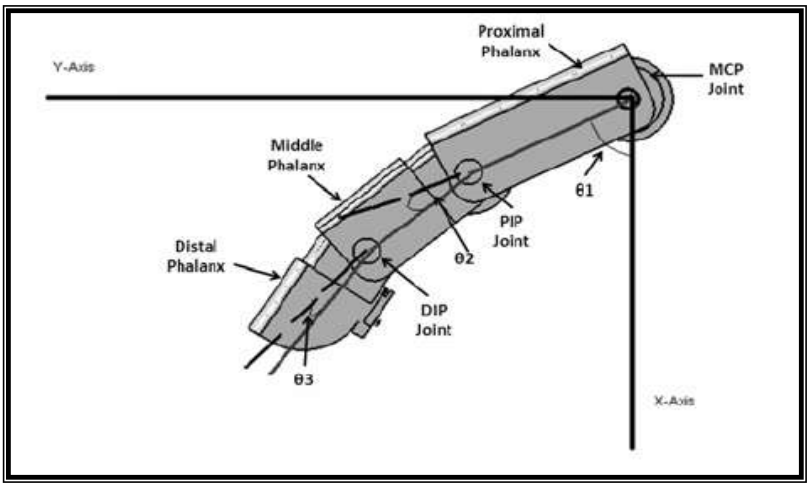

Figure 2.1: Type of Phalange [2]

2.2 Design Concept

Ahmed Jaafar *et al.* (2011) introduce the multifingered anthropomorphic robotic hands that have fourteen degree of freedom (DOF) [2]. The objective of this journal is to mimic the functionality of the biological hand, especially in handling complex object [2]. The bionic hand consists of five fingers where each finger has three different phalanxes it is proximal, middle and distal phalanxes. These three phalanxes were separated by two joints that called the Interphalangeal joint. The design of this bionic hand is done by using CATIA and the fabricated of this prototype is done by using InVision XT-3D Modeler. In this paper the material that is choosed to fabricate this is Acrylic Plastic with the tensile modulus and tensile strength are 1772MPa and 34MPa.

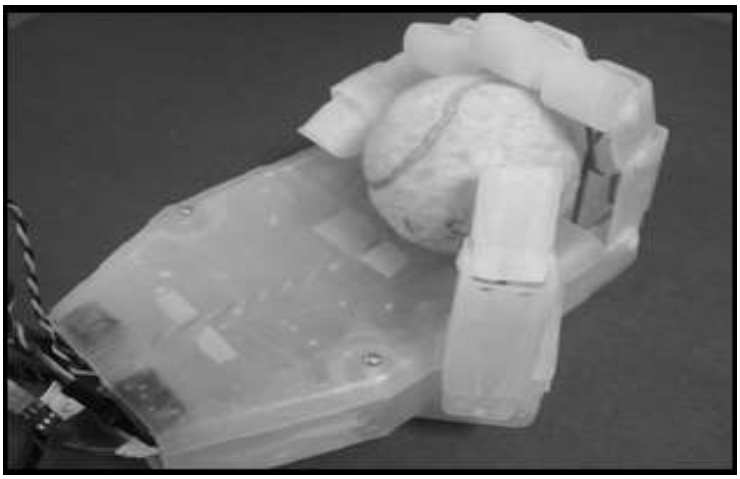

Figure 2.2: Design of bionic hand by Ahmed Jaafar [2]

Whereas in M.C Carrozza *et al.* (2001) the design consists of the 2 degrees of freedom (DOF) for each of the fingers where these bionic hand equipped with three fingers. These papers represent the design and fabrication of novel prosthetic hand base on a “biomechatronics" and cybernetic approach. The objective of this journal is to develop an upper limp prosthesis that can be fielded as a part of the body by the amputee. The prototype fabricated by using Fused Deposition Modeling (FDM) process while acrylonitrile/butadiene/styrene (ABS) plastic is used to construct the body structure for this prototype

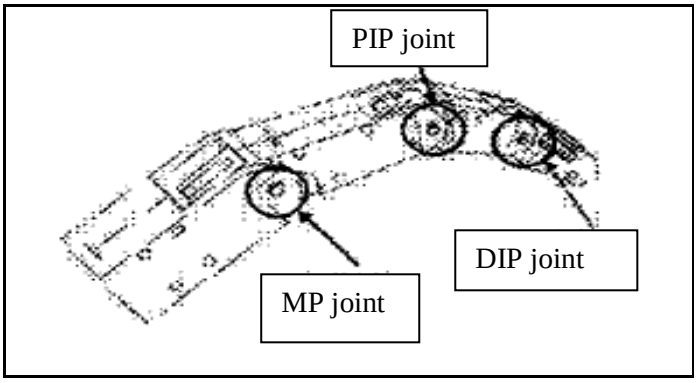

Figure 2.3: Design of bionic hand by M.C Carrozza [3]

According to the Loredano Zallow *et al.* (2007), the biomechatronic approach is used for the design of an anthropomorphic artificial hand. The objective of this journal is to mimic the motion of the human finger [4]. The design of bionic hand consists of (thump, index and middle) with 3 of freedom (DOF) for each finger and 1 degree of freedom (DOF) for ubanation. ProEngineer is used to design and modeling the prototype, where the prototype is constructed by using aluminum alloy while each of the fingers is a shell by carbon fiber. Totally this prototype has ten degrees of freedom (DOF) and 4 degrees of movement.

Figure 2.4: Design of bionic hand by Loredano Zallow [4]

In paper done by W. Widhiada *et al.* (2011) presents how a three fingered gripper can be designed and simulate to provide both gross motion and fine motion of the finger [5]. The objective of this journal is to copy the human hand in term of dexterity and adaptive capabilities to function as either a manipulator or as a prosthetic device [5]. This bionic hand develops with three finger (thump, middle, and index) and seven degrees of freedom (DOF) where all the part is assembling by using SolidWorks program.

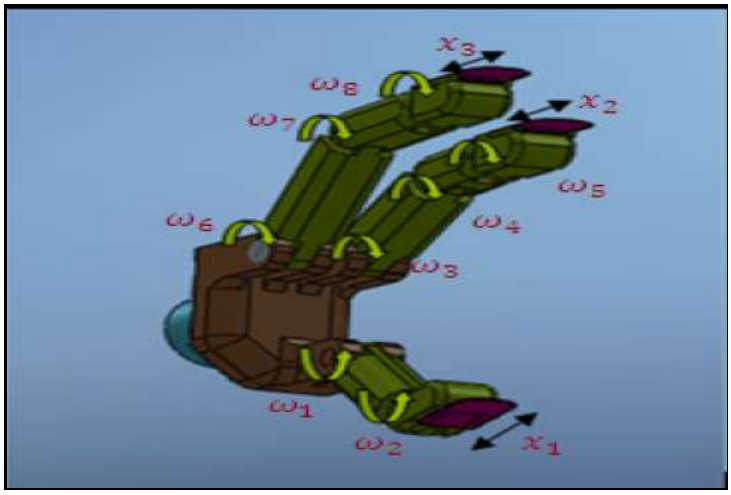

Figure 2.5: Design of bionic hand by W. Widhiada [5]

The design in paper Skyler A. Dalley *et al.* (2010) done by using SolidWorks application to get the true dimensions of design. In this paper, to purpose high strength material, nickel coated thermoplastic are using to create the structure of the bionic hand. In this paper the author represents the design of multi-degree-of-freedom, anthormarphic hand for transradial amputees [6]. The objective of this paper is to provide eight canonical grasp postures [6].

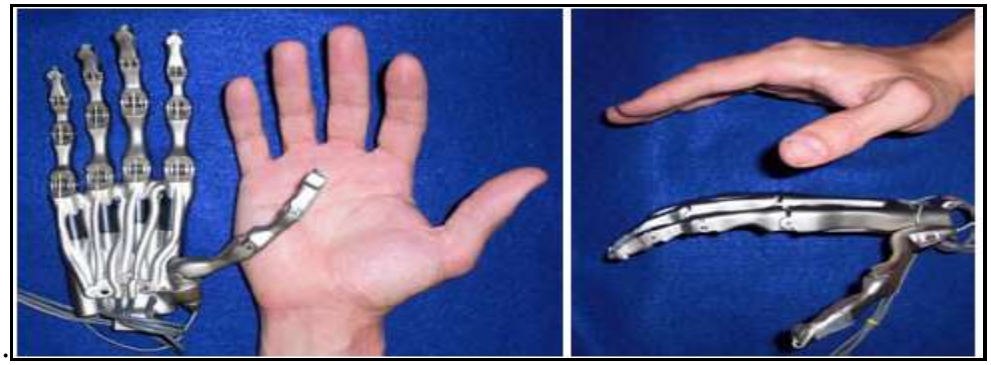

Figure 2.6: Design of bionic hand by Skyler A. Dalley [6]

Preliminary assessment of the ability to perform the activities of daily life living while using the MMC to control a multigrasp prosthesis is proposed by Skyler A. Delly *et al.* (2012) [7]. The objective of this paper is to present a preliminary characterization of the efficiency of the prosthesis during manipulation, capture in the characterization, physical interaction with the environment and demonstrate interdependence between the hand and affected limb [7]. In this paper construction of bionic hand consists of using nine degrees of freedom (DOF) where each of the fingers consists of tree phalange.

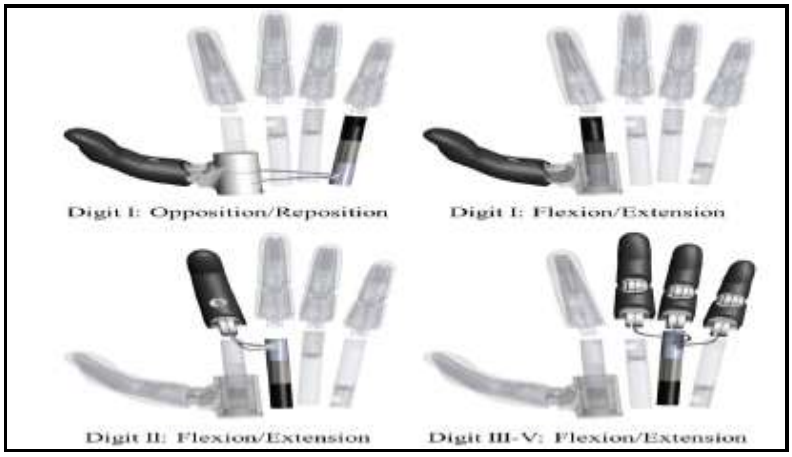

Figure 2.7: Design of bionic hand by Skyler A. Delly [7]

Whereas Praveen Lakkar Srinivasa *et al*. (2013) represent the development of a bionic hand, which perform hand opposition and reposition action (clasp and release) base of the real EMG signal from a below elbow amputee [8]. The objective of this paper is to develop human hand like prosthetic which can provide natural haptic functionality [8]. In this paper the bionic hand is developed by having two degrees of freedom (DOF) below elbow amputee.

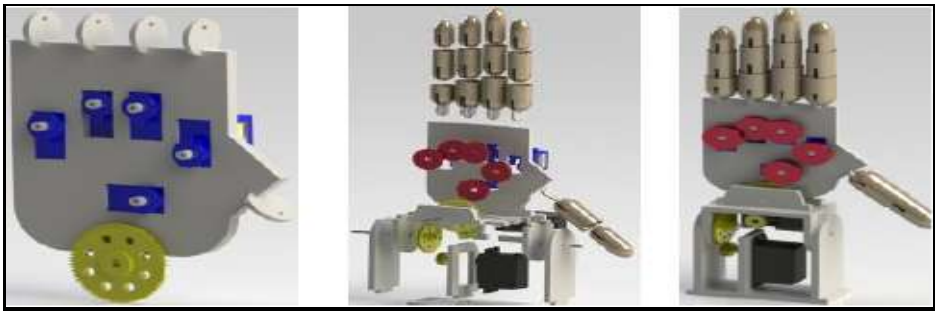

Figure 2.8: Design of bionic hand by Praveen Lakkar Srinivasa [8]