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DESIGN AND DEVELOPMENT OF WIRELESS ROBOTIC HAND

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

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DESIGN AND DEVELOPMENT OF WIRELESS ROBOTIC HAND

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A report submitted in partial fulfillment of the requirement for the degree of Bachelor of Mechatronics Engineering

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UNIVERSITI TEKNIKAL MALAYSIA MELAKA

2014

I declare that this report entitle “Design and Development of Wireless Robotic 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 :…….

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Date : 17 June 2014

Special dedication to my beloved father, mother and my siblings that always giving support in morale and physical.

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ABSTRACT

Hazardous work environments such as in radioactive site and space station give high risk to the worker safety. This risk can be reduced by using robot technology that able to take over the human works. For industry purpose, the robot that needs to be developed must have high performance especially in accuracy, stability and consistency. However, the current industrial robot is not flexible which can't be used for the different tasks. So, multi-purpose robot is proposed to be developed in this project. The objective of this project is to design and developed a robot hand with wireless communication. The robotic hand communicates with human in master-slave manner. This manner will help the robot perform for different task without need to reprogram it. In this project, Xbee wireless module is used because it provides a short-range communication channel. The master part is operated by using a data glove that mounted with sensors to measure the flexion of the fingers, which can wear by a human operator. The movement of human fingers will transferred to the slave robotic hand that will mimic the finger movement. The robotic hand prototype has designed by using SolidWorks software. It designed with 5 fingers and has dimensions similar to human hand. Each robotic finger is powered by servo motor and drive by using wire as the actuator. Wire is used to make a link between finger and motor in order to control the finger flexion by rotating the motor. To control the robot hand system, Atmega328 microcontroller is used to for data glove system and also controls the actuation system for robot hand motion. In master part, a microcontroller is used to process the input signal that it measure from the sensor and transmit the signal to the slave robot hand. While in robot hand, a microcontroller is used to process the receive signal and produce output to perform motor operation.

ABSTRAK

Persekitaran kerja yang berbahaya seperti di tapak radioaktif dan stesen angkasa memberi risiko yang tinggi kepada keselamatan pekerja. Risiko ini boleh dikurangkan dengan menggunakan teknologi robot yang mampu untuk mengambil alih kerja-kerja manusia. Robot yang perlu yang akan digunakan dalam sektor industri perlu mempunyai prestasi tinggi terutamanya dari segi ketepatan, kestabilan dan konsisten. Walau bagaimanapun, kebnyakan robot industri pada semasa ini tidak fleksibel dimana ianya tidak boleh digunakan untuk tugasan yang berbeza. Jadi , robot pelbagai guna telah dicadangkan untuk dibangunkan dalam projek ini. Objektif projek ini adalah untuk mereka bentuk dan membangunkan satu tangan robot yang berhubung tanpa wayar. Tangan robot akan berkomunikasi dengan manusia dengan cara tuan- hamba. Cara ini akan membolehkan robot melakukan tugas yang berbeza tanpa perlu diprogramkan semula. Dalam projek ini, XBee modul digunakan kerana ia memberikan saluran komunikasi pada jarak dekat . Bahagian induk “Tuan” beroperasi dengan menggunakan sarung tangan data yang dipasang dengan sensor untuk mengukur kadar lengkungan jari, yang boleh dimakai oleh manusia sebagai pengendali. Pergerakan jari manusia akan dipindahkan ke tangan robot yang akhirnya akan meniru pergerakan jari itu. Prototaip tangan robotik telah direka dengan menggunakan perisian Solidworks. Ia direka dengan 5 jari dan mempunyai dimensi yang sama dengan tangan manusia. Setiap jari robot dikuasakan oleh motor servo dan dihubungkan menggunakan wayar. Wayar digunakan untuk membuat pautan antara jari dan motor yang bertujuan untuk mengawal lengkungan jari semasa motor berputar. Untuk mengawal sistem robot, Atmega328 mikropengawal digunakan untuk untuk sistem di sarung tangan dan juga mengawal sistem penggerak untuk pergerakan robot. Pada bahagian induk , mikropengawal digunakan untuk memproses isyarat dari sensor yang mengukur lengkungan jari dan menghantar isyarat kepada tangan hamba robot. Manakala, mikropengawal di robot digunakan untuk memproses isyarat yang diterima dan menghasilkan output untuk menggerakkan motor.

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CHAPTER 1

INTRODUCTION

The introduction part will explain the project background, problem statement, objectives, scope of research, and contribution of research.

1.1 Project background / Motivation

Robot hand is the machine mechanisms that can mimic the human hand motion in their operation. Grasping stability and fine manipulation are the important factor in the development of the multi fingered robotic hand. In general, the robotic hand is playing the important role in the application that requires precision and dexterity [1]. Besides, the multi fingered robotic hand is also useful to do a work that unreachable by human such as work in hazardous environments, underwater or in a space station. In this project, the prototype of the robot hand is designed by referring human hand. It has designed with 5 fingers and the robot hand has a dimension likely as a human hand. SolidWorks software is used in designing the robot hand.

Data glove is one of the electromechanical devices that used as the controller for robotic hand movement. Large amount of data can be generated from this multisensory data glove device. The controller has some main components which are the microcontroller, wireless module, and sensor. The sensors are mounted on the glove to measure real time human finger flexion. The sensors will be functioning like the potentiometer where it is able to send an input signal for every angle of finger flexion. To achieve high capability in measuring human finger flexion, the sensor that used together with the data glove must be high accuracy and high reliability [2]. The selection of the

sensor is made in the literature review section. The electrical system of this controller is designed by using Fritzing software.

Wireless communication is the medium for controlling the robot over a distance where human and robot collaborates to perform tasks [3]. The wireless module must be able to transmit the input signal from the data glove to the robot hand system with fast transfer rate ability. In this project, short-range wireless communication is used because the robotic hand is developed for indoor use only with expected distance around 5 to 10 meters. Wireless module that has a simple dialogue interface and easy to use together with microcontroller may have some advantages to be used in this project. The suitable wireless protocol that meets the criteria needed has been discussed and selected in the literature review section.

1.2 Problem statement

Nowadays, robot is commonly used in the industry. Used of the robot give have high implication especially on the production line. This because, robot able to work with faster and accurate than human. Furthermore, robot is very useful to do a work that unreachable by human such as work in hazardous environments, underwater or in a space station. However, current robot is not flexible which can't be used for the different tasks and the robot needs to be reprogrammed for the different task. In this project, robotic hand is proposed to be design and developed with the manual actuation of a passive system. Manual actuation can ensure that the robot able to operate for different tasks without need to reprogram. The challenging thing in developing multi finger robotic hand is to get the accurate and precise grasp motion. The most important aspects to be considered are the percentage error of the robotic finger bending, stability and reliability. Besides, the robot mechanism must have constant performance in order to achieve accuracy in lifetime measurement.

1.3 Objectives

i. To design and fabricate the prototype robotic hand system together with the electrical circuit.
ii. To develop the master data glove and the actuator system for the robotic finger motion.
iii. To analyze the robotic hand performance in term of wireless communication performance, spring performance, finger accuracy, reliability and consistency.

1.4 Scope

The robotic hand is developed based on the master-slave configuration. Data glove is developed as the master that can control the slave robot hand movement via wireless communication. The robot hand prototype has only five Degree of Freedom (DOF) which is one DOF for each finger. The robot hand will use wire-driven method for the actuation system. The robotic hand system is developed to use for indoor application with a low range wireless communication up to 5 to 10 meters. The robotic hand must be able to mimic human finger motion.

CHAPTER 2

LITERATURE REVIEW

The development of this project includes the designing the data glove and the robotic hand finger. The master-slave system is used in the robotic operation where the robotic finger will mimic human finger motion. This project will use Arduino microcontroller rather than usual PIC. This because Arduino provides a complete, flexible, easy-to-use hardware and software platform while the other PIC microcontroller require to select the type of board circuit, language and also the compiler [5]. The robot hand is designed with 26 Degree of Freedom (DOF). Each finger has 4 DOF which is 1 DOF for adduction / abduction and the other 3 DOF is for extension / flexion [5]. All fingers have a different dexterity level from each other although they have same appearances and shape. This because every finger has different movement ranges with different degree of flexion. The robotic hand applications are very ideal because it can provide precise and stable grasping ability [6]. Tension spring is used to move the finger retract back to initial position at 0 degrees when input signal is low [6]. The spring is attached on every finger joint.

Data glove is the master device that able to control the operation of the robotic hand. The data glove is designed with a sensor that attached on every finger [7]. The sensor is used to measure the angle of finger flexion. Microcontroller is used to measure the input signal from the sensor and sent it to the slave that is the robot hand.

This section reviews the research on the important elements in the development of wireless robotic hand. Since the robotic hand using wireless communication, it is important to do some research on it. The first research study focuses on the protocol for the wireless communication. The second research study discusses the existing of robotic hand and mainly focused on the actuator for finger movement. The third research study discusses the sensor selection for the data glove.

2.1 Wireless communication protocol

Nowadays, a robot that controlled wirelessly is very common. There are a lot of on- going and completed wireless robot project around the world [8]. This robotic hand project is using wireless to make communication between 2 points: robot hand and data glove.

2.1.1 Wireless LAN

Wireless LAN is used as a medium to transfer signal from data glove to robot hand. For the communication module, ultra low power chips are used for the transmitter and receiver hardware that based on a frequency of 2.4 GHz [7]. It is to make sure the communication is possible to make parallel data processing. Based on the wireless network architecture, serial peripheral interface (SPI) is used for communication between transmitter and receiver chip [7]. Multiple streams are sent by multiple transmitted antennas using a transmitter system that have multiple inputs and multiple outputs (MIMO). The stream is transmitted through a matrix channel that consists of multiple paths. The signal vector is received by the receiver and decodes into the original information. Nordic Semiconductor nRF24L01+ transceiver chip is used in the development of the wireless communication. The chip contains transmitter, receiver, 8 bit micro-processor 8051 and 2.4GHz ISM band of frequency operation with GFSK modulation. The data is possible to transfer from 1 to 32 bytes in one data packet since the data transfer rate is settable 250kbps, 1 or 2Mbps. However, this wireless communication has some disadvantage which is in static design. This means new node is not possible to add without reconfiguration during network running.

2.1.2 Bluetooth protocol

Another wireless communication technology that commonly used on the robot is Bluetooth. Bluetooth is the technology with short range Radio Frequency (RF) that used to make point-to-point communication [8]. Bluetooth are highly versatile compared other short range wireless technology because of its feature that is robust against the

interferences. To perform a short range wireless communication, class 2 Bluetooth module was chosen with 723kbps maximum data rate. Moreover, class 2 Bluetooth module was chosen compared to the higher class is because of its power consumption [9]. Table 2.1 shows the information about the Bluetooth class. To avoid the buffer overflowing and cancelling the data packets, hardware flow control is actively used with Clear-to-Send/Request-to-Send (CTS/RTS).

Table 2.1: Bluetooth classes [9]

Class	Maximum Power	Operating Range
Class 1	100mW (20dbm)	100 meters
Class 2	2.5mW (4dbm)	10 meters
Class 3	1mW (0dbm)	1 meter

Serial-Port-Profile (SPP) is the communication that is provided by Bluetooth module to interact with each other by using virtual serial port at host [9].

Host Controller Interface (HCI) protocol of Bluetooth module is used to send the data that contains the instruction for the robot to the Handy Board. Bluetooth can perform bi-directional communication where the commands to the HCI will present by the Host (PC) and the Host also receives events back from HCI of Bluetooth module [8]. Bluetooth device is able to support up to 64 kilobytes data packet in length. However, Bluetooth has some limitation where the communication is only one direction and half duplex. Moreover, Bluetooth communication is easily affected by noise.

2.1.3 Zigbee protocol

Zigbee wireless has commonly used for mobile robot as a medium to control the robot movement. Zigbee wireless connection is used to transmit robot motion parameter from PC to robot brain and process the parameters to perform motion control. A Zigbee wireless sensor network is defined as set of low-data-rate communication protocols with short-range wireless networking [10]. The maximum data rate for Zigbee is 250 bits per seconds and it can operate at 868 MHz, 915 MHz, and 2.4 GHz frequency bands. Xbee Zigbee module is used to support Zigbee wireless network and create more stable and

reliable network. Mesh networking can be easy and simple to deploy by using Xbee modules. Moreover, Xbee module is easily handled by a microcontroller or a PC because it has a simple dialog interface.

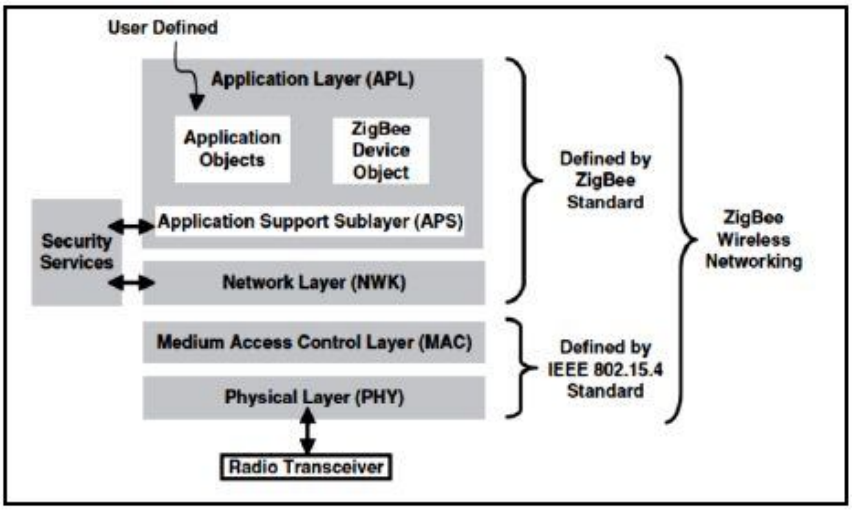

Figure 2.1: Zigbee Wireless Networking Protocol layers [10].

Figure 2.1shows the Zigbee protocol layers which are based on the Open System Interconnect (OSI) basic. Zigbee has some advantages compared to other wireless platform which are more suitable for network application such as larger transmission range, low power consumption and capability for mesh networking [11].

Table 2.2: Wireless technology comparison [11].

	Wireless LAN	Zigbee	Bluetooth
Speed	54Mbps	20~250 Kbps	3Mbps
Power consumption	Highest	Lowest	Medium
Distance	30~70m	30~300m	10~100m
Frequency range	2.4/5Ghz	868 Mhz 915Mhz 2.4Ghz	2.4Ghz
IEEE standard	802.11	802.15.4	802.15.1

2.1.4 Conclusion

In conclusion, Zigbee is the suitable to use as the communication for the robotic hand. This because, Zigbee module has better performance and advantages compared to other wireless platform. Based on the Table 2.2, Zigbee has low power consumption compared to other and it has a better distance range that around 30~300m. For robotic hand application, data speed of 20~250Kbps has enough to meet the requirements for robotic communication.

2.2 Type of actuator

The selection of the actuator that used to drive the robotic hand should be done by considering some critical parameters such as power to weight ratio, efficiency and functionality. This section will discuss the type of actuator that commonly used on robotic hand which is pneumatic actuator, ultrasonic motor and servo motor.

2.2.1 Pneumatic actuator

The purpose if this study is to make some overview of the pneumatic actuator in the development robotic hand. The pneumatic actuator is used in finger joint that have one degree of freedom (DOF). Usually, big compressor is needed when conventional pneumatic actuator is used in order to give enough power to drive a robot hand [12]. The new pneumatic actuator has been developed to get have better performance compared the convenient actuator where consists of rubber balloon and net that covers the rubber balloon.

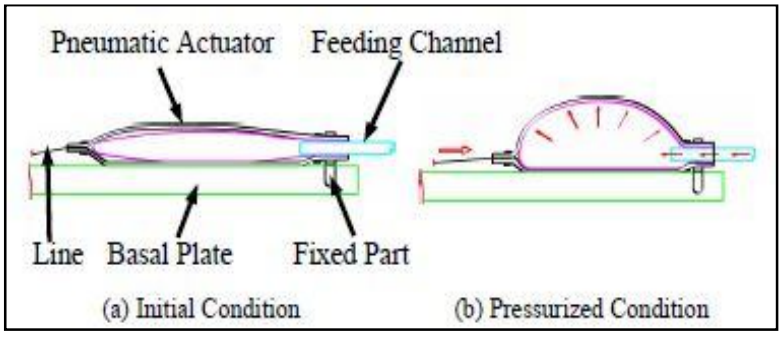

Figure 2.2: Schematic of pneumatic actuator [12].

Figure 2.2 shows a new design of pneumatic actuator with the basic structure that same as the McKibben-type artificial muscle. However this actuator has been improved by covering the net with 0.21mm thickness of rubber balloon that more efficiently to shrink the sent air volume [12]. This can cause the actuator to be driven with low air volume and low pressure. The range operation of robot hand with pneumatic actuator is between -10^{o} to 90^{o} and the robotic hand able to grasp and hold objects up to 500g in weight [12].

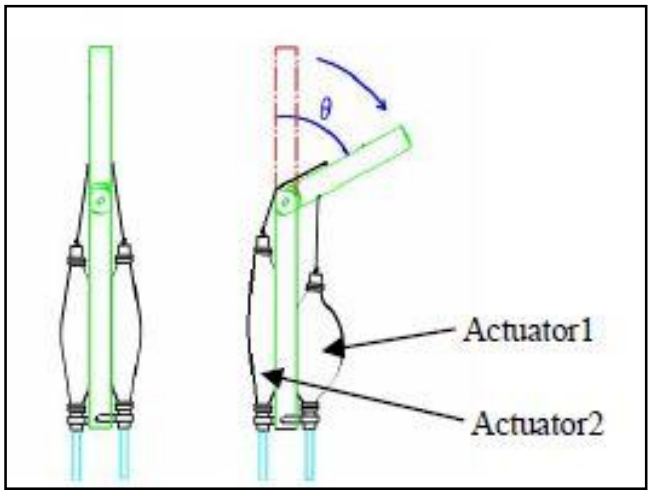

Figure 2.3: Schematic of robot finger with pneumatic actuator [12].

Figure 2.3 shows the operation of the robotic hand finger. When actuators 1 shrink, it will pull the upper part to perform the flexion operation.

2.2.2 Ultrasonic motor

Another actuator that used in the development of robotic hand is ultrasonic motor. This actuator is usually applied to the five-finger robot hand with 20 degrees of freedom (DOF). Ultrasonic is used because it can placed inside the robotic hand since it have characteristic of compact size, light weight and can operate at high torque at low rotational speed [13]. Furthermore, it enables the robot hand to perform a stable grasping motion. However, the robot hand has a risk to break the grasp object since the ultrasonic motor has high driving torque. Moreover, there is some difficulty to control the torque because of the non-linearity characteristic of the ultrasonic motor. Spring is used together with the ultrasonic motor in order to control the elasticity of the joint. By changing the spring coefficient, robot hand would obtain high stability in grasping objects [13].

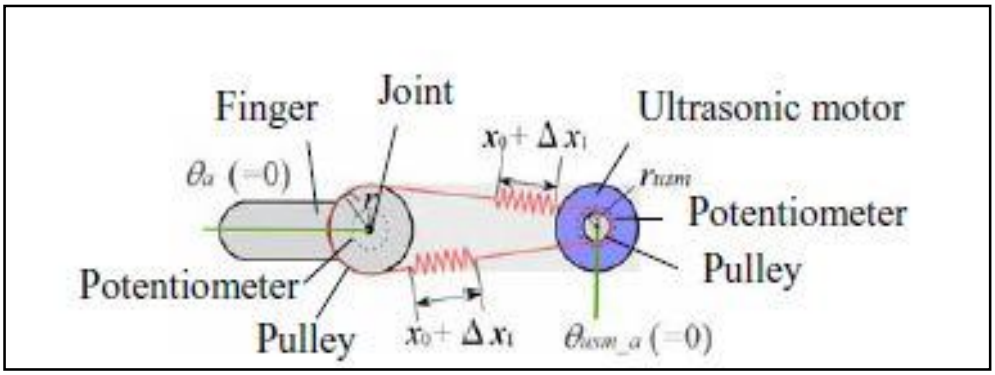

Figure 2.4: Outline of driving method of finger [13].

The rotation angle of the ultrasonic motor is determined by using a potentiometer. The relationship of the motor rotation angle with joint angle can be expressed as:

$$R= \theta_b= r_{usm}.\theta_{usm\_b} \quad (2.1)$$

To achieve highly accurate force control, ultrasonic motor is the suitable actuator because it's precise position control. Besides, the stable and efficient grasping motion can be achieved if the restoring force is used as the output force.

2.2.3 Servo motor

Servo motor also can be used as the actuator for the robotic hand. Servo motor has good performance in speed control and also the torque control [14]. There is also has small size of servo motor that suitable if used in robotic hand. The speed of the finger movement can be adjusted by controlling the rotational speed of the servo motor. PWM control is to adjust and set the servo motor rotational speed. The control period of the servo motor is 0.18us with speed and torque control of 0.125% accuracy error. In order to grasp brittle object, the performance of the servo motor can be tuned by the driver gain to show no overshoot. Figure 2.5 shows the graph of the relationship between finger joint and servo motor. From 'moving' region on the graph shows the joint faster output than input motor speed while the output torque is lower than input motor torque.