THE DEVELOPMENT OF ELBOW JOINT REHABILITATION DEVICE

CHAI GOW XIAO

POLITEKNIK SULTAN SALAHUDDIN ABDUL AZIZ SHAH

THE DEVELOPMENT OF ELBOW JOINT REHABILITATION DEVICE

CHAI GOW XIAO

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Jabatan Kejuruteraan Elektrik

Politeknik Sultan Salahuddin Abdul Aziz Shah

SEPTEMBER 2015

ENDORSEMENT

I hereby acknowledge that I have read this report and I find that its contents meet the requirements in terms of scope and quality for the award of the Bachelor Of Electronic Engineering Technology (Medical Electronic) With Honours

Signature : ....

Name of Supervisor : DR. HJ. ZUNUWANAS BIN MOHAMAD
KETUA PROGRAM
IJAZAH SARJANA MUDA TEKNOLOGI KEJURUTERAAN ELEKTRONIK
(ELEKTRONIK PERUBATAN)
POLITEKNIK SULTAN SALAHUDDIN
ABDUL AZIZ SHAH

Date : 13/3/16

DECLARATION

I hereby declare that the final year project book is an authentic record of my own work carried out of one year Final Year Project for the award of Bachelor Of Electronic Engineering Technology (Medical Electronic) With Honours, under the guidance of Dr. Hj Zunuwanas Bin Mohamad from 7 September 2015 to 01 June 2016.

Signature : ....
Name : Chai Gow Xiao
Registration No. : 08UEU14F3010
Date : 13/7/2016..........................

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ABSTRACT

Stroke is the second largest causes of Year of Life Lost in Malaysia, which ischemic heart disease (17.1%) is the first causes, follow with stroke (9.6%) and the third causes was road traffic injuries (8.3%). Stroke is a brain disease, which it causes spasticity and may occurs muscle weakness and also joint stiffness. Besides that, joint stiffness also will occur after joint trauma and with the Continuous passive motion (CPM) exercise, the joint stiffness can be reduces and also maintain the range of motion (ROM) of the joint. Elbow Joint Rehabilitation Device provides CPM exercises to the patients who have elbow injury or elbow that has undergone surgical procedure and Neurological problems such as stroke and traumatic brain injuries which affected on the elbow. The purpose of this project is to upgrade the existing Elbow Joint Rehabilitation Device to more comfortable to use, more lightly in weight to be handle and carry, and also can operate in DC rechargeable batteries. To develop this project, DC geared motor is use to move the arm/elbow joint with controllable speed and the degree of movement by using PIC (Programmable Interface Controllers). Furthermore, a rechargeable battery is added on the device which to able the device operates in DC power supply. To conduct this project, 20 subjects were involved in the usability testing. During the usability test, the device will be tested on the 20 subjects, and data collected by distributed questionnaire to all the subjects. The collected data was analyses and the results have shown that, 6 subjects are strongly agree that the develop device are comfortable to be used, 11 subjects slightly agree that, the device is comfortable and only 1 subjects are disagree with the comfortability of the device. As a conclusion, the develop Elbow Joint Rehabilitation Device is comfortable to be used.

ABSTRAK

Stroke adalah punca kedua terbesar *Year Life Lost* di Malaysia, dimana penyakit jantung iskemia (17.1%) adalah punca utama, disamping stroke (9.6%) dan diikuti kecederaan jalan raya (8.3%). Stroke adalah penyakit otak, yang akan menyebabkan *spasticity* dan boleh berlaku kelemahan otot dan juga kekakuan sendi. Selain itu, kekakuan sendi juga akan berlaku selepas trauma dan dengan senaman *Continuous passive motion* (CPM), kekakuan sendi boleh mengurangkan dan juga mengekalkan *Range of motion* (ROM) sendi. *Elbow Joint Rehabilitation Device* menyediakan senaman CPM untuk pesakit yang mengalami kecederaan siku atau pembedahan di bahagian siku selain mempunyai masalah neueologi seperti stroke dan kecederaan otak traumatik yang boleh menjejaskan siku. Tujuan projek ini ialah menaik taraf *Elbow Joint Rehabilitation Device* sedia ada untuk lebih selesa digunakan, selain ringan dan mudah dibawa, ianya juga beroperasi dengan bantuan DC bateri dan boleh dicas semula. Bagi membangunkan projek ini, *DC Geared Motor* digunakan untuk mengerakkan lengan / siku dengan kelajuan dan darjah pergerakan yang dikawal dengan menggunakan PIC (Programmable Interface Controller). Selain itu, bateri boleh dicas semula telah ditambah pada alat dan membolehkan alat beroperasi dalam bekalan kuasa DC. Oleh itu, 20 pelajar telah terlibat dalam ujian kebolehgunaan. Semasa ujian kebolehgunaan, alat ini telah diuji pada 20 pelajar, dan data telah dikumpul dengan mengedarkan soal selidik kepada semua pelajar selepas ujian. Data yang dikumpul telah dianalisis dan keputusan menunjukkan 6 orang pelajar bersetuju bahawa inovasi ini sangat selesa digunakan. Dalam pada itu, 11 orang pelajar kurang bersetuju, inovasi ini selasa digunakan dan hanya 1 pelajar tidak bersetuju dengan keselesaan alat ini. Kesimpulannya, *Elbow Joint Rehabilitation Device* yang telah membangunkan selesa diguna.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Stroke is the second largest cause of death in Malaysia. A study of Ummi Nadiah Yusof find out that stroke is the second largest causes of Year of Life Lost in Malaysia, which ischaemic heart disease (17.1%) is the first causes, follow with stroke (9.6%) and the third causes was road traffic injuries (8.3%)[1]. Brain injury from a stroke may affect Hemiparesis (weakness on one side of the body) or hemiplegia (paralysis on one side of the body). When the stroke patients is in hemiparesis, they're not able to move their hands freely, and their joints not able to move in the normal range of motion.

According the observation of the L. D. Schelosky &J. Scott, 25% stroke patients suffer from spasticity within the first 6 weeks of the study. They have observed that spasticity primarily affects the elbow (79% of patients), the wrist (66%) and the ankle (66%) [2]. Spasticity of the elbow joint will causes the arm's muscle weakness and the elbow joint stiffness. Besides that, joint stiffness also will occur after joint trauma and with the Continuous passive motion (CPM) exercise, the joint stiffness can be reduces and also maintain the range of motion (ROM) of the joint.

A study of K. Kang, which the development of rehabilitation robot for post-stroke forearm and wrist also provided the Continuous Passive Motion exercises for stroke patient[3]. Elbow Joint Rehabilitation Device provides Continuous passive motion (CPM) exercises to the patients who have Neurological problems such as stroke and traumatic brain injuries are a highly prevalent condition that results in high cost to the individuals and society[4]. Besides that, it is used during the first phase of rehabilitation process following an elbow injury or elbow that has undergone surgical procedure.

A rehabilitation program support the findings of Gates et al (1992) that post-operative use of CPM improves total range of motion and therefore function[5]. Thus, Continuous Passive Motion exercises are important to the patient's elbow recovery from stroke, traumatic brain injuries and also from elbow injury. By using this device, patients can do their treatment anytime and anywhere and patients can heal in a short period of time.

But the exiting devices are too complex, large, and difficult to be carried to anywhere. Besides that, the current device most with a wheel stand and some of it are with a fixed chair, so the device are difficult to carried, and also it's not stable while the device is in used. Furthermore, current devices are operating in AC power supply, so every times the user need to place the devices close to AC power supply to do their treatment.

1.2 Problems Statement

Existing devices of the elbow rehabilitation therapy are large are too big, complex and difficult to be carried anywhere. Because of the size, the patients should be hospitalized for the elbow rehabilitation therapy. Besides that, the current device those with wheel stand are not stable while the patients are doing the treatment. While the patients using the device, the device may move, and it may probably effect the treatment.

Furthermore, current devices need to operate in AC power supply. Which means the patients or the users need to find an AC power supply to operate the device every times of the treatment.

1.3 Objective

The main objective of this study is:-

1. To develop a lightly and hand ability elbow joint rehabilitation device for stroke patients.
2. To design the control speed circuit for guiding continuous passive motion exerciser and able to operating in a rechargeable batteries.

1.4 Scope of Study

The scope of this study is to develop the Elbow Joint Rehabilitation Device for the post-stroke patient who has hemiparesis or spasticity on their elbow joint.

1.5 Importance of Study

This study is to develop the elbow joint rehabilitation device for the patients who stroke. This device provided the Continuous Passive Motion exerciser which helps the stroke patient reduce their joint stiffness and maintain their elbow joint's range of motion (ROM). Because of the current device are too complex, large and difficult to carries. Besides that, the current device are operating in AC power supply, so user need to find a AC power supply to do their treatment. Thus this study is to develop a more lightly and hand ability and also rechargeable Elbow joint rehabilitation device for the Stroke patients.

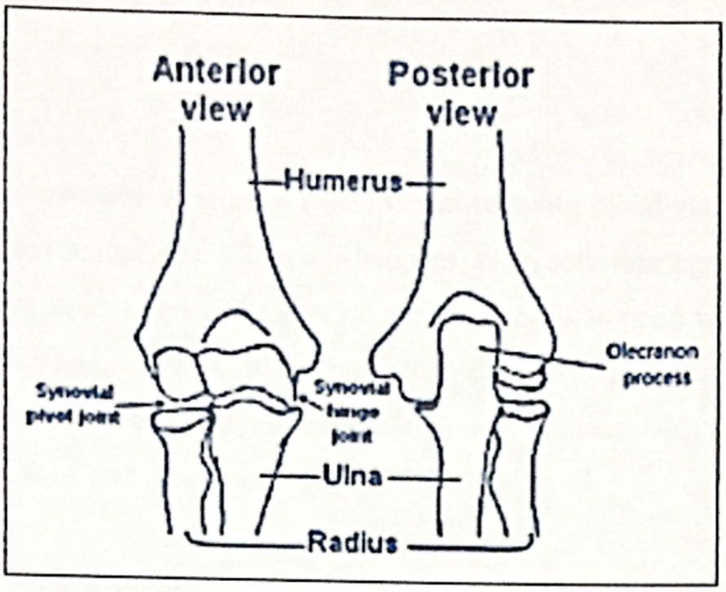
CHAPTER 2

LITERATURE REVIEW

2.1 Elbow Joint

The elbow is the joint connecting the proper arm to the forearm. It is marked on the upper limb by the medial and lateral epicondyles, and the olecranon process. Structurally, the joint is classed as a synovial joint, and functionally as a hinge joint.

The elbow joint is a compound synovial joint, which means that it is a large working structure that is made up of several smaller moving parts, or separate articulations. A synovial joint, otherwise known as a diarthrosis, is the most flexible type of joint, seeing as it achieves its range of movement at the point of contact between the articulating bones. This mechanical area forms the meeting point between the radius and ulna of the forearm with the humerus of the brachial region. It is deemed a compound joint because the joint cavity is continuous with the radioulnar joint, as well as the contact points between these bones and the humerus respectively.



Figures 2.1: The structure of the elbow joint.

Every joint in our human body have its own range of motion, the Figure 2 is the normal range of motion for the elbow joint. The orientation of the bones forming the elbow joint produces a hinge type synovial joint, which allows for extension 0 degrees (straighten out lower arm) and flexion 140 degrees (Bring lower arm to the biceps) of the forearm.[6]

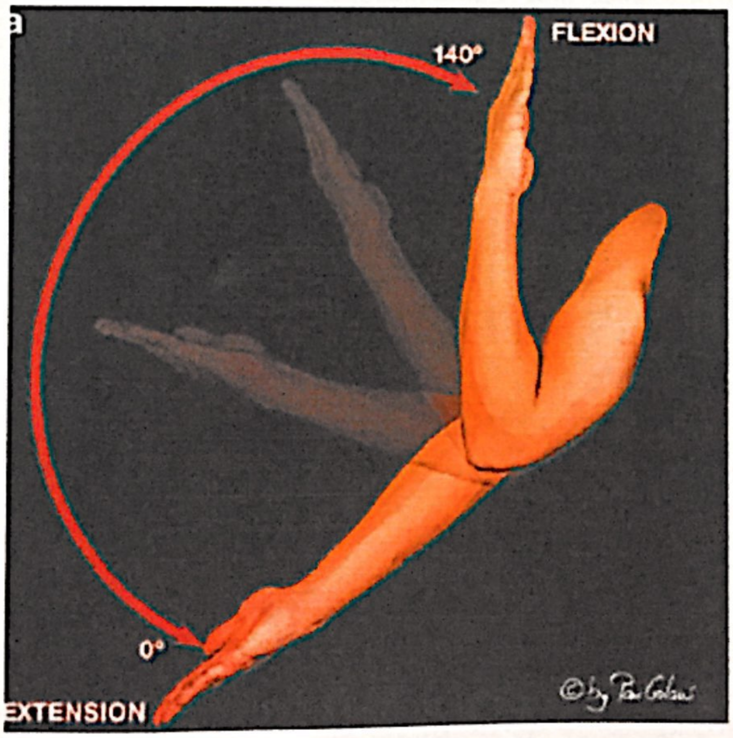


Figure 2.2: The normal range of motion of elbow joint

2.2 Stroke

Stroke occurs when a blood vessel bringing blood and oxygen to the brain gets blocked or ruptures. When this happens, brain cells don't get the blood and oxygen that they need to survive. This causes nerve cells stopped working and die within minutes. Then, the part of the body they control can't function either. The effects of stroke may be permanent depending on how many cells are lost, where they are in the brain, and other factors.

Brain controls human's move, feel, communicate, think and act. Brain injury from a stroke may affect any of these abilities. One side of the body may be paralyzed are common no matter which side of the brain the injury is on. Others are based on which side of the brain the stroke injures.

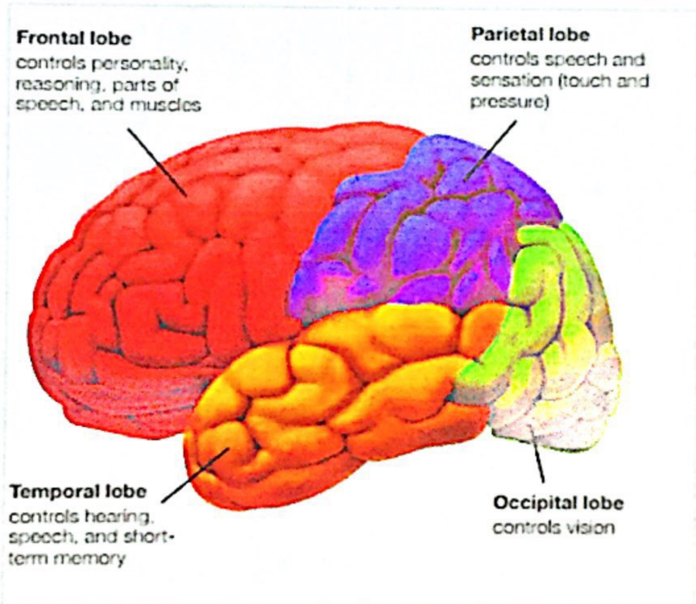


Figure 2.3: Functional of brain

Symptoms of Stroke are sudden numbness or weakness of face, arm or leg (especially on one side of the body), sudden confusion, trouble speaking or understanding , sudden trouble seeing in one or both eyes, sudden trouble walking, dizziness, loss of balance or coordination, and sudden severe headache with no known cause.

2.2.1 Effect of stroke

The effects of a stroke vary from person to person, depending on which part of the brain is damaged and the extent of that damage. For some, the effects are relatively minor and short-lived; others are left with more severe, long term disabilities. Common problems include weakness or paralysis, Cognitive Problems, Problems Using Language and also Vision and Perception Problems

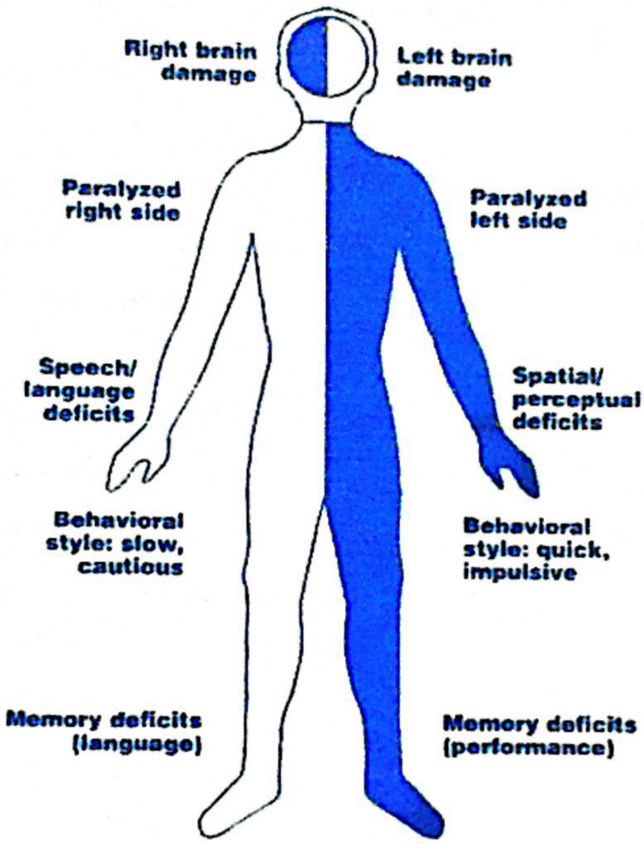


Figure 2.4: Effect of stroke

The most common effects of stroke are weakness or paralysis. Weakness (hemiparesis) or paralysis (hemiplegia) may affect one whole side of the body, or just an arm or leg. The weakness or paralysis is on the side of the body opposite the side of the brain injured by the stroke. This leads to problems with balance or coordination, because the weight of the weak side pulls against the strong side. It can make it difficult for the stroke patients to sit, stand, or walk, even if his or her muscles are strong enough to perform these activities.

The second common effect is Cognitive Problems. Strokes often cause problems with memory, thinking, attention, learning, and other mental activities. For example, trouble following directions, may get confused if something in a room is moved, or may not be able to keep track of the date or time.

Furthermore Problems Using Language also ones of the effects of stoke. Some of the stroke patients may have a problem in aphasia (a-FAY-zha), and trouble understanding speech or writing. They may understand but be unable to think of the right words to speak or write. A person with dysarthria (dis-AR-three-a) knows the right words but has trouble saying them clearly.

Vision And Perception Problems also often occurs in stroke survivors, because of vision and perception problems, will not turn to look toward their weakened side. For example, may not eat food from one side of the plate because he or she doesn't see it.

The most common physical effect of stroke is muscle weakness and loss/less of control movement of arm or leg. Brain damage due to stroke can cause an arm or leg to become paralyzed and/or to develop spasticity. Spasticity refers to the abnormal symptom of having muscle are stiff and resistance in the joints when patients try to make a movement[7][8].

2.3 Continuous Passive Motion

Continuous passive motion (CPM) can prevent development of adhesions and contractures and thus joint stiffness[9]. Continuous passive motion is effectively to reduce the stiffness of the joint and to maintain the normal range of motion. CPM involves movement of a joint without active muscle contraction, and is accomplished with motorized devices that move the affected joint through a prescribed arc of motion for an extended period of time[10].

When the joint is in spasticity condition, increasing of the joint stiffness will be occurs. So that, continuous passive motion was apply to the hemiparesis patients can reduce the joint stiffness and maintain the range of motion of the joint. The study of Mohd Nor Azmi Ab.Patar, he had developed a robotic hand rehabilitation device, which the device provide CPM to help stroke patients reduce the joint stiffness of the finger[11].

Besides that, CPM can also help the patients who have joint injuries, which it provides a stimulating effect on the healing of tendons and ligaments, enhances healing of incisions over the moving joint, increases synovial fluid lubrication of the joint and thus increases the rate of intra-articular cartilage healing and regeneration.

For the joint injury, CPM usually provided during the first two stages of stiffness acts to pump blood and edema fluid away from the joint and periarticular tissues[12]. The first stage of stiffness is bleeding, which it occurring within minutes to hours following articular surgery or trauma. This stage of stiffness is caused by bleeding, which results in distension of the joint capsule and swelling of the periarticular tissues.

The second stage of stiffness is edema, which occurs during the next few hours or days, is very similar but progresses less rapidly. This stage of stiffness is caused by inflammatory mediators that are released by platelets and dead and injured cells. Which may also results in swelling of the periarticular tissues, thereby diminishing their compliance. With swollen and less compliant tissues surrounding it, the joint becomes physically more difficult to move and movement becomes more painful.

A CPM machine or Elbow Joint Rehabilitation Device is an electrical, motor-driven device that helps support the injured or spasticity limbs. It is used to move a joint at variable rates through progressively increasing Range Of Motion (ROM); no muscular exertion is required of the patient [13]. With the help of the CPM device, it can help to increasing the Range of Motion of a joint and also help to reduce the joint stiffness.

2.4 Current Devices

2.4.1 ARMin

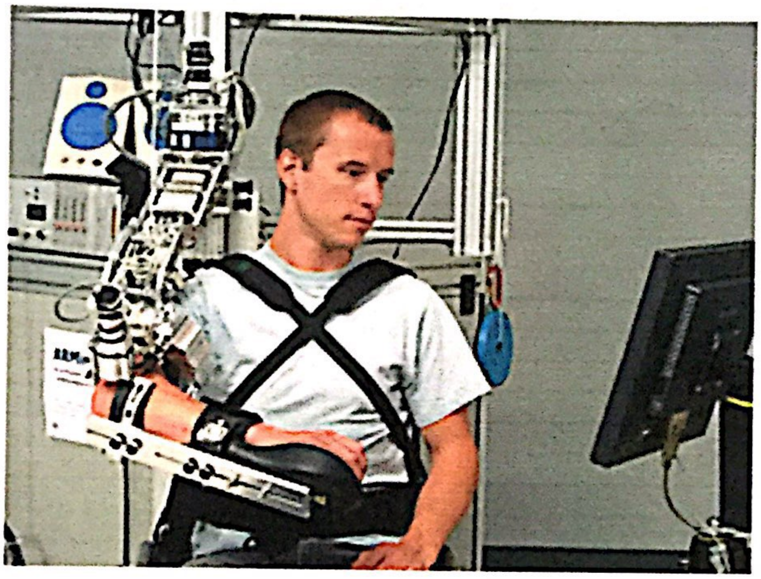


Figure 2.5: ARMin

A custom-developed unique IntelliArm is used to diagnose the biomechanical changes and abnormal couplings at the shoulder, elbow and wrist joints of the impaired arm of patients post stroke [14]

It is a haptic display with semi-exoskeleton kinematics with four active and two passive degrees of freedom. Equipped with position, force and torque sensor the device can deliver patient-cooperative arm therapy taking into account the activity of the patient and supporting him/her only as much as needed.

The haptic display is combined with an audiovisual display that is used to present the movement and the movement task to the patient. It is assumed that the patient-cooperative therapy approach combined with a multimodal display can increase the patient's motivation and activity and, therefore, the therapeutic progress.

2.4.2 Centura Elbow Module (CEM)

Figure 2.6: Centura Elbow Module (CEM)

This easy-to-use module provides anatomically correct elbow extension/ flexion in an abducted position with your Centura Shoulder CPM. Change-over from an existing shoulder pattern is quick and easy; no tools required. CEM features our deluxe hand control, offering the same operational layout as Centura Shoulder, Spectra Knee, Maestra Hand & Wrist and the new Breva Ankle CPM. Pad kit purchased separately.

This device also provided a specific Range of motion for the treatment, which Extension is 10° and Flexion is 135°. Extension is with fixed or adjustable Pronation/Supination in an abducted rotate plane. This device is fixed with the specific chair, which it's heavy to move the device along with the fixed chairs.

2.4.3 Continuous Passive Motion Unit CPM (Elbow)

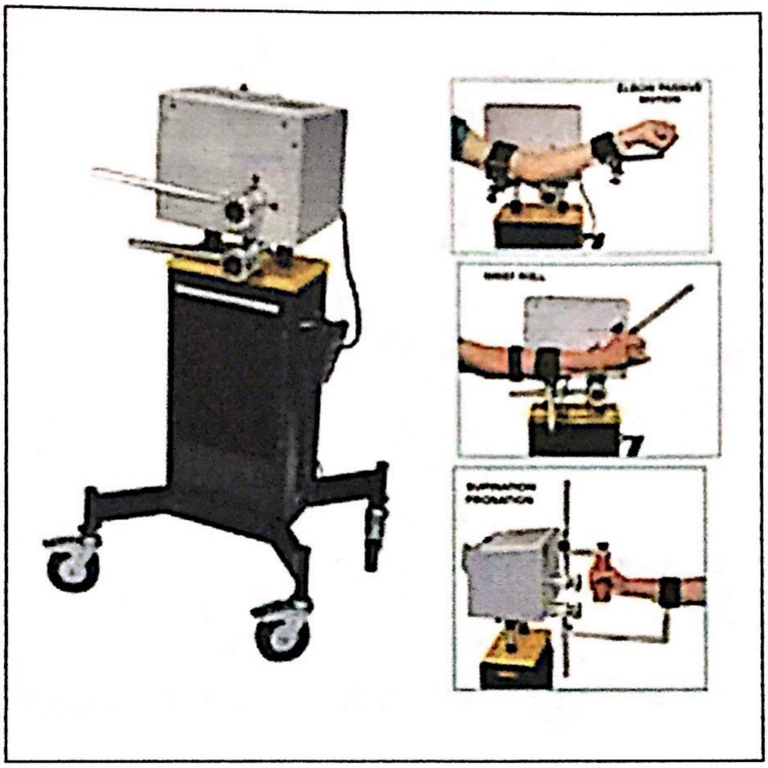


Figure 2.7: Continuous Passive Motion Unit CPM (Elbow)

CPM Elbow, A Micro-Computer controlled unit, represents the latest breakthrough in CPM technology. Solid state circuitry control panel with highly visual LED Digital readouts allows Flexion and Extension of Elbow joint through a prefixed Range of Motion and Time.

Wrist rotation and Wrist roll movement can also be achieved. Unit is fitted on mobile Electrical Jack to adjust height according to patient requirement. Come with necessary accessories for Supination / Pronation, Wrist Roll and Elbow passive motions. Range Of Motion (ROM) Setting for this unit are Programmable from 00 to 120deg for Elbow movements, which it can be control the range of motion for our elbow.

2.4.4 Elbow CPM Machine

Figure 2.8: Kinetec 6080 Elbow CPM Machine

Offers physicians and their patients the utmost in versatility by providing anatomically correct passive motion of the elbow joint with or without synchronized injuries can be avoided thanks to the lockable range-of-motion setting. Elbow CPM therapy is indicated for the treatment of injuries and diseases of the elbow that limit movement of the joint. Post-operative treatment using this device provides an effective deterrent to stiffness and loss of range of motion. Indications include the following:

- Synovectomies
- Surgical releases
- Arthroplasty
- Open reduction and internal fixation of intra-articular fractures
- Contusions
- Flexor-extensor muscle repairs
- Burns

Besides that, this devices also provided a specific Range of motion for the treatment, which Flexion 135 degrees ROM, Extension 0 degrees ROM and Rotation is 180 degrees

2.4.5 Joint Active Systems devices

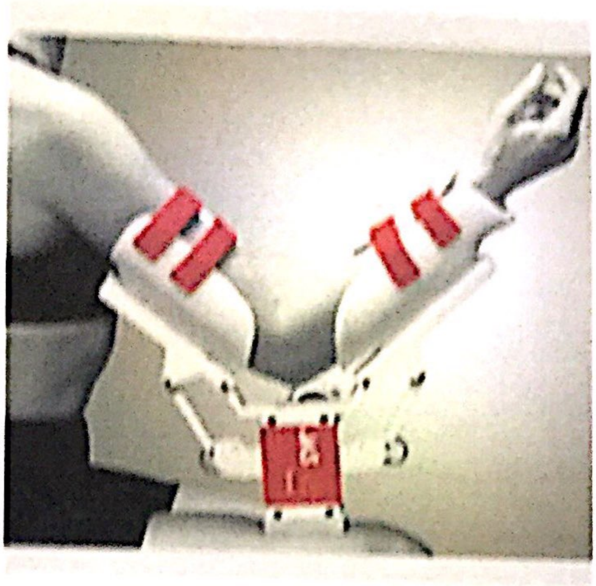


Figure 2.9: JAS Device (Right Sides View)

JAS devices are used to restore a joint's range of motion by gently stretching soft tissues surrounding joints that have stiffened because of injury, surgery or prolonged immobilization. Figure 2.19 shows the right sides view of JAS Device. The device is manually operating and it light in weight. Besides that, it can

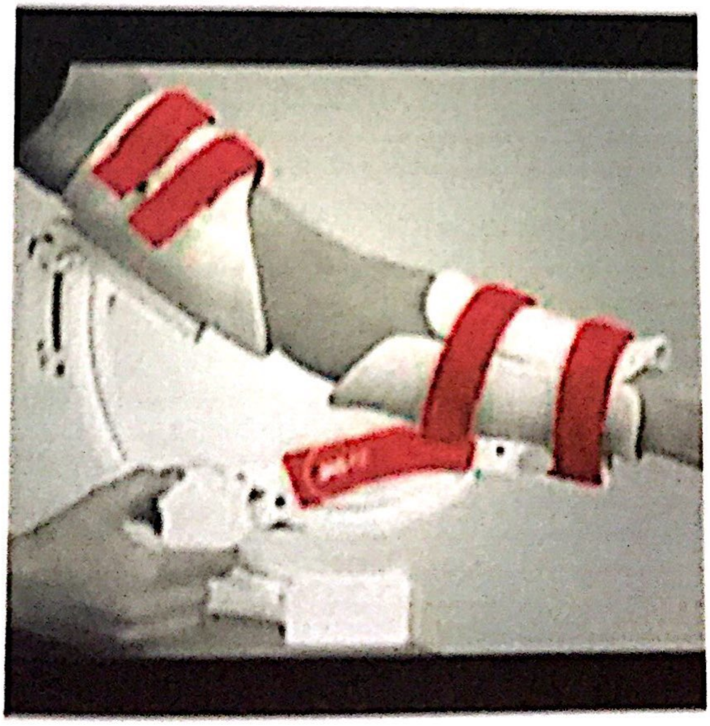


Figure 2.10: JAS Device (Left Sides View)

JAS devices provide Static Progressive Stretch Therapy (SPS) which utilizes the force loading condition known as stress-relaxation. This is the same technique that therapists use when performing manual stretch therapy in the clinic. Which this project will develop an elbow joint rehabilitation device in this design. Develop from this device by adding automatic treatment with difference speed control and add on rechargeable batteries to let the device be able to operate without AC Power Supply.

2.5 DC Geared Motor

Industrial applications use dc motors because the speed-torque relationship can be varied to almost any useful form for both dc motor and regeneration applications in either direction of rotation.[15]

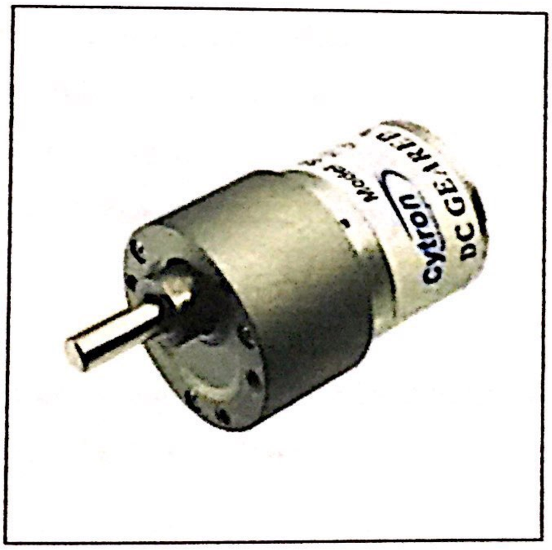


Figure 2.11: DC Geared Motor

Geared DC motors can be defined as an extension of DC motor which already had its Insight details demystified here. A gear assembly attached to the DC geared motor. The speed of motor is counted in terms of rotations of the shaft per minute and is termed as RPM .To increasing the torque and reducing the speed with the help of gear assembly. Using the correct combination of gears in a gear motor, its speed can be reduced to any desirable figure. This concept where gears reduce the speed of the vehicle but increase its torque is known as gear reduction.

Direct current (DC) motors have variable characteristics and are used extensively in variable-speed drives. DC motor can provide a high starting torque and it is also possible to obtain speed control over wide range. For example, if we have a DC motor in a robot, if we just apply a constant power to each motor on a robot, then the poor robot will never be able to maintain a steady speed. It will go slower over carpet, faster over smooth flooring, slower up hill, faster down hill, etc. So, it is important to make a controller to control the speed of DC motor in desired speed. The speed of DC motor is control through duty/PWM cycle. This PWM pulse is giving to MOSFET for triggering purpose.[16]

Cytron DC Geared Motor are used in this study. Below are the dc geared motor Specifications and Features:

- Rated voltage: 12VDC
- Tested voltage range: 9V to 15V
- Speed at free run, 12V: 185rpm
- Current at free run (no load), 12V: 70mA
- Current at loaded (rated), 12V: 410mA
- Stall Current, 12V: 1800mA
- Stall torque, 12V: ~0.8kg-cm (78.4mN.m)
- Weight: 160g
- Gear ratio: 20:1
- Shaft: D-shaped with 6mm diameter, 15.5mm in length
- Motor dimension: 37 x 37 x 75.5mm

2.6 Peripheral Interface Controller (PIC)

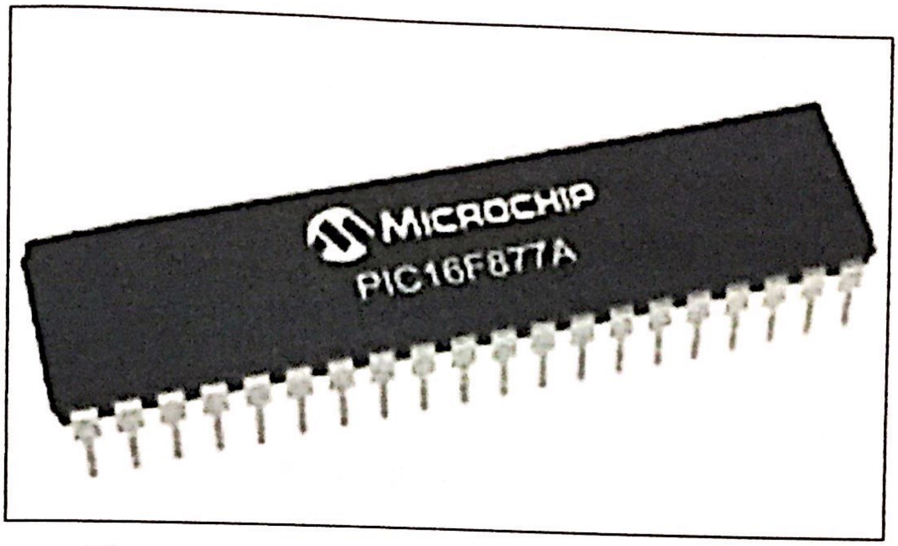


Figure 2.12: Peripheral Interface Controller (PIC)

A PIC's Microcontroller is a device which integrates a number of the components of a microprocessor system onto a single microchip and optimized to interact with the outside world through on-board interfaces; i.e. it is a little gadget that houses a microprocessor, ROM (Read Only Memory), RAM (Random Access Memory), I/O (Input Output functions), and various other specialized circuits all in one package.[17]

The PIC16F877A features 256 bytes of EEPROM data memory, self-programming, an ICD, 2 Comparators, 8 channels of 10-bit Analog-to-Digital (A/D) converter, 2 capture/compare/PWM functions, the synchronous serial port can be configured as either 3-wire Serial Peripheral Interface or the 2-wire Inter-Integrated Circuit (I²C™) bus and a Universal Asynchronous Receiver Transmitter (USART). All of these features make it ideal for more advanced level A/D applications in automotive, industrial, appliances and consumer applications.

Memory of the PIC16F877 divided into 3 types of memories which are Program Memory, Data Memory and Data EEPROM (Electrically Erasable Programmable Read-Only Memory). Program Memory is a memory that contains the program (which we had written), after we've burned it. As a reminder, Program Counter executes commands stored in the program memory, one after the other.

Besides that, Data Memory is RAM memory type, which contains a special registers like SFR (Special Faction Register) and GPR (General Purpose Register). The variables that we store in the Data Memory during the program are deleted after we turn of the micro. These two memories have separated data buses, which makes the access to each one of them very easy. The Third type of memories is a memory that allows storing the variables as a result of burning the written program.

2.6.1 PIC16F877A Pin Diagram

PIC16F877A contains 40 pin, which every pins have its own function. Figure 2.13 have shown the pins diagram and its function of the PIC16F877A. Besides that, from the figure below, each of the pins contains not only one function. The pins of the PIC16F877A are multi-function, as show in the figure 2.13.

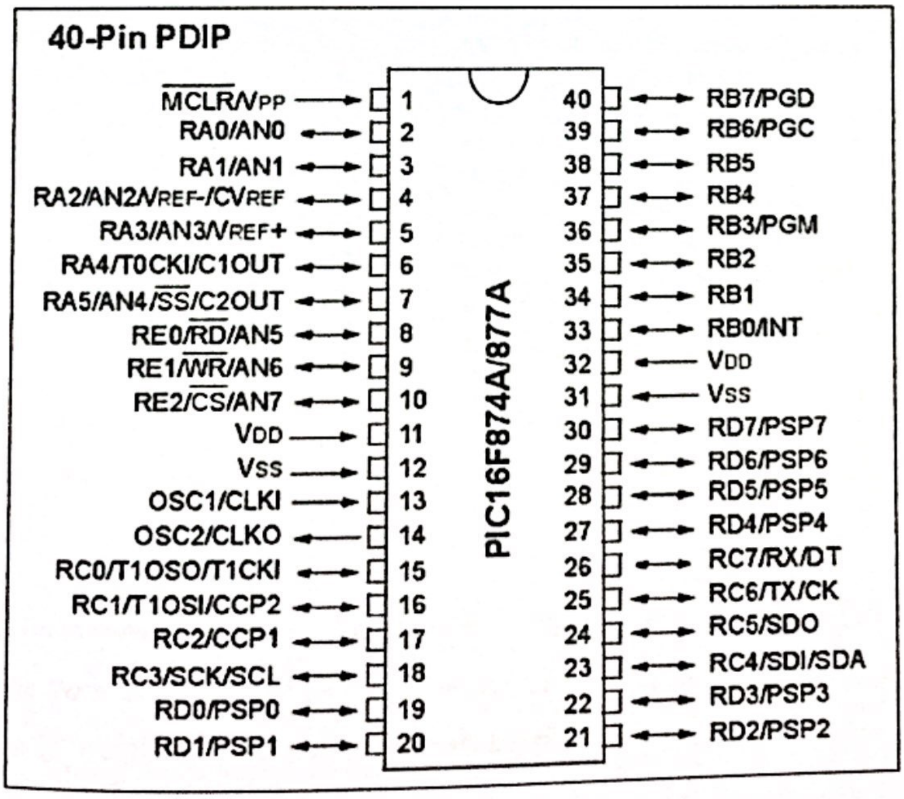


Figure 2.13: PIC16F877A Pins Diagram

These various pin functions cannot be used simultaneously, but can be changed at any point during operation. The table below have descripted every single function which contained in each of the pins.

Table 2.1: PIC16F877A Pin Assignment

Name	Number (DIP 40)	Function	Description
RE3/MCLR/Vpp	1	RE3	General purpose input Port E
		MCLR	Reset pin. Low logic level on this pin resets microcontroller.
		Vpp	Programming voltage
RA0/AN0/ULPWU/C12IN0-	2	RA0	General purpose I/O port A
		AN0	A/D Channel 0 input
		ULPWU	Stand-by mode deactivation input
		C12IN0-	Comparator C1 or C2 negative input
RA1/AN1/C12IN1-	3	RA1	General purpose I/O port A
		AN1	A/D Channel 1
		C12IN1-	Comparator C1 or C2 negative input
RA2/AN2/Vref-/CVref/C2IN+	4	RA2	General purpose I/O port A
		AN2	A/D Channel 2
		Vref-	A/D Negative Voltage Reference input
		CVref	Comparator Voltage Reference Output
		C2IN+	Comparator C2 Positive Input
RA3/AN3/Vref+/C1IN+	5	RA3	General purpose I/O port A
		AN3	A/D Channel 3
		Vref+	A/D Positive Voltage Reference Input
		C1IN+	Comparator C1 Positive Input
RA4/T0CKI/C1OUT	6	RA4	General purpose I/O port A
		T0CKI	Timer T0 Clock Input
		C1OUT	Comparator C1 Output
RA5/AN4/SS/C2OUT	7	RA5	General purpose I/O port A
		AN4	A/D Channel 4
		SS	SPI module Input (*Slave Select*)
		C2OUT	Comparator C2 Output
RE0/AN5	8	RE0	General purpose I/O port E
		AN5	A/D Channel 5
RE1/AN6	9	RE1	General purpose I/O port E
		AN6	A/D Channel 6
RE2/AN7	10	RE2	General purpose I/O port E
		AN7	A/D Channel 7
Vdd	11	+	Positive supply
Vss	12	-	Ground (GND)

Table 2.1 have shown the description of every single function from the Pin 1- Pin 12. From these various pin, every pins are contained more than one function except pin 11 and pin 12 which are function as positive supply and Ground (GND).

Table 2.2: cont. PIC16F877A Pin Assignment

Name	Number (DIP 40)	Function	Description
RA7/OSC1/CLKIN	13	RA7	General purpose I/O port A
		OSC1	Crystal Oscillator Input
		CLKIN	External Clock Input
RA6/OSC2/CLKOUT	14	OSC2	Crystal Oscillator Output
		CLKO	Fosc/4 Output
		RA6	General purpose I/O port A
RC0/T1OSO/T1CKI	15	RC0	General purpose I/O port C
		T1OSO	Timer T1 Oscillator Output
		T1CKI	Timer T1 Clock Input
RC1/T1OSO/T1CKI	16	RC1	General purpose I/O port C
		T1OSI	Timer T1 Oscillator Input
		CCP2	CCP1 and PWM1 module I/O
RC2/P1A/CCP1	17	RC2	General purpose I/O port C
		P1A	PWM Module Output
		CCP1	CCP1 and PWM1 module I/O
RC3/SCK/SCL	18	RC3	General purpose I/O port C
		SCK	MSSP module Clock I/O in SPI mode
		SCL	MSSP module Clock I/O in I^2C mode
RD0	19	RD0	General purpose I/O port D
RD1	20	RD1	General purpose I/O port D
RD2	21	RD2	General purpose I/O port D
RD3	22	RD3	General purpose I/O port D
RC4/SDI/SDA	23	RC4	General purpose I/O port A
		SDI	MSSP module *Data* input in SPI mode
		SDA	MSSP module *Data* I/O in I^2C mode
RC5/SDO	24	RC5	General purpose I/O port C
		SDO	MSSP module *Data* output in SPI mode
RC6/TX/CK	25	RC6	General purpose I/O port C
		TX	USART Asynchronous Output
		CK	USART Synchronous Clock
RC7/RX/DT	26	RC7	General purpose I/O port C
		RX	USART Asynchronous Input
		DT	USART Synchronous Data

Table 2.2 have descripted the Pin 13 until Pin 26, most of the pins are multi-function, except the Port D pins, which this 4 pins are only function as Input or Output.

Table 2.3: cont. PIC16F877A Pin Assignment

Name	Number (DIP 40)	Function	Description
RD4	27	RD4	General purpose I/O port D
RD5/P1B	28	RD5	General purpose I/O port D
		P1B	PWM Output
RD6/P1C	29	RD6	General purpose I/O port D
		P1C	PWM Output
RD7/P1D	30	RD7	General purpose I/O port D
		P1D	PWM Output
Vss	31	-	Ground (GND)
Vdd	32	+	Positive Supply
RB0/AN12/INT	33	RB0	General purpose I/O port B
		AN12	A/D Channel 12
		INT	External Interrupt
RB1/AN10/C12INT3-	34	RB1	General purpose I/O port B
		AN10	A/D Channel 10
		C12INT3-	Comparator C1 or C2 Negative Input
RB2/AN8	35	RB2	General purpose I/O port B
		AN8	A/D Channel 8
RB3/AN9/PGM/C12IN2-	36	RB3	General purpose I/O port B
		AN9	A/D Channel 9
		PGM	Programming enable pin
		C12IN2-	Comparator C1 or C2 Negative Input
RB4/AN11	37	RB4	General purpose I/O port B
		AN11	A/D Channel 11
RB5/AN13/T1G	38	RB5	General purpose I/O port B
		AN13	A/D Channel 13
		T1G	Timer T1 External Input
RB6/ICSPCLK	39	RB6	General purpose I/O port B
		ICSPCLK	Serial programming Clock
RB7/ICSPDAT	40	RB7	General purpose I/O port B
		ICSPDAT	Programming enable pin

From the table 2.3, its show the pin from 27 until the last pin which is the pins 40. From the table above, pins 31 and pin 32 are same function as the pin 11 and pin 12 which are function as positive supply and also Ground (GND). Refer the table above are needed before decided which pins are used and it can only function as follow the pins specific function.

2.6.2 Block Diagram of PIC

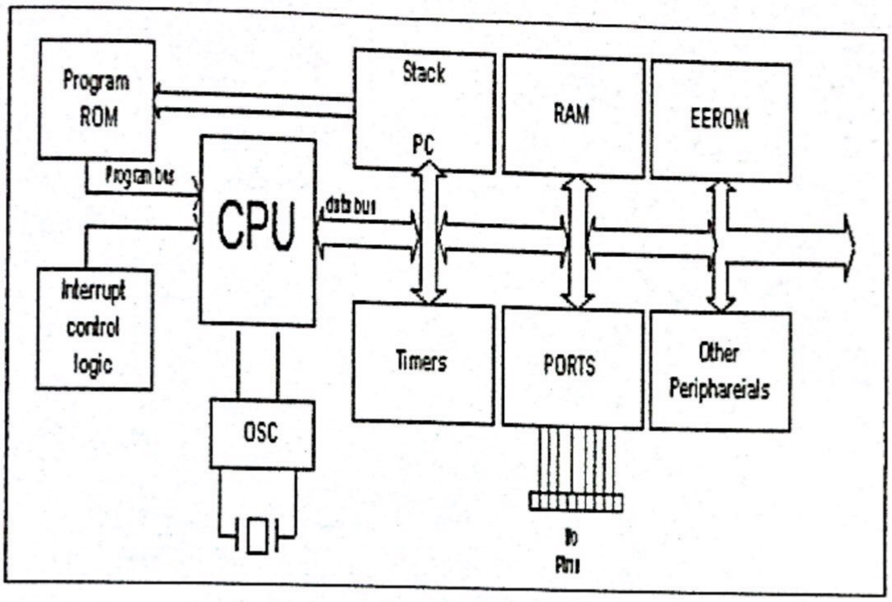


Figure 2.14: Block Diagram of PIC Microcontroller

PIC microcontrollers have a data memory bus of 8-bit and a program memory bus of 12, 14 or 16 bit length depending on the family. All PIC microcontrollers have a mix of different on-chip peripherals like A/D converters, Comparators, weak pull-ups, PWM modules, UARTs, Timers, SPI, I2C, USB, LCD, and CAN etc.

2.6.3 C Programming

C programming is a popular programming language used for creating system and application software. Despite being fairly old, it is widely used because of its efficiency and control. C is a general-purpose programming language, and is used for writing programs in many different domains, such as operating systems, numerical computing, graphical applications, etc. [18]

In order to run a C program a compiler is needed. Compiler change source code (code written by programmer) to object code (code that computer understands) and creates executable file. MPLAB IDE is software which can compile the C program, in order to change the source code to object code.

Figure 2.15: MPLAB IDE v8.56

C language is commonly used to program the PIC. Figure below are the example of C programming.

```
#include <stdio.h>

int main()
{
    int i;
    int a[10];
    printf("Enter student's scores: \n");
    for(i = 0; i < 10; i++) {
        scanf("%d", &a[i]);
    }
    printf("Your student's scores are: \n\n");
    for(i = 0; i < 10; i++) {
        printf("%d\n", a[i]);
    }
    return 0;
}
```

Figure 2.16: Example of C Programming

CHAPTER 3

METHODOLOGY

3.1 Introduction

This chapter is descripted and explained about the process and the method to implementing this study with successful. The detail explanations of the methodology are explained in this chapter such as the process of making the PCB board, Programming and so on.

3.2 Flow Chart

Flow Chart below had showed that the whole process to implementing this study and it has been descripted with detail explanation for every step of the process.

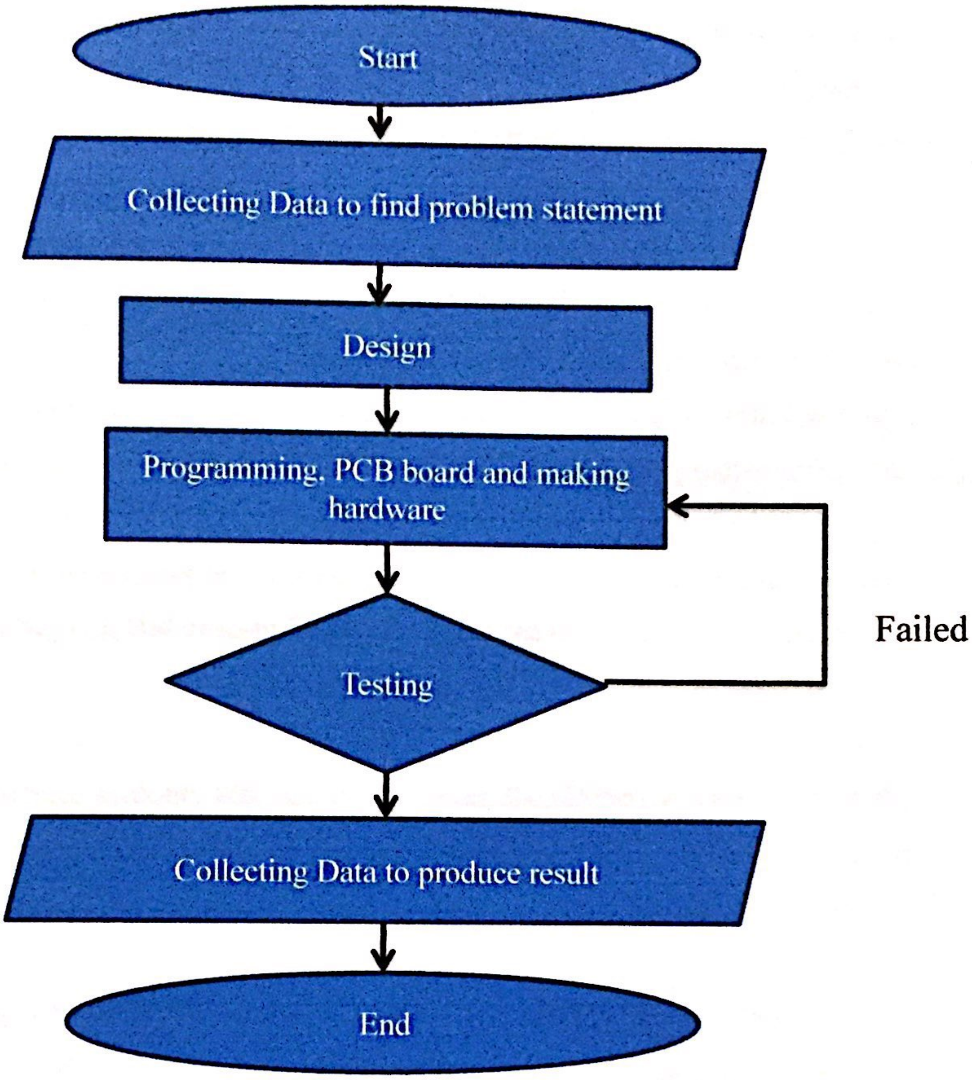


Figure 3.1: Flow Chart of Whole Project

To start this study, data collection was the first step of this study. To collect the data, the interview and attribute questionnaire (APPEDIX 1&2) to the physiotherapist and patients were performed. After that, evaluate the data that collected, then find and create the problems statement.

After problems statement was created, design the shape and the device. Design the elbow joint rehabilitation devices/machine to overcome the problems. Design the suitable shape of the device according the problems statements. Determine the suitable materials, hardware or software that will be use. Planned the software that suitable used to control a motor driver is Peripheral Interface Controller (PIC), because it provides almost all of the many features found in microcontrollers that are made by the many suppliers of these small yet comprehensive logic engines. This use offers advantages such as lower voltage drop when turn on and the ability to control motors [19]. Besides that, DC geared motor was used in this study, because it variously used in the industrial and widely used in robotics, used to control the movement of a robots.

Follow with the step of Programming, making PCB board and hardware. During this process, we will create a PCB board which the electronic part of the device. During the process of making PCB board, programming can be launch simultaneously. Peripheral Interface Controller (PIC16F877A) used to store the programming, and control the devices/machine. PICs are act as a CPU in this device, and it used to control the motor movement in forward and reversed according the human settings. Besides that, designing and making the hardware for the devices/machine also can be executing.

When the hardware is done, test the Elbow Joint Rehabilitation Device. Test the device, ensure the device is functioning and working in good and safe aspect. (If testing failed, return to the step before, redo the process, testing again the devices).

Last step of the whole project process is testing and collect data. Test the device on 30 subjects (20 public and 10 stroke patients) for the clinical testing and usability testing. Then, collect the data from patient by distribute questionnaire and analysis the data by using SPSS. Discuss and conclude the result that had analysed.

3.3 Printed Circuit Board (PCB)

A printed circuit board (PCB) is the board base for physically supporting and wiring the surface-mounted and socketed components in most electronics. PCBs can be single sided (one copper layer), double sided (two copper layers) or multi-layer (outer and inner layers). Conductors on different layers are connected with vies. Multi-layer PCBs allow for much higher component density. For this study, the single sided (one copper layer) have used, because the schematics diagram for this study is not huge and complicated, so single sided PCBs is suitable to be used.

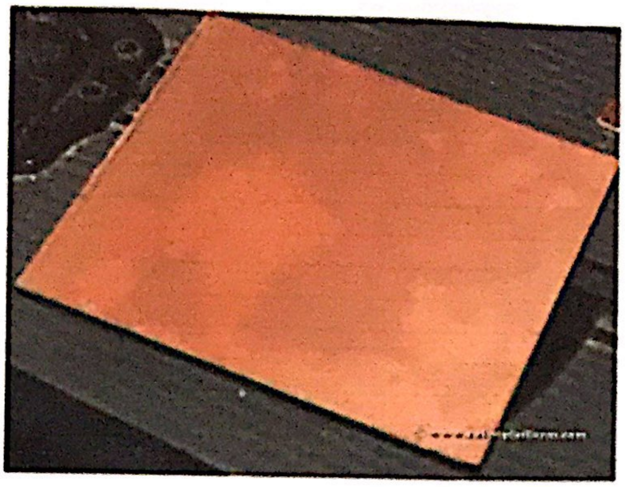


Figure 3.2: Printed Circuit Board (PCBs)

3.2.1 The process of making PCB

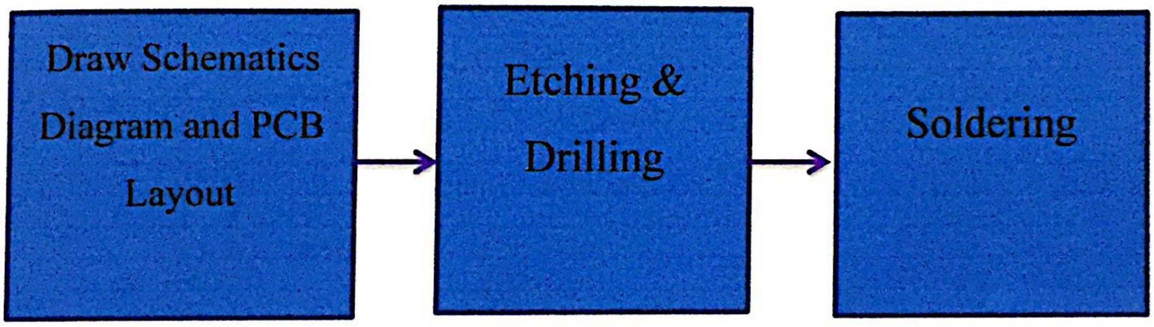


Figure 3.3: Block Diagram of Process Making PCBs

First step, draw the schematics diagram by using Eagle6.0, after the schematics have done, in the file menu, there's a "Switch to board" selection. Click on it to create the PCB layout. Once the layout had done, print the layout onto a glossy paper.

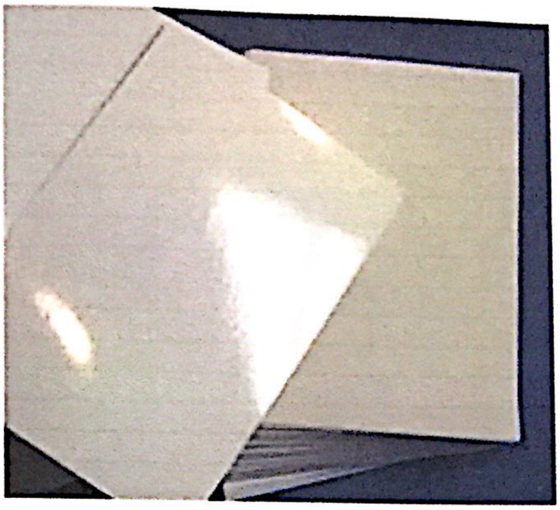


Figure 3.4: Glossy Paper

After that, faced the printed sides of the glossy paper to the Board, then iron it until the PCB layout have transfer onto the Board. Iron Process, which using heat of the iron, to transfer the toner from the glossy paper into the PCBs.

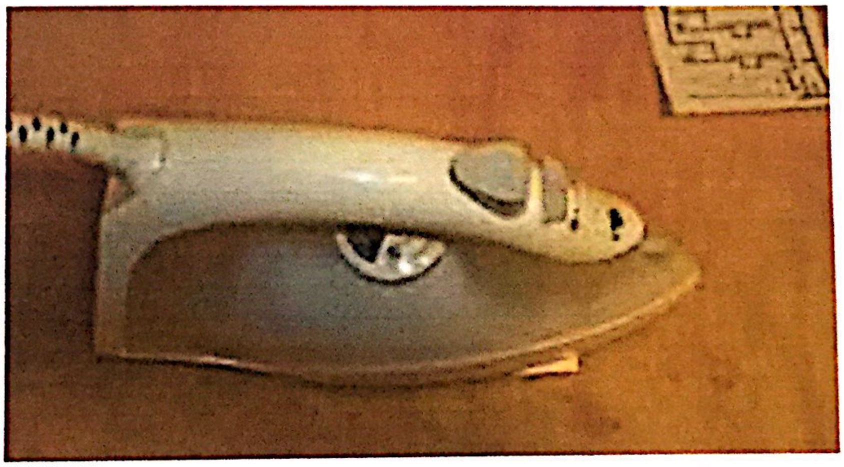


Figure 3.5: Iron process

Proceed to the next step which is etching and drilling process. During the etching process, ferric chloride has used to remove the unused copper on the board.

Figure 3.6: Ferric Chloride Powder

First, puts the ferric chloride into the warm water (warm water help to remove the copper more fast than cold water), then put the board with printed PCB layout into the water. Shaking will help to remove the copper more fasts. Once the unused copper had removed, proceed to the drilling step.

After the drilling process has done, place the components according the PCB layout diagram. Make sure the components have place with the right position and also with the right polarity. After that, solder by using soldering iron and solder lead.

3.4 Programming

PIC16F877A was decided to uses in this project, because it had 256 bytes of EEPROM Memory, which the memory that load into the PIC can be erased and rewrote easily. PIC microcontrollers act as a CPU, which control all the activities of the board and also the movement of the devices. So to program the PIC, C languages has used to program the PIC. The process of programming shown as the diagram below:

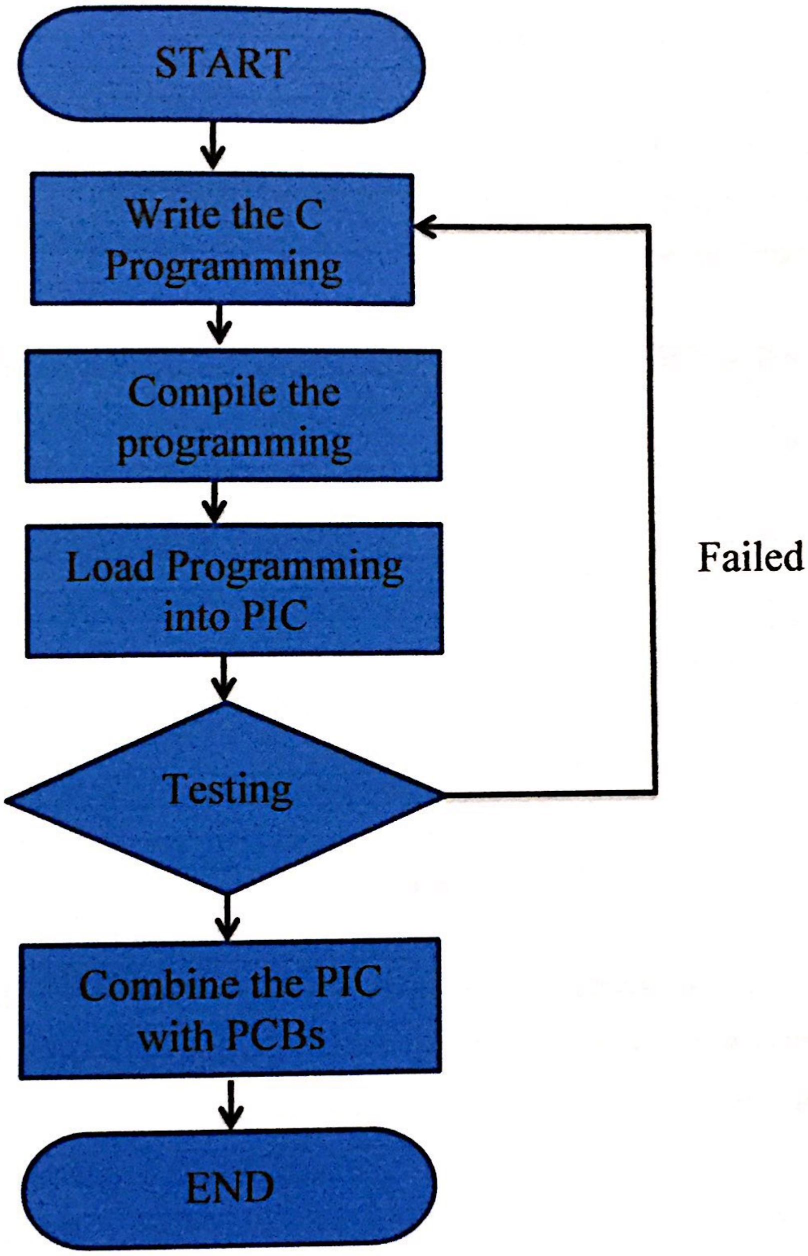


Figure 3.7: Process of Programming

To program the PIC, MPLAB IDE v8.56 was used to execute the programming. First, open the MPLAB, and then create a new project by clicking on 'Project Wizard'. During the creating of a new project, identify the model of PIC that will be used which is PIC16F877A. After created the new project, begin write the programming. The programming codes are wrote in C languages, which because it is easy to be understand by human, so that C languages was chose to be used.

Compile the programming code that have wrote by click on 'Build All' which to checking the code completely non error to be loaded into the PIC. If there is error occur, identify the error and corrected the error. After that, compile the programming again, and make sure there is no error occur. And then, load the programming into PIC by using PIC Programmer Kit. PIC Programmer Kit is shown in the figure below.

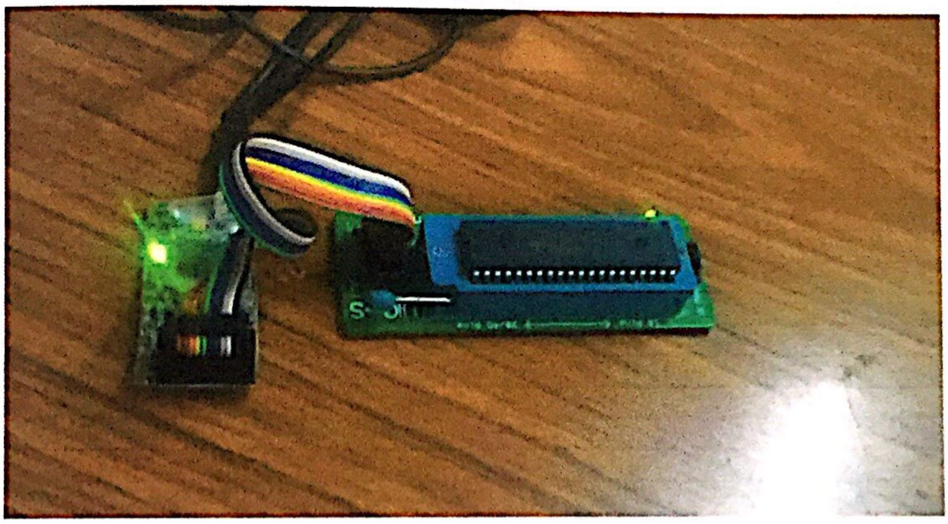


Figure 3.8: PIC Programmer Kit

After the programming have load into the PIC16F877A, attached the PIC into the PCB boards that have done, and connected with the motor and batteries for testing the programming. If the output testing is not the desired output which means testing failed. Return to the step of writing programming, execute the programming and load the programming into PIC16F877A, then re-testing the programming. If no failed, attached the PIC into the PCBs then proceed to the data collection.

3.5 Hardware

Hardware of the project has used AutoCAD 2015 to draw the design of the device that had developed. AutoCAD is used across a wide range of industries, by architects, project managers, engineers, graphic designers, and other professionals. It is software application for 2D and 3D computer-aided design (CAD) and drafting.

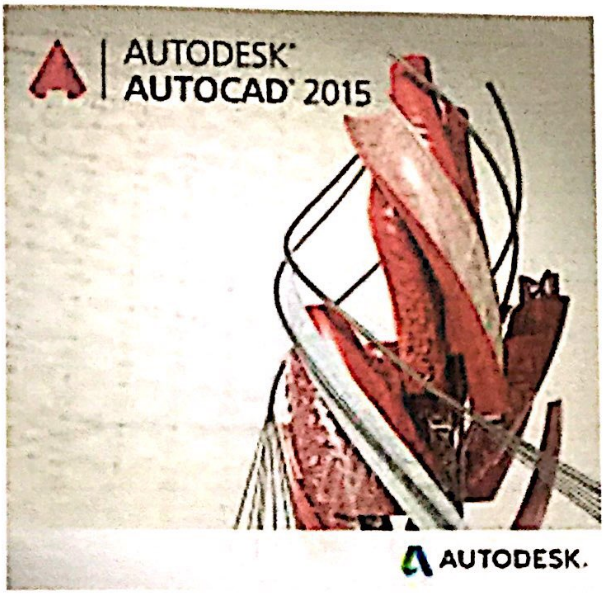


Figure 3.9: AUTOCAD 2015

The Hardware of the device was used two materials to make it which are Aluminium and also Acrylic. The device was planned made in fully aluminium, due to limited time, so the Acrylic have used in the half of the design.

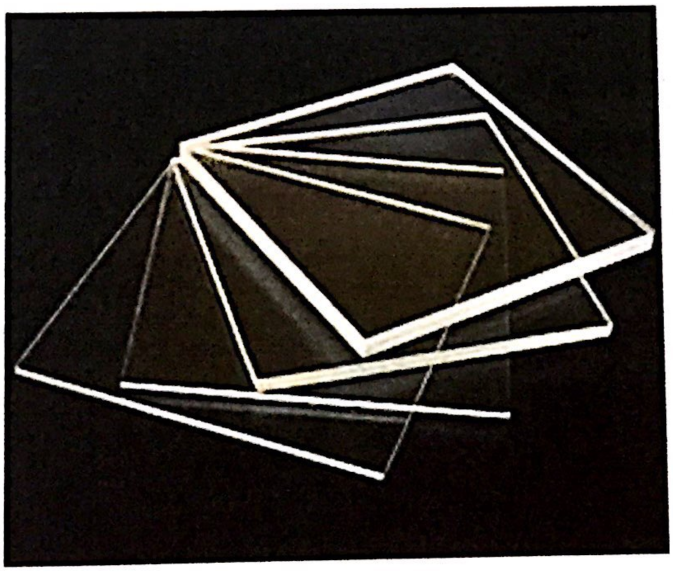


Figure 3.10: Acrylic

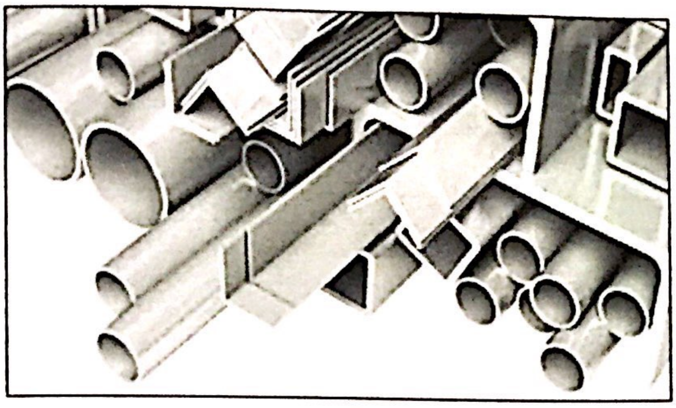


Figure 3.11: Aluminium

Besides that, the application of screw jack was also apply in this project, which it used as mechanical lifting. The DC geared motor was use to rotate the screw, and a nut will moves along the screw. When the motor move forward, the screw will rotate in clockwise, and the nut will moving forward to the motor, at this situation the nut is moving the forearm upward. So when the motor move reverse, the nut will moving reverse from the motor, which the nut will pull the forearm downward. The lifting nut of jack screw is used to decrease friction.

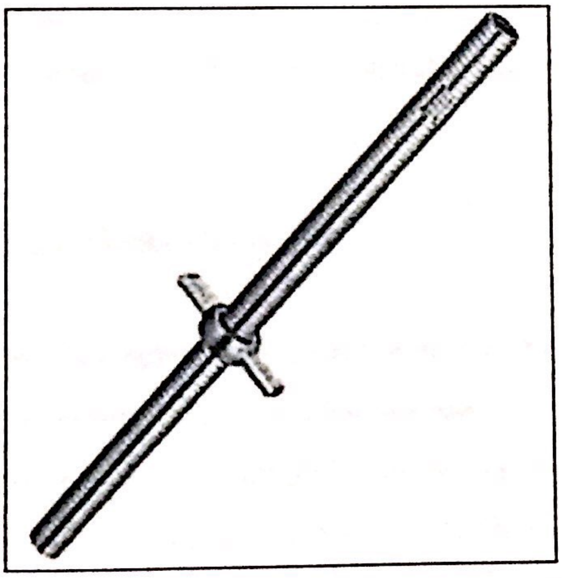


Figure 3.12: Screw Jack

CHAPTER 4

RESULT AND DISCUSSION

4.1 Introduction

This chapter shown the result from our collected data such as questionnaire and the data is analysed and generated graph by using Microsoft Excel. And then the result that analysed is discussed in this chapter.

4.2 Elbow Joint Rehabilitation Device

The figure 4.1 below is the Elbow Joint Rehabilitation Device that has developed. This device provided 5 degree selections which are 10°, 20°, 30°,50°and 70°. Besides that, this Elbow Joint Rehabilitation device also have count setting, which used to set the number of count the device move upward and downward, the maximum number of count can be set are 50 count. This device have two levels selection which the level 1 has provided 10 degree movement, and the level 2 has provided 20°,30°,50° and 70° movement.

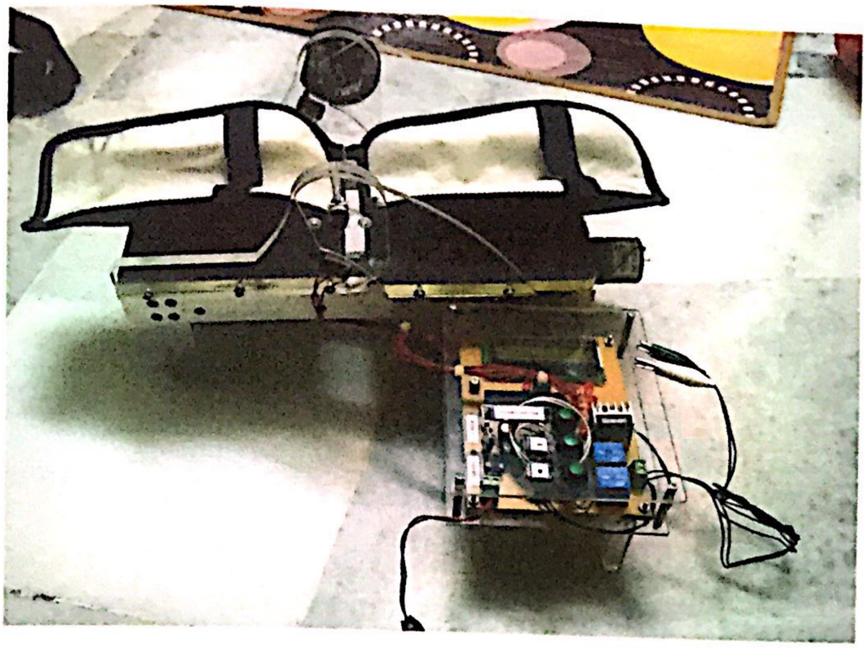


Figure 4.1 Elbow Joint Rehabilitation Device

Furthermore, this developed device has an easy installation, which the devices only need to install the DC rechargeable batteries before implement the treatment. Compared with the exiting devices, the exiting devices have a complex of installation before provided the treatment, which it needs to connect the hand placement pads with the devices and the device also need to operate with the provided stand. But this devices need not to operate with a stands and it have a simple installation.

This developed Elbow Joint Rehabilitation Device has two main parts, which are control panel and the Hand placement pads. The control panel contained reset button, ON/OFF button, increase button, decrease button, Enter button and LCD displays. This Elbow Joint device used two batteries to operate the device which are 9V batteries and 12V DC rechargeable batteries. The 12 DC batteries used to control the DC geared motor movement and the 9V batteries used to power up the control panel and provided the power to the LCD displays.

4.2.1 Structure of Elbow Joint Rehabilitation Device

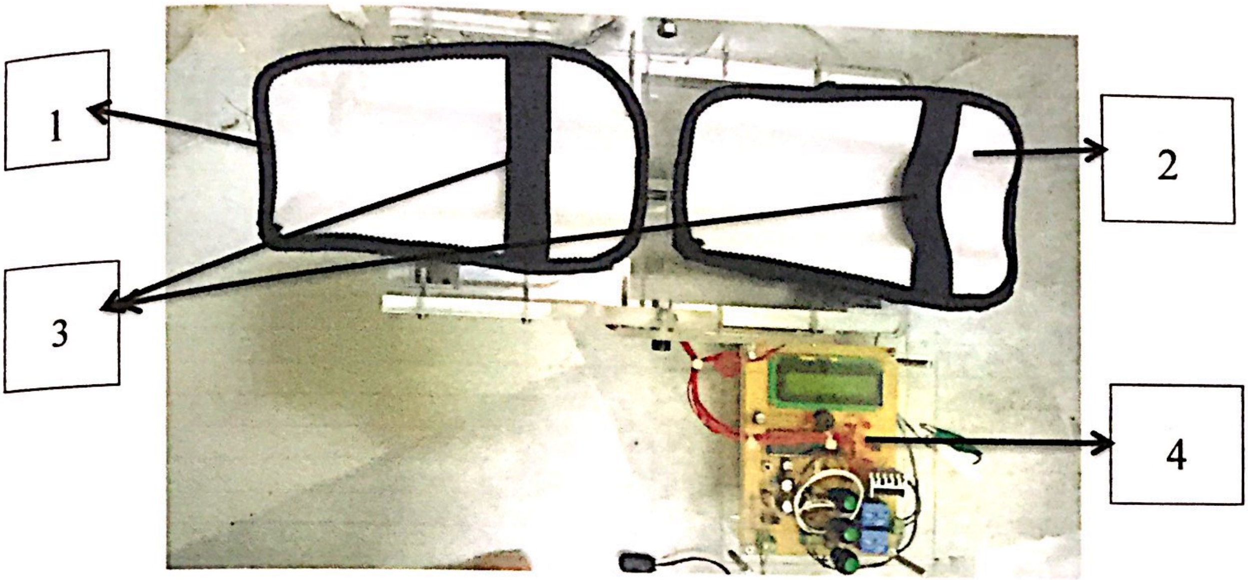


Figure 4.2: Elbow Joint Rehabilitation Device (Top View)

Figures 4.2 had shown the top view of the Elbow Joint Rehabilitation Device, and the Table 4.1 shown the function of each part of the device.

Table 4.1: Function of the Parts of Device

NO	PARTS	FUNCTION
1	Arm Pad	Placement of Arm
2	Forearm Pad	Placement of Forearm
3	Arm & Forearm Straps	Tighten the Arm & Forearm
4	Control Panel	Setting and Control the Device

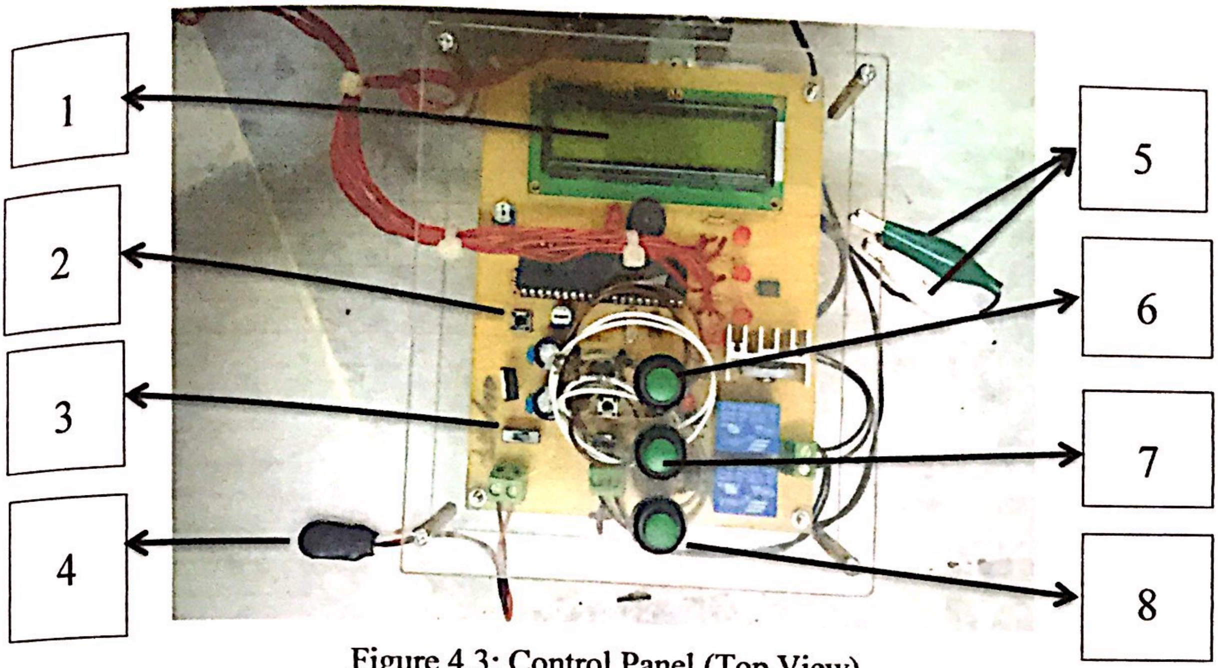


Figure 4.3: Control Panel (Top View)

Figure 4.3 had shown the top view of the control panel and table 4.2 had shown that the Function of the Parts of control panel.

Table 4.2: Function of control panel

NO	PARTS	FUNCTION
1	LCD Displays	Display the number of count
2	Reset	Reset the Device's settings
3	Power Switch (ON/OFF)	ON and OFF the device
4	9V Batteries Connector	Connect with the 9V batteries
5	12V Batteries Connector	Connect with the 12V batteries
6	Enter/ Start	Start the Device
7	Decrease	Decrease the number of count/
8	Increase	Increase the number of count

4.3 Usability test

During this usability testing, 20 normal subjects were tested, and questionnaires were distributed to them. Usability testing have consists of 4 main items which are Comfortability, Strengthens, Speed and Design. These 4 main items data was collected through the usability test, which the subject have tested the developed Elbow Joint Rehabilitation Device, then answered questionnaire.

4.3.1 Comfortability

The data of comfortability about the developed devices was takes. 5 questions are consisted in this part, below is the table of the comfortability.

Table 4.3: Data of Comfortability

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	SLIGHTLY AGREE	STRONGLY AGREE
MY HAND WAS PLACE COMFORTABLE WHILE USING THE MACHINE	0	1	2	1	6
HAND CAN EASILY FIT INTO THE MACHINE	0	1	2	6	11
THIS DEVICE IS EASY TO USE/ EASY TO HANDLE	0	0	2	6	12
THE STRAP IS HARD TO TIGHT UP THE HAND	2	4	1	7	6
THE DEVICE IS STABLE/ LESS MOVING WHILE OPERATING	0	1	2	8	9

From the table above, the graph is generated by the Microsoft Excel, and the graph is shown in the figure 4.1.

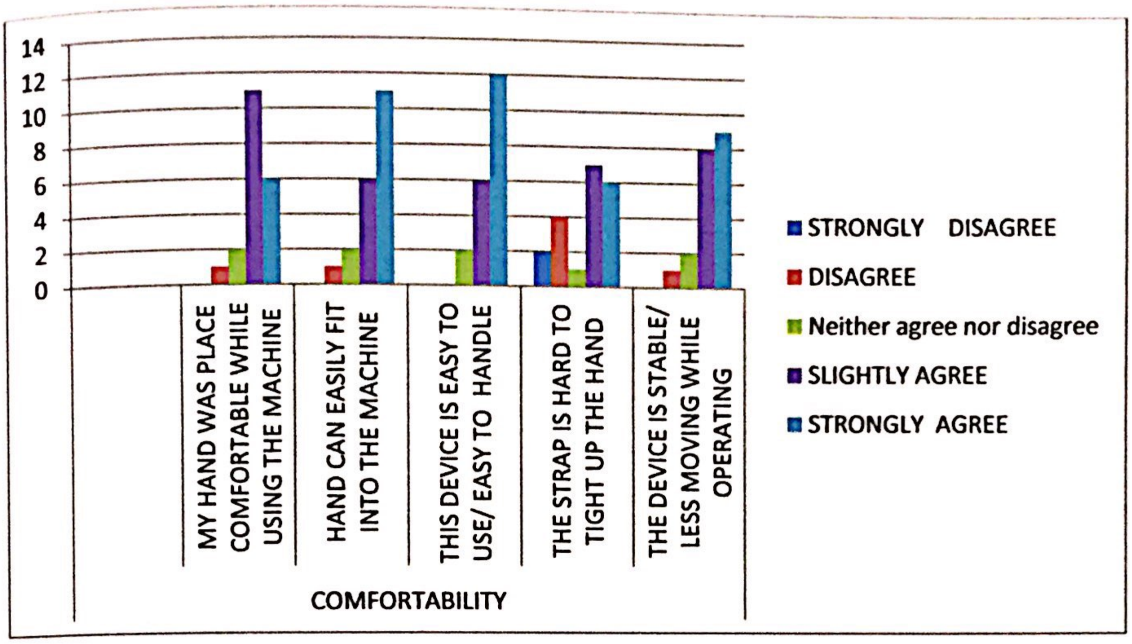


Figure 4.4: Graph of the Comfortability

From the figure 4.4, 11 subjects are slightly agree that their hand was placed comfortable, 6 subjects are strongly agree with that, and only 1 subject is disagree with it. After that, 11 subjects were strongly agreed that their hand can easily fit into the machine, 6 subjects slightly agreed with it and only 1 subject was disagreed.

According the third question, 12 subjects were strongly agreed that the device is easy to be used, 6 subjects were slightly agreed with it, 2 of the subjects were neither agree nor disagree and none of them disagree with it.

Besides that, 9 subjects were strongly agreed that the device is stable and less moving while operating, and 8 subjects were slightly agreed with the statement. 2 subjects were neither agreed nor disagreed, and only 1 of the subject was disagreed that the device is less moving while operating.

More than 10 of the subject think that the strap of the device is hard to be tight up, which we can see from the graph, there are 6 subjects strongly agreed and 7 subjects slightly agreed that the strap is hard to be tightening up their hands. But 6 of the subjects aren't agreed with the statement.

4.3.2 Strengthens

The table 4.4 have shown the data about the strengthened of the developed Elbow Joint Rehabilitation Device.

Table 4.4: Data of Strengthens

	STRONGLY DIASGREE	**DISAGREE**	**EITHER AGREE NOR DIAGREE**	**SLIGHTLY AGREE**	**STRONGLY AGREE**
THE DEVICE ABLE TO MOVE MY HAND UPWARD AND DOWNWARD	0	0	1	7	12
THE MOVEMENT OF THE DEVICE IS SMOOTH/ STABLE	0	0	4	11	5

The second main items Strengthens, which consists of 2 questions which are about the ability of the device moves the hand and the stability of the movements. Figure 4.2 have shown the graph of the feedback about the ability of the device moves the hand and the stability of the movements.

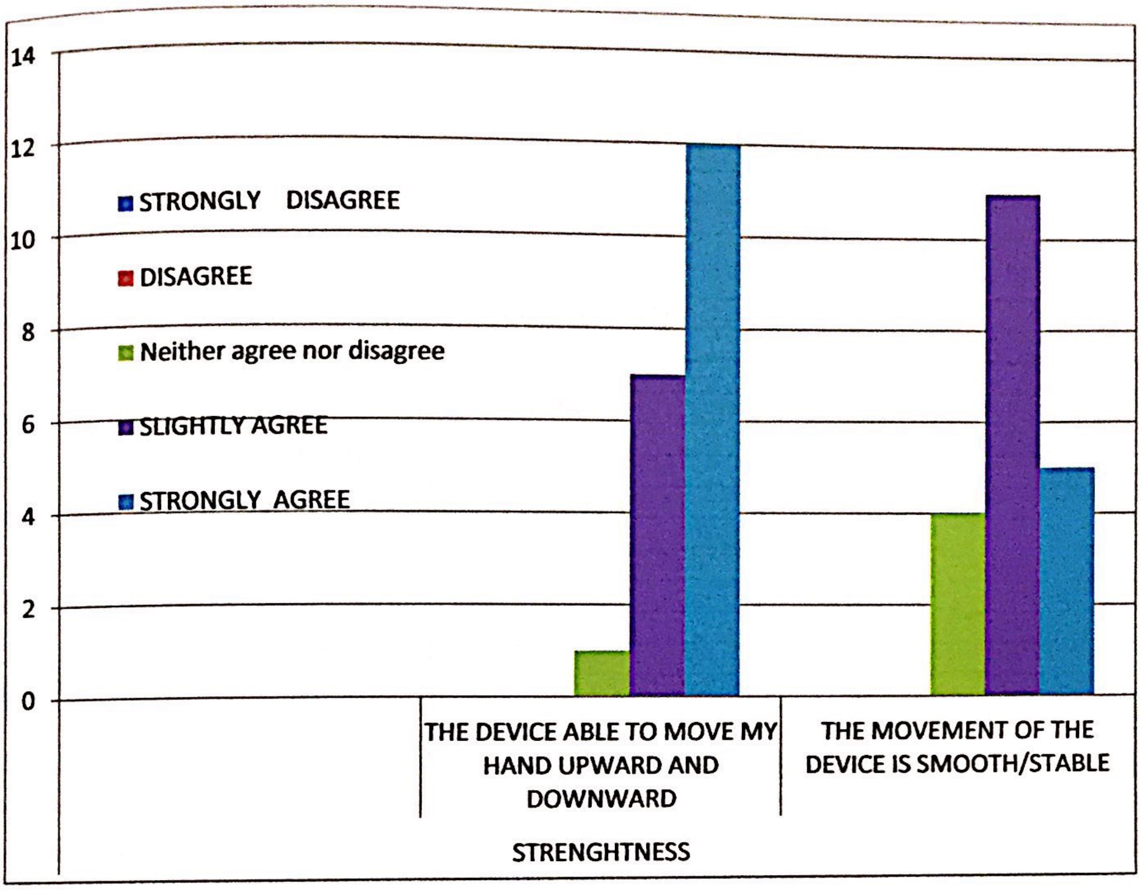


Figure 4.5: Graph of the Strengthens

From the figure 4.5, there were 12 subjects strongly agreed that the devices able to move the hands upward and downwards, 7 subjects were also slightly agreed with the statement, and 1 only subject was neither agreed nor disagreed with this statement.

The second question of this part which is about the stability of the movement, and there are 5 subjects strongly agreed that the upward and downward movement is stable. 11 subjects were slightly agreed with the statement, 4 of the subjects were neither agreed nor disagreed, and there were none of the subject disagreed or strongly disagreed the statement.

4.3.3 Speed

Speed is the third main item that was tested in the usability testing. This part consists of 3 questions. The table 4.3 below have shown the data of speed.

Table 4.5: Data of Speed

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	SLIGHTLY AGREE	STRONGLY AGREE
THE SPEED CAN BE SELECTED EASILY	0	1	3	6	10
THE SPEED OF OPERATION IS SUITABLE FOR STROKE PATIENTS	0	1	1	8	10
THE HIGH SPEED DOES NOT MAKE MY HAND FEELS UNCOMFORTABLE	0	1	3	9	7

According the table 4.5 above the data was generated a graph by using Microsoft Excel, and the graph has shown in the figure 4.6 below.

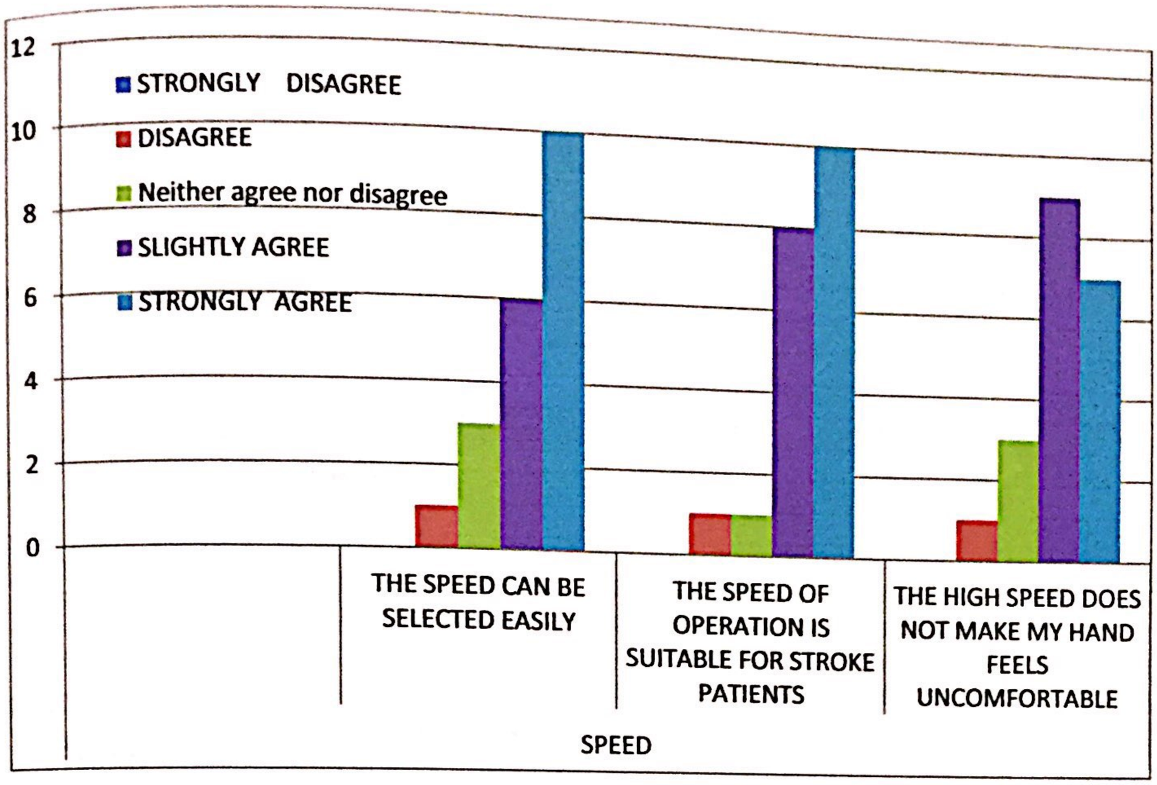


Figure 4.6: Graph of Speed

From the figure 4.6 above, 10 subjects were strongly agreed that the speed of the device can be selected easily. Besides that, 6 of the subjects also slightly agreed with it, and 3 subjects were neither agreed nor disagreed. Only 1 subject was disagreed with it.

The speed of the device is suitable to be used by stroke patients, which there were 10 of the subjects strongly agreed with it. 8 of the subjects also slightly agreed that the speed suitable to be used on stroke patients. And there were an equal subject chose neither agreed nor disagreed and disagreed that the speed suitable for the stroke patients.

The higher speed of the device does not make the user hands uncomfortable, which 7 subject strongly agreed and 9 subjects were slightly agreed with it. And only 1 subject was thinks that the higher speed of the device make his/her hands uncomfortable.

4.3.4 Design

The last main items are Design of the developed device. The table 4.6 below shows the data collected from 20 subjects.

Table 4.6: Data of Design

	STRONGLY DISAGREE	DISAGREE	NEITHER AGREE NOR DISAGREE	SLIGHTLY AGREE	STRONGLY AGREE
THE DESIGN IS SUITABLE TO BE USE IN EVERYWHERE	0	1	3	6	10
THE DESIGN IS LIGHT IN WEIGHT	0	2	3	7	8
THE DESIGN IS EASILY TO BE CARRIED	0	0	4	6	10

From the table 4.6 above shows the data of design, the data was collected and generated or analysis by using Microsoft Excel. And the graph has shown in the figure 4.7 below.

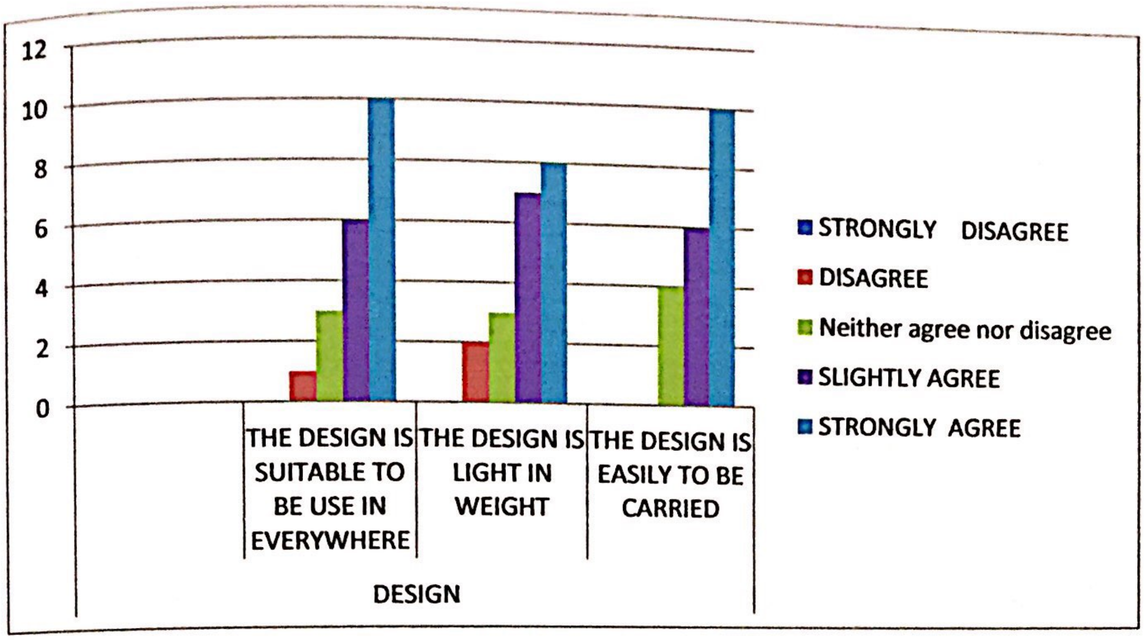


Figure 4.7: Graph of Design

The figure 4.7 has shown the data of design which it collected the data about the design of the developed device. From this design items, there consists of 3 questions. From the 20 subjects, there were 10 subject strongly agreed that the design of the device are suitable used in everywhere, and there were also 6 subjects slightly agreed with it. 3 subjects neither agreed nor disagreed and only 1 subject was disagreed that the design suitable uses in everywhere.

After that, there were 8 of the subjects strongly agreed that the design is light in weight, and 7 subject were also slightly agreed with it. Besides that, there were only 3 subject neither agreed nor disagreed, and only 2 subject disagreed with the statement.

Lastly, the design is easily to be carried were strongly agreed by 10 subjects, and 6 subjects also slightly agreed with the statement. And there were only 4 subjects neither agreed nor disagreed with the statement, and none of the subject disagreed that.

4.4 Technical testing

Technical testing had done in this device, which I've done technical testing to compares, the time of consumption with the difference angle of the movement and the speed. The table 4.7 below have shown that the result Consumption of Time between difference of angle with Difference of Speed.

Table 4.7: Consumption of Time between difference of angle with Difference of Speed

Angle	speed 1	speed 2	speed 3
0°	0s	0s	0s
10°	53s	33s	20s
20°	65s	40s	24s
30°	90s	55s	33s
50°	121s	75s	45s
70°	188s	116s	70s

From the table 4.7 above, the result are analyses and generated a comparison graph by using Microsoft Excel. The result is generated and created a graph as shown as the figure 4.6 below.

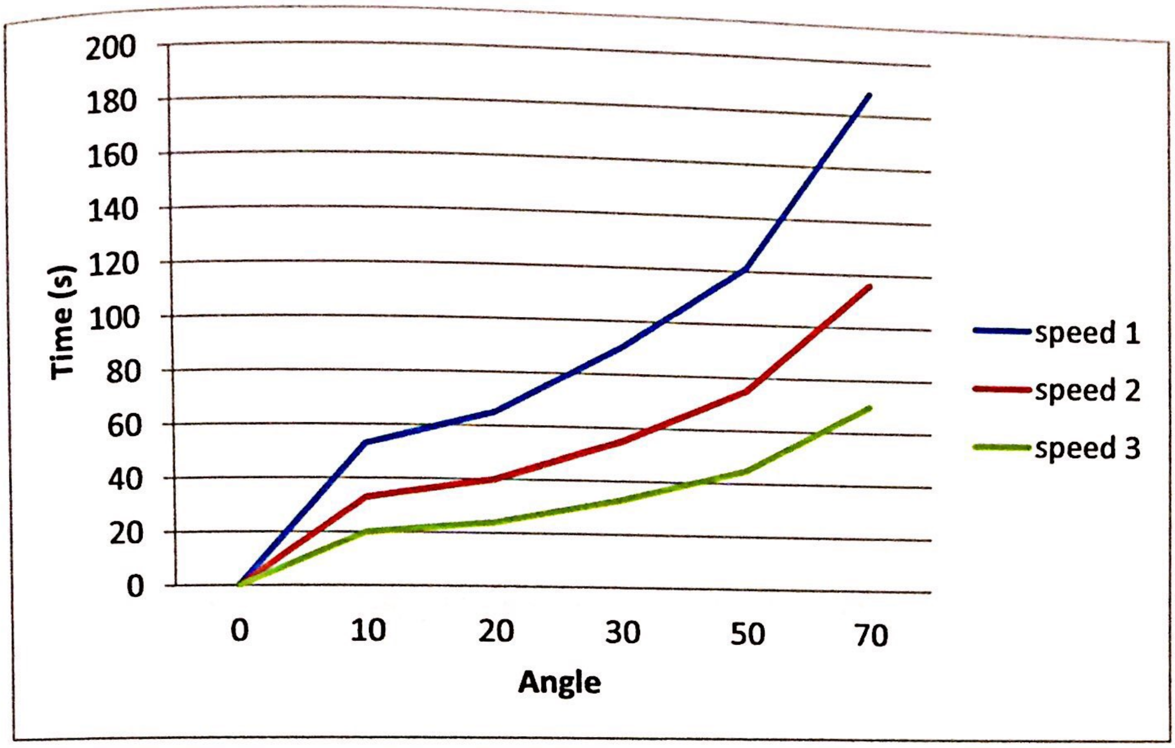


Figure 4.8: Graph of Consumption of time between Difference Angle with Difference of Speed.

From the figure 4.8 above, it have shown that the consumption of time between difference of angle with difference of speed. From the graph, we can see that the slower speed 'Speed 1' need more consumption of time to completed one cycle compared with 'Speed2' and 'Speed 3'. For examples, the time consumption in 70 degree of angle of movement for the 'Speed 1' is 188 second, 'Speed 2' is 116 second and for the 'Speed 3' is 70 second, from the result, can concluded that, the slower the speed, the higher the consumption of time need to completed one cycle.

Besides that, from the graph above can concluded that the higher the angle of movement, the more of time consumption. Which the higher the angle of movement, the higher the time taken to completed one cycle of movement. For an example, the 70 degree angle of movement needed the most higher time consumption compared with the 10,20,30and 50 degree of movement, which the 70 degree of movement need 188 second to completed one cycle of movement.

CHAPTER 5

CONCLUSION AND RECOMMENDATION

5.1 Conclusion

As a conclusion, the Elbow Joint Rehabilitation Device is developed, and it have achieved the objective, which the primary objective is to develop a lightly and hand ability elbow joint rehabilitation device for stroke patients. The second objective is to design the control speed circuit for guiding continuous passive motion exerciser and able to operating in a rechargeable batteries.

A usability test was done, 20 normal subjects was used to measure the comfortability, strengthens, Speed and also Design of the device. During this test, the device was tested on the willingly of the 20 subjects, and the data was collected by distributed questionnaire. Once the testing was done, the data will be analysis by using Microsoft Excel. And the result finding that, the developed device is comfortable to be used. Besides that, it is also well operating with less moving. Furthermore, the developed device is operating in DC batteries, and it was able to move the subject's forearm upward and downward.

5.2 Recommendation

Recommendation of the physiotherapist from Hospital SALAM for this Elbow Joint Rehabilitation Device which is the noise of the device should be reduced, and also recommend the angle of the device moving upward should be increased minimum 90 degree.

Besides that, there is some recommendation from the 20 subjects, which the common comment of the device is the device too much noise while operating. And this problem will be solved for the future research or study.

REFERENCE

[1] U. N. Yusoff, D. Mahat, A. Omar, T. C. Huey, and N. Yoep, "Burden of Premature Mortality in Malaysia," vol. 3, no. 1, 2013.

[2] L. D. Schelosky and J. Scott, "Early development of spasticity following stroke : a prospective , observational trial," *J Neurol*, pp. 1067–1072, 2010.

[3] K. Kang, P. Chin, J. Hua, H. Abdul, Y. Che, A. Leela, T. Narayanan, E. Su, and L. Ming, "Jurnal Teknologi Full paper Development of Reconfigurable Rehabilitation Robot for Post-stroke Forearm and Wrist Training," vol. 2, pp. 79–83, 2015.

[4] K. Xing, Q. Xu, J. He, Y. Wang, Z. Liu, and X. Huang, "A wearable device for repetitive hand therapy," *Proc. 2nd Bienn. IEEE/RAS-EMBS Int. Conf. Biomed. Robot. Biomechatronics, BioRob 2008*, pp. 919–923, 2008.

[5] E. Schuster, "Elbow Passive Motion Rehabilitation Utilizing a Continuous Passive Motion Device following Surgical Release, Manipulation Under Anesthesia, or Post Stable Fracture: A Review," *Kinex Med.*, p. 24, 2006.

[6] F. Malagelada, B. Health, N. H. S. Trust, and J. V. Etzelclinic, "Elbow Anatomy," no. JANUARY, 2014.

[7] P. Rogram, "Jurnal Teknologi P ART - TASK T RAINER IN S IMULATED L EARNING," vol. 4, pp. 71–76, 2015.

[8] S. Advocacy and A. S. R. Guide, "A Stroke Recovery Guide," 2010.

[9] L. A. C. Carolyn Kisner, *Therapeutic Exercise Foundations and Techniques Sixth Edition*. 2012.

[10] J. M. Krumberger, *Continuous Passive Motion (CPM) Machine*, vol. 67. 2004, p. 28ac1.

[11] R. E. D. Evice, "MODEL-BASED SYSTEMS ENGINEERING OF A HAND REHABILITATION DEVICE," *J. Teknol.*, vol. 4, pp. 101–106, 2015.

[12] S. W. O'Driscoll and N. J. Giori, "Continuous passive motion (CPM): theory and principles of clinical application.," *J. Rehabil. Res. Dev.*, vol. 37, no. 2, pp. 179–88, 2000.

[13] J. R. Andrews, G. L. Harrelson, and K. E. Wilk, *Physical Rehabilitation of the Injured Athlete*. Elsevier Health Sciences, 2012.

[14] L. Q. Zhang, H. S. Park, and Y. Ren, "Developing an intelligent robotic arm for stroke rehabilitation," *2007 IEEE 10th Int. Conf. Rehabil. Robot. ICORR'07*, vol. 00, no. c, pp. 984–993, 2007.

[15] J. S. Chauhan and S. Semwal, "Microcontroller Based Speed Control of DC Geared Motor Through RS-232 Interface With PC," vol. 3, no. 1, pp. 778–783, 2013.

[16] M. Aboelhassan, "Speed Control of Dc Motor Using Combined," *Control*, vol. 1, no. 2, pp. 2–6.

[17] R. R. Ambadas and R. P. Chaudhari, "PIC Microcontroller Universal Board," *Int. J. Innov. Technol. Explor. Eng.*, vol. Volume-3, no. 7, pp. 120–122, 2013.

[18] T. Bailey, *An Introduction to the C Programming Language and Software Design*. 2003.

[19] G. Madhusudhanarao, B. V Sankerram, B. S. Kumar, and K. V. Kumar, "Speed Control of BLDC Motor Using DSP," vol. 2, no. 3, pp. 143–147, 2010.

```
#define sw1    PORTE.F0
#define sw2    PORTE.F1
#define sw3    PORTE.F2

#define motor_fw PORTD.F0
#define motor_rw PORTD.F1

#define limit    PORTD.F2
#define limit1    PORTD.F3
#define limit2    PORTD.F4

#define buzzer   PORTD.F5
#define relay    PORTE.F0
#define sec_flag             flag.F0

char flag;
unsigned int minit;
char msec,sec,minutes,hour;
char txt[10];
char count;
char speed;
char level;
char angle;

void set_speed(void);
void set_count(void);
void set_level(void);
void update_status(void);
void forward(void)
{
motor_fw=1;
motor_rw=0:
```

```
}
void reverse(void)
{
 motor_fw=0;
 motor_rw=1;
}
void stop(void)
{
 motor_fw=0;
 motor_rw=0;
}


void interrupt(){

  if (INTCON.T0IF){
   asm{clrwdt}
   msec++;
   if (msec >61){
   msec = 0;
   sec++;
   sec_flag=1;
   if (sec >=60){
    sec = 0;
    minutes++;
    if (minutes >=60){
    minutes = 0;
     hour++;
     if (hour >=24){
       hour = 0;
        }
      }
```

```
    }
   }
  }
  TMR0 = 4;
  INTCON = 0x20; // Set T0IE, clear T0IF
}

void beep()
{
 buzzer=1;
 delay_ms(100);
 buzzer=0;
 delay_ms(100);
}

void main(void)
{
 ADCON1=0x82;
 TRISA=0xFF;
 TRISB=0x00;
 TRISC=0b00000000;
 TRISD=0b00011100;
 TRISE=0x03;
 OPTION_REG = 0b00000110;
 INTCON = 0xA0; // Enable TMRO interrupt
 PORTA=PORTB=PORTC=PORTD=PORTE=0x00;
 LCD_Config(&PORTB,4,5,6,3,2,1,0);
 Lcd_Init(&PORTB);                    // Lcd_Init_EP4, see Autocomplete
 LCD_Cmd(LCD_CURSOR_OFF);             // send command to LCD (cursor off)
 LCD_Cmd(LCD_CLEAR);                  // send command  to LCD (clear LCD)
 Lcd_Out(1,1, " Elbow Joint ");
 Lcd_Out(2,1, "   Sensor    ");
```

```
count = 1;
speed = 1;
level = 1;
pwm1_init(5000);
pwm2_init(5000);
pwm1_start();
pwm2_start();
pwm1_change_duty(255);
pwm2_change_duty(255);
delay_ms(1000);
LCD_Cmd(LCD_CLEAR);
beep();
pwm1_change_duty(10);
pwm2_change_duty(10);
motor_fw=0;
motor_rw=1;
while(!limit);
stop();
set_speed();
LCD_Cmd(LCD_CLEAR);
delay_ms(1000);
set_count();
LCD_Cmd(LCD_CLEAR);
delay_ms(1000);
set_level();
LCD_Cmd(LCD_CLEAR);
delay_ms(1000);
// reverse();
pwm1_change_duty(10);
pwm2_change_duty(10);
motor_fw=0;
motor_rw=1;
```

```
while(!limit);
 stop();
// count=5;
// speed=1;
// level=1;
 do
 {
  update_status();
  if(count>0)
  forward();
  else

   stop();
   beep();
  }
  if(level==1 && limit1 && count>0)
  {
   stop();
   delay_ms(2000);
   reverse();
   while(!limit);
   stop();
   delay_ms(2000);
   count--;
  }
 if(level==2 && limit2 && count>0)
 {
 stop();
 delay_ms(2000);
 reverse();
 while(!limit);
 stop();
```

```
 delay_ms(2000);
 count--;
 }

}while(1);
}
//*******************************************************

void update_status(void)
{
 lcd_out(1,1,"Speed:");
 lcd_chr_cp(speed+0x30);
 if(speed=0)
 {
  pwm1_change_duty(255);
  pwm2_change_duty(255);
 }
 else if(speed==1)
 {
  pwm1_change_duty(180);
  pwm2_change_duty(180);
 }
 else if(speed==2)
 {
  pwm1_change_duty(120);
  pwm2_change_duty(120);
 }
 else if(speed==3)
 {
  pwm1_change_duty(0);
  pwm2_change_duty(0);
 }
```

```
lcd_out(1,9,"Level:");
lcd_chr_cp(level+0x30);

lcd_out(2,1,"Count:");
bytetostr(count,txt);
lcd_chr_cp((count/10)+0x30);



}
void set_speed(void)
{
 lcd_out(1,1,"Set Speed=");
 while(1)
 {
  if(sw1)
  {
   if(speed>=3)
   speed=3;
   else
   speed++;
   while(sw1)
  }
  if(sw2)
  {
   if(speed<=0)
   speed=0;
   else
   speed--;
   while(sw2);
  }
  if(sw3)
  {
```

```
  break;
  while(sw3);
 }
 bytetostr(speed,txt);
 lcd_chr(1,11,txt[0]);
 lcd_chr_cp(txt[1]);
 lcd_chr_cp(txt[2]);
}
}
void set_count(void)
{
 lcd_out(1,1,"Set Count:");

 {
  if(sw1)
  {
   if(count>=50)
   count=50;
   else
   count++;
   while(sw1);
  }
  if(sw2)
  {
   if(count<=0)
   count=0;
   else
   count--;
   while(sw2);
  }
  if(sw3)
  {
```

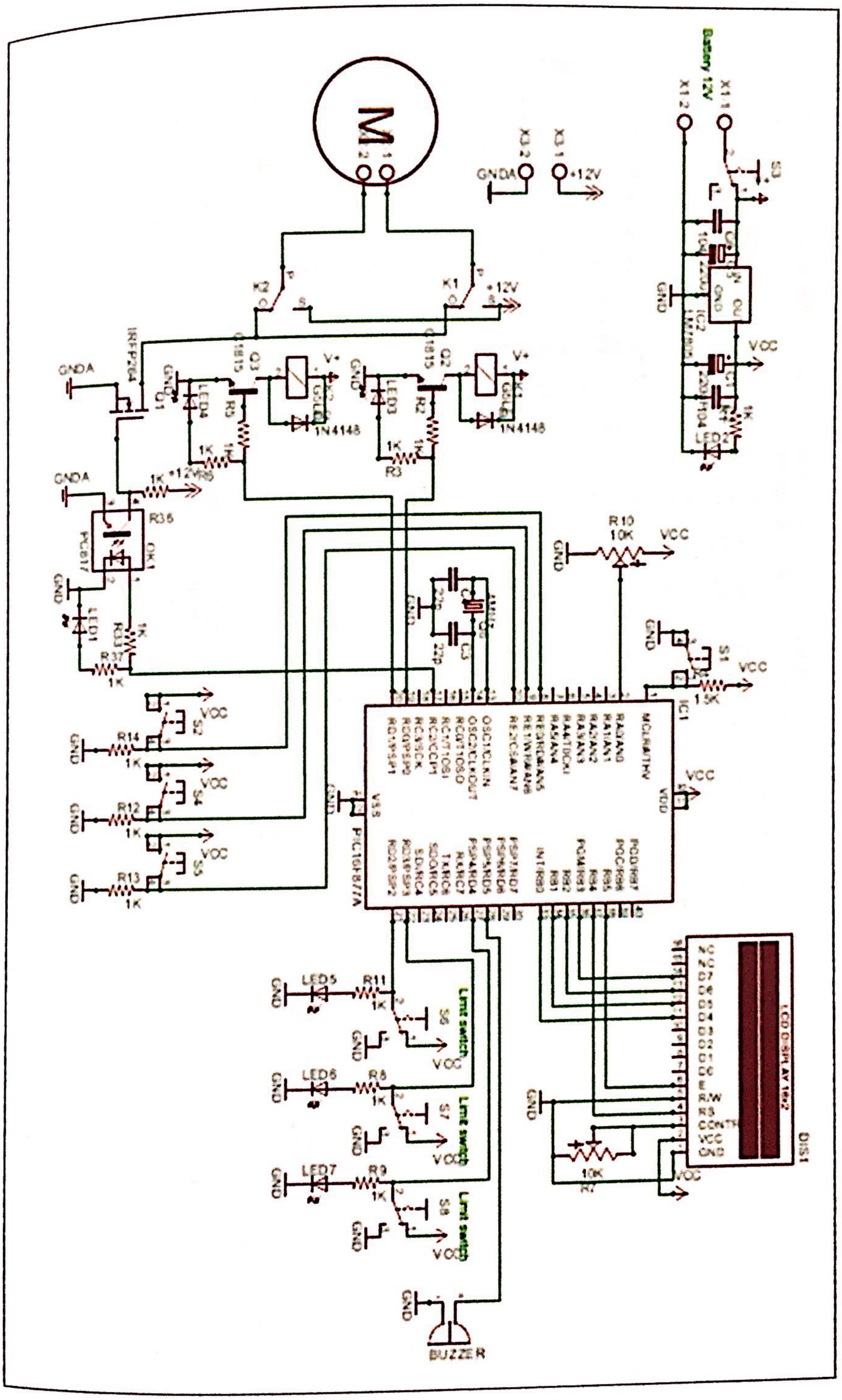
```
 break;
 while(sw3);
 }
 bytetostr(count,txt);
 lcd_chr(1,11,txt[0]);
 lcd_chr_cp(txt[1]);


}
}
void set_level(void)
{
 lcd_out(1,1,"Set Level:");
 while(1)
 {
  if(sw1)
  {
   if(level>=2)
   level=2;
   else
   level++;
   while(sw1);
  }
  if(sw2)
  {
   if(level<=0)
   level=0;
   else
   level--;
   while(sw2);
  }
  if(sw3)
  {
```

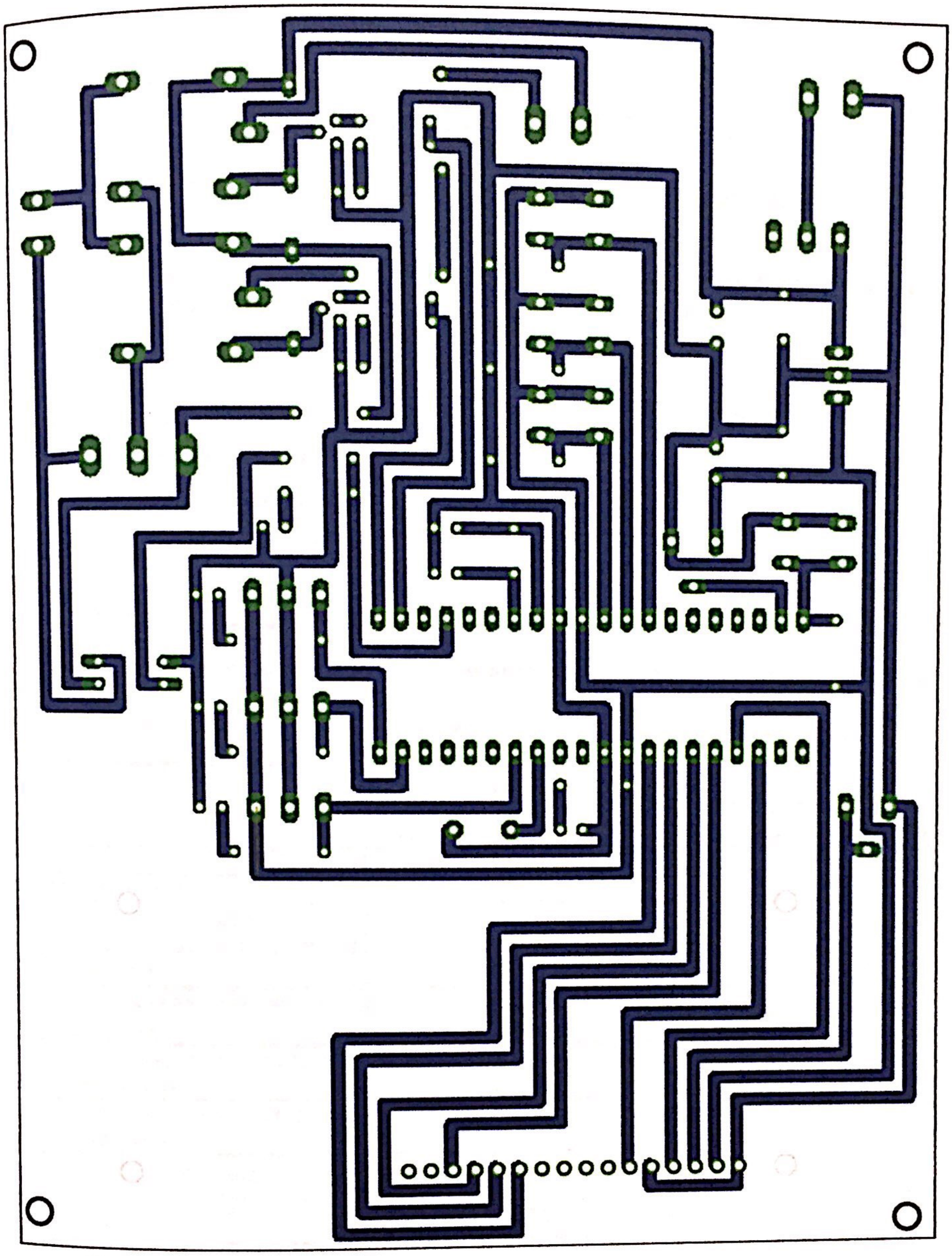
```
break;
   while(sw3);
  }

  lcd_chr(1,11,txt[0]);
  lcd_chr_cp(txt[1]);
  lcd_chr_cp(txt[2]);
 }
}
```

APPENDICE B:- SCHEMATIC DIAGRAM



APPENDICE C:- PCB LAYOUT



APPENDICE D:- QUESTIONNAIRE (USABILITY TEST)

POLITEKNIK
Jabatan Pengajian Politeknik

DEVELOPMENT OF ELBOW JOINT REHABILITATION DEVICE (USABILITY TEST)

The purpose of this questionnaire is to investigate the satisfactory level regarding the Elbow Rehabilitation Device. Please indicate the extent to which you agree or disagree with the following statements by putting a tick (√) in the appropriate box. Your information will be kept private and confidential. Thank you for your time.

AGE: 18-22 ☐ 35-40 ☐
23-28 ☐ 41-46 ☐
29-34 ☐ 47-52 ☐

GENDER: MALE ☐ FEMALE ☐

OCCUPATION: ____________________

Do you have elbow joint problems? (Example: Pain or Injured) ____________________

If you have elbow joint problems, what is the causes? ____________________

		STRONGLY DISAGREE	DISAGREE	Neither agree nor disagree	SLIGHTLY AGREE	STRONGLY AGREE
		1	2	3	4	5
COMFORTABILITY						
	MY HAND WAS PLACE COMFORTABLE WHILE USING THE MACHINE					
	HAND CAN EASILY FIT INTO THE MACHINE					
	THIS DEVICE IS EASY TO USE/ EASY TO HANDLE					
	THE STRAP IS HARD TO TIGHT UP THE HAND					
	THE DEVICE IS STABLE/ LESS MOVING WHILE OPERATING					
STRENGHTNESS						
	THE DEVICE ABLE TO MOVE MY HAND UPWARD AND DOWNWARD					
	THE MOVEMENT OF THE DEVICE IS SMOOTH/STABLE					

		STRONGLY DISAGREE	DISAGREE	Neither agree nor disagree	SLIGHTLY AGREE	STRONGLY AGREE
		1	2	3	4	5
SPEED						
	THE SPEED CAN BE SELECTED EASILY					
	THE SPEED OF OPERATION IS SUITABLE FOR STROKE PATIENTS					
	THE HIGH SPEED DOES NOT MAKE MY HAND FEELS UNCOMFORTABLE					
DESIGN						
	THE DESIGN IS SUITABLE TO BE USE IN EVERYWHERE					
	THE DESIGN IS LIGHT IN WEIGHT					
	THE DESIGN IS EASILY TO BE CARRIED					

RECOMMENDATION/ SUGGESTION TO IMPROVE THIS ELBOW JOINT REHABILITATION DEVICE: