IoT BASED MONITORING SYSTEM FOR UPPER LIMB REHABILITATION DEVICE

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Thesis submitted in fulfillment of the requirements

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ABSTRAK

Tujuan projek ini adalah untuk membangunkan alat pemulihan anggota atas (jari dan lengan) yang boleh dipasang di atas kerusi roda bagi memudahkan proses pemulihan pesakit dan terapi. Tujuan kajian ini juga adalah untuk mereka bentuk dan menganalisis sistem pengesanan kesakitan bagi alat pemulihan menggunakan pelbagai sensor. Sasaran pengguna prototaip ini adalah pengguna yang mengalami kecederaan atau kecacatan anggota atas. Peranti ini memerlukan sistem kawalan, iaitu menekan butang sebagai kawalan manual, dan aplikasi telefon pintar yang telah dibangunkan untuk memantau keadaan kesihatan pesakit. Pembangunan sistem kawalan adalah untuk mengawal pergerakan motor dc yang diletakkan di bawah pergelangan tangan dan di belakang siku serta menerima maklum balas daripada sensor. Penderia yang digunakan ialah penderia FSR yang juga dikenali sebagai penderia daya. Penderia ini digunakan untuk memberi kawalan maklum balas kepada Arduino apabila pesakit berasa sakit semasa rawatan dan ingin menghentikan pergerakan peranti. Selain itu, projek ini juga mempunyai sensor denyutan jantung dan sensor suhu DS18B20. Ia boleh memantau degupan seminit (BPM) pengguna dan memantau perubahan suhu untuk pengguna. Ia menjadi penting untuk menambah pemantauan suhu semasa wabak COVID-19. Untuk mengikuti perkembangan pesat dunia, kajian ini turut mengambil bahagian dalam membangunkan sistem pemantauan pelbagai guna menggunakan Internet of Things (IoT). Program aplikasi telah dikaji dan yang paling menjimatkan dan lebih mudah dikendalikan telah dipilih. Peranti ini menggunakan perisian pencipta aplikasi BLYNK dengan bantuan WIFI pada ESP32. Pada akhirnya, projek ini telah mencapai objektif memandangkan sistem dikawal oleh ahli terapi dan bahagian pesakit akan bergerak mengikut terapi. Sistem IoT mempunyai fungsi untuk memantau kadar denyutan jantung, suhu dan kekuatan daya yang melekat pada tubuh manusia. IoT projek boleh dipertingkatkan lagi dengan memberikan bacaan lanjutan yang lebih lanjut kepada pengguna yang juga boleh memantau kesihatan mereka menggunakan aplikasi dan menambah baik GUI aplikasi menjadi mesra dan pintar.

ABSTRACT

The purpose of this project is to develop a rehabilitation device for the upper limb (finger and arm) that can be mounted on a wheelchair to ease the rehabilitation process for the patient and therapy. The purpose of this study is also to design and analysis the pain detection system for the rehabilitation device using various sensors. The target of the user of this prototype is a user with upper limb injuries or disabilities. The device requires a control system, which is pushing buttons as the manual control, and a smartphone application that has been developed to monitor the patient health condition. The development of the control system is to control the movement of dc motors that are placed under the wrist and behind the elbow and receive feedback from sensors. The sensors used are the FSR sensor also known as the force sensor. These sensors are used to give feedback control to the Arduino when the patient is feeling pain during the treatment and want to stop the movement of the device. Besides that, this project also has a heart rate sensor and DS18B20 temperature sensor. It can monitor the beat per minute (BPM) of the user and monitor the change of temperature for the user. It became essential to add temperature monitoring during the time of the pandemic of COVID-19. To follow the fast growth of the world, this study also takes part in developing a multipurpose monitoring system using the Internet of Things (IoT). App programs were researched and the most economical and easier to handle was chosen. The device uses BLYNK app inventor software with the aid of a WIFI on ESP32. At the end, this project has achieved the objectives given that the system is controlled by therapist and the patient part will move according to the therapist. The IoT system has a function to monitor heart rate, temperature and force strength that attach to human body. The IoT of the project can be further enhanced by giving a further advanced reading to the user which also can monitor their health using the apps and improving the GUI of the apps to be friendly and intelligent.

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LIST OF SYMBOLS

Current	A
DC	Direct Current
Frequency	f
GND	Ground
GHz	Gigahertz
MPA	Megapascal
Mm	Millimetre
Nm	Newton Meter
PWM	Pulse Width Modulation
Second	s
Vin	Voltage Input
V	Voltage
TTL	Transistor-transistor Logic
Time	t
Pin	Power Input
Pout	Power Output
Efficiency	η
Celsius	°C
Fahrenheit	F

LIST OF ABBREVIATIONS

CS	Control System
IoT	Internet of Things
NodeMCU	Microcontroller Unit
ADC	Analog-to-Digital Converter
DAC	Digital-to-Analog Converter
IDE	Integrated Development Environment
I/O Pins	Input and Output
SPP	Serial Port Protocol
FSR	Force Sensitive Resistor
Wi-Fi	Wireless Fidelity
GUI	Graphical User Interface
NDT	Neurodevelopment Treatment
PPG	Photo Plethysmo Graphy

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CHAPTER 1

INTRODUCTION

1.1 PROJECT BACKGROUND

As indicated by the World Health Organization (WHO), rehabilitation is a bunch of mediations required when an individual is encountering or is probably going to encounter constraints in ordinary working because of maturing or an ailment, including ongoing sicknesses or problems, wounds, or injuries. It is a fundamental part of widespread wellbeing inclusion alongside advancement, counteraction, treatment, and concealment. It can assist with getting back, keeping, or improving capacities that are required for everyday life [1]. Rehabilitation can improve our day-by-day life and work. The upper arm is a practical unit of the chest area. It comprises three areas: the upper arm, lower, arm, and hand. It stretches out from the shoulder joint to the fingers and contains 30 bones. It comprises numerous nerves, veins, and muscles. The nerves of the arm are provided by one of the two significant nerve plexus of the human body and the brachial plexus. A portion of the patients experiences upper arm torment because of disease, mishaps, actual impair and some more. These classes of individuals are missing activities that should be possible on wheelchairs [1].

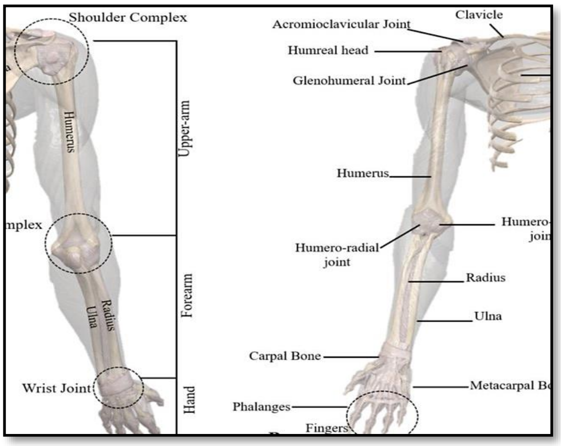


Figure 1.1: Human Upper Limb Anatomy Structure

Rehabilitation Device is a portable device which give rehabilitation toward the patient. This convenient gadget helps patients to distinguish agony and screen their recuperation progress during rehabilitation measures. There are two pieces of this gadget: the lower arm and hand(wrist). This portable device can be controlled by Therapist and patient system which is adjusted manually by physiotherapists to patient’s comfort [1]. This device is consisting of forearm movement, wrist movement, and fingers movement which operates by rotating with the help of motors. This device can be adjusted to a certain angle in the cline to provide a large workspace. The motors implemented in this device can be controlled by the users during the rehabilitation process [1].

1.2 PROBLEM STATEMENT

Hand rehabilitation is a type of therapy performed by an occupational or physical therapist with patients that suffer from conditions affecting the hands and upper extremities [2]. The recent type of rehabilitation device is fully computerized so the therapist can’t have control over patient comfort. With this Therapist and patient support, rehabilitation enables the therapist to control the patient hand for their comfort to make them fasten to return to their productive lifestyle.

Other than that, these devices are intended to give help to clients in various manners [2]. Hand rehabilitation mismeasures are exceptionally fundamental for in an unexpected way capable individual and for those who going through recuperation measures. As of late in the industry, fewer shared recovery devices keep patients from getting tormented during the rehabilitation process. One of the reasons for this hand rehabilitation process is for development in actual capacity in one's hand. This point can be accomplished with the assistance of the pain detection system which is associated with the hand rehabilitation process.

Finally, hand rehabilitation has been done for a long time in a fix position. Challenges such as limited state services to systematically identify those in need, a lack of medical and rehabilitation services to accompany assistive technology [3]. Right steps can be taken with the guidance of physiotherapist but it is quite difficult to be done by on our own due to restricted factors like time, cost, distance and physical limitations. All these factors need to be considered as well. Patients do exercise by themselves without any monitoring system to monitor the recovery progress. Rehabilitation is done without any proper monitoring system with additional electronic technology such as IoT.

1.3 PROJECT OBJECTIVE

This proposed project is to achieve the following objectives: -

1. To develop a rehabilitation mechanism and device for the upper limb region which can be controlled by the therapist.

2. To develop a pain detection system at the upper limb region so that patients can give feedback during the hand rehabilitation process by implementing various types of sensors.

3. To develop a monitoring system based on the Internet of Things (IoT).

1.4 PROJECT SCOPE

The scope of the project is to consent patients on their rehabilitation activity at all places while monitoring their progress interactively with custom-designed apps on mobile phones. There is certain limitation been set for using this device. This prototype device is only for the patient upper-limb region that is controlled by the Therapist/Patient system. This prototype will develop a pain detection system during the rehabilitation process using an FSR sensor. This prototype will develop the body temperature, pinch strength and heartbeat rate using the monitoring system of the Internet of Things (IoT).

1.5 SIGNIFICANCE OF STUDY

The significance of study hand rehabilitation is to improve, keep up, or re-establishing actual strength, cognizance, and versatility with augmented outcomes. Ordinarily, its assists individuals with acquiring more noteworthy freedom after disease, injury, or medical procedure. Rehabilitation of individuals with handicaps is an interaction pointed toward empowering them to reach and keep up optimal physical, sensor, intellectual, psychological, and social function levels.

CHAPTER 2

LITERATURE REVIEW

2.1 REHABILITATION CONCEPT

Rehabilitation is the process of removing, or reducing as far as possible, the factors that limit the activity and participation of a person with a disability so that he/she can attain and maintain the highest possible level of independence and quality of life: physically, mentally, socially and vocationally. Simply put, rehabilitation supports an adolescent, adult, or older person to be as self-sufficient as possible in daily activities, taking an interest in school, employment, leisure, and important life roles such as caring for the family. To achieve full inclusion, many different interventions may be needed, which, depending on the individual's type of disability such as medical care, supply of assisted stive device, therapy (physical and occupational), psychosocial services, etc.

Physical rehabilitation is an important part of the integrated rehabilitation process needed to ensure participation and inclusion in the society of persons with disabilities. Physical rehabilitation includes the provision of assistive devices such as walking aids and wheelchairs along with appropriate therapy allowing optimal use of the device. It must include activities aimed at maintaining, adjusting, repairing, and renewing the devices as needed. Physical rehabilitation is focused on helping a person regain or improve the capacities of his/her body, with physical mobility as the primary goal which is to help people gain their abilities back. [4]

2.2 HUMAN MUSCULAR SYSTEM

The human muscular system is composed of specialized cells called muscle fibers. Contractibility is their primary feature. Movement is regulated by muscles, which are connected to bones, internal organs, and blood vessels. Muscle contraction is the source of almost all movement in the body. The movement of cilia, the flagellum on sperm cells, and the amoeboid movement of certain white blood cells are exceptional cases [5]. Muscle contraction serves a variety of important functions in the body, including posture and joint flexibility. Furthermore, muscle contraction keeps one's posture, such as sitting or standing in place. This is particularly evident in the knee and shoulder joints, where muscle tendons are a major factor in stabilizing the joint. Other seemingly unrelated functions, including temperature regulation and vision, also rely on the muscular system. The muscular system contains more than 600 muscles that work together to enable the full functioning of the body and three recognized muscle types. Each of the three types has its specific functions [5].

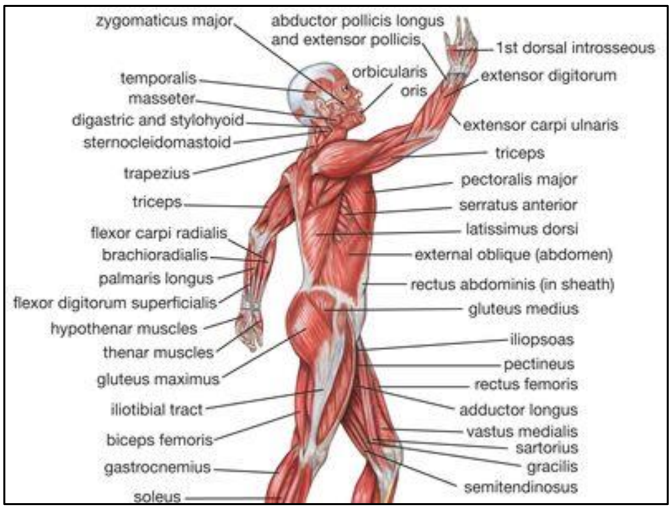


Figure 2.1: Human muscular system

2.2.1 Cardiac Muscle

Cardiac muscle is only found in the heart and is responsible for pumping blood across the body. Our pulse is formed by cardiac muscle stimulating its contractions. The cardiac is also under the control of the autonomic nervous system and the rate of contraction is regulated by nervous system signals. This muscle is powerful and works involuntarily. The cardiac muscle cell, like smooth muscle, has a single central nucleus, but it is also striated, like skeletal muscle and its cell is shaped like a rectangle [5].

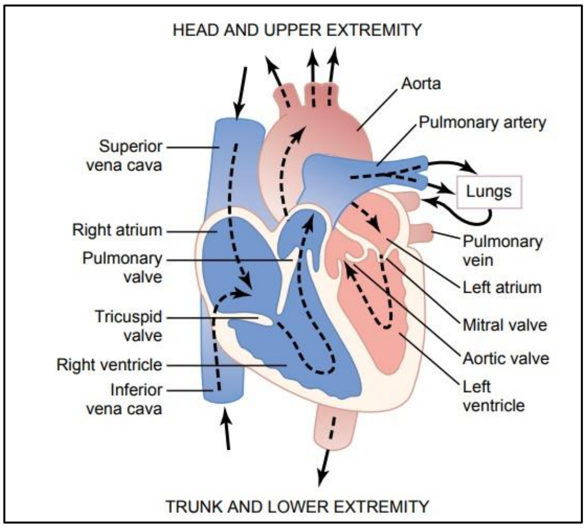


Figure 2.2: Cardiac muscle

2.2.2 Skeletal Muscle

Tendons, tough tissue cables, bind these muscles to the bones and protect them. When a muscle contracts, it pulls on the tendons, which causes the bone to move. Ligaments, which are similar to tendons and help to keep the skeleton together, bind bones to the skeleton together. Skeletal muscles are the only muscles that can be consciously controlled. Thus, these muscles are under conscious, or voluntary, control [5].

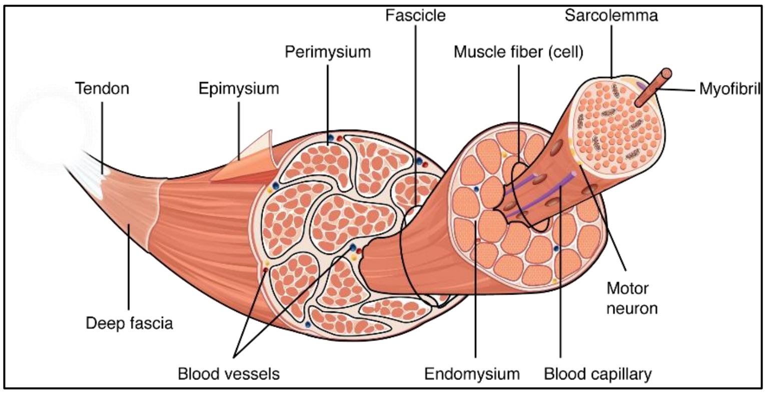


Figure 2.3: Skeletal muscle

2.2.3 Smooth Muscle

Smooth muscle known as visceral muscle is responsible for muscle movements that are uncontrollable and spontaneous. Smooth muscle can be found in your liver, intestines, and blood vessels, among other areas. These muscles carry out all of the functions that your body needs. Smooth muscle is incapable of conscious control and therefore operates involuntarily. The spindle-shaped non-striated muscle cell has one central nucleus. Smooth muscle contracts slowly and in a repeating pattern. It is the weakest type of muscle but has an essential role in moving food along the digestive tract and maintaining blood circulation through the blood vessels [5].

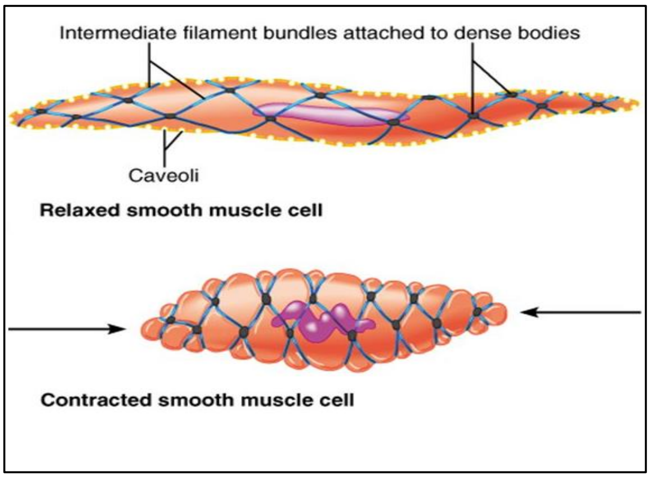


Figure 2.4: Smooth muscles

2.3 HOW MUSCLE WORKS

The strength of a muscle's contraction can be controlled by two factors such as the number of motor units involved in contraction and the amount of stimulus from the nervous system. A single nerve impulse of a motor neuron will cause a motor unit to contract briefly before relaxing. This small contraction is known as a twitch contraction [5]. Not all muscle will produce movement. Isometric contractions are light contractions which increases the tension in the muscle without exerting enough force to move a body part. they are performing an isometric concentration when people tense their bodies due to stress. Holding an object still and maintaining posture are also the result of isometric contractions [5].

Isotonic contractions maintain constant tension in the muscles as the muscle changes length. This situation occurs when a muscle's maximal force of contraction exceeds the total load on the muscle. Isotonic muscle contractions can be either concentric or eccentric. Concentric meaning muscle shortens whereas eccentric meaning muscle lengthens [5]. A concentric contraction is a type of muscle contraction in which the muscles shorten while generating force. This is a typical of muscles which contract due to the sliding filament mechanism and it occurs throughout the muscle. Such contractions also alter the angle of the joints to which the muscles are attached as they are stimulated to contract according to the sliding filament mechanismn[5].

An eccentric contraction results in the elongation of a muscle. Such contractions decelerate the muscle joints and can alter the position of the load force. These concentrations can be both voluntary and involuntary. During an eccentric contraction, the muscle elongates while under tension due to an opposing force that is greater than the force generated by the muscle. The muscle acts to decelerate the joint at the end of a movement or otherwise control the repositioning of a load rather than working to pull a joint in the direction of the muscle contractions [5]. Muscle tone is a natural condition in which a skeletal muscle stays partially contracted at all times. Muscle tone provides a slight tension on the muscle to prevent damage to the muscle and joints from sudden movements and helps to maintain the body’s posture. All muscles maintain some amount of muscle tone at all times unless the muscles have been disconnected from the central nervous system due to nerve damage [5].

2.4 FOREARM

Extending from the wrist to the elbow joint is the region of the upper extremity called the forearm (antebrachium). The forearm helps the shoulder and the arm in force application and the precise placement of the hand in space with the help of the elbow and radioulnar joints [5].

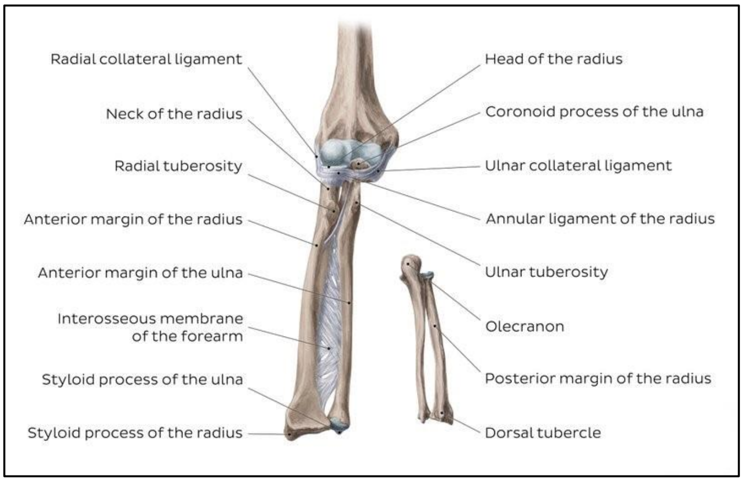


Figure 2.5: Structure of forearm

The forearm consists of two long bones such as radius and ulna. The ulna is located medially and is both longer and larger than the radius which runs in parallel to it laterally. These two bones are held together by the intervening interosseous membrane. These forearm bones articulate with each other in two locations. The head of the radius forms a joint with the radial notch of the ulna proximally while the head of the ulna forms a joint with the ulna notch of the radius distally. Alongside the humeroradial joint, the two radio-ulnar allow the pronation and supination movements of the forearm [5]. The forearm is divided into two compartments by deep fasciae such as the interosseous membrane and the fibrous intermuscular septa. This creates an anterior compartment that contains the flexor muscles and a posterior on which contains the extensor muscles [5].

2.4.1 Forearm Muscle

The forearm is divided into two compartments by deep fasciae such as the interosseous membrane and the fibrous intermuscular septa. This creates an anterior compartment that contains the flexor muscles and a posterior on which contains the extensor muscles. Residing in the posterior compartment of the forearm, the extensor muscles can be further divided into superficial and deep extensors [6].

Superficial extensors consist of seven muscles such as [6] : -

i. Brachioradialis
ii. Extensor carpi radialis longus
iii. Extensor carpi radialis brevis
iv. Extensor digitorum
v. Extensor digit minimal
vi. Extensor carpi ulnaris
vii. Anconaeus

Deep extensors consist of five muscles such as [6] : -

i. Supinator
ii. Abductor pollicis longus
iii. Extensor pollicis brevis
iv. Extensor pollicis longus
v. Extensor indicis

2.5 TYPES OF UPPER LIMB REHABILITATION EXERCISE

Wrist extension and flexion will be one of the exercises for extremely stiff hands and paralyzed hands. Extension describes the movement of raising the back of the hand. Flexion describes the movement of bending the palm down, towards the wrist. For this gentle hand dexterity exercise, hold your arm straight out in front of you and put your wrist and hand straight, the palm of your hand facing down. Bend your wrist down so your fingers point towards the floor. Use your other hand to increase the stretch, gently pull the fingers towards your body. Hold this for 15-30 seconds and return to a straight, neutral wrist palm facing down. The next step will be, to bend your wrist up so your fingertips point towards the ceiling and use your other hand to gently pull your fingers back towards you. Repeat this 10 times. If want to get a good result, do it up to three times a day [7].

Wrist bend movement is also a good physical therapy exercise. Before starting to do this exercise make a loose fist (A person's hand when the fingers are bent in towards the palm and held there tightly, typically to strike a blow or grasp something) and lean the side of your arm on the table or other surface. Bend your fist in towards the underside of your wrist and flex. Then send it back the other way, and extend. Hold each one for several seconds and repeat 10 movements. This also works your mobility and also a range of motion [7]. To maintain and improve hand functionality exercises for the hands are important in rehabilitation following injuries and illnesses. Wrist side movement exercise is one of the best exercises to improve hand functionality. Wrist exercises help gradually improve the strength and movement of the hand and wrist following an illness or injury. First, place your affected hand palm-down on the flat surface. Then use your other hand to bend your wrist side-to-side (a handshake motion). For a good result hold for 5 seconds in each direction [7].

Exercises can improve mobility and decrease the chances of injury and reinjury. Wrist Stretches are easy to do. When it's done properly, it can benefit a person's overall wrist and hand health. A person should do the exercise slowly and gently, focusing on stretching and strengthening. The following wrist and hand stretches may improve strength and mobility [7].

2.6 TYPES OF REHABILITATION EXERCISE

GRIP ANATOMY

Grip strength is determined by the strength of your fingers, forearm, thumb, and wrist. There are 35 muscles involved in the movement of the forearm and hand, with many of these involved in gripping activities. During gripping activities, the muscles of the flexor mechanism in the hand and forearm create grip strength while the extensors of the forearm stabilize the wrist [8]. There are four major joints of the hand, Carpometacarpal, Intermetacarpal, Metacarpophalangeal, and interphalangeal joint, with 9 extrinsic muscles that cross the wrist and 10 intrinsic muscles with both of their attachments distal to the wrist [8].

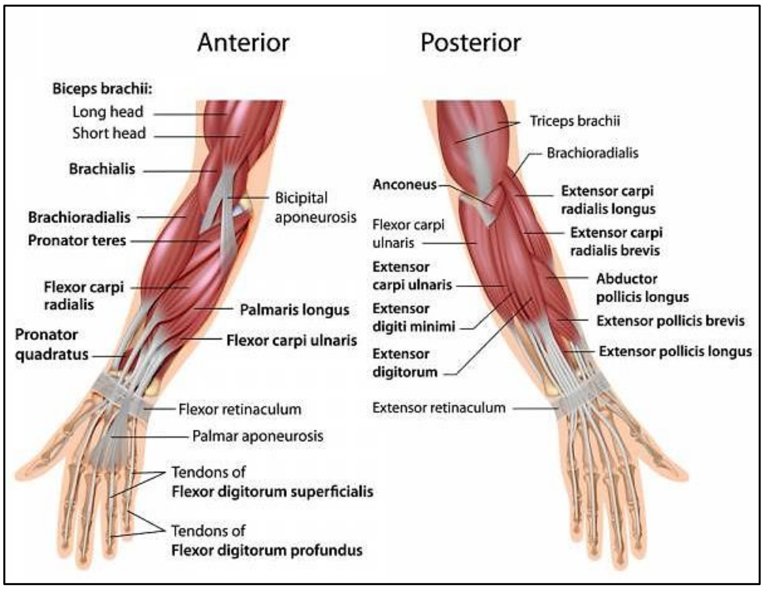


Figure 2.6: Muscles involved during gripping exercise

2.6.1 Types of Grip Training Exercise

They are 3 types of grip training exercises, first is crush grip is which is most commonly thought of as "grip”. It involves a handshake-type grip, where the object being gripped rests firmly against the palm and all fingers. A strong crush grip is useful in bone-crushing handshakes or for breaking objects with pressure. The next exercises that are involved in grip training exercises are pinch grip, the fingers are on one side of an object, and the thumb is on the other. Typically, an object lifted in a pinch grip does not touch the palm. This is generally considered a weaker grip position. The pinch grip is used when grabbing something like a weight plate or lifting a sheet of plywood by the top edge. Care must be taken to avoid cramping the muscles in the hand and the last exercise is support grip typically involves holding something, such as the handle of a bucket, for a long time. This type of strength is epitomized by the "Farmer's walk", where the bucket is filled with sand or water, and carried over a long distance. A great deal of muscular endurance is necessary to have a good carrying grip" [9].

2.7 PHYSIOLOGICAL PROCESSES WHICH EHANCES PAIN

There are several ways to categorize pain. One is to separate it into acute pain and chronic pain. Acute pain typically comes on suddenly and has a limited duration. It is frequently caused by damage to tissue such as bone, muscle, or organs, and the onset is often accompanied by anxiety or emotional distress. Chronic pain lasts longer than acute pain and is generally somewhat resistant to medical treatment. It's usually associated with a long-term illness, such as osteoarthritis. In some cases, such as with fibromyalgia, it's one of the defining characteristics of the disease. Chronic pain can be the result of damaged tissue, but very often is attributable to nerve damage [9].

Chronic pain varies according to weeks, months or even years after the accident as it keeps on hurting. Chronic pain is also described by the doctors as any pain which last for three to six months or even longer. Chronic pain can have real effects on everyday life and mental health. The sensation of pain comes from a series of signal which zip through the nervous system. The injury turns on pain receptors in when injured again. In the form of an electrical signal, they transmit a message which passes from nerve to nerve before it enters the brain. Typically, the signal ceases when the sources of the pain is resolved. The brain absorbs the signal and sends out the message when in pain. But for chronic pain case, even if we have recovered, the nerve impulses keep appearing [9].

2.8 UPPER LIMB REHABILITATION EXISTING DEVICE REVIEW

Upper extremity rehabilitation programs are typically designed and delivered by physical or occupational therapists, based on their assessment of movement impairment. The success of this strategy is determined by the therapist's expertise and expertise, as well as the length of treatment. However, there is no standard approach for evaluating and treating arm movement disability. This leads to the variability in the effectiveness of therapy and to the inability to compare interventions across practitioners and clinics [10]. However, with the present one-on-one hospital session method, long-term care is prohibitively expensive and rarely lasts more than a month after a stroke. To mention a few, neurodevelopmental treatment (NDT) approaches, bilateral arm training, robot-assisted training, and constraint-induced movement therapy have all been demonstrated to enhance upper extremity function following a stroke to varying degrees. The initial degree of motor impairment is the strongest predictor of motor recovery, according to an assessment of the data for upper extremity therapies following stroke by Canadian researchers [10].

2.8.1 Neurodevelopment Treatment (NDT)

The term "neurodevelopmental techniques" encompasses a wide range of approaches. The Bobath, Brunnstrom, and proprioceptive neuromuscular facilitation (PNF) methods are among these. The Bobath technique is the most often used in the treatment of upper extremity dysfunction after a stroke [11]. The neurodevelopmental treatment (NDT) emphasizes the idea that aberrant muscle patterns or tone develop as a result of brain injury after a stroke. Normal patterns must be performed to assist functional and voluntary motions to prevent aberrant tone. Reviewers of NDT vs. other treatment options determined that NDT was not superior to other forms of interventions in various studies. A systematic assessment of specific neurologic treatment approaches found that, when compared to a Bobath (NDT) strategy, no one program outperformed the others in terms of functional outcomes (ADLs), muscular strength or tone, or dexterity, while motor relearning programs were linked to shorter hospital stays [11].

2.8.2 Bilateral Upper Limb Training

Bilateral upper limb training is a new form of stroke rehabilitation training that involves the simultaneous use of both upper limbs with one limb moving actively and the other limb moving actively, passively, or with assistance. Therapists have employed pulleys and other apparatus to move the affected upper limb at the same time as the less impaired upper limb. Through the connection between the upper limbs, the use of the intact limb promotes functional recovery of the injured limb [11]. Through brain networks linked by the corpus callosum, practicing bilateral movements may stimulate the intact hemisphere and aid the activation of the injured hemisphere. Manual or electronic devices, which might be simple in design or part of a sophisticated robotic device, are commonly used for bilateral upper limb training. Bilateral arm training appears to be most beneficial in the early stages after a stroke when brain reconfiguration is at its most rapid. These devices offer enough support, allowing for an endless number of repetitions and a wide range of movements [11]. Some of the exercises offer by manual bilateral upper limb training:

i. Batra

ii. Rehab-Slide Duo

iii. Rocker for ABT

2.8.3 Robot-Mediated Training Devices

Robot-assisted therapy for upper-limb disability has been around since the 1990s. Several robotic gadgets have become commercially available for clinics and hospitals since then. Robotic devices can provide interactive training that is high-intensity, repetitive, and task-specific. Typically, these robots provide impulses to the paralyzed limb while training multi-joint gross arm movements [12]. The majority of robotic systems used in clinical trials or clinical practice allow users to choose between four training modalities:

i. Active

ii. Active-assisted

iii. Passive

iv. Resistive

Large numbers of repetitions—carried out within intense and particular task-oriented training programs—are required to promote neuroplastic changes and increase function, according to a study. This is physically impossible using ordinary treatment methods. The robot may alter the mechanical assistance during the training session based on the patient's motor performance according to performance-based algorithms. The goal is to just provide as much help as the patient needs to finish the task. Robotic therapy is safe and well-tolerated and it has a positive impact on improving motor impairments [12].

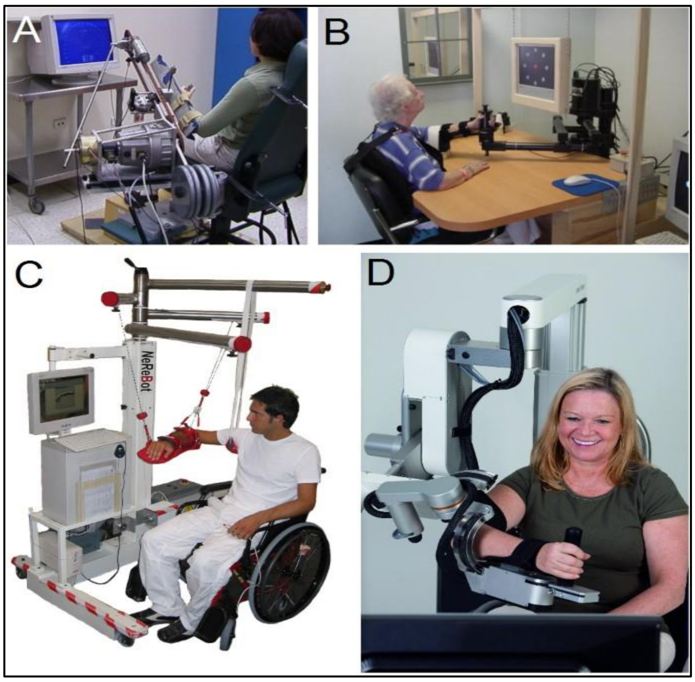


Figure 2.7: Robot-Meditate Training Devices

2.9 CONTROL SYSTEM

Control systems (CS) can be found in a wide range of applications, from aviation and spacecraft to robots and industrial control systems. CS is made up of subsystems and processes that are put together to produce the desired output with the desired performance from a given input [13]. Large equipment can be moved with a precision that would normally be unachievable without control systems. The load requires more power than a human can produce, therefore speed motors provide it, and control systems govern the position and speed. CS is designed for four main purposes: power amplification, remote control, input form convenience, and disturbance adjustment [13]. A control system can alternatively be defined as a set of interconnected components that form a system configuration that provides the desired response. The foundation for system analysis is supplied by linear system theory, which implies a cause-and-effect relationship between system components. As a result, a block can be used to represent a controllable component or process. The input-output relationship depicts the process's cause-and-effect relationship, which in turn depicts the processing of an input signal to produce a variable output signal, frequently with power amplification [14].

2.9.1 Open Loop System

Open loop system is a system whereby its output is dependent on its input thus the action of controlling or the input is independent of its output or it is change in the output of the system. A generic open-loop system is starts with a subsystem called an input transducer, which converts the input to that used by the controller. The controller drives a process or called a plant. The input is sometimes called the reference, while the output can be called the controlled variable [14]. Other signals, such as disturbances, are added to the controller and process outputs via summing junctions, which yield the algebraic sum of their input signals using associated signs. The distinguishing characteristic of an open-loop system is that it cannot compensate for any disturbances that is added to the controller’s driving signal. The system cannot correct for these disturbances, either. Advantages of implementing open loop system is that first of all, the system is not complicated in construction, convenient when output is difficult to evaluate and provide a stable system thus providing simple design. [14]

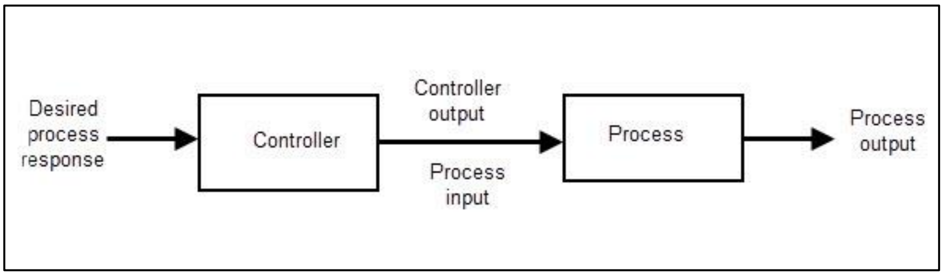


Figure 2.8: Open Loop system

2.10 MATERIAL AND COMPONENT SELECTION FOR SMART REHABILITATION DEVICE

However, there are, obviously, different materials, including metal and artistic, polymers that make up most of the market for 3D printing materials. This is because they can be utilized for modern applications, such as prototyping, yet they are likewise frequently the material of decision for work area printers, particularly those utilizing combined affidavit demonstrating (FDM) processes. Out of the different materials falling under the classification, two of the most famous are PLA and PETG. Known for the simplicity of printing, these two materials are made into fibers that can be utilized by the two novices and specialists with FDM printers. However, they are comparable in more ways than one, there are as yet critical contrasts between the two fibers. [15].

Table 1 Comparison between PLA and PETG filament

PLA	**PETG**
Characteristics: - 1. Extruder temperature: 190 - 220°C 2. Bed temperature: 45 - 60°C 3. Heated bed: Optional 4. No Particular resistance 5. Made from renewable resources 6. Exact and good aesthetic 7. More flexible	Characteristics: - 1. Extruder temperature: 230 - 250°C 2. Bed temperature: 75 - 90°C 3. Heated bed: Required 4. Water/Chemically/Fatigue resistance 5. Oil based polymer 6. Better physical properties 7. More durable
Manufacturers: - 1. Polymaker 2. ColorFabb 3. Hatchbox 4. Filamentum	Manufacturers: - 1. Formfutura 2. ColorFabb 3. 3DXTech 4. Innofil3D
Price per 1kg = RM75.33 – RM100+	Price per 1kg = RM92.00 – RM100+

2.10.1 Microcontroller

A microcontroller (MCU, which stands for microcontroller unit) is a miniature computer that is built on a single metal-oxide-semiconductor (MOS) integrated circuit (IC) chip. A microcontroller is made up of one or more CPUs (processor cores), memory, and programmable input/output peripherals. A tiny amount of RAM, as well as programme memory in the form of ferroelectric RAM, NOR flash, or OTP ROM, is frequently provided on chip. Microcontrollers, as opposed to microprocessors used in personal computers or other general-purpose applications, are developed for embedded applications, and are made up of various discrete chips [16].

2.10.1.1 Arduino

Arduino is composed of a physical programmable circuit board (commonly referred to as a microcontroller) and programming software, or IDE (Integrated Development Environment), which can be run on a PC and is used to compose and transfer PC code to the circuit board. It can attain this using the Arduino programming language and the Arduino Software (IDE).

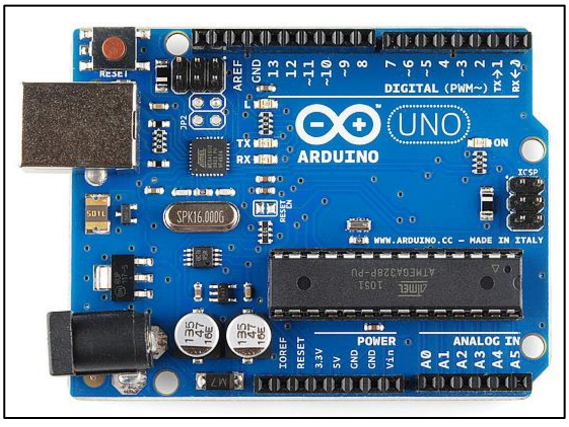


Figure 2.9: Arduino uno V3

Unlike other programmable circuit boards, the Arduino does not require a separate piece of equipment (known as a software engineer) to upload code to the circuit board; instead, a USB link is used. Furthermore, the Arduino IDE makes programming easier by utilising a rearranged version of C++.In a nutshell, Arduino simplifies the functions of the microcontroller. The Uno is a popular board in the Arduino family and an extraordinary option for beginners [16].

2.10.1.2 ESP32

The ESP32 is a single 2.4 GHz Wi-Fi/Bluetooth combo chip built on TSMC's ultra-low-power 40 nm technology. It is intended to provide the best power and RF performance while demonstrating robustness, versatility, and dependability in a wide range of applications and power scenarios [17].

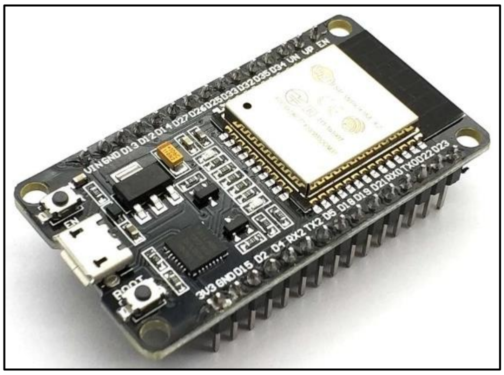


Figure 2.10: Node MCU ESP32

The ESP32 is a highly integrated solution for Wi-Fi and Bluetooth IoT applications, with approximately 20 external interfaces constituents. The ESP32 includes an antenna switch, an RF balun, a power amplifier, a low noise receive amplifier, filters, and a microcontroller as well as power management modules as a result, the entire solution takes up very little Printed Circuit Board space (PCB)region [17].

There are several pins of ESP32: -

i. Power: - Micro-USB: ESP32 can be powered through USB port

ii. 5V: Regulated 5V can be supplied to this pin which is we be again regulated to 3.3V by on board regulator, to power the board.

iii. 3.3.3V: Regulated 3.3V can be supplied to this pin to power the board.

iv. GND: Ground pins.

v. Enable: The pin and the button reset the microcontroller.

vi. Analog Pins: Used to measure analog voltage in the range of 0-3.3V.12-bit 18 Channel ADC

vii. DAC pins: Used for Digital to analog Conversion

viii. Input/Output Pins: Totally 39 GPIO pins, can be used as input or output pins. 0V (low) and 3.3V (high). But pins 34 to 39 can be used as input only

ix. Capacitive Touch pins: These 10 pins can be used a touch pin normally used for capacitive pads x. RTC GPIO pins: These 18 GPIO pins can be used to wake up the ESP32 from deep sleep mode

x. Serial: Used to receive and transmit TTL serial data.

xi. External Interrupts: Any GPIO can be used to trigger an interrupt.

xii. PWM: 16 independent channels are available for PWM any GPIO can be made to work as PWM though software

xiii. VSPI: Used for SPI-1 communication.

xiv. HSPI: Used for SPI-2 communication.

xv. IIC: Used for I2C communication

xvi. AREF: To provide reference voltage for input voltage

2.10.2 DC Servo Motor

The function, or task, of a servo, will be described as follows. A command signal which is issued from the user's interface panel comes into the servo's "positioning controller". The positioning controller is the device that stores information about various jobs or tasks. it's been programmed to activate the motor/load, i.e., change speed/position [18].

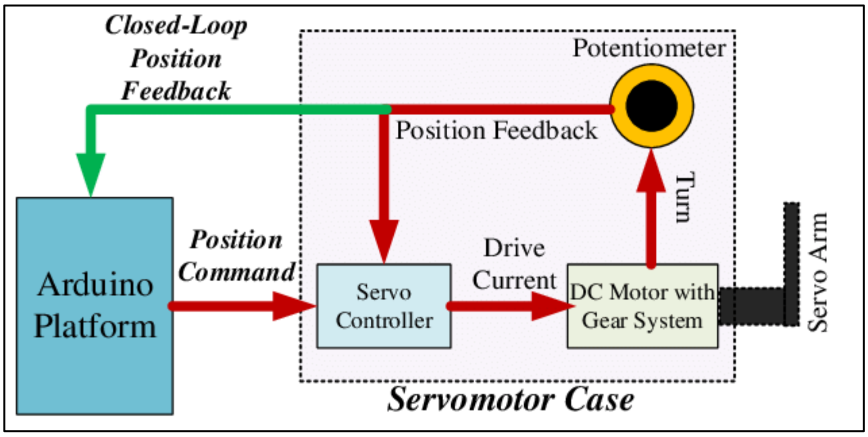


Figure 2.11: DC Servo Motor Block Diagram

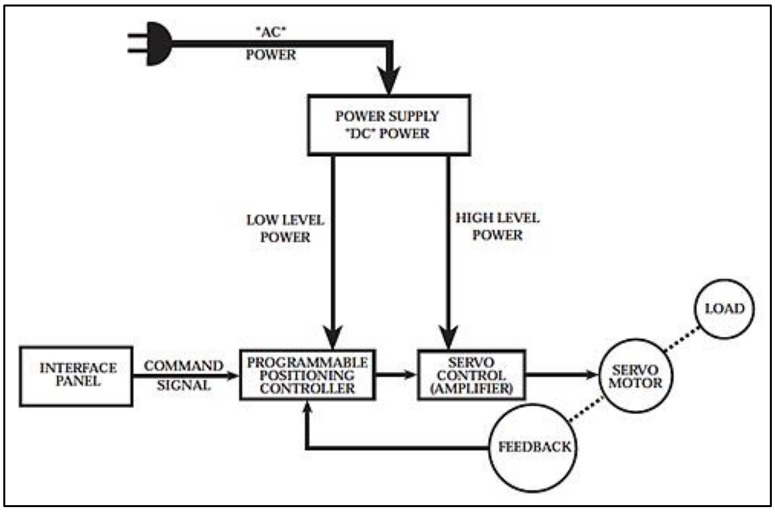


Figure 2.12: DC Servo Motor System

After that, the signal is sent to the servo control or "amplifier" section. The servo control takes this low-power signal and increases or amplifies, it to appropriate levels so that the servo motor can move [18]. To rotate the servo motor at appropriate higher speeds, these low power level signals must be amplified with higher voltage levels, and higher current levels are required to provide torque to move heavier loads. The "power supply," which simply converts AC power into the needed DC level, provides this power to the servo control (amplifier). It also provides any low-level voltage required for integrated circuit performance [18].

The load begins to move when power is provided to the servo motor and the speed and position of the load change. Some additional "device" moves along with the load. This other "device" is either a tachometer, resolver, or encoder that sends or receives a signal from the controller. This "feedback" signal tells the positioning controller if the motor is doing its job correctly [18]. The positioning controller examines this feedback signal to see if the load is being moved correctly by the servo motor, and if not, it makes the necessary adjustments. Assume the instruction signal instructed you to drive the load at 1000 pm. It's spinning at 900 rpm for some reason. The controller will get a feedback signal indicating that the speed is 900 rpm. The controller then detects an inaccuracy by comparing the command signal (desired speed) of 1000 rpm with the feedback signal (actual speed) of 900 rpm. The controller then sends a signal to the servo motor to increase speed by applying more voltage until the feedback signal equals the command signal, indicating that there is no error [18]. As a result, a servo is made up of numerous devices. It is a collection of devices that are used to control the load. The controlled object can be controlled in any way, including location, direction, and speed. As long as the right feedback device (error detection device) is utilized, the speed or position can be regulated about a reference (command signal). Corrections are made after comparing the feedback and command signals. As a result, a servo system is defined as a collection of devices that control or regulate the speed or position of a load [18].

2.10.3 Fundamental of Sensors

Sensors, according to the American National Standard Institute, are devices that produce a useful output in response to a certain measurement. A sensor collects physical data and converts it to a signal that can be processed. The measurement of physical phenomena is converted into an electrical signal using a common sensor [19]. A sensor is a device that measures physical input from its surroundings and converts it into data that can be evaluated by humans or machines. It is a device that detects changes in electrical, physical, or other quantities and generates an output as a confirmation of the quantity change. It's an electronic gadget that transfers signals from one energy domain to another. In the definition of a sensor, the term "input device" refers to a component of a larger system that delivers input to a primary control system such as a microcontroller [19].

The majority of sensors are electronic, but some are more basic, such as a glass thermometer that displays visual data. Sensors were employed to detect smoke, measure temperature, and adjust pressure, among other things. Electric current sensors, magnetic sensors, humidity sensors, flow sensors, pressure sensors, chemical sensors, environment sensors, magnetic switch sensors, and many more types of sensors are categorized depending on their amounts [19]. We choose to use sensors such as a temperature sensor, a heartbeat sensor, and FSR sensor in this research.

2.10.3.1 Temperature Sensor

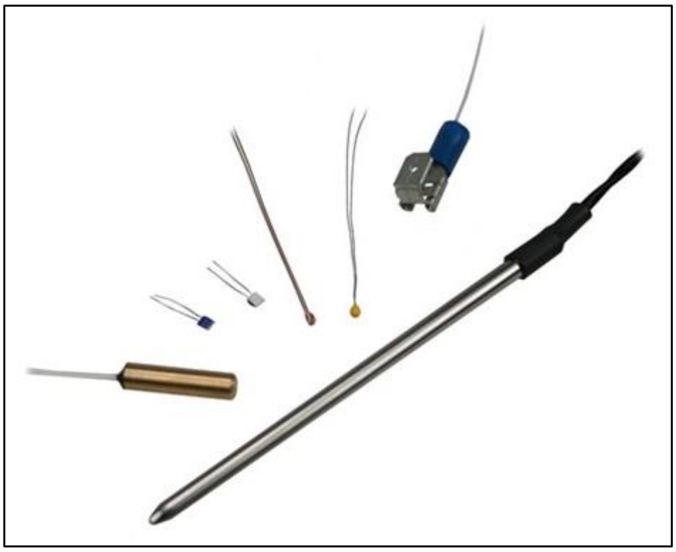


Figure 2.13: Temperature sensor

A temperature sensor is an electronic device that measures the temperature of its surroundings and converts the input data into electronic data to record, monitor, or communicate temperature changes. Contact temperature sensors and non-contact temperature sensors are the two types of temperature sensors. Thermocouples and thermistors are examples of contact temperature sensors [20]. A thermocouple is a type of temperature sensor that uses an electric current or an electromagnetic field to measure the temperature at a single spot. This sensor is made up of two separate metal wires that are joined at one point. The temperature of the metal wire can be detected at the junction, and the change in temperature drives the voltage [21]. Thermocouples have many advantages, including excellent precision, being robust and able to withstand strong vibrations, having a high thermal reaction, a wide temperature operating range, and being inexpensive. Thermostats in offices, homes, offices, and enterprises use them as temperature sensors. Cryogenic and low-temperature applications are used in the food business.

Negative temperature coefficient and positive temperature coefficient thermometers are two types of thermometers. Thermistors are more accurate than thermocouples since they are constructed of ceramics or polymers and can measure within 0.05 to 1.5 degrees Celsius [21]. The advantages of thermistors are their high sensitivity, which allows them to perform well across a narrow temperature range, quick reaction, ease of use, small size, and ability to connect with electronic instruments. Microwaves, boilers, circuit breakers, digital thermometers, 3D printers, and other appliances all use it.

2.10.3.2 Force Sensing Resistor Sensor (FSR)

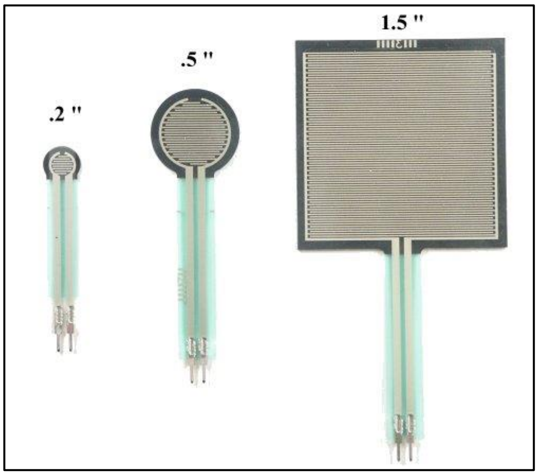


Figure 2.14: FSR sensor

Sensors that measure static and dynamic forces applied to a contact surface are known as Force Sensing Resistors (FSRs). Their response range is mostly determined by the variance in electric resistance. Flexi force and interlink are two common types of FSR sensors that are readily available, inexpensive, and easy to locate on the market [22]. The force-sensitive resistor sensor's general working concept is that it responds to the applied force and converts the value into a quantifiable quantity. An FSR sensor's operation is dependent on the attribute of 'Contact Resistance.' Force-sensing resistors have a conductive polymer coating on their surface that alters resistance in a predictable way when force is applied. This film is made up of electrically conducting and non-conducting particles that are organized in a matrix. When a force is applied to the film's surface, a micro-sized particle contacts the sensor electrodes, changing the film's resistance. The amount of change in resistance readings is used to calculate the amount of force exerted [22].

The simplest way to measure a resistive sensor is to use the analog voltage reading method, which involves connecting one end to the power and the other to ground through a pull-down resistor. The analog input of a microcontroller such as an Arduino is then linked to the point between the fixed pull-down resistor and the variable FSR resistor. As greater pressure is applied, the FSR's resistance changes. The sensor seems to be an infinite resistor (open circuit) while there is no pressure, but as the pressure grows, the resistance decreases [22].

2.10.3.3 Heartbeat Sensor

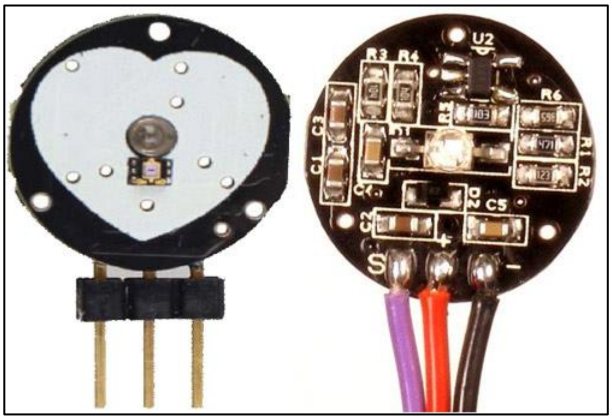


Figure 2.15: Pulse sensor

Pulse Sensor is an all-around planned attachment and-play pulse sensor for Arduino. It very well may be utilized by understudies, craftsmen, competitors, producers, and game and portable engineers who need to effortlessly join live heart rate information into their undertakings. The sensor cuts onto a fingertip or ear cartilage and plugs directly into Arduino with some jumper links. It additionally incorporates an open-source observing application that charts your heartbeat progressively [23].

2.10.4 Internet of Things (IoT)

The Internet of Things (IoT) refers to physical objects (or groups of such objects) that are integrated with sensors, processing power, software, and other technologies that connect to and exchange data with other devices and systems over the Internet or other communication networks [24].

Because of the confluence of numerous technologies, such as ubiquitous computing, commodity sensors, increasingly sophisticated embedded systems, and machine learning, the area has progressed. Traditional domains such as embedded systems, wireless sensor networks, control systems, and automation (including home and building automation) enable the Internet of things both separately and jointly. In the consumer market, IoT technology is most closely associated with products related to the concept of the "smart home," such as devices and appliances (such as lighting fixtures, thermostats, home security systems and cameras, and other home appliances) that support one or more common ecosystems and can be controlled by devices associated with that ecosystem, such as smartphones and smart speakers. The Internet of Things can also be employed in healthcare systems [24].

2.10.4.1 Application of IoT

The diverse variety of applications for IoT devices is frequently classified as consumer, commercial, industrial, and infrastructural [24].

2.10.4.2 Consumer Applications

Consumer-oriented IoT products, such as connected vehicles, home automation, wearable technology, connected health, and appliances with remote monitoring capabilities, are becoming more prevalent [24].

2.10.4.3 Product digitalization

There are various smart or active packaging applications in which a QR code or NFC tag is attached to a product or its container. The tag is passive in nature, but it provides a unique identifier (usually a URL) that allows a user to access digital content about the product via a smartphone. Such passive devices, strictly speaking, are not part of the Internet of Things, but they might be viewed as enhancers of digital interactions. The term "Internet of Packaging" refers to applications that use unique IDs to automate supply chains and are scanned on a broad scale by consumers to access digital content [24].

2.10.4.4 Environmental Monitoring

Environmental monitoring IoT applications often use sensors to aid in environmental protection by monitoring air or water quality, atmospheric or soil conditions, and can even encompass topics such as tracking wildlife movements and habitats. The development of resource-constrained devices linked to the Internet also means that additional applications, such as earthquake or tsunami early-warning systems, can be employed by emergency services to provide more effective assistance. In this application, IoT devices often cover a vast geographic region and can even be mobile. It has been proposed that the uniformity brought about by IoT will transform wireless sensing [24].

CHAPTER 3

METHODOLOGY

3.1 INTRODUCTION OF METHODOLOGY

This chapter will discuss about the planning of implementation of materials chosen in Chapter 2. This project or device is an improvement of the previous project. The methods used in this chapter are aimed to achieve the objectives of this project which will give satisfying results on the performance of control system in rehabilitation device. These methods are accomplished by implementing a new design or updated a preceding design that will ultimately improve the function, and efficiency, and also reduce the cost of the system.

The device is designed using an average height and/or weight of Malaysian. The calculation for the device's length and torque are only for the upper limb's length and weight. The plan of materials and design will be further discussed on the next sub chapters.

3.2 FLOWCHART FOR REHABILITATION SYSTEM

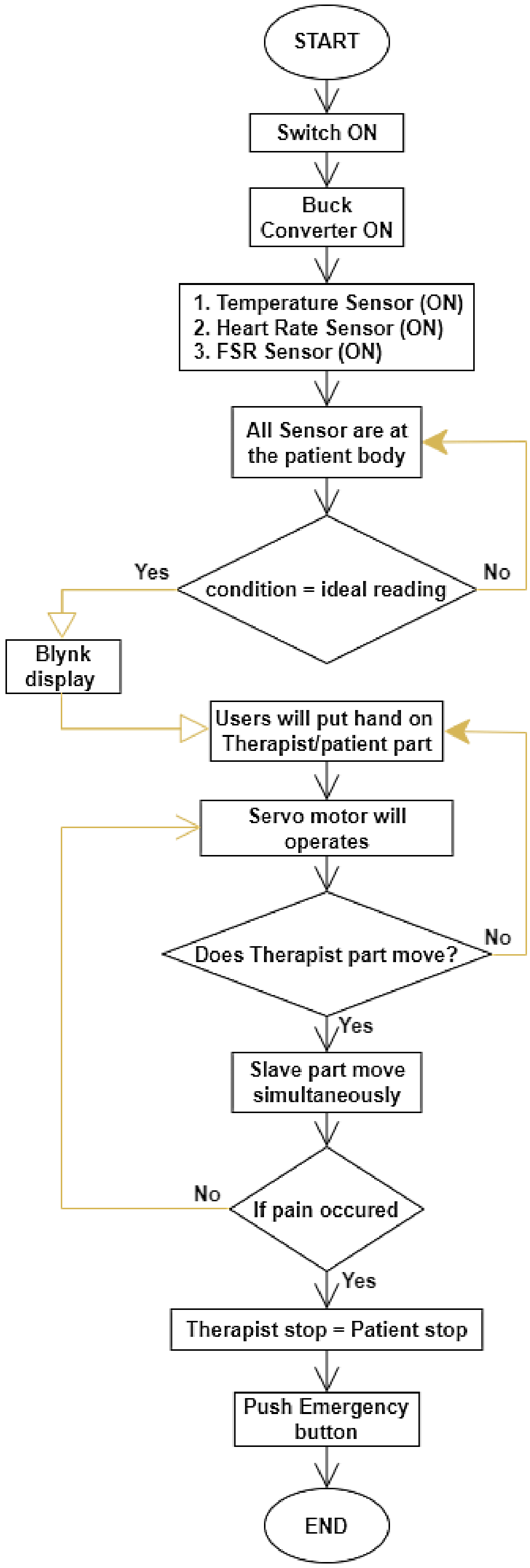


Figure 3.1: Operation Flowchart

The flowchart above shows the process involved in completing the prototype. Initially, the process will be beginning by identifying the problems faced by users who need rehabilitation devices that can help them to ease the recovery. Then, the research is conducted based on the related problems. Next, the material selection process is done by choosing the right material for this project by listing out the materials. The designing and fabrication are done using the chosen material (PETG filament). Analysis of pain detection and health monitoring is done using an FSR sensor, Temperature sensor and Heartrate sensor. After a complete installation, the device is been analyzed and collection of data has been done. Reanalysis and redesigning are done if there is an error that occurs. If there is no error, the outcome is recorded.

3.3 3D MECHANICAL DESIGN

The design in figure 3.2 shows the mechanical part which has been designed in SolidWorks software. The design consists of elbow, forearm and fingers part that printed separately. All the mechanical is printed using 3D printing by using PETG filament as the main material to developed the therapist and patient hand rehabilitation part.

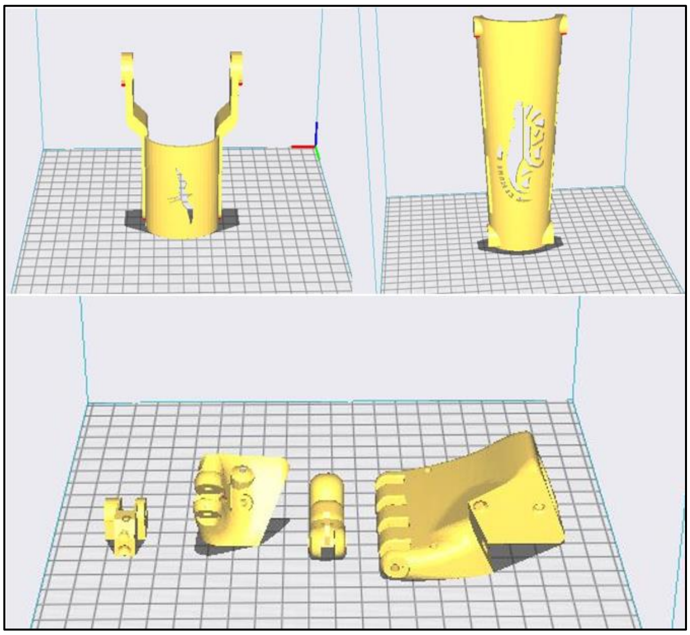


Figure 3.2: 3D design of upper arm rehabilitation

3.4 FUNCTIONAL OPEN LOOP DIAGRAM

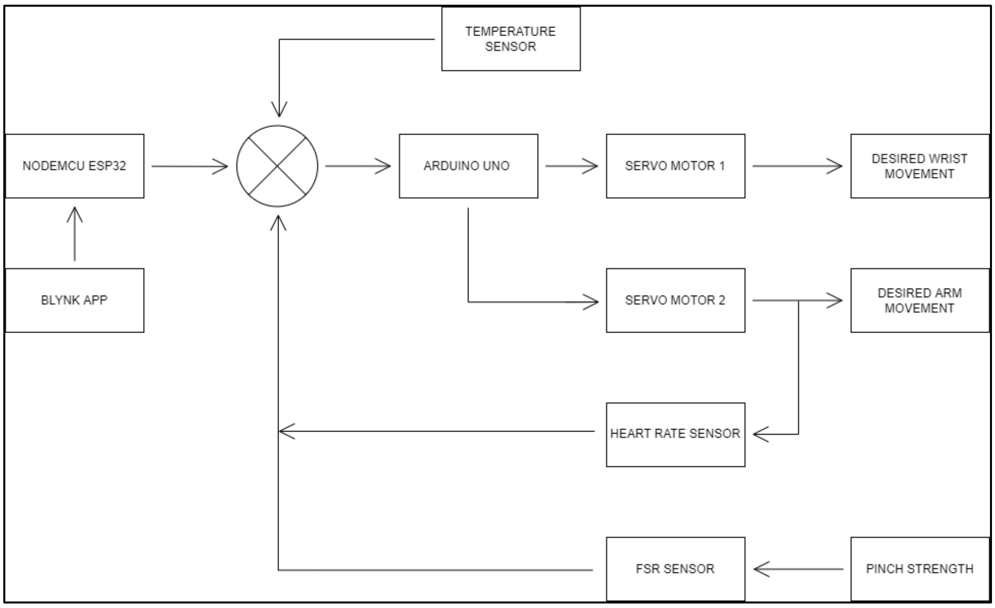


Figure 3.3: System's Block Diagram (Open-loop)

This device implements an open-loop system. This system is used when user want to monitor their body temperature, bpm rate and as well as the applied force at the finger of the user during the rehabilitation process. There is no feedback in this system. When all the sensors were implemented, the output will be obtained during the rehabilitation process.

3.5 INTERFACE

There will be only one type of interface used in this project that is Smartphone Apps. These interfaces allow users to have easier access to monitor the user body health by simply connect to the Wi-Fi. This apps will allow user to connect Wi-Fi with microcontroller that have the function of Wi-Fi.

The main controller that will be used is the Smartphone Apps due to its features to add on interesting interface which will attracts the user. In addition, the smartphone also allows the user to accurately record the prototype results and send them to the cloud server of the user, allowing them to access any gadgets and anywhere. When it is stored on the server, developers can also obtain access to user data. This enables developers to receive reports from several users and to analyze the performance of the user after a long period of time and use Big Data technology to organize the data to present it as Business Intelligence (BI). In this way, based on the feedback of the user and also the reports that will be gained from the data, the device can be further improvised or upgraded.

3.6 OPERATING SYSTEM

The operating system (OS) chosen for this device is the Android OS interface (refer Table 2). Android gives users a lot of flexibility and it's free if developers want an application to be developed based on the user desired. Afterward, this topic will be discussed later.

The main concern of users in the part of security is when the Android OS is easier to be hacked and some private information or valuable data can be stolen from the Android server which can jeopardize the users trust for using the Android. Even though in the term of security level, iPhone Operating System (iOS) is for better than that Android but this can be solved by installing some powerful cyber security apps to ensure the device is safe in sound and fully protected. So, the users have to invest a bit in security.

Table 2 Differences of Android OS and iOS

TYPE	ANDROID	IOS
Customizability	Can change almost anything	Limited unless with jailbreaking
Source model	Open source	Closed, with open-source components.
File transfer	Using USB port and Android File Transfer desktop app. Photos can be transferred via USB without apps	Media files can be transferred using iTunes desktop app. Photos can be transferred out via USB without apps.

App store, Affordability and Interface	Google Play: 1,000,000++ apps. Other app stores like Amazon and Getjar also distribute Android apps. (Unconfirmed ". APKs")	Apple app store: 1,000,000++ apps
Security	Android software patches are available soonest to Nexus device users. Manufacturers tend to lag behind in pushing out these updates. So, at any given time a vast majority of Android devices are not running updated fully patched software.	Most people will never encounter a problem with malware because they don't go outside the Play Store for apps. Apple's software updates also support older iOS devices.
Open source	Kernel, UI, and some standard apps	The iOS kernel is not open source but is based on the opensource Darwin OS.
Voice commands	Google Now, Google Assistant	Siri

3.6.1 Blynk App

Blynk is a platform with iOS and Android applications to control microcontroller, such as Arduino, Raspberry Pi and the preferences over the Internet. It is a computerized dashboard where you can construct a realistic interface for your venture by basically moving gadgets. Blynk is not attached to some particular board or shield. It is supporting equipment of engineer decision. Blynk was intended for the Internet of Things. It can control equipment remotely, it can show sensor information, it can store information, visualize it and do numerous other cool things.

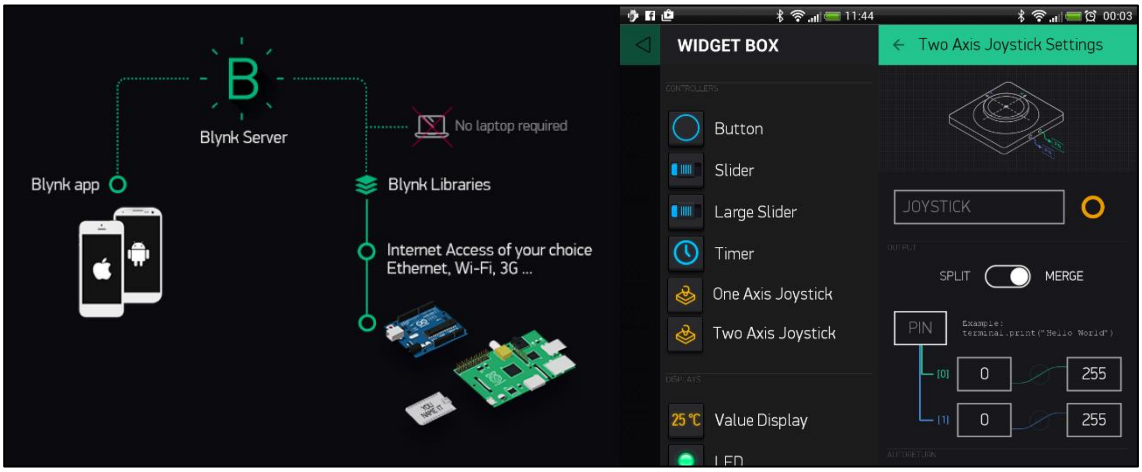


Figure 3.4: Blynk app

While, Android Studio is the official integrated development environment (IDE) for Android application development. It is based on the IntelliJ IDEA, a Java integrated development environment for software, and incorporates its code editing and developer tools. Basically, Android Studio use same ways as Blynk in order to create and designing the app, but the difference is Android Studio use formatted coding language. The official language for Android development is Java. Large parts of Android are written in Java and its APIs are designed to be called primarily from Java. It is possible to develop C and C++ app using the Android Native Development Kit (NDK), however it is not something that Google promotes.

3.7 COMPONENT SELECTION

3.7.1 Esp32 Devkit V1 - Doit

This page serves as an introduction to the ESP32 development board. If you've heard of the ESP8266, the ESP32 is its successor. The ESP32 comes with a slew of new features. The most important feature is that it combines Wi-Fi and Bluetooth wireless capabilities and is dual core.

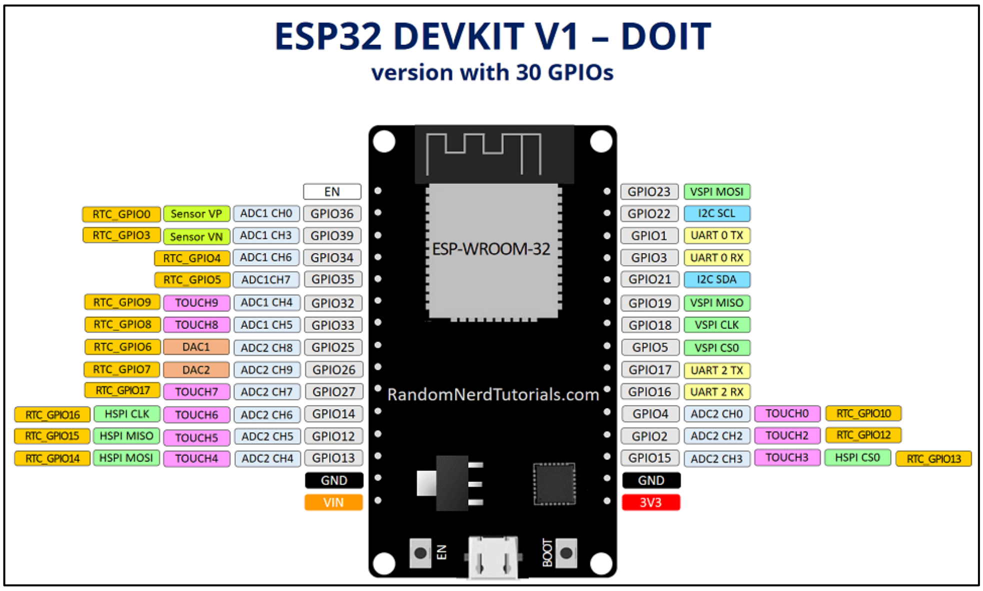


Figure 3.5: ESP-WROOM-32 chip

In this part, we'll be referencing the ESP32 DEVKIT DOIT board. However, the information on this page is also applicable to other ESP32 development boards that use the ESP-WROOM-32 chip.

3.7.2 Emergency Stop Button

An emergency stop push button is a fail-safe control switch that provides both safeties for the machinery and for the person using the machinery. The purpose of the emergency push button is to stop the machinery quickly when there is a risk of injury or the workflow requires stopping. All machinery requires an emergency stop button unless it would not reduce the risk or the machine is hand operated. The buttons are red as standard, often with a yellow background [26].

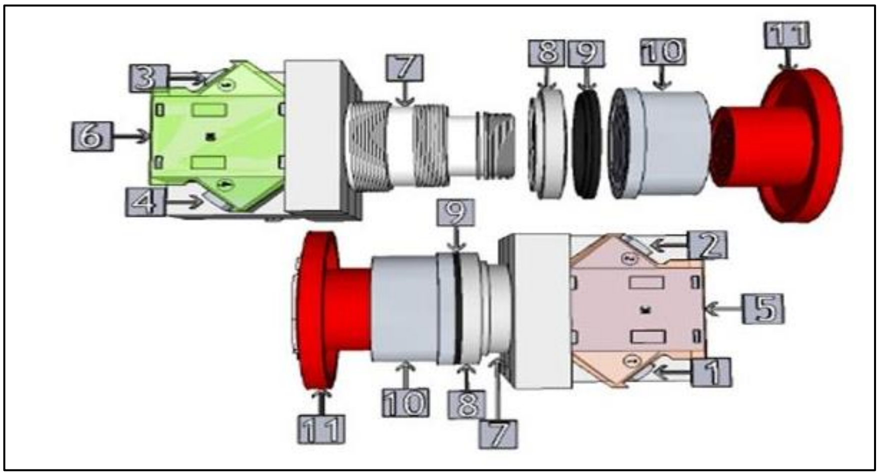


Figure 3.6: Emergency stop button

Table 3 Description of the emergency stop button

1	Terminal 1 (Normally Closed circuit in)
2	Terminal 2 (Normally Closed circuit out)
3	Terminal 3 (Normally Open circuit in)
4	Terminal 4 (Normally Open circuit out)
5	Normally Closed Circuit
6	Normally Open Circuit
7	Switch Assembly
8	Inner retaining nut
9	Rubber seal
10	Outer retaining nut
11	Mushroom button

3.7.3 Lipo Battery

Figure 3.7: Lipo battery 2200mAh

It is very important to have supply voltage from Lipo battery because easy could powerup two servo motors easily because the current produce is higher if compare with other batteries (Such as Li-ion batteries, Ni-MH batteries, Ni-cd batteries, and Lead-acid batteries). The other reasons of choosing Lipo batterie 11.1V because of lightweight and having long life [27].

Specification: -

i. Ordinary Voltage: 11V

ii. Fully-charged: 12.6V

iii. Capacity: 2200mAh

3.7.4 Switch button

Figure 3.8: Switch button

The momentary push-button switch is a type of biased switch. The most common type is a “push-to-make” (or normally-open or NO) switch, which makes contact when the button is pressed and breaks when the button is released. Each key of a computer keyboard, for example, is a normally-open “push-to-make” switch [28].

Table 4 pecification of switch button

TYPE	SPDT ON-OFF
Rating	15A 250VAC
Dielectric Strength	1500VAC 1 minute
Insulation resistance	1000MΩ Min
Contact resistance	50mΩ Max
Operating Temperature	-25°C to +85°C

3.7.5 Voltage Regulator (LM2596)

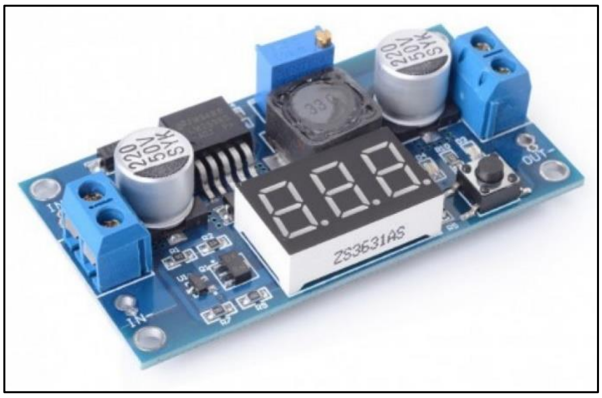


Figure 3.9: LM2596 DC-DC

In order to step down the 12V supply from the source to power up the Arduino Board and servo motor, LM2596 is used. The voltage regulator steps down the 12V to 5V approximately. Basically, the voltage controller keeps up the voltage of a power source inside satisfactory breaking points. The voltage controller is expected to keep voltages inside the endorsed run that can be endured by the electrical gear utilizing that voltage. The LM2596 is a 5V voltage controller that confines the yield voltage to 5V yield for different scopes of information voltage. It goes about as an astounding segment against input voltage variances for circuits and adds an extra safety to the hardware [29].

3.7.6 Servo Motor

Figure 3.10: Servo Motor 15kg

There are two servo motor used in this project. One of them is placed at the elbow for the forearm movement (15KG) and another is placed at the wrist movement (15KG). The model of servo motor use in this project is TD8115 15KG servo. The reasons we choose servo motor because servo motors are typically AC synchronous brushless motors with built-in positional feedback. Servo motors are used in closed-loop motion control systems where angular position, speed and torque can be very accurately controlled. The rotor of a servo motor uses permanent magnets and can be infinitely positioned between magnetic poles on the stator by varying the voltage and current between windings. The other reasons we chosen servo motor is because Servo motors are well suited to precision to applications where accurate control of motor speed, position and/or torque is required. Table 5 shows the Specifications for servo motor [30].

Table 5 Specification of servo motor based on datasheet

SPECIFICATION	SERVO MOTOR 15KG (TD8115)
Operating voltage	4.8V – 7.4V
Current	1800mA – 2200mA
Stall Torque	14.5kg/cm
Maximum stall torque	17.2kg/cm
Operating speed	0.17sec/60° - 0.20sec/60°
Rotation	0° - 180°
Weight	65.5g

3.7.7 Potentiometer

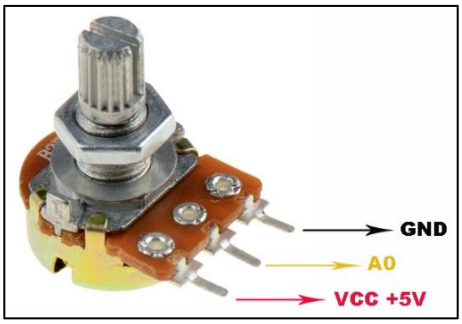


Figure 3.11: 10k ohm potentiometer

10k ohm potentiometer is used in this project to control the servo motor. A potentiometer is a variable resistor from one side to the wiper. The full resistance is across it. So, a 10k potentiometer is 10k ohms across, and the wiper goes from one end (0 ohms) to the other (10k ohms). Similarly, for a 100k potentiometer [31].

3.8 SENSOR SELECTION

3.8.1 Temperature sensor

Figure 3.12: Dallas Temperature sensor

In this project, the DS18b20 sensor is used. The DS18B20 is a 1-wire programmable Temperature sensor from maxim integrated. It is widely used to measure temperature in hard environments like in chemical solutions, mines or soil, etc. The constriction of the sensor is rugged and also can be purchased with a waterproof option making the mounting process easy. It can measure a wide range of temperature from -55°C to +125° with a decent accuracy of ±5°C. Each sensor has a unique address and requires only one pin of the MCU to transfer data therefore it is suitable for measuring the temperature at multiple points without compromising much of the digital pins on the microcontroller [32].

Table 6 Specification of Temperature sensor

Power range	3V to 5.5V		
Operating temperature range	-55°C to +125°C (-67F to +257F)		
Accuracy range	10°C to +85°C (±0.5°C)		
Resolution ratio	9~12 bit		
Connection mode	Black: GND	Yellow: Data	Red: VDD+

3.8.2 FSR sensor

Force Sensing Resistors (FSR) sensors are devices that allow measuring static and dynamic forces applied to a contact surface. Their range of responses is basically depending on the variation of its electric resistance [33]. There are several applications of force sensitive resistor such as it detects or measures a rate of change in force, relative change in force, contact or touch as it detects force thresholds to trigger an action of some sort.

Figure 3.13: FSR sensor

In this project, the shunt mode force sensing resistors is used. Shunt mode force sensing resistors are polymer thick-film devices consisting of two membranes separated by a thin air gap. Force sensing resistors are not pre-calibrated to correlate a force reading to a known SI unit. However, the force measurement output captured by a force sensing resistor can be correlated to the applied force through a calibration procedure. Force sensing resistors are a piezoresistive sensing technology which means they are passive elements that function as a variable resistor in an electrical circuit [33].

3.8.3 Heart rate sensor

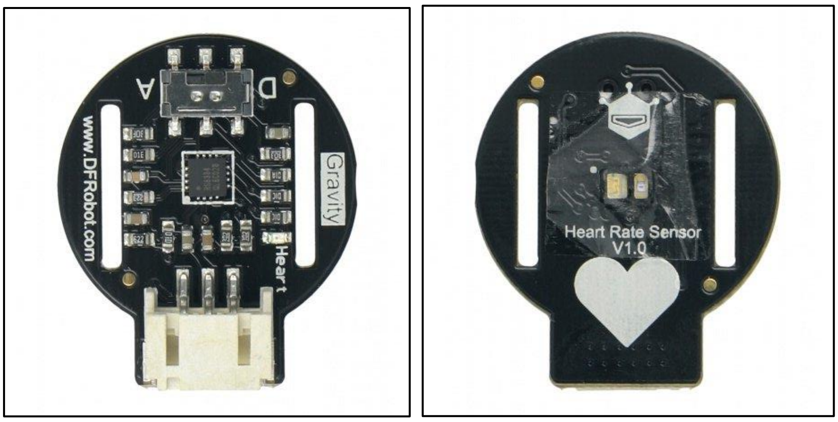


Figure 3.14: DFRobot gravity heart rate sensor

This is DFRobot heart rate sensor which is a thumb-sized heart rate monitor designed for microcontroller. This heart rate monitor sensor is a pulse sensor which is developed based on PPG techniques. This is a simple and low-cost optical technique that can be used to detect blood volume changing in the microvascular bed of tissues. It is relatively easy to detect the pulsatile component of the cardiac cycle according to theory. The sensor has two holes that you can use to attach to your belt. You can wrap on your finger, wrist, earlobe or other areas where it has contact with your skin. A Gravity Interface is adapted to allow plug and play to ease the barrier of usage. Besides, this sensor can also be compatible with Raspberry Pi, intel Edison, joule and curie by means of 3.3V Input Voltage [34].

Table 7 Specification of Gravity heart rate sensor

Name	Gravity: Analog/Digital PPG Heart rate sensor	
IC/Module	SON1303	
Operation voltage (VCC)	3.3V~6V	
Output	(Analog 0 ~ VCC)	(Digital 0 ~ VCC)
Measurement Principle	PPG (Photo Plethysmo Graphy)	
Average power	<10mA	
Dimension	Length: 28mm	Width: 24mm

Features	1. PPG method, convenient and fast. 2. Analog (Pulse wave) & Digital (heart rate), configurable output. 3. 3.3V/5V compatible.

3.9 SOFTWARE SELECTION

3.9.1 Fritzing

Figure 3.15: Fritzing software logo

Fritzing is used to draw an electrical wiring outline. It is an extraordinary open-source apparatus that accompanies huge amounts of electronic parts as of now introduced with the components that permit outlining a schematic which can be added into the wiring diagram [35].

3.9.2 Arduino IDE

Figure 3.16: Arduino IDE software logo

The open-source Arduino Programming (IDE) makes it simple to compose code and transfer it to the board. It keeps running on windows, Mac, and Linux. The environment is writing in C++ and in view of preparing and other open-source programming [36].

3.10 CIRCUIT CONNECTION

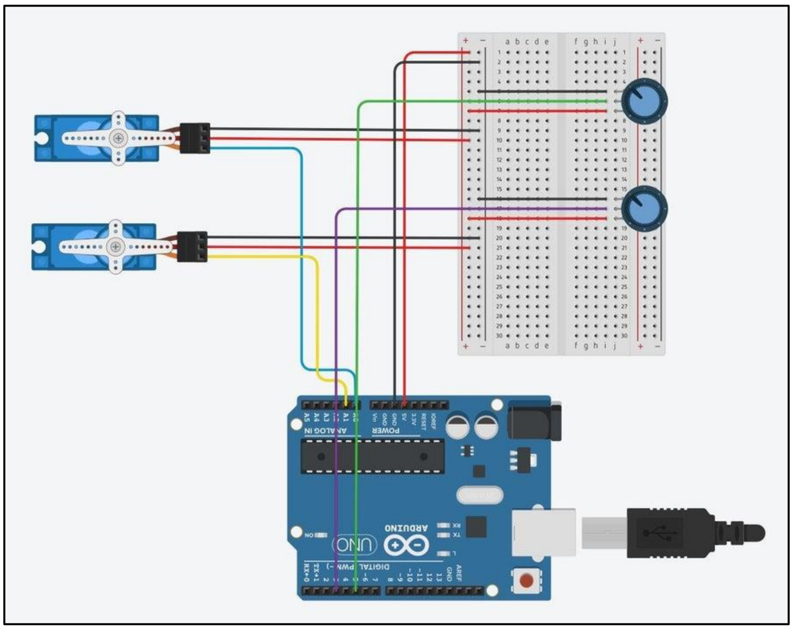


Figure 3.17: Circuit connection of Arduino with Servo motors and Potentiometer

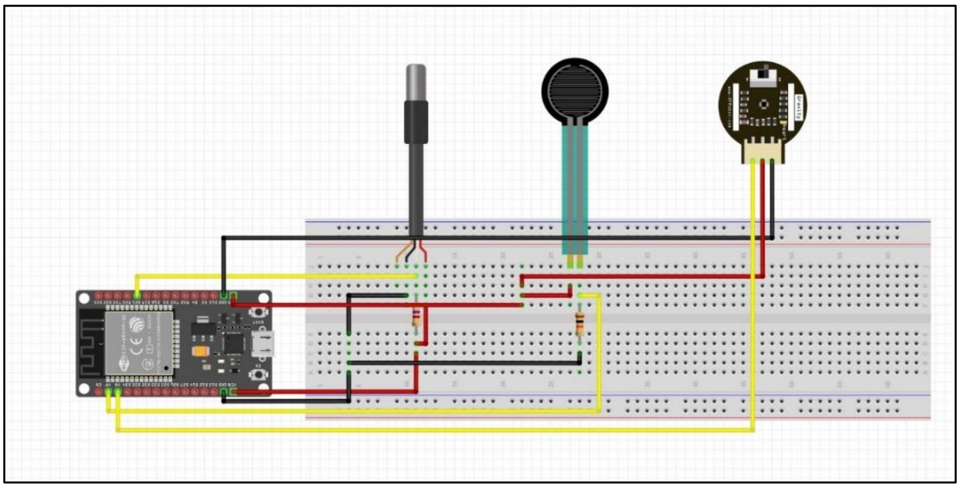


Figure 3.18: Circuit connection of ESP32 with sensors

The system of this prototype is connected as shown in diagrams above. The servo motors are both controlled by the potentiometer. Besides that, sensors receive input and output from Arduino UNO that already programming with C++ language. Next, the voltage regulator is used to step- down the voltage from the Li-po battery before powering up Arduino UNO, ESP32, and servo motor. Finally, this circuit consists of an emergency push button to stop or to break the circuit quickly when there is a risk of injury or the workflow requires stopping.

3.11 TOTAL COST EXPENSES

Table 8 Total cost expenses

NO	ITEM	PRICE(RM)
1	DFRobot Gravity Heart rate Sensor	RM 102.00
2	Digital Servo Motor 15KG	RM 98.60
3	ESP32 board + USB cable	RM 32.90
4	FSR402 FSR Sensor	RM 29.90
5	Switch Button, Jumper Wire, Emergency Stop button, Breadboard, B10K Potentiometer, PCB board	RM 53.70
6	11.1V 2200mAh Lipo Battery	RM 69.60
7	LM2596 DC-DC Voltage regulator	RM 33.50
8	Arduino Uno R3 + USB cable	RM 38.90
9	Junction Box (4*4inch) + (6*4inch)	RM 13.00
10	DS18B20 Waterproof temperature sensor	RM 12.50
11	Spray paint black + 40 pin male header	RM 12.40
12	Bracket 8pcs (75*75) and (50*50) + Tube(H/Shrink)	RM 13.55
13	L bracket × 4 unit	RM 10.00
		TOTAL RM 520.55

3.12 SUMMARY

In this chapter, the author has explained about the flow, method and material that used to design the software and hardware part for the smart upper limb rehabilitation device with monitoring system.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 INTRODUCTION

This chapter explains about results obtained based on the therapist and patient hand movement and system voltage used in this prototype. Besides that, the result of the monitoring system also been implemented in this part with various result. The discussion was made based on the results which were obtained through this prototype.

4.2 PRODUCT DESIGN DIMENSION

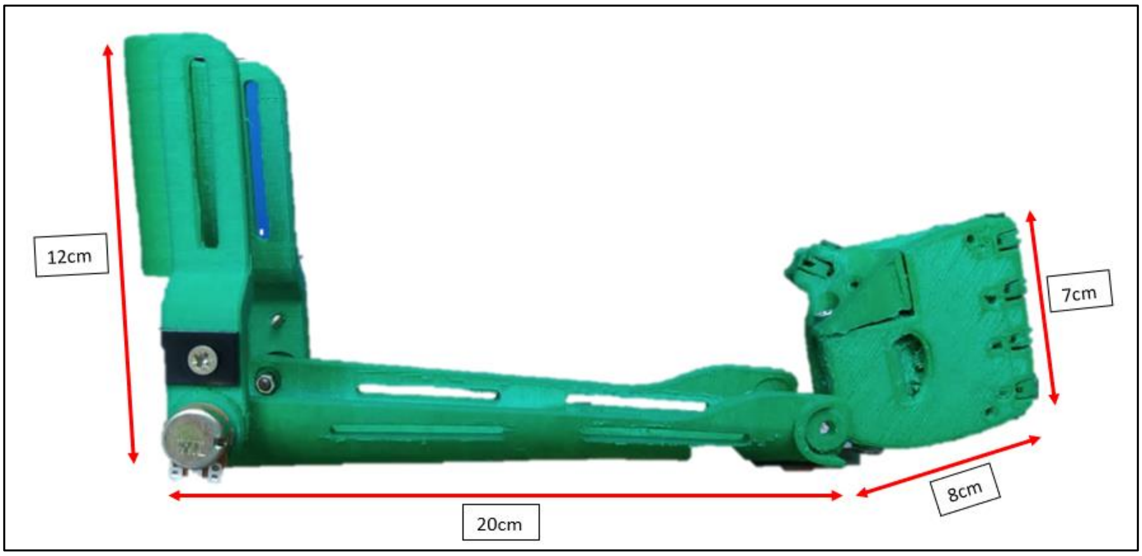


Figure 4.1: Therapist/patient dimension part

4.3 PROJECT DESIGN

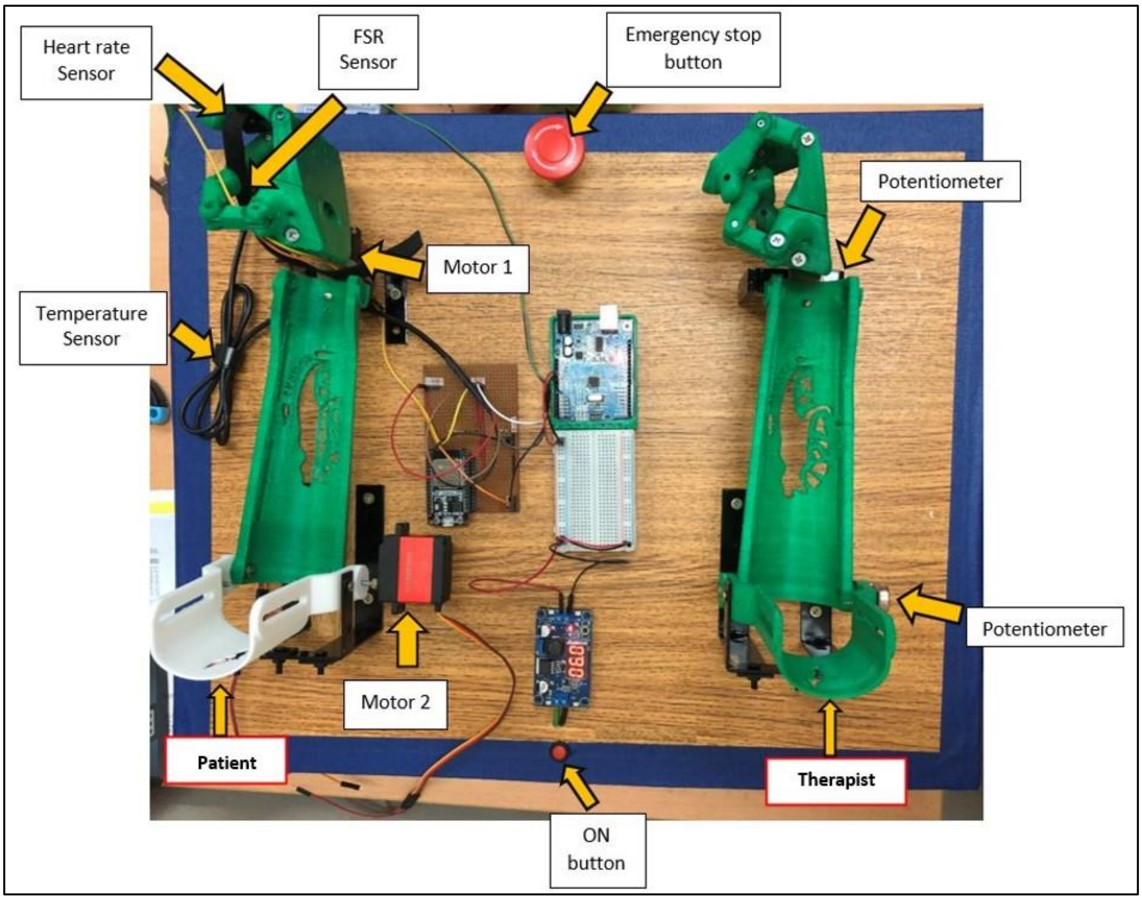


Figure 4.2: Full view of the final design of prototype

The design overall consists of two servo motors and two potential meters used in this project. One of the potential meters is placed at the elbow for lower arm movement and the other is placed at the wrist of the therapist's hand. One of the servo motors is placed at the elbow for lower arm movement and the other is placed at the wrist of the patient's hand.

In this project, there are supporting elements that were attached to the project for a user to rest their arm during the rehabilitation process. Besides that, the patient hand is controlled by the therapist, and the potential meter connected in the therapist's hand joint is controlled by the movement of the patient's hand. There are three different types of sensors such as Temperature sensor, Heartrate sensor, and Force Sensitive Resistor (FSR) sensor. All these sensors will be safely attached to human hand skin to receive or collect data information from patients. Besides that, the user can control the movement pattern of the servo motors and is also able to monitor the applied force during wrist movement as well as monitor their temperature with the muscle contractions during rehabilitation using their smartphones. For safety purposes, this project has an emergency stop button and a fuse so that it can break the circuit connection whenever a patient is in danger situation and to prevent overflow of current respectively. The last part of the design is an ON/OFF mini power switch located at the storage box to control the ON and OFF of the system.

4.4 MECHANISM OF OPERATION

1. Therapist and Patient forearm movement: -

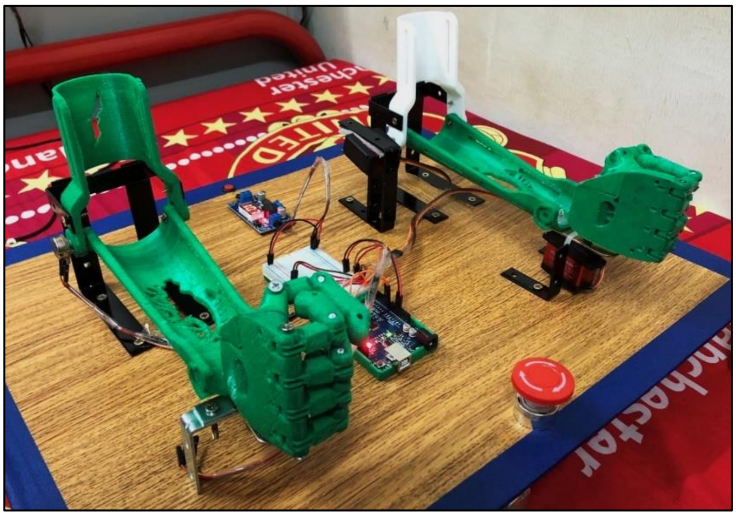


Figure 4.3: Starting position (0 degree of angle)

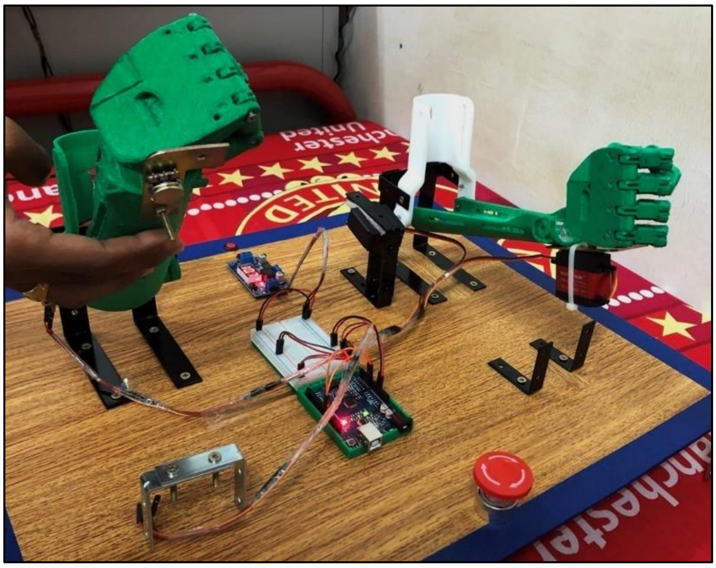


Figure 4.4: Final position (60 degree of angle)

2. Therapist and Patient wrist movement: -

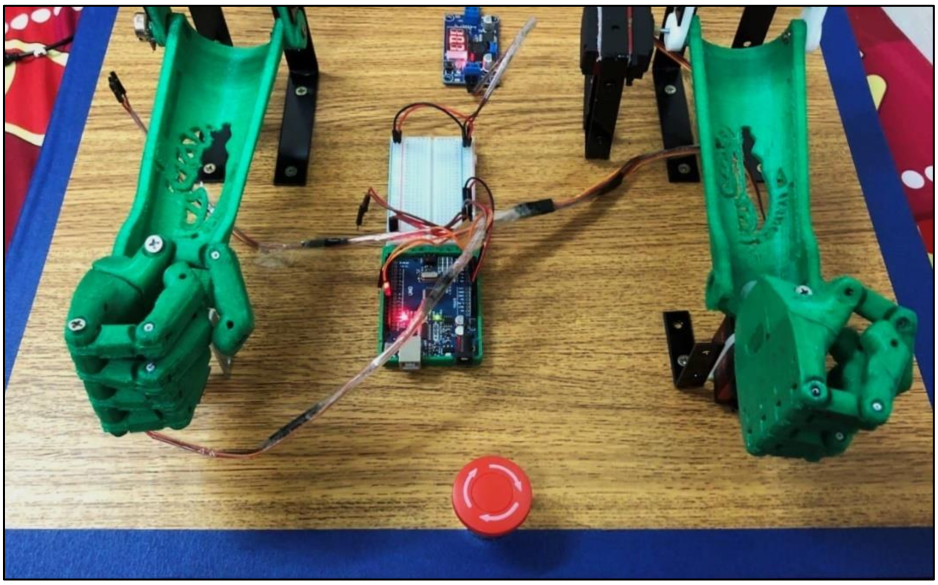


Figure 4.5: Starting position (0 degree of angle)

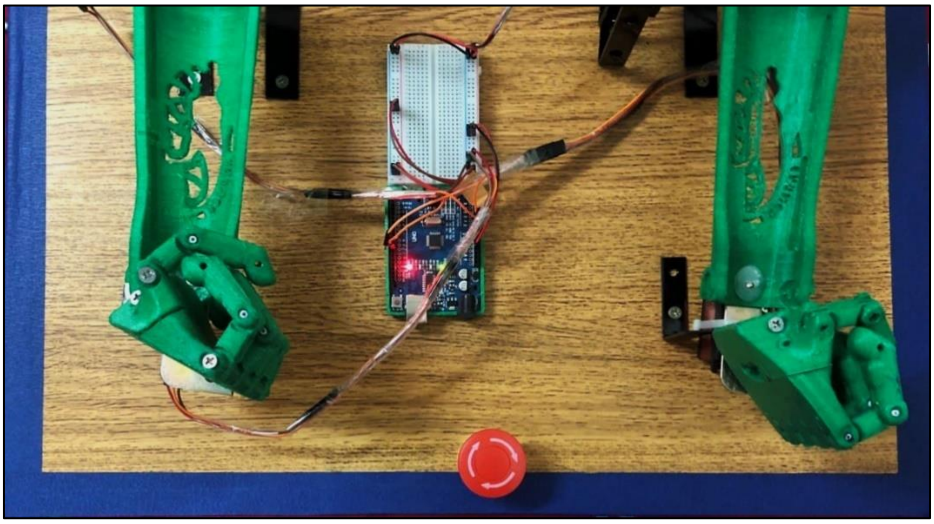


Figure 4.6: Final position (60 degree of angle)

4.5 EXPERIMENTAL RESULT

4.5.1 Prototype measurement of voltage and current in the circuit

Table 9 Voltage and Current data from the system without load

Component	Voltage, V	Current, Ma
Battery	11.68	7
ESP32	3.3	5
Servo Motor (15kg)	7.59	0.632
Potentiometer	7.59	0.632

4.5.2 Graph of voltage

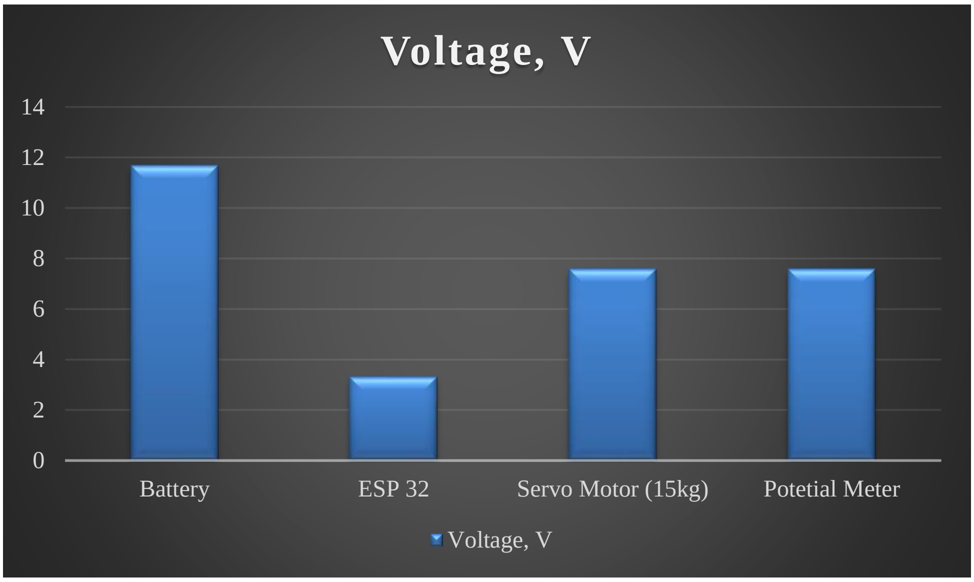


Figure 4.7: Graph of voltage without load

4.5.3 Angle difference between Therapist and Patient

Table 10 Shows the angle difference between therapist and patient

ANGLE	THERAPIST	PATIENT
0°	0°	0°
10°	10°	8°
15°	15°	13°
20°	20°	18°
25°	25°	23°
30°	30°	28°
35°	35°	33°
40°	40°	38°
45°	45°	43°
50°	50°	48°
55°	55°	53°
60°	60°	58°

The table above shows the angle between the therapist's forearm movement angle and the patient forearm movement angle. 12 angles have been tested between both forearms. There are a few milliseconds of delay between the potential meter and servo motor. This experiment is conducted by lifting the therapist's forearm at each angle and calculating the patient forearm angle which was controlled by the therapist's forearm.

4.5.4 Graph of angle difference between Therapist and Patient

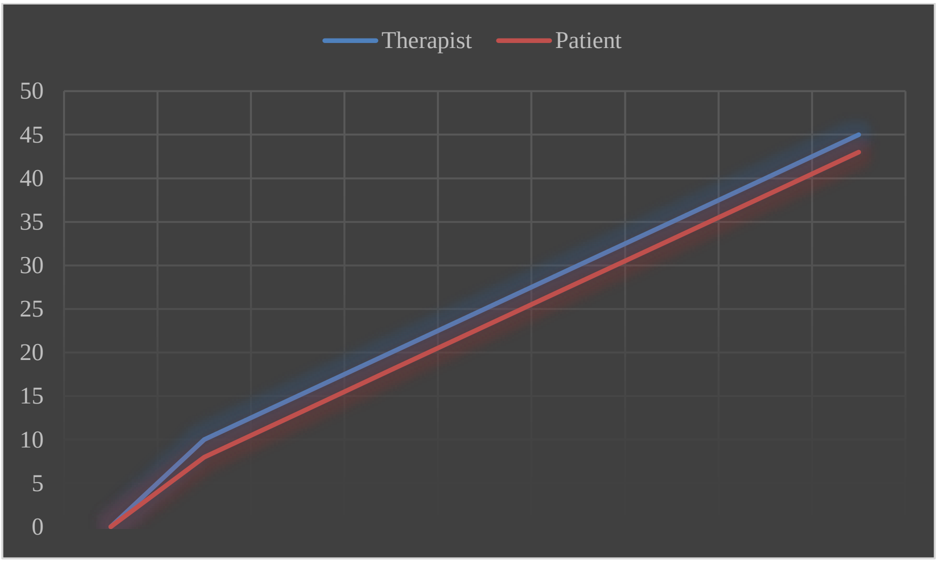


Figure 4.8: Graph of angle difference between therapist and patient

4.5.5 Time delay with weight on patient hand

Table 11 Shows time delay with load

Weight (gram)	Attempt 1 (second)	Attempt 2 (second)	Attempt 3 (second)
200	0.1	0.1	0.1
500	0.1	0.2	0.2
700	0.5	0.5	0.5
1000	0.9	0.9	0.9
1200	1	1	1
1500	1	1.2	1.2

1700	1.1	1.1	1.1
2000	1.1	1.2	1.2
2200	1.3	1.3	1.3
2500	1.3	1.3	1.3
2700	1.4	1.3	1.3
3000	1.4	1.3	1.3

The table above shows the time delay with weight on the patient forearm. There are a total of 12 different weights have been used to test the delay. This experiment is repeated 3 times to get the average value of the delay. We used a plastic bag filled with iron nuts and bolt for weight. Each weight has a different time delay depending on the time.

4.5.6 Graph time delay with weight on patient hand

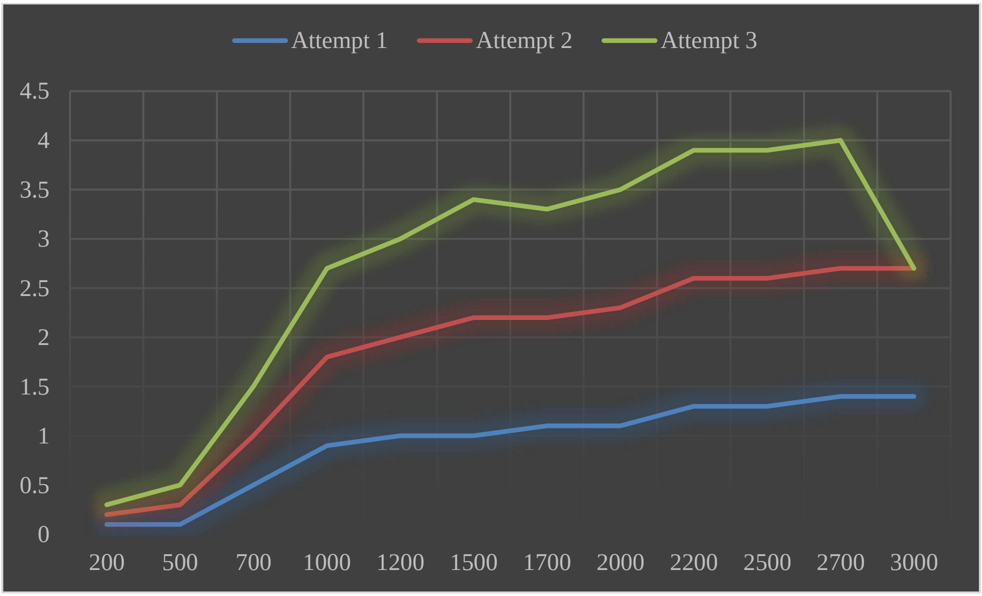


Figure 4.9: Graph of angle difference between therapist and patient

4.6 BATTERY EFFICIENCY

The battery efficiency is calculated based on the time; t used with output voltage. At time t= 0S

Battery voltage, V0 = 11.1V Battery current, A0 = 2200 mH

Pin = V x A = (11.1V × 2200 mH) = 24.42 W

At time t = 402.7 sec

Battery Voltage, V1 = 10.9V

Battery current, A1 = 5.1A

Pout = V1 x A1 = (10.9V × 5.1A) = 55.59 W

Efficiency, η = Pout/Pin × 100%

= (55.59/24.42) × 100% = 22

4.7 DS18B20 TEMPERATURE SENSOR DATA RESULT

In this project, we used DS18B20 waterproof temperature sensor to monitor the temperature of patient body. It became essential to add temperature monitoring during the time of the pandemic of COVID-19. For controller, we connect this sensor with ESP32 because of ESP32 has a built in Wi-Fi module with HT40. Figure 4.9 shows that the serial monitors result of the user when they put the sensor under the armpit.

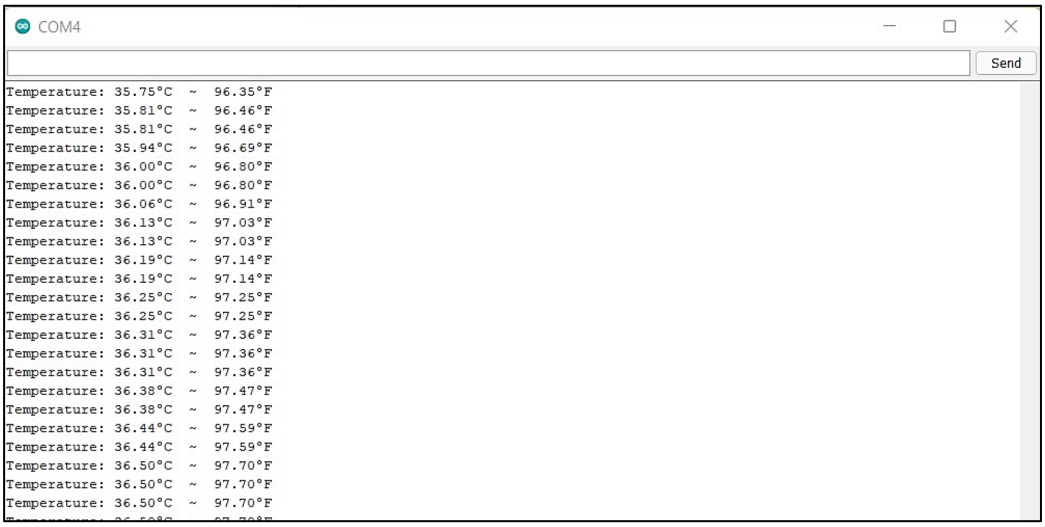


Figure 4.10: The result of body temperature

4.7.1 Program code of Temperature sensor

Figure 4.11: Including the OneWire.h and DallasTemperature.h

First of all, we include an OneWire.h as our library by Paul Stoffregen to lets accessing 1-wire devices made by Maxim/Dallas, for temperature sensor that we used. The SENSOR_PIN 21 is refer to ESP32 pin GIOP21 connected to DS18b20 sensor's DQ pin. Then, we also include a DallasTemperature.h by Miles Burton. This library is compatible with the DS18B20, DS18S20, MAX31820 devices.

Temperature_sensor §

```
#include <OneWire.h>
#include <DallasTemperature.h>
#define SENSOR_PIN  21 // ESP32 pin GIOP21 connected to DS18B20 sensor's DQ pin

OneWire oneWire(SENSOR_PIN);
DallasTemperature DS18B20(&oneWire);

float tempC; // temperature in Celsius
float tempF; // temperature in Fahrenheit

void setup() {
  Serial.begin(9600); // initialize serial
  DS18B20.begin();    // initialize the DS18B20 sensor
}

void loop() {
  DS18B20.requestTemperatures();       // send the command to get temperatures
  tempC = DS18B20.getTempCByIndex(0);  // read temperature in °C
  tempF = tempC * 9 / 5 + 32; // convert °C to °F

  Serial.print("Temperature: ");
  Serial.print(tempC);    // print the temperature in °C
  Serial.print("°C");
  Serial.print("  ~  ");  // separator between °C and °F
  Serial.print(tempF);    // print the temperature in °F
  Serial.println("°F");

  delay(50);
}
```

Figure 4.12: Program code of DS18B20 with ESP32 on Arduino IDE

Figure 4.10 shows that the full scripts of coding program that we construct to reads temperature from DS18B20 and display the readings on the arduino IDE serial monitor as you can see the result is in the figure 4.9. We declare the celcius and fahrenheit as a float function. In our setup function, We set the baud rate to the default 9600 and the we start the initialize the DS18B20 by read the library that we have included above.

Lastly, in our loop function, we read the reading from the DS18B20 sensor. Then, from that reading we convert the value to get the fahrenheit value by using tempF = tempC * 9 / 5 + 32. The output of celcius and fahrenheit will be display along with the text “Temperature:” .

4.7.2 Temperature reading that obtained from the patient

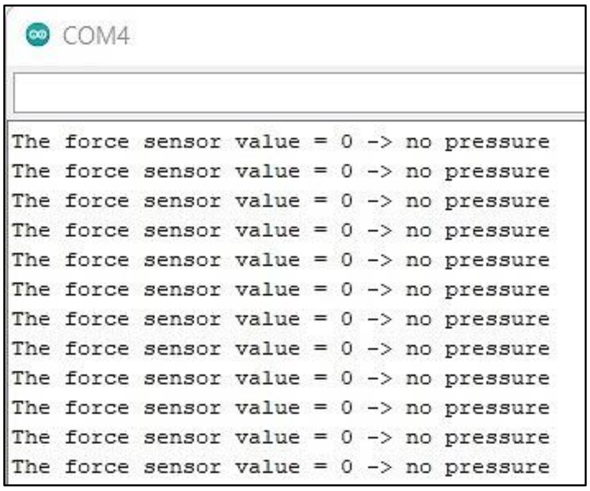
Table 12 Temperature reading in celcius and fahrenheit of the users during rehabilitation process.

USER	TEMPERATURE READING	
	CELCIUS (°C)	FAHRENHEIT (°F)
1	36.35	97.43
2	36.54	97.77

Based on the table above, the temperature reading shown for user 1 and user 2 is approximately in the range of 36.0°C and 37.0°C. Here we can conclude that the result that has been obtain is in normal range that user 1 and user 2 is in good condition to proceed to the next process of the rehabilitation procedurs. If the result of their temperature reading highest than the normal range, they need to postpones the rehabilitation process until the good reading is achieve.

4.8 FSR SENSOR DATA RESULT

The figure below shows the FSR sensor value and condition with ESP32 as our second monitoring sensor that we used. The sensor that we select is force sensitive resistor with thickness less than 0.5mm flat surface. But, the disadvantages of this sensor is their low precision measurement result may differ 10% and more.



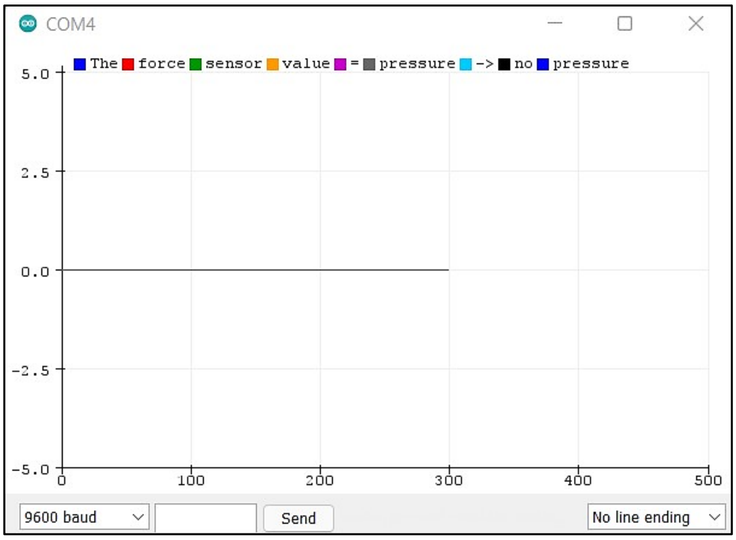


Figure 4.13: The value and graph of the FSR sensor when condition is no pressure

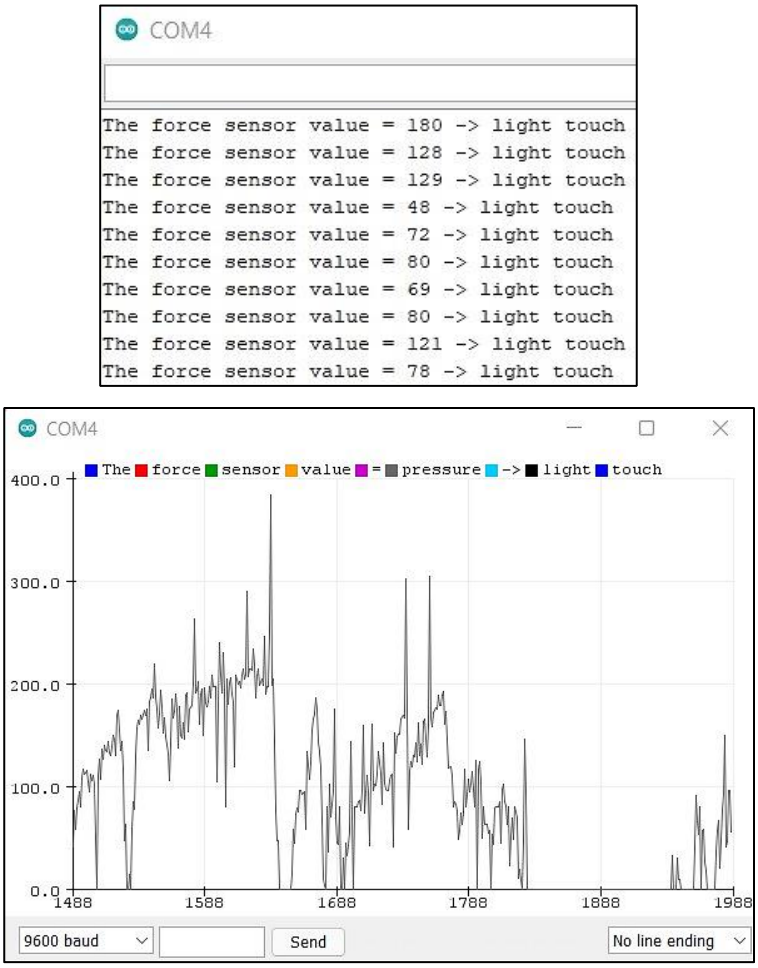


Figure 4.14: The value and graph of the FSR sensor when condition is light touch

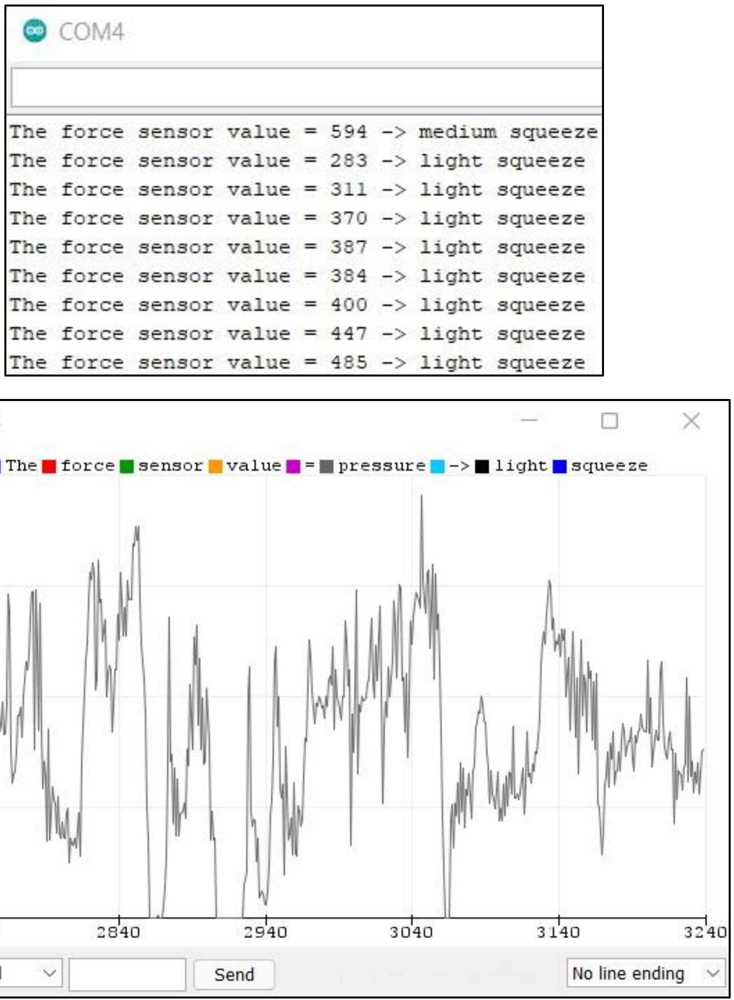
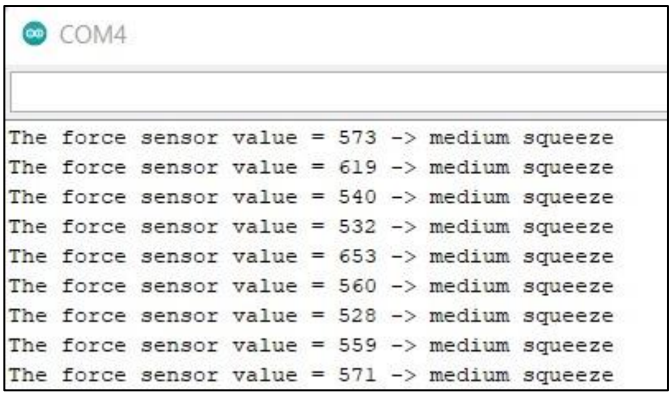


Figure 4.15: The value and graph of the FSR sensor when condition is light squeeze



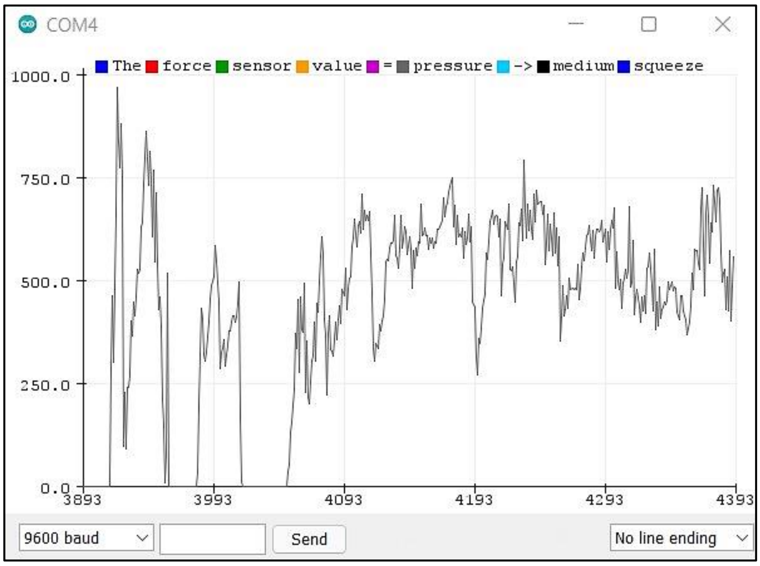


Figure 4.16: The value and graph of the FSR sensor when condition is medium squeeze

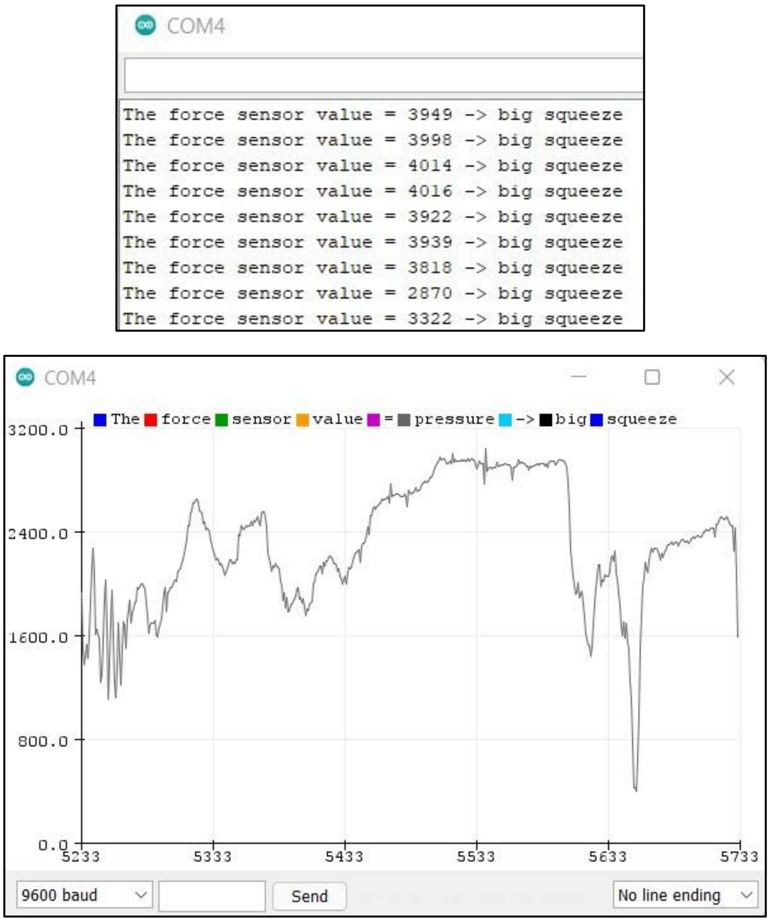


Figure 4.17: The value and graph of the FSR sensor when condition is big squeeze

4.8.1 Program code of FSR sensor

```
FSR_sensor §
#define FORCE_SENSOR_PIN 36 // ESP32 pin GIOP36 (ADC0): the FSR and 10K pulldown are connected to A0

void setup() {
  Serial.begin(9600);
}

void loop() {
  int analogReading = analogRead(FORCE_SENSOR_PIN);

  Serial.print("The force sensor value = ");
  Serial.print(analogReading); // print the raw analog reading

  if (analogReading < 10)       // from 0 to 9
    Serial.println(" -> no pressure");
  else if (analogReading < 200) // from 10 to 199
    Serial.println(" -> light touch");
  else if (analogReading < 500) // from 200 to 499
    Serial.println(" -> light squeeze");
  else if (analogReading < 800) // from 500 to 799
    Serial.println(" -> medium squeeze");
  else // from 800 to 1023
    Serial.println(" -> big squeeze");

  delay(1000);
}
```

Figure 4.18: Program code of FSR sensor with ESP32 on Arduino IDE

First of all, we begin by define the variable of the sensor pin. The sensor pin that we connected with ESP32 is pin 36 which is GIOP36 as our sensor input. In our setup function, we start the serial interface so we can see the output on our computer. We set the baud rate to the dafault 9600.

At the same time, we have our loop function. In here, we first read the rerading from the force sensor. Then, we output this value along with the text "The force sensor value =". Next, we output text to indicate if the pressure being applied is no pressure, light touch, medium squeeze or big squeeze. After the if else block we delay for 1 second and repeat until a new program is uploaded or the ESP32 is switched off.

4.8.2 FSR reading that obtained from the patient

4.8.2.1 Reading data of user 1

Table 13 Applied force by user 1 for different time taken

APPLIED FORCE (N)	TIME TAKEN FOR PINCH (Sec)
0 < 10 “no pressure”	0
10 < 200 “light touch”	15
200 < 500 “light squeeze”	15
500 < 800 “medium squeeze”	10
F > 800 “big squeeze”	2.5

Table 14 shows the applied force by the user 1 for 5 different type of condition. This result is taken based on how long a person can hold their pinch strength on one condition. So, for the 15 second the force is applied by the user 1 to get light touch and 15 second for the light squeeze. Then, for medium squeeze 10 second is taken by user 1. For the big squeeze condition, user 1 is taken less time to hold the sensor. From that result, the time taken for the user 1 is lowest when the applied force is highest. We can concluded, that the user 1 can hold the sensor more longer is in between the 10 < 200 and 200 < 500 newton.

4.8.2.2 Reading data of user 2

Table 14 Applied force by user 2 for different time taken

APPLIED FORCE (N)	TIME TAKEN FOR PINCH (Sec)
0 < 10 “no pressure”	0
10 < 200 “light touch”	27
200 < 500 “light squeeze”	25
500 < 800 “medium squeeze”	10
F > 800 “big squeeze”	5

Table 15 shows the applied force by the user 2 for 5 different type of condition. So, For the 27 second the force is applied by the user 2 to get the light touch and 25 second for the light squeeze decrease steadily. Then, for medium squeeze 10 second is tasken by the user 2. For the big squeeze condition, user 2 is taken 5 second which is is little lower that the medium squeeze. From this result, comparatively the time taken for the user 2 is longest than the user 1.

4.8.3 Radar chart between user 1 and user 2

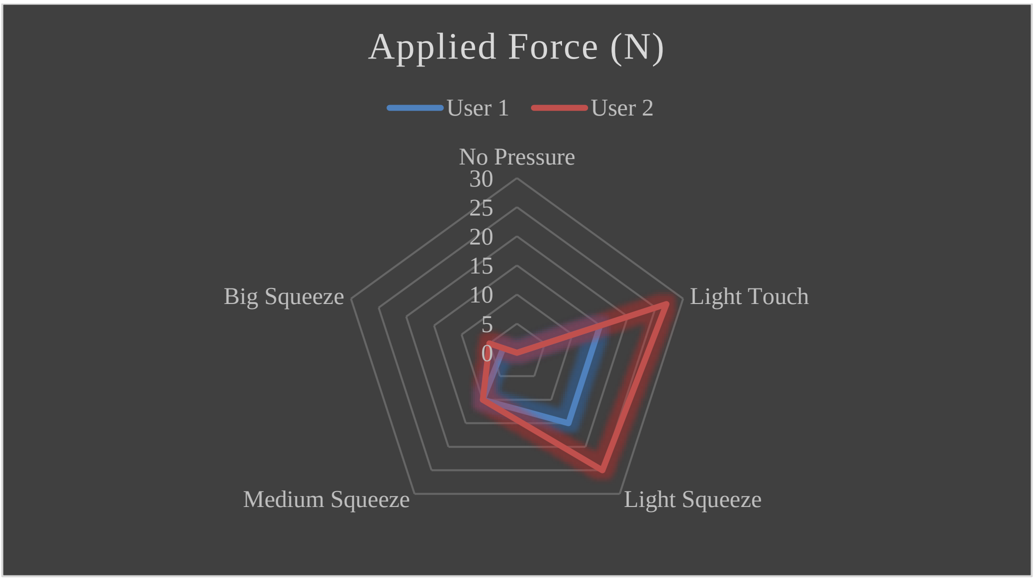
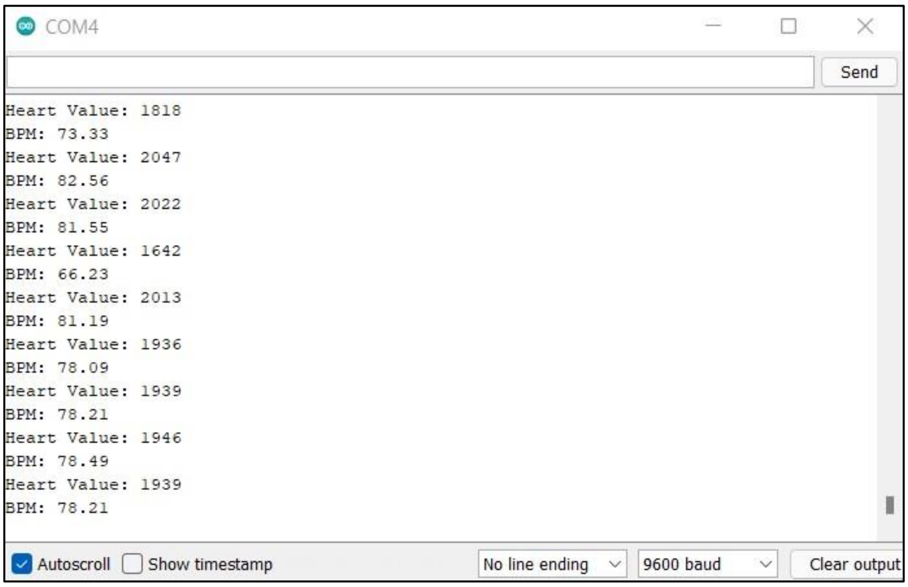


Figure 4.19: The radar chart of applied force between user 1 and user 2

4.9 DFRobot HEART RATE DATA RESULT

Lastly, the third sensor the we used is heart rate sensor connected with ESP32. This sensor will measure our heart interval and convert it by display the bit per minute (BPM) value of the patient. As you can see below is the result that we obtain from the monitor serial of Arduino IDE.



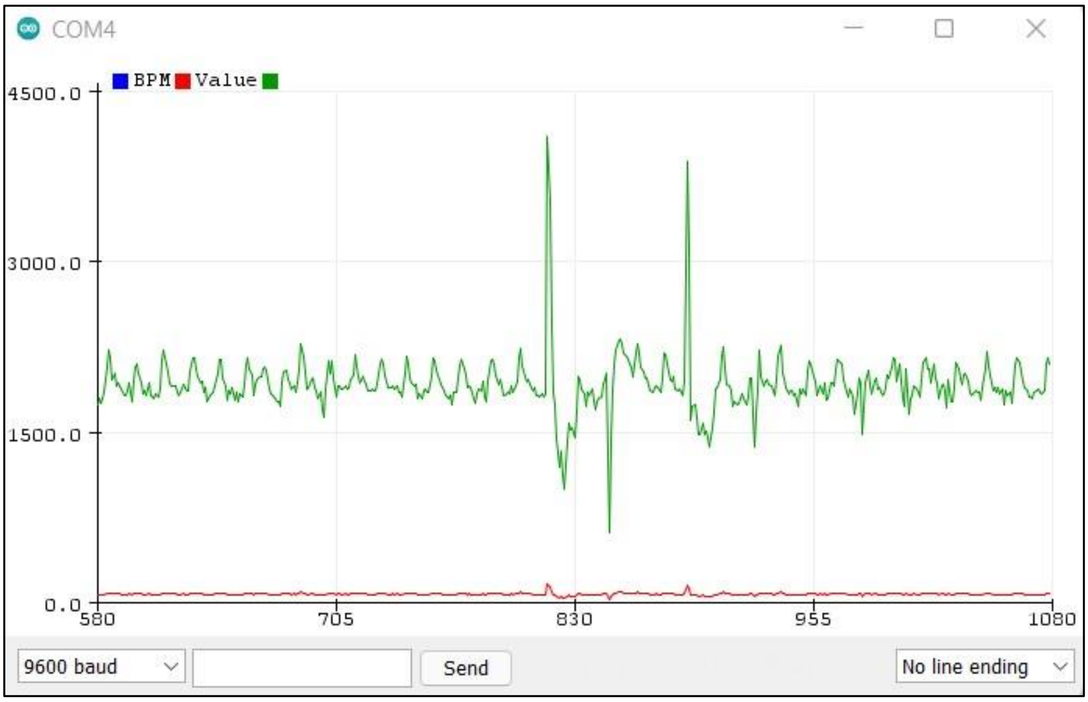


Figure 4.20: The result of heart interval and BPM value and graph.

4.9.1 Program code for heart rate sensor

DFRobot_Heartrate_Analog_Mode §

```
#define heartPin 39
#define LED_BUILTIN 2

float BPM = 0.0;

void setup() {
  Serial.begin(9600);
  pinMode(LED_BUILTIN, OUTPUT);
  digitalWrite(LED_BUILTIN, LOW);
}
void loop() {
  int heartValue = analogRead(heartPin);

  BPM = ((heartValue)/60.0)*1.42;
  Serial.print("Heart Value: ");
  Serial.println(heartValue);
  Serial.print("BPM: ");
  Serial.println(BPM);

  delay(500);
}
```

Figure 4.21: Program code of heart rate sensor with ESP32 on Arduino IDE

For this code, we begin define the variable of the sensor pin. The sensor pin that we connected with ESP32 is pin 39 which is GIOP39 as our sensor input. In our setup function, we start the serial interface so we can see the output on our computer . The baud rate is the same with the ther sensor.

For the loop function, the reading is set from the sensor. Then, the output value will display the text " heart rate value: " and "BPM: ". By measure the interval value, we can calculate the BPM by using the Karvonen method otherwise known as the heart rate reserve (HRR) formula.

4.9.2 Heart reading that obtained from the patient

4.9.2.1 Reading data of user 1

Table 15 Heart rate reading status of user 1

BPM	INTERVAL VALUE, ms	HEART RATE STATUS (ANGLE)
73.35	1819	0°
81.55	2022	0° > 30°
81.55	2022	40° > 60°

Table 16 above shows the heart rate detection status of user 1 for 3 condition angle. The bpm and interval value is increase steadily when the force is applied in the patient part for rehabilitation process. Based on the result shown, heart rate activities can be clearly seen that the process is smooth without any pain occurred.

4.9.2.2 Reading data of user 2

Table 16 Heart rate reading status of user 2

BPM	INTERVAL VALUE, ms	HEART RATE STATUS (ANGLE)
78.21	1939	0°
81.55	2022	0° > 30°
89.40	2216	40° > 60°

Table 17 above shows the heart rate detection status of user 2 for 3 condition angle. The bpm and interval value is increase rapidly and not stable from ideal condition (0° angle) to (60° angle) when doing the rehabilitation process whereas there no pain occurred. Based on the results obtained, the heart rate activites of user 2 can be seen and comparatively highest among the user 1 and user 2.

4.10 BLYNK APPLICATION

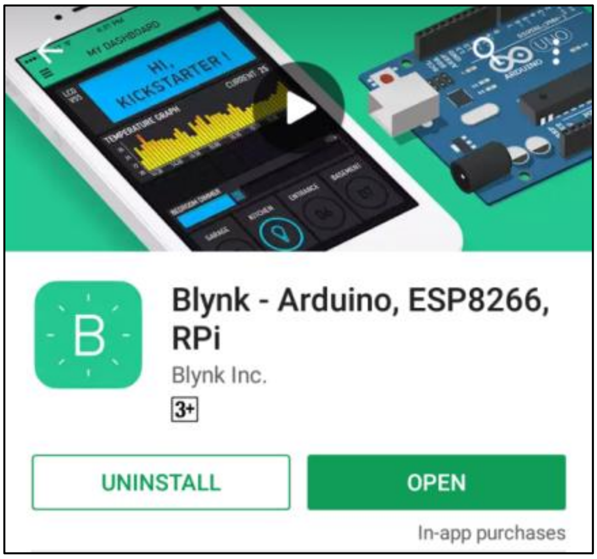


Figure 4.22: Blynk software in android play store

BLYNK, known as the most user-friendly IoT platform, provides a way to build mobile application in minutes. Before start the IoT project, we download this application in android play store which is BLYNK 1.0 the old version of this platform. BLYNK 1.0 is more easier than the 2.0 because everything only doing in the mobile app including editing, constructing and customize.

4.11 BLYNK APP AS HEALTH MONITORING SYSTEM IoT

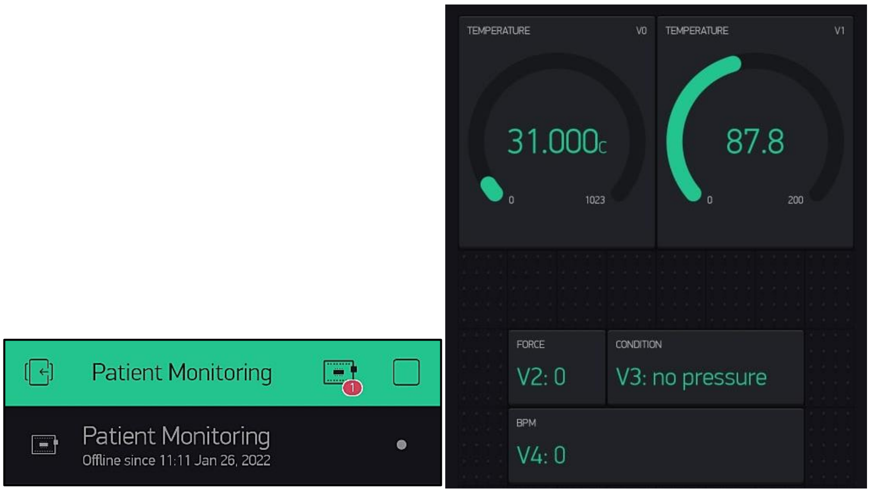


Figure 4.23: Health monitoring system

First of all, we names this platform as Patient Monitoring. This app require WI-FI for activate the app. The figure 4.23 shows the meters and the text box which is the meters will display the value and the level of the temperature while the text box will display the force value, bpm value and the condition of the force applied.

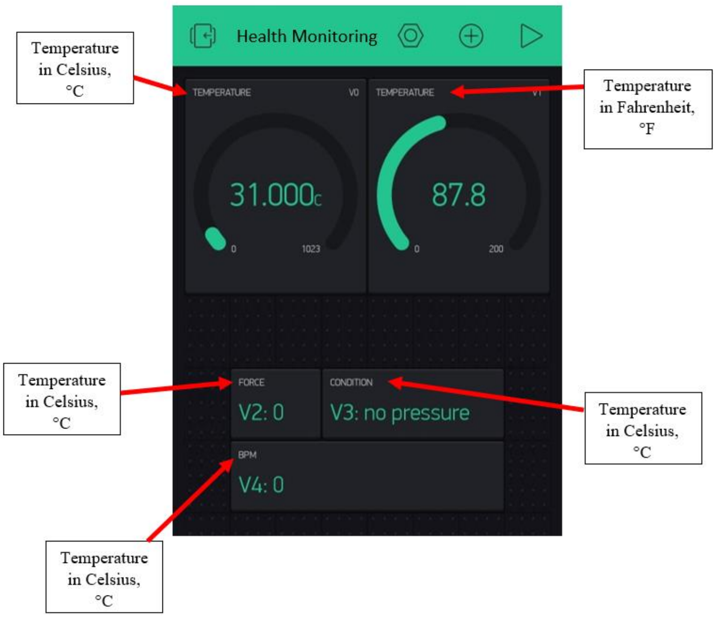


Figure 4.24: Labelling of the health monitoring

The result of the data measured from the FSR sensor, Temperature sensor and Heart rate sensor can be obtained in Blynk application. Form the figure 4.24 below, the app is synchronized and displayed the reading if the sensor is attaching to human body.

Figure 4.25: Data collecting of sensors in patient monitoring system IoT

CHAPTER 5

CONCLUSION

5.1 INTRODUCTION

This chapter concludes the project's overall findings. Furthermore, the objectives are checked in this chapter to see if they have been met. This section also discusses the research's contribution, constraints, and recommendations for further work.

5.2 CONCLUSION

Conclusively, most of the objective for this project has been achieved. This rehabilitation prototype is successfully developed for the upper limb region which can be controlled by the therapist and the patient part will be move according to the therapist. By using various types of sensors, the pain detection system in the upper limb region can provide feedback to the patient during the hand rehabilitation process which can observe the patient condition. This prototype has successful implemented the phone application for monitoring system based on the Internet of Things (IoT). Monitoring of the user will done in real time. This is product is still prototype phase, there is still many improvements can be done so that it suitable to comply Industrial Revolution 4.0. In future, this design can be improvised for small and compact structure and this device can be used in medical rehabilitation with more improvise system and safety futures that concerns of patient's for better patient's recovery.

5.3 RECOMMENDATION

There are improvements can be done for future development on this prototype: -

i. Heart rate sensor can replace with EMG or ECG sensor for better study of user pain detection.

ii. An adjustable 4D arm rest designed for the comfort of all type user with various length.

iii. PETG 3D printing filament can replace with ASA filament for more durable, better surface quality and mechanical properties.

iv. Thingspeak IoT analytics can be used for the cloud storage to save the data of the users for any of the therapist can viewed.

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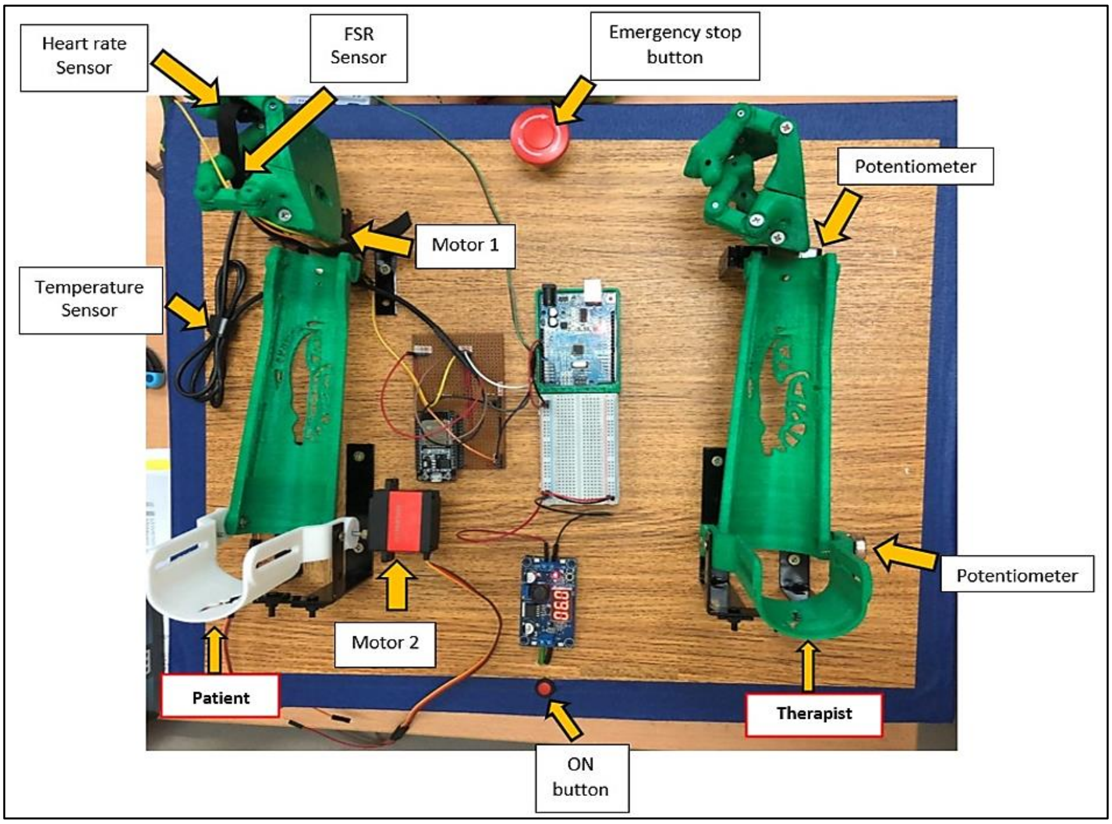
APPENDICES

Appendix A: PROTOTYPE DESIGN



Appendix B: PROGRAMMING CODE

Servo Motor with Arduino uno Coding:

```
#include <Servo.h>
Servo myservo3;
Servo myservo5;
Servo myservo6;
int potpin = 0;
int potpin2 = 1;
int potpin3 = 2;
int val = 0;
int val2 = 0;
int val3 = 0;
void setup()
{
myservo3.attach(9);
myservo5.attach(10);
myservo6.attach(11);
}
void loop()
{
val = analogRead(potpin);
val = map(val, 3, 1023, 0, 176);
myservo3.write(val);
delay(25);
val2 = analogRead(potpin2);
val2 = map(val2, 3, 1023, 0, 176);
myservo5.write(val2);
delay(25);
val3 = analogRead(potpin3);
val3 = map(val3, 3, 1023, 0, 175);
myservo6.write(val3);
delay(25);
}
```

Sensors with ESP32 (IoT) Coding:

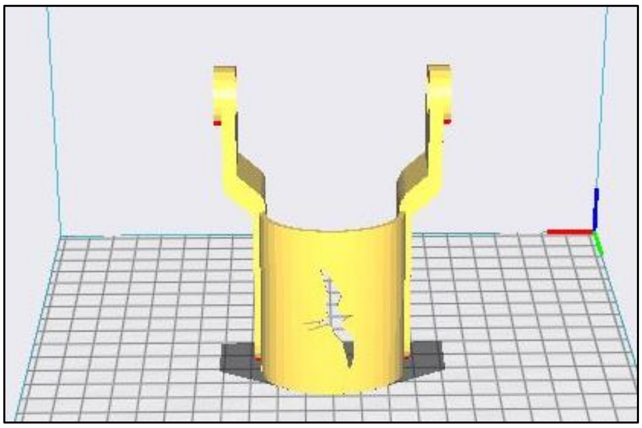
```
#include <Wire.h>
#include <Blynk.h>
#define BLYNK_PRINT Serial
#include <WiFi.h>
#include <WiFiClient.h>
#include <BlynkSimpleEsp32.h>
#include <OneWire.h>
#include <DallasTemperature.h>
#define SENSOR_PIN  21 // ESP32 pin GIOP21 connected to DS18B20 sensor's DQ pin
#define heartPin 39    // ESP32 pin GIOP39 connected to DFRobot sensor pin
#define FORCE_SENSOR_PIN 36 // ESP32 pin GIOP36 (ADC0): the FSR and 10K pulldown are
connected to 36


OneWire oneWire(SENSOR_PIN);
DallasTemperature DS18B20(&oneWire);


float BPM = 0.0;
float tempC; // temperature in Celsius
float tempF; // temperature in Fahrenheit
String conditionForce;

//---------------------------------------------------//
char auth[] = "eiB4zkSS_3ieFAt2wqOCcbER6nubPquq";
char ssid[] = "name";
char pass[] = "pasword";
//---------------------------------------------------//

void sdm_get(void);
bool triggerBlynkConnect = false;
bool isFirstConnect = true; // Keep this flag not to re-sync on every reconnection
BlynkTimer timer;

void myTimerEvent()
{
 // You can send any value at any time.
 // Please don't send more that 10 values per second.
 if (WiFi.status() != WL_CONNECTED)
 {
  Serial.println(F("WiFi not connected"));

  Blynk.connectWiFi(ssid, pass);
 }
 else
 {
  Serial.println(F("WiFi in connected"));
```

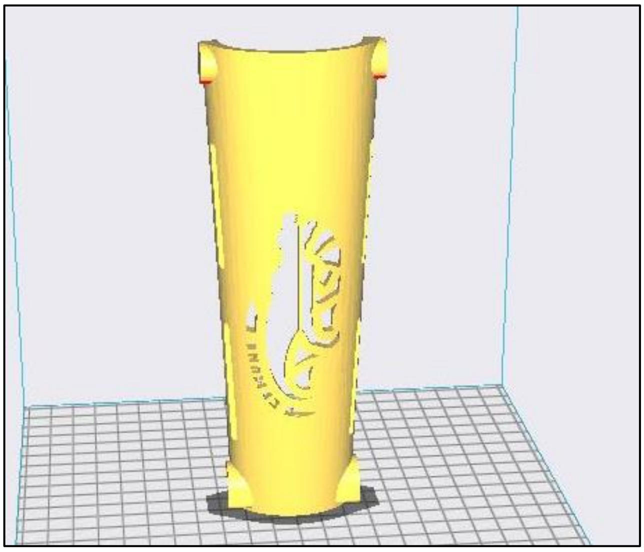
```
  }

  if (!Blynk.connected() && WiFi.status() == WL_CONNECTED)
  {
    if (Blynk.connect())
    {
      Serial.println(F("Blynk reconnected"));
    }
    else
    {
      Serial.println(F("Blynk not reconnected"));
    }
  }
  else
  {
    Serial.println(F("Blynk connected"));
  }

  if (Blynk.connected() && WiFi.status() == WL_CONNECTED)
  {
    loop();
     int analogReading = analogRead(FORCE_SENSOR_PIN);
    Blynk.virtualWrite(V0, tempC);
    Blynk.virtualWrite(V1, tempF);
    Blynk.virtualWrite(V2, analogReading);
    Blynk.virtualWrite(V3, conditionForce);
    Blynk.virtualWrite(V4, BPM);


  }
}

BLYNK_CONNECTED()
{
  triggerBlynkConnect = true;

  Serial.println(F("Blynk Connected!"));
  Serial.println(F("local ip"));
  Serial.println(WiFi.localIP());

  if (isFirstConnect)
  {
    Blynk.syncAll();

    isFirstConnect = false;
  }
}

void setup() {
```

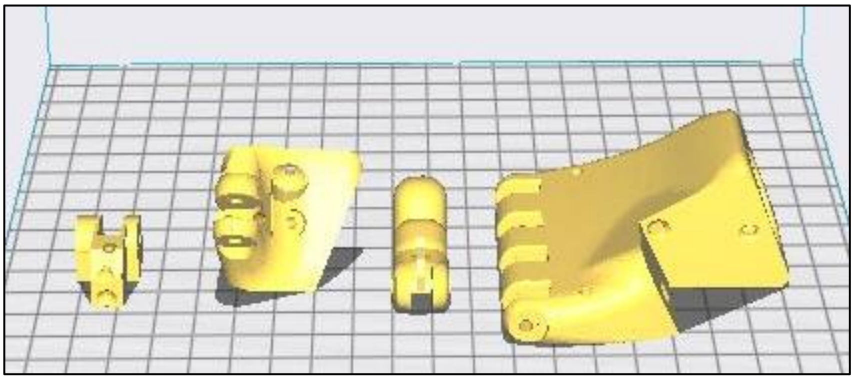
```
  Serial.begin(9600); // initialize serial
  DS18B20.begin();    // initialize the DS18B20 sensor

  Blynk.config(auth);
  Blynk.connectWiFi(ssid, pass);

  if (WiFi.status() == WL_CONNECTED)
  {
   if (Blynk.connect())
   {
     triggerBlynkConnect = true;
   }
   else
   {
     triggerBlynkConnect = false;
   }
}

 myTimerEvent();
 timer.setInterval(1000L, myTimerEvent);      //Every 10 minutes
}

void loop() {

   if (Blynk.connected())
  {
   Blynk.run(); // Initiates Blynk Server
  }
  else
  {
   triggerBlynkConnect = false;
  }

  timer.run(); // Initiates BlynkTimer
  int analogReading = analogRead(FORCE_SENSOR_PIN);
  Serial.print("The force sensor value = ");
  Serial.print(analogReading);

  DS18B20.requestTemperatures();      // send the command to get temperatures
  tempC = DS18B20.getTempCByIndex(0);  // read temperature in °C
  tempF = tempC * 9 / 5 + 32; // convert °C to °F

  Serial.print("Force= ");
  Serial.print(analogReading);      // print the raw analog reading
  Serial.print("\tPulse= ");
  Serial.print("Temperature: ");
  Serial.print(tempC);    // print the temperature in °C
  Serial.print("°C");
  Serial.print("  ~  ");  // separator between °C and °F
```

```
  Serial.print(tempF);    // print the temperature in °F
  Serial.println("°F");

  int heartValue = analogRead(heartPin);

  BPM = ((heartValue)/60.0)*1.42;
  Serial.print("Heart Value: ");
  Serial.println(heartValue);
  Serial.print("BPM: ");
  Serial.println(BPM);


  if (analogReading < 10)          // from 0 to 9
  {
   conditionForce="no pressure";
   Serial.println(conditionForce);
  }
  else if (analogReading < 200)     // from 10 to 199
  {
   conditionForce="light touch";
   Serial.println(conditionForce);
  }
  else if (analogReading < 500)     // from 200 to 499
  {
   conditionForce="light squeeze";
   Serial.println(conditionForce);
  }
  else if (analogReading < 800)     // from 500 to 799
  {
   conditionForce="medium squeeze";
   Serial.println(conditionForce);
  }
  else // from 800 to 1023
  {
   conditionForce="big squeeze";
   Serial.println(conditionForce);
  }

  delay(500);
}
```

Appendix C: OVERALL MECHANICAL DRAWING







Appendix D: GANTT CHART PROJECT PLANNING OF SDP 2

TASK/WEEK	W2	W3	W4	W5	W6	W7	W8	W9	W10	W11	W12	W13	W14
SDP 2 Briefing													
Project meeting													
Specify requirement													
Develop prototype													
Construct the Circuit and monitoring system													
Thesis first draft													
Draft correction													
Thesis second draft													
Finalize porotype and monitoring system													
Presentation SDP 2													