

EXOSKELETON ROBOTIC HAND USING MOBILE APPLICATION

Submitted in partial fulfillment of the requirements for the award of
Bachelor of Technology degree in Biomedical Engineering

By

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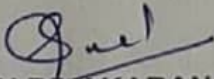
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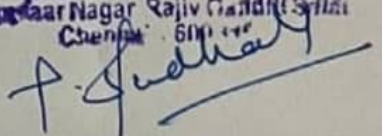
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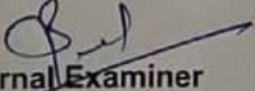
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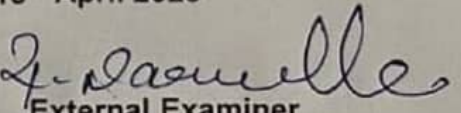
This is to certify that this Project Report is the bonafide work of **MAHALAKSHMI V (39240024) & AKSHARA D (39240005)** who carried out the project entitled '**EXOSKELETON ROBOTIC HAND USING MOBILE APPLICATION**' under our supervision from October 2022 to April 2023.


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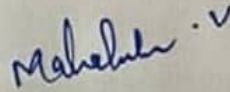
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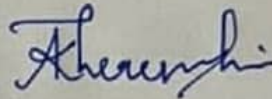
DECLARATION

We, **MAHALAKSHMI V (39240024)** and **AKSHARA D (39240005)**, hereby declare that the Project Report entitled "**EXOSKELETON ROBOTIC HAND USING MOBILE APPLICATION**" done by us under the guidance of **Ms SINDU DIVAKARAN** is submitted in partial fulfilment of the requirements for the award of Bachelor of Technology degree in B. Tech Biomedical Engineering.



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ACKNOWLEDGEMENT

We are pleased to acknowledge our sincere thanks to the **Board of Management of SATHYABAMA** for their kind encouragement in doing this Project and for completing it successfully. We are grateful to them.

We convey our thanks to **Dr T. Sudhakar, M.Sc, PhD Head of the Department of Biomedical Engineering** for providing us with necessary support and details at the right time during the progressive reviews.

We would also like to express our sincere and deep sense of gratitude to our Project Guide, **Ms. Sindu Divakaran**, for her valuable guidance, suggestions and constant encouragement that paved the way for the successful completion of my project work.

We wish to express our thanks to all Teaching and Non–Teaching staff members of the Department of Biomedical Engineering who were helpful in many ways in the completion of the Project.

ABSTRACT

People with neurological disorders such as spinal cord injuries, strokes and traumatic brain injuries often suffer from impairments to hand function or paralysis of some or all of their body parts. Traditional treatments like physical therapy can help the patient to recover but it's time-consuming. Our methodology is designed to assist individuals with mobility issues to control a wearable robotic exoskeleton for their upper limbs. The system is designed using a 3D printer to create the physical structure of the exoskeleton. The system is controlled using an Arduino board and Bluetooth communication to connect the Arm to the Android mobile application. The Arm is equipped with four servo motors that control the movement of the arms, allowing the user to move their arms. The mobile application is developed using the MIT App Inventor software and allows users to control the Robot's movements through an intuitive user interface. The application includes various control features, such as controlling the direction of the arm movements, The applications are numerous, ranging from medical rehabilitation to assistance for people with mobility impairments, such as those with spinal cord injuries or muscular dystrophy. The system can be customized to the user's needs, and the mobile application can be modified to include additional features based on the user's requirements.

Keywords: Android Mobile Application, Exoskeleton, Prosthetic, Robotics, 3D Printer.

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LIST OF ABBREVIATIONS

ABBREVIATION	FULL FORM
ADLs	Activities of daily living
CAD	Computer-aided design
CPU	Central processing unit
CRUX	Complaint robotic upper extremity
EMG	Electromyography
GCD	Gait cycle duration
IDE	Integrated development environment
LCD	Liquid crystal display
PLA	Polylactic acid
SCI	Spinal cord injury
SEMG	Surface electromyography
SExoG	Soft exoskeleton glove
SMPS	Switch mode power supply
SPI	Serial peripheral interface

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CHAPTER 1

INTRODUCTION

Nowadays, many people suffer from hand function impairment or hand paralysis which is caused by neurological disorders such as spinal cord injury, Stroke and traumatic brain injury which causes loss of muscle function in some or all our body parts. According to a study conducted by Christopher and Dana Reeve Foundation, there are about 1 in 50 people approximately 5.4 million people living with paralysis. The leading cause of paralysis was stroke (33.7 percent), followed by spinal cord injury (27.3 percent) and multiple sclerosis (18.6 percent). Approximately 4.5 million people die of stroke every year, and over 9 million survivors survive stroke. There is an overall stroke incidence rate of 2 to 2.5 strokes per thousand people, and there is an estimated 15-40% chance of recurrence over five years (Wolfe et al. 2000). Young children (0–4 years old) and adolescents (15–24 years old) tend to have the highest rates of Traumatic Brain Injury. Falls and motor vehicle accidents are the top 2 causes of Traumatic Brain Injury (Galgano M et al. 2017).

Traditional treatments like physical therapy can help the patient to recover but it's time-consuming, about 20 to 30 sessions are needed for one patient and each session can last for 40 to 60 minutes (Nair et al.2003). Providing therapy to a large number of people is quite impossible due to the lack of therapists. To overcome this problem, wearable rehabilitative assistive devices help individuals complete certain tasks independently. It enhances the user's ability to grasp things and increases the user's independence (Bos RA et al.2016). Individuals with incomplete spinal cord injury can benefit from intensive rehabilitative training like repetitive activity-based training and prolonged peripheral nerve electrical stimulation at sub-motor threshold intensity have been shown to improve the strength and function of individuals with stroke (Beekhuizen et al. 2005).

The exoskeleton is designed to replicate human movement, kinematics, and dynamics of limb motion. Analysing the anatomy of the upper limb and considering the exoskeleton application is necessary to design one. The upper extremity consists of three parts, the upper arm, forearm and hand. Totally, it contains 30 bones, nerves, blood vessels and muscles. The upper limb begins at the shoulder joint, which is referred to as the ball and socket joint. The shoulder joint or

glenohumeral joint performs an extensive range of motions such as abduction, adduction, flexion, extension, internal rotation, and external rotation (Eovaldi et al. 2018).

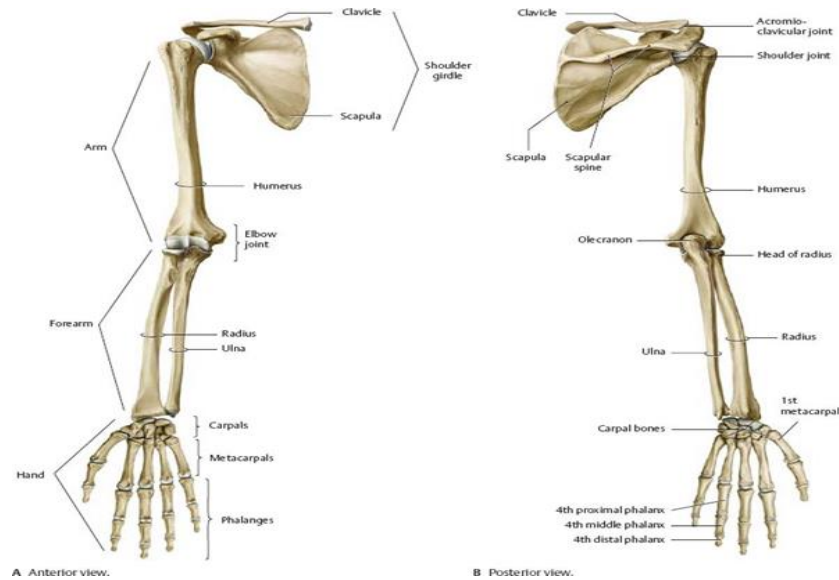


Fig 1.1 Anatomy of Upper Limb

The elbow joint is composed of three articulations proximal radio-ulnar joint, capitellum with the head of the radius and trochlea with the trochlear notch of the ulna in a hinge fashion. The elbow joint allows forearm flexion and extension and supination and pronation. flexion and extension occur at the humou ulnar articulation. Pronation and supination occur at the radio ulnar articulation (Shakweer et al. 2012). The wrist joint is a diarthrodial joint which has eight unique small bones called carpel bones and consists of two rows of carpal bones, The proximal carpal row and the distal carpal row. The wrist joint possesses two degrees of freedom movements, flexion and extension, radial and ulnar deviation (Eschweiler J et al.2022).

In the already existing method, electromyographic (EMG) signals from muscles of the human upper limb are used as the control interface between the user and a robot arm. A mathematical model is trained to decode upper limb motion from EMG recordings, using a dimensionality-reduction technique that represents muscle synergies and motion primitives. It is shown that a 2-D embedding of muscle activations can be decoded to a continuous profile of arm motion representation in

the 3-D Cartesian space, embedded in a 2-D space. The system is used for the continuous control of a robot arm, using only EMG signals from the upper limb. The accuracy of the method is assessed through real-time experiments, including random arm motions. In this Concept, the subject has to wear the electrodes and carry them wherever they go which makes them uncomfortable with lots of wires and devices connected to them always(J. S. Artal-Sevil et al. 2020) . In this project, The Arduino and Bluetooth-based robotic 4-axis arm control project is a cutting-edge technology designed to assist people with mobility impairments. The system is designed using a 3D printer to create the physical structure of the exoskeleton and is controlled using an Arduino board and Bluetooth communication to connect the exoskeleton with an Android mobile application. The arm is equipped with four servo motors that control the movement of the arms, allowing the user to move their arms with the help of the exoskeleton. The mobile application is developed using the MIT App Inventor software and provides an intuitive user interface to control the robot's movements. The project's primary objective is to provide a low-cost, high-performance solution to assist people with mobility impairments, such as spinal cord injuries or muscular dystrophy. The system can be customized to meet the user's specific needs, and the mobile application can be modified to include additional features based on the user's requirements.

CHAPTER 2

LITERATURE SURVEY

Cengiz Tepe et al., (2022) states that, Due to the various finger mobility, the human hand may make a wide variety of hand gestures. Because of this, prosthetic hands may find it simpler to make various hand motions by moving their fingers separately. In this situation, the research's goal is to put forth a model that processes EMG information to allow finger motions to move independently. Myo armbands were used to collect EMG signals. 5 finger motions and resting hand gestures were used to produce the data set. The data set was filtered, the windowing method was used, and it was determined which phase of the preprocessing the gesture took place in. The characteristics of the EMG signals were removed during the categorization step. A successful model was produced, it was discovered when the experimental results were analysed. This work used processing finger data to offer a paradigm for prosthetic arm control. This paradigm is workable for prosthetic arms, and it is anticipated that processing finger data will boost the prosthetic arm's functionality.

Kevin L et al., (2001) considered consumer priorities for the development of neuroprostheses to support standing and ambulation in people who have had spinal cord injuries. The key themes and priorities identified by their participants in relation to this specific technology were independence, ease of movement, ease of control, and the ability to, do what you did before the injury. Exoskeletons differ from neuroprostheses in that they provide structural support and automated movement powered by motors and actuators rather than electrically stimulating the paralysed muscle. However, the functional outcomes for both types of technology are similar in that they relate to the restoration of standing and walking after SCI. As a result, similar priorities may be identified by potential users of exoskeleton technology as those identified by them. However, such assumptions are only hypothetical at this time due to the scarcity of publications on user perspectives of exoskeleton technology to date.

Gui Yin et al., (2020) states that this work outlines methodologies and pilot validation of the EMG-driven speed control of a combined treadmill and exoskeleton with the aim of improving user-system interaction. Using the autocorrelation approach and the Bayesian fusion algorithm, the gait cycle duration (GCD) was derived from the sEMG data. The motion speed of the exoskeleton robotic system was then configured using GCDs that could walk at different rates. Six healthy volunteers were used to test and validate the effectiveness of this sEMG-controlled robotic-assisted ambulation system. The outcomes showed that the GCD was recovered from each individual muscle contraction by the autocorrelation technique. Under a specified walking speed, the GCDs of particular muscles varied between various walking steps. When walking more quickly, EMG signals had larger amplitudes and shorter GCDs. Gait stride length and integrated GCD algorithms produced trajectory joint motion records that resembled sine wave waveforms. A decoder positioned on the hip revealed that the exoskeleton's joint angles were measured in sine waves. High agreement was found between the hip joint motion track of the exoskeleton and the angles projected by the trajectory curve produced by computer algorithms based on the fused GCDs. For an intuitive speed control of the exoskeleton-treadmill system at the user's intentions, the EMG-driven speed-control offered the human-machine inter-limb coordination mechanisms. Patients with incomplete spinal cord hemispheric stroke may be able to utilise the entire system for gait recovery.

Hoppe Ludwig et al., (2021) states that upper limb dysfunction after a stroke limits the ability to do independent everyday activities. They tested a myoelectric elbow-wrist-hand orthosis' usability, functionality, and effectiveness in order to support paralysed or weak upper limbs, restrict dangerous movements and improve functional motion. people who have had a stroke a single-session study was conducted to examine the gadget. The device's ability to be activated in both supported and unsupported shoulder positions, as well as the range of motion in the elbow and the capacity to retain elbow position, were all put to the test. The myoelectric elbow-wrist-hand orthosis effectively treated upper extremity disability following stroke and increased range of motion while in use. All users were able to operate the machine in at least one mode, and the majority were able to lift and hold weights that resembled some commonplace things while using the machine.

Shih-Hung Yang et al., (2021) states that, in order to enable individuals with unilateral hemiplegia to carry out daily tasks on their own, effective bilateral hand training is necessary for rehabilitation programmes. The quantity of hand function training offered in present therapeutic settings, however, is much less than what is required to promote the best possible brain remodelling due to a lack of human resources. In this study, they created a hand exoskeleton that is lightweight, portable, and equipped with a hand-sensing glove for home-based rehabilitation and bilateral hand training. A flex sensor within the hand-sensing glove tracks how the less injured hand moves. The affected hand is then propelled utilising the measured hand movements by the hand exoskeleton. Their hand exoskeleton increases the flexible mechanism for the back of the hand for a better wearing experience and the thumb mechanism enables the pinch gesture in comparison to the previous hand exoskeletons.

Yumiao Chen et al., (2021) states that traditional stiff exoskeletons can be uncomfortable for wearers and exert a lot of strain, which can even change how hands move naturally. In this article, they suggest a low-cost soft exoskeleton glove (SExoG) system for bilateral training that is powered by surface electromyography (sEMG) signals from a non-paretic hand. The structure of soft actuators was altered, and a method for customising their geometrical characteristics was offered. Then, the relevant air-pump pressure values to generate various actuator angle support four hand motions were calculated (extension, rest, spherical grip, and fist). To recognise four hand gestures using sEMG data from the healthy limb, a two-step hybrid model incorporating the neural network and the state exclusion technique has been presented. According to the experimental findings, the pressure values for the four-hand motions were around 2, 0, 40, and 70 KPa. The hybrid model can produce a mean accuracy of 98.7% across the four hand motions. It can be said that the cutting-edge SExoG system mirrors non-paretic hand gestures effectively.

Vélez-Guerrero et al., (2021) states that in order to facilitate the development of activities of daily living in patients who have undergone an injury or have pathological sequelae, neuromotor rehabilitation and recovery of upper limb functions are desirable (ADLs). Modern strategies like robotic-assisted rehabilitation offer crucial elements for successful motor recovery, namely the possibility of implementing individualised training programmes and an objective assessment of

the patient's development. The design, creation, and early testing of a wearable robotic exoskeleton prototype with autonomous artificial intelligence-based processing, control, and safety algorithms are the main topics of this study. The suggested exoskeleton is a 1-DoF device that permits elbow flexion and extension, where the material selection makes it small. A hierarchical control approach supports a variety of operation modes, enabling operation in autonomous, remote control, or leader-follower modes. Laboratory tests demonstrate the integrated technologies' good operation and emphasise their minimal latency and respectable accuracy. The outcome of the trial indicates that, with careful clinical validation and optimization, the device may be useful for supporting neuromotor function diagnostic and rehabilitative processes.

S. Lessard et al., (2017) states that Exosuits and upper-extremity exoskeletons are examples of augmentative wearable robots that may be useful in this effort. But a fundamental flaw in many of these exoskeletons is that they can't adapt to the human body's natural suppleness without a firm base. To meet this problem, they created the Compliant Robotic Upper-extremity eXosuit (CRUX). This robot is a flexible, light, multi-DOF, portable exosuit that enables its wearer to enhance oneself in a variety of novel environments (i.e. outside of a clinic). These qualities are primarily attained by the use of a modified tensegrity design situated along measured lines of minimal extension, where a network of tension members serve as a basis for applying supplemental stresses via carefully positioned power lines. In this study, they discuss the CRUX design process, the archetypal composition of CRUX, and the mimetic control mechanism. They also go over the findings of three studies that demonstrate the effectiveness of CRUX's mimetic controller, the adaptability and compliance of CRUX, and the decrease in metabolic cost experienced by users who exercise CRUX as opposed to those who do not.

Tanvir Ahmed et al., (2021) states that for hand rehabilitation, a brand-new, lightweight robotic device called "Flexohand" has been created. To account for the passive movement of MCP abduction-adduction, Flexohand has been designed with a new compliance mechanism. Sliding locks for IP joints and a wire locking system for finger MCP joints were used to create the isolated and composite digit joint flexion-extension. Additionally, Flexohand's intelligent design naturally permits wrist joint movement during hand-digit activities. To verify the functionality of the

created device, experiments of passive exercises involving isolated joint motion, composite joint motions of individual fingers, and isolated joint motion of numerous fingers were carried out. The results of the experiment demonstrate that Flexohand overcomes the drawbacks of current robot-assisted hand rehabilitation tools.

Artal-Sevil et al., (2020) states that this study describes the creation and application of a neural network-based control system for the management and functioning of a tiny robotic prosthesis. Multiple surface EMG sensors provide the foundation of the gesture recognition system. This has made it possible to easily and successfully control the prototype that has been built. These EMG sensors work as a bridge to identify minute electrical pulses brought on by muscle movement and convert them into an analogue signal that the control module is able to filter and decipher. The creation of robotic systems generally calls for students to be more motivated. As a result, this article shows a cutting-edge electronic application, such as a bionic prosthesis' activation and control scheme. The idea was to mimic how the fingers would actually move. The various ideas are discussed simultaneously, as well as the specifics of how they will be put into practice. The creation of real-time control has been made possible by the use of neural networks as a control technique for the prosthetic hand, with incredibly pleasing outcomes.

Ming Q et al., (2019) presented a powered exoskeleton based on a wheelchair which helps hemiplegic patients to restore impaired or lost upper extremity functions. The exoskeleton is operated via a motion analysis system which consists of 7 sensors which are placed in the elbow joint, shoulder joint and wrist joint of a person. The motion analysis system can able to transmit real-time data by measuring the range of motion (ROM) of different joints. The study shows that the exoskeleton can perform movements of the shoulder and elbow joints with 6 degrees of freedom. The kinematic analysis is performed to analyse the position of the exoskeleton, it has been observed that the exoskeleton does not interfere with the wheelchair which determines the safety of the wheelchair.

CHAPTER 3

AIM & SCOPE

3.1 AIM

The project aims to create a 4-axis robotic arm that can be designed using CAD software and 3D printed using PLA material. The arm will be controlled using Arduino and Bluetooth technology and will be integrated with an Android mobile application developed using MIT App Inventor. The mobile application will provide an intuitive user interface that enables users to control the exoskeleton's movements, including the ability to move the arm in four different axes: X, Y, Z, and rotation. The application will also include additional features, such as the ability to adjust the arm's speed and range of motion.

3.2 SCOPE

The Arduino and Bluetooth-based robotic 4-axis arm control project has a wide scope of applications, particularly in the field of medical rehabilitation. The project's primary scope is to develop a low-cost and efficient solution for individuals with mobility impairments to control the movement of their arms using a wearable robotic exoskeleton. The project's scope also includes the ability to customize the exoskeleton to fit the user's body comfortably, and to modify the mobile application to include additional features or to adapt to different user needs. The project has the potential to significantly improve the quality of life for individuals with mobility impairments, providing them with a cost-effective, efficient, and user-friendly solution for controlling the movement of their arms.

CHAPTER 4

MATERIALS AND METHODS USED

4.1 HARDWARE

4.1.1 Microcontroller

A microcontroller (Fig 4.1) is a small, self-contained computer chip that is designed to control a specific function or system. It typically contains a central processing unit (CPU), memory, input/output (I/O) ports, and other peripherals, all integrated onto a single chip. Microcontrollers are used in a wide range of electronic devices, from simple toys to complex industrial control systems. Microcontrollers are often used in embedded systems, which are specialized computer systems designed to perform a specific function. Examples of embedded systems that use microcontrollers include automotive systems, home appliances, medical equipment, and industrial automation systems. Microcontrollers are preferred in such systems because they are relatively low-cost, consume very little power, and can be programmed to control specific functions. Microcontrollers come in various sizes and architectures, with different levels of processing power and memory capacity. Some of the most common microcontroller architectures include the 8-bit, 16-bit, and 32-bit architectures. The choice of microcontroller depends on the specific application requirements, such as the complexity of the task, the speed at which the system needs to operate, and the available memory and processing power.

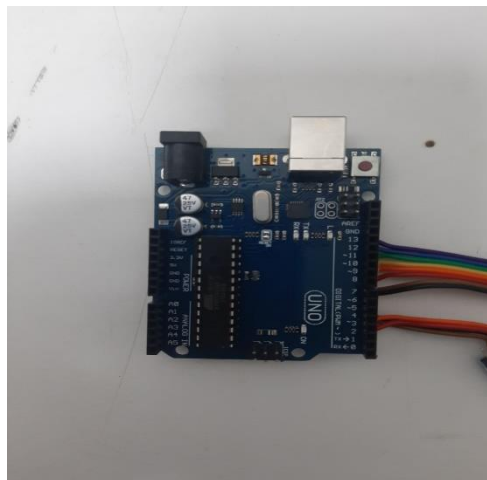


Fig 4.1 Microcontroller

Specifications

Microcontroller: ATmega328

Operating Voltage: 5V

Input Voltage (recommended): 7-12V

Input Voltage (limits): 6-20V

Digital I/O Pins: 14 (of which 6 provide PWM output)

Analog Input Pins: 6

DC Current per I/O Pin: 40mA

DC Current for 3.3V Pin: 50mA

Flash Memory: 32 KB (ATmega328)

SRAM: 2 KB (ATmega328)

EEPROM: 1 KB (ATmega328)

Clock Speed: 16 MHz

4.1.2 LCD Display

LCD displays (Fig 4.22) consist of several layers, including a backlight, a polarizing filter, a layer of liquid crystals, and electrodes. The backlight illuminates the display from behind, while the polarizing filter controls the orientation of the light passing through the display. The liquid crystals are sandwiched between two layers of glass, and they can be controlled by the application of an electric field to change their orientation and control the passage of light. The electrodes are used to apply the electric field to the liquid crystals. LCD displays are known for their low power and high resolution.



Fig 4.2 LCD display

They can display text, images, and video with varying levels of colour depth and brightness. LCD displays are also used in touchscreens, which allow users to interact with the display by touching the screen directly. In electronic devices, LCD displays are often used as the primary user interface or as a secondary display for showing information such as status indicators or settings menus.

4.1.3 LCD baseboard

An LCD baseboard is an electronic circuit board that is designed to provide a convenient interface for connecting an LCD display to a microcontroller or other electronic device. The board typically includes connectors for the LCD display, as well as support circuitry for controlling the display. In addition to providing a simple interface for connecting the display, LCD base boards may also include features such as onboard memory, power regulation, and backlight control. Some boards may also include additional components such as buttons or sensors, allowing developers to easily prototype a complete user interface for their device.

4.1.4 HC-05 Bluetooth Module

HC-05 Bluetooth Module (Fig 4.3) is an easy-to-use Bluetooth SPP (Serial Port Protocol) module, designed for transparent wireless serial connection setup. Its communication is via serial communication which makes an easy way to interface with the controller or PC. HC-05 Bluetooth module provides a switching mode between master and slave mode which means it is able to use neither receiving nor transmitting data.

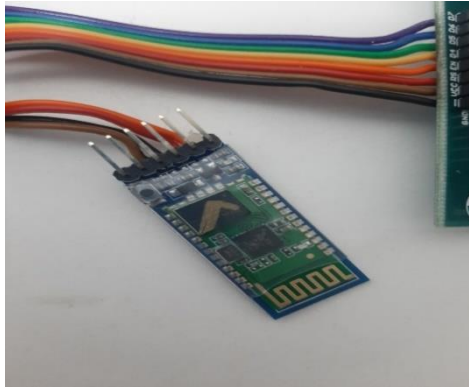


Fig 4.3 HC-05 Bluetooth module

Specification:

Model: HC-05

Input Voltage: DC 5V

Communication Method: Serial Communication

Master and slave modes can be switched

4.1.5 Servo Motors

Servo motors (Fig 4.4) are often used in the joints of robotic arms to provide precise and accurate motion control. A robotic arm typically consists of several jointed segments, each controlled by a servo motor. By adjusting the position and movement of each segment, the robotic arm can perform a wide range of tasks, such as picking up and moving objects, assembling components, or performing surgical procedures. The use of servo motors in robotic arms provides several advantages. First, servo motors allow for precise and accurate control over the movement of each joint. This is critical for many applications, such as assembly or surgical procedures, where even slight errors in movement can have serious consequences. Second, servo motors are capable of providing high torque and fast response times, allowing robotic arms to move heavy loads quickly and accurately.



Fig 4.4 Servo motor

This is especially important in industrial applications, where robotic arms are often used to move heavy machinery or perform other tasks that require significant force. Servo motors are easily controlled by microcontrollers or other electronic devices, allowing robotic arms to be programmed and automated for a wide range of applications. This makes them a highly versatile and adaptable technology for use in a wide range of industries and applications.

4.1.6 Driver Boards

Driver boards are electronic circuit boards designed to control various types of motors, including stepper motors, DC motors, and servo motors. Driver boards provide a simple and easy-to-use interface for connecting and controlling motors, allowing developers and engineers to focus on the design and functionality of their devices without worrying about the details of driving the motor. Driver boards typically include connectors for the motor, as well as support circuitry for controlling the motor. The support circuitry may include components such as transistors, diodes, capacitors, and resistors, as well as microcontrollers or other electronic devices for generating control signals. Some driver boards may also include additional features such as speed control, direction control, and torque control. Speed control allows the motor to be controlled at different speeds, while direction control allows the motor to be controlled in forward or reverse directions. Torque control allows the amount of torque generated by the motor to be adjusted, which is important for applications where precise control over the movement of a load is required. Driver boards are a critical component in the development of many types

of electronic devices, providing precise and reliable motor control for a wide range of applications.

4.2 SOFTWARE

4.2.1 Arduino IDE

The Arduino IDE (Integrated Development Environment) is a software application used for programming and uploading code to Arduino boards. The Arduino IDE is designed to be user-friendly, It includes a simple code editor, a serial monitor for debugging and communication with the board, and a library of pre-written code and functions that can be used to simplify programming tasks. The Arduino IDE also includes a range of advanced features and tools for experienced developers, such as the ability to create custom libraries and access to a range of advanced programming options.

4.2.2 MIT app Inventor

MIT App Inventor is a web-based platform for creating mobile applications for Android devices. The platform provides a visual interface for building apps, using drag-and-drop components and blocks-based coding. This allows users with little or no coding experience to create simple mobile apps quickly and easily. MIT App Inventor includes a wide range of built-in components for creating apps, such as buttons, text fields, images, and sensors. It also supports integration with a variety of web-based services, such as Google Maps and Twitter. One of the key features of MIT App Inventor is its ability to provide real-time testing of apps as they are being built. This allows developers to quickly test and iterate on their apps, without the need for complex setup or configuration.

4.2.3 Python IDE

A Python IDE (Integrated Development Environment) is a software application used for writing and developing Python code. An IDE typically includes a code editor, a debugger, and tools for testing and profiling code. Python is a popular programming language used in a wide range of applications, including web development, data analysis, and artificial intelligence.

4.3 METHODS

4.3.1 Design and 3D print the structure:

The first step is to design the physical structure of the Arm using computer-aided design software. The Model involves the use of a 3D printer to create a robotic arm with four axes of movement. PLA (polylactic acid) is a common material used in 3D printing, known for its ease of use, affordability, and biodegradability (Redwood S et al. 2017). The step is to design the robotic arm using computer-aided design (CAD) software. The design must include four axes of movement, and the individual parts of the arm should be designed to fit together securely. Once the design is complete, the arm parts are 3D printed using a 3D printer and PLA material. The 3D printer uses a computer file of the design to build up the parts layer by layer, following the specifications of the design. The arm is usually designed in CAD software, and the design is then 3D printed using a 3D printer that can print using PLA (polylactic acid) material. PLA is a popular material for 3D printing because it is easy to use, has a low melting point, and is environmentally friendly. The 4-axis robot arm can be controlled using software, such as Arduino software, and can be programmed to move in specific patterns to create 3D objects (Saravanan R et al. 2016). The arm can move the 3D printer's extruder along the X, Y, and Z-axis, and can also rotate the extruder to print objects in different orientations.

4.3.2 Install the servo motors:

The next step is to install the four servo motors onto the structure. The servo motors are responsible for controlling the movement of the arms.

4.3.3 Program the Arduino board:

The Arduino board is programmed using the Arduino Integrated Development Environment (IDE). The program includes code to control the servo motors and communicates with the Bluetooth module.

4.3.4 Develop the Android mobile application:

The Android mobile application is developed using the MIT App Inventor software. The application includes features to control the movement of the arms, such as speed and direction(Wolber.D et al.).

4.3.5 Connect the Arduino board and mobile application:

The Arduino board and mobile application are connected using Bluetooth communication. The Arduino board receives signals from the mobile application, which in turn controls the movement of the arms.

4.3.6 Test and refine the system:

The final step is to test the system and refine it to meet the user's specific needs. The system is evaluated for its functionality, ease of use, and overall performance.

4.4 BLOCK DIAGRAM

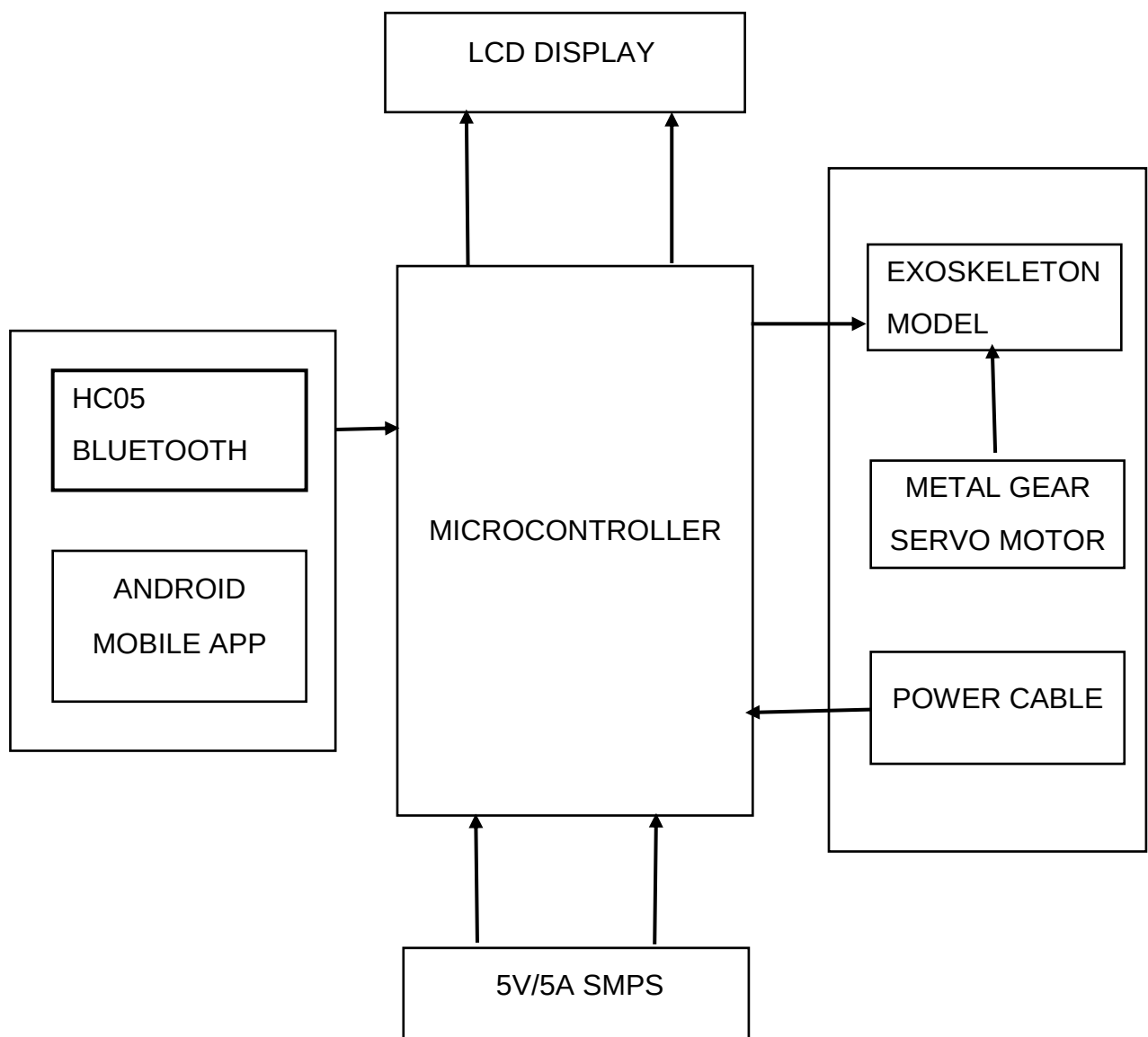


Fig 4.5 Block diagram of the prototype

4.5 WORKING

The proposed prototype (Fig 4.5) consists of a microcontroller in which all the components are connected. The Arduino board is connected to the four servo motors, which control the four axes of the robot arm. The Bluetooth module is also connected to the Arduino board, which allows for wireless communication between the smartphone app and the robot arm. The LCD display indicates whether the Bluetooth is connected to the exoskeleton or not. The smartphone app is developed using the MIT App Inventor platform. The app allows the user to control the movement of the robot arm by sending commands via Bluetooth to the Arduino board. The app interface includes four buttons, each of which corresponds to one of the four axes of the robot arm. The user can press and hold a button to move the arm in a particular direction and release the button to stop the movement. When the user presses a button on the app interface, the app sends a signal to the Bluetooth module, which then forwards the signal to the Arduino board. The Arduino board receives the signal from the mobile application via Bluetooth and sends a command to the appropriate servo motor to move the arm in the desired direction. The Bluetooth module and Arduino board communicate using a specific protocol, such as Serial Peripheral Interface (SPI) or Inter-Integrated Circuit (I2C). The entire system is powered by a SMPS, which can be connected to the Arduino board using a suitable power source. The battery must have enough capacity to power all the components for an extended period of time.

4.6 ALGORITHM USED

The algorithm used in the Arduino and Bluetooth-based robotic 4-axis arm control project involves a simple process of receiving commands from the smartphone app via Bluetooth, interpreting these commands, and controlling the servo motors to move the robot arm in the desired direction. Here is a high-level algorithmic flow for the project:

1. Initialize the system by setting up the Arduino board, Bluetooth module, and servo motors.

2. Establish a Bluetooth connection between the smartphone app and the Arduino board.
3. Wait for incoming commands from the smartphone app via Bluetooth.
4. When a command is received, interpret the command to determine which servo motor should be activated and in which direction.
5. Send a signal to the appropriate servo motor to rotate in the desired direction to move the robot arm.
6. Wait for the servo motor to complete the movement before processing the next command.
7. Repeat steps 3 to 6 until the system is shut down.

This algorithm can be implemented using Arduino programming language, which involves using functions such as "Serial.begin()" to establish a Bluetooth connection, "Serial.read()" to read incoming data, and "servo.write()" to control the servo motors. By following this algorithmic flow, the Arduino and Bluetooth-based robotic 4-axis arm control project can be successfully executed.

CHAPTER 5

RESULTS AND DISCUSSION

5.1 RESULTS

The robot arm (Fig 5.1) is able to move in four different directions, including up, down, left, and right, as commanded by the smartphone app. The arm is also able to rotate 360 degrees at its base. The 3D-printed parts of the robot arm are lightweight and strong enough to support the servo motors and allow for smooth movement. PLA material is used for 3D printing, which is a suitable choice for this exoskeleton. The Android mobile application is developed using MIT App Inventor, which made it easy to create a user-friendly interface for controlling the robot arm.

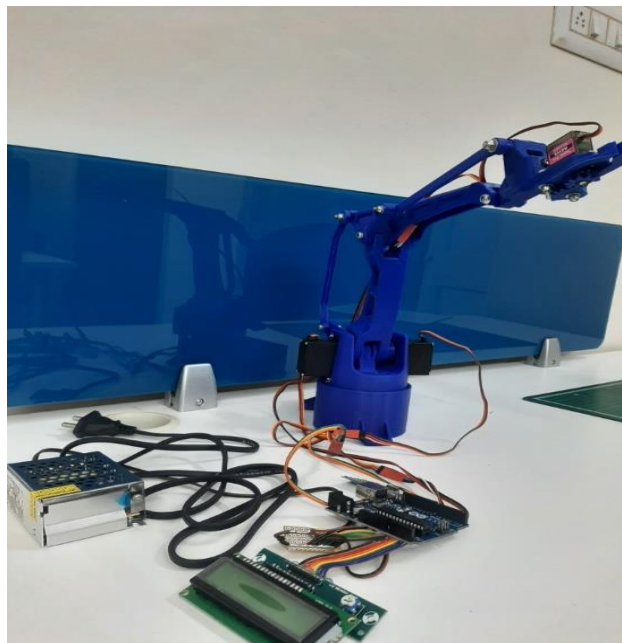


Fig 5.1 prototype

The app allows the user to select the direction of movement and the angle of rotation for the arm, providing a high level of control over the robot. The project's scope for medical applications was also successfully achieved. The robot arm's precise movements and accuracy could be useful in medical procedures requiring delicate movements, such as surgeries or physical therapy.

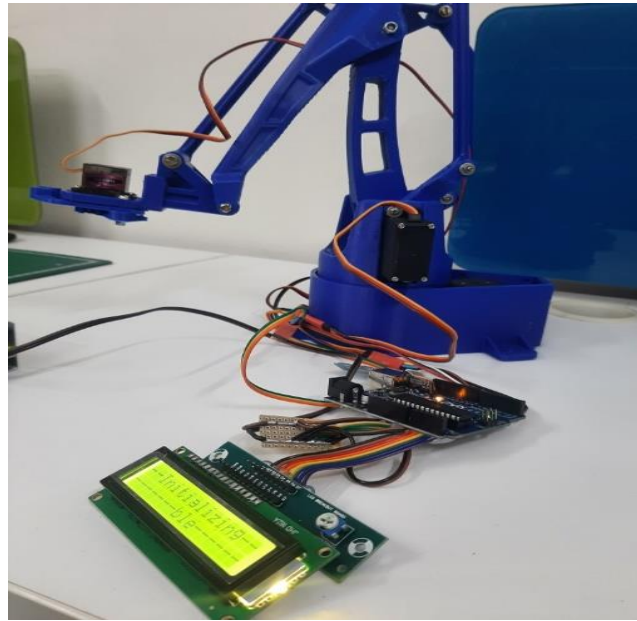


Fig 5.2 Initializing the device

The complete prototype of the model can be seen in Figure 5.1. As in Fig 5.2, the exoskeleton is initialised to be paired with Bluetooth. When the user presses a button on the app interface, the app sends a signal to the Bluetooth module, which then forwards the signal to the Arduino board (Fig 5.3). The Arduino board receives the signal and sends a command to the appropriate servo motor to move the arm in the desired direction. The Bluetooth module and Arduino board communicate using a specific protocol, such as Serial Peripheral Interface (SPI) or Inter-Integrated Circuit (I2C).



Fig 5.2 Bluetooth is ready to pair with the arm

The Arduino board is connected to the four servo motors, which control the four axes of the robot arm. The Bluetooth module is also connected to the Arduino board, which allows for wireless communication between the smartphone app and the robot arm.

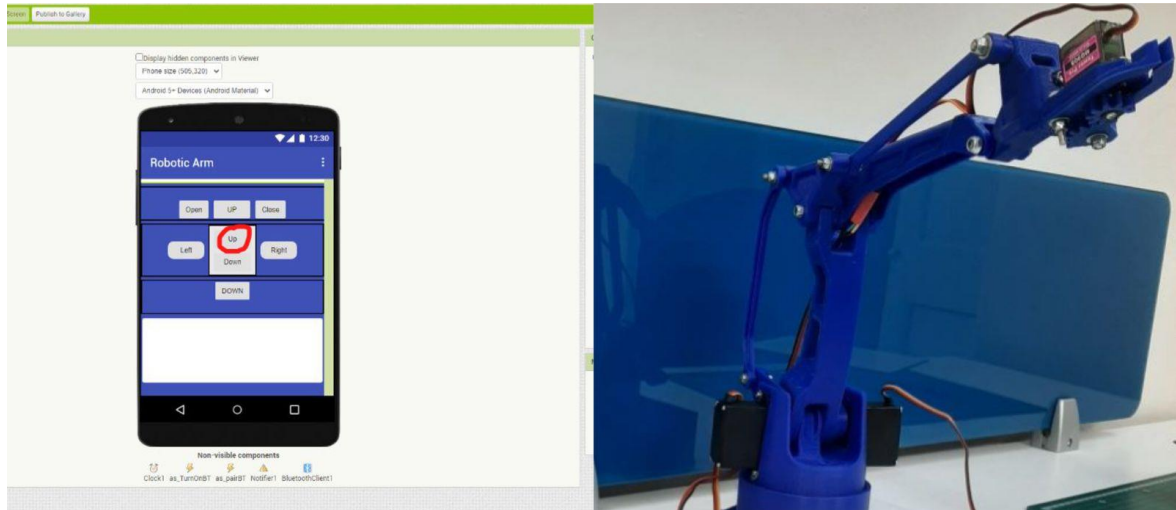


Fig 5.4 The arm moves upwards when the up button is clicked on the mobile app

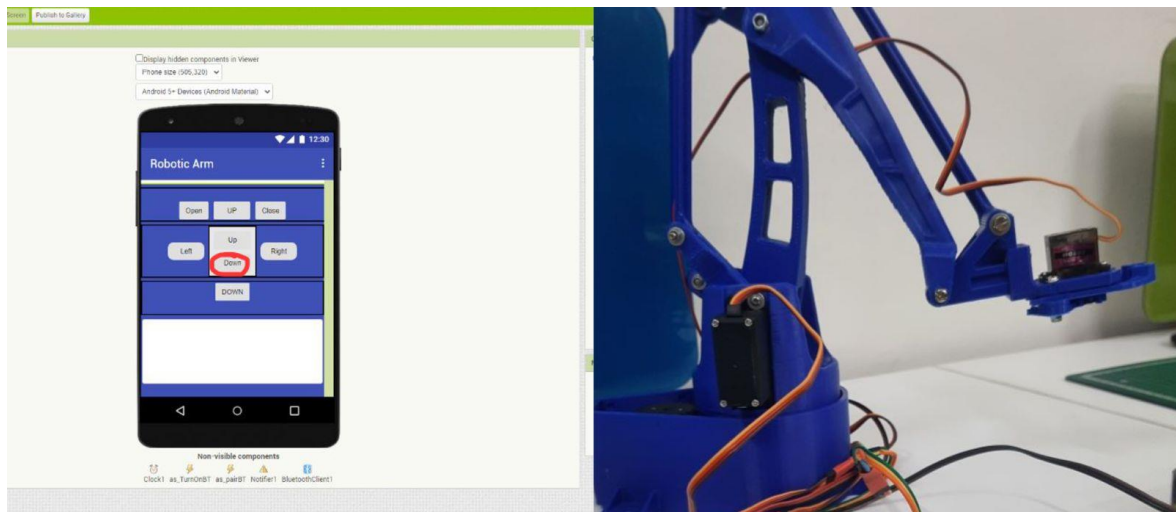


Fig 5.5 The arm moves downwards when the down button is clicked on the mobile app

The smartphone app is developed using the MIT App Inventor platform. The app allows the user to control the movement of the robot arm by sending commands via Bluetooth to the Arduino board. Fig 5.4,5.5 shows that the app interface includes four buttons, each of which corresponds to one of the four axes of the robot arm. The user can press and hold a button to move the arm in a particular direction and release the button to stop the movement.

5.2 DISCUSSION

The project provides an accessible solution to individuals with mobility impairments, enabling them to control the movement of their arms. The project is cost-effective compared to other commercially available solutions, as it uses off-the-shelf components and a 3D printer to create the physical structure of the exoskeleton. The project is highly customizable, allowing users to modify the system to meet their specific needs. The mobile application can be tailored to include additional features, and the exoskeleton can be adjusted to fit the user's body comfortably. The mobile application developed using the MIT App Inventor software provides an intuitive user interface, enabling users to control their movements easily.

CHAPTER 6

SUMMARY AND CONCLUSION

The prototype we have developed helps people to move their hands independently without anyone's help. It has various applications ranging from medical rehabilitation to assistance for people with mobility impairments, such as those with spinal cord injuries or muscular dystrophy. The Arduino and Bluetooth-based robotic 4-axis arm control successfully demonstrated the feasibility of using this technology for precise and controlled movements in medical applications. The project utilized 3D printing technology for creating lightweight and functional robot parts, and the Android mobile application developed using MIT App Inventor provided a user-friendly interface for controlling the robot arm. The robot arm's precise movements and accuracy could be useful in medical procedures requiring delicate movements, such as surgeries or physical therapy. The robot arm was able to move smoothly and precisely in the four directions as commanded by the smartphone app, with the servo motors responding quickly and accurately to the signals sent by the Arduino board. The robot arm was able to rotate 360 degrees at its base, providing flexibility and range of motion, which can be beneficial in medical applications where precise movements are required. The 3D-printed parts of the robot arm were durable and able to withstand the forces generated by the servo motors. One potential limitation of the project is the Bluetooth range, which could be affected by environmental factors such as interference or obstacles. This could limit the range of the robot arm's movements, depending on the location of the user and the robot arm. The project's scope for medical applications was successfully achieved, and the project showcased the versatility of 3D printing and how it can be used to create functional and durable robot parts.

6.1 FUTURE ENHANCEMENTS

Integrating sensors such as force or pressure sensors can provide feedback on the amount of force applied by the robot arm during a medical procedure. This can help prevent accidental injury to the patient. The current project utilizes a Bluetooth-

based control system, but incorporating more advanced wireless technologies such as Wi-Fi or 5G can enhance the robot arm's control system, allowing for more precise and rapid movements. The current Android mobile application developed using MIT App Inventor provides a user-friendly interface for controlling the robot arm. Still, developing a more advanced user interface with more features and options can further enhance the user experience. The current project utilizes a 4-axis robot arm, but adding more degrees of freedom can enable the robot arm to perform more complex movements and actions, providing greater flexibility and range of motion for medical applications. Incorporating AI and machine learning algorithms into the control system can enable the robot arm to learn from its interactions with patients and adapt its movements and actions accordingly, improving the efficiency and accuracy of medical procedures.

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APPENDIXES

