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Dissertation on

‘Transradial prosthesis - Development of a bionic arm using an EEG sensor’

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Aug – Dec 2023

under the guidance of

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FACULTY OF ENGINEERING
DEPARTMENT OF MECHANICAL ENGINEERING
PROGRAM: B.TECH – MECHANICAL ENGINEERING

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CERTIFICATE

This is to certify that the Report entitled

‘Transradial prosthesis - Development of a bionic arm using an EEG sensor’

is a bonafide work carried out by

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In partial fulfillment for the completion of 7th semester course work in the Program of Study **B.Tech in Mechanical Engineering** under rules and regulations of PES University, Bengaluru during the period **Aug – Dec 2023**. It is certified that all corrections/suggestions indicated for internal assessment have been incorporated in the report. The report has been approved as it satisfies the 7th semester academic requirements in respect of project work.

Signature with date & Seal *Internal Guide*	*Signature with date & Seal* *Chairperson*	*Signature with date & Seal* *Dean of Faculty*

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3.			

DECLARATION

We, **Rakshith V, Pranav Adiga, Sanketh Chebbi and Sai Preetham R V**, hereby declare that the Report entitled, '***Transradial prosthesis - Development of a bionic arm using an EEG sensor',*** is an original work done by us under the guidance of **Dr. D Sethuram**, Professor, Department of Mechanical Engineering, and is being submitted in partial fulfillment of the requirements for completion of 7th Semester course work in the Program of Study **B.Tech in Mechanical Engineering**.

Place : Bengaluru

Date **:** 02-12-2023

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ABSTRACT

This paper presents the design, implementation, and analysis of an innovative EEG-controlled robot gripper tailored for individuals with transradial prostheses. Leveraging advanced prosthetic technology, the gripper integrates EEG sensors to harness user attention as a means of actuation. Through a comprehensive ANSYS analysis, we validate the gripper's structural integrity under load conditions, ensuring safety and reliability. The gripper's versatility is tested through usability evaluations across diverse user groups, focusing on improving post-fitting quality of life. The use of 3D printing, specifically Fused Deposition Modeling (FDM), allows for customized and adaptable gripper fabrication. Our findings demonstrate the successful integration of EEG technology, biomechanics, and additive manufacturing in developing an intuitive and efficient prosthetic solution. This research contributes to the evolution of assistive technologies, emphasizing user-centric design, robustness, and practical functionality. The presented gripper showcases a promising advancement in the field, with implications for improving the daily lives of individuals with limb differences.

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CHAPTER 1
INTRODUCTION

Even the most routine everyday duties can become difficult when you lose a limb. Technology-based tools can aid in regaining independence. Even the mind can be linked to an artificial limb with the integration of new technologies. These prosthetic limbs are known as bionic prosthetics. The term ‘bionics’ was first used in the 1960s. It combines the prefix ‘bio’—meaning life—with the ‘nics’ of electronics. Bionics is the study of mechanical systems that function like living organisms or parts of living organisms. Since 600 BC, simple artificial limbs have been in use. While these archaic replacements restored some movement or function to the wearer, they were frequently uncomfortable, challenging to use, had subpar functionality, and were aesthetically unappealing.

Development of a bionic arm that benefits amputees whose hands are amputated just below their elbows, i.e; Transradial Prosthesis. This helps them perform basic daily tasks such as opening doors, grabbing a bottle of water etc.

Before, simple prosthetic arms have been just fixtures on the body that do not help in dynamic human movements that our bionic arm aims to achieve. With generic prosthetic arms, trivial tasks like opening a door or grabbing a bottle of water is difficult for amputees. With our bionic arm, we can help them perform these actions as humanely as possible.

Bionic arm is quite different from a prosthetic arm. A bionic arm is a type of prosthetic arm that incorporates electromechanical components.

A prosthetic arm, on the other hand, refers to an artificial limb designed to replace a missing or amputated arm. It can be powered in three different ways: myoelectric, motor, and by the body. Body-powered prosthetics use cables that are tied to the opposing shoulder and the prosthetic, such that when the shoulder moves, the prosthetic also moves. Similar mechanisms are used by motor-powered prosthetics, but the opposite shoulder controls buttons or switches to generate the desired activity in the prosthetic.

Myoelectric power, which is the electrical impulses produced by contracted muscles, is used by the most sophisticated prosthetic devices. On the residual limb, electrodes are positioned, which records the electrical signals generated when the muscle contracts and moves the prosthetic in accordance.

CHAPTER 2
LITERATURE REVIEW

Sahil Shaikh, et al [1], This project describes how the brain waves can be used to control a prosthetic arm using Brain Computer Interface (BCI). The brain signal acts as command signals and is transmitted to the microcontroller and this command signal is based on concentration level and eye blink strength of the subject. The microcontroller is coupled with servo motors to perform flexion and extension of fingers.

R. Swetha, S, et al[2], In this work, the design of a prosthetic arm is proposed by reconstructing the structure and proportions of an amputated arm using high-precision methods and dimensions. The exported file is entered into computer-aided design software, and the geometry of the socket was designed on the basis of an affected arm and the prosthetic arm was designed according to the mirrored geometry of the unaffected arm.

S. Sree Krishna, et al[3], In this study, a bionic arm made of poly lactic acid polymer, a basic material for 3D printing. The arm is mechanized using artificial tendons which are actuated by smart servo dynamixel AX-12A motors. The final assembled arm provides 7 DOF (5 for fingers, 1 each for wrist and elbow). Information is acquired with the help of Neurosky MindWave Mobile which is incorporated with an EEG sensor.

Dany Bright, et al[4], The BCI system consists of an EEG sensor to capture the brain signal, which will be processed using the ThinkGear module in MATLAB. The extracted brain signals act as command signals that are transmitted to the Microcontroller via RF medium. The designed prosthetic arm module consists of an Arduino coupled with servo motors to execute the command. The flexion and extension of fingers can be successfully controlled with an accuracy of 80 percent.

Taha Beyrouthy, et al[5], The prosthesis is 3D printed and controlled via brain commands, obtained from an electroencephalography (EEG) headset, and is equipped with a network of smart sensors and actuators that provide the patient with intelligent feedback about the environment and the object to be touched. This network gives the arm normal hand functionality, intelligent reflexes and smooth movements.

Dildar Ahmed Saqib, et al[6], The research work presents the design of prosthetic arm and hand. It’s a bioengineering approach in order to develop a robotic arm and hand for the disabled persons, resembling the human upper limb. EMG sensor is interfaced with the upper limb of the human body to receive signals from human muscle and motion of each joint is actuated by its respective motor accordingly.

O A Ruşanu [7], The paper describes the development of an Arduino-based mobile robot controlled by voluntary eye-blinks using a LabVIEW graphical user interface (GUI) and a NeuroSky Mindwave Mobile headset. The system allows users to control the robot's movement through different environments using their eye blinks, as detected by the headset. The authors evaluated the system's performance and found that it was able to achieve a high level of accuracy in controlling the robot's movement.

Sarayu Pai.[8], The research resulted in the development of a controllable dry adhesive tape that mimics the gecko's grip using van der Waals forces. The triangular structures in the tape enable variable contact surface area, increasing grippiness when needed and only the tip area for release. The adhesive has better functionality on smooth surfaces and is being improved for non-smooth materials.

2.1 Literature gap

- Prosthetic arms must be rigid and movements must be as humane as possible. Previous work on this topic hasn't used effective design and operation.
- Limited research on sorting algorithms for the data. We intend to use data sets from the EEG sensor to detect signals more accurately.
- Current literature lacks a comprehensive evaluation of prosthetic arm usability tailored to different user demographics.
- There is a lack of evaluation of the impact of prosthetic arms on improving quality of life after being fitted with a prosthetic arm, which we aim to address.
- The fingertips on the prosthetic arm aren't equipped enough to grip objects except for flexion.
- Limited papers have explored the possibility of using blink strength as actuation.

CHAPTER 3

PROJECT WORK DETAILS

3.1 Problem statement

Development of a bionic arm that benefits amputees whose hands are amputated just below their elbows, i.e; Transradial Prosthesis. This helps them perform basic daily tasks such as opening doors, grabbing a bottle of water etc. Before, simple prosthetic arms have been just fixtures on the body that do not help in dynamic human movements that our bionic arm aims to achieve. With generic prosthetic arms, trivial tasks like opening a door or grabbing a bottle of water is difficult for amputees. With our bionic arm, we can help them perform these actions as humanely as possible.

3.1.1 Need for prosthetic care

Prosthetic care is essential for people who have lost a limb due to injury, illness, or congenital condition. Here are some reasons why prosthetic care is necessary worldwide:
Prosthetic care is crucial for individuals who have lost a limb due to injury, illness, or congenital condition. The benefits of prosthetic care span worldwide, with improved quality of life, better health outcomes, and the potential for economic empowerment among its many advantages. One of the most significant reasons why prosthetic care is necessary is the profound impact it has on an individual's quality of life. With the help of prosthetic devices, people are able to regain their independence and mobility, allowing them to engage in daily activities and social and recreational endeavors. It is undeniable that this contributes greatly to their overall well-being and happiness. Moreover, proper prosthetic care can also lead to better health outcomes. Without a suitable prosthetic device, amputees may experience complications such as joint pain, pressure sores, and muscle atrophy. However, with the assistance of a prosthetic device, these issues can be minimized or even prevented, resulting in better physical health and a reduced risk of related health problems

Overall, prosthetic care is crucial for restoring function and improving the quality of life for amputees worldwide

3.1.2 Objectives

1) Integration of an EEG sensor for precise and responsive control, enhancing the bionic arm's functionality and usability based on users' neural signals.

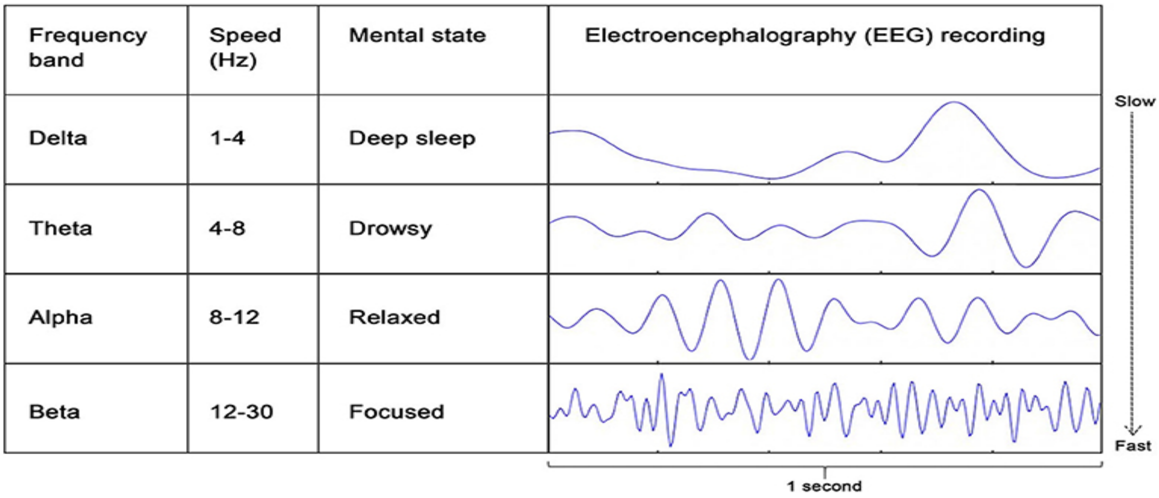
2) Development of a proprietary sleeve for connection of the gripper to the amputated arm that aims to fit different user groups.

3) Development of a sophisticated control engineering system that helps in better transmission of data.

4) To build a robot gripper capable of lifting a water bottle.

3.1.3 Methodology

1. Development of a bionic arm for amputees whose hands are amputated below the elbow, i.e. transradial prosthesis using Fusion 360 and analyze the design using Ansys Workbench to effectively find load ratings of the arm.
2. Analyze the electrical activity of the brain using an EEG sensor via electrodes affixed to the forehead.
3. Sorting the brain waves according to the frequencies like Alpha, Delta etc. and exploring them under various conditions.



Frequency band	Speed (Hz)	Mental state	Electroencephalography (EEG) recording
Delta	1-4	Deep sleep	
Theta	4-8	Drowsy	
Alpha	8-12	Relaxed	
Beta	12-30	Focused	

Figure 3.1 Brain wave frequency chart

4. Make use of a microcontroller such as Arduino and Bluetooth module HC-05 Bluetooth Transceiver to receive and process the data from the EEG sensor.
5. Using a bluetooth module to interpret the data received and display it on the serial monitor in terms of attention values.
6. When attention level reaches a certain threshold, the servo motor is programmed to move by a

certain degree in order to perform a function for a suitable application.

7. With slicing software, we can convert 3D digital models into printing instructions for a specific 3D printer to create an object. In 3D printing technology, 3D objects are created by adding material layer by layer. Slicing software virtually "slices" 3D models into many horizontal 2D layers that are later printed one after another.
8. With the instructions from the slicing software, we can 3D print the prosthetic arm and test it physically.
9. After 3D printing, we assemble the entire arm with fasteners to actuate the end-effectors. Run a final test to make sure all the components work together.

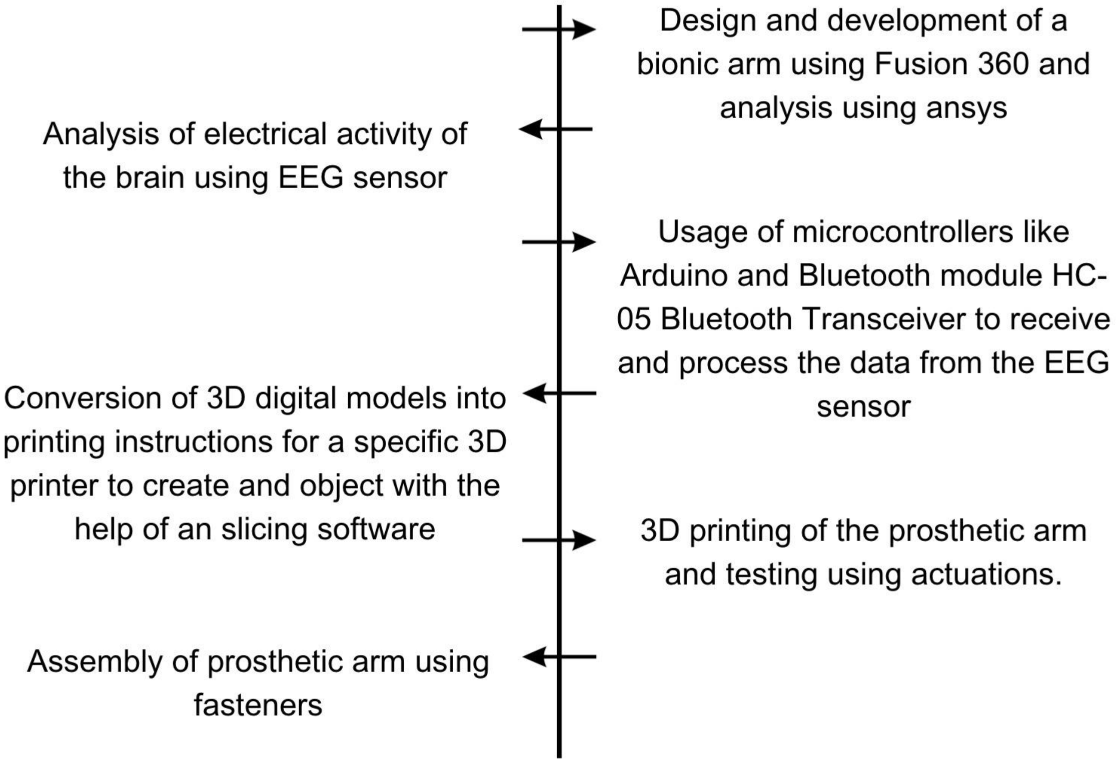


Figure 3.2 Methodology chart

3.2 Design Development

The maximum load that the robotic arm in the image can lift depends on a number of factors, including:

- The weight of the arm itself.
- The weight of the gripper.
- The strength of the servo motor.
- The gear ratio of the arm.
- The distance from the center of mass of the load to the joint where the load is attached.

Sl no	Parameter	Value
1	Module	1.125
2	No of teeth	24
3	Face width	3mm
4	Normal shaft diameter	3mm
5	Pressure angle	20 degrees

Table 3.1 Gear Parameters

A spur gear is a type of cylindrical gear with straight teeth that are cut parallel to the axis of rotation. They are the simplest and most common type of element in mechanical drive systems.[9]
In our project, we employed spur gears as essential components in the transmission mechanism. Spur gears, characterized by their straight teeth positioned parallel to the gear axis, facilitated precise and efficient power transfer within the gripper assembly. By carefully selecting gear ratios, we optimized the system for torque and speed requirements, enabling controlled and reliable movements. The simplicity and effectiveness of spur gears contributed to the overall robustness of our gripper design, ensuring smooth operation and enhancing the gripping capabilities crucial for our project's success.

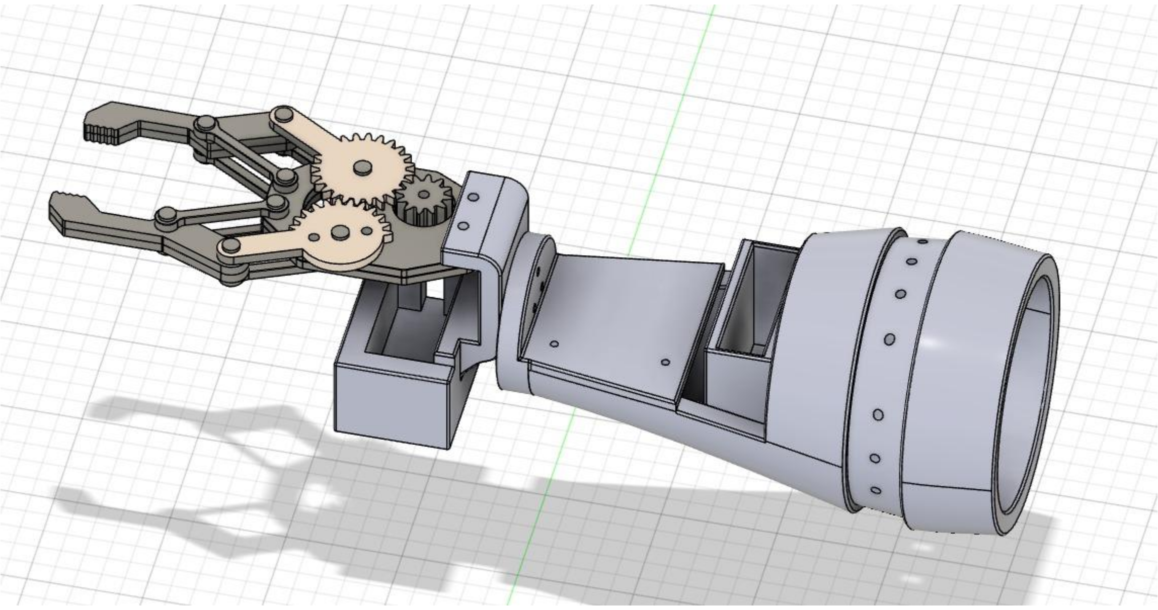


Fig 3.3 Assembly of the robot gripper

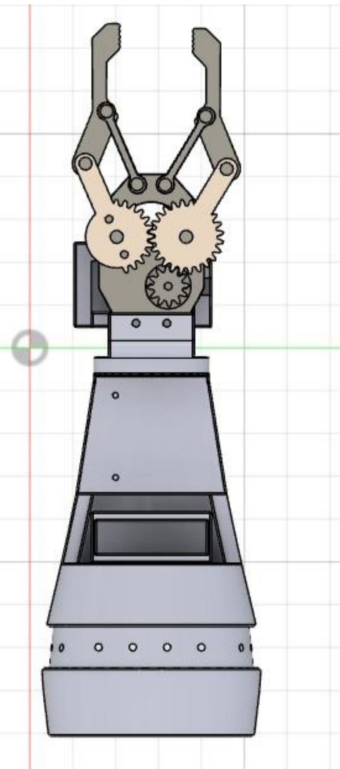


Fig 3.4 Top view of the gripper

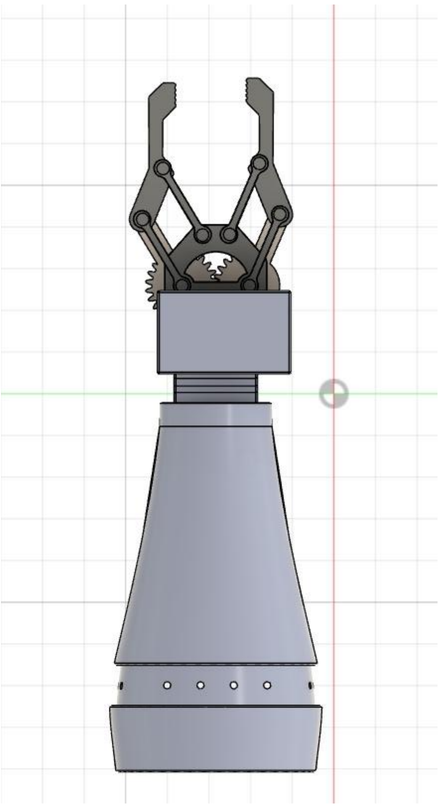


Fig 3.5 Bottom view of the gripper

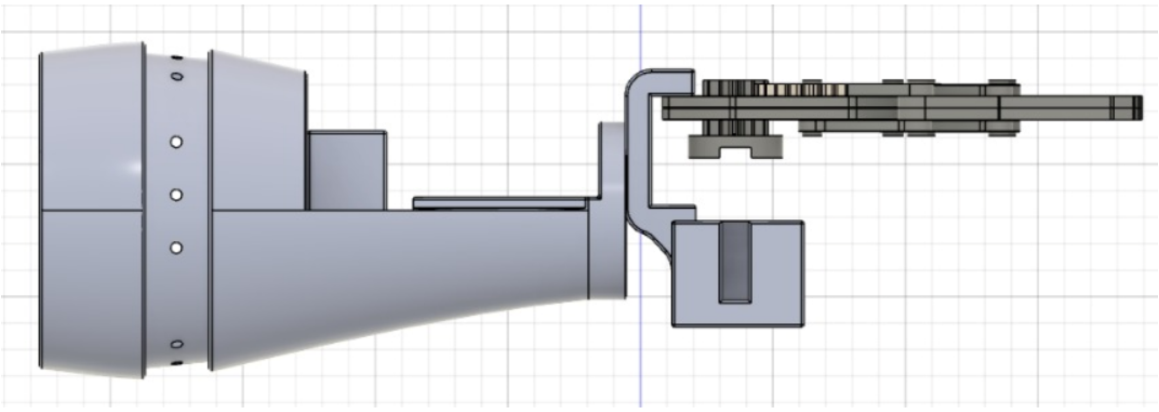


Fig 3.6 Side view of the gripper

3.2.1 Calculations

Calculation of Safe Load Capacity for Robotic Arm:

<u>Given:</u>

Number of teeth of driver gear (pinion): 12
Number of teeth of driven gear: 24
The gear ratio is calculated using the formula:

Gear ratio = Number of teeth in driven gear / Number of teeth in driver gear
Gear ratio = 24 / 12 = 2

To find the maximum weight that the robotic arm can lift, the following equation is used:

Maximum weight = Stall torque / Gear ratio × Lever length

Given:
Stall torque: 36 kg cm
Lever length: 15.05 cm

Maximum weight = 36 kg cm / 2 × 15.05 cm
Maximum weight ≈ 1.20 kg

However, accounting for factors such as friction and Rated torque, a safety factor (FOS) of 2 is applied:

Safe Load = Maximum weight / FOS
Safe Load = 1.2 kg / FOS
Safe Load = 610 grams

Therefore, considering a safety factor of 2, the safe load capacity for the robotic arm is approximately ***610 g.***

3.3 Experimental Setup and Calibration

3.3.1 FT&S MINDLINK EEG HEADBAND

Fig 3.7: FT&S Mindlink EEG Sensor

EEG sensors play a crucial role in measuring the electrical activity of the brain. Be it research, medicine, or other diverse fields, these sensors prove to be a helpful tool in unraveling the mysteries of the brain and diagnosing conditions like epilepsy. From wet and dry electrodes to caps and headbands, there exists a variety of EEG sensors to cater to different needs. While wet electrodes rely on conductive gel to enhance electrical conductivity with the scalp, dry electrodes form a sturdy connection. On the other hand, caps encompass the entire head and employ multiple electrodes, whereas headbands are similar but comparatively compact and use fewer electrodes. A notable example of such EEG sensors is the FT&S MindLink model.

The FT&S MindLink EEG headband is an exceptional choice for various applications, with its lightweight and cozy design ensuring prolonged wear without any inconvenience. Moreover, its compatibility with a multitude of software applications adds to its versatility.

Though there are more advanced EEG sensors in the market, the FT&S MindLink stands out for its affordability, ease of use, and flexibility. Its dry electrode system and comfortable build make it particularly attractive to researchers and other professionals seeking to collect EEG data without causing discomfort to their subjects.

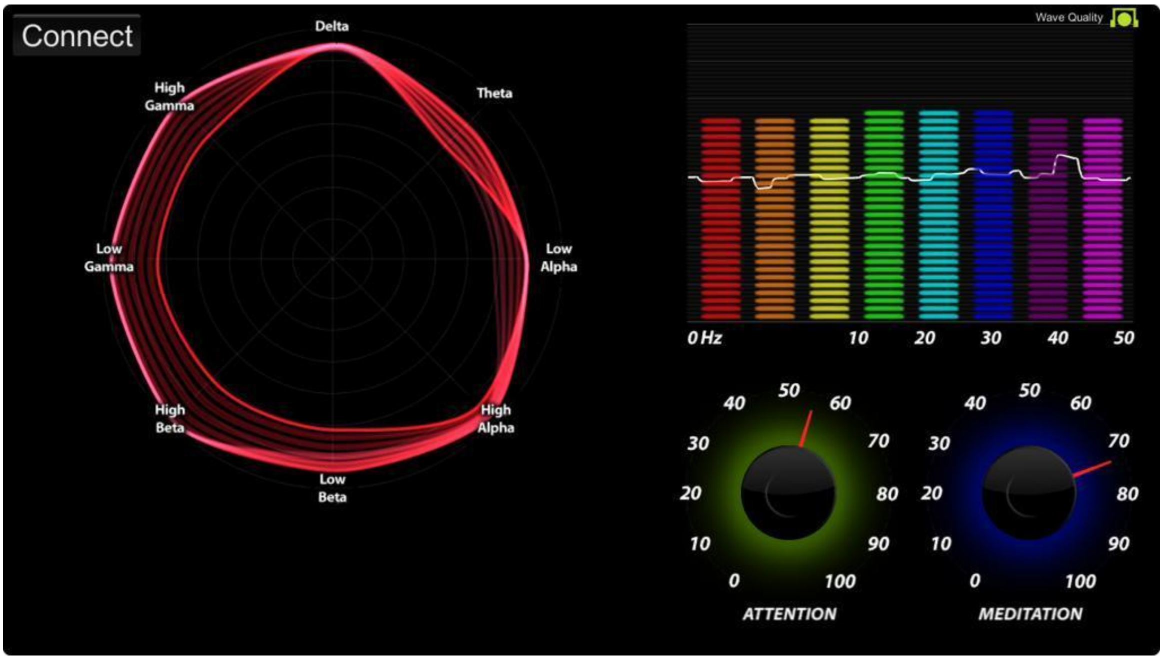
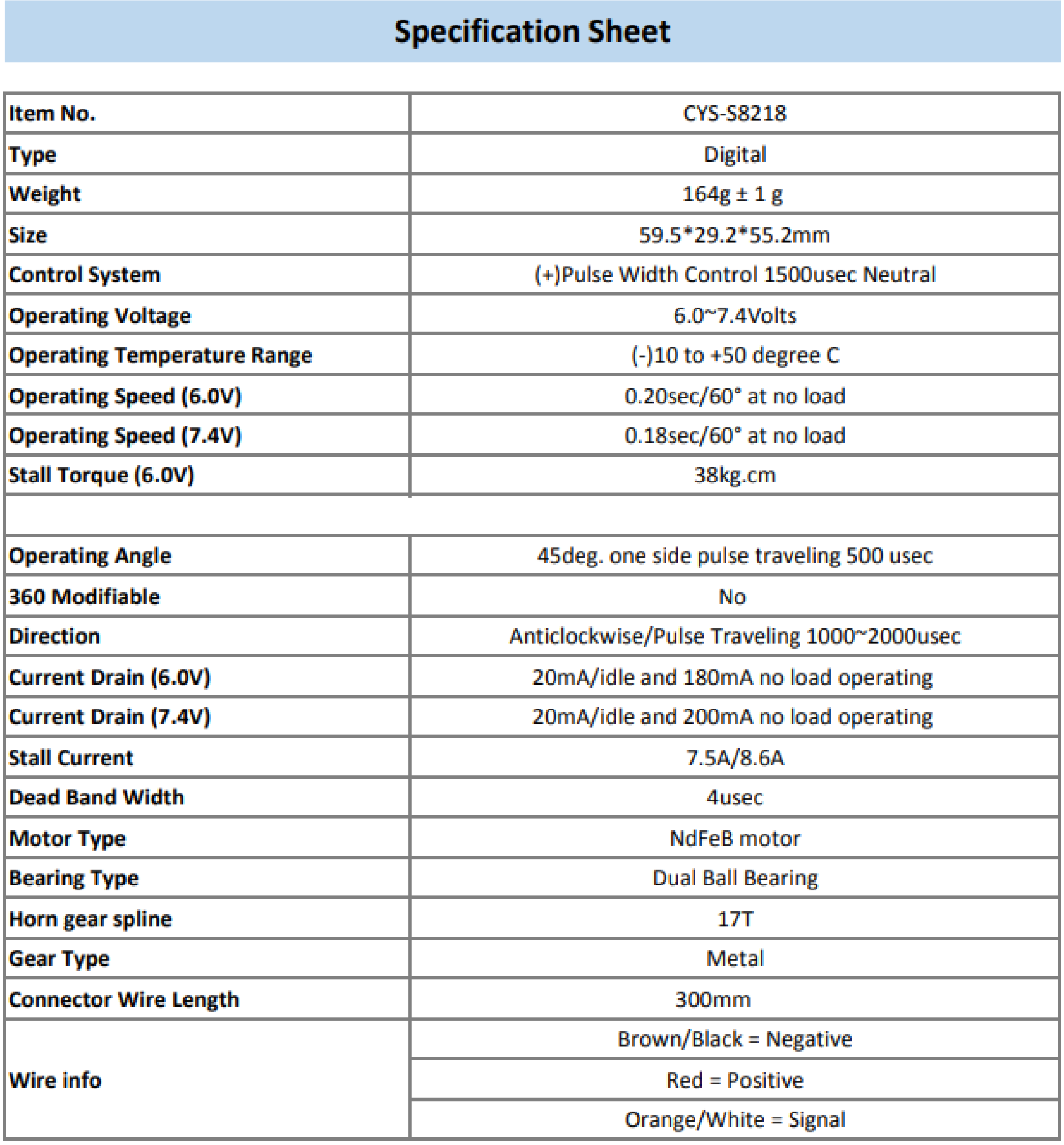


Fig 3.8 Brainwave visualiser

3.3.2 Cys-S8218 SERVO MOTOR DATA SHEET

As a vital part of robotics and automation systems, the servo motor plays a crucial role in granting precise control over angular position, velocity, and acceleration. Utilizing feedback control systems, servos are able to accurately move to designated positions in response to a control signal. Comprising a motor, control circuitry, and a feedback system, the servo's fundamental design often incorporates a potentiometer for continuous monitoring of its position.

The CYS-S8218 servo motor weighs in at just 164g, this digital servo is perfect for a wide range of uses. Its operating voltage range of 6.0 to 7.4 Volts provides optimal performance, delivering an impressive operating speed of 0.20sec/60° at 6.0V and 0.18sec/60° at 7.4V with a no-load condition. With a stall torque of 38kg.cm at 6.0V, this servo is built to tackle tasks requiring significant force. Featuring a control system that utilizes Pulse Width Control, with a neutral point at 1500µsec, precision and accuracy are guaranteed. Its advanced design and specific electrical characteristics make it an essential component for any application that demands precise and powerful motion control.



Specification Sheet

Item No.	CYS-S8218
Type	Digital
Weight	164g ± 1 g
Size	59.5*29.2*55.2mm
Control System	(+)Pulse Width Control 1500usec Neutral
Operating Voltage	6.0~7.4Volts
Operating Temperature Range	(-)10 to +50 degree C
Operating Speed (6.0V)	0.20sec/60° at no load
Operating Speed (7.4V)	0.18sec/60° at no load
Stall Torque (6.0V)	38kg.cm
Operating Angle	45deg. one side pulse traveling 500 usec
360 Modifiable	No
Direction	Anticlockwise/Pulse Traveling 1000~2000usec
Current Drain (6.0V)	20mA/idle and 180mA no load operating
Current Drain (7.4V)	20mA/idle and 200mA no load operating
Stall Current	7.5A/8.6A
Dead Band Width	4usec
Motor Type	NdFeB motor
Bearing Type	Dual Ball Bearing
Horn gear spline	17T
Gear Type	Metal
Connector Wire Length	300mm
Wire info	Brown/Black = Negative
	Red = Positive
	Orange/White = Signal

Table 3.2 Servo Motor Datasheet

Fig 3.9: S8218 Servo Motor

3.3.3 Arduino UNO

The Arduino Uno is an incredibly versatile microcontroller board that is utilized in a variety of electronic projects and prototyping endeavors. This powerful board boasts both digital and analog input/output pins, making it the perfect choice for a wide range of applications. Designed to run on a 5V supply voltage, the Arduino Uno can be easily programmed using the intuitive and user-friendly Arduino IDE. Consisting of 14 digital pins and 6 analog inputs, as well as the ability to communicate through various interfaces, this board provides a solid foundation for connecting with sensors, actuators, and other hardware components. This makes it an invaluable resource for bringing your electronic creations to life.

The centerpiece of our project involves the seamless integration of the versatile Arduino Uno board with the precision-driven CYS-S8218 servo motor. By utilizing the digital output pins, we are able to transmit pulse-width modulation (PWM) signals that dictate the servo's desired position. By connecting the servo's control wire to one of the digital pins, the Arduino becomes the ultimate controller in orchestrating the motor's precise angular movements.

Harnessing the power of Arduino programming, we are able to streamline the arduous task of manually manipulating the servo's position. With the ability to generate a series of instructions, we can automate intricate movements, dictate precise angles, and even respond to external inputs. The simplicity and versatility of the Uno board make it the ideal tool for managing and synchronizing hardware components, ultimately granting us the freedom to implement advanced control tactics for our servo motor within our project.

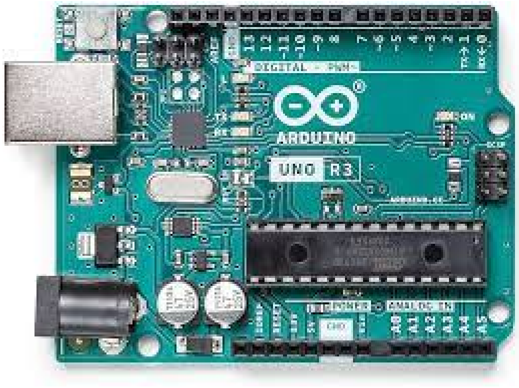


Fig 3.10 Arduino UNO

3.3.4 HC-05 Bluetooth Module

The HC-05 is a Bluetooth module used extensively for wireless communication in various electronic projects, due to its ability to support serial communication, the HC-05 streamlines the process of establishing Bluetooth connections between devices. As part of our project, we incorporate the HC-05 module to establish a wireless link between our EEG (electroencephalogram) sensor and our central processing unit, Arduino .

The HC-05 module is our key to effortless wireless communication. It requires a 3.3V supply voltage, making it compatible with a wide range of microcontrollers. By configuring the HC-05, we unlock its potential to flawlessly receive data from the EEG sensor through its serial interface. This interface creates a smooth pathway between the module and microcontroller. With the help of HC-05's impressive Bluetooth capability, we can gather attention values from the EEG sensor without the hassle of wires. The module acts as the bridge, relaying the data from the sensor to the microcontroller. By programming on the microcontroller, we can easily interpret the received data and take action or display information based on the user's attention levels.

EEG technology is now equipped with wireless capabilities, boosting its flexibility and enhancing user mobility- our system allows for seamless interaction. Additionally, this streamlined approach effortlessly gathers and analyzes attention data, providing a user-friendly and versatile solution for our project

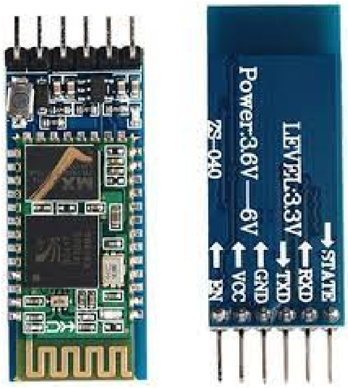


Fig 3.11 HC-05 Bluetooth Module

3.3.5 Circuit Diagram

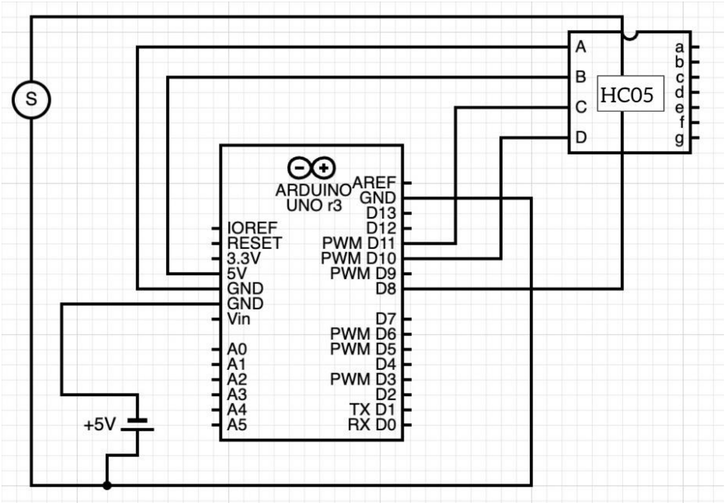


Fig 3.12 Circuit diagram

3.4 Arduino Programming

```
void loop() {
  if (ReadOneByte() == 170) {
    if (ReadOneByte() == 170) {
      payloadLength = ReadOneByte();
      if (payloadLength > 169)
        return;

      generatedChecksum = 0;
      for (int i = 0; i < payloadLength; i++) {
        payloadData[i] = ReadOneByte();
        generatedChecksum += payloadData[i];
      }

      checksum = ReadOneByte();
      generatedChecksum = 255 -
generatedChecksum;
      if (checksum == generatedChecksum) {
        poorQuality = 200;
        attention = 0;
        for (int i = 0; i < payloadLength; i++) {
          switch (payloadData[i]) {
            case 2:
              i++;
              poorQuality = payloadData[i];
              bigPacket = true;
              break;
            case 0x04:
              i++;
              attention = payloadData[i];
              break;
            case 5:
              i++;
              break;
            case 0x16:
              i++;
              break;
            case 0x80:
              i = i + 3;
              break;
            case 0x83:
              i = i + 25;
              break;
            default:
              break;
          }
        }
```

Fig 3.13 Arduino Code Block-1

With the above code block we can read data from MindWave Mobile EEG headset through Bluetooth and control a servo motor based on the level of attention detected. To make this possible, we first import two essential libraries: SoftwareSerial and Servo. The SoftwareSerial library enables seamless communication via Bluetooth, while the Servo library equips the Arduino with the power to control a servo motor. Before diving into the action, we define various constants and variables that will be used throughout the program. These include the LED pin and communication baud rate, as well as variables for storing the data received from the

MindWave Mobile headset.

In the setup() function, the LED pin is set to output mode, the Bluetooth communication is initiated, and the Servo library is initialized.

In the loop() function, the code checks for incoming data from the MindWave Mobile headset via Bluetooth. When two consecutive bytes with a value of 170 are detected, this indicates the start of a packet of data from the headset.

The code then reads the length of the packet, checks if the length is valid, and calculates a checksum for the packet to ensure that the received data is valid.

```
#if !DEBUGOUTPUT
        if (bigPacket) {
          if (poorQuality == 0)
            digitalWrite(LED, HIGH);
          else
            digitalWrite(LED, LOW);
          Serial.print("Attention: ");
          Serial.print(attention);
          if (attention > 60 && !servoActivated) {
            myservo.attach(8);
            servoActivated = true;
            Serial.println("\nActivating servo motor!");
            myservo.write(45);
            delay(5000);
            myservo.write(120);
          } else {
            if (servoActivated) {
              myservo.detach();
            }
          }
```

Fig 3.14 Arduino Code Block-2

This Arduino program integrates an EEG sensor, LED, and servo motor to create an interactive system. Initially excluding debugging output, the program processes a substantial data packet ('bigPacket') and evaluates the EEG signal quality. If the signal quality is deemed satisfactory, an LED is illuminated, serving as a visual indicator.

The program then prints the 'attention' value to the serial monitor, providing insights into the user's cognitive state. Notably, the servo motor is activated only when the attention value exceeds 60 for the first time, as indicated by the conditional check. This activation involves attaching the servo to pin 8, moving it to 45 degrees to simulate a gripping motion, waiting for 5 seconds, and then moving it to 120 degrees. This specific sequence is designed to enable amputees to grip objects, such as a water bottle, offering a tangible and functional outcome triggered by the user's attention level.

This innovative integration of EEG signals and servo motor control holds promise for creating responsive and user-centric prosthetic systems, enhancing the daily lives of individuals with limb differences

3.5 Material Selection and 3D Printing

3.5.1 PolyLactic Acid

Polylactic acid or PLA is a biodegradable and biocompatible polyester that is derived from renewable resources such as corn starch, sugarcane, and other starch-rich plants. It is a polymer made up of repeating units of lactic acid, which is a naturally occurring organic acid.
Polylactic acid, or PLA, finds widespread use in a wide range of manufacturing applications, including medication delivery systems, medical implants, 3D printing filaments, packaging materials, and disposable dinnerware. The spike in popularity can be attributed to its recognition as a sustainable substitute for traditional plastics derived from petroleum.

Key Features and Properties of PLA:

Biodegradability: PLA possesses biodegradable qualities, allowing it to naturally break down in the environment through microbial activity. This eco-friendly attribute contributes to reducing pollution and waste.

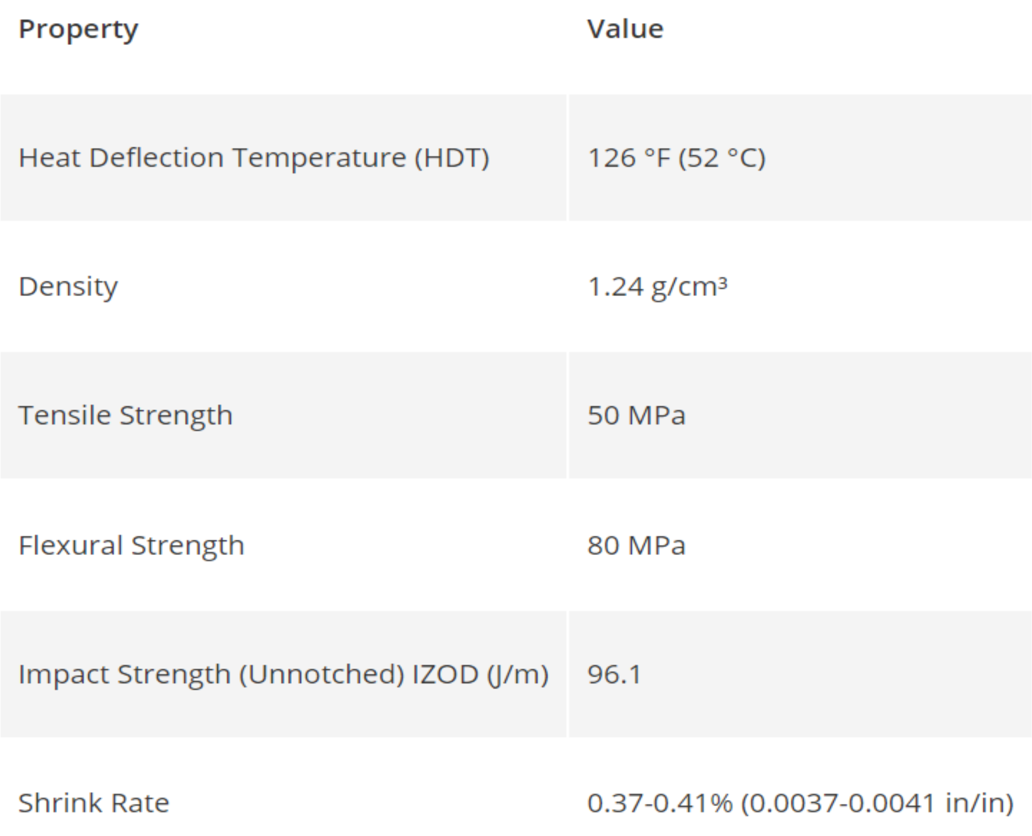
Biocompatibility: as PLA is biocompatible, live tissue does not react negatively to it. Because of this, it's a great material for medication delivery systems and medical implants.

Mechanical Properties: The mechanical strength and stiffness of PLA are moderate. It is adaptable, working with several processing methods like extrusion, injection molding, and 3D printing. By modifying elements like stereochemistry, molecular weight, and polymerization degree, its properties can be precisely controlled.

Thermal Properties: PLA is malleable at lower temperatures due to its relatively low glass transition temperature (Tg), which is between 60 and 65°C. Its usage in high-temperature applications is restricted despite the fact that this feature makes processing easier.

Optical Properties: PLA works well in clear packaging materials since it is translucent and has high light transmission qualities.

Despite the numerous advantages of PLA as a sustainable and biodegradable material, challenges exist, including brittleness and degradation over time in the presence of moisture and high temperatures. Ongoing research and development endeavors aim to address these issues and enhance the overall performance and versatility of PLA.



Property	Value
Heat Deflection Temperature (HDT)	126 °F (52 °C)
Density	1.24 g/cm³
Tensile Strength	50 MPa
Flexural Strength	80 MPa
Impact Strength (Unnotched) IZOD (J/m)	96.1
Shrink Rate	0.37-0.41% (0.0037-0.0041 in/in)

Table 3.3 PLA Properties [11]

3.5.2 3D Printing

3D printing, also referred to as additive manufacturing, has revolutionized the fields of design, prototyping, and production. It differs from traditional methods as it builds objects layer by layer using digital models. This approach offers unparalleled design flexibility, allowing for the efficient creation of intricate and personalized structures. This democratization has sparked advancements in numerous industries, including healthcare and aerospace, driving a culture of innovation and progress.

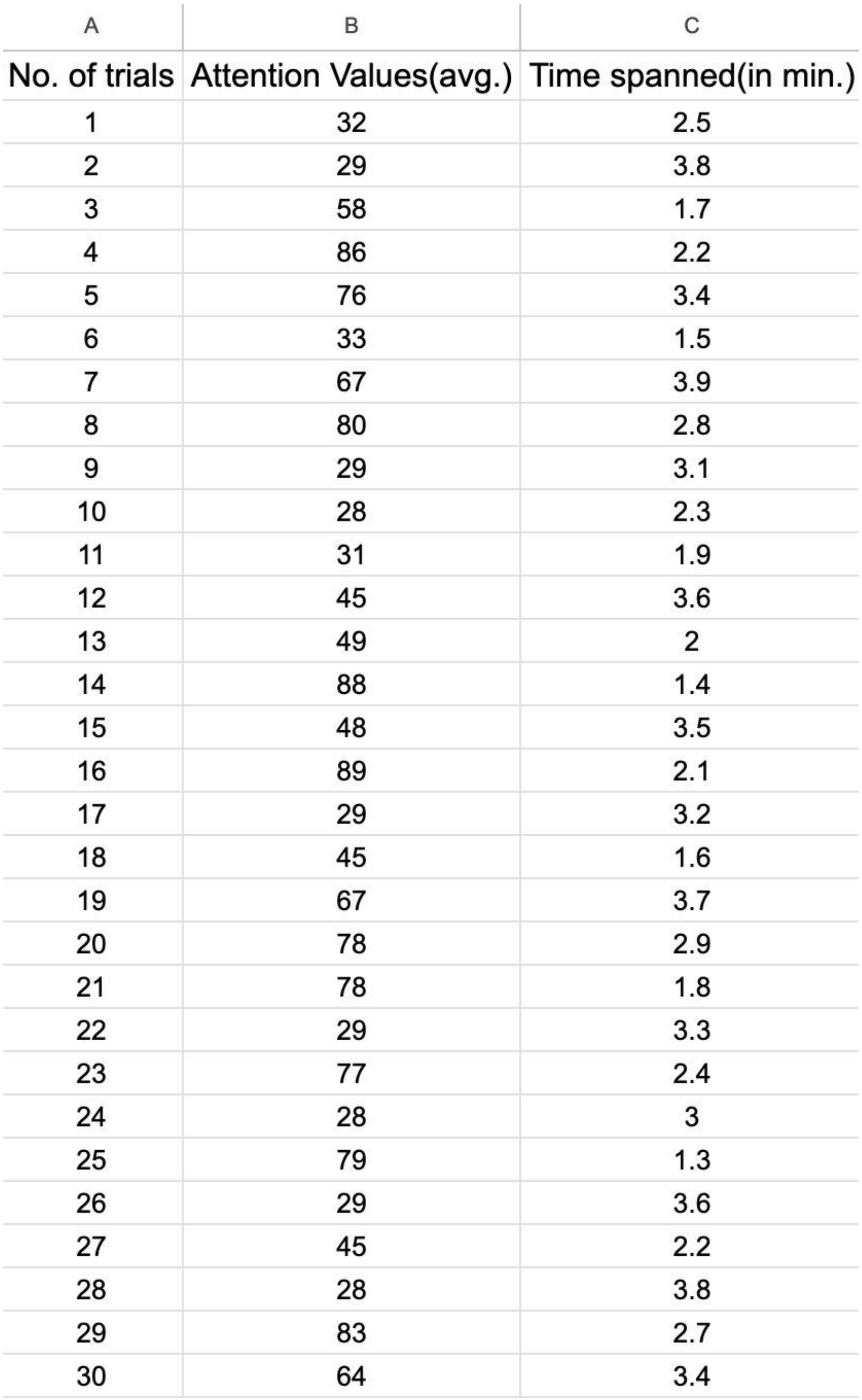
Fused Deposition Modeling (FDM) in 3D Printing: FDM, or Fused Deposition Modeling, is a 3D printing technique due to its ease of use and adaptability. This method involves feeding a heated nozzle with a plastic filament, which is then extruded layer by layer to construct the desired item. This layering process is repeated until the entire three-dimensional structure takes shape. Not only is FDM perfect for creating sturdy and practical prototypes, but its affordability and availability have also led to its widespread usage. From rapid prototyping to low-volume production, FDM remains the go-to choice for many industries.

Incorporating 3D Printing in Gripper Fabrication: Our project takes full advantage of the capabilities of 3D printing, to create a cutting-edge robotic gripper with remarkable versatility and adaptability. Through the layer-by-layer deposition of thermoplastic material, we are able to construct intricate gripper components with unparalleled precision. This approach not only allows for the incorporation of complex geometries, but also guarantees durability and a lightweight design. By utilizing 3D printing in the fabrication process, we are able to quickly prototype and make iterative improvements to the gripper based on testing and user input.

Moreover, the use of 3D printing offers a level of versatility that is essential in creating grippers specifically suited for amputees with transradial prostheses. By harnessing the power of this cutting-edge technology, we are able to design grippers that cater to individual preferences and functional requirements, resulting in a truly customized experience. The adaptability and efficiency of 3D printing make it a crucial tool in developing prosthetic components, paving the way for improved quality of life for those who rely on these devices. To conclude, the incorporation of 3D printing, particularly FDM, into our gripper production process symbolizes the groundbreaking potential of this technology in driving the progress of assistive devices. It offers not only functional solutions, but also personalized ones that cater to the specific needs of the end-user.

CHAPTER 4
RESULT AND DISCUSSION

4.1 Data Evaluation



A	B	C
No. of trials	Attention Values(avg.)	Time spanned(in min.)
1	32	2.5
2	29	3.8
3	58	1.7
4	86	2.2
5	76	3.4
6	33	1.5
7	67	3.9
8	80	2.8
9	29	3.1
10	28	2.3
11	31	1.9
12	45	3.6
13	49	2
14	88	1.4
15	48	3.5
16	89	2.1
17	29	3.2
18	45	1.6
19	67	3.7
20	78	2.9
21	78	1.8
22	29	3.3
23	77	2.4
24	28	3
25	79	1.3
26	29	3.6
27	45	2.2
28	28	3.8
29	83	2.7
30	64	3.4

Avg attention value after 30 trials	**54**

Table 4.1 Data Evaluation

In conclusion, our rationale behind setting the attention threshold for **actuation at 60** in our prosthetic system stems from an empirical examination of 30 carefully conducted trials. It was observed that the average value of attention over the conducted trials was 54 and hence the choice of 60 as the actuation threshold represents a deliberate calibration to strike a balance between functionality and user accessibility. By selecting this threshold, we aim to ensure that the prosthetic actuation aligns with heightened user attention, a crucial aspect for intentional control. Simultaneously, the chosen value is practical and achievable for a diverse user demographic, reflecting our commitment to designing a system that is both precise and user-friendly. This strategic calibration is pivotal in optimizing the prosthetic control mechanism, fostering a seamless integration of technology into the daily lives of individuals undergoing transradial prosthesis, and enhancing their overall experience and independence.

4.2 Ansys Analysis

In our pursuit to create a highly functional robotic gripper, we incorporate static analysis into our design process. This technique allows us to evaluate the distribution of stress, deformation, and safety factors when our gripper is handling a 500ml water bottle. By subjecting our gripper to steady-state loading, we can gain valuable insights into its ability to withstand expected forces. Using ANSYS, we are able to obtain a deeper understanding of the gripper's mechanical response, which aids in identifying potential failure points and guiding iterative design enhancements. This approach not only streamlines and expedites the development process, but also fortifies the reliability and efficiency of the gripper, thus significantly contributing to the overall success of our project. Furthermore, our ultimate objective is to positively impact the field of assistive technologies for individuals with limb differences. The gripper's operation involves grasping and holding a standard-sized water bottle without rapid or dynamic movements; a static analysis has been chosen to provide accurate results. It allows us to assess the structural integrity of the gripper under the anticipated steady-state loading conditions, such as the weight of the water bottle.

Total Deformation:

In our ANSYS analysis of the robot gripper, the total deformation results reveal the extent of structural displacement under applied loads. This crucial output aids in assessing the overall flexibility and resilience of the gripper, guiding design improvements for optimal performance and longevity.

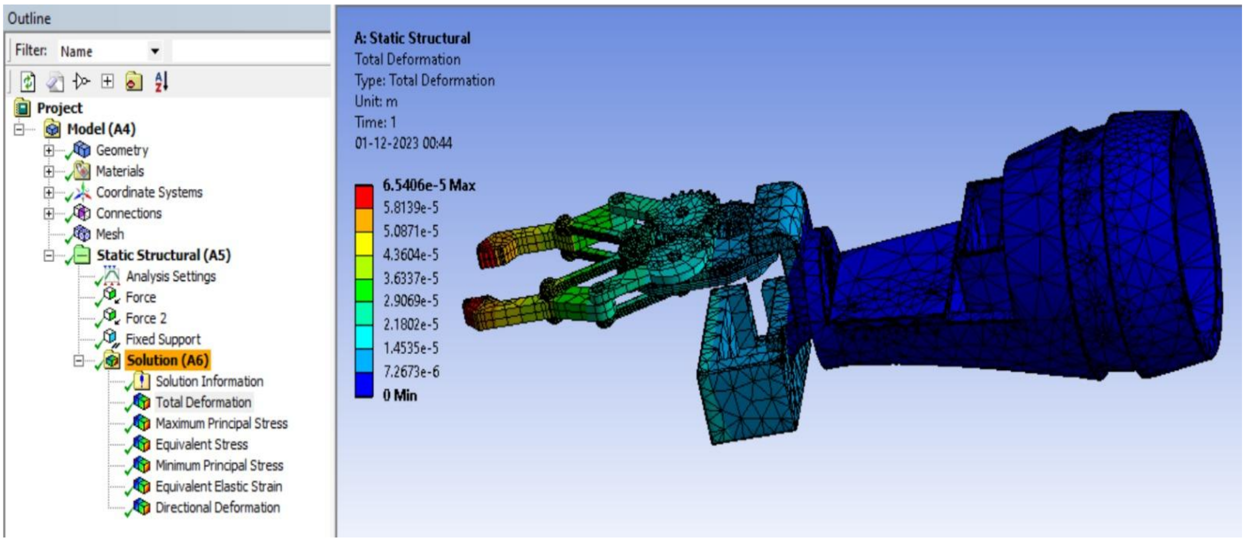
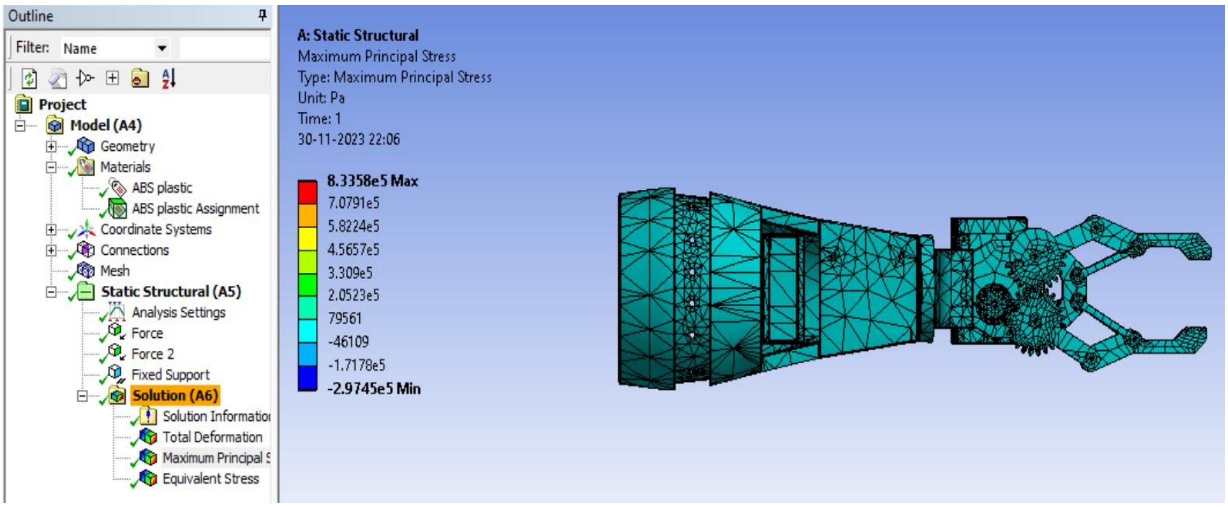

A: Static Structural
Total Deformation
Type: Total Deformation
Unit: m
Time: 1
01-12-2023 00:44

Fig 4.1 Total Deformation

Max Principal Stress:

The ANSYS analysis on our robot gripper includes the evaluation of maximum principal stress, a pivotal indicator of potential material failure. By identifying stress concentrations and critical areas, we ensure the gripper's structural integrity and guide design enhancements for enhanced reliability and safety in real-world applications.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Maximum Principal Stress
Type: Maximum Principal Stress
Unit: Pa
Time: 1
30-11-2023 22:06

Fig 4.2 Maximum Principal Stress

CHAPTER 5

CONCLUSIONS AND SCOPE FOR FUTURE WORK

5.1 Conclusion

In conclusion, our research successfully addresses critical gaps in the existing literature on prosthetic arms. By implementing advanced design principles and leveraging EEG sensor data, our prosthetic arm demonstrates enhanced rigidity and movement precision, marking a significant advancement in the field.

Moreover, our usability evaluation across diverse user groups provides a nuanced understanding of the prosthetic arm's adaptability. The upcoming thorough evaluation of the impact of post-prosthetic fitting on individuals' quality of life is expected to provide valuable insights into the wider implications of integrating prosthetic arms. Our innovative design is set to surpass the limitations of traditional prosthetics, allowing for remarkable functionality in everyday tasks. This is further exemplified by our successful demonstration of the prosthetic arm's ability to lift a water bottle, clearly showcasing its practicality and user-centered design. Our findings pave the way for future advancements in prosthetic technology, marking a significant step towards improving the lives of individuals in need.

5.1.1 Bill of Materials

Sl no	Material	Cost
1	Arduino UNO	₹300
2	FT&S Mindlink EEG sensor	₹8000
3	Cys- S8218 Servo Motor	₹3000
4	HC-05 Bluetooth Module	₹200
5	Jumper Wires	₹40
6	3D printing	₹5000
7	4 Cell battery	₹80
	Total	**₹16,320**

Table 5.1 Bill of Materials

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5.2 Future Scope

Revolutionize Sensory Feedback: Revolutionize the user's experience by integrating advanced sensory feedback mechanisms in the robotic gripper, providing a natural and seamless sense of touch and grasp. This innovation will involve incorporating precision pressure sensors within the gripper, accurately detecting the force exerted during grasping.

Empower Machine Learning and Adaptability: Empower the robotic gripper with machine learning algorithms, allowing it to adapt and customize its movements according to individual user preferences and habits. This technology will continuously learn and improve, ensuring optimal performance and efficiency.

Refine EEG Signal Processing: Push the boundaries of research by investing in refining the signal processing algorithms for EEG sensors. By enhancing the accuracy and speed of interpreting neural signals, the robotic gripper will be able to carry out commands with utmost precision and responsiveness.

Recognize Gestures and Personalize: Unleash the potential of gesture recognition technology and its customization capabilities. Users will be able to effortlessly communicate with the robotic gripper, delivering specific tasks with varying levels of complexity.

Designing for Users: Extensively research the ergonomic needs and preferences of amputees through user studies. Utilize this valuable information to enhance the design of the robotic gripper, prioritizing comfort, intuitiveness, and individualized functionality.

Prioritizing Energy Efficiency: Dedicate efforts towards creating energy-efficient systems and exploring innovative power management solutions. These efforts will aim to prolong the battery life of the robotic gripper, making it easily accessible and user-friendly for daily use.

Partnering with Healthcare Professionals: Foster close collaboration with healthcare experts, such as prosthetists and rehabilitation specialists, to ensure that the technology aligns with the medical and rehabilitation standards.

By focusing on these areas, future research can contribute to the ongoing development and improvement of robotic grippers for transradial prosthesis users, ultimately enhancing their quality of life and level of independence.

5.2.1 Gecko Skin

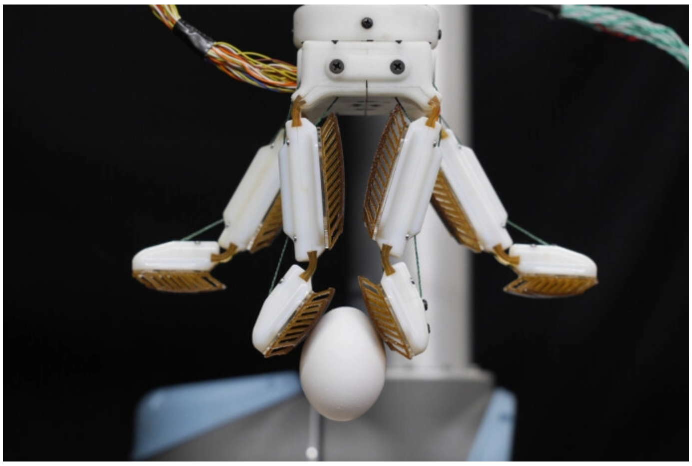


Fig 5.1: Gecko skin on a bionic arm

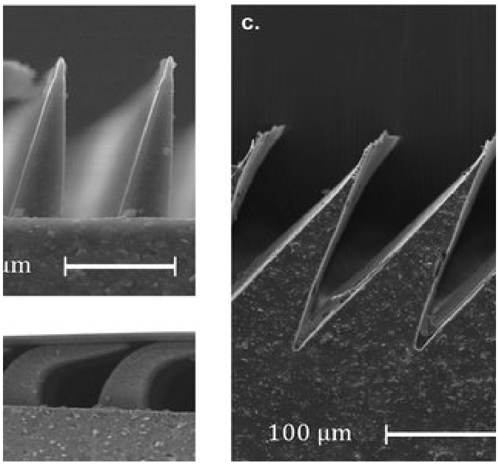
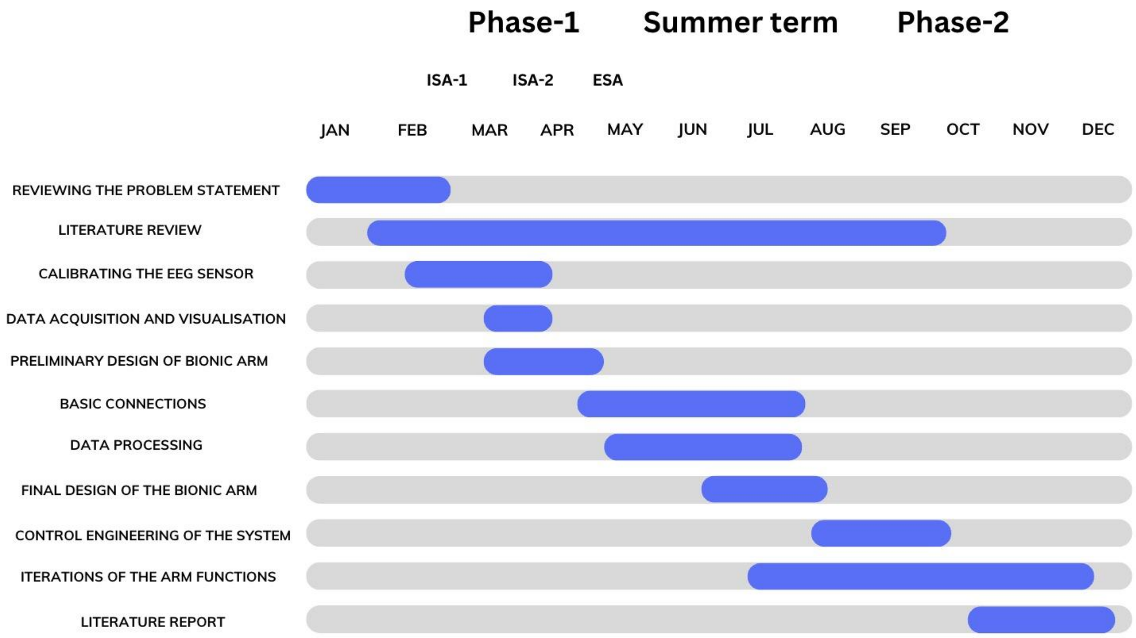


Fig 5.2: Microscopic view of a gecko skin

This incredible material gecko skin has captured the attention of scientists and sparked remarkable progress in various industries. One particularly groundbreaking use of gecko skin is in prosthetic arm technology, where researchers have utilized its adhesive properties to create a game-changing advancement. The team at Stanford University has successfully integrated a gecko-inspired adhesive into prosthetic arms, resulting in improved grip and dexterity for users. What truly will set this development apart is the addition of an EEG sensor, which will interpret and translate the wearer's brain signals into precise movements of the prosthetic hand. The key to this impressive technology lies in the innovative adhesive, which mimics the remarkable abilities of gecko skin. This adhesive effortlessly maintains a strong hold on different surfaces, without leaving any trace.

In order to seamlessly integrate this cutting-edge technology into a project, a thorough understanding of both the mechanics of the prosthetic arm and the functions of the EEG sensor is imperative. Moreover, researchers must possess the proficiency to invent and assess novel gecko-inspired adhesives, capable of effectively adhering to the prosthetic arm and providing the necessary level of grip. Without a doubt, the incorporation of gecko skin in prosthetic arms, controlled by an EEG sensor, has the potential to revolutionize the world of prosthetics, empowering amputees and individuals with disabilities with improved dexterity and abilities.

TIMELINE


Phase-1
Summer term
Phase-2
ISA-1
ISA-2
ESA
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MAR
APR
MAY
JUN
JUL
AUG
SEP
OCT
NOV
DEC
REVIEWING THE PROBLEM STATEMENT
LITERATURE REVIEW
CALIBRATING THE EEG SENSOR
DATA ACQUISITION AND VISUALISATION
PRELIMINARY DESIGN OF BIONIC ARM
BASIC CONNECTIONS
DATA PROCESSING
FINAL DESIGN OF THE BIONIC ARM
CONTROL ENGINEERING OF THE SYSTEM
ITERATIONS OF THE ARM FUNCTIONS
LITERATURE REPORT

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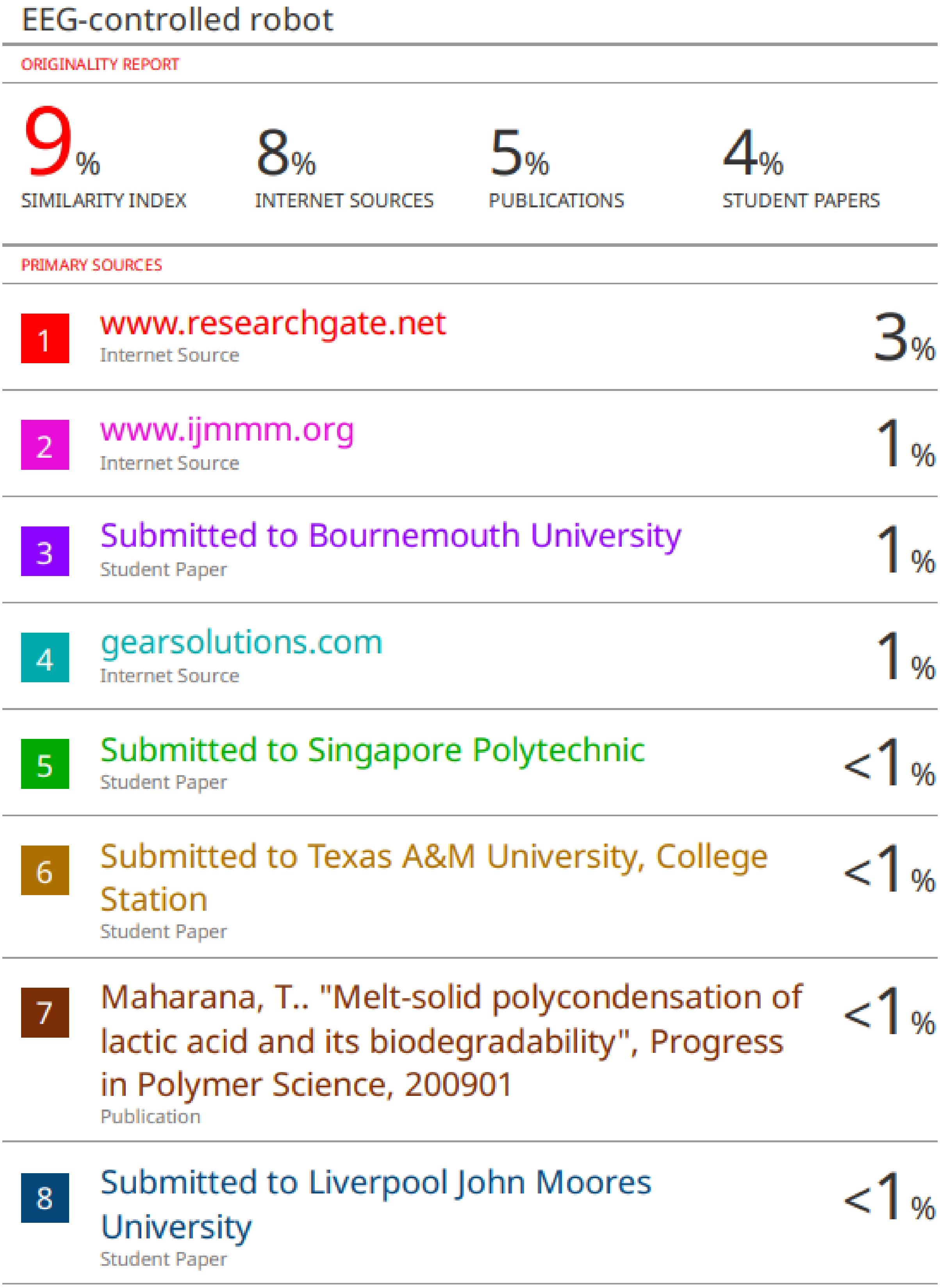

EEG-controlled robot

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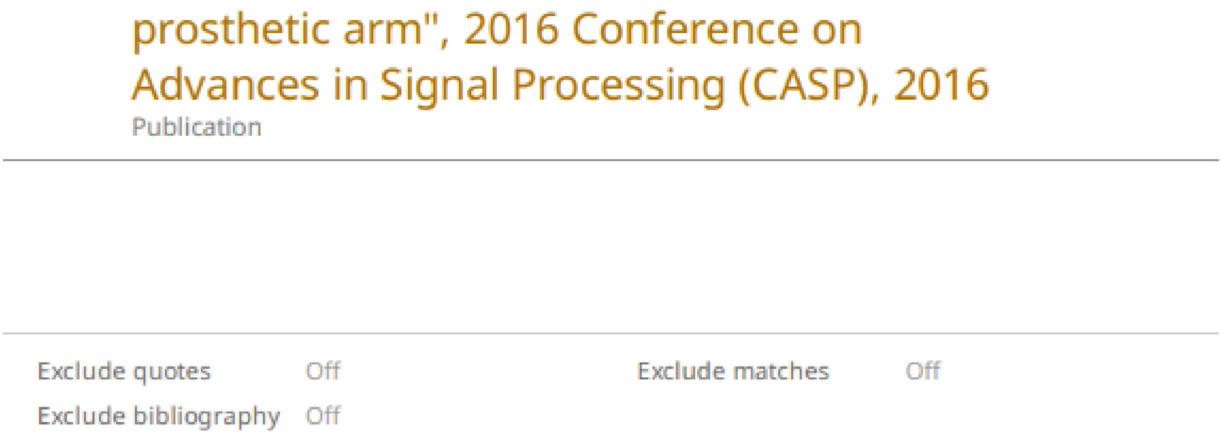

prosthetic arm", 2016 Conference on Advances in Signal Processing (CASP), 2016

Publication

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PES UNIVERSITY
DEPARTMENT OF MECHANICAL ENGINEERING Bangalore, India

Team no: M29

TRANSRADIAL PROSTHESIS-DEVELOPMENT OF A BIONIC ARM USING AN EEG SENSOR

RAKSHITH V (PES1UG20ME141), PRANAV ADIGA (PES1UG20ME075)
SANKETH CHEBBI (PES1UG20ME098), SAI PREETHAM R.V (PES1UG20ME092)
Under the guidance of Dr. D SETHURAM

Introduction:

This project emphasizes the creation of an EEG-controlled robot gripper for transradial prostheses. Integrating brain-computer interface technology and 3D printing, our goal is to enhance assistive technology by prioritizing functionality and user-centric design for improved prosthetic solutions.

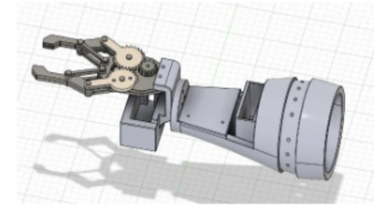


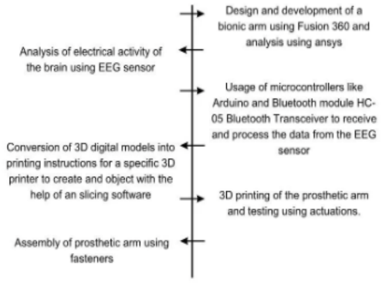
Fig. 1 Robot gripper powered by a servo motor

The main objective of this project work is to develop an *EEG-controlled robot gripper* for transradial prostheses, enabling amputees to perform tasks like lifting bottles, emphasizing functionality and user experience.

Objectives:

- Integrate 3D printing for adaptable and customized gripper fabrication, catering to individual needs.
- Enhance prosthetic functionality for amputees, emphasizing usability in everyday tasks like bottle lifting.
- Conduct ANSYS analysis to validate structural integrity and ensure safety under diverse loading conditions.
- Evaluate the impact of the gripper on users' quality of life post-prosthesis fitting

• Methodology:



Design and development of a bionic arm using Fusion 360 and analysis using ansys

Analysis of electrical activity of the brain using EEG sensor

Usage of microcontrollers like Arduino and Bluetooth module HC-05 Bluetooth Transceiver to receive and process the data from the EEG sensor

Conversion of 3D digital models into printing instructions for a specific 3D printer to create and object with the help of an slicing software

3D printing of the prosthetic arm and testing using actuations.

Assembly of prosthetic arm using fasteners

Hardware

Fig. 2 FT&S Mindlink EEG sensor

Fig. 3 HC-05 Bluetooth Module

Ansys Study:

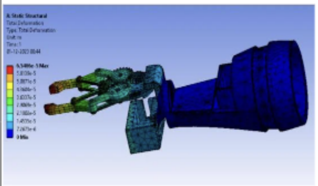


Fig.4 Total deformation

Ansys Study:

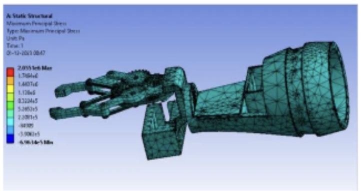


Fig.5 Max Principal Stress

Table

Gear Parameters

Sl no	Parameter	Value
1	Module	1.125
2	No of teeth	24
3	Face width	3mm
4	Normal shaft diameter	3mm
5	Pressure angle	20 degrees

Arduino Circuit Diagram

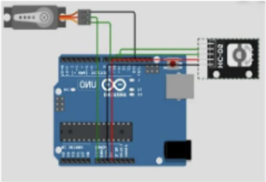
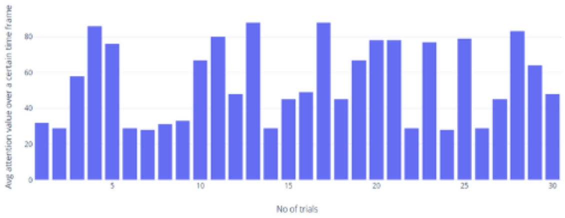
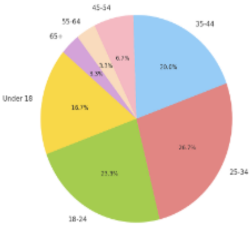


Fig.6 Circuit diagram

Avg Attention values vs No of trials



Distribution of the age group of 30 trials



Conclusion

- Successfully implemented an EEG-controlled robot gripper, enhancing prosthetic functionality for amputees in tasks like bottle lifting.
- Incorporated user-centric design principles, ensuring improved quality of life post-prosthesis fitting.
- Validated structural integrity through ANSYS analysis, affirming reliability and safety in real-world applications.