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Brain-Controlled Robotic Arm System Using EEG Signal

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Abstract- The dream of mind-controlled prosthetics is becoming a reality with EEG-powered robotic arms. These remarkable devices translate the language of the mind into physical actions. Imagine Slipping on a comfortable EEG headset that detects the subtle brainwaves created by the mind during motion. Your thoughts are like a secret code, the headband picks up these signals processed by a software interface and delivered to a microcontroller. This interface sorts the brain activity to find your commands, which are sent to a computer by tiny electrodes that acts as the brain of the robotic arm. This translates your thoughts into instructions for the arm's motors, which perform the motion based on the EEG commands received. The robotic arm should perform the movements of a natural arm as closely as feasible, considering budget, and mechanical component availability. But the ultimate goal remains clear: to create a robotic arm that feels as natural and easy to use as an extra limb.

Keywords- Robotic arm, Raspberry Pi, Machine learning, EEG Sensors

I. INTRODUCTION

Limb loss injuries affect 250,000 to 500,000 people globally impairing physical functioning and mobility. In rich countries, clogged arteries and diabetes are the main culprits. But in poorer countries, injuries are the biggest reason. In developing countries, factors like industrialization, transportation systems, and access to medical care influence causes. Brain-computer interfaces (BCIs) (Claudio Barbiellini Amide, 2022) facilitate control of restorative or assistive devices, and electroencephalography (EEG) is a non-invasive brain activity recording with high temporal resolution. Motor imagery (MI) brain signals are flexible EEG signals used in this research to study brain working and related disorders (McDonald, 2020).

This paper introduces a low-cost robotic arm controlled by EEG signals, which explores the fusion of neuroscience and robotics in creating brain-controlled arms, which can execute tasks with precision and dexterity. The arm's design and mechanics are meticulously considered to replicate the range of motion and functionality of a human arm. Integrating technology and biology offers new possibilities for individuals with limb loss or motor impairments.

The research also examines advancements in haptic feedback technology, enhancing user interaction with the artificial limb (Ji-Hoon and Shim, 2020) The calibration phase is an initial step in the setup, starting with the brain-controlled arm getting to know you and recording your brain signals so it understands how to move when you think about it, and then it takes some practice for you to get the hang of using it, and by using the machine learning and artificial intelligence for this arm it can learn from you too with time, it adjusts to your unique brainwaves and what feels most comfortable, making it easier and easier to control.

II. IDENTIFY, RESEARCH, AND COLLECT IDEA

Many researchers have written on subjects relating to our suggested system. This section will review some of the research's case studies. highlighting the strengths and limitations of their study, as well as our recommended remedies to the problems found in earlier studies. Before deciding on a design solution for this project, a literature review of similar projects is done. They will be explored in greater detail in the subsystem conceptualization sections, but for the time being, they will be discussed briefly here and in Table 1.

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Nann's study (Nann, 2021) employed Electroencephalography/ Electrooculography (EEG/EOG)-based brain neural control to drive a vision-guided semi-autonomous whole-arm exoskeleton for stroke survivors with upper-limb paralysis. The device was evaluated for feasibility, safety, and usability in drinking tasks. The study discovered that following calibration and familiarization, individuals could do the job dependably. Achim Buerkle (Buerkle A, 2021) created a framework for exploiting human EEG data in industrial robots to facilitate collaborative assembly operations. The framework solves issues related to recording and processing EEG signals, linear discriminant analysis, and communication protocols. The ABB IRB120 robot was utilized to determine the framework's practicality. Liwei Cheng's (al C. L., 2022) robotic arm control system uses a combination of EEG and Electromyography (EMG) inputs to control the arm in real time. Researchers are investigating motor imagery-based brain-computer interfaces (BCIs) to increase identification precision and control instructions, by combining MI-based BCIs with EMG bioelectrical signals.

According to the authors of (Abiri R, 2019) and (Leeb R, 2007). This paper investigates the application of deep learning techniques, specifically convolutional neural networks, to object movement imagery for brain-computer interfaces. The study aims to achieve statistically significant accuracy in classifying mental activity associated with imagining an external object moving, using a dataset of 462 trials.

The authors of (Kleih S, 2013) suggest increasing trials and subjects for improved CNN training, optimizing the architecture, and comparing performance to motor imagery studies to create a robotic solution controlled by mental activity, emphasizing embodiment and visual feedback.

Similarly, the authors of (Petoku E, 2021) this study explores CNNs for classifying mental activity in object movement imagery, achieving moderate accuracy but highlighting difficulties in different movement directions. Future enhancements and real-world applications are discussed, considering performance, technical, and safety criteria, literature review, and independent evaluation.

A variety of options influenced the conceptual solution for the robotic arm project. For the robotic human-like components, the InMoov Project, for example, offers several design options. Other initiatives, such as the Reachy Project in (al M. S., 2019), present an alternative perspective on the conceptual solution.

The text discusses various publications on BCI applications, including St. Germain's (Delorme A, 2004) work on controlling the Lego arm using Emokey, Bayreuth et al.'s research on robotic arm operation, and Delorme and Makeig's study on data processing using EEGLAB for independent component analysis.

Table 1 Constructive analysis Table

Journal	Controlling method	Material of arm	Degree of freedom
Restoring Activities of Daily Living Using an EEG/EOG-Controlled Semiautonomous and Mobile Whole-Arm Exoskeleton in Chronic Stroke (Nann, 2021)	EEG/EOG PCB Design	Mostly aluminum and carbon fiber	Nine
Brain-Controlled Robotic Arm for Disabled People Based on Electroencephalography Technology [5]	Not mentioned	carbon fiber	seven
Intelligent Control of Robotic Arm Using Brain Computer Interface and Artificial Intelligence [7][8]	Arduino	Not mentioned	Six
Robotic arm control system based on brain-muscle mixed signals [9]	SSVEP and BCI	Aluminum alloy	seven
Our Arm	ESP32 Raspberry pi	PLA+	12

III. METHODOLOGY

The components used in the project include an EEG Headset Electroencephalography (EEG) is a technique that uses wearable electrodes on the scalp to monitor and record brain activity. Researchers analyze EEG data to understand brain functions and track emotions, contributing to improved well-being and productivity. However, non-brain signals can impede data collection, so cheap EEG headsets are often used (Torad & Salam, Mustafa Abdul , 2021). Dry active comp electrodes as Figure (1) are solid-state electrodes used in electrochemical measurements or

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experiments where this type of electrode is safe to the brain peeled off, requiring no liquid electrolyte. They are commonly used in gas sensors, fuel cells, and batteries. The electrode's components include a preamplifier, snap button, dry sensor, and housing for durability and reliability. The preamplifier as shown in Figure (1) (Dry sensors for SmartBCI wireless EEG) boosts these signals, increasing their amplitude. Amplification is essential for improving the signal-to-noise ratio, ensuring that the desired brain signals are distinguishable from background electrical noise. The ESP32 (J. Rahardjo et al., 2020) is a low-cost, low-power module that integrates dual-mode Bluetooth and Wi-Fi, manufactured by TSMC using their 40 nm process, offering robust, versatile, and reliable performance.

Lithium-ion batteries (M. A. Hannan, 2018) are popular due to their superior characteristics and performance, positive environmental impacts, and recycling potential. They are 3.7 volts, rechargeable, and can be used in various fields like consumer electronics, electric vehicles, medical devices, and renewable energy systems. However, they may experience aging and require proper charging to ensure safety. The EBL 992 Smart Rapid Battery Charger (P. Pérez, March 2022) is a rechargeable battery charger capable of charging various batteries, offering three charging modes, Microcontroller Unit (MCU) -controlled technology, and a user manual. The Encore 802.11n Wireless Router (in S. -M. Xia, 2019), compliant with FCC Rules, supports the IEEE802.11n standard, 300 Mbps data rate, and IEEE 802.11g/b wireless devices, allowing multiple users to share broadband connections. Raspberry Pi 4 Model B (Torad M, 2022) is a high-performance computer with a 64-bit quad-core processor, dual-display support, 8GB RAM (Random Access Memory) , and dual-band wireless LAN, Bluetooth, and Power over Ethernet (PoE)VR capabilities, offering desktop performance comparable to entry-level x86 PC systems. SNCECAM 60kg coreless motor, 6V, self-researched, self-controlled, RS485 control board, 12-bit magnetic coding sensor, suitable for shoulder applications, offers 0-270 degrees angle control, multi-turn continuous operation mode. GOUPRC 40kg is a 5V brushless motor with a stall torque of 40kg, 0-360 degrees, and overload/over-current protection. Feetech STS3032 is a 6V 4.5kg serial bus smart servo with a Transistor-Transistor Logic (TTL)ram control board, 12-bit magnetic coding sensor, and adjustable stall torque. Feetech SCS40TTL is a 40kg serial bus smart servo with a high-quality potentiometer, stall torque of 40kg, and servo mode for overload and over-current protection.

Power banks (M. Krpan, Sept.2021), portable batteries, regulate power in and out, charging devices like cell phones with a USB charger, serving as a financial bank. Small Piezoresistive Film Pad Force Pressure Sensor 100gram (H. -H. Tai, April1, 2022). The piezoresistive effect is a change in the electrical resistivity of a semiconductor or metal when mechanical strain is applied. SMT trimmer potentiometer 3313J-1 is a miniature adjustable electrical component used in precision circuitry, calibrating equipment after manufacturing and requiring fewer adjustments over its lifetime. The Mini Maestro 18-Channel USB Servo Controller (C. Sun, July 2021) is a versatile, compact I/O board that supports USB, TTL serial, and internal scripting for various applications.

As shown in figures (2) and (3), the hardware system uses EEG sensors, ESP32 microcontroller, Raspberry Pi, and a machine learning model to acquire and process EEG signals. The Pi processes the data, calculates control angles, and sends motor control signals.

Figure 1 Dry active electrode.

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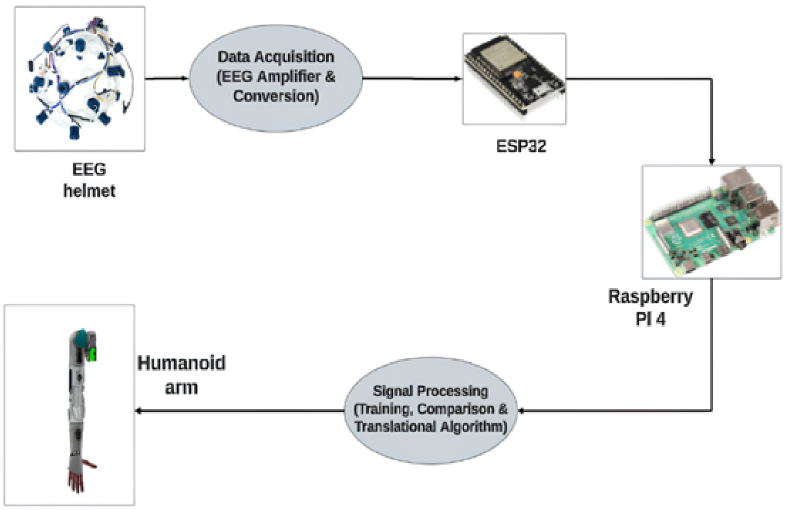

Figure 2 Hardware illustration flow chart.

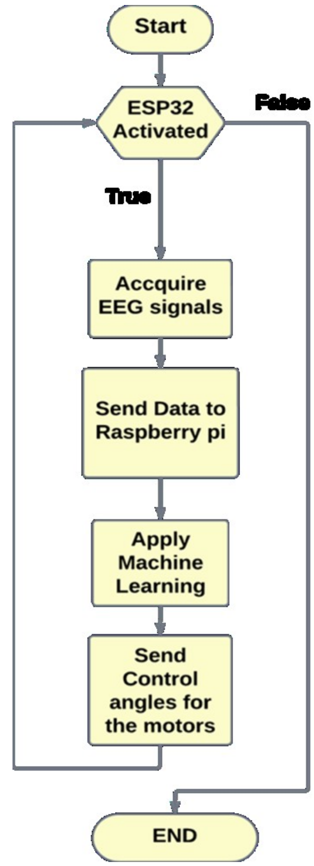

Figure 3 Flow chart.

IV. DESIGN CONCEPT

The Robotic Arm as Figure (4) has 12 DOF (Degrees of Freedom) hardware designed to simulate human hands and arms 7 DOF for arm and 5 DOF for fingers, with 1 DOF for the shoulder joint, 1 DOF for the elbow, 1 DOF for the forearm, and 2 DOF for the wrist. It includes sensing for force, position, temperature, and touch. The arm is modular, making it suitable for low-cost prosthetics and easy to change and upgrade. OpenBCI's Ultra cortex EEG helmet is a lightweight, durable design that prioritizes comfort, adjustability, and compatibility with electrode placement. It features adjustable straps and a modular framework, allowing for customizable fit for various head sizes. The helmet's structure ensures accurate electrode positioning, making it a versatile tool for EEG research and applications.

The robotic arm was designed to meet character and collaborative robotic needs, using dimensions from a medium-sized woman's arms as constraints. The arms are made of PLA 100% filament, with Feetech servos for control and feedback. The shoulder on the torso features elevation-depression and retraction-protraction, allowing for more realistic movements and better gestures. The robots use solid works and pressure sensor pads for feedback.

The robotic arms have 7 DOF, including shoulder pitch, shoulder roll, shoulder yaw, elbow, wrist yaw, wrist roll, and pitch. The hand has 6 DOF, all with small Feetech STS3032 motors to drive the five fingers and thumb roll with wires. The hand has 6 DOF (6motors) and uses four pressure sensors RFP-601

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in fingertips and 7 SMT Trimmer Potentiometers (10K) sensed by a Mini Maestro 18-Channel USB Servo Controller.

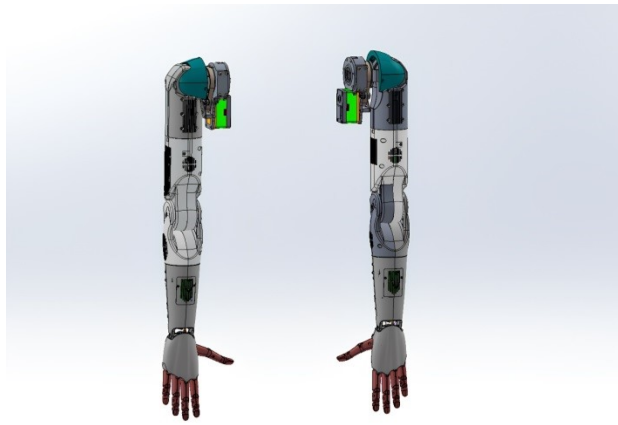

Figure 4 Humanoid arm.

V. Selection of Actuator

To select motors for the robot arm, calculations are made based on design brief specifications and arm weight estimates. The calculations include torque, payload, arm segment weight, and educated guesses about the arm's weight.

A. Shoulder

From the design in solid works: M for the arm = 2.5 Kg, F.S = 1.15

L from shoulder joint to elbow joint = 300mm

τ=F*d sinθ $\tau = \text{mg}*\frac{L}{2}\sin\theta + m\ load * L$

$\tau = 2.5 * 9.81 * \frac{300*10^{-3}}{2} \sin 90 + 0.5 * 9.81 * 300 * 10^{-3}$

$\tau = 5.2\ N.m \cong 53\ Kg.cm$

So, the ideal motor is SNCECAM 60kg.

B. Elbow

From the design in Solid Works: M from the elbow joint to the tips of fingers =1.6 Kg, F.S = 1.15

L from elbow joint to the tips of fingers = 240 mm $\tau = F * d \sin\theta$

$\tau = \text{mg}*\frac{L}{2}\sin\theta + m\ load * L$ $\tau = 1.85 * 9.81 * \frac{240*10^{-3}}{2} \sin 90 + 0.5 * 240 * 9.81 * 10^{-3}$

$\tau = 3.4\ N.m \sim 34.6\ Kg.cm$ So, the ideal motor is Feetech SCS40TTL.

C. Wrist

From the design in Solid Works: M for the hand = 0.65 kg, F.S = 1.15

L from wrist joint to tips of fingers = 110mm $\tau = F * d \sin\theta$

$\tau = \text{mg}*\frac{L}{2}\sin\theta + m\ load * L$ $\tau = 0.65 * 9.8 * \frac{110*10^{-3}}{2} \sin 90 + 0.5 * 9.81 * 110 * 10^{-3}$

$\tau = 0.89\ N.m \sim 9.1 Kg.cm$ So, the ideal motor is Feetech STS3032.

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VI. KINEMATICS ANALYSIS

To achieve human-like behavior for the robotic arm. The human arm is simplified as a rigid kinematic chain connected by three basic joints (shoulder, elbow, and wrist) including 7 DOFS. The kinematic structure of the human arm model is simplified to 7 DOFS, where qi, i = 1, · · ·, 7 and dj, j = 1, 3, 5, 7 are represented in the corresponding Figure (4) (Online human-like redundancy optimization for tele-operated anthropomorphic manipulators). By establishing the table of Denavit-Hartenberg (D-H) parameters (J. A. Q. A.-U. R. M. S. M. K. N. Arshad, 2022), defined in Table 2, it is feasible to calculate the hand pose 0 T7 using forward kinematics function (S. Mazhuvan, 2020) through the joint's coordinates (θj, j = 1, 2, · · · 7) as follow:

$$T_7^0 = T_1^0\, T_2^0 \dots \dots . T_j^{j-1} \dots \dots\, T_7^6$$

where the transformation matrix j −1 T j from joint j − 1 to joint j is.

$$\begin{matrix} \cos\theta j & -\cos\alpha j \sin\theta j & \sin\alpha j \sin\theta j & 0 \\ \sin\theta j & \cos\alpha j \cos\theta j & -\sin\alpha j \cos\theta j & 0 \\ 0 & \sin\alpha & \cos\alpha j & 0 \\ 0 & 0 & 0 & 0 \end{matrix}$$

The joint angles (it, i = 1, 2, · ·, 7) can be obtained based on the geometry relation. Then, the swivel angle ψ will be calculated according to the vector relation between the reference plane and arm plane (H. Su)

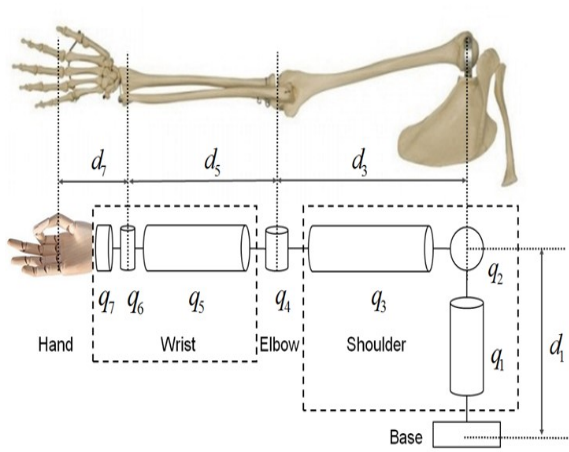

Figure 5 Electrical schematic for Arm

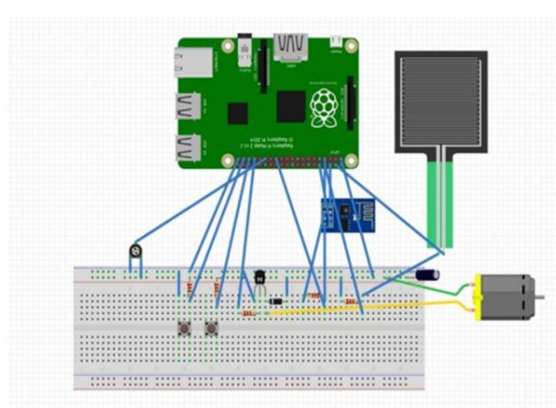

Figure 6 The kinematic structure of the human arm model.

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Table2 D-H parameters of the human arm model

Joint	θi	αi	di	ai
1	$\theta 1$	$-\pi/2$	d1	0
2	$\theta 2$	$-\pi/2$	0	0
3	$\theta 3$	$-\pi/2$	d3	0
4	$\theta 4$	$\pi/2$	0	0
5	$\theta 5$	$\pi/2$	d5	0
6	$\theta 6$	$\pi/2$	0	0
7	$\theta 7$	$\pi/2$	d6	0

VII. Anticipated Benefits

In this comprehensive hardware architecture, the system begins with EEG sensors interfaced with the ESP32 microcontroller, capturing EEG signals. The ESP32, equipped with wireless communication, sends data to the Raspberry Pi for preprocessing and machine learning model execution. The model predicts states or actions, used to calculate control angles for 12-DOF motors. The motor control signals are sent to a motor controller, concluding with the execution of motor commands. The physical architecture involves 3D-printed parts, motors, and flexible tendons for movement. Additive manufacturing is chosen for its cost-effectiveness and flexibility. The choice of Ender 3D printing is explained, comparing the advantages and disadvantages of casting.

The hardware components section as Figure (7) includes an EEG headset, dry active comp electrodes, a preamplifier, snap buttons, dry sensors, and housing for EEG data acquisition. The ESP32 microcontroller, Lithium-ion battery, and EBL 992 Smart Rapid Battery Charger handle power management. The system uses an Encore 802.11n Wireless Router for communication, and a Raspberry Pi 4 serves as the central processing unit. Motors include SNCECAM 60kg, GOUPRC 40KG, STS3032, and SCS40TTL, each with specified parameters. The hardware setup is complete with a power bank, pressure sensors, potentiometers, and a Mini Maestro 18-Channel USB Servo Controller.

Calculations for motor selection involve torque considerations based on the arm's mass distribution. The kinematic structure simplifies the arm to six joints, with Denavit-Hartenberg parameters outlined. Electrical schematics for the EEG helmet and robotic arm, electrode placements, and Fritzing designs illustrate the connections. The robotic arm's mechanical design is tailored to mimic human-like behavior, featuring 12-DOF, modular construction, and various sensing mechanisms.

The Ultra cortex EEG helmet's mechanical design prioritizes comfort and electrode accuracy. The robotic arm's mechanical design involves solid works, PLA 100% filament, and a variety of motors for different DOFs. Each motor's role and specifications, including SNCECAM 60kg, GOUPRC 40KG, STS3032, and SCS40TTL, are detailed. The hand's design includes feedback from pressure sensors and potentiometers. The anticipated benefits of this project are yet to be discussed, providing a thorough overview of the hardware design and components involved in this EEG-controlled robotic arm system.

VIII. Budget

Let us take a closer look at something important in our project: the budget. This section is all about money, including how much we have, where it is going, and the decisions we have made. We want to be clear about how we will use our funds to create a human arm controlled by an EEG helmet.

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We will divide the budget into several parts, such as purchasing EEG technology, developing the prosthetic arm, and incorporating machine learning. By the end of this section, you will have a clear understanding of where the money is going and why, knowing that this financial journey is an essential component of our innovative project defined in Table 3.

Table 3 budget classification

Components	Our price	Compared price	Saving Percentage
Helmet	5345 L.E = 178.15 $	1000$ = 30950 L. E	82%
Motors	18000 L.E = 600 $	6122 ¥ =30610 L. E	41%
Electrical component	14100 L.E = 470 $	------	

IX. Preliminary Result

The project focuses on creating a robotic arm controlled by an EEG headset, incorporating components like dry active comp electrodes, preamplifiers, snap buttons, and sensors. The system uses an ESP32 microcontroller, a lithium-ion battery, a battery charger, router, Raspberry Pi 4, and various motors. The arm's kinematic structure and electrical schematics are presented, while the mechanical design focuses on comfort and accurate electrode placement. The arm features 12 degrees of freedom and is made of PLA or aluminum. In this part, an overview of the achievements resulting from the integration of our EEG helmet and prosthetic arm is presented. Including visual representations, representing the outcomes of our project. The images within this section as Figures (7) and (8) depict the collaborative functionality of the helmet and arm, providing a visual narrative of our success. These visuals serve as snapshots, capturing the essence of our achievement and making it accessible for a comprehensive understanding of the impact our technology has brought.

Researchers have developed a system that combines signal processing and Artificial Intelligence (AI) to control a robotic arm using electroencephalography (EEG) data. The Brain-Computer Interface (BCI) allows users to control the robotic arm through their thoughts, making it particularly useful for physically disabled individuals. The proposed system is non-invasive and employs various AI-based classification algorithms, and regarding the simulation results for the design, will shown and explained in the next paper

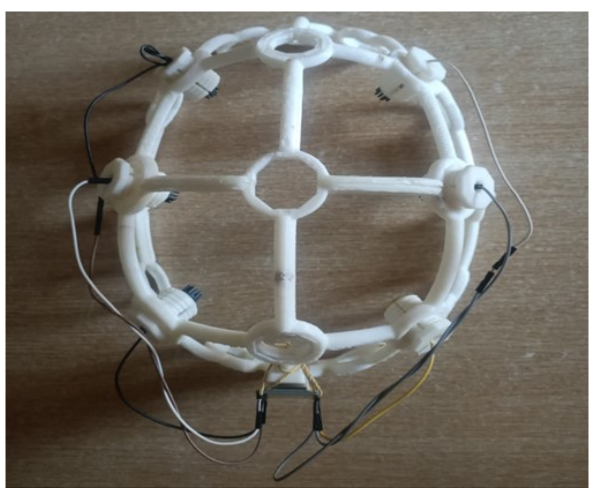

Figure 7 Helmet

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Figure 8 Arm

X. DISCUSSION

The project involves the development of a robotic arm controlled by an EEG headset, incorporating various components such as dry active comp electrodes, preamplifiers, snap buttons, dry sensors, and housing. The EEG signals are processed using an ESP32 microcontroller, powered by a lithium-ion battery. The system also includes a battery charger, a router for communication, a Raspberry Pi 4 for computing tasks, and various motors with specifications like SNCECAM 60kg, GOUPRC 40kg, Feetech STS3032, and Feetech SCS40TTL. And also, a detailed calculation for choosing the appropriate motors based on the design specifications, considering factors such as torque and payload. The kinematic structure of the robotic arm, with Denavit-Hartenberg parameters, is explained for achieving human-like behavior. The electrical schematic for the EEG helmet and the electrode locations using the 10-20 system are presented. The Fritzing designs illustrate the hardware connections for both the EEG system and the robotic arm. The mechanical design of the EEG helmet focuses on comfort, adjustability, and accurate electrode placement. The robotic arm, with 12 degrees of freedom, features modular design, feedback mechanisms, and realistic movements. Material selection involves a comparison between PLA and aluminum, considering factors like strength, recyclability, and environmental impact, where PLA is an eco-friendly, lightweight material used in 3D printing and disposable products, while aluminum is strong, durable, and widely used in construction, aerospace, and packaging. When it comes to cost, PLA is generally low-cost due to its biodegradable nature, whereas aluminum tends to be higher in cost due to energy-intensive extraction and refining processes. In terms of weight, both materials are lightweight, but aluminum offers significantly more strength. Overall, this provides a comprehensive overview of the project's electrical, mechanical, and material aspects, showcasing the integration of EEG technology with a sophisticated robotic arm.

XI. IMPROVEMENT AS PER REVIEWER COMMENTS

In this study, the authors presented an innovative approach to creating a low-cost, brain-controlled robotic arm aimed at enhancing the mobility and independence of individuals with limb loss or motor impairments. The research leveraged the integration of electroencephalography (EEG) signals, machine learning, and robotics to achieve naturalistic and precise control of a prosthetic limb. This interdisciplinary effort was commendable for its potential impact on the quality of life for users and its exploration of the fusion between neuroscience and robotics. The study effectively combined elements of neuroscience, robotics, and machine learning, providing a comprehensive solution to controlling prosthetic limbs using EEG signals. The emphasis on a budget-friendly design made this research highly relevant, particularly for applications in developing countries where cost is a significant barrier. The paper meticulously described the components and design of the robotic arm, including the selection of materials, degrees of freedom, and the integration of EEG technology, which added to the reproducibility and reliability of the study. The potential for real-world applications was clear, with the design aimed at replicating the natural movements of a human arm, which could significantly aid individuals with disabilities. The use of machine learning to adapt to individual brain signals over time is a significant strength, offering personalized and improved control of the robotic arm. The study showed great promise for improving the quality of life for individuals with limb impairments.

XII. CONCLUSION

This project aims to design a robotic arm using EEG signals to address motor function loss, which negatively impacts daily tasks. The project involves identifying the problem, analyzing the literature, and creating a workflow plan. The team members are divided into interests and talents, and constraints like time, budget, and implementation are considered. Environmental, ethical, social, and economic parameters are followed throughout the project. The arm is designed using CAD and 3D printing, with servo motors for correct angles and 12 DOF. The project demonstrates how mental commands can be used in robotic arm control. The integration of EEG signals with

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humanoid arms presents a promising area for future research. This interdisciplinary field combines neuroscience, robotics, and signal processing to improve human-machine interaction. Future work could focus on decoding finer motor movements, intention prediction, and sensory integration for better feedback, enhancing control and dexterity, and preventing collisions. To enhance the robot's capabilities further, several additional features and techniques can be considered as Improved Usability and Accessibility, Advanced Applications and Integration, Assembly for 12 Motors into Robotic Arm, Integration of Signal from ESP32 to Robotic Arm Motors through Raspberry Pi, Testing and Implementation of Machine Learning Technologies

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It is a pleasure for us to be given the opportunity to present this project report as we prepare to enter to demonstrate our understanding of a Brain-Controlled Robotic Arm System Using EEG Signals within the domain of Artificial Intelligence and Robotics. We would like to express our heartfelt gratitude and appreciation to our supervisors, Associated Prof/ Mohamed Ali Elsayed Torad and Eng/ Mohamed Samir Ahmed Mohamed, for their inspiration, invaluable guidance, and for imparting invaluable knowledge to us throughout our studies.

References

[1] L. S. Claudio Barbiellini Amide, "Epidemiology of traumatic spinal cord injury: a large population-based study," spinal cord, pp. 812-819, 8 August 2022.

[2] C. &. W.-M. S. &. W. M. &. H. J. &. K. D. McDonald, ""Global prevalence of traumatic non-fatal limb amputation. Prosthetics and Orthotics International.","," Publish Ahead of Print. , 2020.

[3] K.-H. a. K. Ji-Hoon and Shim, "Brain-Controlled Robotic Arm System Based on Multi-Directional CNN-BiLSTM Network Using EEG Signals," IEEE Transactions on Neural Systems and Rehabilitation Engineering, pp. 1226-1238, 2020.

[4] M. a. C. F. a. T. E. a. L. Nann, "Restoring Activities of Daily Living Using an EEG/EOG-Controlled Semiautonomous and Mobile Whole-Arm Exoskeleton in Chronic Stroke," IEEE Systems Journal, pp. 2314-2321, 2021.

[5] E. W. L. N. e. a. Buerkle A, "EEG based arm movement intention recognition towards enhanced safety in symbiotic Human-Robot Collaboration," Robotics and Computer-Integrated Manufacturing, vol. 70, 2021.

[6] C. L. D. G. e. al, "Robotic arm control system based on brain-muscle mixed signals," Biomedical Signal Processing and Control, vol. 77, 2022.

[7] B. S. S. E. e. a. Abiri R, "A comprehensive review of EEG-based brain-computer interface paradigms," Journal of Neural Engineering, vol. 16, no. 1, 2019.

[8] L. F. K. C. e. a. Leeb R, "Brain-computer communication: Motivation, aim, and impact of exploring a virtual apartment," IEEE Transactions on Neural Systems and Rehabilitation Engineering, vol. 15, no. 4, 2007.

[9] K. T. H. E. e. a. Kleih S, "Motivation and SMR-BCI: Fear of Failure Affects BCI Performance," Proceedings of the Fifth International Brain-Computer Interface Meeting, 2013.

[10] C. G. Petoku E, "Object Movement Motor Imagery for EEG-based BCI System using Convolutional Neural Networks," 9th IEEE International Winter Conference on Brain-Computer Interface, BCI 2021, 2021.

[11] M. S. M. P. e. al, "Mick SLapeyre MRouanet P et al," Frontiers in Neurorobotics, vol. 13, 2019.

[12] M. S. Delorme A, "EEGLAB: An open source toolbox for analysis of single-trial EEG dynamics including independent component analysis," Journal of Neuroscience Methods, vol. 134, no. 1, 2004.

[13] M. A. Torad and Salam, Mustafa Abdul , "Smart helmet using internet of things," International Journal of Reconfigurable and Embedded Systems, vol. 10, no. 2, pp. 90-98, 2021.

[14] "Dry sensors for SmartBCI wireless EEG," mitsar-eeg, [Online]. Available: https://mitsar-eeg.com/2020/11/05/smartbci_dry_sensors/.

[15] J. Rahardjo et al., "Combination of Hardware and Microservices-based VR Game Controller using Mahony Filter,," " 2020 International Seminar on Application for Technology of Information and Communication (iSemantic), Semarang, Indonesia , pp. 614-619, 2020.

Print ISSN 2682-3993

Online ISSN 2682-4000

[16] M. M. H. A. H. Y. Y. a. P. J. K. M. A. Hannan, "State-of-the-Art and Energy Management System of Lithium-Ion Batteries in Electric Vehicle Applications," Issues and Recommendations," in IEEE Access,, vol. 6, p. 19362, 2018.

[17] F. V. a. F. S. P. Pérez, " "A Compact Lithium-Ion Battery Charger for Low-Power Applications,"," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 69, no. 3, pp. 669-673, March 2022.

[18] S. -Z. G. W. B. J. -Y. Q. H. W. a. Z. -S. P. in S. -M. Xia, " "A New Smart Router-Throttling Method to Mitigate DDoS Attacks,"," in IEEE Access, , vol. 7, pp. 107952-107963, 2019.

[19] B. B. A. A. Torad M, "A voice controlled smart home automation system using artificial intelligent and internet of things," Telkomnika (Telecommunication Computing Electronics and control , vol. 20, no. 4, pp. 808-816, 2022.

[20] I. K. A. R. a. J. V. M. M. Krpan, " "Modelling of Supercapacitor Banks for Power System Dynamics Studies,"," in IEEE Transactions on Power Systems, vol. 36, no. 5, pp. 3987-3996, Sept.2021.

[21] B. -A. C. Y. -H. L. Y. -J. L. a. J. -C. W. H. -H. Tai, " "Submillimeter-Scaled PEDOT:PSS/PPy Piezoresistive Pressure Sensor Array and Its Applications in Biomedicine,"," in IEEE Sensors Journal, vol. 22, no. 7, pp. 6418-6425, April1, 2022.

[22] C. L. X. F. a. X. J. C. Sun, "Visual Servoing of Flying Robot Based on Fuzzy Adaptive Linear Active Disturbance Rejection Control," in IEEE Transactions on Circuits and Systems II: Express Briefs, vol. 68, no. 7, pp. 2558-2562, July 2021.

[23] "Online human-like redundancy optimization for tele-operated anthropomorphic manipulators," Scientific Figure on ResearchGate. , [Online]. Available: https://www.researchgate.net/figure/Human-arm-model-q-1-q-2-q-3-q-4-q-5-q-6-q-7-represent-joint-degrees-and-d-1_f1_fig2_329394052. [Accessed 22 may 2024].

[24] ". C. o. R. A. U. B. C. I. a. A. I. A. s. 2. J. A. Q. A.-U. R. M. S. M. K. N. Arshad, "J. A. Q. A.-U. R. M. S. M. K. N. Arshad, "Intelligent Control of Robotic Arm Using Brain Computer Interface and Artificial Intelligence,"," Apllied sciences, , 2022.

[25] S. Mazhuvan, "Brain Controlled Robotic Arm for Disabled People Based On Electroencephalography Technology,," Brain and Cognitive Development., 2020.

[26] N. E. L. V. A. S. G. F. a. E. D. M. H. Su, "] H. Su, N. Enayati, L.Online human-like redundancy optimization for tele- operated anthropomorphic manipulators," International Journal of Ad- vanced Robotic Systems,, vol. 15, no. 6.