MYOELECTRIC TRANSRADIAL PROSTHETIC ARM FOR UPPER LIMB DISARTICULATION TO SUPPORT DISABLED REHABILITATION

Project Reference No.: *47S_BE_3819*

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1. Introduction

A prosthetic arm is an artificial device that is designed to replace a missing or damaged arm. It is typically made of lightweight materials such as plastic or carbon fibre, and it may be operated by electronic, mechanical, or myoelectric means.

Prosthetic arms can come in many different shapes and sizes, depending on the needs of the user. Some models are designed to mimic the natural movements of the human arm, while others are more basic and intended for simple tasks.

A prosthetic arm is a highly engineered and customized artificial limb designed to replace a missing or amputated upper limb, typically from the shoulder down to the hand or wrist. These remarkable devices have been developed to assist individuals who have lost their arms due to various reasons, including congenital conditions, traumatic injuries, or medical amputations. Prosthetic arms are designed not only to restore physical functionality but also to improve the quality of life, mobility, and independence for individuals with limb loss.

1.1 Need for Prosthetic Arm

There are many reasons why a person might need a prosthetic arm. Some people are born without an arm, while others may lose one or both arms due to an accident, injury, or illness.

Prosthetic arms can greatly improve a person's quality of life by restoring their ability to perform daily tasks, such as reaching, grasping, and holding objects. With the help of a prosthetic arm, individuals can regain their independence, participate in activities they enjoy, and feel more confident in their daily interactions with others.

Prosthetic arms can also help prevent or reduce secondary health complications that may arise from having a missing limb, such as back pain or joint problems.

With advancements in technology, prosthetic arms have become more advanced, more comfortable, and more natural-looking than ever before. They can be customized to fit the individual needs and preferences of the user, and can be a great tool for improving their overall quality of life.

1.2 Amputation Types

The type of amputation that is necessary will depend on the individual's medical condition, the extent of the injury or illness, and the goals of treatment. Rehabilitation and prosthetic options may also vary depending on the specific type of amputation.

1. **Above-knee amputation:** This involves the removal of the entire leg above the knee joint.
2. **Below-knee amputation:** This involves the removal of the leg below the knee joint.
3. **Hemipelvectomy:** This involves the removal of the entire leg and a portion of the pelvic bone.
4. **Above-elbow amputation:** This involves the removal of the entire arm above the elbow joint.
5. **Below-elbow amputation**: This involves the removal of the arm below the elbow joint.
6. **Wrist disarticulation**: This involves the removal of the hand at the wrist joint.
7. **Finger or partial hand amputation:** This involves the removal of one or more fingers or a portion of the hand.

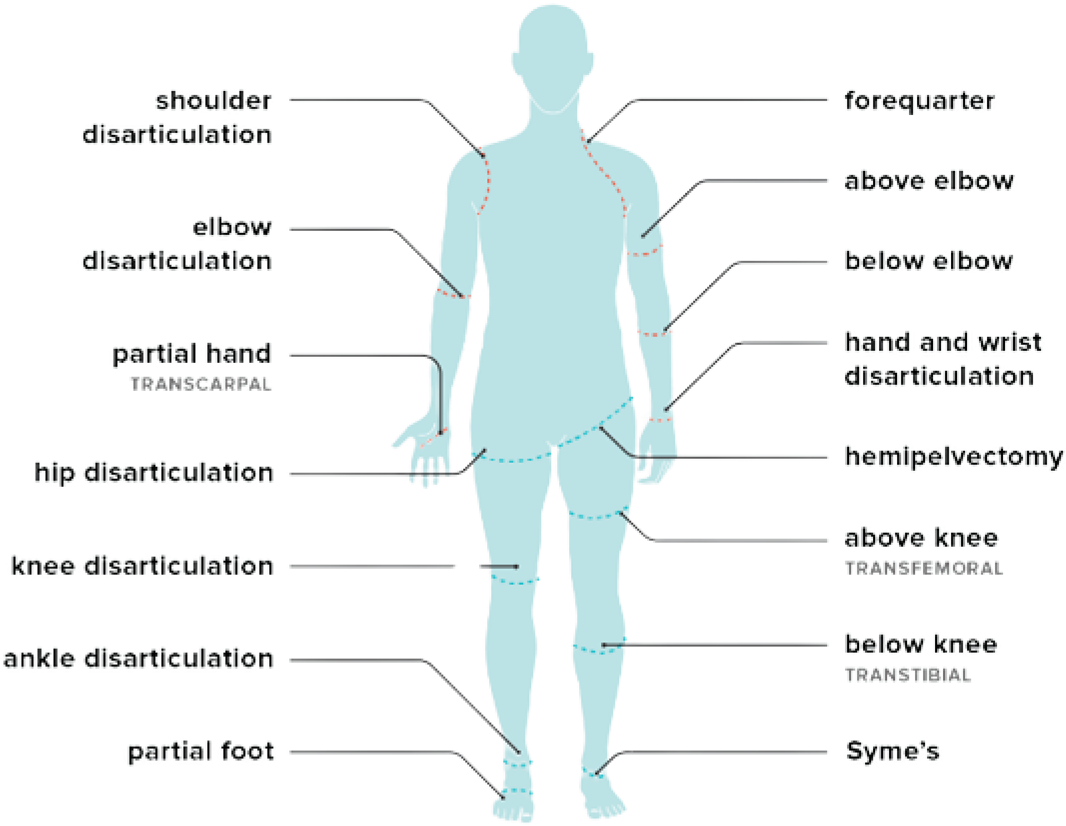


Fig 1: Amputation Types

1.3 Causes of Amputation

The reason for the amputation will determine the level and type of amputation required. It's important to work with healthcare providers and rehabilitation specialists to ensure that the amputation and subsequent treatment plan are best for individual needs.

1. **Traumatic injury:** A limb may need to be amputated as a result of a traumatic injury, such as a car accident or severe burn.
2. **Circulatory problems:** Circulatory problems like peripheral artery disease, which narrows or blocks blood vessels, can lead to tissue death and gangrene. This can result in the need for amputation.
3. **Infection:** An infection that is not responsive to antibiotics can spread and cause tissue death, often leading to the need for amputation.
4. **Tumors:** Cancerous tumors can develop in the bone or soft tissue of a limb. If the tumor cannot be surgically removed, amputation may be necessary.

5. **Congenital defects:** In some cases, a person may be born with a congenital defect that affects the development of their limbs. In these cases, amputation may be necessary to improve the person's ability to function.

1.4 Statistics of Amputation

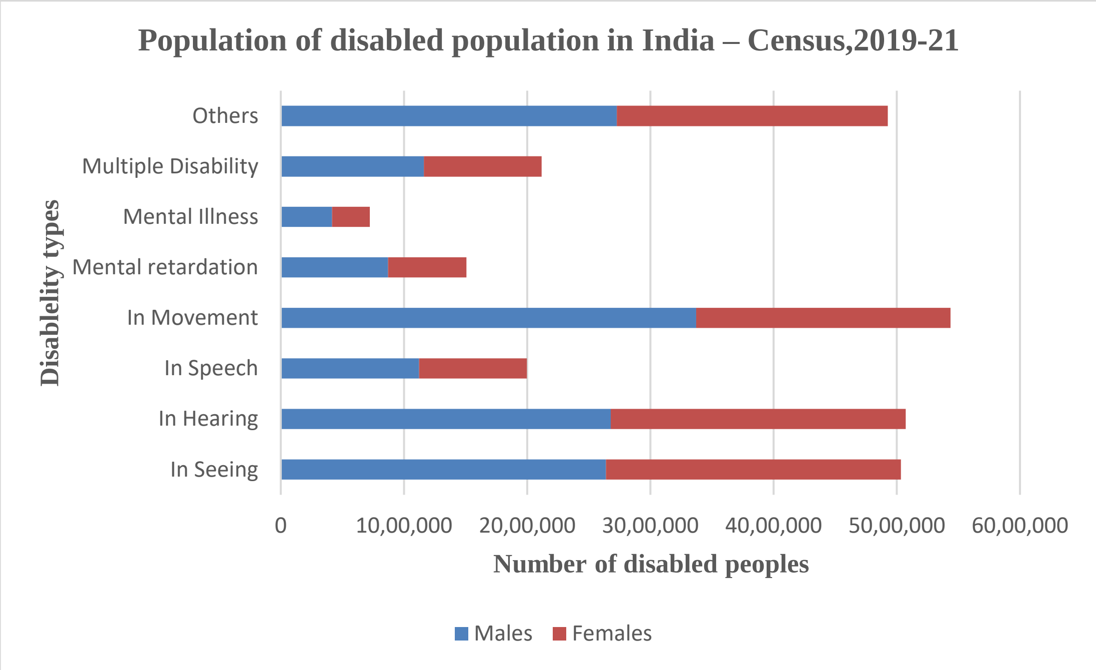
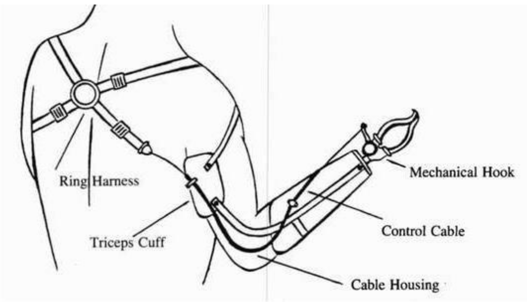


Fig 2: Population of disabled population in India – Census,2019-21

2. Types of Prosthetic Arm

There are many different types of prosthetic arms available on the market today. The type of prosthetic arm that is right for you will depend on your individual needs and preferences. Some of the most common types of prosthetic arms include:

1. **Body-powered prosthetic arm**: This type of prosthetic arm is powered by cables or harnesses that are attached to the user's body.
2. **Hybrid prosthetic arm**: This type of prosthetic arm combines both body-powered and electric components.
3. **Myoelectric prosthetic arm**: This type of prosthetic arm is powered by the electrical signals that are produced by the user's muscles.
4. **3D-printed prosthetic arm**: This type of prosthetic arm is made using 3D printing technology. It is often less expensive than traditional prosthetic arms.



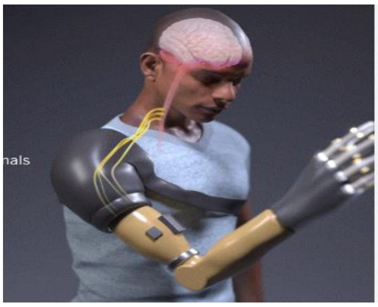


Fig 3: Body-powered prosthetic arm **Fig 4: Hybrid prosthetic arm**

Fig 5: Myoelectric prosthetic arm

Fig 6: 3D-printed prosthetic arm

2.1 Cost and Barriers of Prosthetic arm

1. The cost of a prosthetic arm can vary depending on many factors, including the type of prosthetic arm, the manufacturer, and the complexity of the design. Prosthetic arms can be expensive and may not be fully covered by insurance, which can create a barrier for some people to access prosthetic technology.
2. In addition to cost, there can be other barriers to accessing prosthetic arms. For example, some people may live in areas where medical resources are limited or may not have access to rehabilitation services that can help them learn to use their prosthetic arm effectively.

3. However, there are programs and initiatives that aim to reduce these barriers and improve access to prosthetic technology. For example, some insurance providers may cover some or all of the cost of a prosthetic arm, and there are non-profit organizations that provide financial assistance to those in need.

Sl. No.	Commercial	Cost	Figure
1	Sensorhand (Ottobock) (model: 8E39=8)	$20,000 to $30,000 US	
2	I-limb Ultra Revolution (Touch Bionics) (model: 000311A)	$45,000 to $50,000 US	
3	Bebionic (RSL Steeper) (model: Myo Kinisi)	$30,000 to $40,000 US	
4	Ottobock India	15,00,000₹ to 20,00,000₹	
5	Artificial Limbs Manufacturing Corporation of India (ALIMCO)	40,000₹ Body-powered	

Table i**: Cost of Prosthetic arm**

2.2 Market Models of prosthetic arm

Sl. No.	Commercial	Weight (*grams*)	DoF	Actuators	Grip Force(N) [*Pinch,Power*]	Grasp Speed
1	Sensorhand (Ottobock)	350-500	1	1	[-,100]	30mm/s at tip
2	I-limb Ultra Revolution (Touch Bionics)	504	6	5	[6.54, 136]	1.2 sec
3	Bebionic(RSL Steeper)	495-539	6	5	[12.47,77]	1.9 sec

4	Michelangelo (OttoBock)	420	2	2	[-, 80]	-
5	Remedi	400	6	6	[-, 9.2]	-
6	MANUS Hand	1200	3	2	[-,60]	2.5 sec
7	Smart Hand	520	16	4	[-,18]	1.4 sec
8	Fluid Hand III	400	8	1	[-,45]	1 sec
9	SoftHand Pro	520	2	2	[20,40]	1.5 sec

Table ii : Market Models of prosthetic arm

2.3 Machine learning techniques

Machine learning techniques are a subset of artificial intelligence (AI) that enable computers to learn and make predictions or decisions based on data without being explicitly programmed. These techniques have found applications in a wide range of fields, including computer vision, natural language processing, healthcare, finance, and more. Here are some of the fundamental machine learning techniques:

- **Supervised Learning:** The algorithm learns to predict a continuous numerical output based on input data. Linear regression and decision trees are common algorithms for regression tasks.
- **Unsupervised Learning:** These techniques aim to reduce the number of features or dimensions in a dataset while preserving its essential characteristics. Principal Component Analysis (PCA) and t-Distributed Stochastic Neighbour Embedding (t-SNE) are commonly used for dimensionality reduction.
- **Semi-Supervised Learning:** This combines elements of both supervised and unsupervised learning, where the model is trained on a combination of labelled and unlabelled data.
- **Natural Language Processing (NLP):** NLP techniques involve the use of machine learning to understand, analyse, and generate human language. This includes tasks like text classification, sentiment analysis, machine translation, and chatbots.

- **Reinforcement Learning:** In reinforcement learning, an agent learns to make decisions by interacting with an environment. The agent receives feedback in the form of rewards or penalties and adjusts its actions accordingly. Algorithms like Q-Learning and Deep Q Networks (DQN) are used in reinforcement learning.
- **Deep Learning:** Deep learning is a subset of machine learning that focuses on neural networks with multiple layers (deep neural networks). Convolutional Neural Networks (CNNs) are used for image-related tasks, Recurrent Neural Networks (RNNs) for sequential data, and Transformers for natural language processing.

2.4 Need to measure muscle contraction

Measuring muscle contractions for controlling a hand prosthesis is a fundamental requirement to create a natural and intuitive interface between the user and the prosthetic device. One of the most common methods for achieving this is through the use of Electromyography (EMG), which measures electrical activity in muscles. Here's a step-by-step process on how to use EMG for controlling a hand prosthesis:

- **Signal Acquisition:** The EMG signals are weak, so they need to be amplified to be usable. An EMG amplifier is used to boost the signals.
- **Data Processing:** Extract relevant features from the EMG signals. Common features include root mean square (RMS), mean absolute value (MAV), and waveform shape descriptors. These features help characterize muscle contractions.
- **Calibration:** Each user may have different EMG patterns, so it's essential to calibrate the system individually for each user. During the calibration process, the user performs specific muscle contractions, and the system associates these contractions with desired prosthetic hand movements or grips.
- **Prosthesis Control:** Connect the EMG control system to the hand prosthesis. The decoded EMG signals are used to control the movements of the prosthesis. Ensure that the system provides real-time control of the prosthesis, allowing the user to make quick and precise movements.

- **Feedback and User Training:** Provide sensory feedback to the user to help them understand and control the prosthesis better. This can include visual feedback on a display, auditory cues, or vibrotactile feedback on the skin.
- **Safety and Reliability:** Implement safety measures to ensure that the prosthesis responds appropriately and doesn't cause harm to the user. Ensure that the EMG-based control system is reliable and robust, especially in various environmental conditions and during extended use.

2.5 Problem Definition

Our team visited to Artificial limb centre, JSS hospital, Mysore to conduct field survey on 14th April 2023. The team meets the Doctor and the technical Staff to know about the amputees, disability and Prosthetic arm. There, we know about problems faced by the public to adopt prosthetic arm. The problem faced are as below;

- Cost of the myoelectric prosthetic arm which is around 15lacks to 16lacks.
- In India, for 3 or 2 finger controllable myoelectric prosthetic arm cost around 2 to 3 lacks.
- Amputees need to give there another arm length measurement to manufacture the prosthetic arm, during this process they faces difficulty.
- The weight of the material used in the manufacture of prosthetic arm is high which is around 1 to 2kg,
- Due to high cost of myoelectric prosthetic arm, amputees are going to adopt passive prosthetic arm which cost around 50,000₹,
- Our Mini project is based on Voice controlled prosthetic arm, but its efficiency is based on the noise in the environment. So, now we are making a project on EMG controlled prosthetic arm which improves the efficiency even in noisy environment.

Fig 7: Field survey

2 Literature Survey

[1] Aayushi Khajuria, "Cortical correlates of voluntary postural sway with vibrotactile feedback in transfemoral amputees", Journal: IEEE, Vol.1, Published: 2023.

<u>Inference:</u>

- From this Paper We Learn, Below-knee amputation and there Loss of somatosensory feedback after amputation inflicts a serious challenge for amputees to achieve postural stability.
- Helps to develop yield light weight and compact designs.

[2] Amit Hasan Khan, Fairoz Nower Khan, Lamiah Israt, Md. Saiful Islam, "Thumb Controlled Low-Cost Prosthetic Robotic Arm" Journal: **IEEE, Vol. 1, Published: 2019.**

<u>Inference:</u>

- From this Paper We Learn; a low-cost robotic arm has been proposed which is affordable to above or below elbow amputees.
- Using servo motors, Arduino UNO, end effector etc. to construct the proposed system can enable a person to move, grasp and replace objects that are heavy or require both hands to carry.

[3] Tomasz Kocejko, Radosław Weglerski, Tomasz Zubowicz, Jacek Ruminski, Jerzy Wtorek, Krzysztof Arminski "Design aspects of a low-cost prosthetic arm for people with severe movement disabilities", Journal: IEEE, Vol. 4, Published: 2020.

<u>Inference:</u>

- From this Paper We Learn; the mechanical parts of the designed arm were 3D printed
- the designed prosthetic arm is a part of the hybrid interface with eye tracking movement control.
- Final product is able to freely move an object of a total weight of 1kg.

[4] Taro Shibanoki, Kosuke Jin "A 3D-printable Prosthetic Hand Based on a Dual-arm Operation Assistance Model", Journal: IEEE, Vol. 5, Published: 2021.

Inference:

- From this Paper We Learn; this paper proposes a 3D-printable myoelectric prosthetic hand to enable stable prosthetic control in a series of dual-arm operations.
- The proposed prosthesis involves a state transition model of dual-arm tasks in daily livings.

[5] Luis Vargas, Helen Huang, Yong Zhu, and Xiaogang Hu “Stiffness Perception using Transcutaneous Electrical Stimulation during Active and Passive Prosthetic Control”, Journal: IEEE, Vol. 3, Published: 2020.

Inference:

- From this Paper We Learn about, Haptic feedback which allows an individual to identify various object properties.
- In this preliminary study, paper determines that performance of stiffness recognition using transcutaneous nerve stimulation when a prosthetic hand was moved passively or was controlled actively by the subjects.

[6] Yuma Yamanaka and Masahiro Yoshikawa “A Prosthetic Gripper with Three Opposing Fingers Driven by a Hydraulic Actuator”, Journal: IEEE, Vol. 7, Published: 2020.

Inference:

- From this Paper We Learn, prosthetic gripper with three opposing fingers driven by a hydraulic actuator without electrical components.
- The three fingers are controlled simultaneously by pushing the lever of an operating interface mounted on the user’s upper arm on the affected side.

[7] H. Kareemullaha, D. Najumnissaa, M.S. Murshitha Shajahana, M. Abhineshjayramb, Varshan Mohanc, S. Ayisha Sheerin “Robotic Arm controlled using IoT application”, Journal: Elsevier, Vol. 20, Published: 2022.

Inference:

- From this Paper We Learn about, design and develop a remotely controlled robotic arm that can be used in applications where the engaging human hazardous environment.

- It is proposed to design a 3DOF (degrees of freedom) robotic arm with stepper motor which is controlled through Wi-Fi using the BlynkIoT App with widgets like Joystick and Sliders.

[8] Revanth Damerla, Kevin Rice, Daniel Rubio-Ejchel, Maurice Miro, Enrico Braucher, Juliet Foote, Issam Bourai, Aaryan Singhal, Kang Yang, Hongju Guang, Vasil Iakimovitch, Evelyn Sorgenfrei, Shorya Awtar "Design and Testing of a Novel, High-Performance Two DoF Prosthetic Wrist", Journal: IEEE, Vol. 10, Published: 2020

Inference:

- From this Paper We Learn, design of a novel two Degree of Freedom parallel kinematic prosthetic wrist that incorporates this actuator-transmission combination.
- This first iteration of the proposed prosthetic wrist meets the target torque, speed, and weight but does not meet the target dimensions or range of motion.

[9] Vera G. M. Kooiman, Eline S. van Staveren, Ruud A. Leijendekkers, Jaap H. Buurke, Nico Verdonschot, Erik C. Prinsen and Vivian Weerdesteyn "Testing and evaluation of lower limb prosthesis prototypes in people with a transfemoral amputation: a scoping review on research protocols", Journal: Neuro Engineering and Rehabilitation, Vol. 1, **Published: 2023.**

Inference:

- From this Paper We Learn about, development or testing prosthesis prototype testing and reporting calls for the development of a core set of reported participant characteristics, testing protocols, and specifc and well-founded outcome measures, tailored to the various aims and development phases.
- The use of such a core set can give greater insights into progress.

[10] Junho Park, and Maryam Zahabi "Cognitive Workload Assessment of Prosthetic Devices: A Review of Literature and Meta-Analysis", Journal: **IEEE, Vol. 10, Published: 2020**

Inference:

- Evaluate the effectiveness of a training strategy for reducing cognitive workload (CW) and improving device usability, both task performance and subjective measures should be considered.
- Based on the literature review, a set of guidelines was provided to improve the usability of future prosthetic devices and reduce CW.

3. Project Objectives

Objective 1: To Develop a 3D Printed Myoelectric Prosthetic Arm to Control Hand Movements.

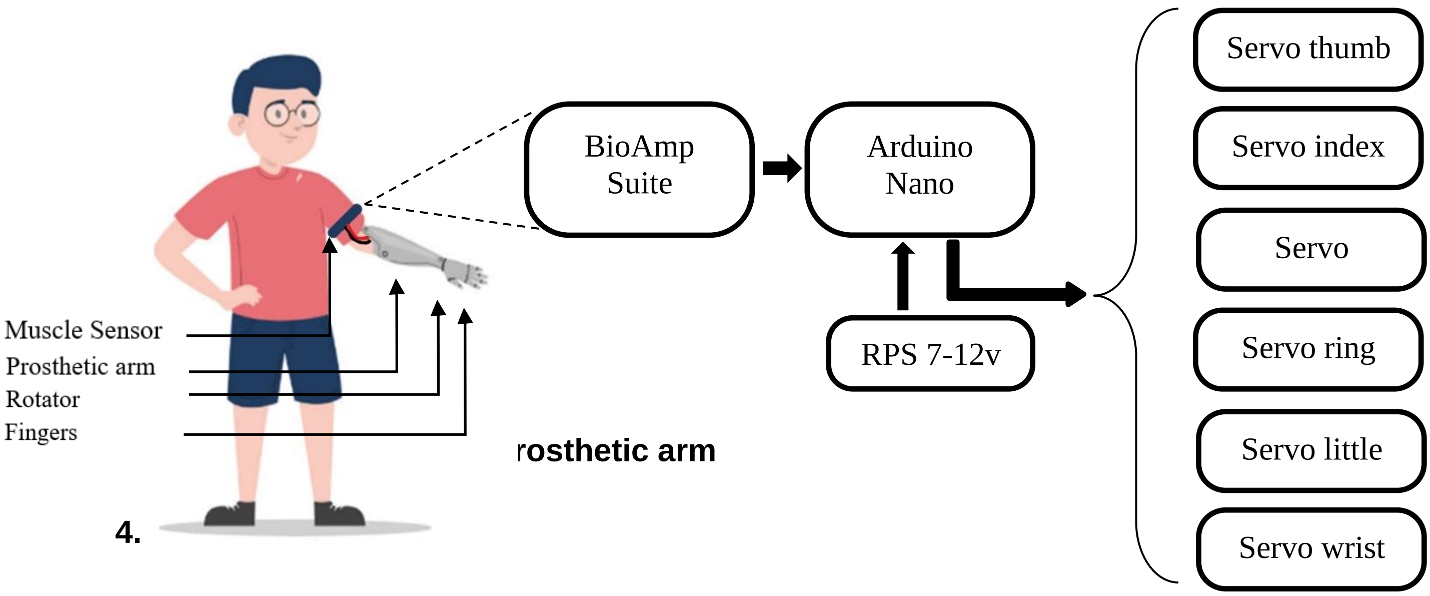
This is achieved by utilising myoelectric sensor (muscle sensor), arduino microcontroller and servo motors to control hand movements.

And also, to deploy a deep neural network on the micro-controller for real-time bionic arm control. Where it uses a 2D Convolutional Neural Network (CNN) as EMG pattern recognition algorithm.

Objective 2: To Develop a Console Application to Measure the arm dimensions.

This is achieved by using PyCharm and python applications with CVzone interpreter.

4. Methodology



The controlling of prosthetic arm is based on Electromyography sensor module, which is controlled by another hand by wearing the band.

Step1: Electromyography sensor will detect the moment of the muscle and produce the value of resistance depending on the EMG signal received on the sensor.

Step2: This produced signal will feed to the micro-controller which transfer the value to the receiver using transmitter.

Step3: The signal from the receiver is feed to another micro-controller which is controlling prosthetic arm, the controller will convert the received value to the pules for angle of rotation of servo motor.

Step4: The servo motor will rotate at angle of 90º and these servo motors are connected to the fingers of prosthetic arm using the fishing wires.

5. Applications & Advantages

7.1 Advantages

There are several advantages of 3D prosthetic arms, including:

1. **Customizability:** 3D printing technology allows prosthetic arms to be customized to fit the unique needs and preferences of the wearer.
2. **Affordability:** Traditional prosthetic arms can be expensive, but 3D printing technology has made it possible to produce prosthetics at a lower cost.
3. **Speed:** 3D printing technology enables the production of prosthetic arms at a much faster rate than traditional manufacturing methods, which means that patients can receive their new arms more quickly.
4. **Lightweight:** 3D printed prosthetic arms are often much lighter than traditional prosthetics, which can make them more comfortable to wear and easier to maneuverer.
5. **Versatility:** 3D printing allows prosthetic arms to be designed for a wide range of activities, including sports, playing musical instruments, and even swimming.

7.2 Application

Here are some of the applications of a 3D prosthetic arm:

1. **Greater mobility and independence:** With a 3D prosthetic arm, individuals can perform daily tasks that they may have previously been unable to do due to their impairment.
2. **Cost-effective:** 3D printing technology has enabled the production of prosthetics at significantly lower costs as compared to traditional manufacturing methods.
3. **Customization**: 3D printing technology allows for the production of prosthetics customized to fit the unique needs and preferences of each individual.
4. **Improved aesthetics:** 3D printed prosthetics can be designed to match the individual's skin tone, making the prosthetic look more natural and aesthetically pleasing.
5. **Enhanced functionality:** 3D printed prosthetics can be designed to have additional features such as sensors and motors which can help individuals to perform more advanced tasks.

8. Budget Proposal

Sl. No.	**Description**	**Cost**
1	Hardware Components and circuits	10,000.00
2	3D printing	3,500.00
3	Project Report	3,000.00
4	Miscellaneous	2,000.00
Total		**18,500.00**

Table iii : budget proposal

9. Implementation Schedule

Sl. No.	PHASES 1	SEP 2023	OCT 2023	NOV 2023	DEC 2023
1	Project Feasibility Study				
2	Time schedule and analysis				
3	Requirement analysis				
4	Component Availability and Purchase				
5	Design & Implementation of Prosthetic arm				
6	Testing of Prosthetic arm				
7	Final Testing and Analysis				
8	Report Documentation				

Table iv : Implementation schedule

Our project will be completed on or before 20th December 2023 as per the above time implementation schedule.

Reference:

[1] Aayushi Khajuria "Cortical correlates of voluntary postural sway with vibrotactile feedback in transfemoral amputees", Journal: IEEE, Published: 2023.

[2] Amit Hasan Khan, Fairoz Nower Khan, Lamiah Israt, Md. Saiful Islam "Thumb Controlled Low-Cost Prosthetic Robotic Arm" Journal: IEEE, Vol.1, Published: 2019.

[3] Tomasz Kocejko, Radosław Weglerski, Tomasz Zubowicz, Jacek Ruminski, Jerzy Wtorek, Krzysztof Arminski, "Design aspects of a low-cost prosthetic arm for people with severe movement disabilities", Journal: IEEE, Vol.4, Published: 2020.

[4] Taro Shibanoki, Kosuke Jin "A 3D-printable Prosthetic Hand Based on a Dual-arm Operation Assistance Model", Journal: IEEE, Vol.5, Published: 2021.

[5] Luis Vargas, Helen Huang, Yong Zhu, and Xiaogang Hu “Stiffness Perception using Transcutaneous Electrical Stimulation during Active and Passive Prosthetic Control”, Journal: IEEE, Vol.3, Published: 2020.

[6] Yuma Yamanaka and Masahiro Yoshikawa “A Prosthetic Gripper with Three Opposing Fingers Driven by a Hydraulic Actuator”, Journal: IEEE, Vol.7, Published: 2020.

[7] H. Kareemullaha, D. Najumnissaa, M.S. Murshitha Shajahana, M. Abhineshjayramb, Varshan Mohanc, S. Ayisha Sheerin “Robotic Arm controlled using IoT application”, Journal: Elsevier, Vol.20, Published: 2022.

[8] Revanth Damerla, Kevin Rice, Daniel Rubio-Ejchel, Maurice Miro, Enrico Braucher, Juliet Foote, Issam Bourai, Aaryan Singhal, Kang Yang, Hongju Guang, Vasil Iakimovitch, Evelyn Sorgenfrei, Shorya Awtar “Design and Testing of a Novel, High-Performance Two DoF Prosthetic Wrist”, Journal: IEEE, Vol.10, Published: 2020.

[9] Vera G. M. Kooiman, Eline S. van Staveren, Ruud A. Leijendekkers, Jaap H. Buurke, Nico Verdonschot, Erik C. Prinsen and Vivian Weerdesteyn “Testing and evaluation of lower limb prosthesis prototypes in people with a transfemoral amputation: a scoping review on research protocols”, Journal: Neuro Engineering and Rehabilitation, Vol.1, Published: 2023.

[10] Junho Park, and Maryam Zahabi “Cognitive Workload Assessment of Prosthetic Devices: A Review of Literature and Meta-Analysis”, Journal: IEEE, Vol.10, Published: 2020.