Myoelectric Prosthetic Arm

Ms. Riya Rajusing Thakur[1], Mrs. Vandana Malode[2], Mr. Atharva Garajkar[3], Mr. Lokesh Bhavsar[4]
[1,2.3,4] *Student, ETC Dept, MGM Jawaharlal Nehru Engineering College Aurangabad,India*

***Abstract*—Our project addresses the high cost of traditional myoelectric prosthetics by developing an affordable, 3D-printed prosthetic arm using readily available EMG sensors, the cost effectiveness can be seen regarding the cost of Material, Sensor and the Shipping cost, this innovative approach significantly reduces manufacturing costs and allows for custom-fitted, user-friendly prosthetics tailored to individual needs. By democratizing access to advanced prosthetic technology, we aim to enhance the independence and quality of life for individuals with upper limb loss, particularly in low-income regions. Our open-source design fosters global collaboration, setting a new standard in affordable assistive technologies and inspiring further advancements in the field.**

***Index Terms*—EMG Sensor, 3D print, Prosthetic arm, Cost effective**

I. INTRODUCTION

The loss of an upper limb significantly impacts an individual's daily life and quality of living. Myoelectric prosthetics, controlled by electrical signals from residual limb muscles, offer advanced solutions by enabling natural and intuitive movements. However, their high cost remains a major barrier, particularly in developing countries and among socioeconomically disadvantaged populations.

Myoelectric prosthetic arms utilize electrical signals from muscle contractions to control device movements, allowing for a range of functions from basic grasping to complex manipulations. These prostheses offer several advantages over body-powered devices, including reduced need for harnessing, effortless strength, multiple grip patterns, and more intuitive control, enhancing user satisfaction and functionality. Despite these benefits, high costs limit their widespread adoption.

Recent technological advancements have paved the way for cost reduction in myoelectric prosthetics. The use of 3D printing enables rapid, cost-effective production of customized parts, reducing manufacturing costs and production times. Additionally, affordable electromyography (EMG) sensors maintain high-end functionality while significantly lowering overall costs. Integrating 3D printing and affordable EMG sensors in myoelectric prosthetics development is a significant step towards making these devices more accessible.

II. LITERATURE SURVEY

The high cost of traditional myoelectric prosthetic arms is a significant barrier for many amputees, particularly in developing countries and for individuals with limited financial resources. This survey explores the growing field of low-cost myoelectric prosthetic arms, aimed at providing affordable and functional options for this underserved population.

Myoelectric prosthetics, capable of translating muscle signals into controlled movements, offer a transformative solution for individuals with limb loss. However, the widespread adoption of these devices is hindered by several factors, including cost, functionality, and user acceptance. This literature review examines key challenges and opportunities in the field, focusing on pattern recognition, EMG signal processing, sensory feedback, degrees of freedom, cosmesis, and cost-effectiveness.

A. Pattern Recognition and EMG Signal Processing

Traditional pattern recognition methods in myoelectric prosthetics primarily map muscle signals to specific movements. While effective for basic tasks, these approaches often fall short in providing intuitive and versatile control. Recent advancements in EMG signal processing, incorporating machine learning and artificial intelligence, have shown promise in extracting more nuanced information from muscle signals. This enables more sophisticated pattern recognition algorithms, potentially leading to improved control and functionality.

B. Sensory Feedback and Degrees of Freedom

The absence of sensory feedback is a significant limitation of current myoelectric prosthetics, hindering object manipulation and interaction with the environment. While progress has been made in developing tactile sensors, integrating them seamlessly into prosthetic devices remains a challenge. Additionally, existing prosthetics often exhibit restricted degrees of freedom, limiting their usability in daily activities. Modern myoelectric arms are striving to address these limitations by incorporating multiple joints, individual finger control, and wrist rotation, offering greater dexterity and functionality.

C. Cosmesis, User Acceptance, and Cost

The appearance of a prosthetic is crucial for user acceptance and psychological well-being. Traditional prosthetics often have an artificial look, impacting users' confidence. Advances in materials science and design have led to the development of more natural-looking and lightweight prostheses. However, achieving a truly lifelike appearance remains an ongoing challenge.

Cost is another critical barrier to widespread adoption of myoelectric prosthetics. High prices limit access for many amputees. Efforts to reduce costs through material selection, manufacturing processes, and accessible component sourcing are essential to increase affordability and expand the user base.

III. METHODOLOGY

The methodology includes the overall tasks performed for the design and development of the proposed system. The methodology is further divided into Design and Workflow.

A. Design

The conceptual design for a low-cost myoelectric prosthetic arm aims to integrate advanced functionality, user-friendly features, and an aesthetically pleasing design while maintaining affordability. Here is an overview of the key components and features:

1. Customizable 3D-Printed Components: The prosthetic arm's main structure and components are designed to be customizable and easily 3D- printed. This allows for personalized fitting to the user's residual limb and ensures comfort and functionality.
2. EMG Sensor Integration: The prosthetic arm incorporates electromyography (EMG) sensors strategically placed on the residual limb to detect muscle signals. These sensors enable intuitive control of the prosthetic arm by translating muscle signals into movement commands.
3. Enhanced Grip Strength and Versatility: The prosthetic hand features multiple grip patterns and strong grip strength to handle various tasks with ease. This includes pinch grips, power grips, and precision grips, providing versatility for everyday activities.
4. Natural Aesthetic Design: The exterior of the prosthetic arm is designed to resemble a natural limb as closely as possible, with customizable covers available in different skin tones. This aesthetic design feature helps the prosthetic arm blend seamlessly with the user's body, reducing self-consciousness and enhancing confidence.
5. User-Friendly Interface: The control interface is designed to be intuitive and easy to use, allowing users to switch between grip patterns and adjust settings effortlessly. This ensures a smooth user experience and minimizes the learning curve for operating the prosthetic arm.
6. Lightweight and Comfortable Design: The prosthetic arm is constructed from lightweight materials to reduce fatigue and discomfort during extended wear. Special attention is paid to ergonomics and weight distribution to ensure maximum comfort and usability.
7. Durability and Reliability: The prosthetic arm is engineered to be durable and reliable, capable of withstanding daily wear and tear as well as occasional impacts. Shockproof and waterproof features are integrated to protect internal components and ensure longevity.
8. Easy Maintenance and Troubleshooting: The prosthetic arm is designed for easy maintenance and troubleshooting, with accessible battery 16 compartments and modular components. Users are provided with clear instructions and support resources for routine maintenance tasks and minor repairs.
9. Portability and Ease of Use: The prosthetic arm is designed to be portable and easy to transport, allowing users to carry out daily activities and travel with ease. Quick-release mechanisms and adjustable straps facilitate easy attachment and removal of the prosthetic arm.
10. Affordability and Accessibility: The overall design prioritizes affordability without compromising on functionality or quality. By utilizing cost-effective

materials and manufacturing processes, the prosthetic arm remains accessible to a broader population.

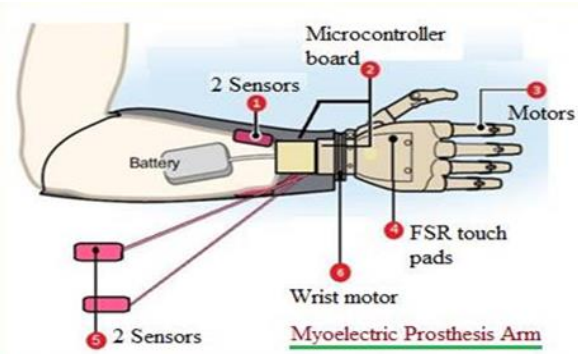

Figure 1: Conceptual Design

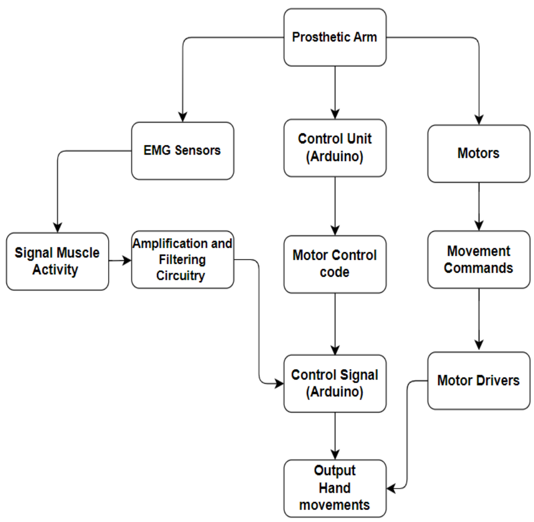

Figure 2. Functional Structure of Myoelectric Prosthetic Arm

B. Workflow

1. Needs Assessment and Conceptual Design: A comprehensive understanding of the target user population is essential for developing an effective prosthetic arm. To this end, in-depth interviews and surveys will be conducted to identify specific needs, preferences, and limitations of individuals with upper-limb amputations. This information will inform the design of the prosthetic arm, ensuring that it meets the functional and aesthetic requirements of the target users. A virtual prototype will be created using 3D modeling software to explore various design options for the prosthetic hand, including different grip patterns and finger configurations. This iterative design process aims to optimize the prosthetic arm's functionality and user experience.

2. Integration of EMG Sensors and Signal Processing: To enable intuitive control of the prosthetic arm, electromyography (EMG) sensors will be strategically placed on the residual limb to detect muscle signals. Advanced signal processing algorithms will be developed to accurately interpret these signals and translate them into corresponding prosthetic hand movements. This research will focus on establishing a robust mapping between muscle patterns and desired hand actions to enhance the prosthetic arm's responsiveness and precision.

3 Mechanical Design, Fabrication, and Electrical Systems: The prosthetic arm's structure will be optimized for weight, strength, and durability while considering cost-effective manufacturing techniques such as 3D printing and injection molding. Modular components will be incorporated to facilitate easy assembly, maintenance, and customization.

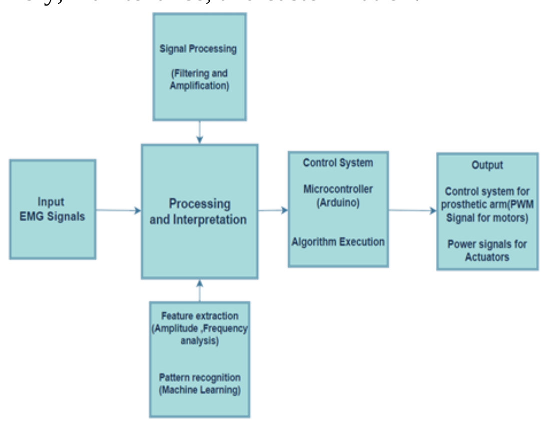

Figure 3. Signal Processing Glass Box (shown the signals as from inputs signals to final output signals processing)

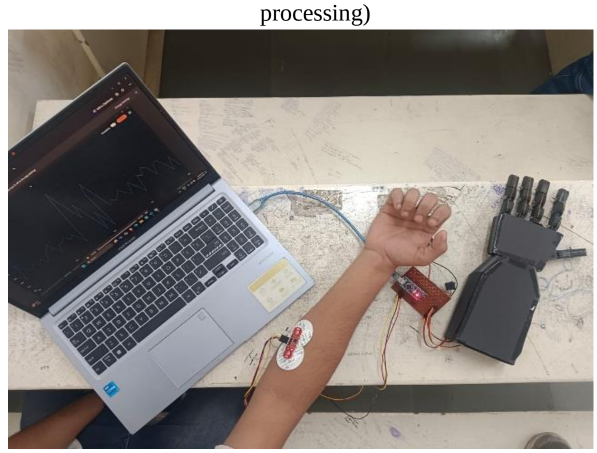

Figure 4. Final Prototype (including EMG sensor, 3D printed arm, microcontroller, circuit working, output waveforms,etc.)

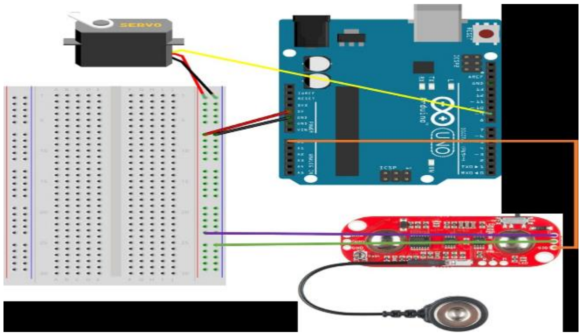

Figure 5. Circuit Connections of sensor, microcontroller, breadboard, etc.

IV. RESULT ANALYSIS

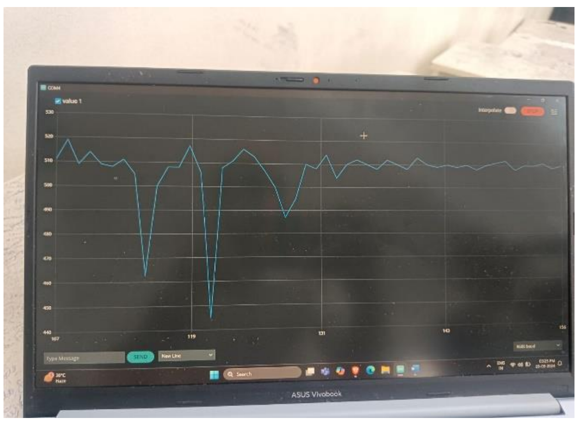

Figure 6. Analytical Output Waveforms of EMG Sensor (the spike waveforms of the sensor as working on the moments like contraction and relaxation)

Here we have to set a threshold value which acts as a switch for the prosthetic arm, the controller will only read a value if the graph crosses that certain threshold value, thereafter that signal will be given to servo motor which is responsible for the movement of the arm.

Factors to be consider	Existing product	Our product
Pattern Recognition Author: - Stephanie L. Carey Derek J. Lura M. Jason Highsmith	Traditional methods map muscle signals to specific movements	Map muscle signals to specific movements as well as the daily most done movements
EMG Signal Processing Author: - Stephanie L. Carey Derek J. Lura M. Jason Highsmith	In this only the emg signal is performed through which only the movements have been done	Advanced techniques like machine learning and artificial intelligence are being used to extract more information from EMG signals
Sensory Feedback Author: - Manfredo Atzori Henning Müller	Their ability to grasp objects and interact with the environment as on basic version.	Now improving their ability to grasp bigger objects and interact with the environment.
Degrees of Freedom Author: - Manfredo Atzori Henning Mülle	The existing products don't offer all such freedom of movement's they are having restricted towards to movement.	Modern myoelectric arms offer increasingly sophisticated movement capabilities, including multiple joints, individual finger control, and even wrist rotation.
Cosmesis and User Acceptance Author: - Stephanie L. Carey Derek J. Lura M. Jason Highsmith	The existing Material developments and design innovations are focusing on creating metals, plastic's and composite material prostheses.	The Material like ABS or PLA+ develop and design innovations like focusing on creating more naturallooking and lightweight prostheses.
Cost and Accessibility Author: - Stephanie L. Carey Derek J. Lura M.	Myoelectric arms remain expensive, limiting access for many amputees. The	The ways of exploring to reduce costs and develop more affordable options the

Jason Highsmith	price of the existing product is appox. Upto 50k or 1 lakh.	product we made is under 10k (it can be exceeding upto 15k.
Cost Comparison (Material)	Prosthetic Components which include connective components (made of aluminium, stainless steel or titanium)	Material used in the prosthetic arm is PLA (Polylactic Acid) Which is typically used in 3-D Printing.
Cost Comparison (Sensors)	Brainwave sensors: Used in some prosthetic arm controllers to read brain signals and translate them into control commands	Electrodes: Detect electrical signals created when the wearer's remaining muscles contract, allowing for control of the prosthetic arm
Cost Comparison (Shipping)	These Prosthetics are Imported from developed countries like US, UK. Which add additional shipping charges.	Prosthetic is made indigenously which reduces the shipping charges?

V. CONCLUSION

This research presents a novel approach to developing affordable myoelectric prosthetic arms by leveraging 3D printing and readily available EMG sensors.

The cost effectiveness can be seen regarding the cost of Material, Sensor and the Shipping cost, this innovative solution aims to democratize access to advanced assistive technology, particularly in underserved populations. The proposed prosthetic arm incorporates customizable components, intuitive control, enhanced grip functionality, natural aesthetics, and user-friendly features, all while maintaining affordability.

VI. FUTURE SCOPE

Future research and development efforts should focus on refining the prosthetic arm's control algorithms, improving sensory feedback, and exploring additional features to further enhance its functionality and user experience.

By fostering collaboration and sharing knowledge through open-source design, this research contributes to a global effort to provide affordable and accessible prosthetic solutions, empowering individuals with upper limb loss to lead more independent and fulfilling lives.

REFERENCE

[1] Purushothaman Geethanjali, Myoelectric control of prosthetic hands: state-of-the-art review, July 2016

[2] Aaron Fleming, Nicole Stafford, Stephanie Huang, Xiaogang Hu, Daniel P Ferris, He Helen Huang, Myoelectric control of robotic lower limb prostheses: a review of electromyography interfaces, control paradigms, challenges and future directions, July 2021

[3] Francesca Cordella, Anna Lisa Ciancio, Rinaldo Sacchetti, Angelo Davalli, Andrea Giovanni Cutti, Eugenio Guglielmelli, Loredana Zollo, Literature Review on Needs of Upper Limb Prosthesis, May 2016

[4] Stephanie L Carey, Derek J Lura, M Jason Highsmith, Differences in myoelectric and body-powered upper-limb prostheses: Systematic literature review, 2015

[5] Manfredo Atzori Henning Müller, (Electromyography Low Pass Filtering Effects on the Classification of Hand Movements in Amputated Subjects), Published Issues Volu,me 3, No. 2, December 2015

[6]] Lillian Y. Chang and Yoky Matsuoka. A Kinematic Thumb Model for the ACT Hand. The Robotics Institute, Carnegie Mellon University. Proceedings of the 2006 IEEE International Conference on Robotics and Automation.

[7] Myoelectric signal based multiple grip pattern prosthetic arm Raj Khatik, Vijaypal Yadav2018

6th Edition of International Conference on Wireless Networks & Embedded Systems (WECON), pp 92-96, year 2018

[8] Christian Pylatiuk, Stefan Schulz and Leonhard Döderlein. Results of an Internet survey of myoelectric prosthetic hand users. Prosthetics and Orthotics International, Sage Publications Dec1, 2