EMG-Controlled Hand Prosthesis: A Raspberry Pi Solution

Yaskara Mota[1] , Maria Eduarda[1], Erika Alves[1], Richardson Menezes[1], Orivaldo Vieira de Santana Junior[1], Helton Maia*[1]

[1]Federal University of Rio Grande do Norte, Natal, Brazil (helton.maia@ufrn.br)

Abstract: This research aims to develop a low-cost, electromyography (EMG)-controlled hand prosthesis using a Raspberry Pi Pico W. EMG sensors capture the muscle's electrical signals, which are then translated into control commands for the prosthesis. The Raspberry Pi Pico processes the data using an on-device artificial neural network and decides on the movement to be performed by the prosthesis. The 3D-printed hardware design of the prosthesis enhances its accessibility and customization, providing an affordable solution for individuals with limb loss.

Keywords: Hand prosthesis; EMG sensors; Raspberry Pi Pico; 3D printed.

INTRODUCTION

Mechanical prostheses are used to assist in the daily activities of those who suffer a limb loss, giving the users a better quality of life after the period of adaptation (Chagas et al., 2023).

The Brazilian Unified Health System (SUS) has an extensive public policy for distributing prostheses and orthoses to those who need them. With their high cost, however, they can only contemplate some of the demand, making it necessary to develop these medical technologies cheaply (Camargo, 2017).

However, there are still technical limitations, such as the slow response of the microcontroller, which leads to high costs for this equipment to be more accessible to users (Silva, 2021).

In Alves's (2023) endeavor to develop a cost-effective prototype, the accessibility of the microprocessor used in Brazil posed a challenge. Consequently, a new prototype was conceived to address these constraints. The Raspberry Pi Pico W microcontroller was selected as an economical substitute for signal processing and analysis, as highlighted by Lima (2021).

In addition, an electromyographic (EMG) sensor is being used, which captures signals of muscle activity as muscle contractions generate electrical impulses. This is called electromyography. There are two types of EMG sensors: surface and intramuscular. (Chowdhury et al., 2013).

For the prosthesis being developed in this work, we selected the surface sensor for its practicality, initially with only three electrodes positioned on the surface of the arm's skin. In this way, we intend to create a system capable of capturing EMG signals, processing them intelligently, and controlling a hand prosthesis in real time.

MATERIAL AND METHODS

The work done in this project can be summarized in three main stages, as shown in Figure 1.

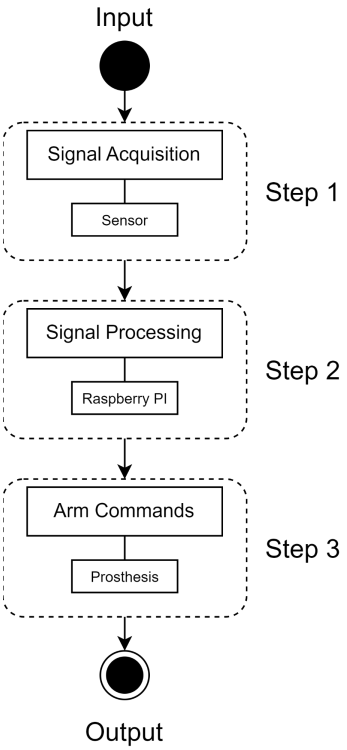


Figure 1 - UML activity diagram to represent the flow of actions within the system under development.

In Figure 1, the initial stage involves capturing signals from the user's arm and converting them to digital using an ADC while the user performs hand opening and closing gestures. Electrodes placed on the user's arm pick up muscle signals, which are then recorded by an EMG sensor and sent to a Raspberry Pi Pico. The subsequent stage involves signal processing on the Raspberry Pi Pico, which includes spectral filtering, data storage, and, importantly, decision-making about the movement of the prosthetic hand based on a neural network classifier. Lastly, in the third stage, the neural network classifier provides an output that will be translated to select commands for the prosthetic hand, directing the execution of the intended movement.

This project utilizes a Raspberry Pi Pico, depicted in Figure 2, programmed using the microPython language within the Thonny Python IDE. Integrating Bluetooth and wireless modules eliminates the need for cables, enabling the development of wearable devices powered by batteries and connected through a wireless network.

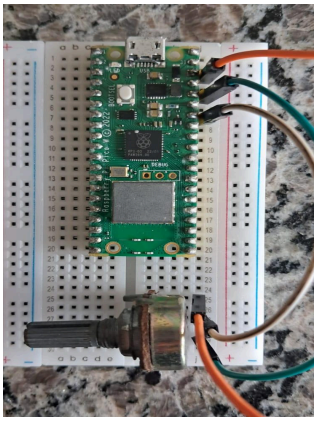


Figure 2. Raspberry Pi Pico W

The electromyographic (EMG) sensor, depicted in Figure 3, captures the electrical signals produced by muscle contractions within the typical EMG frequency range of approximately 50 Hz to 1500 Hz. These signals are then read by the Raspberry Pi Pico's GPIO ports and utilized for subsequent prosthesis control.

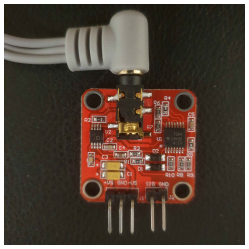


Figure 3. EMG sensor, Muscle Sensor v3 from Advancer Technologies.

The circuit, powered by batteries, illustrated in Figure 4, shows the connection of the Raspberry Pi with the EMG sensor, highlighting the flow of signals within the circuit for capturing muscle signals.

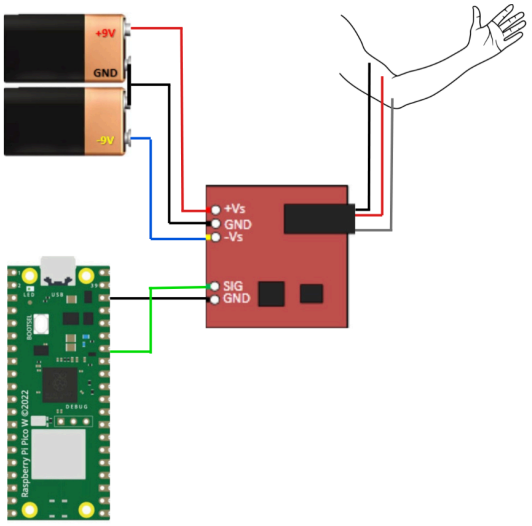


Figure 4. Circuit diagram with Raspberry Pi and EMG sensor

RESULTS AND DISCUSSION

The results obtained so far are preliminary. Setting up the system has proven to be challenging, particularly regarding the computational routines, such as signal recording and analysis in real-time.

Regarding hardware, we are currently working on printing the first version of the prosthetic hand. This prototype will initially focus on opening and closing the hand, responding to commands generated from the muscle signals in the user's arm.

Figure 4 illustrates the acquisition of electromyographic signals for two distinct hand gestures: open and closed. These gestures represent the two primary classes of signals that require analysis for intelligent and accurate control of the prosthesis movement.

While we work towards a fully functional prosthesis, our efforts are concentrated on signal acquisition and processing using a Raspberry Pi Pico. We acknowledge the platform's memory limitations and challenges in achieving real-time performance.

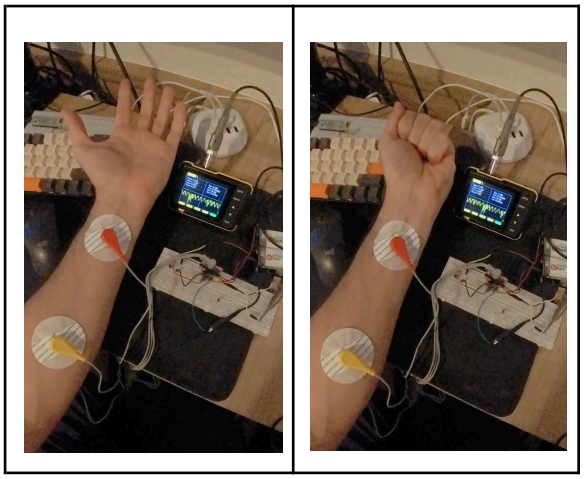


Figure 4. Setup for acquiring open and closed hand signals.

Our next objective involves developing a neural network that can interpret muscle signals to control specific prosthetic movements. Although deploying this neural network on the device presents a considerable challenge, we plan to leverage TensorFlow Lite for this purpose.

This project is inherently multidisciplinary, involving the design and 3D printing of a prosthetic hand, integration of electronics, processing of biosignals, and implementation of intelligent algorithms. It requires us to continuously advance our expertise across multiple domains and stay updated on the latest advancements in these fields.

The research team is deeply committed to pursuing this project until we can deliver a tangible solution for users in need. Initially, our focus is on conducting comprehensive testing, but our long-term goal is to create a truly beneficial device for society.

CONCLUSION

This research explores the development of an affordable and accessible EMG-controlled hand prosthesis using a Raspberry Pi Pico W. While still in preliminary stages, the team has successfully captured and processed EMG signals corresponding to hand open and close gestures. Challenges remain in optimizing real-time processing and deploying a robust neural network classifier for accurate prosthetic control. Despite these hurdles, the team remains committed to refining the design, overcoming technical limitations, and ultimately delivering a functional and impactful solution for individuals with limb loss.

ACKNOWLEDGMENTS

The Federal University of Rio Grande do Norte (UFRN) and the School of Science and Technology (ECT) support this research. The Robotics and Automation Laboratory (LAR) has been essential for developing this work.

REFERENCES

LIMA, T. F. O. Desenvolvimento de sistema de baixo custo para monitoramento e controle de processos de usinagem usando Raspberry Pi®. 2021. Dissertação (Mestrado) - Universidade de São Paulo, São Paulo, 2021.

CHOWDHURY, R. H. et al. Surface electromyography signal processing and classification techniques. Sensors, v. 13, n. 9, p. 12431-12466, 2013.

LORRAIN, T. et al. Study of issues in the development of surface EMG controlled human hand prostheses. Journal of Materials Science: Materials in Medicine, v. 19, n. 3, p. 1075-1083, 2008.

SILVA, J. M. Projeto e desenvolvimento de sistema de acionamento para prótese de mão open source. 2021. Trabalho de Conclusão de Curso (Graduação) – Universidade do Vale do Rio dos Sinos, São Leopoldo, 2021.

AZZAHRA, M.; FADHILAH, I.; RUSDI, M. Implementasi osiloskop digital menggunakan Raspberry Pi Pico W berbasis OS Android. Prosiding Konferensi Nasional Social & Engineering Polmed (KONSEP), v. 4, n. 1, 16 jan. 2024.

CHAGAS, B. B.; AMORIM, B. C. Adaptação à prótese, funcionalidade, qualidade de vida e efeitos da prática esportiva em pessoas protetizadas do membro inferior: uma revisão de literatura. 2023. Trabalho de Conclusão de Curso (Graduação em Fisioterapia) – Faculdade de Ciências Humanas e da Saúde, Pontifícia Universidade Católica de São Paulo, São Paulo, 2023.

ALVES, E.; MAIA, H.; ARF, O. Classification of Hand Gestures Using sEMG Signals and TensorFlow Lite for Microcontrollers. In: CONGRESSO BRASILEIRO INTERDISCIPLINAR EM CIÊNCIA E TECNOLOGIA, 2023, Online. Anais [...]. Recife: Even3, 2023.

CAMARGO, T. A. Custos de órteses, próteses e materiais especiais não contemplados no Sistema Único de Saúde (SUS) em hospital de ensino brasileiro. 2017. Dissertação (Mestrado) - Universidade Estadual Paulista, Botucatu, 2017.