Design and Development of a 3D Printed Myoelectric Hand Prosthesis

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***Abstract*—The starting point for this research was the need to develop an affordable solution for the large number of amputees who, due to economic limitations, cannot afford prostheses, as they are often prohibitively expensive. With this in mind, the prices of some commercial prostheses were considered to offer a more accessible alternative. Given the socioeconomic condition of amputees in Brazil, the goal of this thesis was to achieve a low-cost solution by applying different systems in the design and fabrication of a myoelectric prosthesis for individuals with transradial amputation. To this end, the necessary theory was specified to understand the systems used, as well as the standards and equipment that were fundamental in the design and fabrication of the myoelectric hand prosthesis prototype. Theoretical calculations of the braided cord mechanism were also presented, along with experimental tests that helped validate the parameters, ensuring that the hand prosthesis designed in this research functions correctly. Furthermore, this research details the final design of the prosthesis using the "Autodesk Inventor 2024" software and the subsequent fabrication via 3D printing using the "Simplify3D" software. After the hand prosthesis was fabricated, a price comparison was conducted between the myoelectric prosthesis developed in this research and other commercial prostheses. Upon completing the study, design, and fabrication of the myoelectric hand prosthesis for individuals with transradial amputation, the conclusions were drawn and the recommendations for the use of this prosthesis were presented.**

Keywords—Prosthetic hand; transradial amputation; EMG sensor; 3D print.

I. INTRODUCTION

Currently, several companies produce commercial prostheses; however, these devices are highly expensive due to their specialized mechanisms, the materials used, and more complex signal processing. Such advanced technology is often inaccessible to developing countries. Therefore, one of the main objectives of this project is to develop a low-cost myoelectric hand prosthesis through 3D printing, making this technology more accessible to amputees who lack the financial resources to afford more expensive options. Digital manufacturing is a rapidly evolving technology, with 3D printing being a prominent example. This technology is widely used across various fields due to its ability to utilize a broad range of materials with high precision and the capability to produce complex shapes.

In the healthcare sector, 3D printing is increasingly employed to reduce costs and make advanced solutions more accessible to the general public. For instance, 3D-printed hand prostheses are gaining significant attention due to their ability to offer a wide range of possibilities, including cost and manufacturing time reductions. Electromyography (EMG) is a technique used to measure the electrical activity of muscles during contraction. By recording the sum of action potentials from muscle fibers beneath the skin, EMG provides an indication of muscle activity, with higher readings corresponding to greater muscle engagement. Each year, many individuals suffer from accidents resulting in limb loss, a life-altering event that severely impacts the ability to perform daily tasks. Prosthetic limbs play a crucial role in restoring some functionality to amputees, enabling them to regain a degree of normalcy. This highlights the importance of ongoing advancements in prosthetic development to enhance the quality of life for those with limb loss (1). This research focuses on designing and constructing a transradial hand prosthesis that is controlled by EMG signals. The EMG signal is captured by eight sets of three electrodes (sensors) placed on the user's arm. These electrodes detect a very small voltage emitted by the brain when a person intends to move their hand or another body part. This small voltage is then amplified to a range of 0 to 5 volts before being processed by a microcontroller. The EMG sensor's microcontroller classifies six movement patterns, from which only the "fist" pattern is used to control five DC micro-motors responsible for finger movement. Additionally, a force sensor estimates the pressure the prosthesis applies when gripping an object, enabling feedback control. The hand prosthesis prototype developed in this research features 5 degrees of freedom with a controlled mechanical system. Moreover, thanks to 3D printing, the prosthesis is lightweight and durable due to the materials used, with a cost that aligns well with its functionality, quality, and utility.

II. MATERIALS AND METHODS

A. EMG

Small electrical currents are generated by muscle fibers before muscle movement occurs. These currents are produced by the exchange of ions across the muscle fiber membranes,

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which is part of the signaling process that causes the muscle fibers to contract. The signal, known as an electromyogram (EMG), can be measured by applying conductive elements or electrodes (sensors) to the surface of the skin or invasively within the muscle. Surface electromyography is the most common measurement method, as it is non-invasive and can be performed by non-medical personnel with minimal risk to the patient (2). The EMG signal typically has an amplitude between 0 and 6 mV, and the useful frequency range is between 0 and 500 Hz, with the majority of energy concentrated between 50 and 150 Hz. According to the Nyquist-Shannon sampling theorem, also known as the Whittaker-Nyquist-Kotelnikov-Shannon sampling theorem, Nyquist's theorem states the following (3):

If the highest frequency contained in an analog signal xa(t)x_a(t)xa(t) is Fmax=BF_{max} = BFmax=B, and the signal is sampled at a rate Fs>2Fmax≡2BF_s > 2F_{max} \equiv 2BFs>2Fmax≡2B, then xa(t)x_a(t)xa(t) can be fully recovered.

If this criterion is not met, there will be frequencies whose sampling coincides with others (known as aliasing).

Considering this, the sampling frequency must be equal to or greater than 300 Hz. (4).

B. *Actuators Used in Prosthetics*

An actuator is a device capable of transforming hydraulic, pneumatic, or electrical energy into the activation of a process, with the purpose of generating an effect on an automated system (5). The most common actuators used in hand prosthetics are micromotors, DC motors, servomotors, and linear micromotors. Below is a description of each:

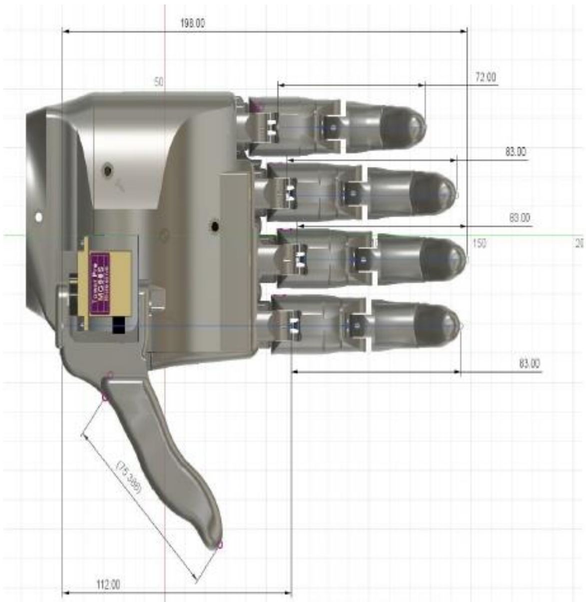
DC micromotors, are ideal for prosthetic applications due to their small size and significant power (6). Additionally, these micromotors often include a gearbox that increases their torque, with gear ratios ranging from 5:1 to 1000:1, and they are available in 6V and 12V versions.

Servomotors, A servomotor is a powerful device that contains a small motor with a speed reducer and torque multiplier, along with a circuit that controls the system. The rotation angle of the shaft is typically 180º, but it can be easily modified for a full 360º rotation, similar to a standard motor. The servomotor is responsible for providing mobility to the robot (7).

III. Results and Discussion

The design of the right hand was based on the DIN 33402 standard, using measurements that represent the 95% of the majority of males, as shown in Figure 1.

Figure 1- Dimensions of the Hand Prosthesis



Reference: Author.

The design and fabrication of the myoelectric prosthesis were achieved at a lower cost compared to commercial prostheses. The implementation of a controlled mechanical system with the mentioned components resulted in effective functionality at a reduced cost. The use of 3D printing for the prosthesis significantly impacted cost savings during manufacturing without compromising the prosthesis's durability or aesthetics.

References

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[1] Sadun, A. S., Jalani, J., & Sukor, J. A. (2016). Force Sensing Resistor (FSR): a brief overview and the low-cost sensor for active compliance control. *First International Workshop on Pattern Recognition, 10011*, 1001112. https://doi.org/10.1117/12.2242950.

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