ASSISTIVE TECHNOLOGY: BIONIC HAND CONSTRUCTION

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ABSTRACT
Amputations of lower or upper limbs are recurrent around the world and have affected thousands of people for several years. People with such disabilities inevitably become dependent on other people. Making them, most of the time, people incapable of contributing to the labor market, retiring them in conditions that are subappropriate for their level of education. Helping people who have difficulties in performing small tasks to become independent, or even to include them again in the job market and in society are motivations for writing this work. In recent decades, an innovative and promising new technology has emerged to give hope to these people called Assistive Technology. This work seeks to study human morphology, analog and digital data and converters through the use of the *Myo ArmBand* bracelet. It also seeks to introduce concepts of microcontrollers, programming languages with the use of the free development platform *Arduino Uno*. A 3-finger bionic arm model designed to be able to pick up and recognize the electrical signals of a normally functioning arm, and to reproduce such movements as reliably as possible on the bionic arm. We intend to contribute to future applications in people who have a disability or limb amputation.

Keywords: *Myo*. Micro controller. Assistive Engineering. Prosthesis.

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INTRODUCTION

Imagine waking up in the morning, and turning off the alarm clock. Getting up, brushing your teeth, combing your hair and putting on clothes. Soon after, make scrambled eggs for breakfast. And finally have a fresh coffee reading the newspaper.

This is a seemingly simple routine that normal people do most of their days. But for some people these seemingly simple tasks, for some they are very complicated and impossible to be carried out masterfully and quickly. There are currently around 10 million amputees, more than 3 million of whom are in the upper limbs alone (ADVANCED AMPUTEE SOLUTIONS). The average number of amputees per year is more than one million and this number has been increasing alarmingly in recent years (ADVANCED AMPUTEE SOLUTIONS). Prosthetic companies cite a figure of more than 90% of amputees would pay huge amounts of money to be able to have their normal functions again, which justifies the high investment in these technologies recently.

Assistive technology is named, like the entire arsenal of resources and services, everything that contributes to providing or expanding functional abilities of people with disabilities and consequently promoting independent living and inclusion (SARTORETTO; BERSCH, 2017). It can also be defined as a wide range of equipment, services, strategies and practices designed and also applied to alleviate the problems encountered by individuals with disabilities (COOK AND HUSSEY, 1995).

In Brazil, the Technical Aids Committee (CAT), established by ORDINANCE No. 142, OF NOVEMBER 16, 2006, defines assistive technology as:

> [...]Assistive Technology is an area of knowledge, with an interdisciplinary characteristic, which encompasses products, resources, methodologies, strategies, practices and services that aim to promote functionality, related to the activity and participation of people with disabilities, disabilities or reduced mobility, aiming at their autonomy, independence, quality of life and social inclusion[...] (ACT VII - TECHNICAL AID COMMITTEE (CAT) - NATIONAL COORDINATION FOR THE INTEGRATION OF PERSONS WITH DISABILITIES (CORDE) - SPECIAL SECRETARIAT FOR HUMAN RIGHTS - PRESIDENCY OF THE REPUBLIC).

The objective of assistive technology is to provide people with disabilities with greater independence, a better quality of life, through the expansion of their communication, mobility, control of their environment and actions, integration with family, friends and society.

Assistive technology always needs resources. We mean any and all items, equipment or parts thereof, machines, products or systems manufactured in series or personalization used to increase, maintain or improve the functional capabilities of people with disabilities.

In a more punctual definition, resources can range from a simple cane used to help people with any sick leg, to a complex system such as electrodes inserted inside a person's brain.

The recent advancement of technology increasingly allows the development and implementation of assistive systems. Systems in which they allow biological beings to interact with mechatronic systems. Gradually, assistive technology began to integrate psychological and cognitive aspects into the study, a set of processes, dialogues, and actions through which a human being uses and interacts with a computer (BAECKER; BUXTON, 1987*).* This interaction is important because it has several applications in various areas, such as military applications. However, its main application today, and also the one that will be the focus of this work presented here, is the recovery or replacement of lost and/or atrophied movements.

Assistive technology has a great challenge, as its intention is to build extensions or replacement of mobile joints (prostheses), which simulate the anatomy of the human or animal body, which adapts very easily to various responses of the environment.

The project, through logical and programmable devices, servo motors, sensors and microcontroller, etc., will be responsible for the movements in the bionic hand with the use of the movement of the muscles and nerves of a forearm. It is important to note that for this work the tests will be performed on forearms with normal functions not atrophied as the input signals to the system. The development of this project was carried out by the immense interest in this type of technology, as it is a field with very fast and promising development, there is also the fact that there is the growing investment in research through various renowned institutions in the field of bioengineering, it has been increasing. It is worth explaining that the hand will have only three fingers and will perform movements of opening, closing and bending the "fist". A computer program written in C language (*Arduino* standard) reads the signals captured *by the Myo ArmBand,* transcribe them into digital signals through a digital analog converter and finally send commands for hand movement.

In this work it is developed with the construction and control of a bionic hand through sensors and electro-electronic devices and programming languages.

OBJECTIVES

GENERAL:

Build a bionic hand. Controlled through electrical stimuli provided from a biological source such as an unstunted human forearm.

SPECIFIC:

The specific objectives entail:

- Model biological mechanisms through electromechanical devices.
- Use the C programming language to assemble a control interface for the *Arduino Uno microcontroller*.
- Explore the efficiency and reliability of the *Myo ArmBand*.
- Contribute effectively to assistive engineering.

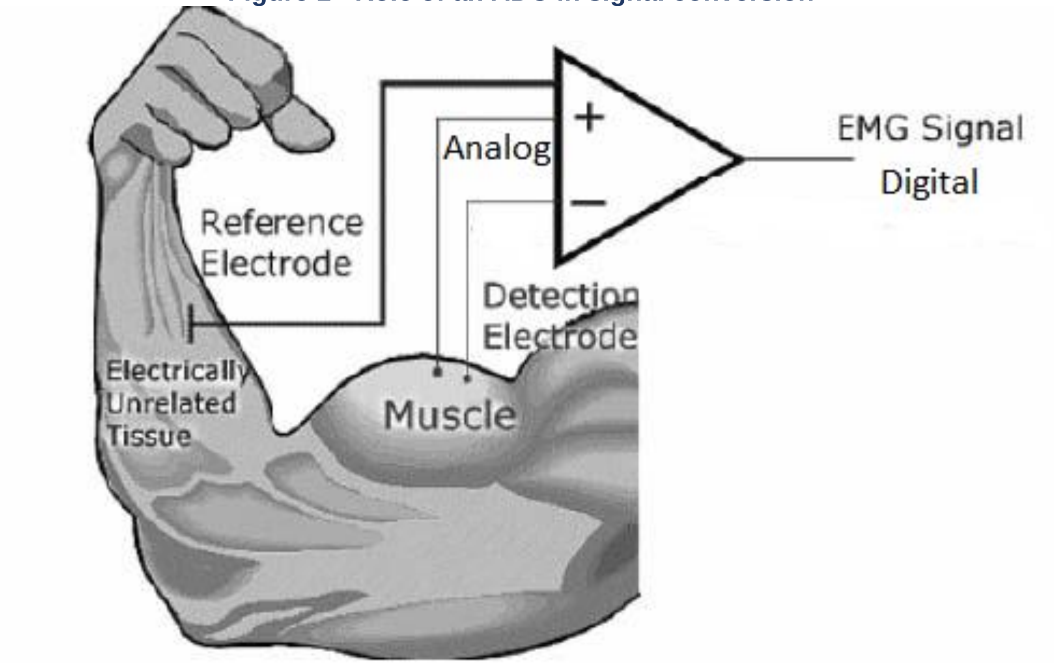
STATE OF THE ART

The term adaptive technology is often used synonymously with assistive technology, however, they are different terms. Assistive technology refers to any item, piece of equipment or product system, commercially acquired, modified and/or customized, that is used to increase, replenish or improve the functional capabilities of individuals with a disability (*ASSISTIVE TECHNOLOGY ACT OF* 1998). Andwhile adaptive technology encompasses items that are specifically designed for people with some type of disability and would rarely be used by people with non-stunted or absent functions. In other words, assistive technology is any object or system that enhances or maintains the capabilities of people with or without disabilities. While adaptive technology is any object or system that is specifically designed for the purpose of increasing or maintaining the capabilities of people with a disability (*ASSISTIVE TECHNOLOGY ACT OF* 1998, S.2432). Consequently, adaptive technology is a subset of assistive technology.

The purpose of this work is the development of a bionic hand, moved by a myoelectric sensor present in the *Myo Armband* located on a person's forearm. To know how the data from analog inputs is transformed into digital output data, and after conversion, finally, to understand how the signal is used by the microcontroller and perform the movement of the bionic hand. For this it is necessary to understand the operating principle of some components such as sensors, EMG electromyography, microcontroller, IMU inertia unit meter and converters.

We contextualize our principles from the sensor. A sensor is a device that has the function of detecting events or changes in its contour, sends the information to the computer, where a microcontroller processes the input data and provides an output signal suitable for the stimulus. In this work, a sensor is used with the function of converting real-world data (Analog) into data understandable by a computer (Digital) using an Analog-to-Digital Converter (ADC) as can be seen in figure 1.

Figure 1 - Role of an ADC in signal conversion



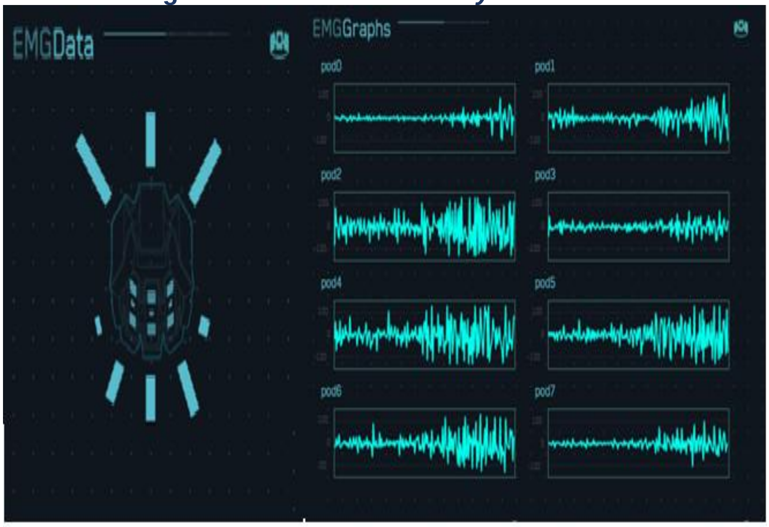
Source: Raez, 2006 with adaptations

The sensitivity of a sensor indicates how much its output changes, when the amount of input to be measured suffers some variation, that is, its smallest unit of variation can be said to be the sensitivity of the sensor. For example, if the mercury in a thermometer moves 1 cm when the temperature changes by 1 °C, the sensitivity is 1 cm/°C (it is basically the Dy/Dx slope characteristic of a linear function).[4]

Electromyography or EMG is a technique commonly used in electrodiagnostic medicine. Usually to evaluate and record the electrical activity or absence of it that is produced by the muscles due to the excitation of the same to perform a movement. EMG is performed with the use of an instrument called an electromyograph that pick up an analog signal called an electromyogram. An electromyograph detects the electrical potential generated by muscle cells at the instant of time in which these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, or to analyze the biomechanics of human or animal movement. An example of an EMG sianl is presented in Figure 2.

[4] An affine function or function of the 1st degree is characterized by presenting a law of formation of the type $f(x) = a \cdot x + b$, in which the coefficients a and b are real numbers, in addition to necessarily being non-zero ($a \neq 0$). The graph of an affine function is a line that can touch the x-axis of the Cartesian plane at a single point.

Figure 2 - EMG Date of a *Myo Armband*

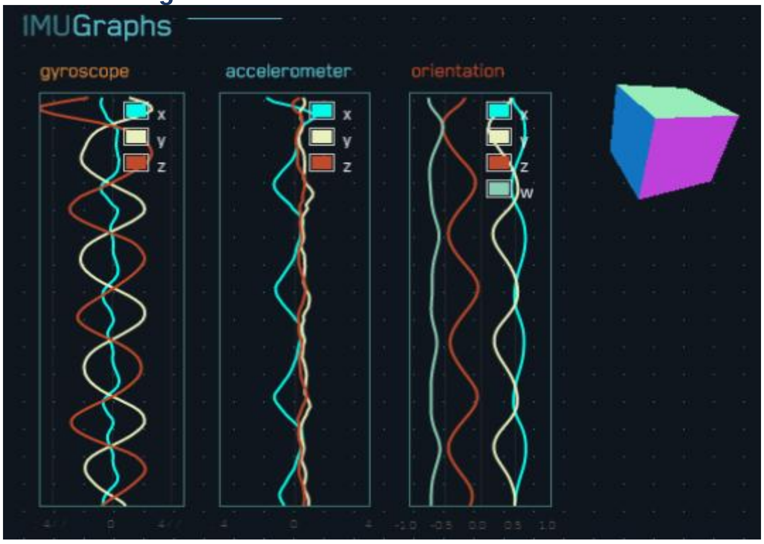


Source: http://diagnostics.myo.com/

The inertial measurement unit or (IMU) is an electro-electronic device that measures and describes the specific forces of a muscle or a nerve. The IMU has the ability to measure the rate of angular drive. In some cases, the magnetic field that surrounds the body can also be measured using a combination of accelerometers and gyroscopes contained in the device, as shown in figure 3. Sometimes the use of magnetometers helps to improve the quality of the signal. IMU's are used in the areas of technology, mainly in aerospace engineering to maneuver aircraft such as: drones, airplanes, unmanned aerial vehicles (UAV's), spacecraft, satellites and extraterrestrial landers. The data collected from the IMU's sensors also allows the tracking of the position of vessels, by a method known as "dead counting", [5]widely used in military applications.

[5] *Dead Counting or* Hydroacoustic Aided Inertial Navigation *consists of an inertial measurement unit (IMU) measuring the vessel's own movement, like a* Speed Log *. The IMU is an essential component in an inertial navigation system (INS), which processes the IMU sensor data on a computer. The IMU data is processed along with the position data from a hydroacoustic reference system on a computer, which then gives unique output of combined data characterizing the ship's position, the speed, heading, and trend are updated at 300 Hz, based on the IMU readings, and corrected each time a new acoustic position is measured.*

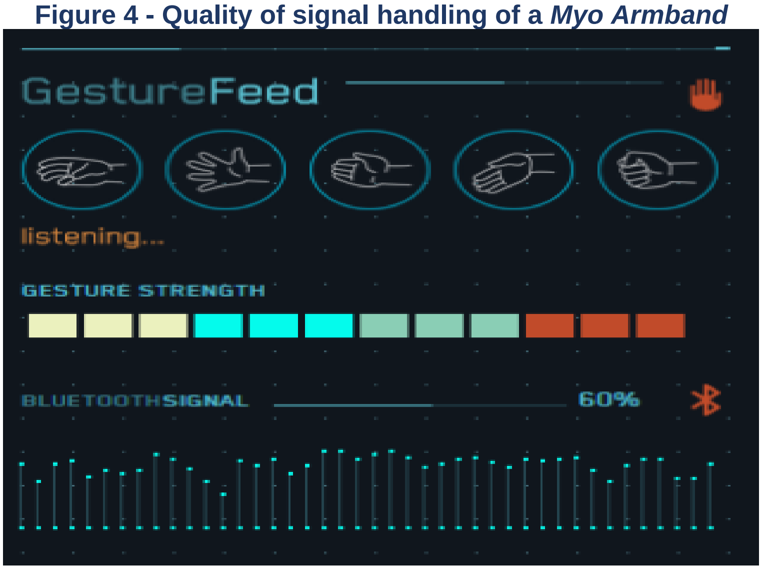
Figure 3 – IMU Date of a *MYO Armband*



Source: http://diagnostics.myo.com/

In *Myo Armband* , IMU's are used to detect the three-dimensional variations of the device. IMU's enable control instructions with more than one degree of freedom (movement in three axes, rotation and translation, both as a function of time). With this, it is possible to capture this signal and convert it to the movement of an electronic device just by moving the sensor itself. The quality of the signals of IMU's are more accurate than EMG's due to the capture of physical quantities in a higher order of magnitude such as gravity, since EMG's work with values in milli-volts. There are also major external interferences from various factors such as temperature, physiological factors such as body fat, atrophic or hypertrophy, these factors have a great influence during signal treatment. The strength treatment of the incoming EMG signal is shown in Figure 4.

Figure 4 - Quality of signal handling of a *Myo Armband*



Source: http://diagnostics.myo.com/

There are three basic components for the construction of a myoelectric device (prostheses, the *Myo* or any other type of device controlled by muscle stimuli), by analyzing each of these factors, we can realize their importance in this process.

I. Signal Acquisition: To acquire a muscle signal, most devices rely on the small electrical signal produced by the muscle cell. More commonly known as electromyography (EMG). An EMG electrode is attached to your skin that detects the small differences in the electrical signal, or the difference in electrical potential over time during the stimulus.

EMGs are usually small patches or devices pressed heavily against the muscles, otherwise it would not have a good response. Some EMG medical readings are actually done intrusively. To do this, a needle (used as an electrode) is introduced into the muscle to obtain a reading with great reliability. This better signal is due to the fact that it is captured without the interference of the skin layer, fat and/or external factors such as temperature. The *Myo* is equipped with external contact electrodes, without the existence of any part or sensor that enters the body or limb, but it is still possible to obtain readings with good quality.

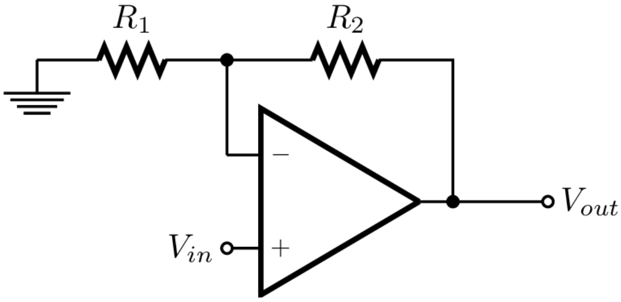
II. Signal amplification: Amplifying the signal is of paramount importance for the process, before the signal processing is done, some type of high band and/or low band filtering can be incorporated. Operational amplifiers (AMP OP) are used in Myo. An operational amplifier is an amplifier that can have very high gains, most of them have two signal input terminals, one designated as the negative inverter terminal (-) and the other identified as the positive (+) non-inverter terminal. The amplifier output voltage is the difference between the inputs (V+) and V(-), multiplied by the open-loop gain ():G_{open}

$$V_{out} = (V_{+} - V_{-}) * G_{open} \quad (1).$$

Where, *Vout* is the output voltage of the system.

An example of an amplifier can be seen in figure 5, in this case the signal amplification will be a function of the gain and the resistances R1 and R2, the impedance is considered too large or infinite.

Figure 5 - Simple voltage amplifier



https://commons.wikimedia.org/wiki/File:Opampnoninverting.png.

Where, R1 and R2 are different resistances.

For the amplifier in figure 5 there is a negative feedback, in this case we call it non-inverter configuration, currently the most used in the construction of amplifiers in electrical, electronic and acoustic systems:

$$\frac{V_{out}}{V_{in}} = \frac{1+\frac{R_2}{R_1}}{1+\frac{1}{G}+\frac{R_2}{GR_1}} \quad (2).$$

For very large values of G, one can consider only the numerator of this equation for signal amplification with a very small error.

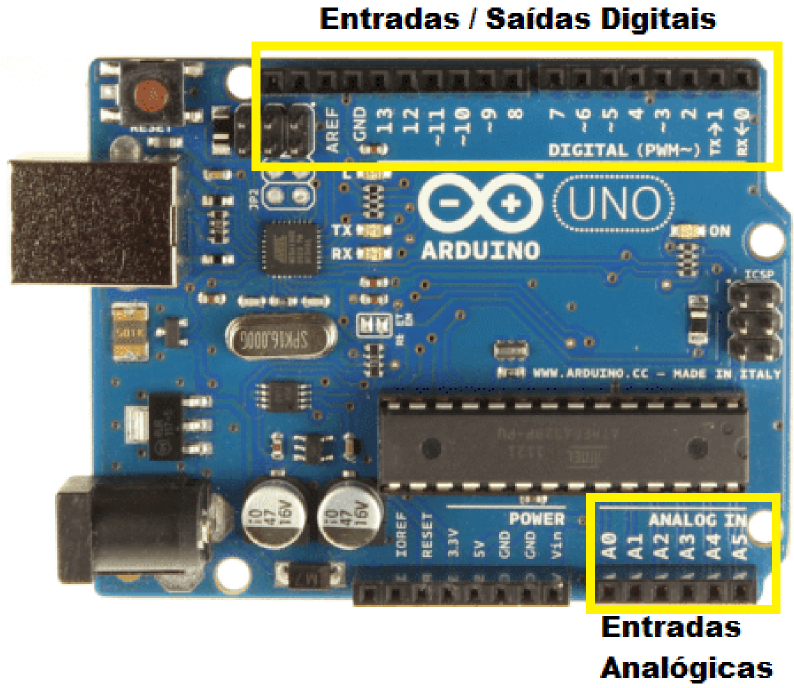
$$\frac{V_{out}}{V_{in}} = 1 + \frac{R_2}{R_1} \quad (3).$$

Amp designs must comply with the "Two Golden Laws" of amplifier designs that use negative feedback, which are:

i. There are no chains at the entrances.
ii. The voltages, i.e. the potentials with respect to the ground, at the two entrances tend to be equal.
iii. Analysis and interpretation of the signal, this is a very complicated part because it involves data inputs from biological sources. To overcome these difficulties, Myo's developers developed an algorithm for the bracelet to detect a number of gestures (five predefined gestures) and represent their respective outputs. Signal processing consists of the analysis and/or modification of signals using a pre-programmed algorithm. The algorithm will extract filtered information from these signals and make them more appropriate for a specific application, as in this case in Myo's pre-programmed commands. Signal processing can be done in only two ways: analog or digital, while objects of interest in signal processing can include sounds, images, radio signals, TV signals, and many others.

The microcontroller is in fact the one that will coordinate the movement of the hand. In this work, *Arduino Uno* was used, due to its low cost, good response, speed and a programming language based on C/C++. The *Arduino UNO* is a micro-controlled development board based on ATMEGA328P. It contains by itself the necessary basics (input and output pins, oscliator crystals, resiores and current adapter source, etc...) for the micro controller to work without the need to add electronic components, but there is a wide variety of modules available on the market. Figure 6 represents all the hardware inputs and outputs of an *Arduino UNO board*.

Figure 6 - *Arduino UNO* and its input (in) output (out) pins



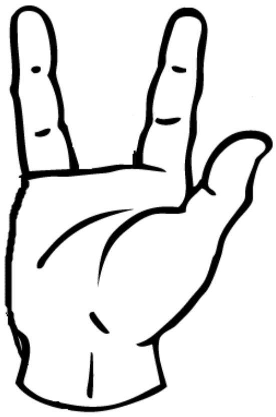
Source: https://www.arduino.cc/en/Guide/HomePage.

METHODOLOGY

In this project, in its first step, the articulated hand will be built, then it will be mechanized so that it could be used. Thus, a hand mold is necessary, the hand of the author of the project was used as a mold.

The modeling of the human hand will have the shape of a mechanical claw. The mechanical grippers functioned as mechanical fingers driven by a motor mechanism, such as electric, pneumatic or hydraulic actuators. The fingers are appendages (extensions of the body) of the claw that make direct contact with the object that is to be moved, grabbed, compressed or released, fixed without the possibility of lengthening or shortening. The human hand configuration (five fingers) is the one with the greatest versatility to perform the manipulation of objects of the most varied types (SALISBURY; CRAIG, 1982). When comparing the quantitative value of fingers, it is noted that a two-finger claw can handle approximately 40% of objects in the most varied ways. A three-fingered claw can handle about 90% of all objects, and a four-finger claw would handle 99% of these objects (MATSUOKA, 1995). In this way, the use of a hand with only three is justified because it meets a high degree of manipulation of objects. Each finger will have three joints in itself with the exception of the thumb which will have only two joints, just like the human hand. A representation of the mold can be seen in figure 7.

Figure 7 - Appearance of the three-finger bionic hand



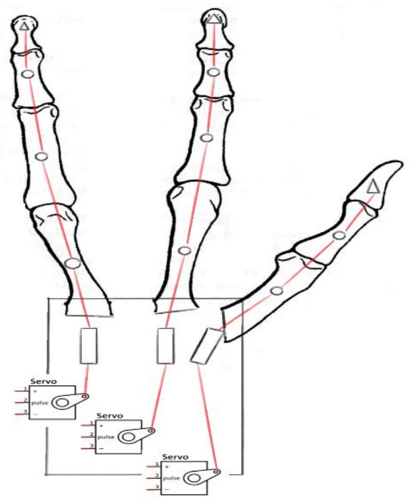
Source: Authorship

Imitating the great versatility of movements produced by the human hand is a complex task and requires a high degree of knowledge in anatomy and electronics. Due to the large number of muscles, degrees of freedom available, it is possible to move easily in the infinite combinations of the spatial axes X, Y and Z as represented in figure 8. Thus, this work is restricted to a degree of freedom with locomotion only on the Z axis, opening and closing it, all of them driven by servo motor, as shown in figure 9.

Figure 8 - Anatomy of the human hand with a large number of muscles that allows its great versatility of movement in the spatial axes

Source: http://anatomia-simples.blogspot.com.br/

Figure 9 - Appearance of the hand after its construction



Source: Authorship

For the construction of this part of the work, the following materials were necessary and their respective values and characteristics represented in the tables below.

SERVO MOTORS

Table 1 - Servo Motor

Component	Servo motor
Quantity	4
Price (R$)	3.05
Price (USD)	0.97
Price (RMB)	6.10

Table 2 - Servo motor description

Dimension (mm)	22 x 21.5 x 12.4
Weight (grams)	9

Speed	0.12second/ 60degree (4.8V no load)
Torque (4.8V)	17.5oz /in (1kg/cm)
Working Temperature (Degrees Celsius)	-30 to +60
Voltage(V)	3.0~7.2

RESISTORS

Table 3 -Resistors

Component	Resistors
Quantity	Several
Price (R$)	100pcs/0.50
Price (USD)	100(pcs)/0.32
Price (RMB)	100pcs/1.00

CONNECTORS

Table 4 -Connectors

Component	Connectors
Quantity	Several
Price (R$)	100pcs/0.50
Price (USD)	100(pcs)/0.32
Price (RMB)	100pcs/1.00

As the actuator will manipulate elements, some standards have been standardized by international organizations for the homogenization of results, according to the ISO/DIS 14539 (1998) standard, as follows:

I. Geometry of the fingers and palm;
II. Positioning of the fingers on the palm;
III. Shape of the fingers and their movement during grasping;
IV. Number and positioning of actuators;
V. Number and positioning of sensors;
VI. Power transmission mechanisms;
VII. Manipulator-effector clamping mechanism;
VIII. Type and gripping force;
IX. Operation time (grasping, cycle time);
X. Type of control system employed (force and/or position);
XI. Number and material of fingers;
XII. Number of degrees of freedom of the fingers;
XIII. Geometry, weight, maximum and minimum temperature, magnetic properties and surface characteristics of the object to be manipulated.

With the hand ready, the next step is the setup and control process, in which case the project will be developed in three stages:

1. *Myo Setup*, the *Myo experience* starts with "*Myo Connect*", which interacts between the software and the *Myo* clamp itself, to provide basic control of pre-programmed applications. *Myo Connect* is the tool created by *Thalmic* to facilitate setup and have a better experience to explore the capabilities of the *Myo* armband. *Myo Connect* can be downloaded for free directly from the developer's website through the *link* ,; developer.thalmic.com/downloads.

The Myo Connect Software provides a *menu* with a few options and commands. After its installation, enter the "first steps" tab, "basic configuration" then a basic tutorial, follow these instructions to configure the *Myo armband*.

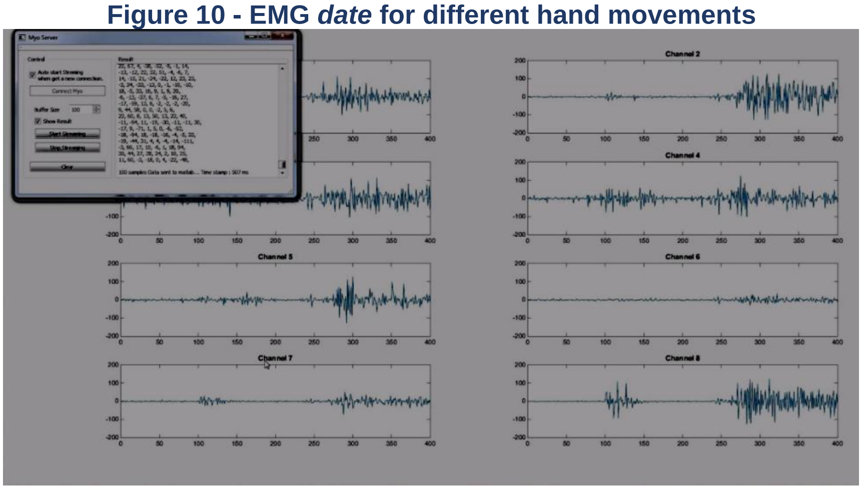
Myo Connect has built-in features to control certain presentation and media applications on *Windows* and *Mac OS X*. *Myo Connect* will automatically allow control of these applications if executed in the foreground.

MYO SCRIPTS

In addition to the built-in capabilities to control applications, *Myo Connect* provides scripting support. *Myo Scripts* allows response to clamp events and issues commands to the system. Scripts can be loaded and managed through the Application Manager, available in the *Myo Connect menu*.

2. Myo interaction, *Arduino* and codes. With *Myo connect* properly installed and configured to perform the movements, it is first necessary to obtain the EMG and IMU *data*. The codes used here were obtained directly from the developer's website except for some minor adjustments in the original base code, this code can be observed in appendices A and B, its results can be observed in the following figures:

Figure 10 - EMG *date* for different hand movements



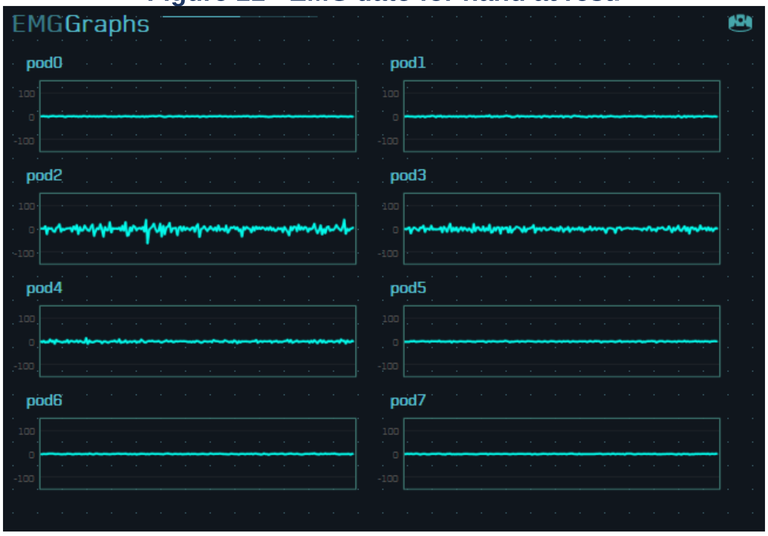
Source: http://diagnostics.myo.com/

In these *scripts*, only five moves will be of paramount importance in the development of the same thing. They are:

RELAXED ARM

In this configuration, there is no movement of the device, as the arm is at rest and will serve as the basis for the analysis of the incoming EMG signals. Figure 11 shows the characteristic EMG for this movement.

Figure 11 - EMG *date* for hand at rest.

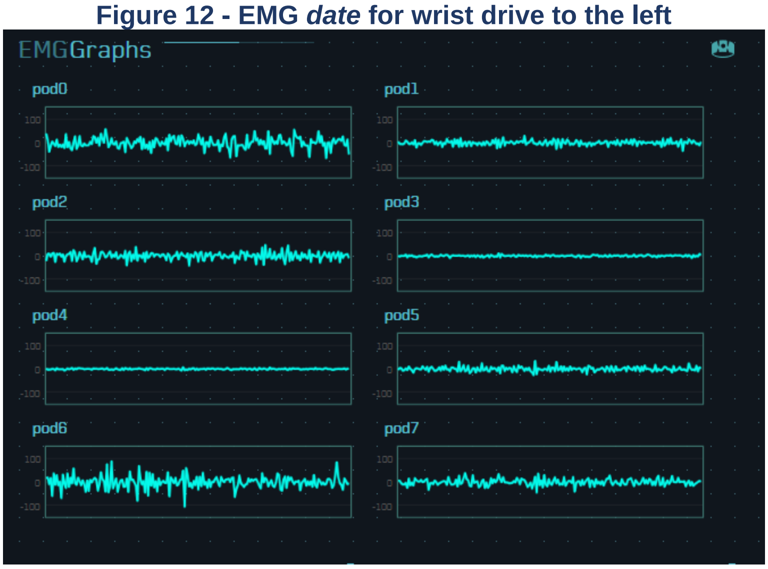


Source: http://diagnostics.myo.com/

LEFT PULSE

This command will trigger the negative movement on the Z axis, interpreting this signal the bionic hand will move vertically downwards. Figure 12 shows the characteristic EMG for this movement.

Figure 12 - EMG *date* for wrist drive to the left

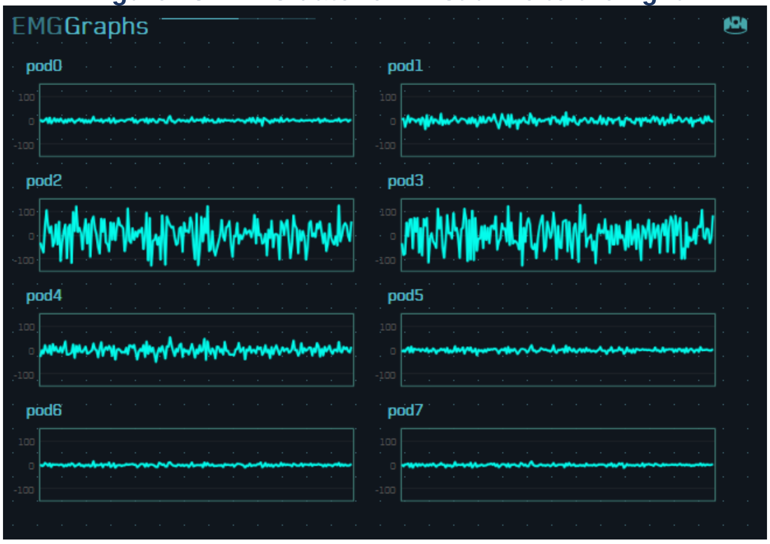


Source: http://diagnostics.myo.com/

RIGHT PULSE

This command will trigger the positive movement on the Z axis, interpreting this signal to the bionic hand will move vertically upwards. Figure 13 shows the characteristic EMG for this movement.

Figure 13 - EMG *date* for wrist drive to the right

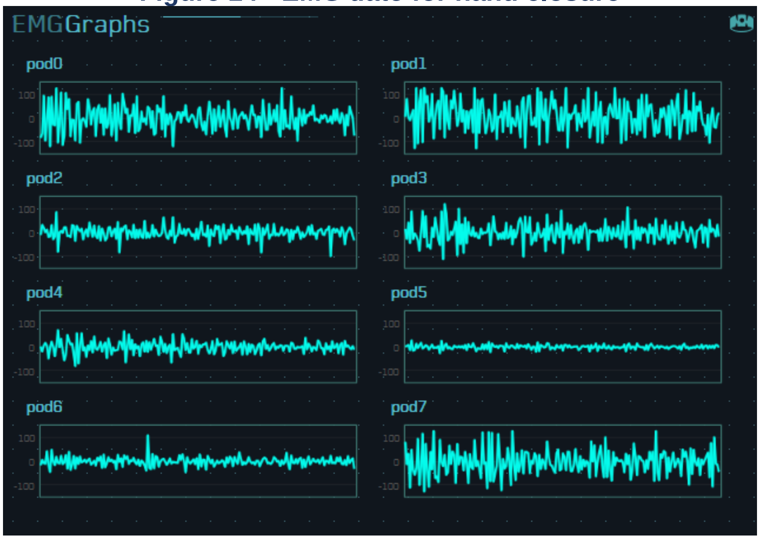


Source: http://diagnostics.myo.com/

CLOSING HAND

This command will activate the servo motors, interpreting this signal the bionic hand will close and hold in that position until the opening command is executed. Figure 14 shows the characteristic EMG for this movement.

Figure 14 - EMG *date* for hand closure

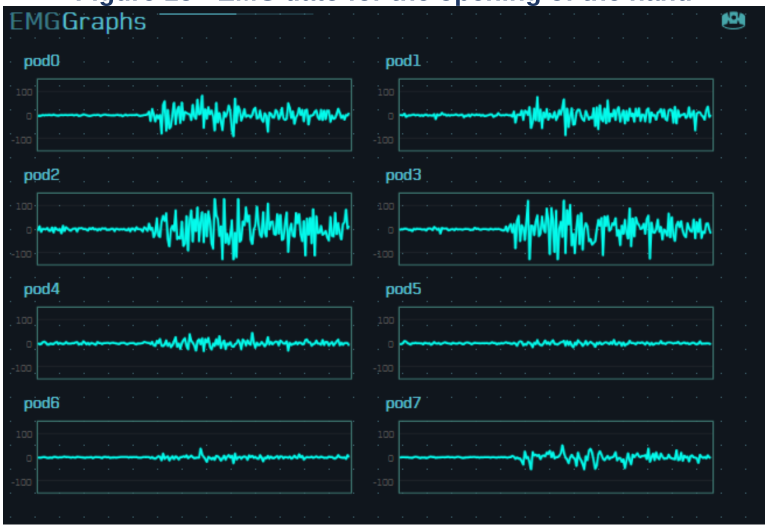


Source: http://diagnostics.myo.com/

OPENING HANDS

This command will revert to the movement of the servo motors, interpreting this signal by bionic hand will open only by the relaxation effect of the servo motors. Figure 15 shows the characteristic EMG for this movement.

Figure 15 - EMG *date* for the opening of the hand

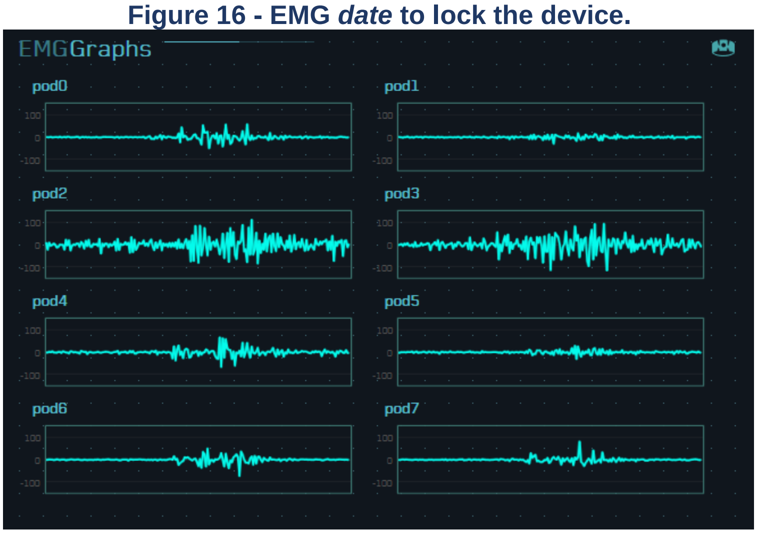


Source: http://diagnostics.myo.com/

LOCKING THE DEVICE

This command will be to lock the device, its activities in the last command executed, the signal for the lock will be the double pinch movement with a time interval of less than 2 seconds. Figure 16 shows the characteristic EMG for this movement.

Figure 16 - EMG *date* to lock the device.



Source: http://diagnostics.myo.com/

Once the configuration, identification and storage of these commands is finished, you can finally move on to the third and final step, which is the interaction between Myo and *Arduino* to perform the described hand movements.

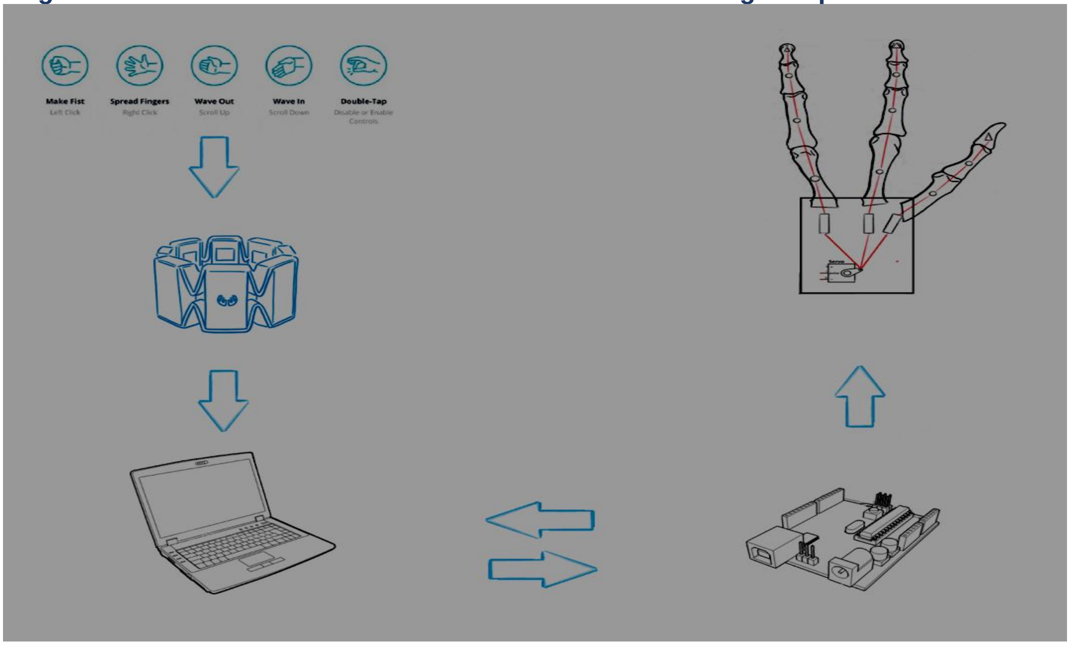
3. Arduino Interaction - Robotic hand.

In this stage, everything presented in figure 17 is joined, that is,

I. The data collection that is carried out by *Myo* in direct contact with the person's forearm.
II. Sending the data to the computer, where the *Myo connect software* will be responsible for its reception, filtering, treatment and later sending it to the *Arduino UNO.*
III. Communication between the *Arduino* and *Myo Connect* will be carried out through an algorithm, transmitting in real time the position of the arm where the sensor is located with the servos present in the hand.

The algorithm written in C language in which it will be loaded into the Arduino's memory for interpretation of the data described above, can be viewed in detail in Appendix B.

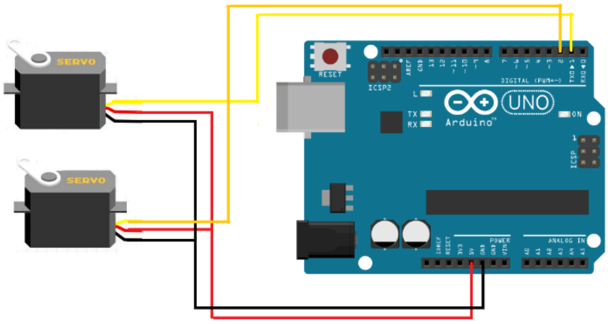
Figure 17 - Communication flow chart between the first signal up to the hand drive



Source: Authorship

With all the parts configured, just load the algorithm to the Arduino and make the connections as represented in figure 18:

Figure 18 – Connections between the Arduino and the servo motors



Source: Authorship

Materials used for this part of the work.

ARDUINO UNO MICRO CONTROLLER

Table 7- *ARDUINO UNO*

Component	*ARDUINO UNO*
Quantity	1
Price (R$)	8.90
Price (USD)	2.67
Price (RMB)	17.80

Table 8 – *Arduino UNO Features*

Micro Controller	ATmega328P
Operating Voltage (V)	5
Supply voltage (V)	7-12
Supply voltage limits (V)	6-20V
Digital I/O pins	14 (of which 6 can be PWM outputs)
Analog Input Pins	6
Direct current per I/O pin (mA)	40
Direct current for pin 3.3V(mA)	50
Flash memory	32 KB (2KB used for the bootloader)
SRAM (KB)	2
EEPROM (KB)	1
Clock Speed (MHz)	16

MYO ARMBAND

Table 9 - *MYO ArmBand*

Component	*MYO Armband*
Quantity	1
Price (R$)	587,33
Price (USD)	189,18
Price (RMB)	1299,00

Table 10 – MYO *ArmBand Description*

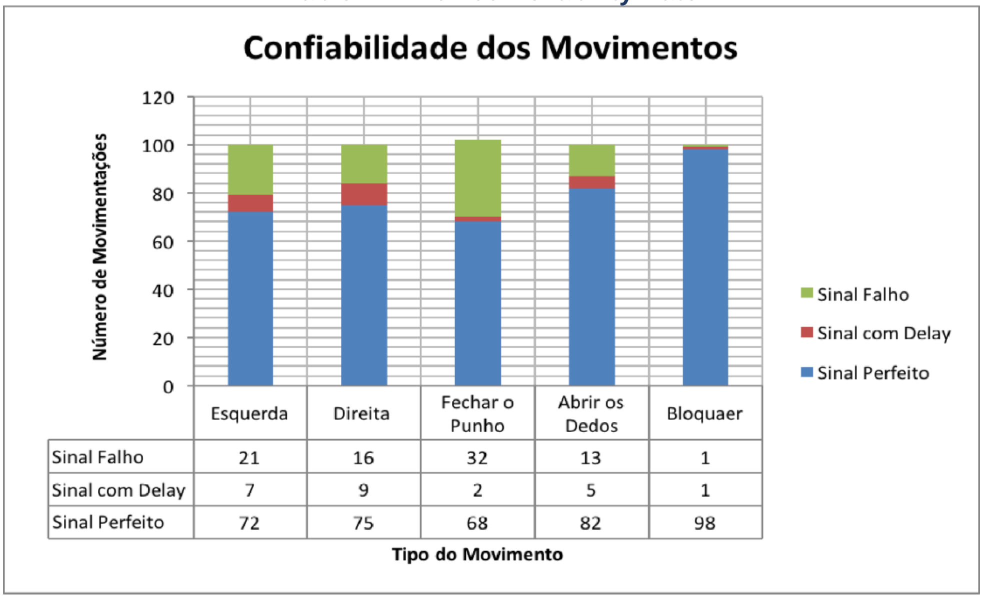
Perimeter (cm)	19 -34
Weight (grams)	93
Width (cm)	1,15
Sensors	EMG, IMU
Processor	ARM Cortex M4

In addition to these materials, it was necessary to use glue, plastic, wires, adhesive tape and styrofoam, not accounted for because they are common materials present in laboratories.

DISCUSSION AND RESULTS

With the functional prototype, the results obtained are the movement of the hand itself. Large heaps of numerical data arranged in tables with values of nerve stimuli (EMG) or spatial orientation as time functions in which they were exported in tables in spreadsheet file extension (The spreadsheet extension is . CSV). These spreadsheets were omitted here and not arranged in the appendices because they are extensive files and even with little time to capture data they generate long tables with more than 10000 outputs. This data is used by the control software for real-time hand movement as can be observed by the interaction algorithms in attachments one and two. It is also extremely important for the preparation of EMG graphs, among others, and the comparison between the expected and obtained values. To determine the accuracy of the system. Setsof 100 repetitions of each movement were performed. Theirresults were then represented by table 11.

Table 11 - Device Reliability Rate



Source: Authorship

Reliability is the ability of a system to perform and maintain its operation in routine circumstances, as well as in hostile or unexpected circumstances. Based on table 11, it is concluded that for this experiment there is an average reliability of about 79%, that is, the ratio between movements performed by the hand collected, filtered and interpreted by the system with its correct correspondence in the movement of the bionic hand is approximately

8 out of every 10 attempts. When comparing this value with the values of a human hand whose correspondence rate on the commands sent by the brain and executed by the hand can be greater than 99.99% (on a smaller scale, 10 out of 10). This value of 79% accuracy is still relatively low. Mainly due to the requirement when it comes to handling dangerous things such as fuel, knives, or precision such as driving, playing ball, etc.

Comparing the results obtained in this work with other works in the same area gives a relatively good value for its reliability, in its best projects in something around 90%. This result is obtained by using more modern sensors than *Myo* and also with the use of more sensitive and accurate software than those used in this work. Some biographies also mention the increase in degrees of freedom with the addition of Cartesian axes and in some cases their modeling, already in polar axes, these values are reduced below 50%. These results are due to the high degree of complexity to capture this signal, great difficulty in filtering signals with very small current values and also the need to use many servo motors and electronic components that are resistant, light, fast and compact.

CONCLUSION

I can confirm that at the end of the work that the goal of building a bionic hand with movement on an axis with the function of grasping was achieved, although the project still has some flaws such as the success rate in the interpretation of the movements being around 79%. It is necessary to consider that this data changes abruptly when the blocking command is removed, which in the end has no function for the movement of the hand, but had its correct response in almost all attempts.

The proposed architecture of the myoelectric control interface presented satisfactory performance. In the same way that the set made met the requirements of the proposed control structure, we realized that a very reliable means of communication between the *Myo bracelet* and the controller was established.

Arduino , being a free platform, maintained good performance and excellent responses to the commands given to it.

No tests were carried out with amputee users or even with those with coordination problems.

The movement engineering of the human body is extremely complex, very difficult to be copied, reproduced with efficiency, mobility and natural speed. Assistive technology is advancing very fast; in the not-too-distant future, there is hope that people with amputated limbs or for the pleasure of becoming superhuman will be able to enjoy this technology cheaply and efficiently.

For a future work, the addition of one more degree of freedom, and/or the addition of independent movements of each finger are desired, although it should be studied with caution, as these are extremely difficult processes and should proceed in short and gradual steps. In order not to become something too complex to program, control and also to obtain better results than those presented in this work.

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