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IAN DOS REIS AND ARAGÃO

Brain-Computer Interface: A New Frontier for Human-Machine Interaction

Final report

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Brain Computer Interface: A New Frontier for Human-Machine Interaction

Dissertation presenting the final delivery of the Pro- Scientific Initiation project by the Superior School of Advertising and Marketing.
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Summary

The research and innovation of human-machine interfaces (HCI) are constantly developing; the more intuitive and friendly the interface, the more productive its use will be. Several companies and laboratories invest time in studies of more fluent interaction techniques, seeking to facilitate the relationship between man and the technology around him.

Given this scenario, to improve the man-machine relationship, interfaces interact directly with the nervous system, fostering an area of study known as Brain-Computer Interface (BCI), providing new possibilities for the development of the HCI area. In the state-of-the-art BCI, this work investigates the functionalities and understanding of the treatment of biological signals, going through the capture and processing of movements, from muscles (EMG - Electromyography) in a mysterious way through the BCI device, the Myo.

At the end of the study, a deep knowledge of BCI and its multidisciplinary applications was obtained, which allowed the prototyping of an application using the enhancement of human-machine interaction in home automation. Besides this, it was glimpsed the capacity of continuity by implementing interactions with other devices, still putting on the horizon new studies on the area of signal processing.

Keywords: Human-Machine Interaction. Brain Computer Interface (BCI). Electromyography (EMG). Human Computer Interface (HCI). Myo Armband.

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1. Introduction

1.1 The State-of-Art of Human-Machine Interaction

1.1.1 Man-machine interaction and its evolution

The interface between humans and machines is constantly subject of intense research and innovation since there is the assumption that the more intuitive and friendly this interaction is, the more productive the work development will be (HEWETT et al., 2014). Over years of studies and tests, a new area was established to address this specific subject; this area is known as Human-Computer Interface (HCI) (GREEN; PAUL, 2008). In this context, the HCI study area proposes developing or improving the security, utility, effectiveness, and usability of the entire environment that uses or is affected by computer technology.

Innovations in the HCI area generate new business models, such as, for example, the innovation of the mouse, which when invented enabled greater productivity at work. Currently, several companies and laboratories invest time and effort in studying more fluent man-machine interaction techniques. In this race to overcome existing limits, touch screen interfaces, augmented reality, virtual reality (VR - Virtual Reality), among others, have been created. Google developed devices such as Google Glass VR glasses to increase man's interaction with the environment around him. Because it is wireless, it is not limited and has a connection to a computer.

Figure 1 - The interaction of Virtual Reality

Image taken from the website: https://cdn.sagaentretenimento.com.br/uploads/2016/05/gear-vr-hero.jpg

In addition to these forms of Human-Machine interaction, there are techniques that work with signals captured by the central nervous system by specific sensors. Through these techniques, interactions known as Brain-computer interface (BCI) were developed, which now stand as a new frontier of implementation for HCI areas.

As with HCI, there are several commercial devices for working with BCI. Among these devices, some bracelets capture signals from the forearm, process them, and then translate them in some form to a machine, allowing to mimic human movements; this device is further detailed below. In this work, the BCI of this bracelet genre is used.

Figure 2 – Interaction controlling a Drone through Myo

Image taken from the website: https://tech-bit.ru/image/img_dop/wysiwyg/3/Early_Prototype_Myo_AR_Drone_2.jpg

The eccentricity of the BCI area matches its way of capturing biological signals from the nervous system, interpreting them, classifying them, and transforming them into deterministic commands for machines. There are two ways to capture these physical signals; they can be captured invasively or evasively. The technique is called invasive when the capture sensors somehow invade the human body to obtain the signals; on the other hand, it is called elusive when the capture sensor obtains the signals through the surface of an area of interest. In addition to this, the techniques differ concerning the site from which the signals are extracted. Therefore: 1) when the signals are captured directly from the central nervous system (brain), these signals are signals from an electroencephalogram (EEG); 2) when the signals are obtained from the cardiac system, these signals are signals from an electrocardiogram (ECG); 3) when the signals are obtained from the somatic system, coming basically from the muscles, these signals are signals from electromyography (EMG) (BEAR et al., 2002).

In this research, an investigation is developed that envisions the acquisition of biological system signals through a BCI device that in commands that are used by another device (IoT) in a mimification process. The signals collected here are EMG captured from the somatic system, forearm, for reasons of accessibility and practicality of study. Once the technique employed in this work is defined, in order to capture the signals, a the market is employed for capturing signals in the human body; its specifications and details are presented in the topic "The development of interaction" (1.1.5), showing why this device is used..

The following sub-topics explain the neuroscience studies that originated the techniques used to develop this scientific initiation. There is also a historical contextualization to modern neuroscience studies that gave birth to the principle of BCI interaction. Next, in another topic, the solution to be proposed by this work to overcome some of the limitations imposed by the touch technologies created by HCI so that it could be worked; the emergence of interaction (BCI), from the development of interaction (EMG) to the use of these studies to be applied use of interaction (Myo).

1.1.2 Discovering the action potential

The studies of the brain are as old as science itself. Still, when researchers realized that the best approach to understanding the function of the brain came with interdisciplinarity, they were able to produce a new perspective of study for the most complex organ of the human body (BEAR et al., 2002).

From this new perspective, the Italian scientist Luigi Galvani and the German biologist Emil da Bois proved that muscles can move when stimulated electrically and that the brain can generate electricity. Thus, a new concept for science emerged: the nerves were like wires capable of conducting electrical signals to and from the brain (BEAR et al., 2002).

Figure 3 - Action potential illustration

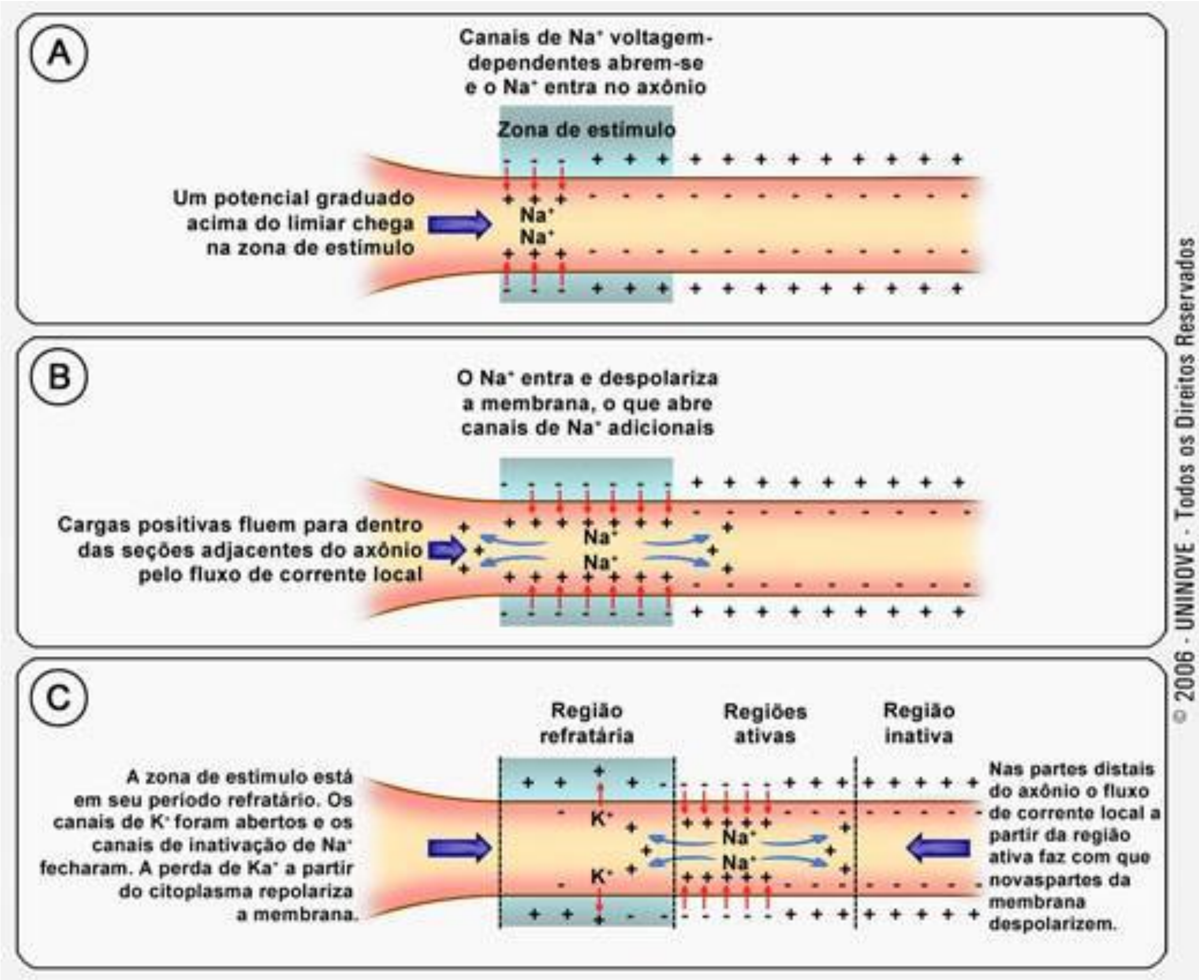


Image obtained from the website
http://ead.uninove.br/ead/dps/biof02/imagens/a06_img04_biof02.jpg

The proof of the electrical capacity of the brain generated new studies by Julius Bernstein (1902). He based himself on Nernst's concept of gas diffusion to explain the electrical potential in the brain. He postulated that this neural activity potential occurs due to the high permeability of K+ (potassium ion) across the cell membrane, in contrast to other ions, due to the higher concentration of this ion in the intracellular medium about the extracellular medium (MR, 1999).

In the 1940s, the physiologist Andrew Fielding Huxley and his partner Alan Lloyd Hodgkin developed the voltage-clamp technique (TH.; JS., 2003). The method controls the voltage across a small isopotential area of a nerve cell by an electronic feedback circuit. This current is equivalent to the ionic current that flows through the membrane in response to a voltage step (voltage-step) (GRABIANOWSKI, 2007). This discovery later yielded, in 1963, the Nobel prize in medicine and physiology to Huxley and his partner Hodgkin for being the first mathematical model for the generation of the action potential of a neuron.

Thanks to Huxley's studies, neuroscientists have developed a new field of study, computational neuroscience, which is the area of neuroscience that has as its objective the apprehension of brain functions in terms of information processing which is only reduced in the nervous system (CHURCHLAND et al., 1993).

The studies of two great scientists provided the development of this new area of neuroscience: Wilfrid Rall, a neuroscientist considered one of the founders of computational neuroscience, for having initiated biophysically realistic computational modeling of neurons and dendrites, using cable theory to build the first multicompartmental model of a dendrite (RALL, 1962), and passive and active compartmental modeling of the neuron (RALL, 1964); David Marr, a neuroscientist and psychologist who integrated findings from psychology, artificial intelligence (AI), and neurophysiology into new models of visual processing, focused on the interactions between neurons, suggesting computational approaches to the study of how functional groups of neurons in the hippocampus and neocortex interact, store, process, and transmit information (DAWSON; MICHAEL, 1998).

With the advances in computational neuroscience, the neural models proposed by Wilfrid Rall, David Marr, and other neuroscientists sought to approximate computer processing to the "processing" performed by the brain. They seek a human computational mimicry similar to that performed by the central nervous system (CNS). Creating computer models that reproduce the computational properties of the encephalon help neuroscientists understand how specific study features develop without the use of an invasive method (BEAR et al., 2002). The information provided by these models is usually discussed as a "technological discipline that deals with parallel, distributed, and adaptive information processing systems autonomously developing information processing capabilities as responses to the information environment." (HECHT-NIELSEN, 1990).

Based on neurocomputing studies, a remarkable technological advancement in HCIs as possible became something as ubiquitous in society, such as standard computer interaction interfaces (VALLABHAENI et al., 2014). Likewise, a need has been stimulated to create interfaces connected directly to the human body. This is because there are inefficiencies in a machine's most common interaction mechanisms. Thus, a more advanced study of the neurocomputing area is needed.

With the development of a communication pathway between the brain and the machine, it has been possible to add new functionalities to the Brain-Computer Interface (BCI) study, opening up many applications. There is a new area of development to add new and more complex functionalities to the HCI. One of the applications of HCI is to allow people who have some muscle movement restriction to somehow ease their interaction restriction, for example. Thus allowing users who are unable to generate muscle movements for everyday interaction with the machine to mitigate this deficiency.

1.1.3 The interaction that revolutionized conventional methods

The processing power of modern computers and our understanding of the human brain Nowadays, there is a wide variety of studies to develop new technologies. We consider the potential to manipulate computers or machines through human "thought" and the power to work an action without being physically performed (HEWETT et al., 2014). The development of research in BCI does not exist only for the search of more convenient ways for human-machine interaction. There are a large number of people who have some physiological disability. Thus, the development of BCI can be considered a way to improve the quality of life of these people, therefore existing a vast potential market.

Figure 4 - Capture of stimuli in the BCI interaction

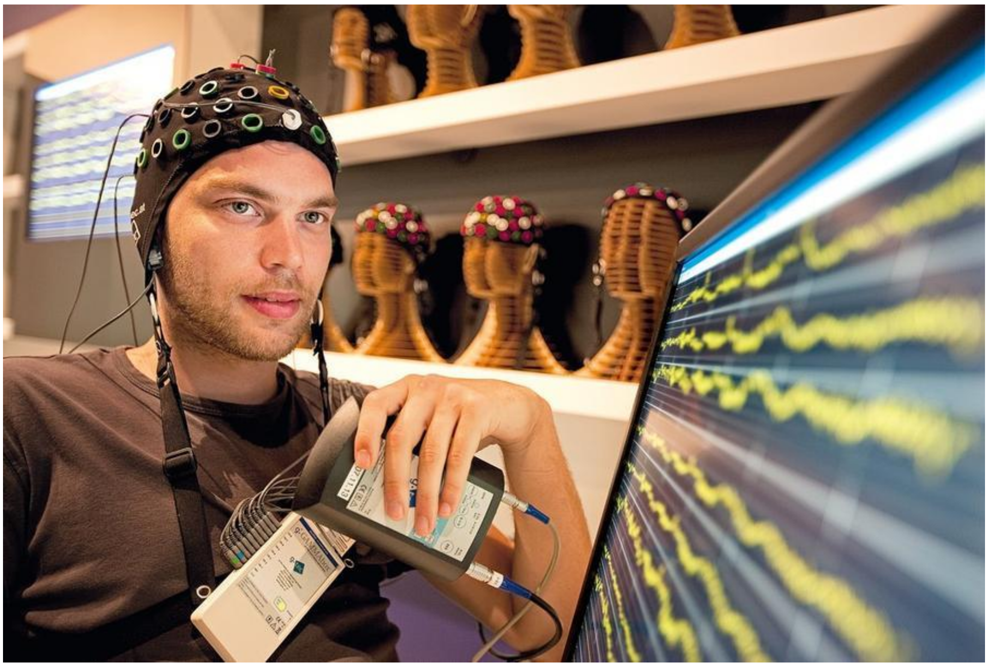


Image taken from http://www.science-in-amsterdam.nl/files/images/Brain%20and%20Cognitive%20Science.jp g

The integration of a BCI system allows direct control of, for example, a computer application or a neuro-prosthesis, solely by human intentions as reflected by the appropriate brain signals (WOLPAW et al., 2002). The reason for the use of BCI interaction is said to be the better integration with the brain's functioning. Every time we think, move, feel or remember something, our neurons are at work. A work done by small electrical signals, generated by the electrical potential and carried by the K+ ions in the membrane of each neuron, these signals are called action potentials (AP). Specific electrical devices can capture these signals; when transmitted across the membrane, they can be detected, interpreted, and used by researchers to interact with some instrument.

Another less invasive technique to capture the signals emitted by the CNS is to use a set of electrodes attached to the scalp to "read" the signals from the brain; this technique is known as EEG (WOLPAW et al., 2002). Regardless of the procedure implemented, the most challenging task is interpreting the brain signals to accomplish the desired movement for those who cannot physically move. What is done to "interpret" these signals is to employ algorithms with computer learning that interpret the captured calls. Thus the software can seize the signs associated with the thought of the action and analyze it in the direction that the device performs that action.

é Technologies using BCI have also gained popularity in the form of measurement devices. They allow accessing and "decoding" macroscopic brain states in real-time, such as attention, performance ability, emotion, etc. Moreover, the signals obtained by BCI techniques make it possible to optimize and improve human performance and potentially achieve new categories of commands. The development of such a device is a highly interdisciplinary research topic, bringing together scientific research from many different fields from psychology to neurophysiology, physics, engineering, mathematics, and computer science. Thus, it focuses mainly on data analysis and computer science to develop the BCI interaction.

Although its initial focus was on applications for patients who have lost some motor function, nowadays, the applications of this research area are getting more expansive, with new purposes to be investigated, such as game development, monitoring of mental states, and decoding of diseases. Brain mapping research is often used to repair human cognitive or sensorimotor functions. Recently, BCI technology has also been used for a larger audience, i.e., non-medical purposes (GRABIANOWSKI, 2007).

Figure 5 – Myo and the interaction with a mechanical arm

Image taken from https://i.ytimg.com/vi/LSuzMxQDmzg/maxresdefault.jpg

Such innovative applications have seen a substantial increase in interest, which serves as evidence for the promising BCI technology for non-medical uses with an improvement in ease of use without requiring minimal training with a general usability and short control latencies (GRABIANOWSKI, 2007). Given this, the possibility of detecting neural signals to interpret their electrical differentials to translate macroscopically what they mean and from which location in the brain they originate is constituted—directing them to an electroencephalogram device that provides a reading to be studied and worked on by researchers. Hans Berger, a German psychiatrist who enabled vast advances in BCI interfaces and the development of EEGs in 1929. It was an enormous historical breakthrough providing new neurology and psychiatric diagnostic tools at the time (MILLETT, 2001).

Berger's research has generated a vast separation between systems that use EEG activity and those that started to use EMG activity, activities caused by muscle movements that are much simpler and easier to capture for their study and treatment. Despite this vast advance, even today, it is still an arduous job to capture and isolate the various brain wave segments to precisely detail the nerve impulse and perform its treatment.

1.1.4 The study of interaction with the human body (EMG)

Throughout history, in the search for understanding the functioning of the central nervous system (CNS), there was the discovery that there are specialized cells for this system; these have the characteristic to receive and transmit electrical stimuli and are known as neurons. To study the structure of nerve cells, researchers had to overcome several obstacles: the microscopic size, cutting measures, the lack of staining for differentiation of cells with the naked eye, among others. With the development of the microscope, artificial dyes that react with the cells and give them a specific coloration, and other research techniques, it was possible to study the nervous system further.

All tissues and organs of the body are made up of cells whose specialized functions and the way they interact determine the organs' functionality. The brain is the most sophisticated and complex organ in the human body, but the basic strategy used to unravel its function is not very different from that used to research the pancreas. One method is to start by getting a sense of how the brain's cells operate individually and then look at how they act together. Neural systems are groups of neurons that transmit information to other neural systems and other systems in the human body. This information travels through neurons, including the muscles, which specialize in making movements. Electrical impulses transmit these signals by the neuron, the electrical potentials, and chemical means between neurons (BEAR et al., 2002).

Figure 6 - Illustrative model of a neuron

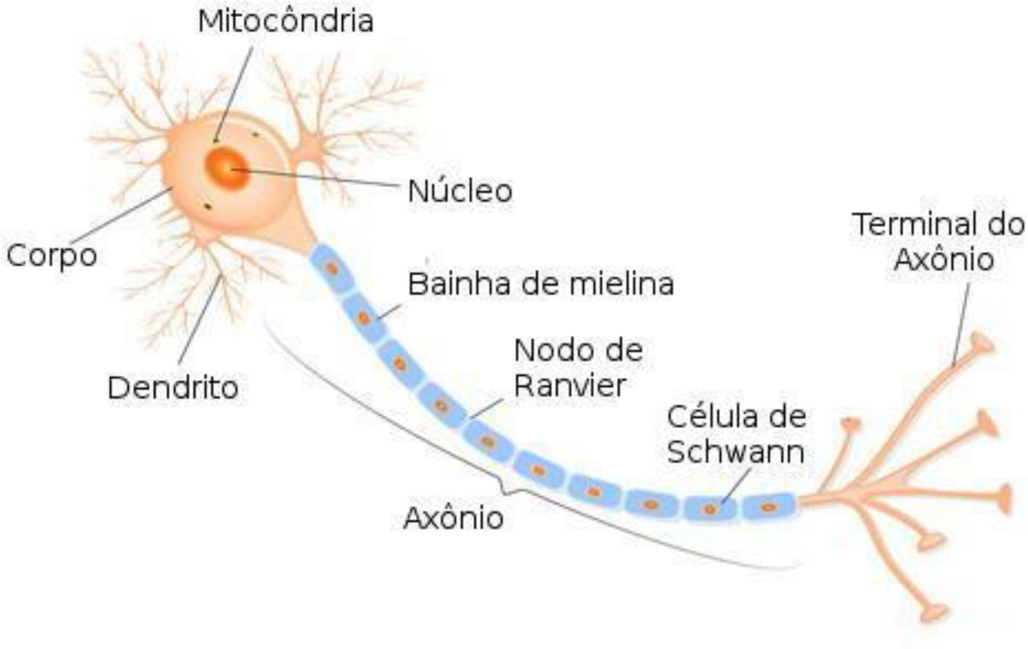


Image taken from the website: http://www.infoescola.com/wp-content/uploads/2010/01/estrutura-neuronio.jpg

The first researchers who discovered the electrical potential of the neuron concluded that the neuron conducts the captured information using electrical signals that travel through the axon. The researchers compared the state of the neuron to transmit electrical signals like what a telephone cable conducts. With more accurate observations and tests, they soon concluded that in a copper telephone cable, the information is transmitted over long distances and at high speed, because the telephone cable is an excellent conductor of electrons, it is well insulated from any external interference; whereas in neurons, the transmission presents a superb dissipation of energy, due to the medium if the myelin sheath did not exist.

The chemical medium in which neurons exist are conductors of electricity, so the electrons transported by the axon end up leaking into the saline extracellular medium. To mitigate this effect, the myelin sheaths that surround the axon exist. The dissipation of the action potential occurs in the nodes of Ranvier, and for this reason, they are rich in connections with other neurons. Some researchers seek to find information codification in the frequency of action potentials of individual neurons, treating data transmission in a manner analogous to Morse code (BEAR et al., 2002).

There are two models of neurons capable of generating and conducting action potentials; they include both nerve cells and muscle cells because they possess an excitable membrane. When an excitable membrane is not generating impulses, it is at rest. And, in the cytosol on the surface of the membrane, there is a negative electrical charge compared to the external command. This difference in electrical charge is called the resting potential (BEAR et al., 2002). The action potential is simply the reversal of this condition, and for a millisecond, the membrane's electrical potential becomes positive.

Figure 7 - Action potential graph

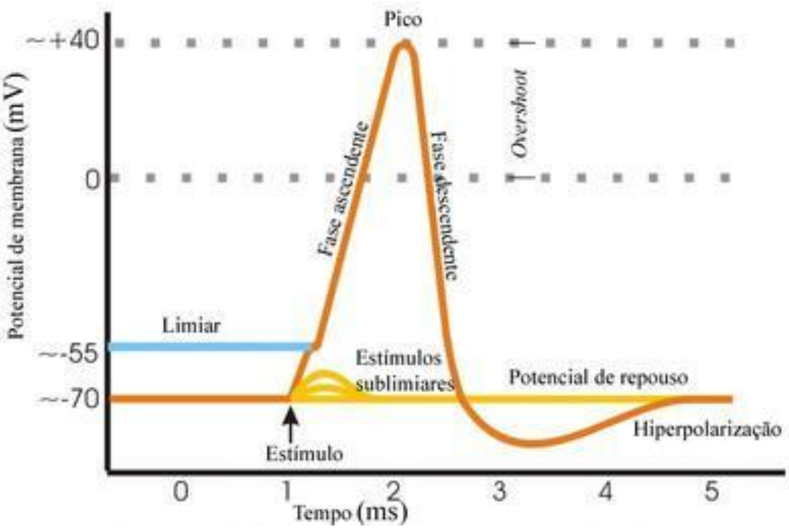


Image taken from the website: http://1.bp.blogspot.com/-rEHVnDDzuls/U2CEQUrIxjI/AAAAAAAAAE5Y/xJBhQWLOgI o/s1600/potencial+de+acao2.png

From discovering the action potential, scientists began to develop techniques to capture the stimuli transmitted by the neuron, to monitor the electrical activity of the excitable membranes of the nervous system. Its main objective is to analyze the speed of electrical conduction and the state of the motor units to detect lesions of the peripheral nervous system and muscle localizing the lesion within the motor unit (MU) and to be able to quantify such lesions. The motor unit action potential (MUAP) is the temporal and spatial summation of the individual action potentials of all the fibers of a MU.

One of the techniques created is electromyography (EMG), which monitors the membranes, representing the measurement of sarcoma action potentials as a voltage effect as a function of time (RALL, 1964). The EMG is an algebraic summation of the electrical potentials generated in the muscle fibers during different categories of contraction, detected under the working area of electrodes applied to an area of the human body. An EMG can be affected by muscular, anatomical, and physiological properties of the human body and is thus performed by controlling the peripheral nervous system, making it possible to evaluate the neuromuscular system.

In the acquisition of the EMG signal, the amplitude of the PAUM derives from several factors such as the firing rate, characteristics of the muscle fiber membrane, diameter of the muscle fiber, the distance between the active muscle fiber and the EMG signal detection site, the surface area of the electrodes' pickup, and the extent to which the electrodes are distributed over the muscle, i.e., the location of electrode placement (BEAR et al., 2002). The best place of the electrode is between the motor point and the tendon of muscle insertion; in addition, their capture bars should be perpendicular to the muscle fibers and their tuning surfaces separated. To establish a more reliable standardization of the analyzed data, the SENIAM (Surface EMG for a Non-Invasive Assessment of Muscles) details these procedures, with recommendations for configuration and positioning of the electrodes on the human body (SENIAM, 2017).

Usually representing the measurement of action potentials as a voltage effect as a function of time. There are three main methods used for the detection of muscle signals from electromyography, the insertion of needles into the muscle belly and restricted motor units (invasive), the attachment of electrodes on the skin in the region corresponding to the muscle belly, but with a paired metreage to reduce noise from the site of origin of the acquired signal (evasive), and a method of fixing a matrix or mesh of electrodes on the skin as multichannel high-density allowing a larger area of capture in the muscle belly enabling the perception of various changes of action potentials of the excitable membranes (BEAR et al., 2002).

For different situations, different types of electrodes and analyses:

- Analysis of the signal in the time domain, that is, the possible increase in the number of MUs activated during a muscle request.

Regarding the time domain analysis, the amplitude of the signal assimilated by superficial muscles is reduced by factors such as skin and subcutaneous fat tissue resistance, which vary from one location to another. In this logic, one cannot compare absolute EMG values between individuals, from one muscle to another, and even for the same muscle if the placement of the electrodes is changed. In the time domain, the signal can indicate the time at which a given power started and ended its activation and the amount of its activation in the amplitude of the signal received in the EMG. In this analysis profile, we can use the RMS (Root Mean Square) values, the integral, and the rectified value by the average frequency, which provides us with parameters of the signal amplitude (KIMURA, 2013).

- Analysis of the signal in the activation frequency domain, that is, how many times in the unit of time the MUs are activated in an isometric or dynamic condition.

In the frequency domain, it is possible to determine the frequency content of the EMG signal. A commonly used method to characterize it is the mean frequency (Fm), which represents the center value of the frequency spectrum. Alternatively, the median frequency (Framed) is the frequency that divides the range into two halves based on the energy content of the signal. These parameters reflect the speed of muscle fiber conduction, and the recruitment of MUs decreases with an individual's exposure to muscle fatigue, exhibiting changes before any force modification; thus, they are applied primarily as an indication of the onset of contractile fatigue (KIMURA, 2013).

The latter technique allows for an estimate of the conduction velocity of action potentials. Usually, the evaluation of muscle function through signal analysis has applications concentrated in the clinical area to diagnose neuromuscular diseases and rehabilitation (physical therapy) to re-educate muscle action and reveal muscle action in specific movements.

Figure 8 – Obtaining signals by EMG in the muscle

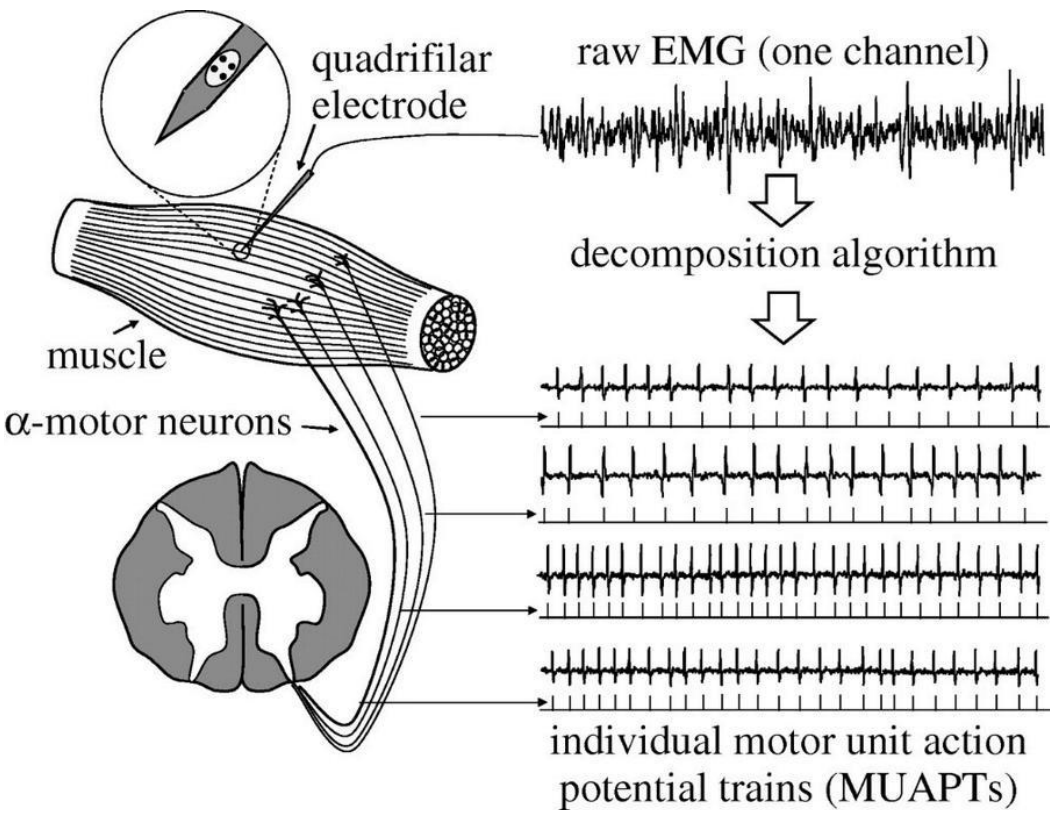


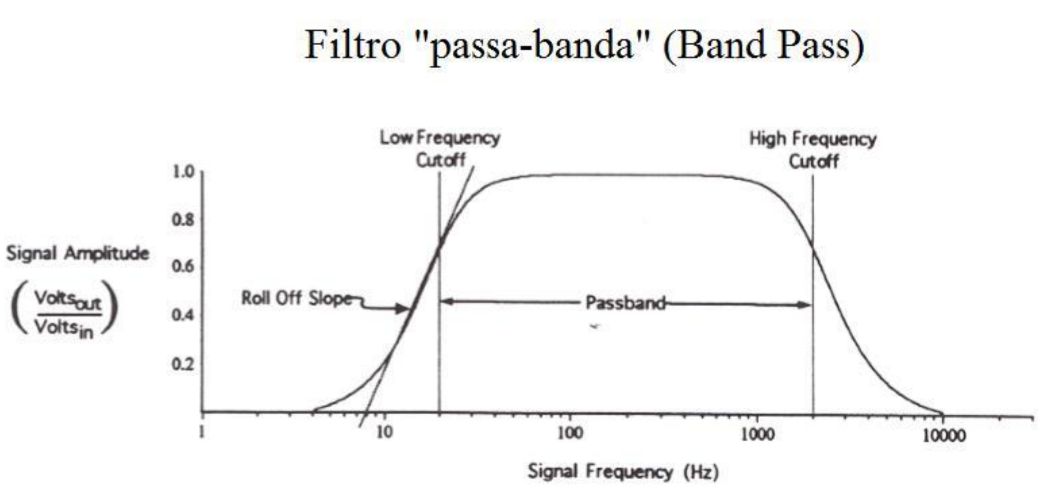
Image taken from the website: http://d29qn7q9z0j1p6.cloudfront.net/content/roypta/367/1887/357/F3.large.jpg

After data collection, necessary procedures are required for signal processing. The EMG signal captured in the human body is analog (a continuous movement in time), converted to a digital signal registered by the computer. For this, specific parameters must be adjusted in the signal acquisition, depending on the task and the objectives (PH.; M., 2006). The tissue between the muscle fiber and the electrode site creates a filter effect, whose bandwidth decreases with increasing tissue thickness. This means that the greater the consistency of this tissue, the greater is the impedance (noise) for signal capture. Impedance is the resistance biomaterials (skin, cartilage, fascia, muscle, bone, ligament, fat, etc.) offer to an alternating current.

Filters attenuate signals in various areas of knowledge; they can be originated by Hardware, analog circuits (amplifiers, resistors, capacitors), and Software or Digital filters, specific algorithms such as Butterworth Chebyshev, among others. In EMG, when the noise frequency differs from the frequency of the signal of interest, its use enables signal cleaning. The collected signal, or raw signal, is subjected to a specific and valuable filtering process since it minimizes the probability of noise in the treated signal. Thus, the frequency of the electrical network used by the devices for the signal collection technique tends to use a frequency of 60Hz, at a voltage of 120 V. While the signals from the different muscle fibers collected range from 70 to 125 Hz, slow fibers, and from 125 to 250 hertz for fast fibers (KIMURA, 2013).

The first filter passed is called the band rejection filter (Band Stop), in which the signals collected at frequencies near 60Hz (frequency in electric average) are removed. Another filter used is the band delimiter called the "bandpass filter" (Band Pass) that delimits the frequency spectrum to the desired amplitude, for example, 20-250Hz. Once the signal has been obtained and processed, it quantifies the density of the collected signal spectrum.

Figure 9 - Band Pass Filtering Example



Two commonly used ways to obtain this value are the integral of the EMG signal (iEMG) and the RMS. The iEMG is calculated by integrating the entire area in the frequency spectrum filled by the EMG signal. Since this spectrum has a Gaussian delineation, i.e., a mean equal to zero, the RMS solves this drawback widely used in investigations involving EMG. Another implemented treatment is the Fast Fourier Transform (FFT) algorithm, which generates the median and means frequency values since it has excellent precision for muscle fatigue analyses.

Electromyography has numerous applications, notably in clinical medicine, for the diagnosis of neuromuscular diseases; in rehabilitation, in the re-education of muscle action (electromyographic biofeedback); in anatomy, to reveal muscle action in specific movements; and in biomechanics, to serve as a tool to indicate some phenomena.

However, in this scientific initiation, it is used with the application in biomechanics. In this area, the register of the electromyography activity allows us to investigate which muscles are used in a particular movement in the sense of serving as an indicator tool of phenomena such as the level of muscle activation during the execution of the action, the intensity, and duration of the muscular solicitation, and to enable inferences regarding muscle fatigue, but mainly for those who do not have the whole arm.

The study and analysis of the electromyography signal identify events that occur over time with specific frequency patterns. In the frequency domain, the changes occurring in the spectrum of the action potential in the electromyographic signal already allows us to identify and quantify the median or average signal frequency of a given movement, even though it is so sensitive to changes in recruitment, capture, of the motor units of different users.

Therefore, once the electromyographic signal has a static function in the distribution of frequencies in the intervals of interest provided by pre-programmed movements, it becomes possible to capture the action potentials and translate them into a machine code.

1.1.5 Interaction development and use (Myo)

One of the most exciting areas for technology development in recent years has been gesture control. It allows users to interact with computers without touching any input, such as a keyboard or mouse. There are no doubt several devices that perform these approaches. However, not all technologies can be accurate and realistic to human movements.

Figure 10 – The Myo bracelet

Image taken from https://www.myo.com/

Thalmic Labs, a company started by three engineering graduates from the University of Waterloo, has developed an armband called Myo with innovative technology. Based on impulses captured from the human body, the bracelet captures human gestures and transforms them into machine code. This innovation comes from studies of BCI interaction and analysis of the interaction of EMG with the human body.

Myo captures the electrical activity of muscles through a set of electromyography (EMG) sensors that work with a mesh of electrodes with high-density multichannel, allowing a more accurate capture of muscle contractions, combined with a gyroscope, accelerometer, and magnetometer to recognize gestures and arm movement to interact with an interface or machine.

For accurate capture of human body movements, Myo uses a gyroscope, accelerometer, and magnetometer to measure the speed and direction of the user's arm movement. When users make gestures with their hands, the forearm muscles emit various bioelectric signals. At the same time, advanced built-in sensors receive these signals analyze them with their built-in algorithm to send the result of the device's gesture perception. The collected data is communicated via Bluetooth translated into motion on the screen of an intermediary interface, thanks to motion detection algorithms that perform calculations on the changes occurring in the action potential spectrum in the EMG signal.

The armband is inserted in a market that has generated many applications by being a significant technological breakthrough as the first stand-alone device used in gesture capture. Its biggest competitor, the Leap Motion controller, uses infrared cameras to enable minimally decent gesture control and needs to be within a short distance of a computer. Unlike other gesture control devices, which rely on positioning via a monitoring camera, the Myo works only by reading the EMG. The Myo allows users to control a computer from distances more significant than a few meters, quite unlike Leap Motion and its competitors. Likewise, there is a requirement for proximity to a controller by Leap, which makes its use more like a keyboard and mouse interaction.

For software development using Myo, the Thalmic Labs website provides a portal for developers to access the development tools, with step-by-step explanations for their use, detailing how it is possible to develop with its SDK (Software Development Kit) and its APIs (Application Programming Interface)—giving programmers access to a virtual library that acts as the manual for the Myo development platform and how to start their project. In addition, the portal for developers has a forum for questions in which the developers themselves help with problems encountered in the system and examples of coding created on the bracelet. You can see release notes, bugs, and known bugs, providing an overview of what's new in the release of each version.

The development of human-machine interaction proposed by the bracelet goes far beyond the technologies developed so far. And, for the use of a controller like Myo, the user has to be more conscious of being involved with the computer for the fluidity of this use. Since Myo does not depend on an interaction with another device to interpret the captured movements, the bracelet can be managed during a wide variety of tasks. Gesture control promises a revolution in how we interact with computers, the same way that touches computing has (the interaction through the most conventional methods, mouse and keyboard). It could then surpass the technology coming from HCI interaction.

The Myo bracelet gains even greater prominence about other technologies present in its area of action by presenting an Application Programming Interface (API), an interface where the set of programming standards allows the construction of applications, and a Software Development Kit (SDK), this is a development package that will enable programmers to develop applications to run on the specific platform of the device.

Figure 11 - Illustration of EMG collection using Myo

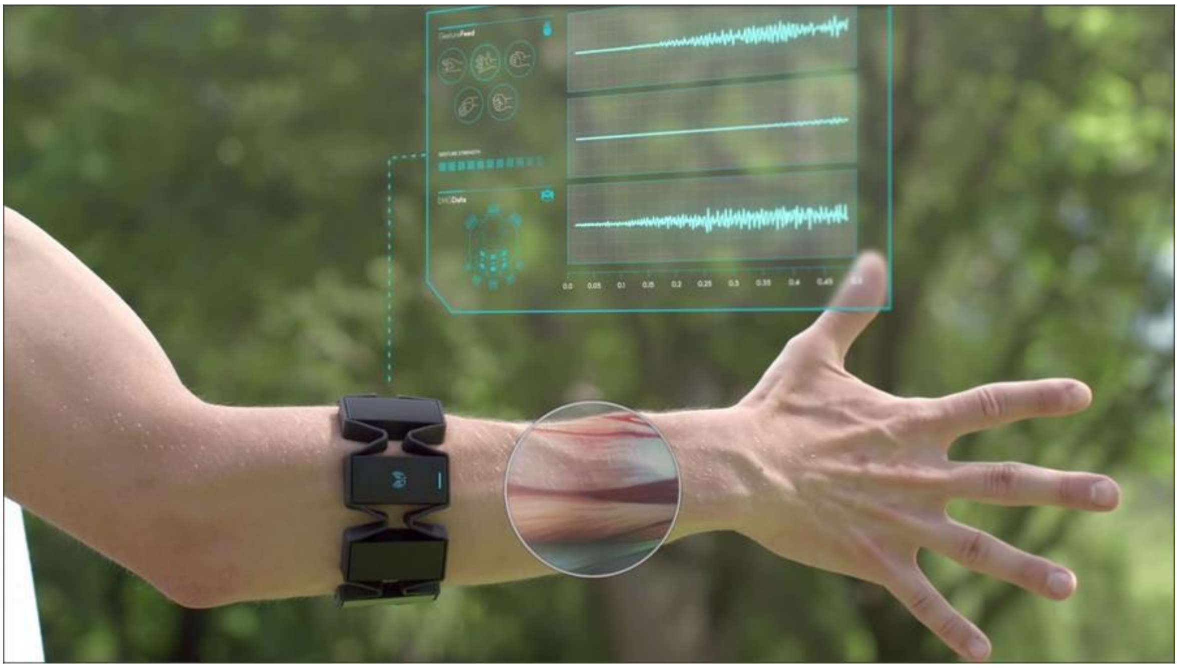


Image taken from https://i.ytimg.com/vi/te1RBQQlHz4/maxresdefault.jpg

With all these features presented in Myo's libraries, there is a massive facility for new software development. Because its development kit gives open APIs and a free SDK, it is possible to build solutions with broad access to new technologies on the market and thus integrate very well with recent trends in science.

But this does not necessarily mean that gesture control will be a "cure-all" for all computer interactions since touch computing is prevalent. Touch computing has taken off by HCI interaction, primarily through handheld mobile devices such as smartphones and tablets. However, touch interaction on desktops is known to cause discomfort to users over long periods and present limitations by repetitive use. And BCI interaction comes exactly to attack this market and provide new human-machine interactions that will please and make human life more manageable.

There is an expectation that a few years from now, it will not be difficult to imagine people wearing and using a Myo armband or similar to control various electronic devices without a repetitive interaction. In this way, there may be a new set of devices employed to connect more and more items used in everyday life to the same technological revolution caused by the Internet of Things, but this time provided by BCI interaction. Prominent CEOs (Chief Executive Officer) envision these new forms of interaction, meaning that computer interaction is evolving beyond a simple touch, in their own experience, to form a further user interaction. Nerve impulses could be a command interpreted and coordinated by home automation, drones, computer games, virtual reality, and more.

1.2 Objectives of the research developed

Human performance in computers and information systems has been an area of research and development that has expanded dramatically in the last few decades. This has been done using powerful computational tools to analyze data collected according to experimental psychology methods.

Much of these studies of human-machine interaction come from HCI. Since this is an interdisciplinary subject that relates computer science, design, and ergonomics to create the interaction between humans and machines that happens through the user interface provided by software and hardware, this interaction, in particular, is achieved through easy-to-interact peripherals such as mice and keyboards. This interaction has been well developed in terms of performance to maximize the use of computers, being as simple, safe, and pleasant as possible (REBELO, 2014). The development of this technology is well delimited by depending on a repeated human action, a "click," to formulate the interaction.

Figure 12 – Myo being used to control a robot.

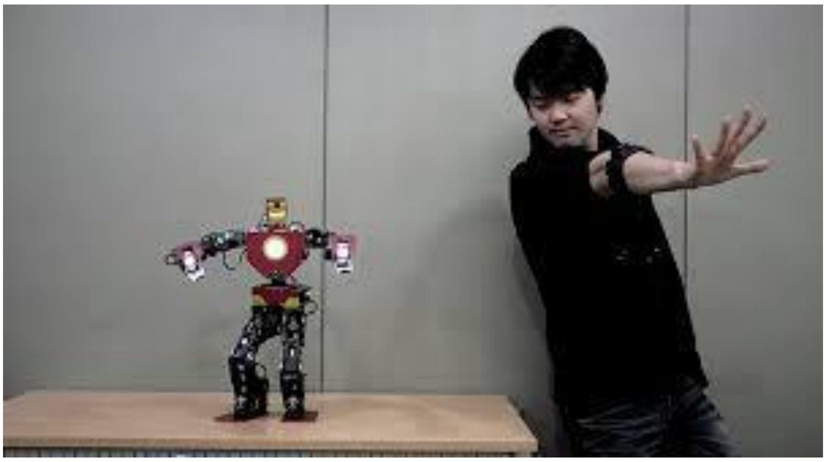


Image taken from the website: https://cdn.betakit.com/wp-content/uploads/2015/03/thalmic_myo.png

With the growth of the neuroscience area, new research was developed to understand the nervous system operation better. Thanks to the significant advance of computing, new investigation models were emerging, and the BCI improved.

The potential of the studies coming from the BCI makes it possible to improve the HCI, for not presenting any limitation to human-machine interaction and for being of easy human interaction by the potential to manipulate computers or machines with nothing more than a thought. However, this form of exchange was not created just for the sake of convenience, in the world population, there are countless disabled people unable to use the interaction provided by HCI, touch computing, and BCI comes to fill this market need, as much as to innovate our traditional interactions.

With the Myo device coming from the BCI technology, it is possible to develop a new form of human-machine interaction improved from HCI and thus supplied a current market need for exchange. This device captures the signals coming from the human body and transforms them into machine code as a development platform of easy access and acquisition, different from the more conventional voltage-clamp methods used by neuroscience in an invasive collection model. Using the Myo device does not make it the only area of study to be worked on in the scientific initiation project. Neuroscience, with its signal collection methods and the understanding of the human body, are the areas that enable the development of technology and the interaction itself. And thus, a State-of-Art of BCI becomes the most relevant for developing the final product of this initiation.

Given its employability, therefore, this scientific initiation's objective is to develop an interface, or a program, with the integration of the Myo, demonstrating its total control to perform several functions with the stimulus of the impulses generated by the user's arm. To achieve complete control of the bracelet, it is necessary to understand how it works; a study developed through the following steps:

1) EMG know-how, to know how to interpret the signals captured in the human body in an attempt to identify the types of muscle contraction and transmissions of nerve signals coming from the CNS, so that it is possible to identify a specific gesture of the human body;

2) Understand how Myo captures signals so that it is possible to make the bracelet recognize other gestures produced by the human body, in addition to the movements already recognized by the device, in a factory version;

3) Understanding the features available in Myo's APIs for your uses.

4) Study the SDK and the language used in it to create software for the bracelet.

5) Myo connection tests with different people, with an experimentation of use in amputees.

6) Collection and analysis of data in the device, of signals coming from the human body.

7) Connect Myo to an Arduino board to develop an example of a very simple connected interface to interact with the device.

To demonstrate the capability of Myo's functionality concerning integrated devices, it is planned to use the device in conjunction with an Arduino module, a free, single-board hardware electronic prototyping platform, for an exemplification of interaction with Myo. Arduino is an accessible, low-cost, flexible, and easy-to-use board. The forum will develop a device focusing on the Internet of Things (IoT) to connect various electronic devices used in everyday life with the new model of interaction little-used interacting the BCI with an IoT.

Figure 13 - IoT Integrated Systems

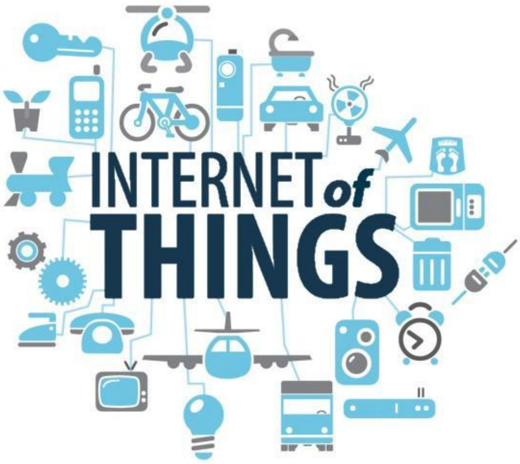


Image taken from the website: https://pinaclsolutions.com/content/mixed-content/iot-it-is-big-and-it-is-clever/IoT.png

1.3 Systematization of interaction

For the execution of the scientific initiation project, it is indispensable to conduct bibliographic research as a basis for the program and the use of the scientific process to prepare and execute the study. Both methodologies are crucial to develop the project for the research area of the initiation to be worked on since, in most scientific studies, the scientific process is often used for a better understanding of the work and the construction of the project to become more easily executable.

To carry out bibliographical research, a series of inquiries are necessary to understand the work and the study techniques to be used. This way, studies of the results, Neuroscience, unraveling the nervous system (Mark F. Bear); Docu-mentation of the Myo SDK (Thalmic Labs); The Myo API reference scripts; Arduino Libraries (Arduino) were made. In addition to all the research required, it is also crucial to have proof of the studies.

To conduct and prove these studies, a sample data collection of the experiment and the placement of a method is required, to prove the thesis. The scientific process performed consists of a few step-by-step steps for the construction of the final report:

1) Observation, study, typically performed during experiments, designed to test a particular hypothesis;

2) Replication, regardless of whether the observation is experimental or clinical, it is essential that it can be replicated before being accepted by other researchers;

3) Interpretation, in the moment before believing that the observation is correct, an interpretation is necessary, which depends on the knowledge and perceptions perceived about the project. Thus, interpretations do not always stand the test of time, often great discoveries are made when old interpretations are reinterpreted in a new light.

search.

4) Verification, step to prove the observation made about the experiment, accepts that the observation made is a fact.

The observation step is performed with the study of the EMG. It is conducting a study of graphs and functions that generate the analysis of nerve impulses. This step is fundamental for a possible elaboration of techniques to capture new gestures and become new functions for Myo, increasing the number of resources for creating the final software.

It also consists of researching Myo's work framework, its programming interface, and the software development package so that it is possible to integrate the equipment thoroughly for the creation of a new utility that makes new functions and can adapt them to the movements identified by the EMG and to respond adequately to the user.

To study Myo's working framework, it was necessary to deepen the study of the algorithms used in its applications, obtaining greater clarity in reading the code and the operation of the device's logic.

Likewise, a study of the framework's programming language uses some functions of the device's SDK to perform the electrocardiogram and myography analyses on the user's body to identify which impulses are provided by different gestures.

The replication stage comes after the study of its development platform. This step required several tests to confirm the integration of the device with the user and to ensure that it works with different users so that it is always in perfect synchrony and with accurate responses. In the search for more excellent knowledge and data analysis for the project's development, a large number of tests will be carried out with volunteers to understand the electrical impulses coming from the human body.

The interpretation step consists of developing software to test the observation made, that is, software that can interact with a simple system with an Arduino board by capturing the EMG signals coming from the user's body. And, thus, create a human-machine interaction through Myo. If there is time, create an IoT with Myo to better demonstrate the functionalities of a BCI interaction with the natural world to improve the HCI interaction, using the benefits of BCI interaction.

In the final verification stage, a reflection is made on the work opening a discussion about the results obtained from the development of the scientific initiation project to conclude if it was possible to get the desired results and if it is possible to make the HCI contribution. Also, about the learning obtained with the studies carried out by the initiation and what this made possible in totality, and the possibilities for new studies formulated from this and if this was a good choice as a research area.

1.4 An overview of the search

Human-Machine Interaction addresses research on the composition of the aspects of the characteristics found in human interactions with the technological environment around them. Presenting studies and their contextualization for the elaboration of the subject served as a support for the work. To describe the conjuncture of the work, this topic presents all the chapters of the proposed research.

The first chapter presents the previous studies carried out to elaborate the work, along with the historical contextualization that provided the basis of the knowledge used in the scientific initiation. The introduction is supported by studies and examples of the successive phases of research to obtain electrical signals from the human body and a brief explanation of the apparatus used to develop the learning process. Finally, a summary of the work anticipates the issues to be worked on throughout the text, bringing the reader closer to the themes.

The second chapter covers the study of the apparatus used to implement interaction. It explains how the signal processing occurs to interpret the poses, mimic the user's arm movements through its spatial representation, and finally, how the device communicates with other devices to transmit the collected data. Through experiments to obtain electromyographic signals from the user's body, to perform an analysis of the behavior of the electric potential and assimilate it with the use of the bracelet.

The third chapter explains the interaction design, using a Myo device as a receiver of the data. An intermediary device to perform control of the interaction and present the data through an interface. The Arduino is the final platform and executor of the exchange to fulfill the IoT role. With the organization of the interaction performed, and then the choice of a path for elaborating a user interface.

The fourth chapter exposes the development of the interaction planned in chapter 3. From the conception of an IoT prototype using the Arduino platform to making software so that the intermediary interface can control the interaction. Explaining the main algorithms and functionalities used to generate the project.

The fifth chapter reports the experiments worked during the scientific initiation. With the consequence of the created software and the elaborated interaction's interpretation, several APIs were used to obtain the idealized prototype. Elaborated from the development demonstrated in chapter 4.

The sixth chapter exposes a discussion about the themes worked on, the development of the software, the learning obtained in the scientific initiation, and what this brought as a result of the studies carried out. Next is the conclusion of the research work, with its possibilities for future work, to be developed from the survey obtained in this scientific initiation with new capabilities of interaction from the human body.

2 The BCI Device

This chapter explains how the BCI device of the study conducted, the Myo, works, how it interacts with the user, collects data, captures signals, and communicates with other devices to develop an interaction. This chapter is the basis of the development presented in this scientific initiation; without it, the understanding of planning an exchange would not exist. In the following topics, it will be explained why a BCI interaction through this device.

2.1 What is Myo

Figure 14 - Myo Armband

Image taken from the website: https://learn.adafruit.com/assets/30334

Throughout the research and thinking about the future of technology, more specifically, how to interact with digital devices in a natural and mobile environment. An idea was introduced for a handheld device, using EMG signals from the forearm, rather than the technologies already on the market, such as touch, voice command, or motion-capture-based control. This is a mobile technology, which can travel with the user wherever they go. Being an exact and innovative technology, this device is a great way to enhance human communication, specifically BCI, as described in section 1.1.5 of the Introduction chapter.

Some of the technologies commonly encountered by enthusiasts do not have such transformative capabilities; they are limited to camera-based motion ones, Microsoft's Kinect, or Sony's PlayStation Move. These devices were introduced to use body movements to control other electronic devices (IoT). However, most data acquisition technologies restrict the user from being stationary in front of an interface or forcing them to move within a reference frame of the device.

The mobility interface used for the study in question offers an extensive list of uses to present a wide range of implementation capabilities. With the support for software performance on computers, smart TVs, music players, and smartphones, it has become an interaction to connect much of the digital world. As these valuable and intuitive technologies become more present in everyday life, these new control devices, based on biological sensors, make it possible to enter a new level of interaction.

A device used to capture muscle contractions and accurately measure human movements through gesture capture. It allows the users of this device to interact with an interface like a computer through more intuitive interaction. To capture and represent the user's movement, it uses a series of modules such as a gyroscope, an accelerometer, and a magnetometer, which allow for spatial representation.

To perform the processing of the data collected by the bracelet. These must be sent in wireless communication to a computer, where the data are processed and translated into commands to operate another device, usually an electromechanical system. The data processing is done on the changes occurring in both the action potential spectrum in the EMG signal and its spatial movement through a Quaternion.

With the result of integrating the bracelet data, a graphical interface was developed to present the collected data and thus assist in decision making. These represented interactions end up generating a high level of communication with the device, breaking the barrier of an exchange.

Thus, this chapter explains how the device processes signals and obtains a pose or gesture, represented by the EMG; the interpretation of the user's arm movements through the use of a Quartenion; how the Myo device communicates to transmit and process data.

2.2 The acquisition and processing of signals by the Device

Myo is a device that presents much of its power through the transformation of user interaction, using signal processing techniques to create a BCI interaction. No doubt, the way this transformation occurs is intriguing; as simple as it may seem, this interaction is highly complex, requiring plenty of techniques to accomplish. After all, Myo represents an independent and unique way of collecting signals from the human body.

Various factors affect the data collected by the EMG to perform signal collection by the device. Most of the array in the data collected is generated by anatomical muscle differences; factors such as arm circumference, forearm strength, arm hair, and even body fat influence the signal measured at the skin surface. Reducing the impacts of these variations is a major ergonomic factor of armband design updates (MACHINE-LEARNING-TEAM, 2014).

Figure 15 – The Myo Hardware

Image taken from the website: https://learn.adafruit.com/assets/30336

One of the main reasons developers have been necessary to improve the cuff for signal collection is physiological changes in the muscles daily. As much as the way an individual performs a fist gesture looks like the way another individual performs the same movement, at a microscopic look, under the skin's surface, there is much more than meets the eye when noticing a gesture.

To reduce the impacts of signal behavior, scientists use a large amount of collected data to maintain the algorithm used and minimize the differences in EMG interpretation by updating the device's software. This is precisely why the need for more data collection is so important (MACHINE-LEARNING-TEAM, 2014).

Since it is possible to update and modify the software used by the sensors to measure the body's electrical signals, one gains the autonomy to transform and implement it in different forms and purposes, over large amounts of data collected in the study conducted to be able to improve the performance of the device continuously. And thus understand how the sensors of the bracelet work, how they perform the collection, and how they register the obtained data.

The Myo bracelet has electromyographic (EMG) sensors that capture these signals to perform biological signal processing. More specifically, eight separate desensor modules were used to read the muscle activities and discover the gesture that the user performed. The reading order of these sensors corresponds to the order of the sensors shown in figure 16. This is also the order of signals received from the EMG data through the calls in the SDK (BERNHARDT, 2015a).

Figure 16 - Order of EMG sensors

Image taken from the website: http://developerblog.myo.com/content/images/2015/05/EMG-Channel-Assignments.jpg

EMG transmission data are inactivated by default at the beginning of an interaction with the bracelet. This is because this data has a high bandwidth and therefore consumes a lot of power when transmitted. To enable the transmission, it is necessary to call one function, setStreamEmg, in this case, Enable, from the SDK of the device.

This function makes it possible to perform the transmission of the device's data effectively. It removes interference from nearby electrical signals from the collection (specifically from the powerline). Otherwise, it can discard some collected data. With the function set up to perform the group, it is necessary to set a parameter for collecting the appliance data, usually performed in the onnagata role, to normalize the collected data (LABS, 2014).

Thus, the function returns an array of 8 elements in which each one corresponds respectively to each of Myo's sensors. Myo's data collection parameter is written in four notification vectors EmgDataXCharacteristc. The splitting of the data is done to have better detail in the analysis since if the sending was established only by the parameter for the device data collection, the sending would be done only by one vector and would make an analysis considerably complex by mixing new data with old ones (LABS, 2014). The reading is then divided into two sequences sent in each data update, as detailed in Figure 17.

Figure 17 – EmgDataCharacteristics Vector Example

```
EmgData0Characteristic
    Sample1
    Sample2
EmgData1Characteristic
    Sample3
    Sample4
EmgData2Characteristic
    Sample5
    Sample6
EmgData3Characteristic
    Sample7
    Sample8
EmgData0Characteristic
    Sample9
    Sample10
etc
```

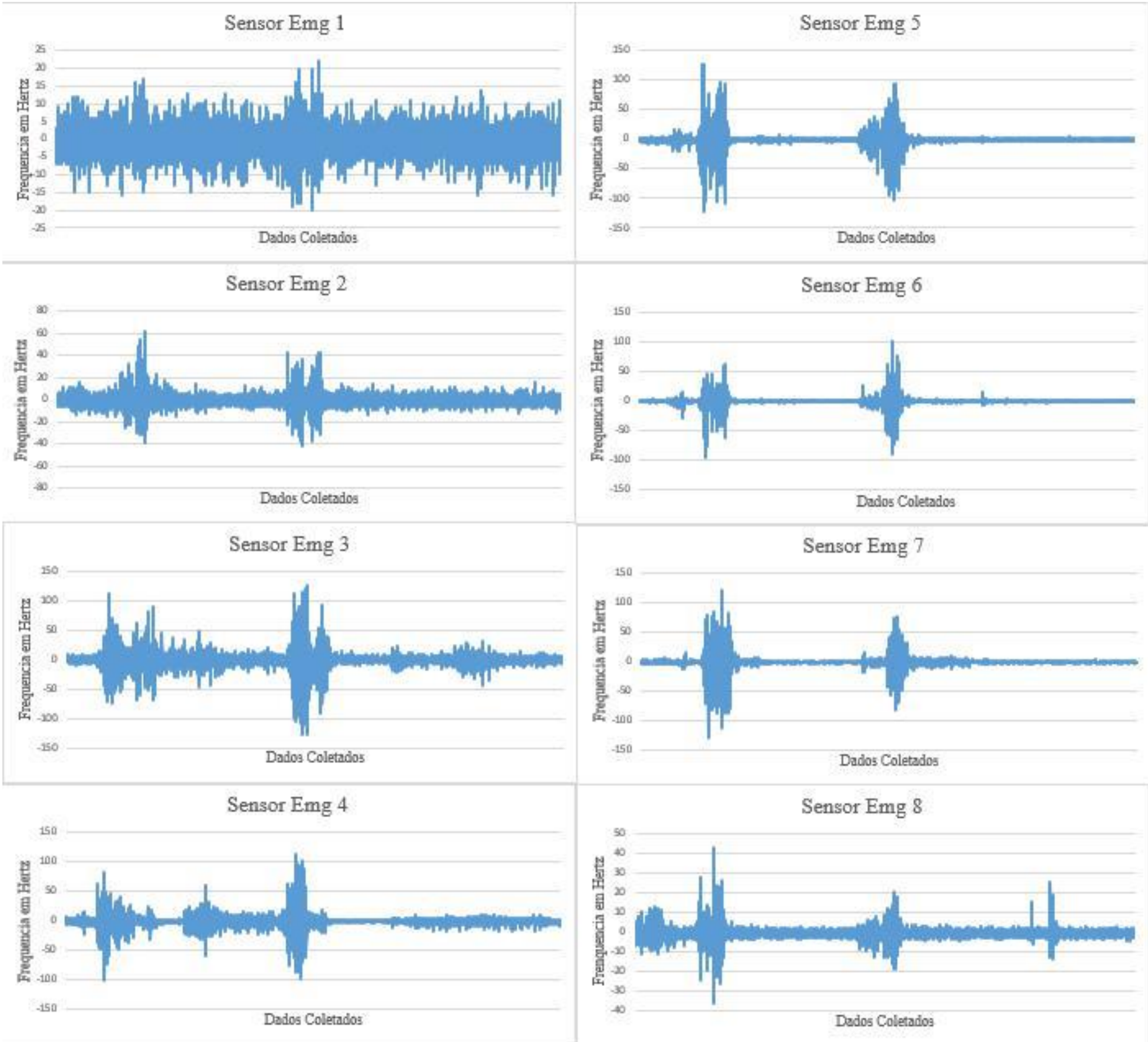
The data collected for a sample is read at a consistent rate (every 5ms), so you can figure out the timing based on which feature and matrix the data comes from, so if there is a lost transmission, there is only a gap in the data. Each EmgDataCharacteristic works with sending in a data frequency enough to reach up to 200Hz (BERNHARDT, 2015a).

To demonstrate the signal collection by the armband, a C++ application was developed to show how the data collection and processing of the Myo is performed. The collected data is stored in .csv spreadsheets so that it is possible to prepare graphs to perform an analysis of the collected information, as shown in graphs 1 and 2.

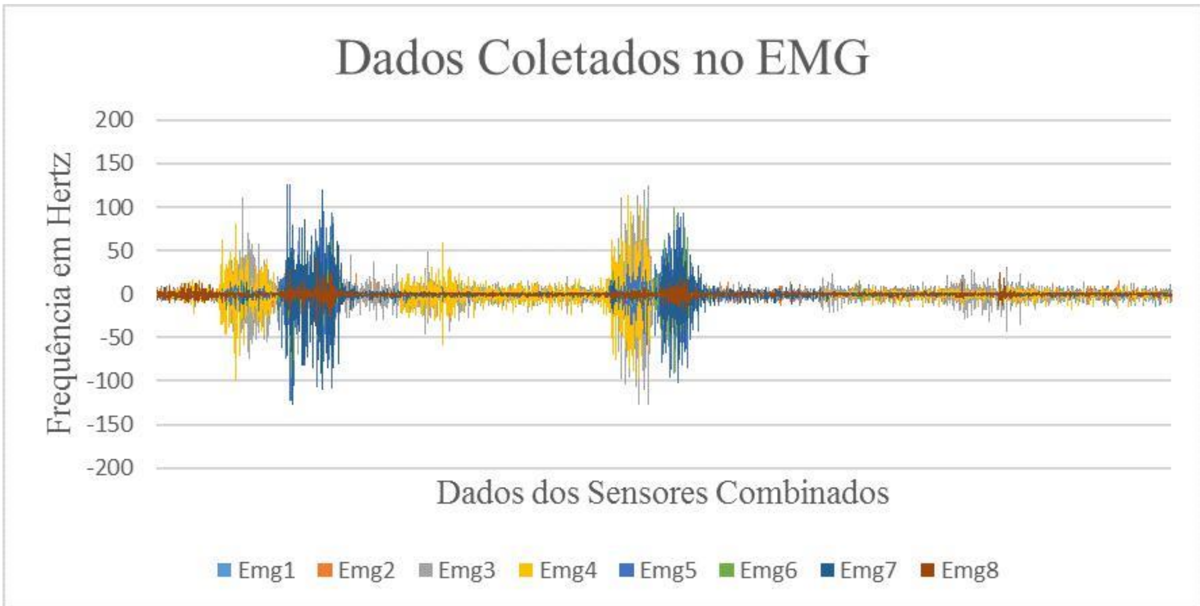
From the data collected and understanding the programming operation involved to perform the EMG data collection by the BCI device. It is noticeable that this data acquired by the cuff has already undergone data processing by the device's collection algorithms. This means that this collection is not pure, exposed directly from the muscles. It is a "classifier output," The device uses its signal processing algorithms to identify this signal, such as a wrist, for example.

The previous study was carried out in the introduction chapter in the subtopic "The study of interaction with the human body." It becomes understandable to correlate the method of signal collection commonly employed in the study of EMG with the way the bracelet acts to capture and identify a user's gestures. Much of the EMG analysis procedures used the technique. The SetStringEMG function establishes the entire collection parameter by employing filters such as Band-Pass up to 200Hz, BandStop cutting interferences from electrical signals close to the collection, and defining a time-domain analysis of the movement every 5ms.

Graph 1 - Data from the electromyography collection of each bracelet sensor



Graph 2 – The EMG collected by Myo



With an understanding of how the data is collected and stored. The application was developed to collect the data from all the sensors of the Myo device. Serving as the basis of studies for the understanding of the algorithms used. Thus, the EMG shows itself to be a tool of excellent applicability for the understanding of muscle activity, widely used for a better experience of neuromuscular involvement. In response to the application employed, it can also be understood as the quantification of the electrical signals of the skeletal muscles.

Once the biophysical mechanisms involved in muscle contraction are understood, along with the methodological steps required to identify the EMG technique, it remains to understand the apparatus used for collection since the collected signal, or raw signal is subjected to a specific filtering process, minimizing the probability of noise in the treated signal.

As mentioned in the introduction chapter, the obtained and processed signal goes through quantifying the density of the collected signal spectrum. In the time domain, the signal can indicate the time at which a given muscle started and ended its activation and the amount of its activation (amplitude of the EMG signal). In this type of analysis, we can use the RMS values (root mean square value), the integral (iEMG), and the rectified value by the average frequency, which gives us parameters of the signal amplitude.

Employing descriptive statistics in the identification process makes it possible to make an intelligible reading of the data obtained. For this, we use the number of peaks (maxima) together with the peak amplitude (in mV) to be able to use the Fourier algorithm (FFT) and generate the average and median frequency values, obtaining an incredible precision of the variability of the signal collected by the device; the RMS, which uses the firing rate, duration and speed of the electrical signal from the motor units to square the individual amplitudes, calculating the average of the courts of the amplitudes and obtaining the square root of the process. RMS calculation is considered to provide the most significant insight into the amplitude of the EMG signal since it gives a measure of the signal power while producing a waveform that is easily analyzable; signal normalization to simplify the reading and analysis of the signal, usually by dividing the values obtained by a reference value, for example, the average value of the movement, or the maximum value. Or signal rectification is a method of signal treatment where the interest is in the signal modules.

For the correct interpretation of the data concerning the electrical activity of the analyzed muscles, the normalization of the EMG signal is essential for comparisons between different collection days, analyzed powers, studies, and especially between individuals, in an attempt to minimize existing differences related to height, body mass, muscle mass, training level, and other aspects. This information may be significant for detecting muscle force production. Still, it is also necessary to design orthopedic implants and surgical treatments, in the development of biomechanical models, mainly in the basic understanding of the human musculoskeletal mechanical system and in processes of neuromuscular adaptations to training.

Thus, through the biomechanics used by the BCI device, the recording of electromyographic activity allows the investigation of which muscles are used in a given movement, the level of muscle activation during the execution of an action, the intensity, and duration of the muscle request, inferring in the way the device detects a pose by deciphering the EMG collection. Thus, it is of utmost importance to understand the data that leads to electromyography, understood today, and applied on a large scale in various areas of knowledge.

In the next topic, continuity is given to the application created by employing other sensor modules with their respective techniques through the Myo interface. It is obtaining a greater understanding of the power of this device and its actual capacity. In a few words, the performance of data collection through the bracelet will enable the construction of a more complex and well-crafted application, serving the purpose of integrating the bracelet with an IoT device.

2.3 Classification of a movement by the Device

The first part of the research that seeks to understand the functionalities of Myo was done around its primary and most attractive feature, the understanding of human gestures through EMG processing and collection. But to perform the excellent mimicry of human interaction, Myo uses a combination of motion sensors, so the armband can identify and copy the user's arm movement, increasing the immersion of the experience with the final device.

The Myo utilizes inertial measurement sensors to perform motion classification to use an Inertial Measurement Unit (IMU), specifically the Invensense MPU-9150 9-dof motion sensor (figure 18). This unit was embedded in the Myo to perform integration and utilization of all orientation data captured by the device: about the various angles, axes, and universal magnitude measures that interact with us in everyday life, in a simplified approach to treating the spatial orientation of an object (STARLINO, 2009).

Applications using IMU units are typically used for high-tech devices. For example, they are often incorporated into Inertial Navigation Systems (INS) that use the raw IMU measurements to calculate attitude, angular rates, linear velocity, and position relative to a global reference frame. The INS manufactured by IMU forms the backbone for the navigation and control of many commercial and military vehicles and essential components in the guidance and supervision of unmanned systems. The data collected from the IMU's sensors allows a computer to track the position of a craft, using a method known as data computation (JOHNSON, 2011).

Figure 18 - Invensense MPU-9150 9-dof motion sensor

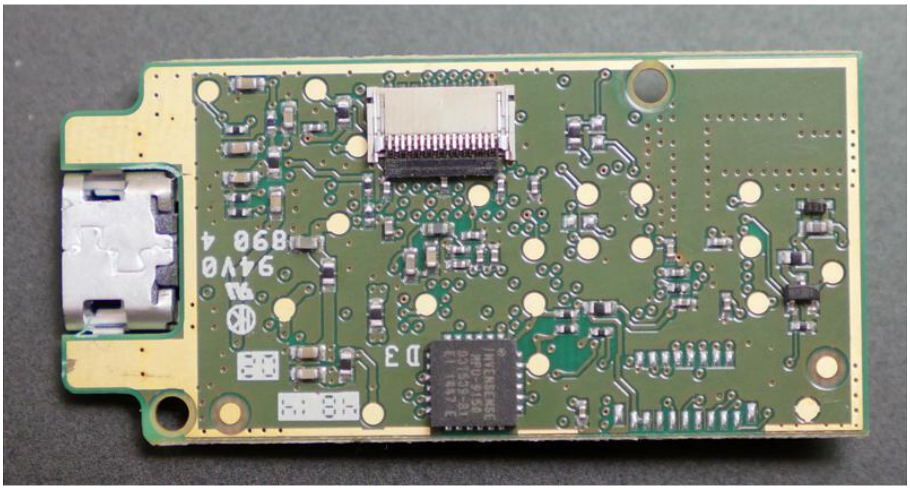


Image taken from the website: https://learn.adafruit.com/assets/29292

2.3.1 Detecting the guidelines

To better explain how the IMU units work, first, it is necessary to understand the operation of the sensor modules that the device features, such as the accelerometer, the gyroscope, and the magnetometer.

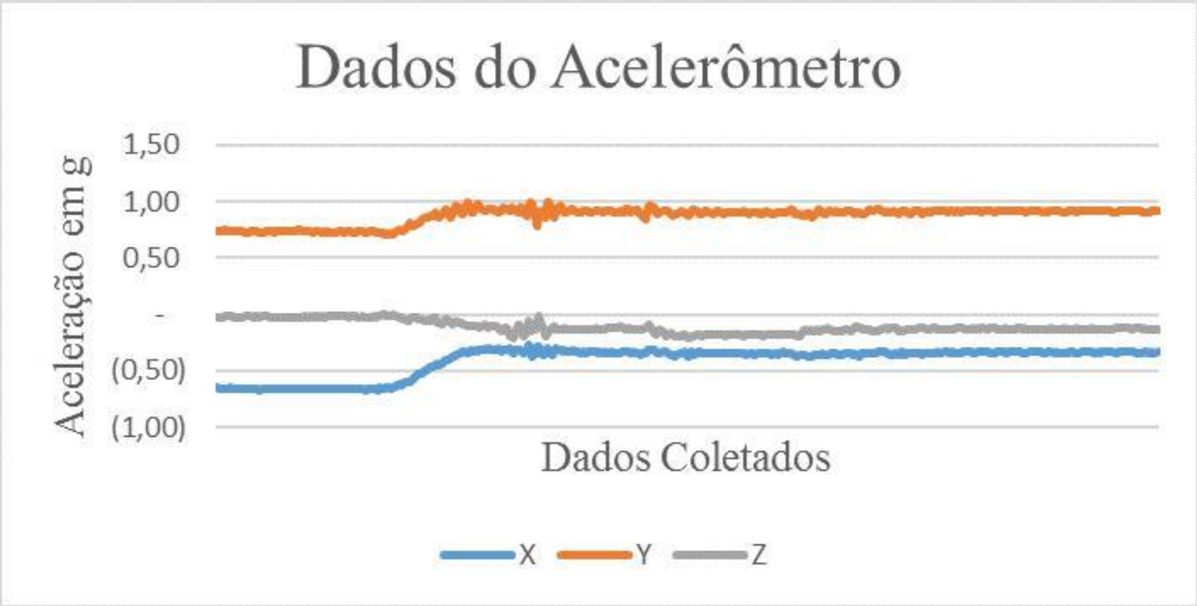
The accelerometers are used to detect both static (e.g., gravity) and dynamic (e.g., sudden start/stop) acceleration. Because they are affected by the acceleration of gravity, an accelerometer can tell how an object is oriented relative to the earth's surface, detect a specific motion, and detect whether the thing is in free fall (SPARKFUN).

The accelerometer measures the action of gravity in all three axes (x, y, and z), working with selectable ranges of measurement and detection of gravity variation. In the case of the Myo, the accelerometer works in a more sensitive field, i.e., in a smaller total measurement range, subjected to accelerations between +2g and -2g.

Using the data collected by the same application used in the previous topic, the data collection of the accelerometer of the Myo was recorded. The group made by the device is registered through the function on accelerometer data; this function returns the acceleration collected in each axis of action, in units of "g." With the data collected in the .csv spreadsheets, it was possible to create a graph to illustrate the effect of acceleration in the three axes of action around the clamp, see graph 3.

Gyroscopes measure angular velocity, how fast something rotates around an axis. For example, when trying to monitor the orientation of a moving object, an accelerometer may not provide enough information to know precisely how the thing is oriented. Whereas, unlike accelerometers, gyroscopes are not affected by gravity, so they make a great complement to capture measurements. The angular velocity is usually represented in units of revolutions per minute (RPM) or degrees per second (°/sec). The three axes of rotation are called x, y, and z and are roll, pitch, and yaw, respectively.

Graph 3 – Acceleration on each axis in Myo

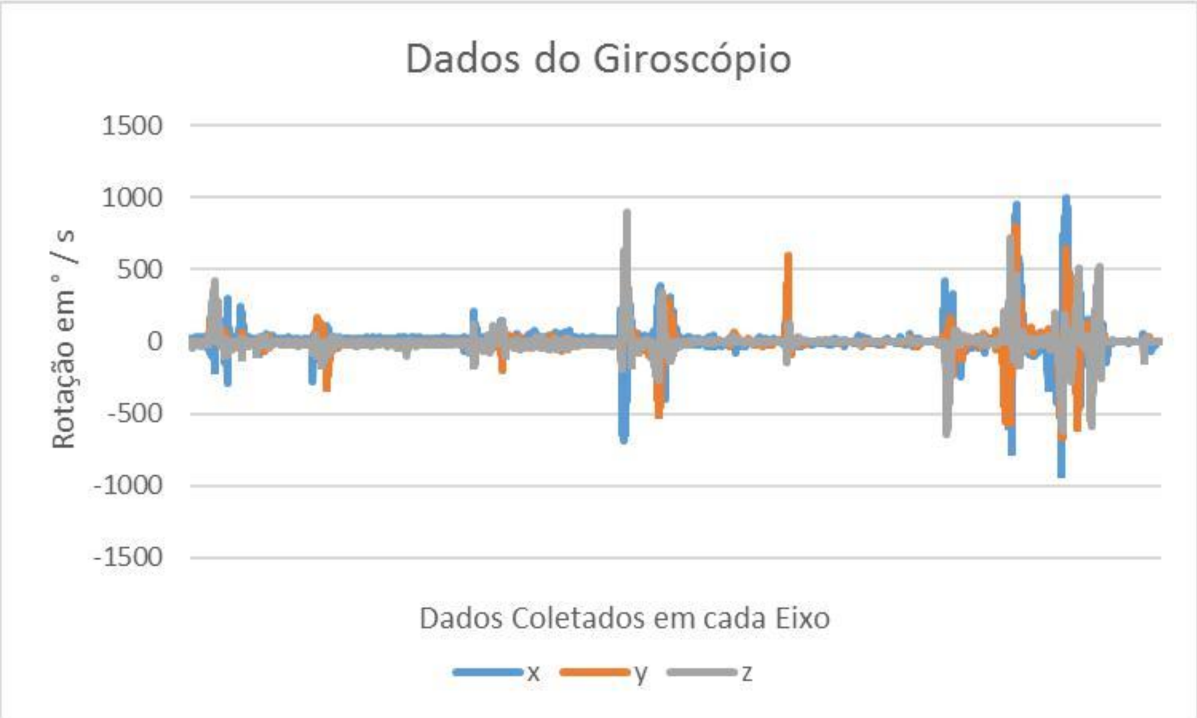


Using the on gyroscope data function from the Myo SDK, it is possible to obtain an example of the annotation of the measurements performed by Myo, see graph 4.

The Magnetometer is an instrument used to measure nearby magnetic fields' intensity, direction, and directions; it also functions as a digital compass. In this way, it provides the differential for calculating the UMI units by making this set of sensor modules much more complex and cohesive with reality, increasing its accuracy for the analysis.

Gyroscopes and accelerometers are great, but by themselves, they don't give a good enough range of information to be able to calculate things like orientation, position, and velocity comfortably. To measure these and other variables, the two sensors are combined to create an inertial measurement unit (IMU) that provides two to six degrees of freedom (DOF) (STARLINO, 2009).

Graph 4 – The rotation acquired by the bracelet



2.3.2 The concept of a movement

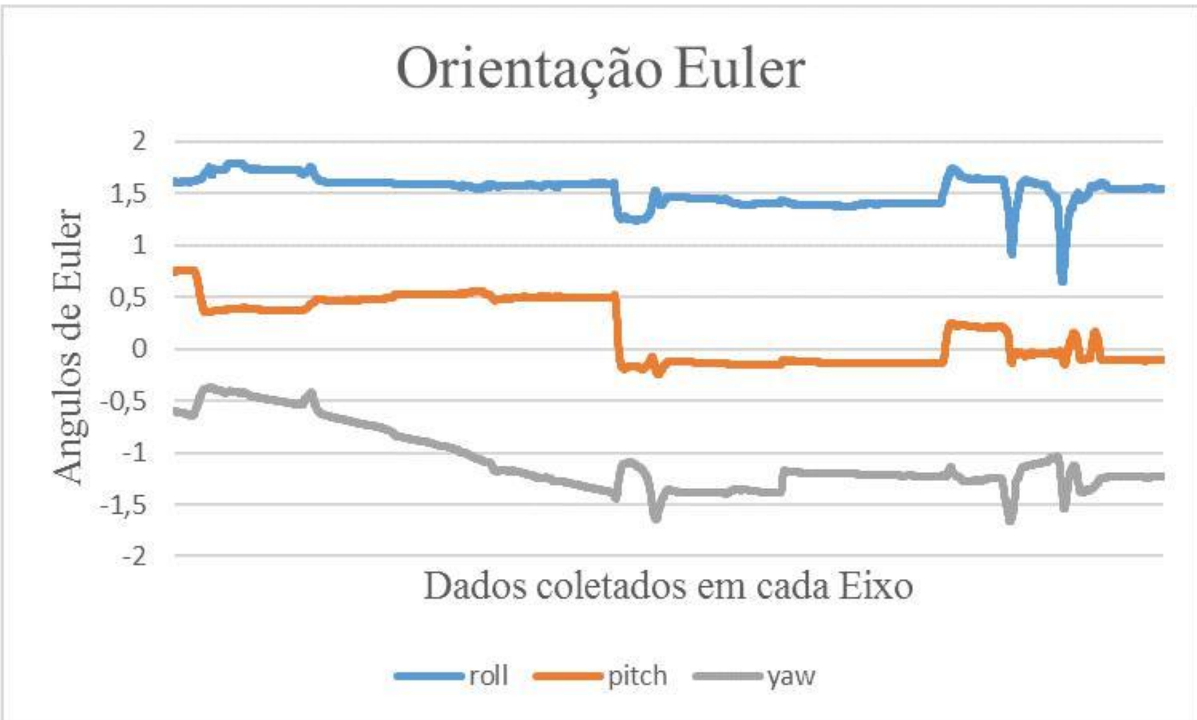
An inertial measurement unit (IMU) works by sensing linear acceleration using one or more accelerometers and rotation rate using one or more gyroscopes. The accelerometers measure acceleration along specified axes, while the gyroscopes measure acceleration about the axes. Some IMU modules also include a magnetometer commonly used as a heading reference. Typical configurations contain one accelerometer, gyro, and magnetometer per axis for each of the three axes of the device: roll (F), pitch (j), and yaw (y) (SPARKFUN).

The results obtained by the inertial measurement unit are provided by the degrees of freedom; they are rotations of Euler angles (yaw, roll, pitch), being more accessible values to handle. Especially for working with only one particular axis of motion or for each axis to work differently. It is also a more understandable way to express an orientation or a rotation for the user.

Although using Euler angles to represent the inertial measurement unit is a more excellent way to describe the rotation of the axes. Because the way the technique of orientation data through only Euler angles is performed makes it have some flaws (BERNHARDT, 2015b). For this reason, the Myo device works using another form of spatial representation, the annotation using Quartenion units; this measurement is explained in the next topic. The flaws of a model using Euler angles are described in the appendix "The Gimbal Lock."

To perform a more straightforward explanation of the device's spatial orientation, it was necessary to use a function to transform the collected Quartenions to Euler angles through the developed application. This way, a graph was created representing the spatial changes of the device around each of the axes, roll, pitch, and yaw; see graph 5.

Graph 5 - Record of Myo's orientation



To transform the Quartenion units recorded by the Myo, it is necessary to parameterize the spatial rotations in three dimensions using Euler angles (GRAPHICS, 2017). Using the function shown below, it is possible to obtain the "Euler parameters."”.

For Euler:

$$f = \tan 1 \frac{2(q_0q_1+q_2q_3)}{1\ \ 2(q^2 1+q^2 2)}$$

$$q = \sin 1\ (2(q0q2\ \ q3q1))$$

$$q$$

$$y = \tan 1\ \ \frac{2(q0q3+q1q2)}{1\ \ 2(q22+q23}$$

Through the function represented, it was possible to elaborate an algorithm to transform the units in the created application, see Figure 19.

Figure 19 - Algorithm used for the transformation of Quartenions

```
        // Calculate Euler angles (roll, pitch, and yaw) from the unit quaternion.
        float roll = atan2(2.0f * (rotation.w() * rotation.x() + rotation.y() * rotation.z()),
            1.0f - 2.0f * (rotation.x() * rotation.x() + rotation.y() * rotation.y()));
        float pitch = asin(max(-1.0f, min(1.0f, 2.0f * (rotation.w() * rotation.y() - rotation.z() * rot
ation.x()))));
        float yaw = atan2(2.0f * (rotation.w() * rotation.z() + rotation.x() * rotation.y()),
            1.0f - 2.0f * (rotation.y() * rotation.y() + rotation.z() * rotation.z()));
```

2.3.3 Understanding a movement

The Myo armband has a wide range of sensors to aid the accuracy of the calculation, thus obtaining recognition of the exact position of the device by measuring the UMI. It then becomes possible to report the body-specific force, angular rate, and magnetic field surrounding the body using a combination of accelerometers, gyroscopes, and magnetometers.

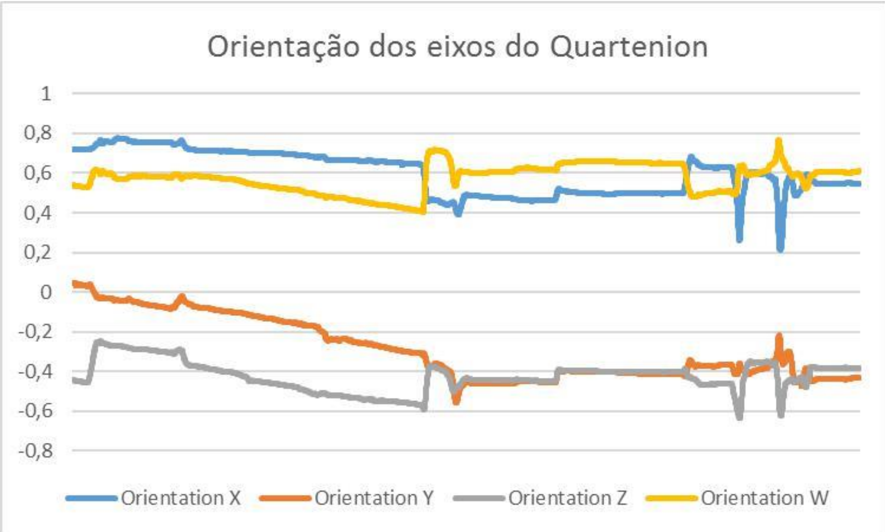
All to ensure accurately that the movement maneuvers that an arm performs are well reproduced. Since, for the reproduction of human movements, it will be required to rotate some part of the arm at some point. So in the collection mechanism provided by the Myo SDK, each motion transformation has an orientation property stored as a quaternion. Giving the ability to keep a more complex motion via a "center" or "lifted" orientation and calculate the rotations relative to that.

This is the most significant benefit of using Quaternion units. Smoothly and directly rotating a set of Euler angles is highly complex. With quaternions, it is as simple as multiplication. Usually, taking the current orientation (as a quaternion) as a basis and multiplying it by the rotation (of another quaternion) you wish to apply (HAMILTON, 1843).

This is also probably the essential feature for calling the function a Quaternion. A unit quaternion (which is what all valid orientations are) is the same operation, different from a direction obtained by Euler's angle. Quaternions are not scary; the library provided by the Myo SDK enables straightforward spatial representation through their use. The Quaternion class of the Myo SDK has almost all the algorithms needed to use the Myo armband and perform spatial representation (LABS, 2014). Engines used by development platforms such as Unity's have fairly comprehensive solutions for using Quartenions.

Using the application created for understanding the orientation of the Myo, it was possible to obtain the orientation data of the bracelet using Quartenions, using the on orientation data function of the SDK. Through this function, the data is stored in a .csv spreadsheet, which enables the construction of the graph, see Graph 6.

Graphic 6 - The graphic representation of a Quartenion



The graphical representation of a Quartenion is not the best way to illustrate a spatial model. Therefore, in chapter 4, a better illustration is worked out for this unit to enable a better understanding. In chapter 5, the functionality of the Quartenion is demonstrated through the graphical interface of the application created to show Myo's functionality in this scientific initiation.

Thanks to the accuracy obtained to determine an orientation of the IMU data. Myo can measure which arm the user is positioned on, the right or the left. Through the SDK's onArmSync function, it is possible to determine the user's arm by enumerating the XDirection variable. This variable allows the capture of the distance and rotation of the bracelet axis to the user's wrist, with the length and process of the bracelet axis to the user's elbow. By enumerating these two distances, Myo can determine which arm it is located on. This calculation is performed about the position of the Thalmic Labs logo, present in the center of the bracelet (LABS, 2014).

Thus, with the proper representation of a Quartenion, in chapters 4 and 5, it is better demonstrated how the result of this collection is obtained, since, because the application created in C++ does not present a graphical interface, it is not possible to perform the best representation for these two functions.

2.4 Communication by the Device

To provide a practical and convenient interaction for the user, the bracelet has a wireless communication to transmit collected data to an intermediary interface, which performs the processing of these data. This transmission is done through wireless communication technology, Bluetooth, more specifically Bluetooth Smart. In this topic, the study of the communication available for the connection of the device is made to use it for the development ahead.

2.4.1 Wireless communication

Bluetooth is a wireless communication technology developed by Ericsson in 1994. The idea is to enable devices to communicate quickly, easily, and without cables, as long as one device is close to the other. Based on a short-range, low-cost radio link, data transmission is done using radiofrequency, allowing one device to detect the other regardless of their position. It is only necessary that both are within proximity, providing greater freedom of movement (BLUETOOTH, 2017b).

It is a technology created to work worldwide, so it was necessary to adopt an open radio frequency that is accepted almost anywhere on the planet. The ISM (Industrial, Scientific, Medical) band, which operates at a frequency of 2.45 GHz, is the closest to this need and is used in several countries, with variations ranging from 2.4 GHz to 2.5 GHz. Bluetooth enables the exchange of data over short distances. The main applications are: connecting to headsets, keyboards, and mice (and other devices that need to save power) and, of course, transferring files such as music and pictures (TOWNSEND, 2014).

Traditionally, Bluetooth pairing guaranteed an ideal case in early versions of the communication technology. Two paired devices have a random PIN—a fundamental part of the Bluetooth security model would confirm that the correct devices were connecting. In the real world, however, most users ended up pairing simple machines, such as a Bluetooth headset or a stereo gateway (speaker).

As there was no need to enter a PIN on these devices, the user would need to remember the number selected by the manufacturer. Naturally, it would be something extremely "secure," such as "0000" or "1234". Being an unnecessary hassle, basically.

For this reason, as technology has advanced, in Bluetooth Smart, the pairing process has been simplified. Thus, an application lets a user choose from a list of compatible devices and connects immediately. This is a good thing. However, even this may require the creation of more UIs (User Interface) than is desired. It is also worth noting that while this was an example, the same function exists for many uses; the pairing is handled so that you don't have to worry about it.

In the hands of an adventurous developer, ThalmicLabs has enabled the creation of Bluetooth Smart support in several ways by releasing the coding of its communication protocol. In the case of the Myo platform, it was used as a Bluetooth Low Energy (BLE) chip, which can run its code acting as a GATT (generic attribute name) client, and then make a direct connection to an intermediary device. Whether that device is a computer or not, the pairing is handled automatically by Myo Connect so that it is not a problem (BERNHARDT, 2015c).

2.4.2 The concept of wireless communication

Bluetooth Low Energy (BLE), sometimes called "Bluetooth Smart," is a wireless personal area network technology and a lightweight subset of classic Bluetooth and was introduced as part of the Bluetooth 4.0 core specification. It multiplies range speed and thus increases data transmission capacity for greater accuracy required of BLE transmissions and is essential for IoT applications. It is intended to provide low power consumption and considerably reduced power costs (TOWNSEND, 2014).

There is an abundance of wireless protocols for engineers and product designers. And one of the factors that make BLE so attractive is its easy way to design something that can talk to any modern mobile platform such as iOS, Android, and Windows phones.

BLE works like the data transaction of a GAP, controlling connections and advertising, response and scanning functions for Central and Peripheral devices. GAP is an acronym for Generic Access Profile. It makes a device visible to the outside world and determines how two devices can (or cannot) interact. Peripheral devices are small, low-power, resource-contracted devices that connect to a more powerful Central device (BLUETOOTH, 2017b).

2.4.3 Understanding wireless communication

After understanding the operating requirements of the BLE. A basic outline of what is going on to talk to any BLE device and the Myo clamp specifically would be:

The GAP discovery, peripherals, represents the Myo clamp in the communication created. The Myo will send advertising packets containing a unique 128-bit UUID to the Control Service to appear for other devices to make the connection. An interface is normally used to select the desired device to establish the connection between devices. Using BLE has a "tap" feature (behavior), which from the strength of the signal, two devices connected by proximity, leaving the MAC address of the device stored for later connections. The "tap" detection is based on the massive increase in signal strength you get from two Bluetooth radios nearby. It becomes trivial to take advantage of this feature with the Myo bracelet (BERNHARDT, 2015c)

Finally, the bracelet interaction is treated as a GATT server and connected device as the client. The bracelet exposes a set of features (grouped into services) that provide data access and control capabilities. GATT procedures can now be used to read and write feature values and subscribe to notifications or functionality indications.

To explain exactly what the Myo armband can provide with its BLE as open-source—making it possible to develop a new implementation using its benefits.

Everything is specified in the FirmwareVersionCharacteristic in the Myo SDK, such as the GATT Characteristic IDs. Like the possibility to capture data like IMUDataCharacteristic for motion data and ClassifierEventCharacteristic, as well as the EMG data, broken into four different EmgDataXCharacteristic, as it becomes possible to create a communication to handle such a level of bandwidth (GREENBERG, 2015).

Thus, it is possible to use control commands to put the Myo in the communication's desired state. By default, the Myo armband would not send IMU / Pose / EMG data just by the connected application, having to assign the characteristics (Enable) of the respective functions for its use. Creating the Myo support on various platforms becomes trivial through the device's communication protocol, and you can connect it to anything.

Due to the freedom to run your code. So, for example, building an Arduino project that talks directly to a Bluetooth LE module attached to the board instead of going through the traditional path to a computer. As was the case with the development of an engineer Valentin Roland, he created his MyoBridge library integrated with the Myo SDK enabling new interactions with the device, which many are now using.

There are numerous possibilities for connecting to the Myo, giving a wide range of options for working on human-machine interaction in this scientific initiation. In the next chapter, this range of possibilities is explored, justifying the choice of developing the interaction itself with the device.

3 The integration of Architectures

This chapter deals with the organization of developing interaction with Myo and explains the development platforms provided to design an application that interacts with the device. The way that the integration of the bracelet with the platforms was outlined to be able to choose the best way to perform control of the interaction process with the Myo. Thus, throughout this chapter, there is a discussion about the best way to realize a project with the bracelet.

3.1 Device development platforms

The Myo brings numerous development possibilities through the Software Development Kit (SDK), made available by the scientists at Thalmic Labs (LABS, 2015). Through these SDKs, any developer can venture out to create interactions using the device. However, it should be essential that this developer obtain knowledge of its operations, communication protocols, features, and platforms available to perform a good development.

To practice a good improvement of the scientific initiation project, the study of the development possibilities of each SDK was invaluable. Since, to succeed in constructing an adequate integration for the man-machine interaction, it is essential to think of ways to integrate the Myo's hardware with an interface to control the data collected by the device and run them on the Arduino platform to demonstrate the BCI interaction. This sequence of steps to realize the BCI interaction is the art of expressing a model or concept of information used in activities that require explicit details of complex systems, such as integrating the bracelet, conceptually called Information Architecture. Thus, for the created system to ensure a good user experience, it is necessary to organize the designed architecture to create a pleasant integration with the Myo device.

To help understand and design how to use the capabilities of each development kit, by exploring the characteristics of each available SDK, it is possible to determine what their basic functionalities are. Since each one has its operations and capabilities, they may differ and not present all available features. Thus, table 1 was created to illustrate the development possibilities in their current versions for creating interaction using the bracelet.

Analyzing the table, the characteristics of each development platform become clear, related to their respective platforms. The operations they can implement and that they cannot achieve in the current version available cannot perform due to restrictions. Thus, we use it to organize the architectures of the interaction with Myo.

SDK	gestures	IMU	IN G	Application complete	Platform
keyborad mapper	Yea	No	No	No	Windows/OSX
Myo Script	Yea	Yea	No	No	Windows/OSX
Platform SDK	Yea	Yea	Yea	Yea	Windows/OSX
unity	Yea	Yea	No	Yea	Windows/OSX
Android SDK	Yea	Yea	No	Yea	android
iOS SDK	Yea	Yea	Yea	Yea	iOS

Table 1 - The features available for each SDK

The architectures serve as the basis for the communication development with the bracelet for the project. They are models or concepts of information used to explicitly detail the system of collecting and sending data, control, and execution. In the following topics, the architectures designed for the progress of the interaction are described, characterizing their advantages and disadvantages, and finally, the choice of the architecture used for the development.

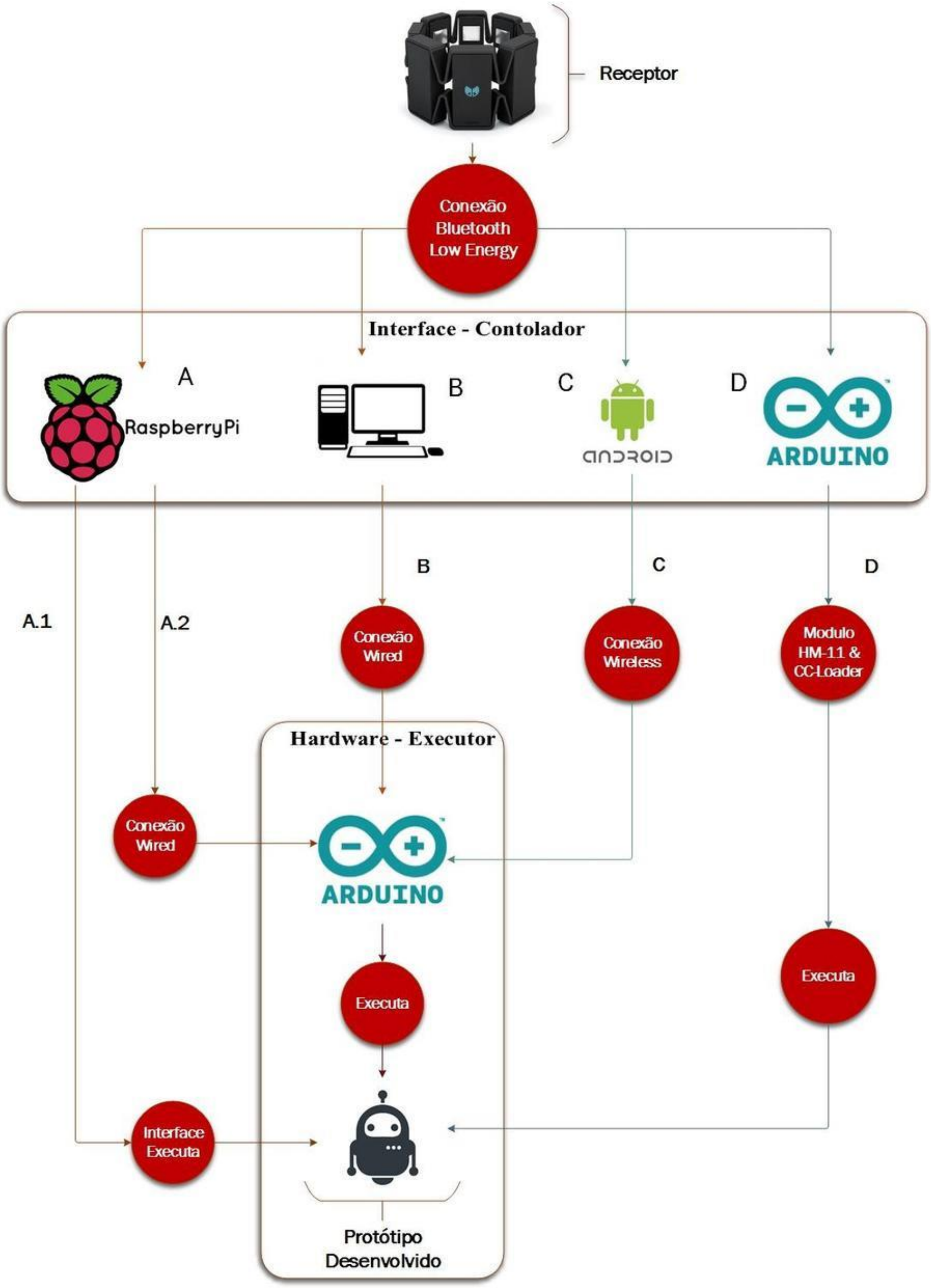
3.2 The architectures for using Myo

Exploring the development possibilities presented in table 1, it becomes plausible to use a logical representation of possible ways of connecting the bracelet to the project to use the communication with an intermediate interface. It is feasible to process the data collected by Myo to control a device, to represent the control of the BCI interaction with an IoT. The device in question will be conjectured using the free hardware platform Arduino, but this will be the next chapter's topic.

Seeking to implement a logical representation of the possible ways to connect the device, the data flow diagram, diagram 1, was formulated. This diagram makes it possible to discuss the best ways to use the communication with the device.

Analyzing the developed flowchart, Myo can connect to four possible areas of interaction, chosen to fulfill the role of controller of the interaction. This role is essential because some platform needs to process the data collected by the device to give instructions to the executing hardware, IoT. The interfaces chosen to fulfill this duty are the Raspberry Pi, a computer, an Android device, and directly with the hardware that does the function of executing the commands received, as the final device of the interaction.

Diagram 1 - Flowchart of architectures for development



The possibilities in each area of interaction are extensive, with many resources for different forms of development. From the development possibilities of each of the interfaces, it is necessary to choose one to be the focus of the final project. It is therefore essential to explore the characteristics of each one, as well as their advantages, disadvantages, and implementation challenges. For the most appropriate choice for the project's development, the one that is most conducive to the plans of human-machine interaction will be the chosen integration. The next topic discusses each one of the interfaces searching for the most adequate for the project.

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3.3 The characteristics of each architecture

As a matter of good development practices used in software engineering, to choose a good technique for implementation, it is necessary to know a problem thoroughly to obtain the best solution. In this case, this problem is to define the best architecture for the development.

Using methodologies and methods for an analysis of the software structure, it was deduced that by obtaining knowledge about its advantages and disadvantages, it is possible to reach an adequate solution for this problem. In the same way, achieving a solid understanding of the implementation of each interface serves as a motivation to implement your choice (SOMMERVILE, 2007) then actually. Following this logic, we will explore the characteristics of each control interface shown in the previous topic to choose the best implementation architecture.

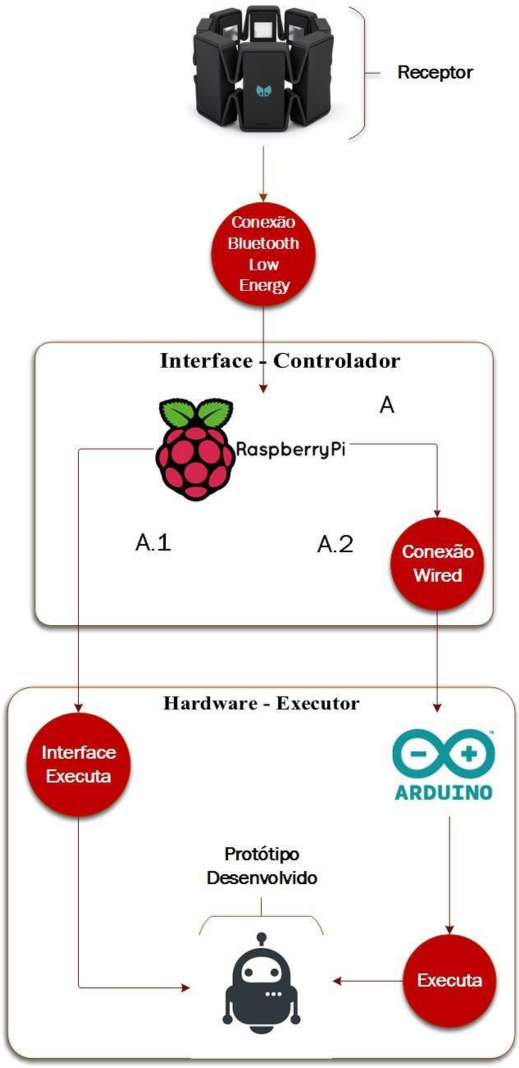
3.3.1 Raspberry Pi (A)

The Raspberry Pi interface is a computer the size of a credit card, leaving nothing desired compared to the essential functions. They are commonly used to promote the teaching of Computer Science in many schools worldwide. Moreover, it has a vast capacity to interact with the outside world and develop digital projects. The Raspberry Pi was designed to operate operating systems (OS) with the Linux distro base. Still, by presenting hardware used in old smartphones, it can employ OS of mobile devices, besides those based on Windows 10 IoT (FOUNDATION, 2017).

Unfortunately, the SDKs developed for Myo do not present versions for use in a Linux distribution. However, the Raspberry Pi can use a Windows 10-based operating system, especially IoTs. This way, we can use the SDK developed for Windows, making the interface present practically the same forms of development as the computer interface.

As shown in diagram 2, there are two ways to develop an interaction using the Raspberry Pi interface (A). The first (A.1) would be through the GPIO that the interface provides easy usability. The second (A.2) would be through the USB connection with the Arduino platform. We will then discuss the advantages and disadvantages of integrating the architectures and thus conclude on their possible use in the project.

Diagram 2 – Architecture through the Raspberry Pi



• Pros:

The first form of integration (A.1) provides the same functionality as an Arduino board to create an interface for interaction with the environment. Using the Raspberry Pi's hardware to perform all the processing benefits is superior to the Arduino's. Besides generating a great advantage of portability for the development of an IoT.

The second form of integration (A.2) provides an advantage of the organization, management, and greater possibilities for development. Since we can use the Raspberry Pi exclusively to fulfill the processing of the data collected through the Myo and develop an interface dedicated only to BCI interaction, leaving the function of implementing the development of an IoT to the Arduino platform. It presents a better range of features than the Raspberry Pi because it was developed specifically for this purpose and has been on the market for longer, providing a much more comprehensive range of features.

In general, unlike a Computer, it is highly portable, providing greater mobility for IoT development without relying on large amounts of power for its operation.

- Cons:

The interaction developed from the Raspberry Pi interface had not been programmed by the Myo development team, as on any platform using a Linux distribution. It came about because of the difficulties of creating a portable interaction using a computer by installing a version of OS Windows, a version for Microsoft's Tablets. However, the true potential of the Raspberry Pi lies in the running using a Linux-based operating system, which is native to the hardware developed.

Thus, the Raspberry Pi development would not have technical assistance provided by the companies that created the hardware used in the interaction. The company that developed the interface does not support using Windows on its system and Thalmic Labs for operating the Myo SDK on a Linux platform.

The Raspberry Pi still relies on a constant power supply despite its portability. The system's power can be provided by a Power-Bank, a portable power source commonly used to charge cell phones so that it doesn't have to be fixed to an outlet. Still, this feature would increase the size of the IoT considerably, decreasing its portability. Another challenge would be the ventilation required for the minicomputer to maintain its processing speed at a constant level without losing its capacity to perform. In other words, it would require the use of a case designed for its use..

- Conclusion:

The interaction developed by the Raspberry Pi would be a way to simplify the interface designed by the computer. When we think about the mobility aspect of this project for the user, even depending on a constant power source. However, the interaction created using this system would be as laborious and robust as it would raise the production cost of the project. In comparison to the cost of the Arduino, the Raspberry Pi is considerably more expensive. The possibilities and advantages of using the interface make it a good option for conjecturing an architecture integrating the use of Myo.

3.3.2 Computer (B)

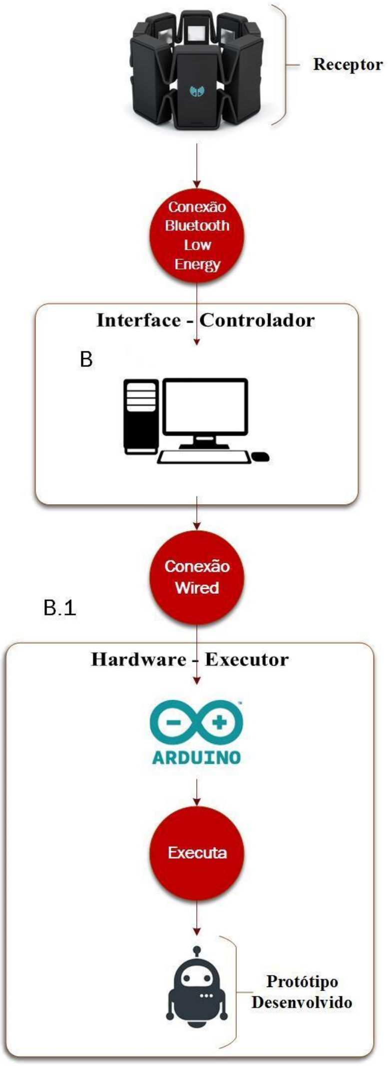
The interaction developed by the Computer interface has the most extensive range of development forms available for Myo, as shown in the numerous SDKs for OSX or Windows, in table 1. Presenting the possibility of conceiving an application operating in C++ through the Platform SDK, or the constitution of an application using Lua Script in Myo Script, as a multiplatform creation through a website employing WebSockets and javascript and the development of games or interactive animations using the Unity development platform.

As this presents the unlimited possibility for development, the Com-puter was the interface that received full support from the community involved in numerous SDKs, enabling a comprehensive form of implementation regarding the use of Myo. This development feature comes from the interface's huge processing potential, better-integrated architecture, and hardware. Thus, enabling the creation of more complex projects without significant difficulties.

The development of the architecture of interaction through the computer for the development of an IoT uses the great potential of interface development, together with the use of the Arduino platform for the development of the device. As described in the data flow illustration below:

It is noticeable by looking at diagram 3 that there is a single method to perform the proposed development employing the platform(B) for building an interaction disposing of Myo, focusing on designing an IoT prototype. It is done through the cable connection (B.1), using USB with the Arduino platform. This way, its advantages, and disadvantages are discussed for the integration condition of the architecture, and thus be able to conclude about its possible use in the project.

Diagram 3 - Computer Architecture



- Pros:

The integration of the Computer development interface brings the benefits of creating a complex application and presenting the most significant amount of features and varieties of development for Myo. It has the full support of developers and a large community, be easy to design an interaction when using it as an interface. Without a doubt, the Computer presents the most significant development potential.

• Cons:

Although an interaction developed employing the computer interface presents the most significant potential for progress. For the focus of creating an exchange using an IoT device. It does not provide the desired mobility for project creation. The platform depends on large amounts of power to present such a potential, i.e. it is essential to be connected to an outlet. It is a large and robust interface compared to other architectures.

• Conclusion:

Unfortunately for developing an IoT, using the computer the interaction created becomes a hindrance for the user. However, for testing, data collection, and experimentation with the BCI interaction provided by Myo, this interface is undoubtedly the best choice for development.

3.3.3 Android (C)

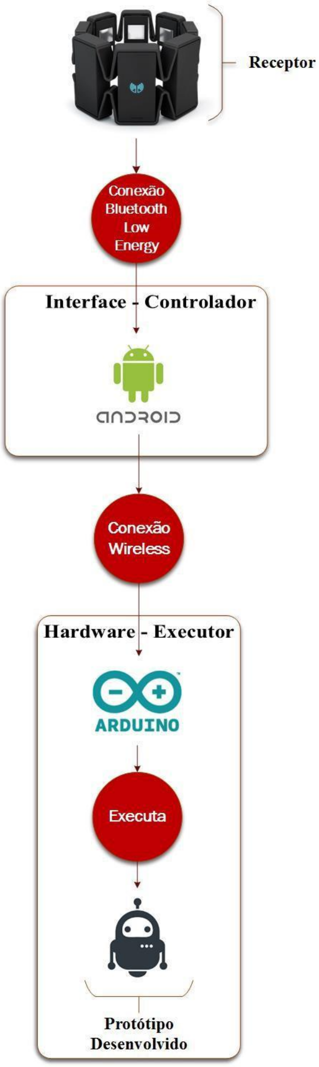
The interaction developed by the Android platform was designed to bring the most significant mobility of use to the user through the use of Myo together with the service in applications such as coordinating the music player on Spotify by gestures identified by the bracelet or playing a mobile game by capturing the user's arm movement to command the game object.

After all, having a smartphone nowadays has become essential to establish basic human communication needs and increase the level of technological interactions and possibilities through the device. Besides being able to represent the potential of a computer in the palm of your hand and utilizing the advantage of the mobile device is present in the everyday life of many. The Myo developers created the SDK for Android and iOS to increase the occurrences and possibilities of BCI interaction through the convenience of controlling a multifunctional device available at all times to perform an exchange.

For the use of the Android interface, the architecture was proposed to conceive greater mobility. Thus, both the Myo and the Arduino platforms are free to bring the most significant mobility to the user. As in the data flow illustration below, Myo connects to the Android interface through Bluetooth, and the latter bridges the connection to the Arduino.

Analyzing the data flow from diagram 4, it is clear that there is only one way to perform the proposed development using the interface (C) to build the interaction. The integration of the platforms is done through the wireless connection (C.1), being able to use the link via Bluetooth or Wi-Fi with the Arduino platform to ensure the mobility of the architecture. Thus, it is discussed the advantages and disadvantages of the way of integrating the architecture to conclude about its possible use in the project.

Diagram 4 – Architecture through Android



• Pros:

The integration of the Android development interface brings with it the benefits of a connection that provides convenience, practicality, and ease of use for the user. Because the smartphone has become a standard item in people's lives around the world, it has a wide variety of services. You can use it to create numerous connections, such as for developing an IoT. Android also features mobile application development, which brings a more friendly and interactive interface to the user on different platforms.

• Cons:

The disadvantages of using the Android interface would be related to the Myo SDK developed since it does not present the EMG data collected by the bracelet. Thus, it is not possible to create an application capable of recognizing new gestures using the resources provided by Thalmic Labs. However, a library developed by the community can collect the data. However, it does not support any problems available to developers.

- Conclusion:

The interface that brings the most significant benefits to the user in the interaction created uses the architecture organized for the Android platform, being the most interactive and friendly to use. Even though, unfortunately, there is no possibility of EMG data collection made available by the SDK developed so far. It is still possible to recognize standard gestures for user interaction.

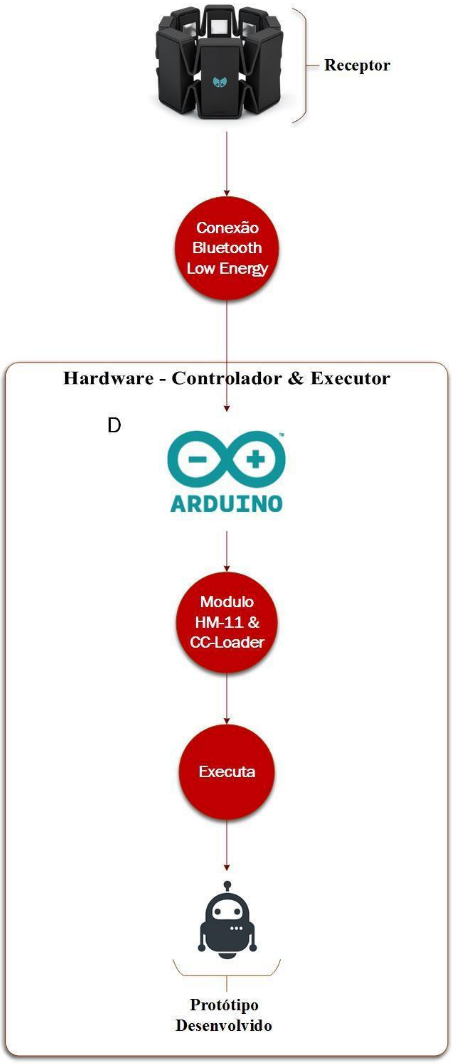
3.3.4 Arduino (D)

The interaction developed using the Arduino platform is the most intriguing. Because it is a direct connection with the development of the IoT device, unlike the others, this architecture would not need two devices, the intermediary that would control the information received by Myo and the executor hardware that would command the data to the IoT module. After all, unlike the Raspberry Pi, which has a computer-like architecture, the Arduino does not have high performance for software and application development. It is typically used exclusively for prototyping.

The direct development in the Arduino interface is developed using the Myo Bridge library. The Arduino, through the HM-11 & CC-Loader modules, can establish the connection with Myo, process the collected data, and then have the platform perform the desired function in the developed IoT. The research-engineer Valentin Roland developed this library with his autonomous project. He is not part of the Myo development team but has made his automation available for the community to use.

Analyzing the data flow, from diagram 5, for the progress of the Arduino architecture, it is clear how the proposed development can be carried out using the interface (D) for the construction of interaction. The integration of the platforms is done through the HM-11 & CC-Loader modules (D.1), which through a Bluetooth connection with the Myo device, can process the collected data. We will then discuss the advantages and disadvantages of the form of integration of the architecture and thus conclude on its possible use in the project.

Diagram 5 – Architecture through Arduino



- Pros:

With the Arduino performing the processing and automation of an IoT, this architecture brings the most significant mobility and autonomy to the user. Since the proposed interaction does not depend on more than one interface, in power issues, it would rely only on a power supply that can be an internal battery built to not rely on a connection with the outlet.

- Cons:

Although the interaction developed using this architecture is practical, no resources for directly connecting Myo to the Arduino were provided by Thalmic Labs. Thus, the development of this interaction would not be assisted. Also, the developed project would not present a UI for the user since the Arduino has no interface for interaction.

• Conclusion:

There has been very little development using this form of interaction to date. There is no support for this platform provided by Thalmic Labs, making it susceptible to various bugs and glitches with no quick or practical solutions leaving the development complex. Arduino is also not as intelligent a platform as the others; its processing capacity is limited, with less competence for the gradual development of a project through great complexity..

3.4 The architecture chosen for the interaction

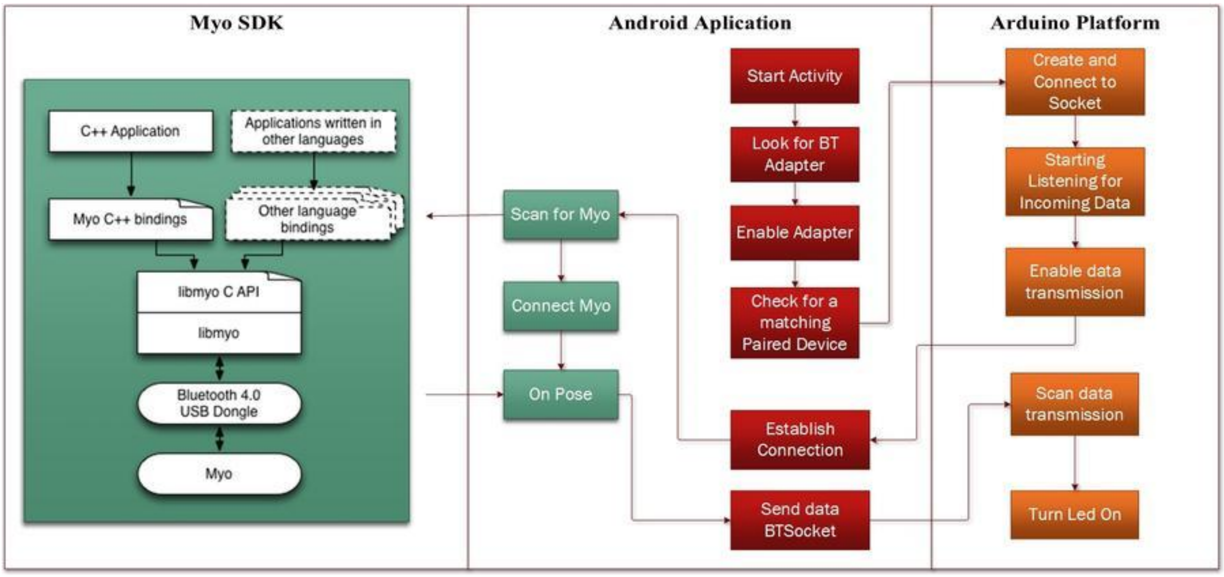
After discussing the positive and negative points about each architecture, it is necessary to choose one to develop the human-machine interaction. Undoubtedly, they all presented an advantage for a form of use that would bring significant benefits to the interaction created. However, to choose one to perform the development with the focus of using an IoT device, the most interesting architecture to explore this area is the one provided by the Android platform (C), section 3.3.3.

Connecting Myo to a mobile device interferes directly with people's daily lives, which brings a great advantage for interaction. Since using the bracelet with the Android interface, the BCI interaction will be more accessible to all people, ensuring more uses for Myo when exploring its functionality with mobile applications.

With the choice of architecture to design the interaction, the focus is given on how the communication between the interfaces occurs to perform the data processing. Android will serve as the bridge of communication to interpret the bracelet data through Myo's SDK, with the other side of the communication that will be the prototype developed through the Arduino platform. Ready to execute an action according to the information sent by Android. The flowchart, represented in diagram 6, illustrates the system software stack from Myo to Android to Arduino.

A great place to start is by doing something simple in response to a pose to demonstrate the capability of the BCI interaction provided by Myo. So an IoT was built to light up a led corresponding to a gesture captured by Myo. As simple as this process may seem, it is essential for automation. For example, instead of a led, it could be a lamp in an apartment; the difference would be the installation of the Arduino, with which components it would work. However, the application would be the same, the collection, the identification of the poses, the sending of the data to the automation; the difference would be only the functioning of the Arduino.

Diagram 6 – Android Application Communication Software Stack



The autonomy of a project like this brings a new form of interaction to everyday life, with a wide diversity of applications, for example, home automation. Not interacting with a switch, but only with a gesture to automate a residence brings incredible convenience to people's lives.

In the next chapter, the development of this interface, from the automation in the Arduino playing the role of an IoT to the communication bridge made by Android..

4 The Beginning of Interaction Development

This chapter deals with the beginning of the development of the interaction chosen at the end of the subject of the previous one. It contemplates the conception of choice made for developing an IoT, fulfilling the purpose of demonstrating the interaction with Myo. It is starting from the explanation of the concept of the prototype that illustrates the operation of an IoT module to the development of the Android application that bridges the connection between the bracelet and the Arduino—serving as a control interface for the project. Thus, throughout this chapter, there are numerous explanations of how the interaction works to exemplify the process followed.

4.1 The elaboration of the Prototype

Arduino is used in thousands of different projects and applications thanks to its performance quality. Such as for building low-cost scientific instruments, proving principles of chemistry and physics, or getting started with programming and robotics. It is widely used to progress stand-alone interactive objects or to be connected to a host computer for development. It is becoming a vital tool for learning new things (ARDUINO, 2017).

Thus, Arduino becomes an excellent choice for prototyping in screening for an IoT development. Since this is an open-source electronics platform based on simple-to-use hardware and software, it is an intuitive program for learning. Intended for any interactive project, it can sense the environment by picking up inputs from many varieties of sensors and affecting the surroundings through controllers such as lights, motors, and other actuators.

A typical Arduino board consists of a logic controller, some memory-mapped digital and analog I/O lines, and a serial or USB interface to connect to a computer used to program and interact in real-time. The board does not have any networking capabilities, but it is common to combine one or more Arduinos by using appropriate extensions called shields. The Arduino interface used for development work on the computer is simple and modern, allowing resources to be programmed in various languages and development forms.

Arduino simplifies working with microcontroller modules and is capable of performing numerous tasks. Due to the ability to program in C/C++. This allows you to create many input and output operations by defining just two functions in the application to make a program work. The functions, setup() and loop(), are used for design, while the other is called to repeat a block of commands until the board is shut down. The open-source software (IDE) makes it easy to create the code and send it to the board, a cross-platform application written in Java, derived from the Processing and Wiring projects (ARDUINO, 2017).

Through the understanding, applicability, and functionality of the Arduino hardware and software. The following topics explain how it was elaborated, the mode of use, its prototyping applicabilities for the development of a project, serving as a test of the interaction with Myo—representing an example of standalone home automation. However, as a simplified model, it was implemented to test the integration and operation of the entire system. This implementation has the simple function of turning a light on and off through a Myo user pose. Despite the simplicity, it is possible to validate the proposed model. Moreover, it deals with wide use in home automation applications, for example.

4.1.1 The prototype design

The primary purpose of the Arduino in a system is to facilitate the prototyping, implementation, or emulation of the control of interactive services, at the household, commercial, or mobile level, in the same way that a Programmable Logic Controller controls industrial operating systems. With it, you can send or receive information from basically any electronic system, like identifying the approach of a person and varying the light intensity of the room according to their arrival or opening the windows of an office according to the sunlight energy and ambient temperature.

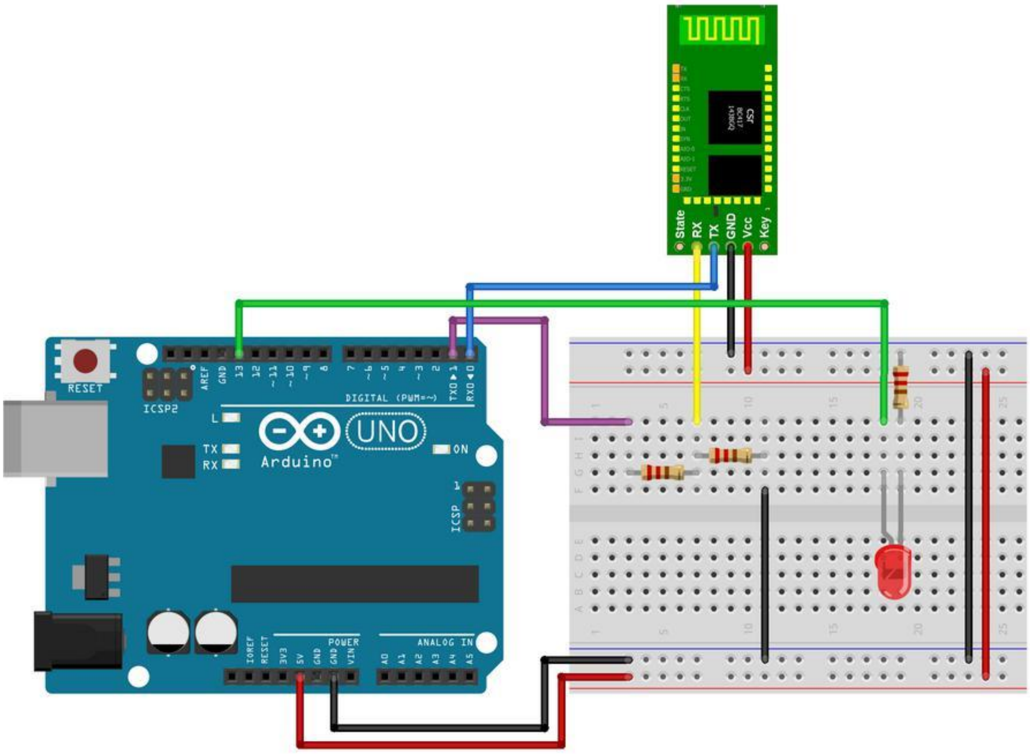
Based on its primary purpose and to demonstrate it in an IoT system, a prototype was elaborated to represent the interaction with Myo at the domestic level. It interline-ges a mobile application and a home automation system that aims to control the electrical equipment. However, the representation of the prototype is a simple interaction, focused only on the automation of a lamp. In this case, represented by a led connected to the Arduino, since there is no need for a demonstration in an actual circuit to evidence a BCI interaction for such a task.

Thinking about the interaction between the prototype platform and the mobile device, it was employed the use of the HC-05 module to constitute a communication via Bluetooth. When about to elaborate the circuit for prototyping, an element to which attention was paid is the signal level used by the module for serial communication. Since some modules work with 5v, others with 3.3v, the HC-05, in particular, uses the voltage of 3.3v.

The converter itself provides the power supply to the Bluetooth module through the GND (Ground) and Vcc (Direct Current Voltage) pins. The TX (Transmit) pin of the FTDI is connected to the module's RX (Receive) pin, and the RX is connected to the TX. Used a voltage divider to avoid damaging the component; for testing purposes, two resistors connected to the RX pin in the Bluetooth module, one of 1.5K and another of 2.2K, generating a signal level of approximately 3.1 v, sufficient for experimentation (OLIVEIRA, 2016).

After performing the preparation calculations for the composition of the circuit, diagram 7 was prepared to explain the module's organization together with the Arduino board and led to emphasize the performance of a lamp.

Diagram 7 - Circuit used for the prototype design



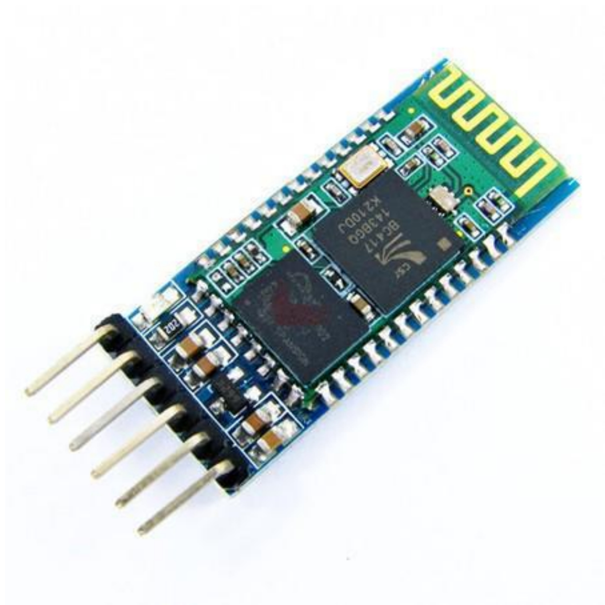
4.1.2 How the prototype works

After preparing how the circuitry of the prototype would work, next, there is the elaboration of the operation of the components. However, to carry out the practice, it is essential to think about how the communicability of the board operates, in the direction of how it will act from the communication with a mobile application. So, initially, the search for the understanding of the Bluetooth module.

The Arduino Bluetooth modules are divided into two types, those that operate in slave mode, i.e., only accept connections from other devices, and those that work in both enslaved person and enslaver mode, allowing them to connect to other Bluetooth devices. When two or more devices communicate over a Bluetooth connection, they form a piconet network (BLUETOOTH, 2017a). In this communication, the machine that initiated the relationship takes on the role of master, while the other instruments become slaves. It is up to the master to regulate the transmission of data on the network and the synchronism between them.

In the case of the developed prototype, the HC-05 module, illustrated in figure 20, was used. This module can act in master and slave mode. Seeing the functionalities of each form of operation, it was defined that this module would work in slave mode. Because the prototype does not present an interaction area for the user to control the communication, the model has a single purpose of acting in the electrical circuit. On the other hand, the developed application performs the role of an intuitive interface for the dweller to interact with his home with better convenience and practicality.

Figure 20 - The HC-05 bluetooth module



The characteristic by which a device uses Bluetooth depends on the capabilities of its user profiles. The profiles provide standards that manufacturers must follow to allow machines to use Bluetooth in a compatible way. To accomplish this task, each profile uses particular options and parameters at each protocol level (BLUETOOTH, 2017a).

Thus, for the communicability of the mobile device with the prototype, the solution was programmed using the SSP profile (Serial Port Profile) because it has a simple implementation and would solve the communication mode worked by the HC-05 module. Similarly, any application can perform this kind of communication in several mobile devices operating a virtual serial port, as if there was an actual serial cable connecting the two devices

To implement the communication through the SSP profile. A program was prepared in which the Arduino executes the function of turning a led on or off by checking the serial port of the Bluetooth module. By verifying available data received by the communication with the cell phone, identifying a specific message in the light performance.

To monitor the established connection, two steps in the module's programming were definedTo monitor the established connection, two steps in the module's programming were defined:

- First, a communication frequency is established by the setup() function in the Arduino to configure the board's serial.
- Second, the loop() function monitors the developed serial to check the collected information. Thus, to control the data obtained from the SSP profile, a selection and a repetition structure are started to collect all the data from the frequency used

The received commands are employed as forms of control for other Arduino functions and methods. Thus, in figure 21, there is a demonstration of the algorithm developed to establish the SSP communication and perform the SSP communication and monitor it to capture the received messages.

Figure 21 – Algorithm used to control Arduino communication

```
char command;
String string;
boolean ledon = false; //Boleano utilizado para realizar o controle do Led
#define led 13   //Led connectado ao digital pin 13

//Estabelece a serial para a conexão
  void setup()
  {
    Serial.begin(9600);
    pinMode(led, OUTPUT);
  }
//Realiza o controle da conexão
  void loop()
  {
    if (Serial.available() > 0)
    {string = "";}

    while(Serial.available() > 0)
    {
      //Armazena os dados coletados na conexao
      command = ((byte)Serial.read());

      if(command == ':')
      {
        break;
      }

      else
      {
        string += command;
      }

      delay(1);
    }
```

After the Bluetooth communication control is established, the received data are worked on to identify the message of a specific command to turn the light on or off. To proceed and act on the lighting function, a selection logic is employed to investigate a particular message to affect the automation of the light. In the case of the development used, the Arduino tries to identify two characters to perform this control. The logic applied follows in the programming language, demonstrated in figure 22.

Figure 22 – Selection structure created to turn the light on or off

```
//Caso o dado coletado seja igual, o Led é aceso
if(string == "TO")
{
    ledOn();
    ledon = true;
}
//Caso o dado seja igual, o Led é desligado
if(string =="TF")
{
    ledOff();
    ledon = false;
    Serial.println(string);
}
```

In the next topic, the second part of the interaction is defined, the control bridge performed by the Android application. This will be the treatment of the signals received by the BCI device, which, based on the collected data, will transmit the order established for the project prototype to act based on the codes demonstrated in the current topic. Explaining the operation of Bluetooth communication, treatment, transmission and highlighting them in the following topics.

4.2 The communication bridge, the Android application

Android is an operating system based on the Linux system, currently developed by Google. With a user interaction based on direct manipulation, the Android system is mainly designed for mobile devices with a touch screen. Today, the Android platform is one of the most widely used mobile devices, especially cell phones for software developers. The forum brought an exciting niche market, the development of applications (FORNI, 2017).

Android Studio is the official integrated development environment (IDE) for Android applications. This offers a wealth of features to increase productivity in creating Android apps on a flexible build system based on Gradle, with a fast emulator and a unified environment to develop to all Android devices (DEVELOPERS, 2017) and becoming the chosen platform for the progress of the project application.

4.2.1 The communication bridge to the Arduino

In addition to establishing communication with the Arduino, it is essential to maintain control of the Bluetooth connection of the Android device. The device plays the role of master in touch, where it is responsible for regulating the transmission of data on the network and the synchronism between the devices. The communication control is then implemented through the application created to activate the connection and collect and transmit data coming from the Myo in the interaction with the user.

To establish the connection from the mobile device, the Bluetooth control instance offered by the platform, a variable called myBluetooth, receives the reference from Android. It is possible to stabilize the management of the device communication. It also checks the Bluetooth communication activity in the device through a selection structure to see if it is active or not, as shown in the example of the algorithm in Figure 23.

Figure 23 - Algorithm for controlling the device's bluetooth communication

```
//Se o dispositivo possuir Bluetooth
myBluetooth = BluetoothAdapter.getDefaultAdapter();

if(myBluetooth == null)
{
    //Mostra uma mensagem que o dispositivo nao possui bluetooth
    Toast.makeText(getApplicationContext(), "Bluetooth Device Not Available", Toast.LENGTH_LONG).show();

    //termina o apk
    finish();
}
else if(!myBluetooth.isEnabled())
{
    //Pede ao usuario para ativar o bluetooth
    Intent turnBTon = new Intent(BluetoothAdapter.ACTION_REQUEST_ENABLE);
    startActivityForResult(turnBTon,1);
}
//chama o metodo para listar os dispositivos pareados
btnPaired.setOnClickListener((v) → { pairedDevicesList(); });
}
```

After the Bluetooth device control is activated, the paired devices list method searches for devices that have the Bluetooth communication active to find other devices ready to pair. The process stores the data of these found devices in a list. It lists and displays the device names in an interface where users can select the desired device to pair with.

Exploring the method's functionality to manage found devices has two logical structures: a selection and a repetition structure. The method structures collect all the data found in the Bluetooth communication of the cell phone through the variable created in the previous example, using it to search for other devices with active transmission. After the collection, the data will be implemented in a list object, of type ArrayList, created to be adapted and represent a list in the Android application layout. The structure of collection and pairing with other devices are described in the example algorithm in Figure 24.

Figure 24 – Algorithm for choosing a device to connect

```
private void pairedDevicesList()
{
    //Encontra os dispositivos pareados atraves da conexao
    pairedDevices = myBluetooth.getBondedDevices();
    //Cria uma lista para armazenar os dados dos dispositiovs
    ArrayList list = new ArrayList();

    if (pairedDevices.size()>0)
    {
        for(BluetoothDevice bt : pairedDevices)
        {
            list.add(bt.getName() + "\n" + bt.getAddress()); //Pega o nome e o endereco dos dispositivos
        }
    }
    else
    {
        //Mensagem de erro caso nao ache nenhum dispositivo
        Toast.makeText(getApplicationContext(), "No Paired Bluetooth Devices Found.", Toast.LENGTH_LONG).show();
    }
    //Transforma a lista em um Adapter para utilizar no Layout
    final ArrayAdapter adapter = new ArrayAdapter(this,android.R.layout.simple_list_item_1, list);
    devicelist.setAdapter(adapter);
    devicelist.setOnItemClickListener(myListClickListener); // Metodo chamado quando o dispositivo da lista for

}
```

After the user selects a device, a connection between the cell phone and the found device needs to be established. As explained in the Arduino topic, the established link must use the SSP profile for Bluetooth communication. However, to establish a connection using the SSP profile, the application must meet some fundamental requirements for setting up serial cable connections emulated using RFCOMM, which are expressed in terms of the services provided to applications and defining the features and procedures required for interoperability between Bluetooth devices (learn more at http://www.amd.e-technik.uni-rostock).

To establish communication with the Arduino, we use the previously created variable myBluetooth to collect the data and show the pairing with the device. Then, another variable called brocket is designed to emulate a serial cable between the two devices, creating the RFCOMM connection through the SSP profile. The RFCOMM carries the user data, modem control signals, and configuration commands. With the SSP connection established, this can interact with the prototype, demonstrated later in the light automation. The logical structure used to secure the SSP connection is shown in the algorithm in figure 25.

Figure 25 - Algorithm to establish the SSP connection

```
private class ConnectBT extends AsyncTask<Void, Void, Void>  // Tratamento UI
{
    private boolean ConnectSuccess = true; //Se der certo, esta quase conectado

    @Override
    protected void onPreExecute()
    {
        progress = ProgressDialog.show(MainActivity.this, "Connecting...", "Please wait!!!");  //mostra um dialogo de progresso
    }

    @Override
    protected Void doInBackground(Void... devices) // Enquanto mostra o dialogo de progresso, a conexao e feita em background
    {
        try
        {
            if (btSocket == null || !isBtConnected)
            {
                myBluetooth = BluetoothAdapter.getDefaultAdapter();//Pega o dispositivo movel bluetooth
                BluetoothDevice dispositivo = myBluetooth.getRemoteDevice(address);//Conecta-se ao endereco do dispositivo e checa s
                btSocket = dispositivo.createInsecureRfcommSocketToServiceRecord(myUUID);//Cria o RFCOMM (SPP) conexao
                BluetoothAdapter.getDefaultAdapter().cancelDiscovery();
                btSocket.connect();//inicia a conexoa
            }
        }
        catch (IOException e)
        {
            ConnectSuccess = false;//Se ocorrer um erro e possivel checar a excecao
        }
        return null;
    }
```

With the communication ready, through the use of the brocket variable, to then send data from the Android application to the Arduino device through the SSP connection. Two methods are then used to act on the state of the prototype's lighting, one to turn the light off the other to turn it on. Both ways send a message through RFCOMM, using specific characters so that the prototype can identify the letters in the selection structure defined in the algorithm at the end of the Arduino topic. The algorithm used for sending messages is shown in Figure 26.

Figure 26 - Algorithm to control the LED

```
//Funcao para desligar o Led
private void turnOffLed()
{
    if (btSocket!=null)
    {
        try
        {
            //Envia mensagem para desligar o Led
            btSocket.getOutputStream().write("TF".toString().getBytes());
        }
        catch (IOException e)
        {
            msg("Error");
        }
    }
}
//Funcao para ligar o Led
private void turnOnLed()
{
    if (btSocket!=null)
    {
        try
        {
            //Envia mensagem para ligar o Led
            btSocket.getOutputStream().write("TO".toString().getBytes());
        }
        catch (IOException e)
        {
            msg("Error");
        }
    }
}
```

The prototype is established after communication from the Android application to the Arduino. The path to Myo automation is complete so that there will be no hindrance to collecting signals for obtaining a pose. In the goal of using the data obtained from the BCI device to perform home automation, made from a user gesture, obtained by the bracelet. The implementation of the communication with Myo by the developed application is described in the following topic.

4.2.2 The communication bridge to Myo

For the application to establish communication with the bracelet, some frameworks must be implemented so that the Android IDE can interact with the device's SDK classes. Myo has a set of software for Android development, the Myo Android SDK. From this framework, it is possible to interact with the bracelet using the device's classes to control the resources provided by Myo with greater ease.

However, to be able to use the development kit, some fundamental changes in the operation of the application are required. The Myo Android SDK requires default settings at the Android Application Programming Interface (API) level. So applications using the SDK need to set their minSdkVersion to a level equal to or higher than 18. Several functions necessary for the implementation will be unavailable in the Android operating system (LABS, 2014).

With the change in the application level, it becomes possible to utilize the degree of functions that the Myo SDK offers. To enable the parts of the development kit, you import its dependencies into the Gradle repository. In this way, whenever the application instantiates, the Myo class references are installed so that the application can establish a connection with the bracelet. It is also necessary to implement permission protocols for Bluetooth and internet communication because the user needs to allow these forms of communication to work with Myo and the Arduino.

After performing the implementations in the Android application, it will be able to receive and handle any communication events with Myo provided by the SDK classes. Thus, it can work with the data collected by the bracelet and return functions according to the identified poses or even the device's movement. It gives room to establish a connection with Myo through the application.

To establish the communication with Myo, we use a variable that is quite common for an Android application and Intent. This, by default, gives origin to an operation to start an activity, especially from the Myo SDK. The Scan Activity provides a screen where the user can select the bracelet he wants to connect to. So without much trouble, the bracelet is ready to send data to the application.

An excellent way to establish the connection activity with Myo is to put it as one of the options in the application menu. The way demonstrated in the example of figure 27, ensuring a good user experience (UX), where he will not have difficulties performing the pairing when desired.

Figure 27 – Creating the connection with Myo

```
//Inicia o Menu na aplicacao
@Override
public boolean onCreateOptionsMenu(Menu menu) {
    super.onCreateOptionsMenu(menu);
    MenuInflater inflater = getMenuInflater();
    inflater.inflate(R.menu.menu_led_control, menu);
    return true;
}

//Caso selecionado Myo Scan
private void onScanActionSelected() {
    // Inicia o ScanActivity para scanear Myos e conectar-se a um.
    Intent intent = new Intent(this, ScanActivity.class);
    startActivity(intent);
}
```

With the connection with the bracelet established, it is possible to explore the functionalities of Myo. One of the possibilities of interaction with the bracelet, without a doubt, is to demonstrate the device's movement. In a way that, exploiting the capacity of the bracelet's motion sensors, it can identify and copy the user's arm movement. Thus, using the method in the Myo library, it is possible to represent the rotation of the device through a Text View applied in the layout of the Android application.

Transforming the quaternion obtained in the orientation of the bracelet into Euler angles to represent more intelligible manipulation in the results collected by Myo. Thus, the Text View in the application will have the same rotation in tips on each rotational axis as the bracelet on the user's arm. Figure 28 shows the algorithm used to capture the user's movements.

Figure 28 – Algorithm used to represent the movement of the bracelet through the use of a Quartenion

```
// onOrientationData() e chamado sempre que o Myo fornece a sua orientacao atual
// representado como um quaternion.
@Override
public void onOrientationData(Myo myo, long timestamp, Quaternion rotation) {
    // Calcula os angulos de Euler (roll, pitch, and yaw) atraves do quaternion.
    float roll = (float) Math.toDegrees(Quaternion.roll(rotation));
    float pitch = (float) Math.toDegrees(Quaternion.pitch(rotation));
    float yaw = (float) Math.toDegrees(Quaternion.yaw(rotation));

    // Ajusta o roll e o pitch para a orientacao do Myo no braco.
    if (myo.getXDirection() == XDirection.TOWARD_ELBOW) {
        roll *= -1;
        pitch *= -1;
    }

    // Aplica-se a rotacao no TextView usando o roll, pitch, e yaw.
    mTextView.setRotation(roll);
    mTextView.setRotationX(pitch);
    mTextView.setRotationY(yaw);
}
```

However, the main functionality that should be explored is to perform the light automation of the prototype. As discussed earlier, to exploit the power of the BCI interaction provided by the Myo device, the ability to recognize user gestures was used to perform light automation on the Arduino prototype. The poses that the device can identify by factory default are instantiated through a function obtained from the bracelet's SDK.

Thus, using a selection structure, it is possible to perform a treatment to identify each pose. So that, from this structure, one of the previously developed functions, turnOnLed or turnOffLed, is initiated to send a message through Bluetooth communication, turn the light on or off, to the Arduino prototype. Figure 29 shows the algorithm used to identify the possessions, and from two, perform the home automation.

Figure 29 – Algorithm used to capture a pose by the bracelet

```java
// onPose() e chamado sempre que o Myo prover uma pose nova.
@Override
public void onPose(Myo myo, long timestamp, Pose pose) {
    // Lida com os casos da enumeracao das Poses e muda o Textview de acordo.
    // Baseado na pose recebida.
    switch (pose) {
        case UNKNOWN:
            mTextView.setText("Hello world!");
            break;
        case REST:
        case DOUBLE_TAP:
            int restTextId = "Hello world!";
            switch (myo.getArm()) {
                case LEFT:
                    restTextId = "Left Arm";
                    break;
                case RIGHT:
                    restTextId = "Right Arm";
                    break;
            }
            mTextView.setText(getString(restTextId));
            break;
        //Caso seja indentificado FIST, envia o comando para ligar o Led
        case FIST:
            mTextView.setText("Fist");
            turnOnLed();
            break;

        case WAVE_IN:
            mTextView.setText("Wave In");
            break;

        case WAVE_OUT:
            mTextView.setText("Wave Out");
            break;
        //Caso seja indentificado FINGERS_SPREAD, envia o comando para desligar o Led
        case FINGERS_SPREAD:
            mTextView.setText("Fingers Spread");
            turnOffLed();
            break;

    }
```

Finally, with the fulfillment of each step of the planning, finalized. It is possible to verify the communication developed from the bridge created by the Android application between the Arduino and the Myo bracelet. Demonstrating if the functionalities of the BCI occurred without any problems, or if there were any, what is necessary to correct such challenges found in the interaction created. The partial results obtained in the Human-Machine Interaction are presented in the next chapter.

.

5 Results Obtained

With the development of the project accomplished, this chapter discusses the results obtained in exploring the tests performed in the previous chapters. Contemplating the elaboration and refinement of the investigation completed, recalling essential topics along with their results, and presenting the development results proposed in the last chapter. Finally, portraying the problems and challenges encountered in the research with their possible solutions to improve the project carried out.

5.1 The pursuit of the research developed

Seeking to overcome characteristics of the limitations of an interaction with a computer and improve the standard behaviors in current uses. The development of the research project involves the evolution of models of human interactions with machines to innovate the patterns of human-machine interfaces (HCI), exploring interactions as from brain-computer interfaces (BCI) to work with signals captured by the nervous system, as a new frontier of implementation of the conventional exchange.

Starting from the use of a device to capture signals from the forearm that takes advantage of signal processing techniques, being able to translate a human command to a machine to imitate human movements. It becomes possible to break one barrier among several levels of the relationship between a human and a binary code. In developing an interaction, the more intuitive and friendly it is, the more productive the development using it will be. Not only for convenience but also to supply the need for the lack of existing communication possibilities due to their limitations.

Thus, to develop a way to overcome these common interaction barriers in everyday life. An experiment was proposed in which time and effort were invested in studying human-machine interaction techniques. To facilitate the communication of the human being, with the environment around him, without being limited to the conventional means of input. Through the study of neuroscience, employing techniques that collect and process various signals from the human body makes developing a programmed interface possible.

Through the programming research technique employed, the object of exploration uses gesture recognition, machine learning, and mixed reality, trying to combine the best aspects of both facts and proposing to develop a design centered on the goal of performing signal processing. In this way, the relationship was worked with a focus on which is considered to be stopped in time, with industrial maturity.

An interaction that focuses on supplying ways of living with a device and has suffered little technological investment over the years. Compared to the innovations presented in the market, the use of a switch to control light is extremely outdated; new techniques can make this interaction more comfortable. This device has always presented a scarce exchange in terms of capacity or convenience being something commonly applied.

On the other hand, to this peculiarity of outdated interaction, the idea of using a technology that complements this relationship manifests itself—elaborated in the form of representing a more practical and disruptive situation. Two technologies that gain more significant publicity for their impact on a person's life were used. The Arduino is a platform that popularizes the concept of accessible hardware and a mobile application as the integration of digital devices in the palm with multiple functionalities—providing a more intuitive and user-friendly relationship than a simple switch.

As a result, an integration in which an IoT device and a mobile application operate in tandem to the Myo bracelet, acting in the state of light—conducted in the project’s programming, using the IoT created to perform automation in the form of the morning. The mobile application managed the communication bridge, in real-time, between the Arduino and the signals coming from the bracelet and impacting the human relationship with an object that presented a certain industrial maturity. Since, with the BCI technique, it becomes possible to improve the relationship patterns between men and machines.

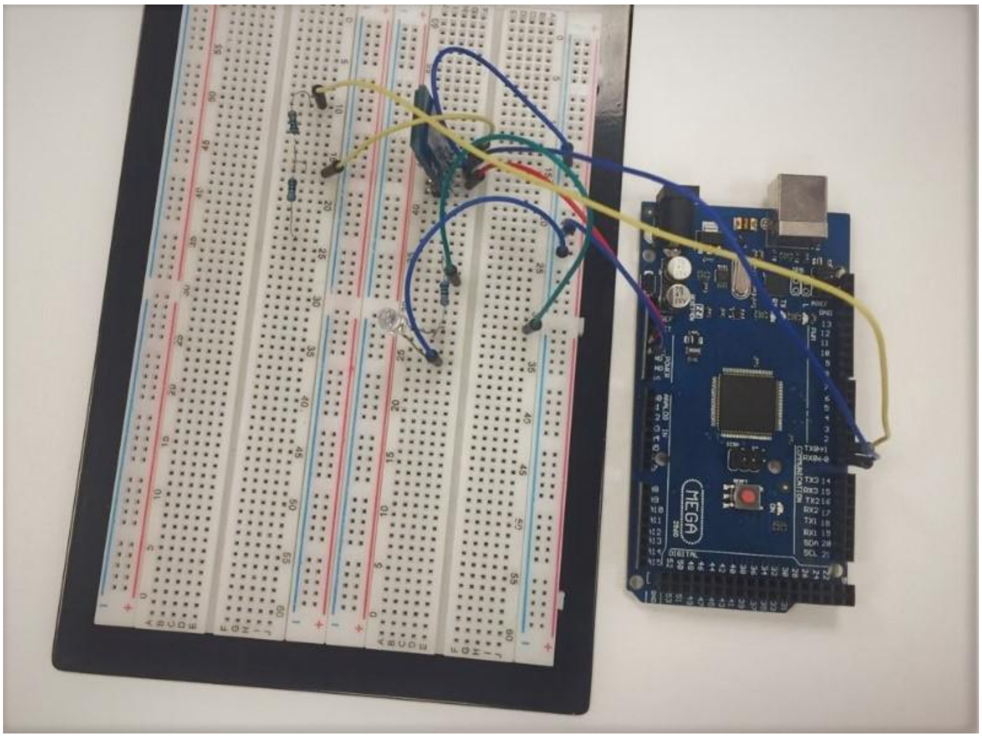
5.2 The interaction developed

After the explanation delivered in the chapter, "The beginning of the development of the Interaction.” This topic addresses how the programming of the logic functions and algorithms used in the program were applied to the conception of the proposed communication. It seeks to consolidate a solid base for explaining the conceived interaction, exemplifying the behavior of the prototype manipulated by the Arduino platform and the Android application.

To break the barrier of inconvenience related to the interaction arising from turning on or off a lamp through a switch, serving as the actuator or exemplifying a final interface for the communication elaborated. The use of an IoT device was colored by prototyping circuitry using the free hardware platform Arduino. As discussed in the previous chapter, the hardware uses the Bluetooth communication provided by the HC-05 module to communicate with a led. It symbolized the automation of a light bulb without the need to implement it in an actual circuit, represented in figure 30.

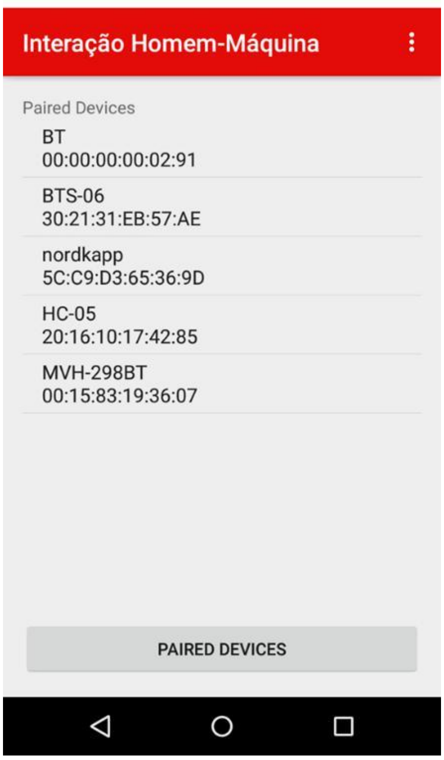
To fulfill the roles of controlling the data collected by the bracelet, bridge the communication between the Myo and the Arduino, and perform the automation of the prototype. The mobile application coordinates these functionalities as an interface to control the data and the functions that support the action between the devices.

Figure 30 – IoT device developed through the Arduino platform for this project



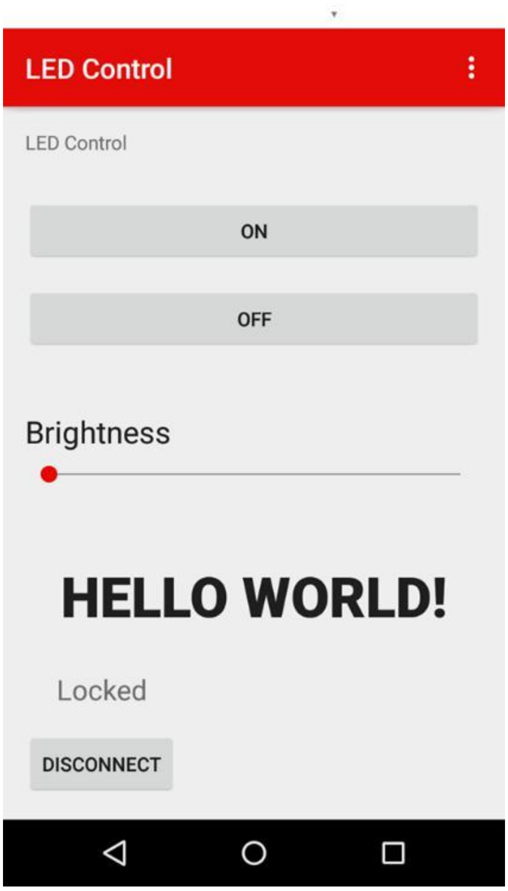
The first part of the interaction is to communicate with the prototype and the mobile application. Thus, from the logic developed to establish the control of the Bluetooth communication and the pairing of the Android device. In the initial screen of the application, communication control is implemented, displaying to the user the devices found to pair them with the device and start the connection. In the case of the project in question, the device selected for the link is the HC-05, the Bluetooth module used in the Arduino, represented in figure 31.

Figure 31 – Application screen for bluetooth pairing with the IoT



When the connection with the IoT device is established, the user gains access to the prototype's lamp automation on the main screen of the interaction project application. This interface represents the proposed use of innovation of HCI interaction, exposing the convenient and straightforward condition of the evolution of this interaction, interacting with a residence. From the buttons represented on the screen, the user can manage the state of the lamp, being able to set the brightness of the led according to the lack of lighting.

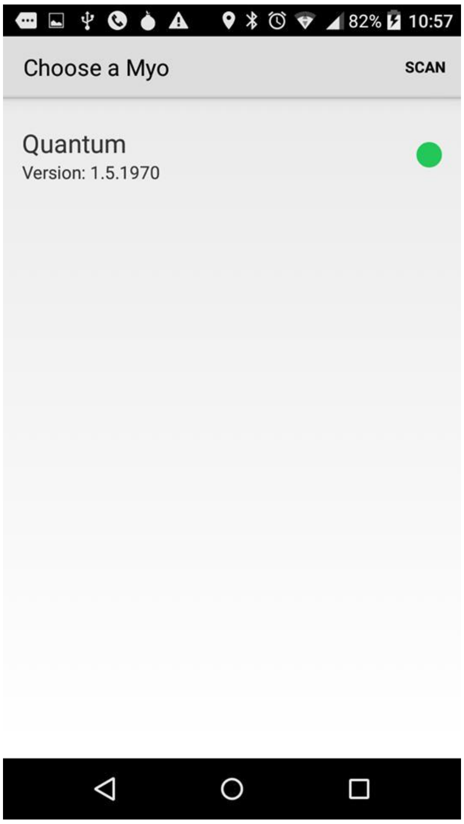
Figure 32 - Main screen of the mobile application



However, as presented, the essence of the interaction developed is breaking the conventional through the applicability and reformation guaranteed in a BCI interaction. In this way, effecting the connection with the BCI device manifests itself in the possibility of perfecting an open exchange. Using the functions available in the Myo SDK, the screen represented by figure 33 is implemented in the application. This allows the user to connect to the device, and the application can use the collected nerve impulses to control the lamp.

With the connection with Myo established, the application returns to its main screen, figure 34, ready to act with the interaction coming from the bracelet. This way, the application starts to capture the movement of the user's arm, symbolized by the illustration "Left Arm," in which the device detects its position according to the acceleration of gravity. This illustrates the capability of the interaction when using the quaternion mentioned in chapter two. Now the user can perform the pre-programmed gestures ("Fist") to turn on the light and ("Finger Spread") to turn off the prototype's light. Through the communication between the devices, the user gains more mobility, convenience, and practicality, coming from the BCI interaction.

Figure 33 – Application screen for pairing with Myo

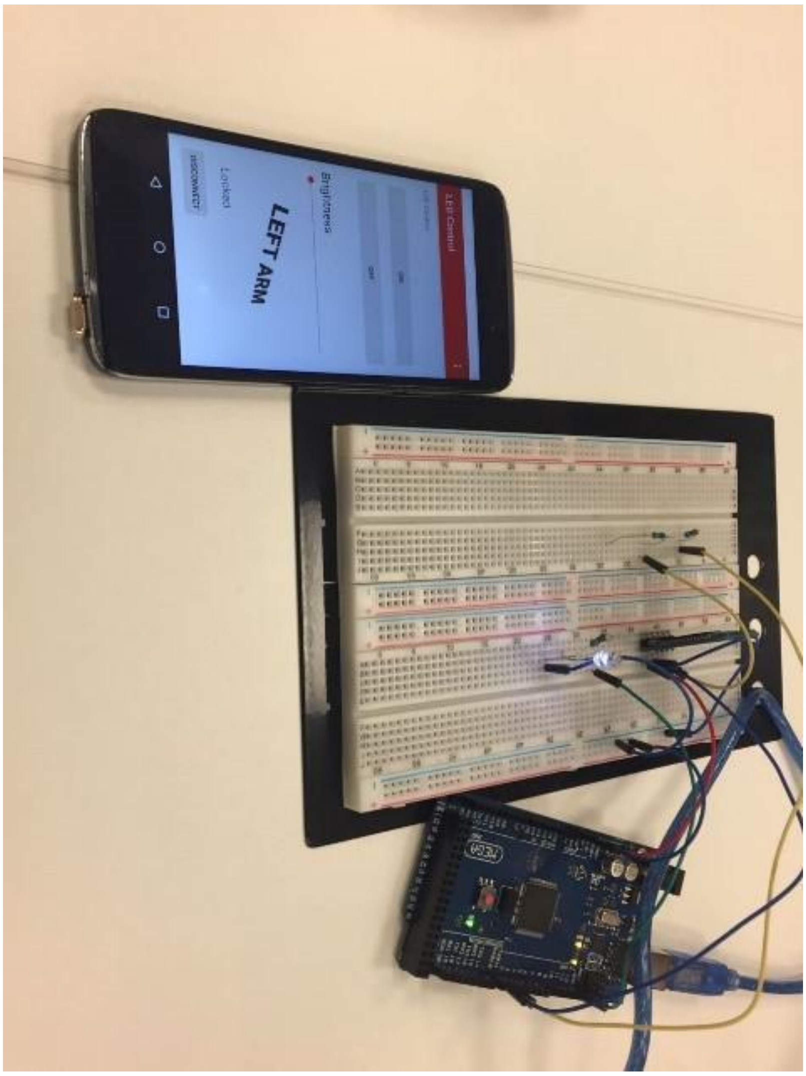


Through BCI interaction, the user no longer depends on the conventional means of HCI interaction, interacting with the automation of the light independently from his mobile device and having exclusively to make the pairing with the bracelet, independent of the buttons and clicks provided by the interface to automate the lamp. Thus, with the transmission of the nervous stimulus collected by the BCI device, the user can perform a high-level interaction, fulfilling the purpose of the Human-Machine interaction.

Figure 34 – Main screen of the application with Myo paired

By continuing the interaction through the interface of an Android application, some challenges needed to be solved to ensure more refined applicability and pertinent to the functionality of the developed system. After all, such challenges promoted specific dilemmas in the communication of the devices. Thus, in the next topic, to optimize the software created and the interaction with the user, the implementation of some transformations in the system will be discussed.

Figure 35 - Prototype of the entire framework implemented for the project concept test



5.3 Necessary adjustments

The results obtained in the communication formulated from the Android and Arduino interfaces software made it possible to identify specific difficulties in the interaction that originated with the Myo bracelet. So that, for future developments of the application via Android, these should be reviewed to promote superior connectivity of operation for the system. This will ensure more good usability for the user.

The impasses found in the developed interaction were verified in the connection of the Bluetooth with the Arduino and the identification of a Myo pose in the Android application. As a result of these problems, communication becomes scarce, limiting the understanding between the devices and the failure of gesture recognition in, bracelet automation.

The adversity in the communication of the devices occurs from the sending of 30 or more messages through the Bluetooth serial. Thus, the message exchange begins to oscillate to a point where it does not accept more information. Consequently, it stops sending. This causes the user to disable the communication and restart the mobile application with the Arduino module to re-establish the connection between the devices. This becomes a significant setback for the interaction developed, caused by the constant reconnection setback.

To solve the Bluetooth communication between the devices, it was essential to make a readjustment in the Bluetooth settings in the Arduino module. It was identified that by the absence of a library and a version in the configuration software of the HC-05 and easily solved during the code debugging stage, which led to the implementation of new projects.

The challenge encountered in identifying the Myo gestures in the Android application was due to the imprecise collection structure during its operation. There was no correct exception handling, adequately optimized, providing a nuisance to the application. In general, the lack of this approach leaves a program subject to many possibilities without a related objective. This causes an overflow of data and options for the system to interpret. It was letting the application generate an inadequate response. In the case of the developed interaction, the turning on of the led, through the identification of gestures on the bracelet.

To solve the inaccuracy of the structure used for gesture identification, it was necessary to analyze the developed code of the Android application. It sought to remove unused or poorly optimized lines of code, aiming to increase the program's precision and obtain an exception handling that supposedly caused the overflow of the data used to identify a pose. Thus, the application was satisfactorily optimized to find expected results for the developed integration.

With the development challenges solved, the Human-Machine interaction was successfully developed. We are demonstrating the power of a BCI interaction, innovating the standards of a conventional exchange. Thus, only one chapter remains to be elaborated. To conclude the work, the chapter "Final Considerations" portrays the learning obtained so far, with impressions about the development, experiences, and perspectives for future careers in this research area.

6 Final Considerations

To finish with the development of this scientific initiation project satisfactorily and to discuss the knowledge obtained, the proposal worked on, the interaction developed, the impressions on the subject, and finally, to approach new work possibilities. Chapter six, "Final Considerations," presents the work's conclusion, marking the fascinating study on BCI Interaction, neuroscience studies, and its development.

6.1 Epilogue

This scientific initiation work aimed to study the interactions between man and machines. It was investigating the teachings that provided the conception of current technologies, until the progress of new areas of study that provided a new evolution for Human-Machine Interaction, evidencing the excellent learning focus of numerous development research in the area.

Through the learning obtained about human behavior, to gesture and interact with the environment, study areas such as HCI have generated new business models searching for more fluent techniques and interactions. In this way, research has been done on circumstances where the more intuitive and friendly interaction is, the more productive its use will be. On the other hand, areas of study have emerged with techniques aiming to achieve a high-level interaction, overcoming limitations arising from traditional means, as a new frontier of implementation.

To achieve high-level interaction, the growth in the neuroscience field has enabled investigations seeking to understand how the nervous system works, providing for the formation of the BCI study area. New research models present the potential to manipulate computers with nothing more than a thought, that is, with ease of human interaction and without limitations. What provides the extraordinary, the remarkable possibility for a debilitated person to recover their movements and interact again with the environment around them without being subjected to the coat of others.

Given its employability, the area of study provided by the BCI was subject to research to develop a form of control that could perform several ordinary functions through the collection of nerve stimuli to demonstrate the power coming from this interaction. The results of this research were evident made explicit during the development of this research report, notwithstanding the epilogue portrayed below, expressing the acquisition of knowledge experience for teaching training obtained during the execution of the proposal

6.2 From practice to experience denoted

Through BCI, there is a competence that encourages a multidisciplinary committee that has expanded the scope of traditional computer science knowledge through medicine. Related development capability involving these subjects provides practical preparation for the assimilation of an experiment that can awaken clarity and consensus of understanding exploring the communication of such different areas.

Therefore, the know-how for the development using the BCI device employed promoted changes for the composition of a work confronting the traditional way of implementing a system. It is transferring part of the scope of study to understand the processing of biological signals, which are assimilated by this device to succeed in an interaction. This is an incredible learning opportunity in the neuroscience field, which opens up numerous research possibilities for the continuity of academic training in this multidisciplinary field, which will be the subject of the next topic of this chapter.

In addition to the knowledge obtained to assimilate the device's data processing and highlight a form of control that expresses the power of a BCI interaction. The importance provided by mobility to the user originated the implementation of an interface in which the device's signal processing for a visual representation of data collection was evidenced. The distinction that comes from the usefulness of a mobile application benefited the study since it would directly influence people's daily lives. In other words, its applicability would be susceptible to real action since a large part of the population owns smartphones and uses them too often.

The interaction with the device has gradually evolved. So that, near the end of most of the project's scope, implementing an IoT to exemplify the practical development capability by assimilating a natural experiment in communicating a BCI interaction concerned the integration of the Arduino platform. I was using an IoT prototype and having an assertion in the discipline interdisciplinary project of the Information Systems course. There was the possibility of associating the two projects to assemble the learning in a single plan contemplating integrating a BCI interaction using the IoT created in the interdisciplinary subject.

Thus, the module conceived and presented in this project served as the basis for a proof of concept developed in the discipline of the course of the system, which gave greater completeness and functionality in a real scenario. Since the project succeeded in a product with added value for the Startup OnHouse, organized by the group to which the initiator is a member. The aggregation of the IoT prototype generated an artifact for innovation in home automation by taking power from a BCI interaction to the most extraordinary simplicity, aptitude, and liking for Human-Machine interactions.

Although the research and study phase employed for the selection of the development in support of the Arduino platform exploited for the IoT used in the OnHouse proposal is not explicit in the project report, this stage manifests itself as the support for the preparation for the construction and fundamental optimization, which generated the basis for the definition of the methodology used in the scientific initiation. To ensure total process efficiency, justified in the preparation of the prototype developed in the interdisciplinary discipline.

Still, despite the satisfactory result obtained, it is estimated that there would be more excellent contributions if an investigation were done into the evolution of the BCI area with other devices, which can be done through a new research proposal and the acquisition of new equipment. The possibilities brought about by the evolution of the study of BCI have provided plans for future work that would have been inconceivable without the aid of funds from the PIC program. Thus, the next topic will discuss the continuity of the Human-Computer Interaction proposal as a new research project to explore the capacity of a BCI interaction further.

6.3 Future works

At the current juncture of the scientific initiation project, the anticipated research and progress have been contemplated. However, not all the potential of BCI interaction has been realized so far. The device, the target of the study (Myo), has exposed a competence for development using BCI techniques, a core area in modern technological innovation research.

This area innovates every day in academia, forwarding many expectations in technological advancement and medicine. Thus, there is an exceptional competence for Human-Machine Interaction, imminent in the study’s progress using the techniques learned with the armband. To evolve and advance the scope of multidisciplinary teaching proposed by the BCI area of study, it is intended to develop a new research project to explore an interaction capable of uniting the admirable with the amazing.

Achieving the insight of the processes performed by the bracelet interface, with the understanding of the biological process that comes from the human body. Some steps presented themselves of diverse relevance in the purpose of implementing a new research project:

Allusive to the treatment of biological signals, the collection step presented a certain lack in collecting the physical process sample rate. A fundamental step for elaborating new techniques to capture new gestures, making them new functions to be implemented.The testing stage alludes to the techniques used by the device in the elaboration of algorithms that describe the gestures. This can then add to understanding the method, verification, and reproduction. The expectation of development applied to medicine to mimic human movements through the improvement of a device capable of acting in this area.

The application of a repository of samples, developed and made available by the French company InMoov (http://inmoov.fr/), encouraged research in robotics and mechatronics, used by students in various parts of the world. It is directing itself more and more to complement the two teaching areas that work with human interactions with machines before the BCI interaction. The new project development proposal enables the replication of some techniques obtained in the current work and through the evolution using these further steps for exchange, capable of overcoming extraordinary limitations between man and machine.

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Appendices

APPENDIX A – The Gimbal Lock

Figure 36 - Myo and the Gimbal

Image taken from the video: goo.gl/21gn3G

IMUs (inertial measurement units) are widely employed in devices that require knowledge of their exact position as tools applied in the study of body motion. However, the way the orientation data technique is performed, through Euler angles only, causes some imperfections. Since spatial rotations are complex mathematical models, they can lead to a lock if used on imprecise grounds. Since they do not commute, they are challenging to combine and interpolate, constituting large puzzles such as the Gimbal Lock. This led to the most famous and unforeseen event during the Apollo 11 mission to the moon.

The Gimbal consists of a rotor and three concentric rings, figure 36. A Gimbal Lock, or Gimbal Lock, is when two or three rings of the Gimbal system are in the same position, brought into a parallel configuration, "locking" the Gimbal's rotations so that it only rotates in two-dimensional space. This problem usually occurs in cycles, causing problems for animations (3D visualizations) and for procedures that use Euler rotations. This "locking" of the device results in losing a degree of freedom in a 3-dimensional articulated mechanism. However, the word "lock" is misleading; the Gimbal is not locked, all three axes of this system can still rotate freely in their respective suspension axes. But due to the parallel orientation of two axes, there is no fourth axis available (rotor, Figure 37) to accommodate rotation along with one of the axes (BERNHARDT, 2015b).

Figure 37 - Gimbal with four actuation axes

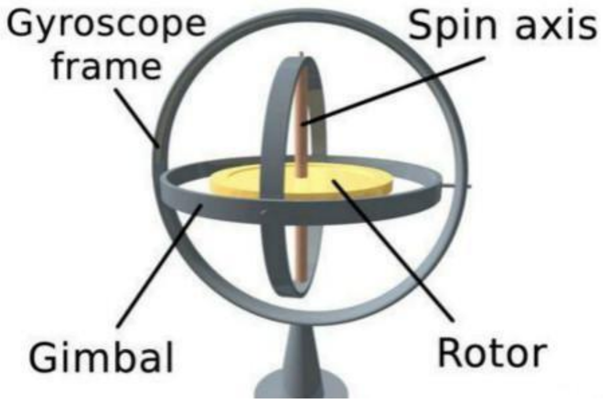


Image taken from the website: goo.gl/QQFmXR

Inertial navigation systems (INSs) operate as the most critical coordination component, IMU applications. Most vehicles, such as spacecraft, rely on this system to steer their way around the globe or universe. In the scenario presented above, the spacecraft of the Apollo 11 mission had a set of gimbals to implement the IMU. Although the mission engineers knew the gimbal lock problem, they refused to use the fourth ring. This resulted in the misfortune that the rotational system of the spacecraft "froze.” Thus, from this point on, the spacecraft had to be manually moved away from the position in which the Gimbal joint had been locked. This led to the manual realignment of the platform, an extremely complex maneuver for a pilot, compared to the performance of the ship's exceptionally innovative computer systems. Resulting in a process in which the pilot realigned the boat, using the stars as spatial reference points (JONES, 2011).

The modern reality is to avoid using Gimbals altogether; in the context of inertial navigation systems, this can be done by mounting inertial sensors directly on the body of the vehicle, such as a strapdown system. Integrating rotation and acceleration sensors and digitally using quaternion methods to derive the orientation and speed of the car. Because there are several solutions for a given direction, it is possible to represent rotations with quaternions nicely and unambiguously. The Quaternion is a rotation method that uses a quaternion to describe an orientation in three dimensions; they provide a convenient mathematical notation for representing orientations and rotations of objects in three dimensions, as a four-dimensional extension of the complex numbers, as follows: [x, y, z, w]. Compared to Euler angles, they are simpler to compose and avoid the problem of gimbal locking. Compared to rotation matrices, they are more compact, numerically stable, and efficient (HAMILTON, 1843).

APPENDIX B - On House

Figure 38 - On House

On the house is a Startup created by the initiator of this project, with three other colleagues from the Information Systems course, during the teaching of the subject Interdisciplinary Project in the fourth semester of the study.

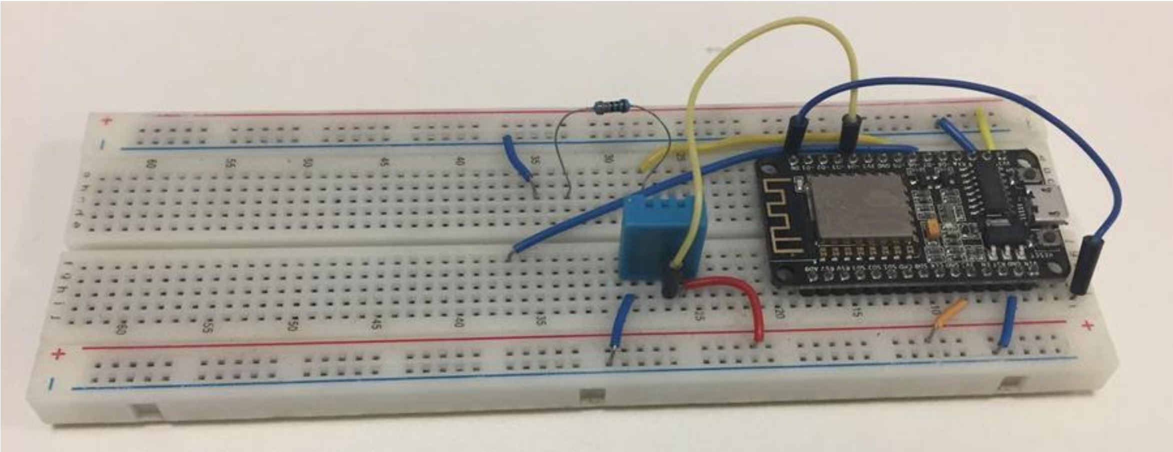
The subject Interdisciplinary Project, in turn, whose purpose is the consolidation of the theoretical and practical training of the semester, through the integration of learning exercised during the semester, has as its final delivery the presentation of a commercially viable product using in its conception the concept of the Internet of Things (IoT).

This product aims to act in the home automation market, specifically for use in tiny homes or offices, because nowadays, automation hardly combines good performance and low implementation costs. This solution is in the context of providing an economically more accessible alternative for this technology to the market.

Thus, in parallel to the scientific initiation project, the idea employed of BCI was used to improve the On House project, allowing the interaction between men and machines to be employed in an industrial application, even in a simple prototype for controlling a power switch.

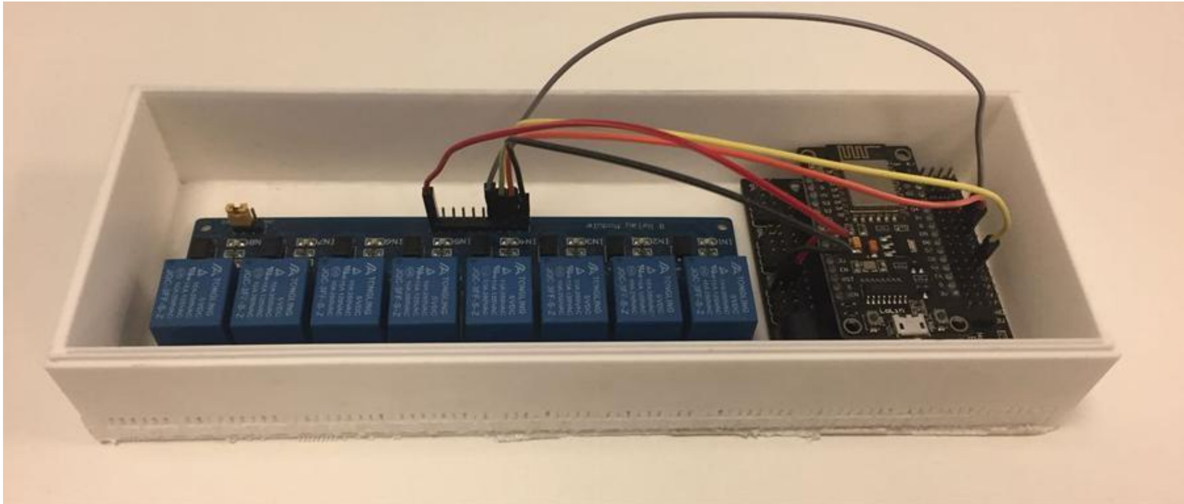
For this, a proof of concept was built using IoT technology from the Arduino free hardware development platform and a Cloud Service to act in controlling the platform. The following figure, 39, presents the prototype using Arduino and allowing the control of a led behind the startup project.

Figure 39 - On House Proof of Concept



The following figure already presents a second prototype, which can be connected to a conventional home power network.

Figure 40 - On House Development Prototype



Furthermore, a demonstrative video can be accessed through the link: https://goo.gl/vXh76d. An illustration of this video can be seen in Figure 41 below..

Figure 41 - On House Demo Video

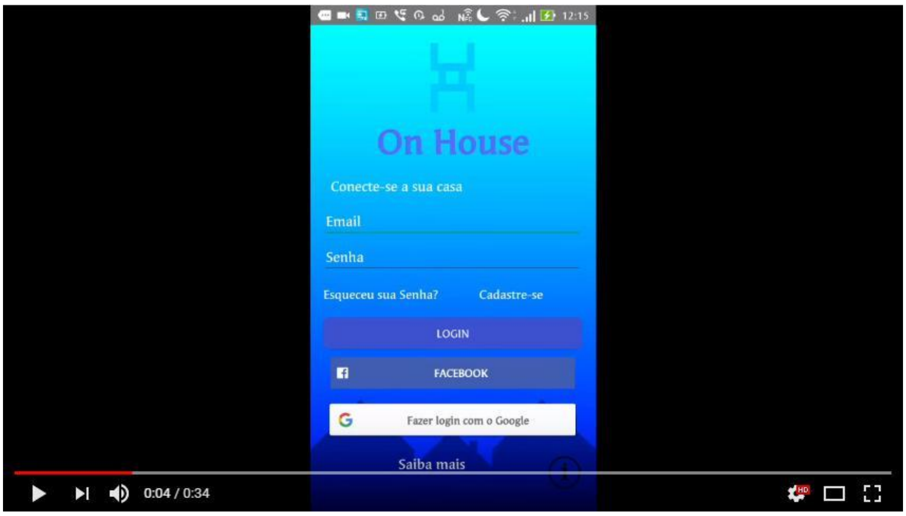


Image taken from Youtube: https://www.youtube.com/watch?v=SZMCbKRvh_U

APPENDIX C - Data Processing and Collection

During the development of chapter two, "The BCI Device," an application was implemented to collect data from the Myo bracelet. As a result of this collection, ".csv" spreadsheets were obtained, which were used to make decisions about the possible classification of the movements that the user wanted to perform. A series of data from the several that were collected are illustrated in figure 42.

Figure 42 - Example of collected EMG data

	A	B	C	D	E	F	G	H
1	Emg1	Emg2	Emg3	Emg4	Emg5	Emg6	Emg7	Emg8
2	3	4	-3	1	0	0	0	5
3	-3	2	4	-1	1	-1	-2	-1
4	2	6	-2	-1	-2	-1	0	0
5	-7	-6	8	7	2	-1	-1	-7
6	2	-2	-6	-2	1	1	0	3
7	-3	-5	-1	0	-3	-2	-3	-4
8	3	-1	0	0	-2	0	1	2
9	0	-1	-1	-5	0	0	0	0
10	-4	-3	2	1	-3	-2	-3	-3
11	1	1	-1	0	-2	0	1	-3
12	-3	-1	0	-3	1	1	0	3
13	-1	-2	0	1	-3	0	-2	1
14	-4	-4	0	-1	-2	-2	0	-6
15	1	-2	-4	-6	-1	-1	-1	3
16	-5	-5	-6	2	1	0	-2	-3
17	6	7	-1	-3	-3	-1	4	3
18	-2	3	-1	-2	-1	0	-1	-2
19	-1	1	6	4	0	-1	-1	1
20	-3	-6	-9	0	-1	-2	-2	-3
21	-3	-2	-4	2	0	0	-3	-2

To enable better analysis and further use of the data for scientific research and sample calculations, a collection of other information, illustrative graphs, and sample series are available at: https://goo.gl/oxt6Dp.