Introduction:

Prosthetic limbs are created with the main objective of helping individuals who have undergone limb amputation to regain some of their physical capabilities. However, the management of these prostheses is a complex and challenging task that requires ongoing efforts to address its numerous issues. Despite this, there has been a growing interest in using EMG-based prosthetic control in recent times, primarily because it offers a non-invasive solution that can deliver more natural and intuitive control over the prosthetic limb. In this report, we present our work on EMG-based prosthetic control using the MuscleBioAmp BisCute sensor and Arduino and discuss the challenges and opportunities of this technology.

Our report aims to explore and detail our attempts at developing EMG-based prosthetic control using the MuscleBioAmp BisCute sensor. Specifically, we sought to create a mechanism that could help physically challenged individuals control their prosthetic limbs in a more natural and effortless manner. As such, our focus was on designing and implementing an EMG-controlled servo rotation system that would enable users to operate their prosthetic gripper with greater ease and precision. Ultimately, our efforts aim to improve the lives of people with physical disabilities by providing them with a more effective and user-friendly solution for controlling their prosthetic limbs.

2.2 **SELECTION OF COMPONENTS**

- 2.a. EMG sensor
- 2.b. Arduino UNO
- 2.c. Servo SG90 Motor
- 2.d. Jumper Wires (M-M, M-F)
- 2.e. Breadboard

2.2.1 Electromyography (EMG)

Electromyography is an electrodiagnostic medicine technique for evaluating and recording the electrical activity produced by skeletal muscles.An EMG detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order or to analyze the biomechanics of human or animal movement.

There are two kinds of EMG:

1. **Surface EMG**
2. **Intramuscular EMG**

Surface EMG assesses muscle function by recording muscle activity from the surface above the muscle on the skin. Surface electrodes are able to provide only a limited assessment of the muscle activity. Surface EMG can be recorded by a pair of electrodes or by a more complex array of multiple electrodes. More than one electrode is needed because EMG recordings display the potential difference (voltage difference) between two separate electrodes. Limitations of this approach are the fact that surface electrode recordings are restricted to superficial muscles, are influenced by the depth of the subcutaneous tissue at the site of the recording which can be highly variable depending of the weight of a patient, and cannot reliably discriminate between the discharges of adjacent muscles. Intramuscular EMG can be performed using a variety of different types of recording electrodes.

Several analytical methods for determining muscle activation are commonly used depending on the application. The use of mean EMG activation or the peak contraction value is a debated topic. Most studies commonly use the maximum voluntary contraction as a means of analyzing peak force and force generated by target muscles. EMG can also be used for indicating the amount of fatigue in a muscle. The following changes in the EMG signal can signify muscle fatigue: an increase in the mean absolute value of the signal, increase in the amplitude and duration of the muscle action potential and an overall shift to lower frequencies. Monitoring the changes of different frequency changes the most common way of using EMG to determine levels of fatigue.

2.2.2 Arduino UNO (micro-controller)

A microcontroller (sometimes abbreviated C, uC or MCU) is a small computer on a single integrated circuit containing a processor core, memory, and programmable input/output peripherals. Program memory in the form of Ferroelectric RAM, NOR flash or OTP ROM is also often included on chip, as well as a typically small amount of RAM. Microcontrollers are designed for embedded applications, in contrast to the microprocessors used in personal computers or other general purpose applications.

Microcontrollers are used in automatically controlled products and devices, such as automobile engine control systems, implantable medical devices, remote controls, office machines, appliances, power tools, toys and other embedded systems. By reducing the size and cost compared to a design that uses a separate microprocessor, memory, and input/output devices, microcontrollers make it economical to digitally control even more devices and processes. Mixed signal microcontrollers are common, integrating analog components needed to control non-digital electronic systems.

Arduino UNO is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with a AC-to-DC adapter or battery to get started.

Servo SG90 Motor

Servo motors (or servos) are self-contained electric devices that rotate or push parts of a machine with great precision. Servos are found in many places: from toys to home electronics to cars and airplanes. If you have a radio-controlled model car, airplane, or helicopter, you are using at least a few servos. In a model car or aircraft, servos move levers back and forth to control steering or adjust wing surfaces. By rotating a shaft connected to the engine throttle, a servo regulates the speed of a fuel-powered car or aircraft. Servos also appear behind the scenes in devices we use every day. Electronic devices such as DVD and Blu-ray DiscTM players use servos to extend or retract the disc trays

The simplicity of a servo is among the features that make them so reliable. The heart of a servo is a small direct current (DC) motor, similar to what you might find in an inexpensive toy. These motors run on electricity from a battery and spin at high RPM (rotations per minute) but put out very low torque. An arrangement of gears takes the high speed of the motor and slows it down while at the same time increasing the torque. The gear design inside the servo case converts the output to a much slower rotation speed but with more torque (big force, little distance). The amount of actual work is the same, just more useful. Gears in an inexpensive servo motor are generally made of plastic to keep it lighter and less costly.

Jumper Wires

Jumper wires are simply wires that have connector pins at each end, allowing them to be used to connect two points to each other without soldering. Jumper wires are typically used with breadboards and other prototyping tools in order to make it easy to change a circuit as needed. Fairly simple. In fact, it doesn't get much more basic than jumper wires. Jumper wires typically come in three versions: male-to-male, male-to-female and female-to-female. The difference between each is in the end point of the wire. Male ends have a pin protruding and can plug into things, while female ends do not and are used to plug things into. Male-to-male jumper wires are the most common and what you likely will use most often.

Breadboard

The breadboard is the bread-and-butter of DIY electronics. Breadboards allow beginners to get acquainted with circuits without the need for soldering, and even seasoned tinkerers use breadboards as starting points for large-scale projects.

The two larger pieces of wire down each side are typically used to connect a power source to the board. They are usually referred to as power rails.

The other smaller pieces of wire running perpendicular all the way across the board are used for components in your circuit. This diagram will help visualize this pattern from the top.

The power rails run horizontally in two rows at the top and bottom. Meanwhile, the vertical columns run inwards as we move along the board.

Background:

Traditionally, prosthetic limbs are controlled using switches or buttons, which are often difficult to operate and do not provide natural and intuitive control. EMG-based prosthetic control, on the other hand, uses electrodes to detect the electrical activity of muscles and translate it into movement of the prosthetic limb. This approach offers the potential for more natural and intuitive control, as the user can control the prosthetic limb simply by thinking about the movement they want to make.

Methodology:

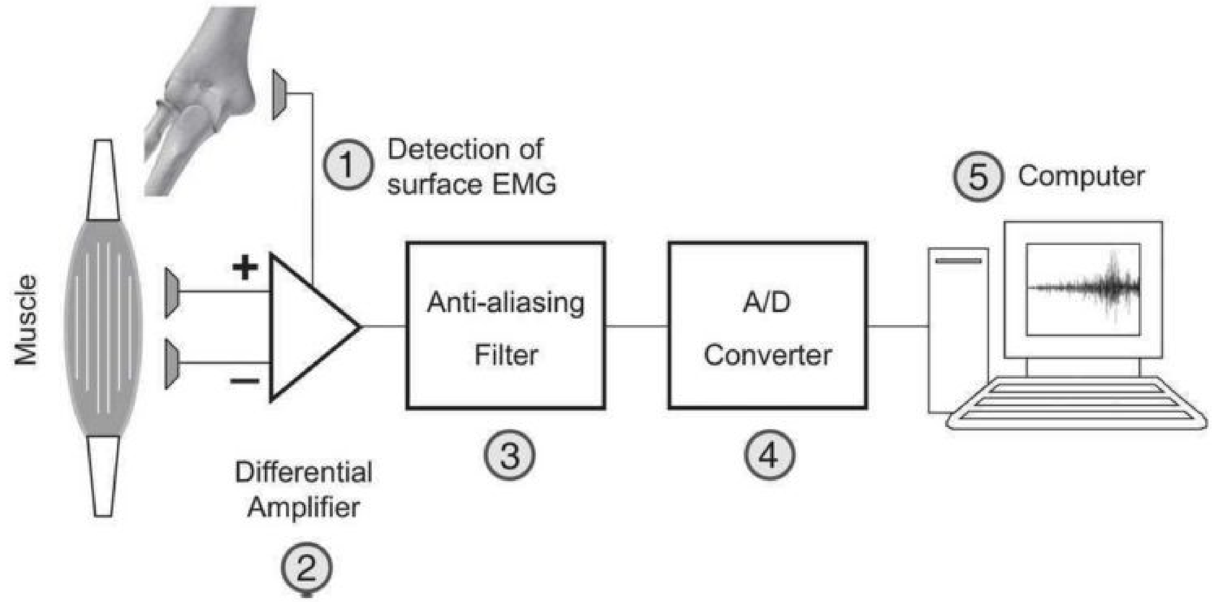
In our study, we employed the MuscleBioAmp BisCute sensor manufactured by Upside Down labs to capture electromyography (EMG) signals. The BisCute sensor was assembled as a do-it-yourself (DIY) kit, which required soldering the components together. We then linked the sensor to an Arduino board and created a code that could read the envelope of the EMG signal. To operate the prosthetic limb, we set a threshold of 15 for the EMG signal. Whenever the reading of the signal surpassed 15, the servo would rotate by 180 degrees. This approach allowed us to control the prosthetic limb using EMG signals generated from the patient's muscles. Our results suggest that the BisCute sensor could be an effective tool for capturing EMG signals and controlling prosthetic limbs.

Features & Specifications:

- **Input Voltage:** 3.3 – 30 V
- **Input Impedance:** 10^11 Ω
- **Fixed Gain**: x2420
- **Bandpass filter**: 72 – 720 Hz
- **Compatible Hardware:** Any development board with an ADC (Arduino UNO & Nano, Espressif ESP32, Adafruit QtPy, STM32 Blue Pill, BeagleBone Black, Raspberry Pi Pico, to name just a few) or any standalone ADC of your choice.
- **BioPotentials:** EMG
- **No. of channels:** 1
- **Electrodes:** 3 (Positive, Negative, and Reference)
- **Dimensions:** 3.0 x 4.5 cm
- **Open Source:** Hardware + Software

How EMG is measured?

Surface EMG assesses muscle function by recording muscle activity from the surface above the muscle on the skin. Surface electrodes are able to provide only a limited assessment of muscle activity. Surface EMG can be recorded by a pair of electrodes or by a more complex array of multiple electrodes. More than one electrode is needed because EMG recordings display the potential difference between two separate electrodes.



Steps to be followed:

1. First thoroughly clean the intended area with soap to remove dirt and oil.
2. Connect the electrodes or use the arm band provided
3. Place the sensor on the desired muscle. Place the sensor so one of the connected electrodes is in the middle of the muscle body. The other electrode should line up in the direction of the muscle length.
4. Place the reference electrode on a bony or nonadjacent muscular part of your body near the targeted muscle.
5. Connect the sensor to the Arduino Board.
6. Run the code for envelope detection
7. Observe readings in the serial plotter in the Arduino IDE
8. Flex the hand, the readings appear on the serial plotter and the servo rotates by 180 degrees
9. Relax the hand, the servo comes back to original position or rotates back by 180 degrees.

Results:

Our initial results showed that EMG-based prosthetic control using the MuscleBioAmp BisCute sensor and Arduino was possible. However, we faced some problems at the start in acquiring the EMG readings. These problems were related to the proper placement of the sensor and the correct interpretation of the EMG signals. We also observed some variability in the EMG signal readings, which could be due to the individual differences in muscle activation patterns.

Discussion:

EMG-based prosthetic control has the potential to provide more natural and intuitive control for prosthetic limbs. However, the variability in the EMG signals and the challenges in acquiring reliable and consistent signals remain challenging. Future work could focus on improving the sensor placement and signal processing algorithms to overcome these challenges. Another potential avenue for research could be to explore the use of machine learning algorithms to improve the accuracy of EMG-based prosthetic control.

Conclusion:

In conclusion, we have demonstrated the potential of EMG-based prosthetic control using the MuscleBioAmp BisCute sensor and Arduino. Our initial results showed that the system was able to control a prosthetic limb based on EMG signals. However, we faced some challenges in acquiring reliable and consistent EMG signals. Our work highlights the potential of EMG-based prosthetic control and the need for further research in this area to improve the accuracy and reliability of this approach. Ultimately, EMG-based prosthetic control has the potential to significantly improve the quality of life for individuals with limb amputation.