MYOELECTRIC PROSTHETIC ARM

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Abstract- *The myoelectric prosthetic hand is a prosthetic hand for upper limb amputees so that they can gain a certain amount of functionality of a prosthetic hand.*

The myoelectric prosthetic hand works on the principle of electromyography.

A myoelectric sensor or EMG sensor senses the signals from the muscles and then using the Arduino, the servo motor is rotated such the the fingers contract.

In this research paper we will study the myoelectric prosthetic arm as a project in detail.

Keywords*: Myoelectric prosthetic hand, electromyographic sensor, servo motor.*

I. INTRODUCTION

The myoelectric prosthetic hand as the name suggest is a prosthetic hand for upper limb amputation. Many people in the world lose their hand in accident or at places such as war zones and they are left with no attention and care.

The main purpose of myoelectric prosthetic arm is to provide a prosthetic hand which not only work as a support but have certain level of functionality of the normal hand.

This project aims to provide the subject the ability to pick up things, hold objects and place them at desired place. This will be achieved by providing the subject the ability to move the fingers by stimulating the leftover arm muscle where the sensors are placed.

In this project the subject is allowed and empowered to open and close the fist and through this action only the subject will be able to pick up things, hold them and place them at desired places.

The myoelectric prosthetic arms present in the market are way costly such that normal person who belongs to middle class family can hardly afford it and those who belong to lower class cannot even think of having a myoelectric prosthetic arm.

The average cost of myoelectric prosthetic arm in India exceeds one lakh rupees which is very high for a lower and middle class family to afford.

Further many of the amputees are street beggars due to lack of attention by the family and negligence by the society. This project aims to build a project which even this class of amputees can afford.

There have been attempts made to reduce the cost of prosthetic arm by using 3D printing technology and they have succeeded to reduce the cost up to fifteen thousand rupees by using 3D printed body for the prosthetics but it is still high price to pay for the lower class of society.

This project uses waste material for the body of the prosthetic and economic sensors and single servo motor to reduce the cost from fifteen thousand to five thousand rupees only which is an amount a lower class person can consider to pay.

This project is based on the principle of electromyography. An EMG sensor is attached to the leftover hand muscle sensor which senses the signal from the muscle and then sends the signal to the arduino which in turn rotates the servo motor such that it pulls the fishing lines drawn in the fingers and the fingers close.

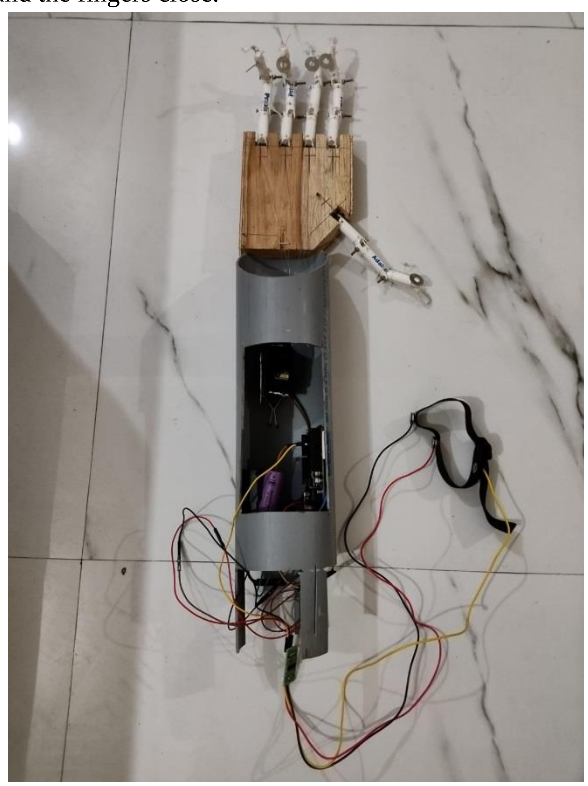

Figure 1: Myoelectric prosthetic arm

II. METHODOLOGY AND OPERATION

A. Components Used

The following components are used in the myoelectric prosthetic hand:

1) EMG sensor

An electromyography (EMG) sensor is a device used to detect and measure the electrical activity produced by muscles. It essentially records the electrical signals generated by muscle cells when they contract. Here's a detailed breakdown of how EMG sensors work:

Muscle Contraction and Electrical Activity: When a muscle contracts, it generates electrical impulses caused by the movement of ions across cell membranes. These electrical signals, known as action potentials, propagate along the muscle fibers and can be detected on the surface of the skin.

Surface EMG vs. Needle EMG: EMG sensors can be classified into two main types: surface EMG and needle EMG. Surface EMG sensors are placed on the surface of the skin over the muscle of interest, while needle EMG sensors are inserted directly into the muscle tissue. Surface EMG sensors are non-invasive and more commonly used for applications such as monitoring muscle activity during physical therapy or assessing muscle function in sports science. Needle EMG sensors are more invasive and are typically used in clinical settings for diagnostic purposes to assess muscle and nerve function.

Electrode Placement: In surface EMG, electrodes are placed strategically over the muscle belly to capture the electrical signals produced during muscle contraction. Proper electrode placement is crucial for accurate signal detection and interpretation.

Signal Amplification and Processing: The electrical signals detected by the EMG sensor are very weak, so they need to be amplified to make them measurable. Once amplified, the signals are processed to remove noise and interference. This processing may involve filtering techniques to isolate the relevant signals from background noise and other artifacts.

Data Analysis: The processed EMG signals can be analyzed in various ways to extract useful information about muscle activity. This analysis may include measuring parameters such as signal amplitude, frequency, and duration. Additionally, techniques such as signal decomposition can be used to identify individual motor unit action potentials within the overall EMG signal.

Applications: EMG sensors have a wide range of applications in both clinical and research settings. In clinical practice, EMG is used to diagnose neuromuscular disorders, assess muscle function, and monitor progress during rehabilitation. In research, EMG is used to study muscle physiology, biomechanics, and motor control. EMG sensors are also increasingly being incorporated into wearable devices for applications such as gesture recognition, prosthetics control, and human-computer interaction.

Overall, EMG sensors play a crucial role in understanding the electrical activity of muscles and have numerous applications in healthcare, sports science, and human-computer interaction.

2) Electrodes

Electrodes are the components that come into direct contact with the skin or muscle tissue to detect the electrical signals produced by muscle activity. There are different types of electrodes used in EMG sensors, including surface electrodes (e.g., adhesive electrodes placed on the skin surface) and needle electrodes (e.g., fine wire electrodes inserted into the muscle tissue). The choice of electrode depends on factors such as the depth of signal detection and the invasiveness of the measurement.

Muscle electrodes, also known as electromyography (EMG) electrodes, are specialized sensors used to detect and measure the electrical activity produced by muscles. These electrodes play a crucial role in various applications, including medical diagnostics, rehabilitation, sports science, and research.

3) Arduino Uno

The Arduino Uno is an open-source microcontroller board based on the Microchip ATmega328P microcontroller (MCU) and developed by Arduino.cc and initially released in 2010. The microcontroller board is equipped with sets of digital and analog input/output (I/O) pins that may be interfaced to various expansion boards (shields) and other circuits. The board has 14 digital I/O pins (six capable of PWM output), 6 analog I/O pins, and is programmable with the Arduino IDE (Integrated Development Environment), via a type B USB cable. It can be powered by a USB cable or a barrel connector that accepts voltages between 7 and 20 volts, such as a rectangular 9-volt battery. It has the same microcontroller as the Arduino Nano board, and the same headers as the Leonardo board. The hardware reference design is distributed under a Creative Commons Attribution Share-Alike 2.5 license and is available on the Arduino website. Layout and production files for some versions of the hardware are also available.

The word "uno" means "one" in Italian and was chosen to mark a major redesign of the Arduino hardware and software. The Uno board was the successor of the Duemilanove release and was the 9th version in a series of USB-based Arduino boards. Version 1.0 of the Arduino IDE for the Arduino Uno board has now evolved to newer releases. The ATmega328 on the board comes preprogrammed with a bootloader that allows uploading new code to it without the use of an external hardware programmer.

4) MG995 servo motor

The MG995 is a popular model of servo motor, particularly in hobbyist and robotics applications. Here's a detailed overview:

Basic Functionality: A servo motor is a rotary actuator that allows for precise control of angular position. Unlike regular DC motors, which rotate continuously when a voltage is applied, servo motors are designed to move to a specific angle and hold that position. They are widely used in various applications requiring controlled motion, such as robotics, remote-controlled vehicles, model airplanes, and industrial automation.

Construction: The MG995 servo motor typically consists of a motor, gearbox, control circuitry, and feedback mechanism. The motor provides the rotary motion, while the gearbox reduces the speed and increases the torque output. The control circuitry interprets input signals (usually in the form of pulse-width modulation, PWM) to determine the desired position of the motor shaft. The feedback mechanism, often a potentiometer, provides positional feedback to the control circuitry, allowing for closed-loop control of the motor's position.

Specifications:

Operating Voltage: Typically operates at 4.8V to 6V, though some variants may have different voltage ratings.

Torque: The MG995 servo motor is known for its relatively high torque output compared to other hobbyist servo motors. Depending on the specific model and voltage, it can provide torque ranging from around 10 kg/cm to 15 kg/cm.

Speed: The speed of the motor varies depending on the load and voltage but generally falls within the range of 0.16 to 0.20 seconds per 60 degrees rotation.

Operating Temperature: Typically operates within a temperature range of 0°C to 55°C.

Dimensions: The MG995 servo motor is commonly available in a standard size with dimensions of approximately 40mm x 20mm x 37mm.

Weight: Depending on the variant, it weighs around 55 to 65 grams.

Control Interface: The MG995 servo motor typically accepts control signals in the form of PWM pulses. The width of the pulse determines the desired position of the servo motor shaft. A pulse width of around 1.0ms typically corresponds to one extreme position (e.g., 0 degrees), 1.5ms corresponds to the center position (e.g., 90 degrees), and 2.0ms corresponds to the other extreme position (e.g., 180 degrees).

Applications: Due to its high torque, relatively fast response time, and affordability, the MG995 servo motor is widely used in various robotics and hobbyist projects. It can be used for tasks such as controlling robot arms, steering mechanisms in remote-controlled vehicles, moving camera platforms, and operating control surfaces in model airplanes.

Overall, the MG995 servo motor is a versatile and widely used component in the hobbyist and robotics communities, offering precise control of angular position and sufficient torque for many applications.

5) Battery

Lithium-ion (Li-ion) batteries are rechargeable energy storage devices known for their high energy density, lightweight design, and long cycle life. They are widely used in various electronic devices, ranging from smartphones and laptops to electric vehicles and renewable energy storage systems. Here's a detailed overview of lithium-ion batteries:

Composition:

Anode: The anode (negative electrode) of a lithium-ion battery is typically made of graphite or other carbon-based materials. During charging, lithium ions are extracted from the cathode and intercalated into the graphite structure of the anode.

Cathode: The cathode (positive electrode) of a lithium-ion battery is typically made of lithium metal oxides, such as lithium cobalt oxide ($LiCoO_2$), lithium iron phosphate ($LiFePO_4$), or lithium manganese oxide ($LiMn_2O_4$). The cathode material determines the specific energy and voltage characteristics of the battery.

Electrolyte: The electrolyte is a conductive solution or polymer that allows lithium ions to move between the anode and cathode during charging and discharging. Most lithium-ion batteries use a liquid electrolyte composed of lithium salts dissolved in a solvent, such as ethylene carbonate or propylene carbonate. Solid-state electrolytes are also being developed to improve safety and energy density.

Separator: The separator is a porous membrane that separates the anode and cathode while allowing lithium ions to pass through. It prevents short circuits and ensures the safe operation of the battery.

In our project we have used two 3.7V 2000mAh cells in series to power our prosthetic hand.

6) Fishing lines

Fishing line is a crucial component of our project. It's typically a long, thin, and durable cord or filament designed to withstand the forces exerted by fish and the environment.

In our project we have used fluorocarbon fishing line which is of diameter 0.35 mm and can bear up to 12.5 kg of weight.

7) Used pen body

Bodies of used pens are reused to make fingers of the prosthetic hand. Plastic pens were used because they are easy to hole and cut.

8) Teak wood

Teak wood is renowned for its durability, strength, and natural beauty, making it a highly sought-after material for various applications.

In our project we have used teak wood for making the palm of the prosthetic hand and fixing the fingers in it.

9) PVC pipe

PVC pipes, short for polyvinyl chloride pipes, are versatile and widely used plumbing materials known for their durability, affordability, and ease of installation.

PVC pipes are made from a synthetic polymer called polyvinyl chloride (PVC), which is a type of plastic. PVC is produced by polymerizing vinyl chloride monomers through a chemical process.

In our project we have used PVC pipe as the forearm of the prosthetic arm.

It also serves as platform to mount the servo motor, arduino uno and the battery.

10) Jumper wires

A jump wire (also known as jumper, jumper wire, DuPont wire) is an electrical wire, or group of them in a cable, with a connector or pin at each end (or sometimes without them – simply "tinned"), which is normally used to interconnect the components of a breadboard or other prototype or test circuit, internally or with other equipment or components, without soldering.

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.

11) Iron rod

2mm diameter iron rods are used to join the fingers to the wooden palm.

12) Nuts and bolts

2mm diameter nuts and bolts were used to join the fingers joints to each other.

13) Elastics

Elastics are fixed to the fingers to max them return back to flat hand position when the fishing lines are loose.

B. Working

The myoelectric prosthetic hand as mentioned earlier works on the principle of electromyography.

The electrodes are attached to the electrode band and the electrode is worn in the leftover hand of the amputee.

There are three electrodes needed for a single EMG sensor, the three electrodes are positive, negative and reference electrodes which are connected to the EMG sensors in the respective pins.

The ground and Vcc pins of the EMG sensor are connected to the negative and positive terminals of the battery and the output pin is connected to analog input pin A0 of the arduino uno.

The arduino uno is also powered by the battery and the program is uploaded into it.

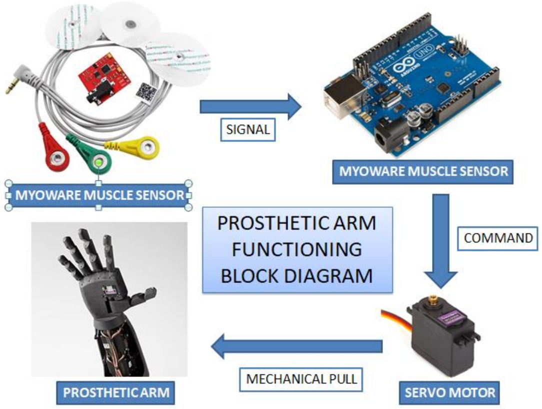

Figure 2: Block diagram

The analog output pin 3 of the arduino uno is connected to the input pin of the MG995 servo motor and the servo motor is also powered by the battery by connecting ground and Vcc pins to negative and positive terminals of the battery.

The servo motor, EMG sensor, arduino uno and the battery are mounted on the PVC pipe and the wooden palm is attached to it.

Using the iron rod and nuts and bolts the fingers are also attached into the grooves made in the wooden palm.

The fishing lines are drawn into the fingers and connected to the MG995 servo motor. The elastics are also stitched to the outer portion of the fingers.

When the muscle is stimulated and is contracted the very small electric signal is generated and potential difference is produced at the electrodes.

The electrodes sense the electrical signal and send it to the EMG sensor which processes and amplifies the signal and give analog value as the output which is input into the arduino uno.

The program in the arduino uno first processes the signal from EMG sensor to form an envelope signal and then the envelope signal is compared with the threshold value.

If the value is graeter than the threshold value which is set to be 50 then the servo motor is set to 180 degree angle else 0 degree angle is set to the servo motor.

As the servo motor rotates to 180 degree, the fishing lines are pulled and the fingers are contracted to make a fist.

When the servo motor rotates back to 0 degree then the fingers are released and the elastics pull back the fingers to the normal position.

This way using electromyography, a myoelectric prosthetic arm is designed which can pick, hold and place objects.

This project will be very helpful in providing help to the upper limb amputees.

III. CONCLUSION AND FUTURE SCOPE

This project is a proof for the fact that the advancing technology of electromyography is very helpful in building up the prosthetics.

It also shows that using EMG sensors we can help lots of people with different amputees and how useful the EMG sensors are.

Our project is a classic example of how vast the use of Arduino can range and the area or scope of the usage of Arduino is so wide. It also shows how important the Arduino is when considered for the electronics project.

This project also highlights the importance of servo motors and also the servo library of the Arduino.

This project brings us to the conclusion that we can achieve myoelectric prosthetics at very low cost that its market price if we desire to.

There are several modifications that can be done in our project. The weight of the prosthetic arm can be further reduced by using more light-weight materials in building the prosthetic arm.

The degree of freedom can be further increased my increasing the number of servo motors.

More functions such as thumbs up. Pointing etc… can be achieved by using more number of EMG sensors.

Each finger can be controlled separately if we increase the number of sensors and motors both.

More advanced sensors can be used to increase the speed and the functionality both for the Myoelectric Prosthetic Arm.

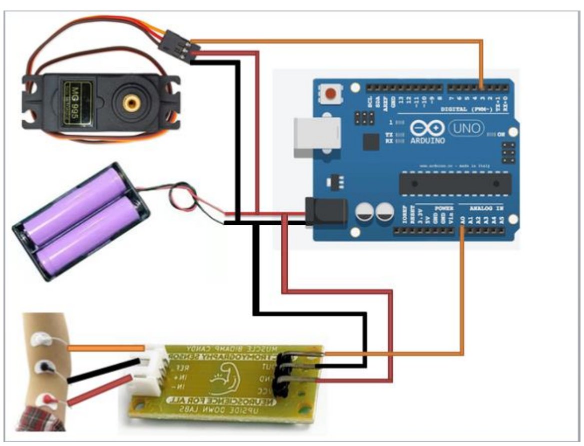

Figure 3: Circuit diagram

Overall we can say that there is a lot future scope for advancing in the field which our project belongs to.

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