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Low-Cost EMG Based Bionic ARM using Servo Motor and Arduino

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***Abstract:** Robotics is one of the technological advancement in the field of both medical and engineering. The main idea of this project is to change the standpoint of remote controlled robotic arms to manually controlled bionic arms. The primary goal of his project is to create a rehabilitation device that can help an upper arm amputee to attain their day-to-day tasks. This project is based on the design and development of the 3D printed arm structure. The whole system is the association of electrodes controlled by the EMG sensor that is attached to the 3D printed arm. This robotic bionic arm is developed using Arduino, EMG sensor, servo motor and MLX temperature sensor. The tension that are generated by the muscle contraction and relaxation results in the voltage level variation. On the bases of the different values obtained, the threshold value is sampled and the bionic arms fingers close, open, pick and place the objects according to the muscle movements. This technology not only used as prosthesis by the upper arm amputee patients, but also has its many favorable applications in the field of surgical operations like doctor operating a patient with the help of robotic arms rather than his own hands, humanoid robotics, etc.*

***Key words:** Bionic Arm, Robotics, Arduino, EMG Sensor, Servo Motor, Muscle Movement.*

I. INTRODUCTION

The most invaluable possession to any human being is their body parts. The loss of any single body part can cause the person to suffer rest of their life. For a human, among all the organs in their body, their upper limb including hand, fore arm and their upper arm is the most valuable organ. Absence of partial or complete human hand due to limb amputation is challenging and plays a significant impact in their fortune making them feel inferior and difficult to do their daily chores.

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Amputation of limb can be stressful, frightening and even distressing. Prosthetics is a field that aims to enhance the quality of life of an individual with any disabilities by providing them a device which helps them to improve their quality of life. The term prosthesis is derived from a new Latin word from Greek " prostithenai" meaning " to add to " or " to put in addition ". The upper limb of the human has 3 sections - the hand, forearm and the arm. The movement of the each section of the human hand is enhanced by the coordination of the nervous system musculoskeletal system and its surroundings. Robotic bionic arms are similar to the human hand. The coordinate control of the biological normal hand is more complex one, making it quite challenging to produce the biological control in any artificial hand. When it comes to the artificial robotic arms, all the control features of the human hand should be extremely match, so that the user could perform their daily chores effectively and independently [1].

The 3D printed arm has been designed and developed in order to mimic the normal biological arm. The bionic arm typically consists of modular components including arm, forearm and hand. 3D printed arms are typically made up of light weight and durable materials like PMMA plastic material. The design of the artificial arm incorporates the joints and sensors for the natural movement with the myo-electric sensor to detect the muscle signal for precise control of the bionic arm. The design of the 3D printed bionic arm aims for the aesthetics, functionality and user comfort, allowing the user for comfortable adjustments to fit the users specific needs and preferences [2].

II. OBJECTIVE

The foremost objective of our project is to provide an artificial robotic arm to the people with upper arm amputation.

- Bionic arms are very helpful for the people who lost their upper arm and if it is paralyzed.
- Most highly effective.
- Low cost. The whole arm can be manufactured foe 15000. It will be more affordable by the users when compared to the existing systems.
- Safe to use and the 3D printing material used is bio-compatible and does not cause any irritation to the user.
- Light weight. The 3D printed parts are comparatively less weight when compared to the robotic arm that is made with other materials.

A. Need for the Project

Amputation condition brings great hurdles in the life of the disabled individual. The sour truth is that, the disabled person finds difficulties due to their inability to perform their daily routine chores and their social activities in such a way they would have done it before.

When it comes to the present prosthetic arms, they do not reach the expected outcome for the disabled person. Lack of tactile feedback is also a major problem for the poor working of the existing prosthetic arms [3]. The existing prosthetic arms lack interface between the prosthetic arm and the human bio signal. Unfortunately, due to the increase in the limitation of the clinical limitation and availability of the prosthetic devices, nearly 10 - 20% of upper limb amputees do not use the prosthetic arms. Of those amputees who use prosthetic arms, only 50% of the users use the electric prosthetic arm. With the growing demand for the advanced artificial prosthetic devices, the development of new, more sophisticated and affordable prosthetic devices has become increasingly necessary [4][5][11][12][13][14][15].

III. METHODOLOGY

The whole process gets started from the brain. The neural activity in the motor context to the spinal cord, then the signal is sent to the muscle parts via the motor neurons. Excites the muscle causing to release the calcium ions by the muscles and immediately create the mechanical changes in the human muscle. This mechanical change by the muscle involves depolarization, which is detected by the EMG sensor for the prosthetic arm movement. The experimental setup includes Arduino, servo motor, EMG sensor, MLX temperature sensor and a regulated power supply. In this project, Arduino is used as a micro-controller because; it can read wide range of system inputs. In this system, SG90 servo motors are used, because it uses some pulse width modulation signals to control its speed and position, thus making it precise and accurate. EMG sensor is used to detect and record the electrical activities that are generated by the muscle movement. This allows the user to control the bionic arm by contracting some specific muscles, enabling the precise movement of the prosthetic arm. In addition to this, MLX temperature sensor is added to the system to enhance the user experience by providing the real time temperature feedback. This can help to prevent the user discomfort and can help to save the 3D printed arm from damages due to holding hot objects.

A. 3D Printing

3D printing or additive manufacturing is the creation of three-dimensional objects based on CAD models or 3D digital models. It is added by adding materials together (such as molten plastic, liquid, or powder), often layer by layer, through various processes by which information is deposited, joined or solidified under computer control in a computer system.

B. Dimension:

Symmetry in arm length is important for the wearer to avoid severe muscle asymmetry and muscle pain caused by imbalance. Therefore the arm design is designed to fit the size of the actual arm.

C. 3D Printing of Arm:

The 3D model of the bionic arm is designed and assembled to ensure full harmony of the arm and hand. The hand has 9 degrees of freedom and 4 degrees of movement. Can perform difficult tasks with precision. Five motors are connected to the tooth by springs to achieve a straight line. Linear actuators have feedback that allows for precise fingertip control. The product was printed using Poly Methyl Metha Acrylate (PMMA) material to provide a durable structure. Completely handcrafting requires less than 2kg of metal. The total weight of the bionic arm is just under 350 grams. Fig. 1 - 3 depicts the 3D structure of Palm of the arm, Thumb finger of the arm and Fingers of the hand.

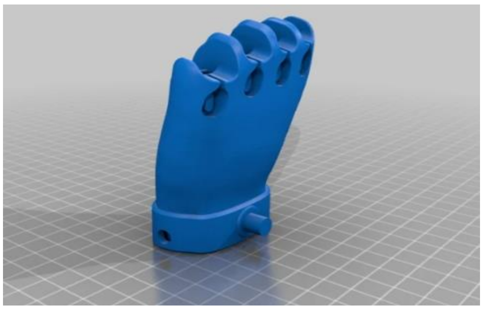

Figure 1: Palm of the ARM

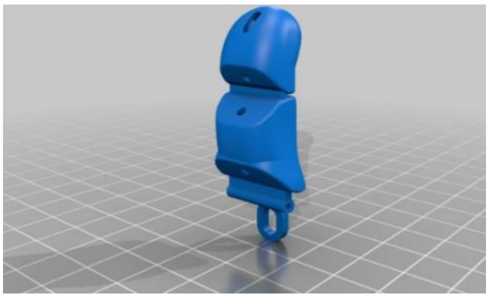

Figure 2: Thumb finger of the ARM

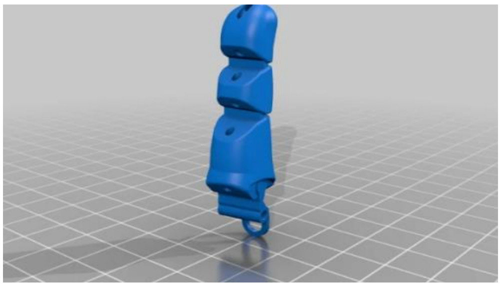

Figure 3: Fingers of the Hand

Resolution:

The resolution of the material is about 0.15 MM

Infill:

The infill used to make arm is about 70%

Filament Material:

The filament material we have used is PMMA. Figure 4 shows the fully printed bionic arm structure.

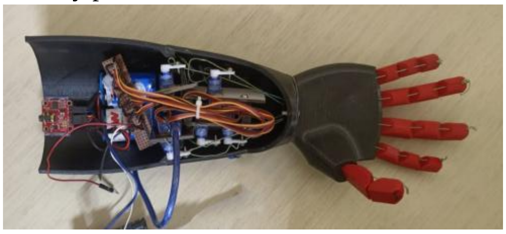

Figure 4: 3D Printed ARM

Stress and Strain Analysis

Finite element analysis in Auto-desk Inventor becomes very much easier when the assembly is correct and the joint forces, loads and constraints are given correctly. The motion of each part of the bionic arm is pre-loaded and transferred to fine element analysis. Confinement issues are crucial for the analysis of any physical model. If there is a heavy load on an object, the load must create a reaction force on the object. Physical limitations determine results. We limit the product of the robotic arm according to our purpose. Each arm on a robot has at least one joint.

Although the connection does not change during this process, the voltage direction will change as the object moves over time. It offers various motion loads in its stress analysis module. We check all of them from time to time, including external loads, body loads and gravity. We only create a time series as many times as there are time steps between them. In this example, we use 25 time steps from 0 to 7.5 seconds. We selected 6 time points where stress and change were clearly visible. The load capacity in this model is achieved through assembly. Stress is analyzed dynamically because we need to know how the tension changes during the movement of the part. When the task or time changes, the loading time and limit will also change and adjust themselves. Now, after the simulation is finished, we will obtain the voltage distribution. Figure 5 shows the stress and strain analysis of the 3D printed arm.

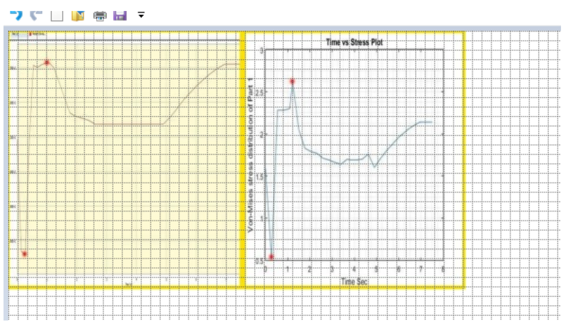

Figure 5: Stress and Strain Analysis

Block Diagram

The EMG electrodes are placed on the human hand and the EMG signals are acquired using the EMG sensor. The unwanted noise signals are removed from the EMG signal acquired using the band pass EMG filtering. The signal is sent to the Arduino that is programmed to run the servo motor when the signal frequency reaches the given frequency. The servo motor runs based on the Arduino commands. Figure 6 shows the block diagram of the entire system.

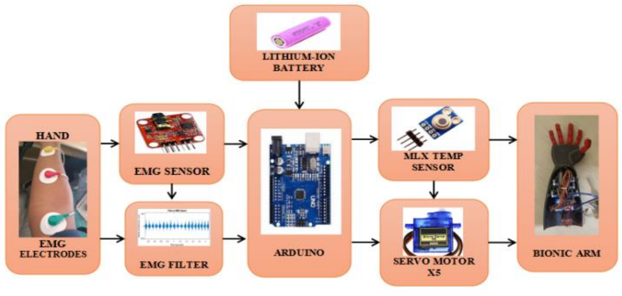

Figure 6: Block Diagram

Hardware Components

The proposed methodology includes a simple electronic system that includes the following components: EMG sensor, Lithium-ion battery, Arduino UNO, MIX temperature sensor, and Servo motor.

EMG Sensor

An EMG sensor shown in Figure 7 is an electronic device used to detect and record the electrical activity produced by muscles. It measures the electrical signals generated by muscle contractions and can give valuable information about muscle function, including strength, activation patterns, and fatigue. EMG sensors typically consist of electrodes that are placed on the skin overlying the muscles of interest. These electrodes pick up the electrical signals produced by muscle fibers during contraction, which can then be amplified, processed, and analyzed to assess muscle activity.

Figure 7: EMG Sensor

Lithium-Ion Battery

A Lithium-ion battery (Li-ion) shown in Figure 8 is an energy storage device and also rechargeable that utilizes lithium ions as the primary carrier of electrical charge between the battery's positive and negative electrodes during charge and discharge cycles. It is a portable electronic device due to its high energy density, lightweight, and long cycle life. They typically consist of one or more cells containing layers of electrodes (anode and cathode) separated by an electrolyte, allowing for the reversible movement of lithium ions between the electrodes during the charging and discharging processes [6].

Figure 8: Lithium-Ion Battery

Arduino UNO

Arduino UNO shown in Figure 9 is a micro-controller and also it is an open-source hardware and software platform [7][8]. It consists of digital and analog input and output pins that are used to control various components like sensors, displays, LEDs, and motors. It also contains a USB interface for communication with the computer and also with power jack. In Arduino UNO the executive codes are given based on this Arduino get works.

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Figure 9: Arduino UNO

Mix Temperature Sensor

The MIX temperature sensor shown in Figure 10 is a type of sensor that measures temperature using a thermistor [9]. The MIX temperature sensor typically consists of a thermistor enclosed in a protective housing, along with circuitry for signal conditioning and output. It is designed to accurately detect and measure temperature changes in its surroundings.

Figure 10: MIX Temperature Sensor

Servo Motor

A servo motor shown in Figure 11 is a type of rotary actuator that allows for precise control of angular position. It consists of a motor, a feedback device, a control circuit. They operate based on feedback control, where the control circuit continuously monitors the actual position of the motor shaft and adjusts the applied voltage to maintain the desired position. This feedback loop enables servo motors to achieve accurate and repeatable motion control tasks.

Figure 11: Servo Motor

Cost Estimation

In market, other prosthetic hands like zeus prosthetic arm, covvi hand adams hand ranges from 2.5 lakh to 25 lakh, which cannot be afford by amputees in the society. But low cost emg based bionic arm using servo motor and Arduino can be manufactured with only around 15000 to 20000 rupees.

Future scope and discussion

The future scope of the Bionic arm is promising, by enhancing sensor feedback, customization, and accessibility [10]. We will implement it with user-friendly gloves to encourage the individual to not distinguish from their hands and planning to implement a grip sensor. To improve functionality, user experience, and comfort we are planning to progress neural and brain-computer interfaces for more accuracy. Also planning for tailoring the bionic arm to individual users' needs, anatomical variation, and preferences. These developments will undoubtedly have a profound impact on the lives of amputees, also improving the quality of life

IV. CONCLUSION

The purpose of this proposed system is to design and produce a feasible and effective device for upper arm amputees. A 3D-printed bionic arm is designed for right-arm amputees. The 3D printed bionic arm was made to have low cost, less in weight and durability. The bionic arm has the potential to improve the emotional well-being of the person who lost arms. By providing more functional replacements, user can feel confident and comfortable in their daily interactions. This innovation method not only aims to improve physical function but also to enhance their overall quality of life. The integration of an EMG sensor in prosthetic bionic arms represents a significant advancement in the field of prosthetics. This innovative technology offers amputees a more intuitive and natural means of controlling their prosthetic arms, leading to improved independence, functionality, and overall quality of life.

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Ethical Approval and Consent to Participate	No, the article does not require ethical approval and consent to participate with evidence.
Availability of Data and Material	Not relevant.
Authors Contributions	All authors have equal participation in this article.

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