IJIRCCE

e-ISSN: 2320-9801 | p-ISSN: 2320-9798

INTERNATIONAL JOURNAL OF INNOVATIVE RESEARCH

IN COMPUTER & COMMUNICATION ENGINEERING

Volume 12, Issue 4, April 2024

INTERNATIONAL STANDARD SERIAL NUMBER INDIA

Impact Factor: 8.379

| DOI: 10.15680/IJIRCCE.2024.1204337 |

Smart Bionic Arm

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ABSTRACT: An EMG-controlled prosthetic arm is a remarkable advancement in the field of assistive technology which utilizes electromyography (EMG) signals generated by the user's muscles to accurately interpret their intended movements. These signals are then translated into real-time commands that control the prosthetic arm's various functions such as individual finger movement and wrist movement. These movements enable the action of gripping, lifting, and manipulating objects. This technology enables users to regain a high level of dexterity and natural movement, enhancing their overall quality of life and restoring a sense of autonomy. Further we will recreate the sense of touch using the principle of phantom limb and physical sensors like haptic and force sensors and giving feedback to the user targeting their residual nerve endings. EMG-controlled prosthetic arms hold immense potential for revolutionizing the lives of individuals with limb loss, facilitating seamless integration of advanced robotics with the human body.

KEYWORDS: 3D print, EMG based control, Electromyography (EMG) signal, hand prosthesis.

II. INTRODUCTION

The most valuable possession to any human being is their body. Absence of a human limb is a challenging situation, which makes one truly adore the working of our body. Bionic arm that has wide uses and applications in the domain of disability is a bio-mechanical device. Our proposed system is an array of mechanical motors which will pull the strings that will execute the flexion and extension of interphalangeal joints, combined with some electrodes controlled by the EMG muscle sensor integrated in a 3D printed mechanical design. Additionally, a mechanism to carry out wrist motion will be installed. The motors will assist in executing the necessary muscular movement when the model determines the type of movement based on the voltage level provided by the EMG sensor.

Despite living in a technologically advanced world, amputees still don't have access to fully functional and low-cost bionic arms and face several challenges when using said bionic arms. Some challenges include limited dexterity & movement, lack of sensory feedback and high costs. We plan to address these issues while creating our model. The core objective of our project is to design a low-cost bionic arm, using electromyography signals derived from the skeletal muscles and implement it by generating motions as similar and precise as the human arm. The goal is to facilitate the grab motion, wrist moment and a sense of touch to the amputee.

II. LITERATURE REVIEW

Over the years, notable advancements have been made in the field of prosthetic arms using EMG (Electromyography) signals. Our report is an amalgamation of 8 research papers in a summarized form where each paper has information related to the development and understanding of EMG based prosthetic arm. An artificial device known as a prosthetic arm replaces a person's missing limb that they might have lost due to an accident, any trauma or even due to defects at birth or fetal stage. The arm is controlled by brain signals which have many different ways by which they can be captured. One method is to take these signals from the surface of the muscles.

In the first publication, single channel EMG recording is used to study the prosthetic arm controlling approach for someone who has had a trans humeral amputation. The major features of this paper were signal conditioning, feature extraction and envelope detection but this project failed to provide independent functionality of each finger and the arm had just 1 degree of freedom [1]. The current investigation into prosthetic arms is still in the clinical testing stage, involves intrusive procedures, raises ethical questions, and is currently gathering data on the implants' long-term effects. The paper "Towards the Control of Individual Fingers of a Prosthetic Hand Using Surface EMG Signals" aims

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towards enabling individual finger movement for any prosthetic arm. They were not able to make a working model but they did collect EMG data by monitoring able bodied people. They were successful in executing 10 individual finger movements and 2 group finger movements using 32 bipolar electrodes [2]. Muscles produce myoelectric impulses as they contract. These signals follow a typical pattern and are used to control prosthetic limbs. Several features are taken from distinct signal time segments in order to record and maintain this pattern. The ANN that is utilized for classification then receives these signals as input. After this step, the control signals for prosthetic devices are procured. The goal of this strategy is to increase the functions that can be managed by a single signal channel. These were the primary conclusions. However, this experiment just examined the EMG data and did not use a prosthetic arm [3]. Acquisition and processing of EMG signals is one of the areas of active research. The amputee arm's EMG signal is obtained, and it is processed to produce the appropriate control signals that can be used to power prosthetic devices. This research classifies different movements for control of dexterous prosthetics using a single channel EMG. The outcomes highlight the crucial part that the analogue front- end plays. Without moving the electrodes, the circuit is sensitive enough to record even the smallest finger movements and records the EMG with a good signal-to-noise ratio. Subsequent research aims to broaden the scope of EMG signal acquisition to include additional essential movements and to enhance classification accuracy in the process [4].

People who suffer from paralysed human parts can use a prosthetic arm. This project makes use of the impulses coming from the muscles which are also known as electromyography. The three primary components of the complete network are the following: (1) a prosthetic arm; (2) an Arduino- controlled system for controlling the prosthetic hand; and (3) a portable EMG sensor. Three- channel EMG data is sent to the controller system via the Arduino communication protocol in the typical control operation. Every two seconds, the Arduino will run the algorithm and produce a result. This work effectively demonstrated the potential of EMG signals and offered guidance for improving prosthetics; it is simple to fit humans and extract signals from the human body [5]. This work reports the development of a realistic EMG pattern recognition research platform for less than Rs. 25,000, or less than 20% of the total cost of the equipment of EMG signal acquisition. The issues with the acquisition system's development were discovered to be the noise reduction, artifacts, and grounding system. These issues were effectively resolved with appropriate selection of parts for circuit design, systematic experimentation, and testing of the assembled circuitry. This work examined the effects of TD, FD, and TFD features on SLR, DT, LMT, NN, LDA, and SVM classifiers in addition to developing a low-cost system. This system only identifies 6 hand movements and cannot be used for prolonged time [6]. Every year, there are more numbers of accidents taking place in Bangladesh. People are losing important body parts, such as arms and limbs, or their lives as a result of those accidents. In order to keep costs to a minimum, the prosthetic arm and the EMG analogue frontend were designed and implemented locally, and an amputee volunteer served as the test subject for both projects. An amputee was able to successfully operate the prosthetic arm. The accuracy of the arm was then determined by testing it on six different healthy participants. For each person, there were thirty trials in order to determine the system's accuracy. Additionally, the system's total accuracy after all trials was almost 87%. However, it was not wearable and only allowed for individual finger movements of the arm [7]. Since the 1960s, myoelectric prostheses have been studied. However, there are yet few real-world uses for these prostheses. With the help of PR, an embedded hardware system for multi-DOF EMG driven prosthetic arm driving and control was successfully built in this work. The system can be worn and is completely practical and might be used for onboarding testing and training. Since what they have is a prototype, it is not attractive, stable for long term use and lacks a proper structural design. Future work on this research will concentrate on finding solutions to these issues and conducting a methodical comparison between traditional and PR-based myoelectric prosthetic arms [8].

III. PROPOSED SYSTEM

A. *Components Used:*

- Arduino Uno Board
- Servo Motors
- Electromyography Sensor
- Gyroscope Sensor
- Force Sensor
- Touch Sensor
- Button Vibrator Sensor
- NPN Transistor
- Jumper Wires

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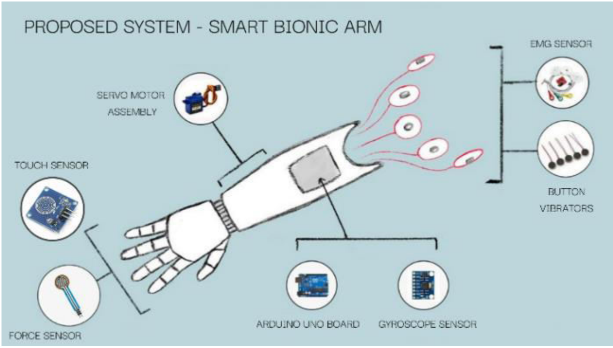
B. *Description of the Proposed System:*



Our proposed system is an Arduino based model. It is a 3-D printed realistic robotic arm with casing for motors and other elements. The whole device is a combination of electrodes governed by the EMG muscle sensor that is merged in a 3-D printed mechanical design along with other smaller units. The force sensors and touch sensor along with button vibrator is placed on the tip of the finger to give the user a sense of touch. Gyroscope sensor with a servo motor is placed on the wrist of the arm to enable the movement of the wrist.

Our Proposed System is an Arduino based model. It is a 3-D printed realistic robotic arm casing for motors and other elements. In our proposed system we made use of EMG sensors where 'myo' refers to muscles which record electrical activity produced by skeletal muscles. Each finger of our hand is connected to different muscles or tendons. Regardless of an amputee having a severed arm their muscles are still intact. When amputation surgery is carried out by surgeons, they usually perform another surgery known as Targeted Muscle Reinnervation (TMR). TMR involves rerouting severed or injured nerves to new muscle targets using microsurgical techniques to provide the nerve endings with a new muscle to innervate. The preserved nerves are placed on an optimal muscle group on the amputated limb. TMR enables amputees to control their limb prosthetics using natural muscle movement. The respective muscles are targeted through the EMG sensor and it records and converts those signals through the AUB which then sends a 5-digit binary code. This 5-digit binary code in return controls the servo motors which will be connected to all the 5 fingers of the bionic arm. This empowers the user to control the fingers with the natural feeling of moving their fingers.

We have included three main features in our project, The very first feature involves movement of fingers with the help of EMG Sensors. The EMG Sensor detects electrical activity from a muscle using conductive pads placed on the skin. Each finger is connected to separate muscle namely the flexor and extensor muscle groups. Through multiple tests we get amplitude ranges for each movement. An EMG band is worn on the forearm which calculates the relative difference between the signals of the sensors. After attaching the EMG Sensor and doing a flex motion we got an amplitude range of 540 to 660, we set this as a threshold, so when we flex our arm it sends a signal to rotate the motors.

Second feature is, wrist movement using gyroscope sensor. For us, we can easily rotate our wrists, an amputee has to rotate their whole arm. Gyroscope Sensor calculates the angular displacement according to an axis, it is placed on the forearm and it is programmed to rotate 20 degrees on the servo motor attached to the wrist, per 5-degree rotation in Gyroscope Sensor. Third and one of the most important feature is of feedback, it is made up of two parts –
Firstly, we have five force sensors connected to the fingertips of the mechanical arm which are each connected to a button vibrator, these will be attached to the nerve endings at the residual limb. This will replicate the sense of touch for each finger. Secondly, using touch sensors, we extend its surface area by conductive strips all over the whole surface of mechanical arm, when touched it vibrates all five motors in a pattern.

C. *Circuit Diagram of Proposed System*
The following Circuit Diagram represents the connection between AUB, EMG sensor along with Servo Motor. It chiefly explains how the signal is extracted from the muscles utilizing the following circuit connection. The input pin of EMG Sensor is an analog pin. The output is received via PWM pin. EMG Sensor has three electrodes namely, Signal, Ground and Power Supply. The signal wire is connected to the analog pin and the rest two electrodes are used for

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ground and VCC. Each servo motor is connected to the PWM pin which gives an output by moving the servo motor by acting as a switch.

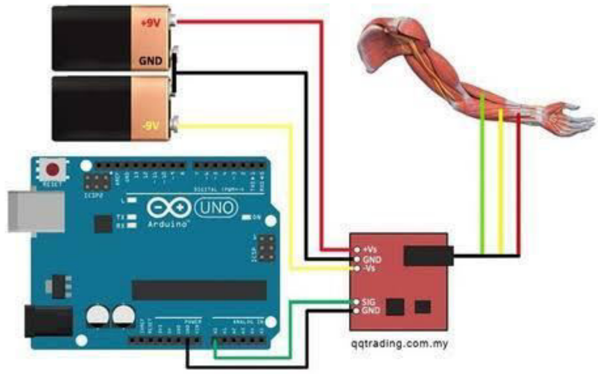

Fig 3: Interfacing of AUB, Servo Motors and EMG Sensor.

The following Circuit Diagram represents the connection between AUB, Force Sensor, Touch Sensor and Button Vibrator Sensor. Force Sensor is connected to analog pin power supply is given. The potential difference will be sensed by both force sensor and touch sensor, both these sensors will act as an input resulting in analog input value. Button vibrator sensor is connected to PWM pin since output is found at PWM pin. NPN Transistor is added to button vibrator to control the high-current loads received from servo motors. Basically, it acts as a switch.

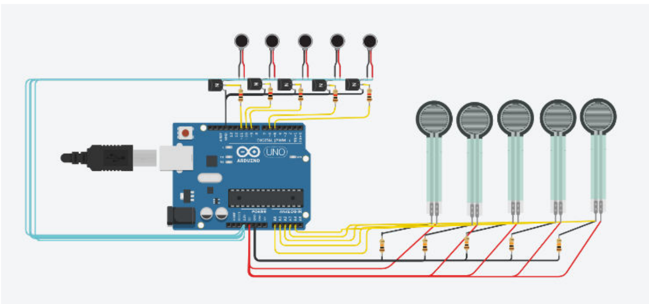

Fig 4: Interfacing of AUB, Force Sensor, Touch Sensor and Button Vibrator Sensor

D. *Prototype Model*

Our Prototype model includes the working of EMG Sensor and Servo Motors The palm has flexible tubes with slits, and are connected to strings which are then attached to the motor. When the motor rotates these strings will get pulled and bend the finger. We have fixed the servo motors on the pipe to balance the weight and to make it gyroscopic. Also, they rotate along with the palm so the finger mechanism works separately from the wrist mechanism.

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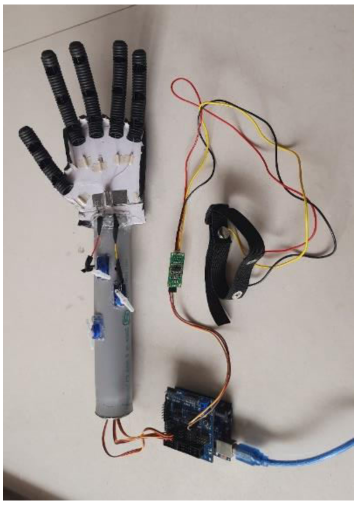

Fig 5: Prototype Model

IV. SIMULATION RESULTS

After running the Arduino Code, We check the peak signals via the serial plotter. The signal peaks realtime when we close our palm. Testing this on several people and several different spots on the arm, we summate a threshold. Here we got a threshold of 550, so whenever we close our palm and the signal crosses threshold, the servo motor attached to the mentioned pins rotate.

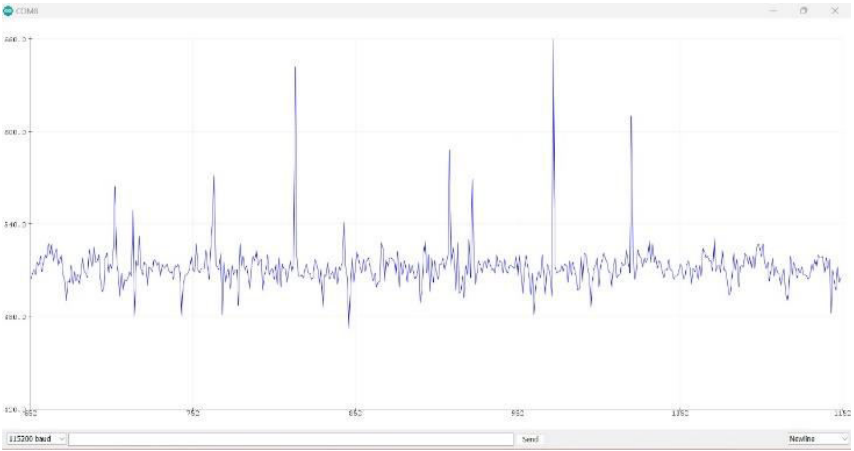

Fig 6: Graphical representation of the signals sent by the EMG sensors

We get a bionic arm that is capable of performing real-time finger movements and operation of wrist. Further we get a feedback mechanism from the force sensors to the residual arms nerve endings. The Arduino is programmed to read the voltage level on the pins in order to continuously monitor the analog output of the force sensor. This voltage level is converted into a numerical number by the Arduino's ADC (Analog to digital converter) which will indicate the force applied to the sensor. When the loop is iterated by the Arduino, it will compare the current sensor reading to a pre-set threshold value. The Arduino will carry out some set of instructions when the threshold is crossed. In particular, the digital pin attached to the button vibrator's control pin will receive a digital high signal from the Arduino. The button vibrator is activated by this digital high signal. This causes the button vibrator to function, which is, it starts to vibrate. The intensity and time for which the vibrations must go on can be controlled and set according to the needs and application. Bionic arms are capable, to some degree, of mimicking human motion. With the ability to mimic human motion, the system is capable in the field of disability where people have a missing limb or have to be amputated. Bionic arms can repeat actions and motions with the accuracy of a few thousands of an inch while being operable 24

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hours a day, making them a highly desired commodity in the field of disability. Bionic arms are impacting the various sectors of industry in a positive way and the benefits are still growing with newer robotics coming out with new specs.

V. CONCLUSION AND FUTURE WORK

The main objective of the creation of this bionic arm is to present user a mechanical arm which feels as realistic as the original arm. Delivering all the sensory and motor functions is valued in this project along with affordability of the final product.

With emerging technological advancements in the field of biomechanics, moving forward we can make use of better efficiency sensors for EMG control. More precision in sensing the muscle fluctuations can lead to more accurately working mechanical arm. We can make use of Haptic sensors which will be able to recreate the sense of human touch more accurately at the nerve endings of the residual limb. The main goal will be building the arm with lightweight materials and altering the mechanism so that minimal materials are utilized while taking into account the environment and weight of the arm, making it as light as 700gm. Further, the arm can be modified by making use of EEG sensors for people with motor neuron diseases like Cerebral Palsy and Lou Gehrig's disease. The technology used involves planting electrodes that pick up on the brain's signals and hence it will allow people to move, feel, and use the new limb in an intuitive, natural way.

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