THE BIONIC ARM

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***Abstract*—** The bionic arm is an electro-mechanical device that can be primarily used and applied in the field of disability. The whole device is the combination of electrodes governed by the EMG muscle sensor that is merged in a 3D printed mechanical design along with other smaller units. The device detects the type of muscular movement based on the voltage level provided by the EMG sensor and according motion is performed. with the help of servomotors. There is a variation in the values of the voltage level for different muscular movements. The tension that the muscle generates during their contraction and relaxation also creates a variation of the voltage level. Based on the different values the thresholds were sampled and the bionic arm based on these varying voltage level shows according motion.

***Keywords*— Electromyography, EMG Muscle Sensor, Bionic arm.**

I. INTRODUCTION

The most valuable possession to any human being is their body. Absence of human hand is a challenging situation, which makes one, truly adore the complexity of human body. With the aim of implementing the knowledge of electronics field, which would primarily play a role in improving the lives of this particular disabled group of people the project, is motivated.

Until recent times the design of such arms has progressed relatively slowly. Early innovations such as wooden arms are traditional version of such arms. History shows that for a long time, bionic arms have remained passive device that offer little in terms of control and movement. However, recent times have given advancements in such devices. Slowly we are approaching an advanced trans-human integration between the machine and human body.

II. OBJECTIVE

- To design a microcontroller based bionic arm using electromyography signals derived from the skeletal muscles and implement it by generating various useful motions.

III. LITERATURE REVIEW

Until recently, robots were mainly used in factories for automating production processes. In 1970s, the appearance

Of factory robots led to much debate on their influence on employment. Mass unemployment was feared. Although this did not come to pass; robots have radically changed the way work is done in countless factories. New robotics no longer concerns only factory applications, but also the use of robotics in a more complex manner. Several arms such as the Bebionic 3 and iLimb are myoelectric controlled robotic arms commercially available to the public. Numerous more prosthetic arms exist in research labs around the world, which are usually developed as prototypes to test advanced designs and concepts. Research prosthetics are generally more complex in terms of mechanical design, control, and monitoring systems but are inferior to commercial devices in terms of practicality, cost and robustness [1]. The human hand comprises of 27 bones (depending on the individual), more than 30 individual muscles and over 100 named ligaments, nerves and arteries. Prostheses aim to replicate the functions of the human body and return functionality to Persons with missing extremities. No current prosthetics can match the dexterity, flexibility and fluidity of the human hand. We can move forward/backward, up/down, left, and right. At the same point, we can also rotate around 3 different axes. The human neck for example has 3 degrees of rotational freedom we can look left/right, up/down and tilt our head sideways. Therefore, in total a single point can have a maximum of 6 degrees of freedom (3 Translational, 3 rotational) the human finger in total has 4 degrees of freedom. Three of these are the rotations of each joint (DIP, PIP, MCP) which combine to control flexion and extension of the finger. The Knuckle (MCP joint) also allows for abduction/adduction (wiggling the finger from side to side).In the thumb the lower CMC joint also allows for abduction/adduction, which gives 5 DOFs in the thumb.

Fingers and all joints in the human body are actuated (moved) via contraction of muscles and tendons [2].

The vast majority of commercial prosthetic fingers are actuated through a joint linkage system powered by DC electric motors. All joints in the finger are controlled through a single actuator, which means the entire finger has only a single degree of freedom these fingers can only open/close in a single way. In reality, a human finger has control over individual joints so is capable of flexing in a variety of ways. Dexterity arises from the numerous degrees of freedom of the human hand. The fine motor control a person has over their individual finger joints allows for a vast array of intricate tasks achieved. In contrast, commercial prostheses are limited to simple tasks partially due to the lack of fine control in the fingers. For example, trying to knit, sew or play a musical instrument, as a guitar with a modern commercial prosthetic device would be extremely difficult if not impossible. Another critical design point in commercial prosthesis is durability. The average user will wear a myoelectric prosthetic hand in excess of 8 hours per day. Therefore, prosthetic arms for commercial use must be robust, lightweight and packaged into a closed system that can be attached to an amputee. Mechanical complexity determines the degrees of freedom in the system; however, there is usually a trade-off because increasing complexity can lead to an increase of the size of the device and reduce robustness and durability [4]. The Bebionic 3 is a world leading commercial myoelectric arm. Like others of its kind, the Bebionic 3 uses a predefined grip system. A user can select from 14 different grip patterns using muscle activity around their upper forearm [5]. The user does not essentially have control of individual finger movements, rather they can select a grip pattern and then use muscle activity to activate the movements of that specific grip. One of the most advanced modern prosthetic arms is the 22 degree of freedom Intrinsic Hand developed at the John Hopkins Applied Physics Laboratory. This hand has been developed through DARPA initiative and funding and has unmatched mechanical dexterity. To achieve such fine control designers incorporated 15 miniature DC motors directly in the fingers, palm and wrist. The Intrinsic Hand is able to replicate almost every movement of the biological human hand. Using standard EMG sensing techniques there is no way of obtaining enough control for a user to practically use all the degrees of freedom of this device.

However, DARPA is further funding the development of a prosthesis/brain neural interface to connect the users' nervous system directly to inputs in the arm. Another interesting method of actuating prosthetic hands is by using shape memory alloys (SMAs). SMAs return to a predefined shape or size when subject to the appropriate thermal procedure (heating or cooling).There are two major problems with this method though designing a precise control system for SMA actuators is very complex. Contraction rate of the SMA, spring response and varying weights of objects grasped all contribute to this problem. Heating the SMA and then waiting for it to cool can take quite some, which makes closing and opening a finger a relatively slow process. A great benefit it that they are noise free and low weight. Over the past couple of years, developing 3D printed bionic limbs have become quite popular. InMoov is an independently run project developing a life like humanoid robot from 3D printing technology. The entire project is open source and provides great mechanical design insight into producing 3D printed robotic body parts. We also used InMoov for the design of our bionic arm. The open source nature of this project allows the public to access computer aided designs and follow step by step guides on how to 3D print and assemble this system. Tendons actuated through servomotors placed in the forearm control InMoov fingers. The problem with the InMoov hand is that the Servos take up the entire forearm leaving no room for it to be attached to a stump between the elbow and wrist.

The bionic arm we created focuses on those people who cannot buy the expensive arms out there in the market. It only performs picking and holding small objects to some extent. Although there is huge level of improvements between the past designs and recent trends in the field of prosthetic arms, the proposed system has its own constraints. The system depends on the muscular simulation rather than neurological simulation in the case of recent advancements. Similarly, the thermal phenomena for movement of the arm are not significant in the case of proposed system. However, the system has potential of rotational and transitional motions and the force factor for holding the objects up to a certain extent.

IV. Problem Statement

In a scenario where a person can expose ones potential to the fullest by learning, sharing, exploring and trying different things, disability can be proven a curse. The handicapped and disabled people are unfortunately not capable of performing day-to-day tasks that normal people can perform and this consequently leads to disabled people lagging behind in this modern era where there is always a struggle for existence. In this area of disability regarding absence of arms, the proposed arm helps people to perform day-to-day actions like normal hands up to certain extent.

The bionic arm we created also performs actions like holding picking objects of small mass and dimensions to some extent such as bottles. The motion includes complete opening of the hand, closing of hand in the form of fist, rotating the wrist in the form of fist and pointing of index finger. These motions have their own significances and purposes that can be used in day-to-day life. Moreover, although there is availability of modern advanced prosthetic and bionic arms, these are out of reach of majority of the people and this proposed bionic arm can be implemented in an optimum cost margin thus making this technology more available to the people who need it. Thus, the proposed bionic arm is motivated by the problems stated and is expected to solve such problems relatively along with its own drawbacks as well.

V. Working Principle

A. *Materials*

- Arduino Uno
- Servo Motors
- Electrodes
- EMG muscle sensors
- The prosthetic arm

B. Methodology

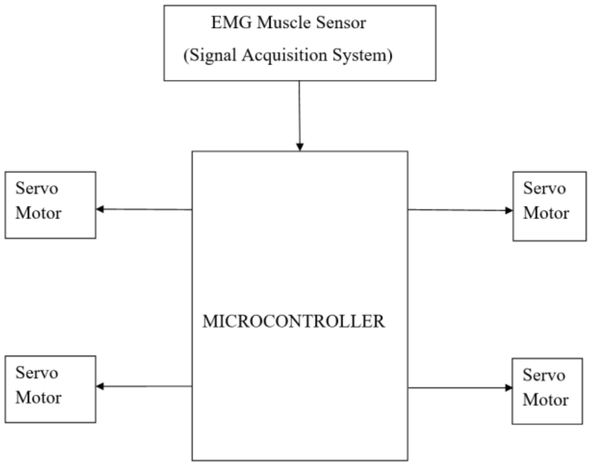


Fig 1: Block diagram of proposed system

The basic concept is to use the input derived from electromyography data to control a robotic arm. The input values from the muscle sensor extracted in accordance to the amount of muscle contraction as well as the number of contracted muscles or in other words, the stronger the muscle contraction the higher the number of activated muscles, the higher the recorded voltage amplitude will be. This happens due to the contraction of muscles fibers when the potentials are geneSrated in motor neurons. When the neuron and axon exceed the threshold in Postsynaptic Membrane of Neuromuscular junction, it becomes a muscle action potential. Difference in the potentials, the muscles potential is propagated in both directions of muscles fiber triggering the process of the sliding of action filaments on myosin., Various number of fibers are activated on contractions of Muscles Unit (MU) with the combinations of activations and synchronizations. The frequency of MU refers to contractions, relaxing after each activation that produces temporal pules of two or more MU firing in combinations. Activations and synchronizations control contractions of Muscles Unit (MU). The wrist in the proposed arm has six degrees of freedom, the thumb having 5 degrees of freedom and the remaining 4 fingers having 4 degrees of motion individually.

Fig 2: Placement of electrodes

Since EMG activity is even measurable when we do not move our body i.e. during stationary positions, a system is designed to remove such beheaviours.The input values fetched from the sensor are very low, appropriate filtering and amplification is used to map the signals. This amplification and filtering process is a mechanism built within the sensor itself. The type of motion is based on these input values and the servomotors are operated in such a way that corresponding rotational or transitional motions are performed. As shown in the figure the differentiating electrodes are kept in the forearm area whereas the reference electrodes are placed in the elbow region. The difference read by the differentiating electrodes serves as input to the microcontroller.

Regarding the protocols and guidelines while interfacing the EMG sensor v3 with the microcontroller, the sensor needs to be supplied ±18 V and a ground supply. If the supply exceeds the EMG sensor is prone to destruction. Likewise, the operation needs to be based on an area with low electric field due to electrical interference. The data provided by the EMG sensor is also dependent on the psychological state of the host. Likewise common ground supply needs to be arranged for reduction of unwanted oscillations.

VI. Flowchart Of The System

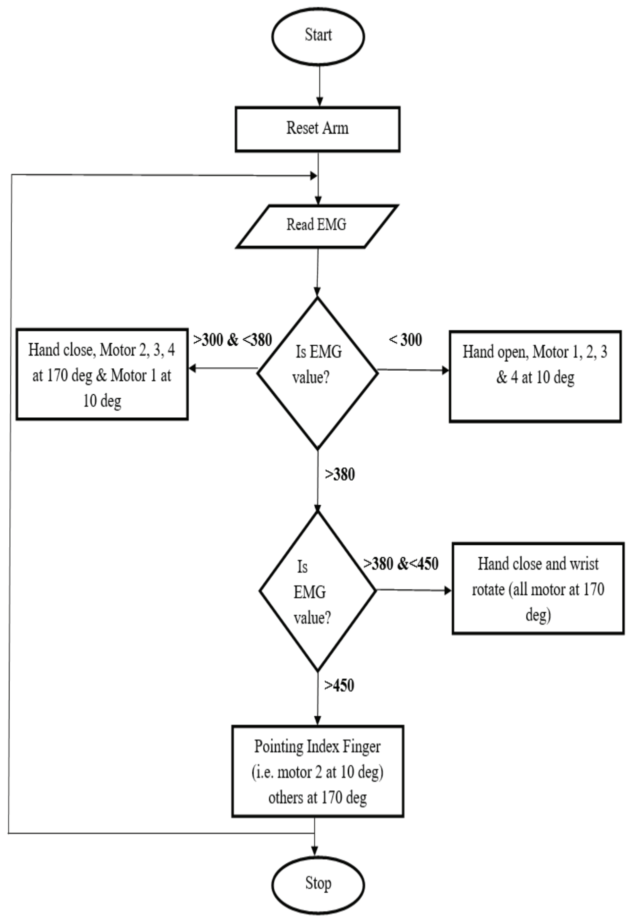


Fig 3: Flowchart of the system

The values read by the EMG sensor are the main working basis for the motion of bionic arm as different values lead to different type of motions. Initially the arm is in reset position, the reset position signifies the hand open condition which is taken as the reference position. According to individual basis, the readings vary and the arm needs to be calibrated accordingly. The readings mentioned in the flowchart are according to the muscular motion of one of our project members. Motor one governs the wrist motion; motor two governs the index fingers motion, motor three controlling the thumb and motor four regulating the remaining finger motion. If the EMG value is greater than 300 microvolts all the motors are rotated by 10 degrees that leads to the opening of hand accompanied by the fishing lines creating an interface between the motors and the fingers. Similarly if the value falls on else condition i.e. value being in between 300 micro volts and 380 micro volts, closing of hand occurs due to rotation of motor 1 which controls the wrist by 10 degree and other motors controlling the fingers by 170 degrees leading to the complete closure of palm. Likewise, if the value falls to be in between 380 microvolts and 450 microvolts all motors rotate by 170 degrees which makes the hand close and the wrist rotate resembling of fist. Again, if the value comes to be greater than 450 micro volts, motor 2 rotates by 10 degrees and other motors rotate by 170 degree which finally leads to a fist with pointed finger. The value is read constantly and corresponding motions are performed based on the nature of EMG values as mentioned above. The response time between arrival of EMG signal and movement of the arm is generally dependent on the delay parameter mentioned in the code and processing capacity of the sensor. The proposed bionic arm is found to have a delay of 500ms when tested by a microsecond timer.

VII. Result And Discussion

The graphical representation along with the value of readings in tabular form for various type of motion represented by the arm is attached along. The nature of readings given by the EMG sensors for different positions are compared graphically. The reading observed when the hand is at open position is taken as the reference position and is compared to various motion of hands. The first graph compares the nature of readings between the hand at open position to hand at close condition whereas the second graph compares the nature of values between the reference position and hand being closed and rotated position. Likewise, the third graph represents the comparison between the reference position and the pointing index finger position. The values can be concluded to be stable up to applicable state. The minor fluctuations are due to practical factors such as sensitivity of equipment, readings from transient states and so on.

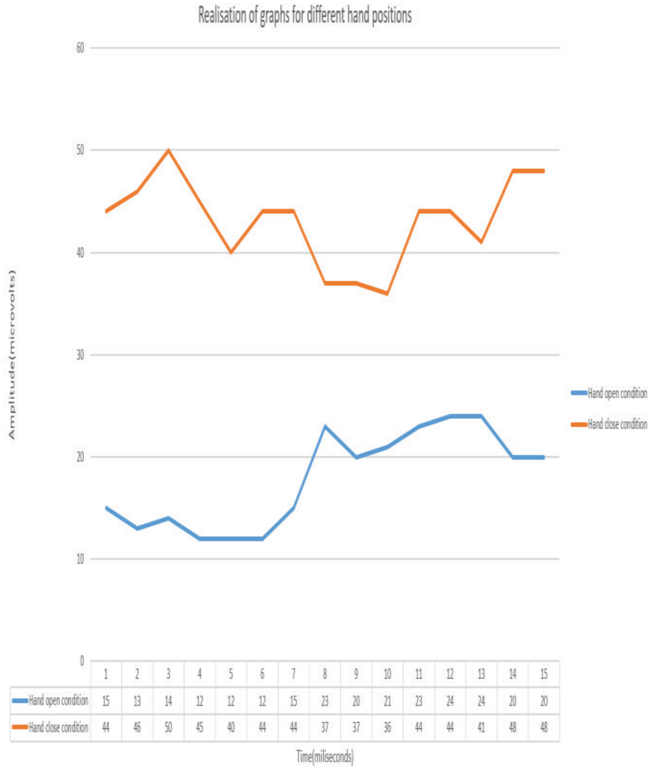


Fig 4: Graph for hand open and hand closed position

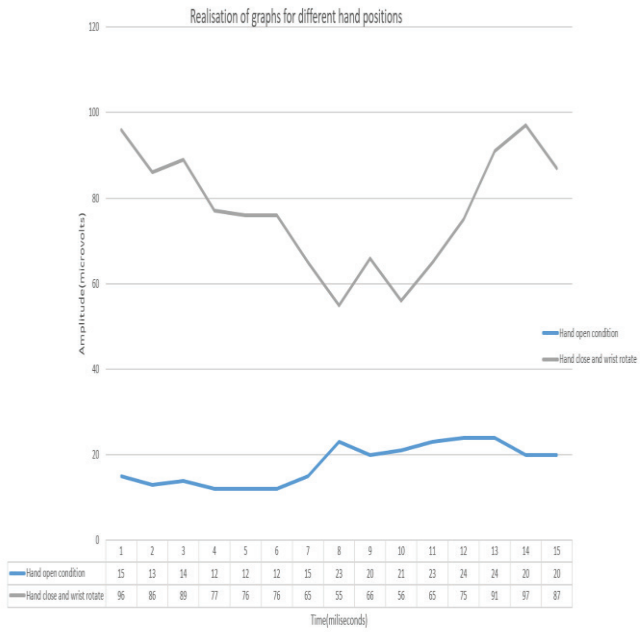
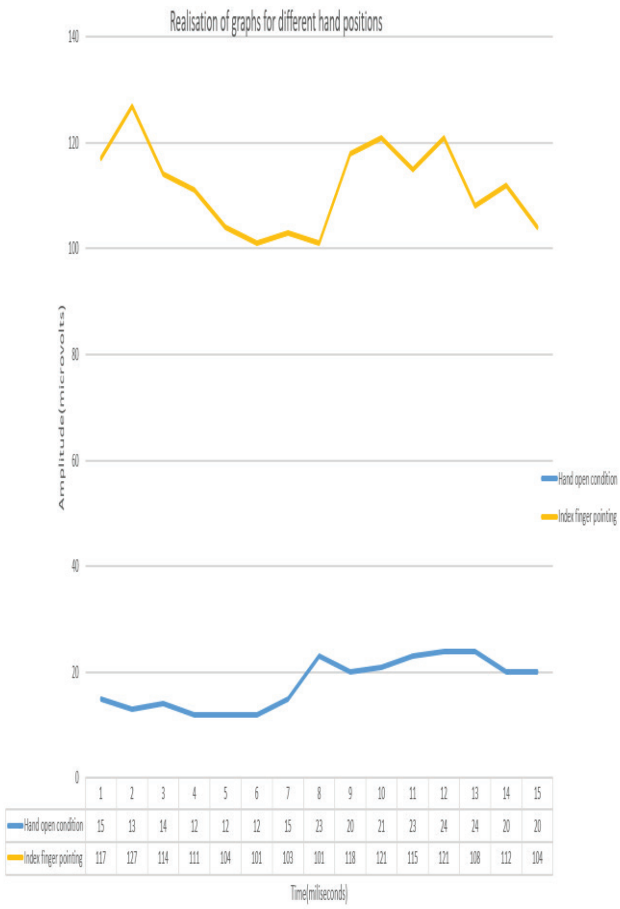


Fig 5: Graph for hand open and hand close and wrist rotate position



	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Hand open condition	15	13	14	12	12	12	15	23	20	21	23	24	24	20	20
Index finger pointing	117	127	114	111	104	101	103	101	118	121	115	121	108	112	104

Fig 6: Graph for hand open and index finger pointing position

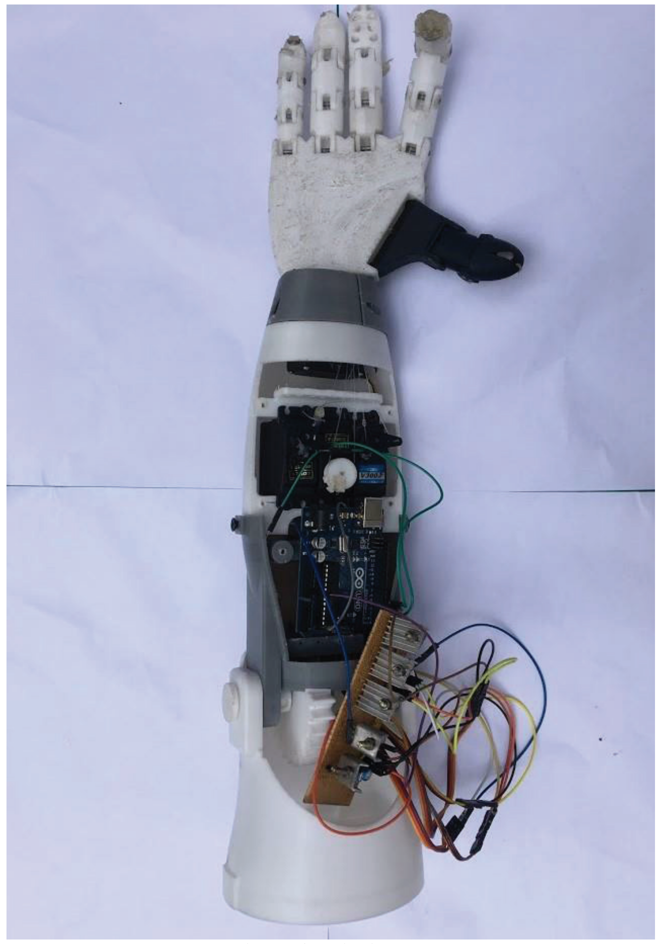


Fig 7: The Bionic Arm

Considering the advantage of lightweight system over a bulky one, the arm is 3D printed keeping it ahead of the traditional arms, which have a heavy delay in range of motions due to their weight factor. EMG sensor is the main working tool; the rotational motion of the servo motors placed inside the bionic arm governs the motion. The fishing line interfaces the motors and the fingers. In this way, the motions with respective EMG values govern different motions by the rotation of servomotors where the fishing line serves as a link.

VIII. Conclusion

Thus, a 3D printed Bionic Arm is designed whose operation is governed by the intensity of contraction and rarefaction of the muscles in the hand. The operating tools for the motion are servomotors whose nature of rotation depends on the desired movement. Thus, system is capable in the field of Disability, hospitality industry like Restaurants and areas where normal human hands are prone to risk. Therefore, the bionic arm can satisfy each application along with its limitations as well.

IX. Future Enhancement

The limitations of the project serve as a scope for future enhancement. The grip factor for capturing of objects with a higher weight considering the force and tensile factors can be improved. Likewise, the motion of fingers on individual basis can be controlled in the future. The natural motion of the wrist that is 360 degrees is limited to 180 degree in the current pretext but it can be expanded up to 360 degrees in the future.

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