AFFORDABLE MYOELECTRIC PROSTHETIC ARM*

BY

VIDHI RAY[1], RAM CHOKDA[2], HIMANGA JYOTI CHOUDHURY[3], MONIKA NAGRALE[4], BISWAJEET CHAMPATY[5]♣

[1-4]*School of Engineering, Ajeenkya DY Patil University, Pune, Maharashtra 412105, India*

[1]*vidhi.ray@adypu.edu.in*

[2]*ram.chokda@adypu.edu.in*

[3]*himanga.jyoti@adypu.edu.in*

[4]*monika.nagrale@adypu.edu.in*

[5]*biswajeet.champaty@adypu.edu.in*

ABSTRACT

The individuals with upper limb amputation have been reported to be over 3 million worldwide. Losing a hand greatly changes the individual's standard of living and also affect their emotional and social well-being. It becomes quite difficult for the amputees to even perform the basic everyday tasks. Several commercial prosthetics devices are available but most of them are extremely expensive at thousands or lakhs of rupees. Therefore, an economical prosthetic hand is a need for underprivileged individuals with upper limb amputation. We aimed to make the design simple and moderately functional rather than attempting a complex design which would make it costlier, heavier and also demanding on power consumption. This paper presents a typical myoelectric hand which extracts myoelectric signals from the residual arm of the amputee using the surface electrodes. The signals are then processed using the myoware sensor to allow the fundamental hand movements like opening and closing of hand with the help of a servo motor and string-based actuation. The interfacing of the components is done using Arduino UNO.

KEYWORDS

Economical Prosthetic hand, Myoware sensor, String-based actuation.

I. INTRODUCTION

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♣ Corresponding Author

The ongoing advancement in prosthetic technologies has pushed the boundaries with innovations such as multi-articulating and lifelike hands like those manufactured by Ottobock. However, these advanced technologies are often unaffordable by the underprivileged population with upper limb amputation living in the developing countries. They also lack the basic medical and engineering facilities to manufacture and provide this product to all. Therefore, in the developing countries only 5% of the amputees own a prosthesis. [1] To address this situation, we proposed to design a cost-effective myoelectric prosthetic hand for the underprivileged amputees. The device allows the disabled to perform basic hand movements which were lost due to accidents, diseases or congenital defects.

The device is attached to the residual arm of the amputee to restore the basic functions of natural arm. A prototype prosthesis was created using cardboard, straws and strings which performed basic operations like opening and closing of hand. The device includes a servo motor, myoware sensor with three surface electrodes and a microcontroller, preferentially Arduino UNO. The three electrodes are attached on the muscle body of the residual arm to extract EMG signals from the body using the myoware sensor. The servo motor allows the movement of fingers. The microcontroller interfaces the EMG sensor with the servo motor.

Figure 1 shows a block diagram of the signal flow in a myoelectric prosthetic hand. It includes EMG sensing which senses the muscle activation in the residual arm through the electrodes attached on skin and a control system which actuates the hand based on the input signals received from EMG sensor. [2]

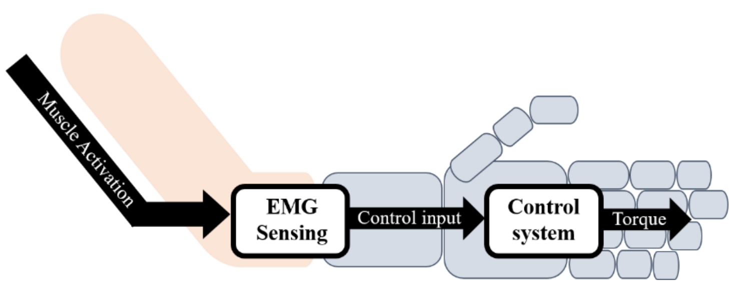

Fig. 1 Block Diagram of signal flow in myoelectric hand

II. REQUIREMENTS

Myoware sensor (Advancer Technologies), Ag/AgCl surface electrodes, SG90 servo motor, Arduino UNO, breadboard. Arduino IDE was used for control system design. Cardboard, straws and strings were used for the prototype design.

III. BACKGROUND RESEARCH

A. Anatomy

As shown in figure 2, there are no muscles present in fingers and thumb of a natural hand. The muscles required to control the movement of fingers are present in the forearm and palm region of hand. These muscles connect to the fingers via tendons. The two muscles that allows the open and close movement of hand are flexor digitorum and extensor digitorum present in forearm region. The flexor digitorum present on the front side of the hand allows the flexion of each finger and the extensor digitorum present on the back side of the hand allows the extension of each finger. The interossi muscles present in the palm region of hand allows side to side movement of fingers. [3]

Product name	**Manufacturer**	**Number of actuators**	**Price (INR)**	**Characteristics**
Rehabilitative robotic glove	AIM laboratory of Worcester Polytechnic Institute	5	~30.5k/unit	Durable string-base actuation Used for rehabilitation purpose The servo motors actuate the cables used to open and close the user’s arm [3]
Bebionic Hand	Ottobock	5	~8.36 Lakh/unit	Passive thumb rotation Adaptive grip (https://www.ottobock.in/artificial-limbs/upper-limb/solution-overview/bebionic-hand-with-individual-finger-movement/)
Hero Arm	Open Bionics	3 or 4	~60k/unit	First FDA approved 3D printed prosthesis Personalized, Robust & Powerful Gripping Feature Haptic vibrations to provide notifications (https://openbionics.com/hero-arm/)
Limbitless arm	e-NABLE	1	~27k/unit	An open-source design consisting of a muscle sensor, a single motor for

				torque, Arduino and Kevlar survical cord for open and close movement [6]

TABLE I: COMPARISON OF COMMERCIALLY AVAILABLE PROSTHETIC HAND

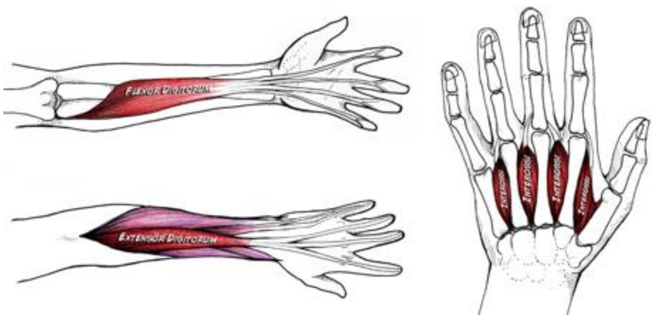

Fig. 2. Muscles for finger movements

B. Existing Technologies

A brief comparison of commercially available upper limb prosthesis has been made in the Table I based on the number on actuators, cost of the product and its characteristics.

IV. METHODOLOGY

A. Prototype Design and System Integration

The prototype design was created using cardboard, straws and strings to check the actual functionality of the system. This system will be further used in 3D printed hand.

Fig. 3 Prototype design

The device includes a servo motor, myoware sensor with three surface electrodes and a microcontroller, preferentially Arduino UNO. The three electrodes are attached on the muscle body of the residual arm to extract EMG signals from the body using the myoware sensor. The servo motor allows the movement of fingers. The microcontroller integrates the EMG sensor and servo motor. [8]

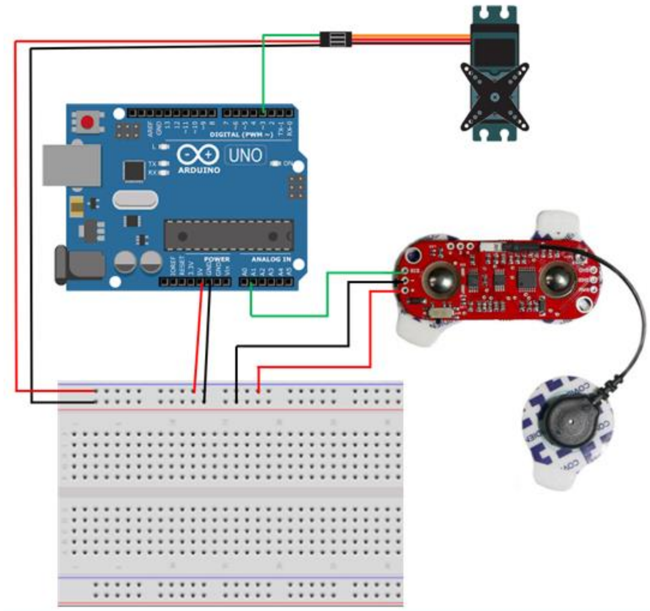

Fig. 4 Circuit Diagram

B. EMG Sensor Placement

The placement of sensor should be in the middle of the muscle body and it should also align with the orientation of the muscle fibres. The EMG sensor was placed on different areas of forearm and biceps to read the myoelectric signals. [9] Figure 5 shows the different positioning of electrodes

(a) Flexor digitorum muscles

(b) Extensor digitorum muscles

(c) Bicep muscles

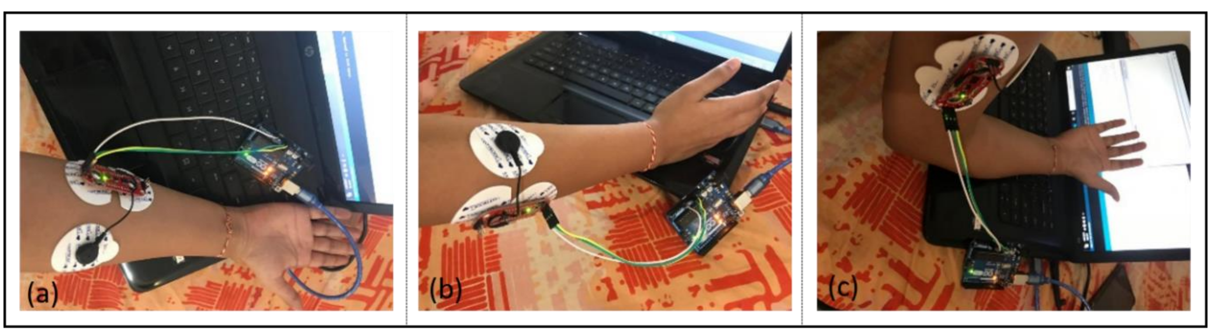

Fig. 5 Positioning of electrodes (a) Position 1 (b) Position 2 (c) Position 3

C. Actuation Unit

The hand movement is achieved by the use of servo motor and strings. When the EMG signal is acquired from the sensor, it signals the Arduino to command the servo motor to either open or close the hand based on the values obtained. The strings from each finger are collectively attached with the servo motor which is programmed to rotate at 180º angle. Based on the signal obtained, the motor is actuated to allow open and close movement of hand. [10] Figure 6 shows the (a) open and (b) close movement of hand.

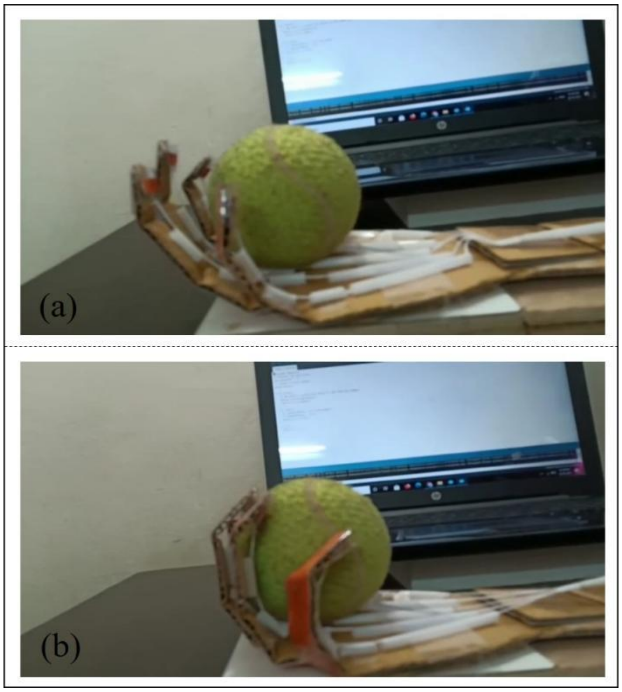

Fig. 6 Working Prototype (a) open movement (b) close movement

V. RESULT

A. Final Values

EMG signals were acquired from five subjects, each of different age group. The values were recorded for fundamental hand movements like opening and closing of arm. An average of all these values was taken to code the Arduino. Table II shows average value of five subjects performing open and close movement by placing the sensor at three different positions. The prototype was developed using cardboard, straws and strings to check the working of the system. The prototype was tested for grasping an object and the results were satisfactory. The average value from the sensor after converting into digital signal for the candidate on an open hand was around 48 and for the closed hand it was around 116. The system was programmed according to it. The sensor was placed in the three positions mentioned in figure 5.

Hand Movement	**EMG sensor placement**		
	Position 1	**Position 2**	**Position 3**

Open hand (rest position)	45	50	50
Close hand (fist)	115	110	123

TABLE II: FINAL VALUES

B. Cost Estimate

The primary objective of this project was to develop an affordable prosthetic hand for the disadvantaged population. For this purpose, we took an estimate of the total cost of the device. Table III shows the device cost by part. The final cost of the product is estimated to be 15k INR. Commercially available prosthetic devices are extremely expensive at thousands or lakhs of rupees. [9] Therefore, our device would be a more sustainable choice for the disabled in developing countries.

SR NO	**Product**	**Company**	**Number of Piece**	**Price (INR)**
1.	Myoware EMG sensor	Advancer Technologies	1	2885
2.	Servo motor (SG90)	Towerpro	1	100
3.	Arduino UNO	Arduino	1	500
4.	3D printed hand	-	1	10000
5.	Miscellaneous	-	-	1000

TABLE III: THE DEVICE COST BY PART

VI. CONCLUSION

We developed a low-cost myoelectric prosthetic arm capable of performing the fundamental hand movements like flexion and extension of fingers. The EMG signals were extracted by placing the electrodes on the muscle body of arm. Myoware sensor was used for this purpose. A single servo motor was used for the actuation of fingers. Arduino interfaced the myoware sensor with the servo motor. To program the Arduino, the average value of five candidates were taken by placing the electrodes at three different positions on forearm and bicep. The functionality of the system was verified by applying it on a prototype design made up of cardboard, straws and strings. The results of the system were satisfactory making it suitable to implement on a 3D printed hand. The overall cost of the system was estimated to be quite low (approximately 15k) compared to the commercially available prosthetic devices. The goal of developing a simple design with basic functionality to make it affordable for the low-income population was thus achieved.

A. Future Work

A self-designed sensor would reduce the cost and also give more accurate values. The product lacks feedback mechanism. Use of touch or force sensors at finger tips would provide feedback of the force asserted during grips making it more lifelike. Use of single servo motor for each finger would allow more hand gestures. All the measurements of EMG signals for hand movements were conducted on subjects who weren't amputees. So, there is a possibility of the values to slightly differ when taken from an amputee. The fundamental goal of the project was to make a low-cost device which would always be an improvement to work on.

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REFERENCES

[1] M. Moreo, "Parametric design of a 3 D printable hand prosthesis for children in developing countries," 2016.

[2] B. Peerdeman, "Myoelectric forearm prostheses: State of the art from a user-centered perspective," Journal of Rehabilitation Research & Development (JRRD), 2011.

[3] M. A. D. I. RBE, "Rehabilitative Robotic Glove," 2012.

[4] "https://www.ottobock.in/artificial-limbs/upper-limb/solution-overview/bebionic-hand-with-individual-finger-movement/".

[5] "https://openbionics.com/hero-arm/".

[6] "http://enablingthefuture.org/upper-limb-prosthetics/the-limbitless-arm/".

[7] https://corewalking.com/muscles-fingers/.

[8] S. Sundarsan, "Design and Development of EMG Controlled Prosthetics Limb," pp. Pages 3547-3551, 2012.

[9] N. T. N. Nguyen, "Developing Low-cost Myoelectric Prosthetic Hand," p. 47 pages + 2 appendices, 2018.

[10] http://www.ee.ic.ac.uk/pcheung/teaching/DE1_EE/stores/sg90_datasheet.pdf.