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Affordable Bionic Arm Based on Electromyography Sensor

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Abstract :

Over the past decade, the number of individuals suffering with disabilities is rising at an alarming rate due to the factors such as increase in population growth, ageing factors and the occurrence of long-lasting diseases. Limb amputation presents multi-directional challenges as it affects sensation of the body, function of the body, career, self-image and family relationships. To address this issue, bionic arms are suggested. Bionic arms operate by gathering signals from an amputee muscle. Though EMG based bionic arms are existing in the market, utmost of them is too costly to be economically accessible or it is overloaded with heavy weight for long time wearing. This proposed work demonstrates the construction and working of a cost effective, robust and flexible bionic arm controlled through Arduino microcontroller. The designed bionic arm consists of a 3–D printed hand material, a myoware sensor for monitoring muscle activity, an arduino processor, six motors and an extremely stretchable hand glove. The use of myoware sensor has allowed developing the bionic arm to realize the natural movements of the hand. The bionic arm was designed and implemented using 3-D printing and casted with silicone material. The affordable bionic arm has been tested in real time on amputees and results show that it can grasp various objects effectively.

Keywords **—Sensor, control, 3-D printing, microcontroller, bionic arm and electromyography.**

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I. INTRODUCTION

During the last decade, with the rising population, unparalleled use of two-wheeler and four-wheeler vehicles and developing urbanization in India, the number of persons facing road accidents have increased dramatically. Currently road traffic injuries accounts for most of the deaths in India. As per the report given by Institute for health metrics and evaluation

(IHME), road traffic injuries found to be the eighth leading cause of deaths in India in the year 2017. It has been projected that there are roughly 0.62 amputees in India per thousand of population. It transforms to close to three million individuals affected with amputations in the country. The human body contains many parts and out of these, hand is one of the vital part. Hand parts are very gentle and intricate structure. This gives muscles and joints in the hand part a wide variety of actions and accuracy. The hand movements help the body perform important essential actions such as pushing, pulling and/or grasping lighter and weightier objects, feeding oneself, playing, cutting the objects, writing etc. It symbolizes multiple degrees of freedom and can perform integrated functions.

Hands are also quite susceptible; nevertheless Tendons, nerve fibers, blood vessels and thin bones are all sited right underneath the skin and are lone covered by a thin cover of muscle and fat. Usually, the palm is protected by a strong pad of tendons, which enables a powerful grip for holding the objects. In general, the human hands are utilized throughout the day for carrying out basic livelihood activities, and often come into contact with potentially harmful objects. So as a result, hand injuries occur quite often.

The human hand presented in Fig.1, comprises of namely thumb finger, index finger, middle finger, ring finger and little finger. The hand has a total of twenty-seven bones and over twenty joints and it involves the use of thirty three different muscles. Bones are highly accountable for rigidity within a segment of a hand, joints provide the convenient freedom of movement and muscles serve to transfer rigid segments on each other.

Fig. 1: Diagram of Hand and Wrist

Hand wounds can be grouped such as fractures and dislocations, infections, high pressure injuries, lacerations, broken hand and burns. The occurrence of hand injuries exhibits unexpected working results in the day-to-day activities of an individual because the hand region is a unique anatomic region, in line to be used in almost all the occupations or professions. Hence, even a small level of amputation may lead to a disability that will limit the individuals from performing basic activities such as pushing, pulling and/or grasping lighter and weightier objects perpetually. As there are so many amputees in the world, thus it is imperative to develop a prosthetic hand. A lot of robotic hands have been designed and developed by many organizations all over the world in modern years. The ubiquitous developments in science and engineering technologies have led to the development of prosthetic hand based on muscle operated sensors. Prosthetic devices have the tendency to restore some, if not all, mobility, and functionality to the individual wearer. Prosthetics are non-natural devices designed to replace a missing body part, for example a leg or a hand, which may be missing in a trauma, infectious disease, accident or due to birth defect. The working principle of prosthetics is based on EMG signals. EMG is abbreviated as Electro Myography. In simple, EMG signal is nothing but study of electrical signals in muscles. EMG signals are particularly utilized for biomedical or clinical applications. The nervous system in our human body controls the contraction and relaxation activities of the muscles. Hence this signal is a complex signal and is dependent on the anatomical and physiological properties of the muscle movements. The EMG signal gets corrupted with noise as it encounters with different tissues in the human body. Muscle tissue conducts minute electrical voltages analogous to the nerve cells. A typical EMG signal amplitude varies between (0-10) mV in the frequency range of (0.1 to 400) Hz.

Nevertheless, the increases in number of people suffering from hand amputation, very few works have been reported in the literature as follows: T. Lenzi*et al.* in his work studied the reaction of ten healthy subjects on an elbow powered exoskeleton. The experimental results reveal the system works under different dynamic conditions and at stable operation [1]. A. Pantelopoulos*et al.* systematically analyzed the current state of the art research and developments in wearable biosensor system implementations. It mainly focused on multiparameter sensing system design, vital sign measurements and its background awareness [2]. A wireless wearable device capable of measuring and handling EMG signals for real-time EMG-based hand gesture recognition is proposed in [3]. A SVM recognition algorithm was also proposed. R. Ahsan *et al.* deliberated the recent advances and developments on various procedures used for EMG signal classification which can be useful for future comparative studies [4]. S. Teng*et al.* presented the work related to the design of a configurable CMOS IC front-end for recording of wide-ranging range of biopotentials in 350nm CMOS technology. A prototype was fabricated and recording were carried out practically [5]. J. Cabibihan*et al.* discussed the step-by- step methodology for creating the precise shape and size of an amputated arm through three-dimensional printing and silicone casting. The designed prosthetic arm exhibited highly accurate results with respect to dice similarity coefficient, relative mean distance and percent error [6]. An affordable robotic controlled hand using arduino microcontroller is implemented in [7]. The designed 3D printed bionic arm exhibited accurate natural movements of both the arm and hand. The design and implementation of a cost-effective robot is presented in [8]. J.K. Paik *et al.* proposed the novel design of arm of a humanoid robot that precisely mimics the natural appearance and movement of human body with 8-DoF hand. It employs a novel algorithm to avoid obstacles and the agile hand is skilled to grasp various objects [9]. Y. Jiang *et al.* developed an accurate simplified electromyograph prosthetic hand, which includes a lightweight robotic hand with two motors and a 32-bit microprocessor [10]. The design of a cost effective surface electromyography sensor for myoelectric prosthesis is carried out in [11]. The sensor was tested in real time applications with respect to emphasis on response time, amplitude sensitivity and signals to noise ratio.

The bionic arm implementation is as shown below. Section- II gives details about the block diagram of bionic arm, details related to myoware sensor and 3-D printed hand palm section. Section – III shows the experimental set up and working results with photos. To sum up, Section-IV gives the conclusions of the proposed low-cost bionic arm.

II. HARDWARE DETAILS OF BIONIC ARM

The implementation of bionic arm is presented in Fig. 2. It consists of arduino board, myoware sensor, six servo motors and a 3-D printed arm. In this diagram, first gel is applied on the amputee hand and surface electrodes are fixed it to measure the activities of the muscles. The system consists of six servomotors i.e., five separate DC motors to control each finger and one separate servomotor for controlling the rotation of twist. EMG signals are read by a popular sensor called myoware muscle sensor.

A. *Myoware Sensor*

The myoware muscle sensor is utilized in this work to record the electrical activity produced by muscles in the arm. It operates at a voltage of (3-5.2) V and has inbuilt polarity protection [12]. The board includes an onboard potentiometer for automatic manual gain adjustment and also includes signal strength LEDs for ease of restoring. The waveforms associated with respect to myoware sensor are presented in Fig. 3. The layout of myoware sensor is shown in Fig.4.

B. *3D printed hand-palm section*

This is the important component of the entire work. Although there are many 3-D printed hand models freely available, nevertheless most of them look like robotic virtually and doesn't look like normal human hand. The movement of wrist will control the opening or closing action of the fingers. As the wrist bend the entire fingers close at the same time, forming fist. The 3-D printed hand-palm section is displayed in Fig. 5.

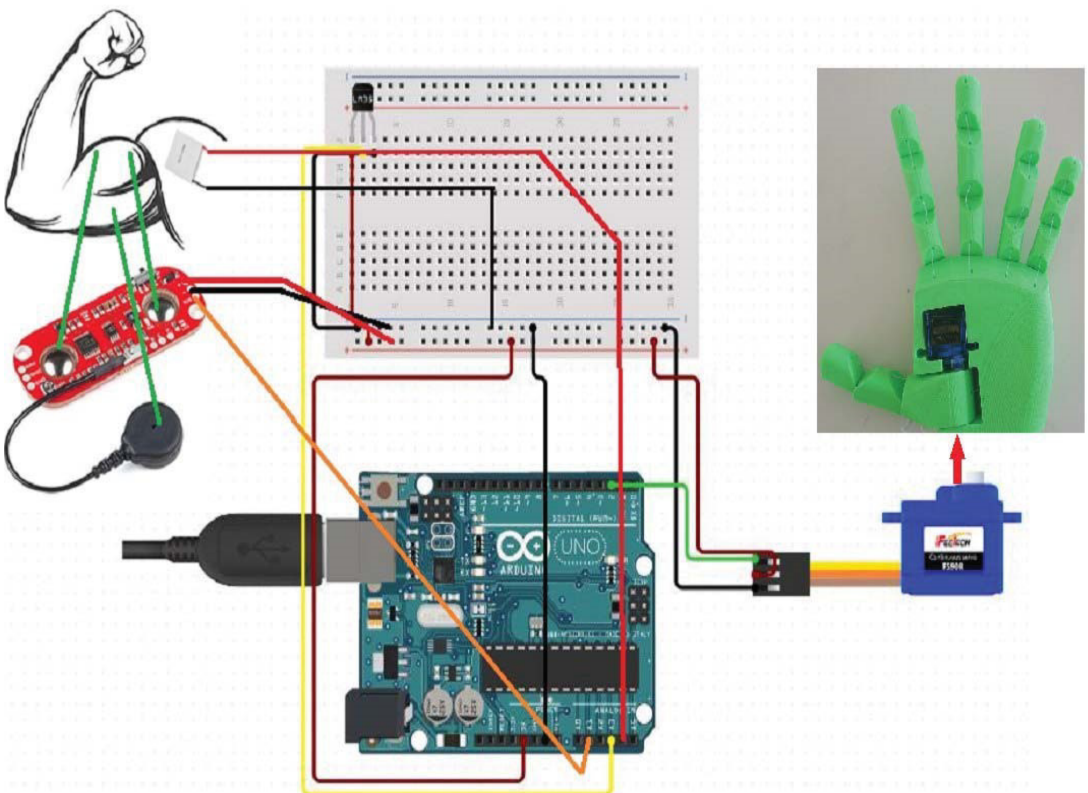


Fig. 2: Implementation of Bionic

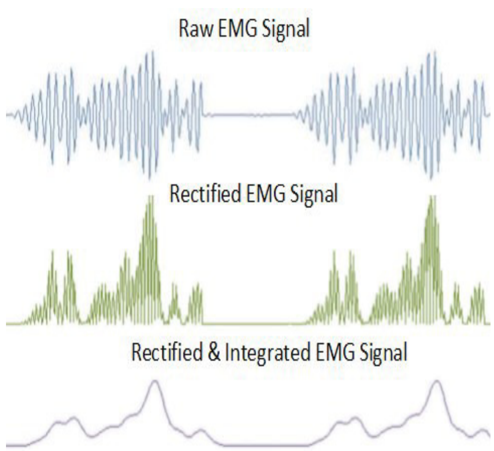


Fig. 3: Waveforms associated with myoware sensor

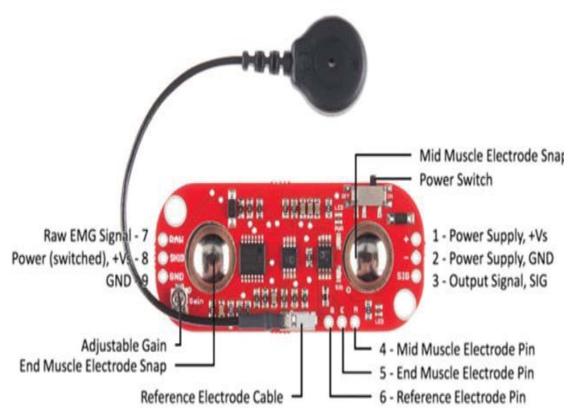
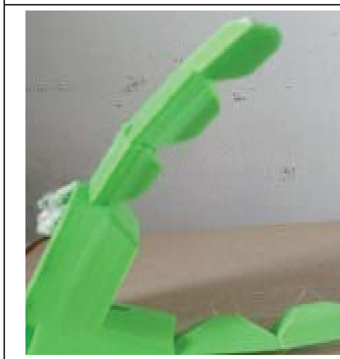


Fig. 4: Myoware sensor

When an individual i.e., person suffering from hand disability, lays the bionic arm on his hand and flexes muscles just below their elbow, the myoware sensors detect very small electric potentials. These EMG potentials are read by the arduino processor and based on the written code; corresponding bionic hand movement occurs. i.e., the processor makes a correct decision to control the finger or fingers of the bionic arm. The closing and opening movements of bionic arm are initiated by the same type of muscles in the arm. The arduino board has six analog input pins (A_0, A_1, A_2, A_3, A_4 and A_5) and fourteen digital pins that can be used either as input or output.

In general, a natural human hand can exhibit hundreds of various gestures. But the proposed bionic arm in this work is designed to perform limited gestures such as point, fist, rest, pinch, wrist flexion and rock. Table 1 presents the different gestures offered by the bionic arm.

Bionic arm gesture	**Description of the gesture**
	Point (All the four fingers are closed except index finger)
	Fist (All the five fingers closed)
	Rest (All the five fingers are open)
	Wrist Flexion (All the wrist movesupto 50 degree from the rest position)
	Rock (All the three fingers close except index and pink fingers)
	Pinch (All the three fingers close except the ring and pinky fingers)

Table

From the above gestures, it is clear that the fingers can move in different angles of rotation which is almost the same as the natural human hand movements. The approximate total cost of the proposed bionic arm is found to be Nine thousand four hundred rupees only. Fig. 6 and Fig.7 shows the ability of the bionic arm to grasp different objects:

Fig. 5: Gripping and lifting the bottle

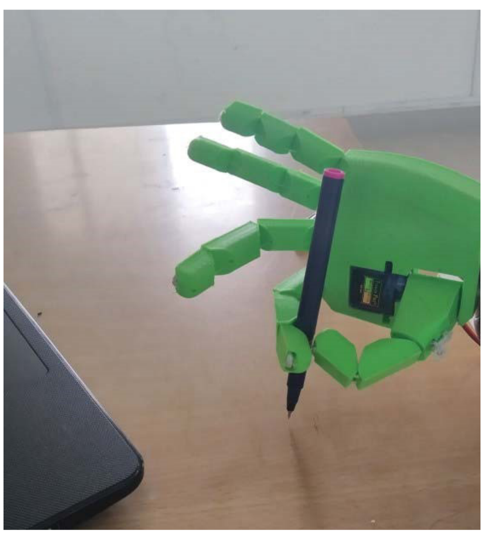


Fig. 6: Gripping and writing with pen

IV. CONCLUSION

The proposed work effectively presents the developed affordable bionic arm for grasping various objects and working in real-time activities for persons affected with disabilities. The main physical characteristics considered in this bionic arm implementation were light weight, lesser price, and natural control. The recent advancements in 3D printing technologies played a vital part in attaining the proposed objectives. The designed 3-D printed bionic arm consists of five fingers and is realized by six DC motors, one for each finger and the last one for wrist hand. All the motors were placed inside the palm. EMG signals from the muscles carry valuable data regarding the nerve system operation. These were detected using myoware sensor. Experimental results when tested on amputees demonstrate that it can grasp various objects effectively and can be fitted to young, aged people to elderly people. For continuation of the proposed work, the bionic arm should be modelled for kids' size and for lifting objects of heavier weight.

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