Design of an Exoskeleton for Hand Rehabilitation

Ankita L. Dharmik
Department of Electronics and Computer Science,
RTMNU Nagpur - 440033
India
ankitadharmik3@gmail.com

S. K. Atre
Department of Electronics and Computer Science,
RTMNU Nagpur - 440033
India
atreshivk@gmail.com

Satish J. Sharma
Department of Electronics and Computer Science,
RTMNU Nagpur - 440033
India
sharmasat@gmail.com

***Abstract*- An Exoskeleton is a device used to assist a person with disabilities to perform routine tasks in daily life. In the present work, an exoskeleton is designed in the laboratory using an in-house facility of 3D printing for a prosthetic hand that helps an amputee with hand loss and a person having a disability in moving palm and fingers. In the designed prototype, an EMG muscle sensor is used to acquire the signals from the muscles of the hand and convert them into voltages. These low-level voltages are then fed to a signal conditioning circuit and subsequently to the microcontroller. The microcontroller is programmed in such a way that servo motors rotate according to the voltages received from these sensors. In this way, movements of the fingers are directed by servo motors which rotate according to muscle activities, thereby enabling a person to perform routine tasks very effectively.**

Keywords: Exoskeleton, Prosthetics, EMG, Servomotors

I. INTRODUCTION

An exoskeleton has the potential to provide effective support to individuals to overcome their disabilities in lifting or grasping. These can be resolved by providing rehabilitation using an exoskeleton. The development of an exoskeleton requires hardware design for the affected organ and software-based control algorithms to ensure desirable coupled system performance[1]. Y. Shen, et al. have predicted that within a few years, hand exoskeleton systems will begin to appear for assisting paralyzed individuals and augmenting performance while wearing a space suit. Later, applications extended to rehabilitation, which requires a better human in the loop [2,3]. F. Birous, et al [4] have presented a multitude of approaches to solving the problems of transmitting motion from the actuator to the fingers of the patient[5]. Yahay Zweiri, et al. presented a design model of a powered elbow exoskeleton that assisted the elbow joint movement for weak or disabled people by controlling the assistive torque, whose direction was determined through EMG signals from the biceps and triceps [6,7].

EMG is a biological signal generated by muscle activity and is required for the functioning of the prosthesis. It is produced by the depolarization and repolarization of the muscle fibers. Exoskeleton devices are developed with great interest to assist human motion and most of them are focused on rehabilitation procedures. Exoskeleton development can be focused on solving the challenges of our main applications which are rehabilitation, exercising, motion, assistance, and extension of human capabilities[8].

In the present work, a microcontroller-based exoskeleton for the hand has been designed using EMG sensors and servo motors. The movement of the prosthetic hand is according to the rotation of servo motors, thereby imitating a real hand.

II.METHODS

A. SYSTEM DESCRIPTION

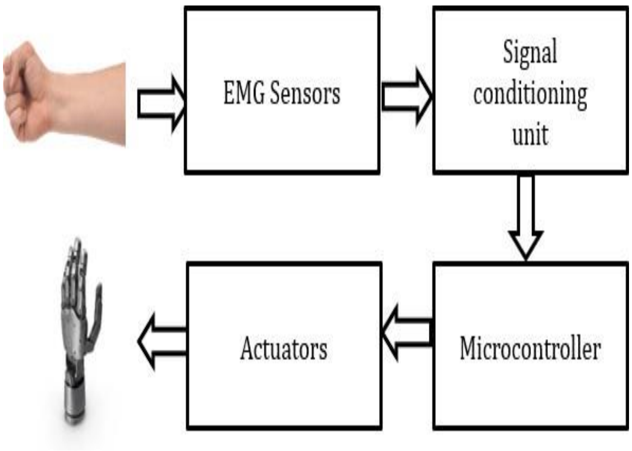


Fig.1: Block Diagram of the Exoskeleton System

Figure 1 shows the block diagram of the Exoskeleton system developed in the laboratory. It consists of an EMG sensor, signal conditioning unit, microcontroller, and servo motors as actuators. EMG sensors (electrodes) are attached to the arm at specific positions to generate a low-level signal corresponding to muscle movements. Measuring an electrical potential generated due to muscle activities is referred to as electromyography (EMG) and this technique has been widely used in medical research for the diagnosis of neuromuscular disorders. However, due to the availability of microcontrollers having special and powerful features, the application of EMG sensors and circuits can be utilized for the rehabilitation of an organ [9] [10]. After determining the specific group of muscles such as the bicep, forearm, or calf, the position of placement of these electrodes is decided. The skin should be cleaned thoroughly before attaching the electrodes. Proper positioning of these electrodes on the arm is very important and critical in case a person is performing a very intricate task. In the present work, one electrode is placed in the middle of the muscle, the second electrode is placed at one end of the muscle and the third electrode is placed on a bony or non-muscular part of the body near the targeted muscle.

Signals generated by EMG electrodes are of a very low level and buried in the noise and require proper signal conditioning. A preamplifier and filter circuit (module V3.0) is used for this purpose. Thus, the signal becomes suitable to be applied to the microcontroller [11]. Arduino board is used in designing the present system. It has an Atmega328 microcontroller with an inbuilt 8-channel, 10-bit ADC. The output of the signal conditioning unit is fed to the ADC and utilized to actuate the servo motors.

Servo motors are tiny and lightweight with high output power and can rotate approximately180^{o} (90^{o} in each direction). The microcontroller is programmed to rotate these servo motors according to the signals generated due to muscle activities. Due to their small size, these motors are easily fitted in the present 3D-printed prosthetic arm [13].

The design of the prosthetic hand is carried out using the 3D printer. For printing the parts of the hand, the .stl file can be created using software like CAD, Thinker CAD, etc.

Fig.2: Experimental setup of Exoskeleton Prototype

B. SOFTWARE

Fig. 3 shows the flowchart for the designed software to control the activity using Arduino IDE. Microcontroller I/O pins are initialized for the EMG sensor module and servo motors. The data from the EMG sensor, read using ADC is utilized to generate the PWM signal which varies according to the muscle movements. The angle of rotation of servo motors varies by the PWM signal. Finally, the rotation of motors controls the movement of the designed exoskeleton.

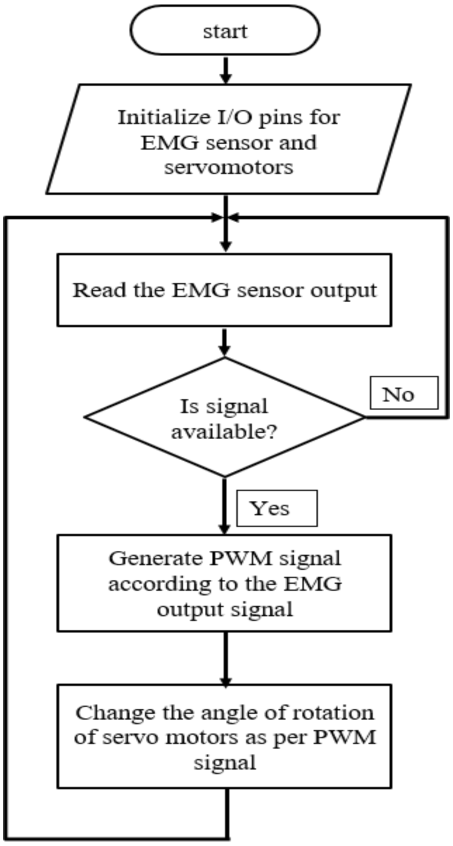


Fig.3: Flowchart of the Operation of the Exoskeleton

III. RESULTS

The servo motors rotate at respective angles according to the signals generated from muscles. Fig. 4 shows the muscle activity graph generated according to muscle movements.

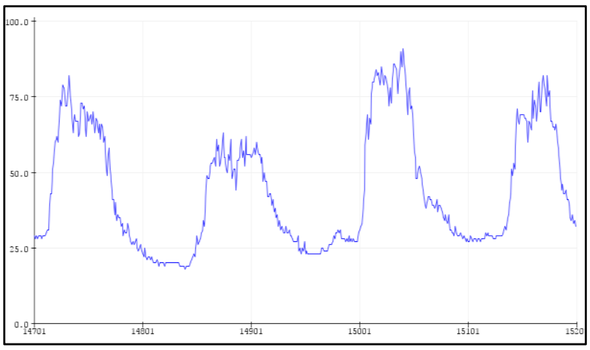
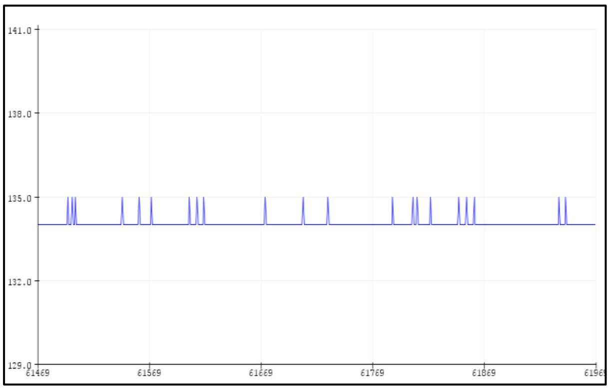


Fig.4: Waveform showing the combined result of Various muscles movements

(a)

(b)



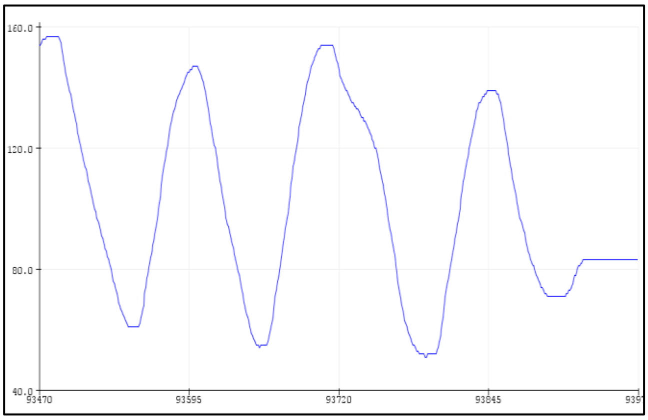
(c)

Fig.5: Screen-shot of the Result when the hand is open

Fig. 5 shows the screenshot of the hand when it is open. The muscles are relaxed as there is no contraction of these muscles in this position as shown in Fig. 5(a). As a result, the fingers of the prosthetic hand are also in a relaxed condition as seen in Fig. 5(b). Fig.5(c) shows the graph of the electrical activity corresponding to the position of the hand.

(a)

(b)



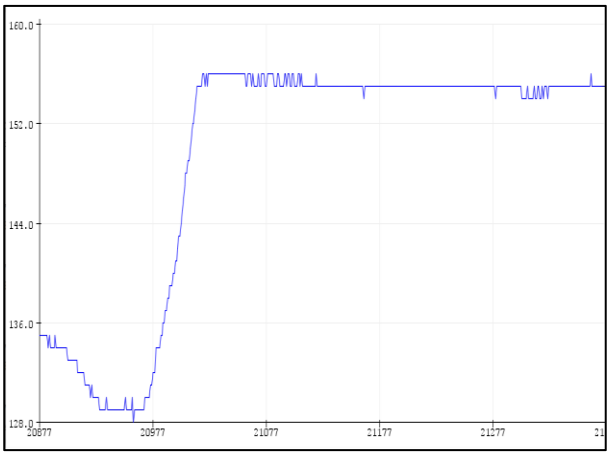
(c)

Fig.6: Screen-shot of the Result when the hand is partially closed

Fig.6 (a) shows the screenshot of the hand when it is partially closed to hold any object. The muscles are contracted according to position. As result, the fingers of the prosthetic hand are also contracting in a similar condition Fig. 6(b). Fig. 6(c) shows the electrical activity corresponding to the position of the hand.

(a)

(b)



(c)

Fig.7: Screen-shot of the Result when the hand is closed

Fig. 7(a) shows the screenshot of the hand when it is closed or when the muscles are contracted. As a result, the fingers of the prosthetic hand are also in closed condition Fig. 7(b). Fig.7(c) shows the electrical activity corresponding to the position of the hand.

IV. CONCLUSION

The developed prototype in the laboratory is found to work effectively for normal functioning of the activities in the case of an exoskeleton for hand rehabilitation. The design of the present prototype can be extended for start-ups to take over for mass production.

REFERENCES

[1] Y. Kamikawa and T. Maeno, "Underactuated Five-finger Prosthetic Hand Inspired by Grasping Force Distribution of Humans", *Proc.2008IEEE/RS J. Int. Conf. Intl. Robots Syst.*, pp.717-722,2008.

[2] C. L. Taylor and R. J. Schwarz, "The Anatomy and Mechanics of the Human Hand", *Artif. Limbs Rev. Curr. Dev.*, vol. 2, no. 2, pp. 22-35, 1955.

[3] R. F. Weir, "Design of Artificial Arms and Hands for Prosthetic Applications" *Standard Handbook of Biomedical Engineering & Design*, New York: McGraw-Hill, pp. 32.1-32.61, 2003.

[4] Xiong Yang, Toshio Fukuda, Y. Shen, Haojian Lu, Haotian She, "State of the Art: Bipedal Robots for Lower Limb Rehabilitation", *Applied sciences .,* vol. 7, no. 11,2017.

[5] F. Birous , Radu Catalin Tarca, Simona Dzitac, Ioan Dzitac, "Preliminary Results in Testing of a Novel Asymmetric Underactuated Robotic Hand Exoskeleton for Motor Impairment Rehabilitation", *Symmetry,* vol. 12, 2020.

[6] Yahay Zweiri, Mohammad I. Awad, Irfan Hussain, shramana Ghosh, "A Double-Layered Elbow Exoskeleton Interface With 3-PRR Planar Parallel Mechanism for Axis Self-Alignment", *Mechanisms and Robotics,* vol. 13, pp. 1-35,2020.

[7] R. Colombo, F. Pisano, S. Micera, A. Mazzone,C. Delconte, M. C.Carrozza, "Robotic Techniques for Upper Limb Evaluation and Rehabilitation of Stroke Patients", *IEEE Trans. Neural Syst. Rehabil. Eng.*, vol. 13, no. 3, pp.311-324, Sep. 2005.

[8] S. Ueki, H. Kawasaki, S. Ito, Y. Nishimoto, M. Abe, T. Aoki, "Development of a Hand- assist Robot with Multi-degrees-of-freedom for Rehabilitation Therapy", *IEEE/ASME Trans. Mechatron.*, vol.17, no.1, pp.136-146, Feb.2012.

[9] H. C. Fischer, K. Stubblefield, T. Kline, X. Luo, R. V. Kenyon and D. G. Kamper, "Hand Rehabilitation Following Stroke: A Pilot Study of Assisted Finger Extension Training in a Virtual Environment", *Topics Stroke Rehabil.*, vol. 14, no. 1, pp.1-12, 2007.

[10] T. Worsnopp, M. Peshkin, J. Colgate and D. Kamper, "An Actuated Finger Exoskeleton for Hand Rehabilitation Following Stroke", *Proc.* IEEE10th Int. Conf. Rehabil. Robot., pp. 896- 901,2007.

[11] E. Cands, "An Introduction to Compressive Sampling", IEEE Signal Process. Mag.,vol.25, pp.21-30, Mar.2008.

[12] D. J. Atkins, D. C. J. Heard and W. H. Donovan, "Epidemiologic Overview of Individuals with Upper-limb Loss and their Reported Research Priorities", *J. Prosthet. Orthot.*, vol.8, no.1, pp. 85-92, 1996.

[13] W. Muellbacher, C. Richards, U. Ziemann, G.Wittenberg, D. Weltz, B . Boroojerdi , "Improving Hand Function in C hronic Stroke", *Archives Neurology*, vol. 59, no. 8, pp. 1278-1282,2002