International Journal of Engineering & Technology, 7 (2.8) (2018) 1-6

International Journal of Engineering & Technology

Website: www.sciencepubco.com/index.php/IJET

Research Paper

Design and simulation of bionic glove for rehabilitation of the paralytics

Aparna B [1], Anithakrithi B [1], Naveena P [1], Yaswanth Kumar M [1], Avinash M [1], S Sivanandam [2] *

[1] SRM University, Chennai
[2] Professor and Head, Department of ECE, Siddartha Institute of Science and Technology, Puttur, Andhra Pradesh, India
**Corresponding author E-mail: ssnandam@gmail.com*

Abstract

Repetitive therapy can improve dexterity and hand movement among the paralyzed and stroke affected patients. The assistance of simple robotic technology may enhance the recovery rate of such patients. The study aims at developing a low cost bionic glove rehabilitation device which aids in providing effective finger exercises for physiotherapy by the use of a potentiometer. The prototype is designed in the form of a wearable glove for easy use. It includes an ATMEGA-328 microcontroller that is programmed using Arduino software for controlling the device. The motion of the fingers during therapy is achieved using a metal gear servo motor while the linear potentiometer controls the angle. This device can be used in rehabilitation to provide repetitive therapy for fingers at home with limited supervision by the physiotherapist for the paralytics. The performance of the device is simulated and evaluated using the Proteus Intelligent Schematic Input System (ISIS) software. The results obtained from the simulation can be used to improve the features of the device for effective practical implementation.

Keywords: *Paralytics; Bionic Glove; Potentiometer; Wearable Glove and Arduino.*

1. Introduction

Paralysis is a neurological disorder that causes immobility of a specific part or the whole body. A paralyzed patient may not be able to perform his or her daily activities. Stroke and spinal cord injury may have similar effects on the body and would require effective treatment. In such cases, rehabilitation plays a vital role in the early recovery of the paralyzed and the stroke affected patients. Rehabilitation therapy is a process that aids paralyzed patients to regain sensory, physical and intellectual functions. The therapy includes exercises that improve the dexterity of the hand muscles to retrieve the functional abilities of the patient in case of paralysis, stroke, epilepsy and other ailments having similar effects on the muscles. According to the WHO 2017 fact sheet, approximately 50 million people worldwide have epilepsy and respond to treatment positively for approximately 70% of the time [1]. Thus, effective and dedicated therapy can help in improving the mobility of affected muscle groups.

According to the single-blind randomized controlled trial done by Masiero et al., 2007, patients who were given robotic therapy in addition to conventional therapy has proven to reduce motor impairments to a greater extent. Thus, simple and complex sensor based robotic technology can ease the rehabilitation therapy [2]. C.Rajasekar et al., 2015 have developed a wearable device with an embedded accelerometer sensor, flex sensor and a force sensitive resistor was developed to monitor the rehabilitation activity of the paralyzed patients. Several experimental conditions of the finger and wrist joint such as fist making exercise, water bottle take off, wrist flexion and extension were identified and thus the patterns for both normal and upper limb paralyzed subjects were investigated. Yet, the device does not have any therapeutic effect on the patient [3].

A wearable device developed by Xing K et al., 2008 is driven by a pneumatic muscle actuator (PMA) to provide assistive forces for release and grasping movement of the fingers. The device also includes a biofeedback system to integrate the input from the user. The restricting factor is such a design is that it does not apply for a wide range of patient hand sizes and is not durable [4]. A similar therapy device developed by He et al., 2005 is also pneumatic muscle driven and designed for upper extremity therapy, but the slow response time and lower precision decreases the efficiency of the device [5]. Syed et al., 2012 developed a robotic arm controller based on a micro controller and flex sensors attached to a glove used to perform pick and place operations [6]. An arduino based assistive device employing flex sensors was developed by Ambar et. al., 2011 for the monitoring of rehabilitation development . But, the flex sensor employed in the device has poor repeatability and durability [7]. The soft robotic glove designed by Polygerinos et al., 2015, for combined assistance with activities of daily living involves a complex design with reinforcing fibers which provide specific flexion trajectories [8]. The HEXOSYS rehabilitation device developed by Iqbal et al., involves a portable exoskeleton for rehabilitation, but the design is complicated and not cost effective [9].

Repetitive exercise has proven to improve muscular strength and movement coordination in patients with impairments. The ARM-in robot developed by Nef et al., 2005 primarily aims at rehabilitation of spinal cord injured and stroke affected patients. It is based on a wall mounted rehabilitation system and requires the patient to regularly visit the clinician [10]. According to the principles of stroke rehabilitation by Langhome et al., 2011, task-specific and context specific training should preferably be given in the patient's environment [11]. A major difficulty to overcome in providing repetitive therapy is that the patient is required to spend

Long hours at the clinic under the constant supervision of the physiotherapist.

This is very tiring to the patient throughout the procedure. These limitations are overcome by the proposed bionic glove as it is a therapeutic device which provides rehabilitation activity by assisting the movement of the paralyzed fingers of patients. The prototype uses a glove of size 9x10 inches, which can be replaced by other glove sizes for flexible use by varied patients. It uses a linear potentiometer that ensures a longer lifespan and durable performance. It facilitates physiotherapy in the home environment, as it is portable.

2. Materials and methodology

The block diagram of the proposed Bionic glove prototype consists of the potentiometer input unit, Arduino interfacing unit and the servo motor controlled glove as shown in Figure 1.

The power supply is given by a 9V battery to the Arduino UNO board. As per the robotic arm developed by Katal et al., 2013 a servo motor with a stall torque of 10kg/cm is employed to perform pick and place operations with precision [12]. The bionic glove employs a metal gear servo motor with a torque of 11kg/cm, operating on 4.8V to achieve better motion and flexibility. According to Krishna.R et al., 2012, the pick and place robot is operated using a servo motor with better accuracy in medical and industrial applications [13]. In our proposed design, the servo motor, potentiometer and the Arduino board is permanently fixed on a plastic plate which is attached to the wearable glove and can be placed on the forearm of the patient during therapy. The glove is made of a light weight synthetic material which is easy to wear and includes an adjustable velcro band. Nylon strings are used to pull the fingers of the glove upwards with the help of a servo motor. One end of the four nylon strings is sewn to the glove material and the other end is tied together with the rim of the servo motor. The rim diameter varies directly with the angle of finger motion implying that a higher angle movement requires a larger diameter.

Potentiometers also called variable resistors, are three terminal analog input devices. In this device, a 10K linear type potentiometer is used to control the input. The rotating contact of the potentiometer provides a variable resistance of 3KΩ to 9.5KΩ. The potentiometer has three basic connections: +Vcc, input signal, and ground. These pins are connected to the respective pins on the Arduino UNO board. The advantages of using the potentiometer as an input sensor are:

- Accuracy in achieving the required angle of finger movement.
- Easy adjustment of angle of the finger movement by the user based on their activity level.
- Longer lifetime of the sensor.

The Arduino UNO board is based on the microcontroller ATmega328 and is powered by the 9V battery. Due to the high torque of the servo motor, a single motor is sufficient to facilitate the movement of four fingers together excluding the thumb. It has a programmable range of rotation from 0 to 180 degrees. The servo motor is interfaced with the Arduino board through three connections: the power supply pin, signal pin which is connected to one of the PWM (Pulse Width Modulation) pins on the Arduino board and the ground pin. The potentiometer is connected to the analog input pin of the microcontroller and the servo motor is connected to the digital output pin of the microcontroller.

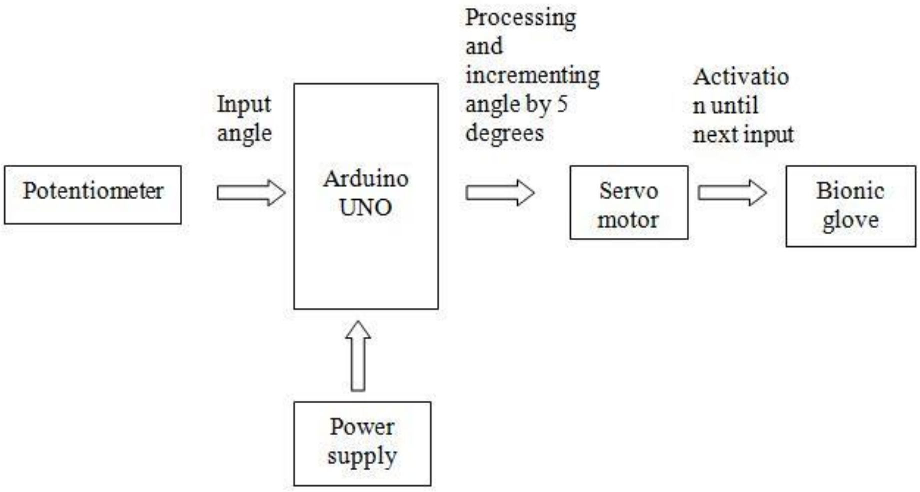

Fig. 1: Block Diagram of the Bionic Glove.

3. Device schematics

The Arduino board consists of an internal crystal oscillator with a 16MHz frequency for the internal clock timings. The Arduino can be interfaced with the computer for keeping track of the potentiometer value and the servo motor value from the serial monitor present in the Arduino software. The provision of a manual reset enables user specific programming of the Arduino board [14]. In this device, Arduino software version 1.8.1 is used to program the Arduino UNO board.

The schematic representation of the Bionic glove prototype is shown in Figure 2.

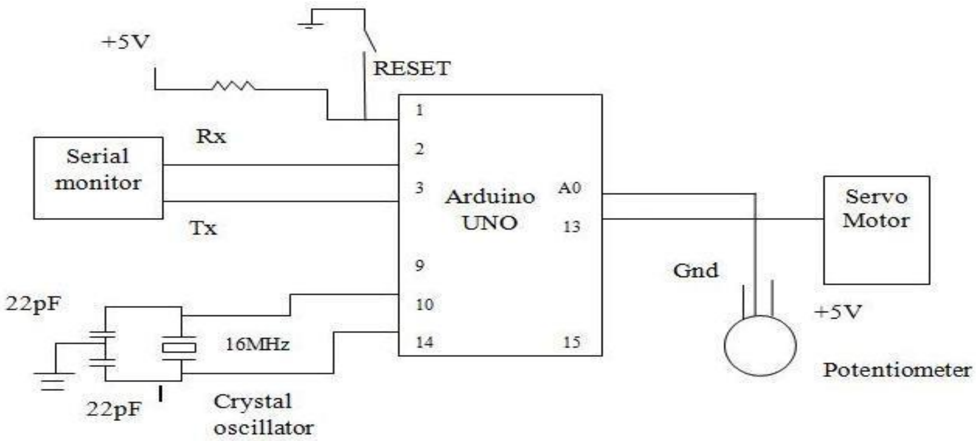

Fig. 2: Schematic Representation of Bionic Glove.

4. Working

The angle of movement of the servo motor depends on the input from the potentiometer. The Arduino board is pre-programmed in such a way that the angle of displacement of the servo motor is 5 degrees greater than the actual angle to be displaced. This feature is to encourage the patient's efforts in exercising the paralyzed fingers. The program also includes a repetitive training period at a fixed angle until a varied input is given to the potentiometer.
The potentiometer can be varied to get different degrees of rotation of the servo motor. The potentiometer is first kept at minimum. The degree of rotation of the servo motor varies linearly with the resistance change of the potentiometer. But the servo motor produces a displacement of 5 degrees instead of the base value of 0 degree due to the increment programmed in the Arduino board. The potentiometer is then varied gradually towards the maximum depending upon the requirement of the patient. As the potentiometer value is increased the degree of rotation of the servo motor also increases. When the potentiometer value is at the maximum, the servo motor rotates 180 degrees thus pulling the fingers of the glove upwards. The servo motor rotates 5 times for each potentiometer value thus enabling therapy for the patient.
After each cycle of 5 rotations the servo motor is programmed to pause for a short period of time for a respite of the patient. Then the servo motor continues to rotate for another cycle according to the newly set potentiometer value by the patient. The Bionic glove prototype can be switched on and off by disconnecting the battery from the device. Thus the degree of movement of the fingers and the duration of the therapy is decided by the physiotherapist based on the ability of the patient. The experimental setup is shown in Figure 3.

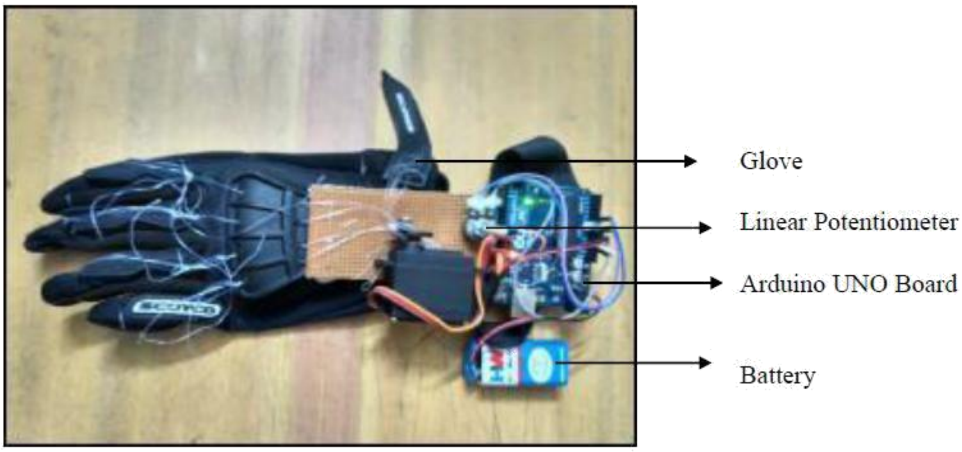

Fig. 3: Experimental Setup.

5. Results

The bionic glove prototype is simulated using the Proteus ISIS Professional software to test the performance of the bionic glove. The virtual components of the device are connected according to the circuit diagram in the simulation window. The simulated circuit is given in the Figure 4.
The virtual Arduino UNO board is used to process the analog signals from the 10k linear potentiometer to run the servo motor. A virtual terminal is used to view data at the output of the serial port of the Arduino. It is connected to the RxD, TxD pins of the arduino. A virtual oscilloscope is connected to the PWM pin of the servo motor to visualize the servo motor output. The program for the virtual arduino board is uploaded in the .hex format and run in the simulation window. The virtual terminal is used to view the initial and incremented potentiometer values along with the servo motor values.
The servo motor's angle of rotation ranges from 0 to 180 degrees. Thus, the resistance values of the 10k linear potentiometer are also mapped to the range of 0 to 180 units for easier assessment of the performance characteristics. The corresponding values of the potentiometer and servo motor are viewed in the virtual terminal as shown in Figure 5.

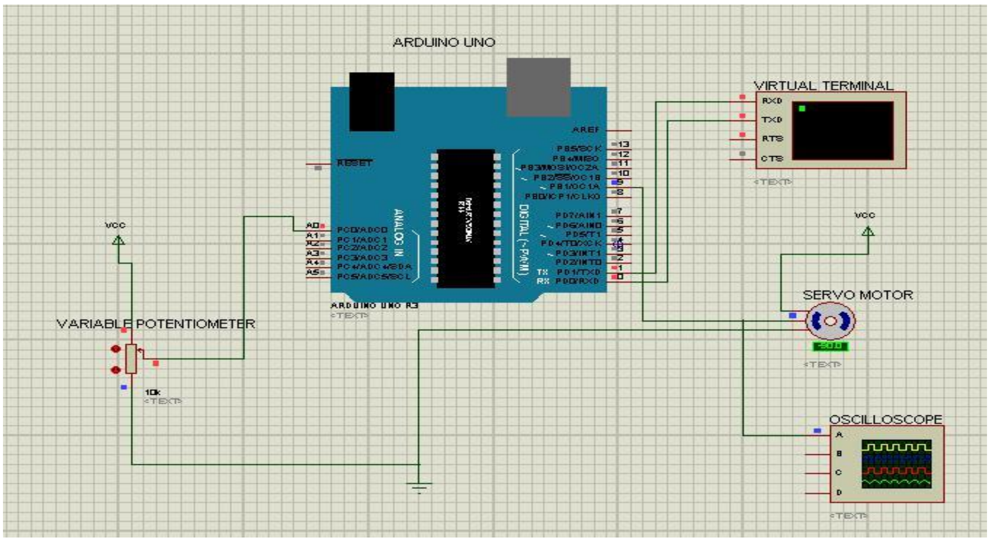

Fig. 4: Simulated Bionic Glove.

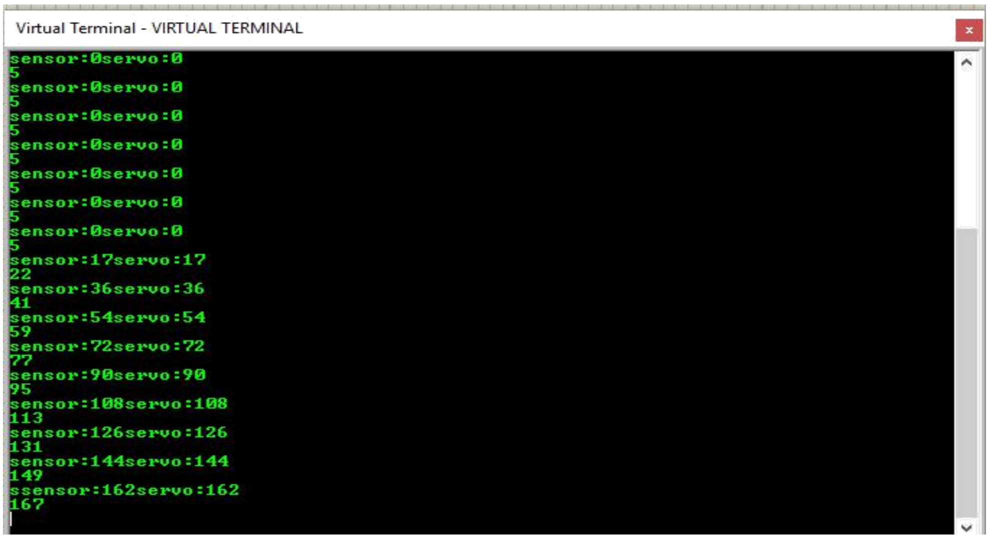

Fig. 5: Virtual Terminal.

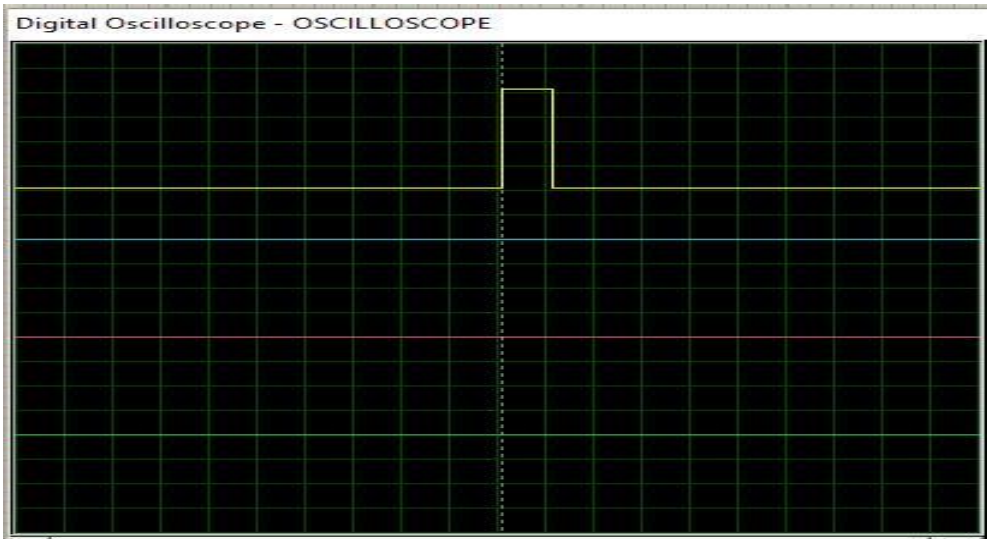

Fig. 6: Pulse Signal with Minimum Potentiometer Value.

The output of the servo motor is given as a pulse signal with varying time period that is viewed in the virtual oscilloscope. The resulting pulse with minimum potentiometer value is shown in Figure 6.

Similarly, the output pulse when the potentiometer value is set to maximum is shown in Figure 7.

The time period and amplitude of the pulse signal are recorded for a set of random potentiometer input values. The simulated values are given in Table 1.

From table 1 it is seen that the potentiometer value and the servo value are equal which emphasizes the accuracy of the bionic glove. The plot of the pulse width with respect to the potentiometer value is a linear curve as shown in Figure8.

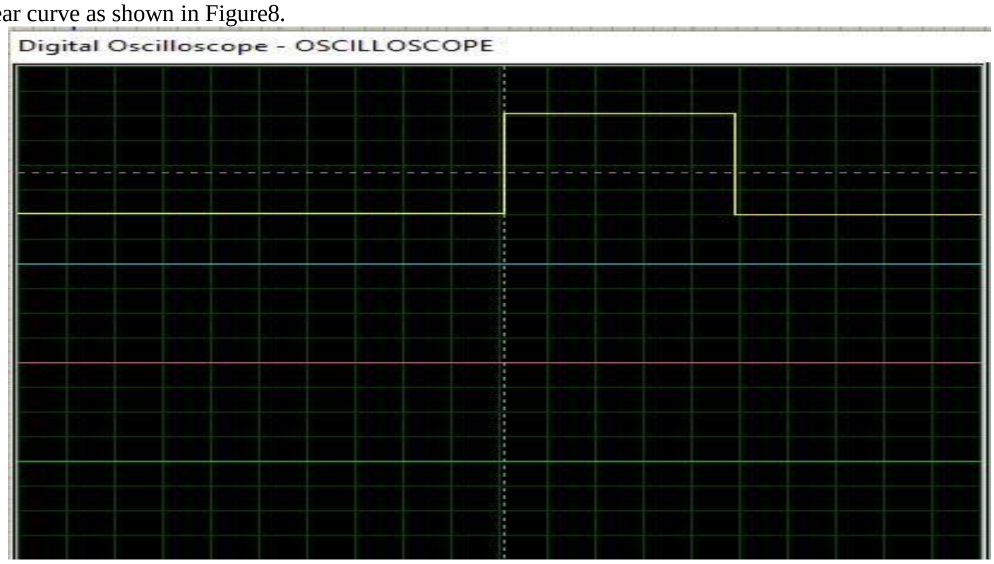

Fig. 7: Pulse Signal with Maximum Potentiometer Value.

Table 1: Observations from the Simulated Study

Sensor (potentiometer) value	Servo value	Servo value+5	Amplitude (V)	Time period (ms)
0	0	5	2	0.5
17	17	22	2	0.75
36	36	41	2	0.9
54	54	59	2	1.05
72	72	77	2	1.25
90	90	95	2	1.5
108	108	113	2	1.6
126	126	131	2	1.8
144	144	149	2	2.05
162	162	167	2	2.25
180	180	180	2	2.5

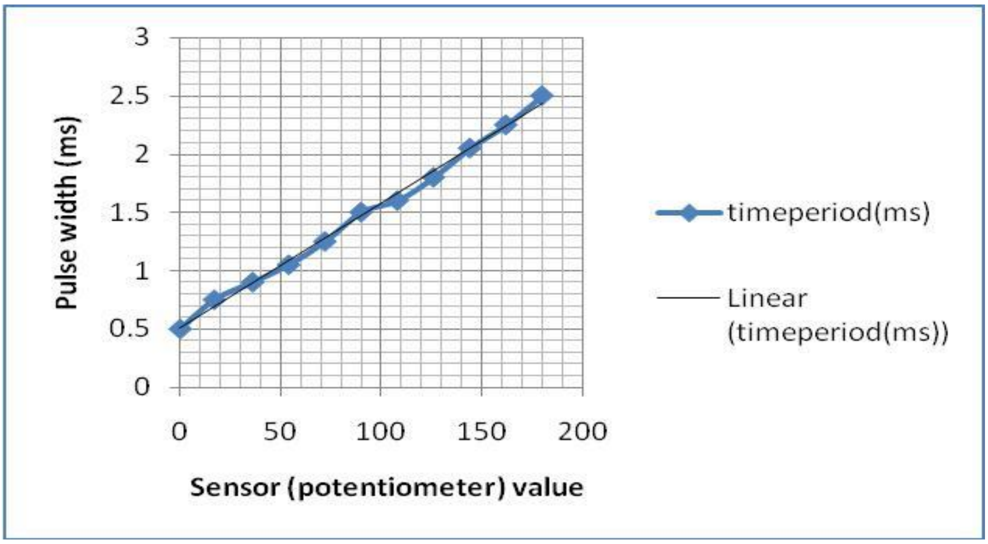

Fig. 8: Plot of Pulse Width versus Potentiometer Value.

The graph depicts a steady increase in the width of the pulse signal as the input potentiometer value increases and thus verifies the linearity of the bionic glove. Also, the simulated results exhibit excellent reproducibility which implies that the bionic glove is efficient for repeated use. On the basis of the results this prototype may be modified for clinical use. The modified device, if used on a paralytic patient with upper limb immobility, may produce better results by helping in early recovery of the patient and enabling them to do everyday activities. This device may help in the relaxation of the stiff muscles and enhancement of blood perfusion in the paralyzed region.

6. Limitations and future work

From the simulation, it has been concluded that the Bionic glove prototype requires a few modifications for improved performance. The patient's voluntary effort to move their fingers is not encouraged by this prototype. A feedback system to detect the user input can be added for more convenient use. Future work includes an open type glove for easier use by the patient. An automated angle control and a display system showing the angle of movement can be augmented with the Bionic glove for better user interface.

7. Conclusion

A prototype of the Bionic glove for rehabilitation of the paralytics was developed and simulated. The use of potentiometer ensures a greater lifetime of the device and accurate motor movements. The developed prototype is light weight, low cost and compact for portability. The patient can undergo therapy at required angles of finger movement by simply tuning the potentiometer value. Thus, the device is useful for short term rehabilitation therapy applications.

References

[1] www.who.int/mediacentre/factsheets/fs999/en/; accessed on 02.04.2017.

[2] Masiero, S., Celia, A., Rosati, G. and Armani, M., 2007. Robotic-assisted rehabilitation of the upper limb after acute stroke. Archives of physical medicine and rehabilitation, 88(2), pp.142-149. https://doi.org/10.1016/j.apmr.2006.10.032.

[3] C. Rajasekar, A. Vanitha, J. Jaisha. 2015. A Wearable Rehabilitation Activity Monitoring Device for Paralyzed Patients Finger. International Journal of Innovations in Engineering and Technology. 6: 213-222.

[4] Xing K, Xu Q, He J, Wang Y, Liu Z, Huang X. 2008. A Wearable Device for Repetitive Hand Therapy. Proceedings of the 2nd IEEE/RAS-EMBS International Conference on Biomedical Robotics and Biomechatronics. 919-922.

[5] He, J., Koeneman, E. J., Schultz, R. S., Huang, H., Wanberg, J., Herring, D. E., ... & Koeneman, J. B. 2005. Design of a robotic upper extremity repetitive therapy device. In Rehabilitation Robotics, 2005. ICORR 2005. 9th International Conference on (pp. 95-98). IEEE.

[6] Syed, Abidhusain, Zamrrud Taj H. Agasbal, Thimmannagouday Melligeri, Bheemesh Gudur. 2012. Flex sensor based robotic arm controller using micro controller. Journal of Software Engineering and Applications. 5 (05): 364-366. https://doi.org/10.4236/jsea.2012.55042.

[7] Ambar, R., Ahmad, M.S., Ali, A.M. and Jamil, M.A., 2011. Arduino based arm rehabilitation assistive device. Journal of Engineering Technology, 7, pp.5-13.

[8] Polygerinos, P., Wang, Z., Galloway, K. C., Wood, R. J., & Walsh, C. J. 2015. Soft robotic glove for combined assistance and at-home rehabilitation. Robotics and Autonomous Systems, 73, 135-143. https://doi.org/10.1016/j.robot.2014.08.014.

[9] Iqbal, Jamshed, Nikos G. Tsagarakis, Angelo E. Fiorilla, and Darwin G. Caldwell. 2010. A portable rehabilitation device for the hand. Engineering in Medicine and Biology Society (EMBC), 2010 Annual International Conference of the IEEE. 3694-3697. https://doi.org/10.1109/IEMBS.2010.5627448.

[10] Nef, Tobias, and Robert Riener. 2005. ARMin-design of a novel arm rehabilitation robot. 9th International Conference on Rehabilitation Robotics. 57-60.

[11] Langhome, P., Bernhardt, J., & Kwakkel, G. 2011. Stroke rehabilitation. The Lancet, 377(9778), 1693-1702. https://doi.org/10.1016/S0140-6736(11)60325-5.

[12] Katal, G., Gupta, S., & Kakkar, S. 2013. Design And Operation Of Synchronized Robotic Arm. International Journal of Research in Engineering and Technology, eISSN, 2319-1163.

[13] Krishna, R., G. Sowmya Bala, S. Sastry ASC, B. Bhanu Prakash Sarma, and Gokul Sai Alla. 2012. Design and implementation of a robotic arm based on haptic technology. International Journal of Engineering Research and Application. 2(3): 3098-3103.

[14] Warren, J. D., Adams, J., & Molle, H. 2011. Arduino for robotics. In Arduino robotics (pp. 51-82). Apress. https://doi.org/10.1007/978-1-4302-3184-4_2.

[15] S. V. Manikanthan and D. Sugandhi " Interference Alignment Techniques For Mimo Multicell Based On Relay Interference Broadcast Channel " International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE) ISSN: 0976-1353 Volume- 7 ,Issue 1 –MARCH 2014.

[16] P Bala Gopal, K Hari Kishore, B. Praveen Kittu "An FPGA Implementation of On Chip UART Testing with BIST Techniques", International Journal of Applied Engineering Research, ISSN 0973-4562, Volume 10, Number 14 , pp. 34047-34051, August 2015.