Simple Robotic Hand in Motion Using Arduino Controlled Servos

Tran VanHuy[1], Dao Tuan Minh[2], Nguyen Phan Kien[3], Tran Anh Vu[4]

Hanoi University of Science and Technology, School Electronics and Telecommunications, 1 Dai Co Viet st, Hanoi, Vietnam

Abstract: ***In this paper, a prosthetic hand is designed using the solid work to simulate a hand model action. A glove with flex sensors attached is use to control the prosthetic hand. Each flex sensor will be used to control one servo motor. Signals from flex sensors are sent to the Arduino Uno kit to process and control servo motors. The fishing lines are attached to the fingers as tendons to help them move. An Arduino combined with servo SG90 to control the action of the prototype. In the future, it will be applied for remote control in bilateral teleoperation.***

Keywords: Robotic hand, control, servo motor

1. Introduction

There are so many patients who are disable in hand after going through accidents or sustained neurological damage. In the United States, approximately 500,000 people (171 per 100,000) experience a stroke each year [1]. This high stroke incidence, in combination with an aging population, which implies future increases in incidence, greatly strains national healthcare services and related costs [2]. In the majority of these cases, patients experience either partial or total absence of hand motion ability, and this loss of functionality can greatly restrict activities of daily living and considerably reduce quality of life. High intensity and task specific upper limb treatment consisting of active, highly repetitive movements is one of the most effective approaches to arm and hand function restoration [3-5]. Unfortunately, standard multidisciplinary stroke rehabilitation is labor intensive and requires one-to-one manual interactions with therapists. Treatment protocols entail daily therapy for several weeks, which makes the provision of highly intensive treatment for all patients difficult [6] Therefore, a mechanic is required to support this work automatically.

Many research groups have developed robotic devices for upper-limb rehabilitation [7-10] for training the proximal upper limb (shoulder and elbow), distal upper limb (forearm and wrist). Numerous robotic rehabilitation systems have been developed for the hand that consists of multi-degree-of-freedom exoskeletons [11-16]. These systems are typically expensive and are designed for in-clinic use as they are generally not portable.

An intelligent prosthetic hand is defined as a hand that mimics the natural movements of the human hand. In order to appropriately mimic the motion of the human hand, its natural motions must be studied carefully. For instance, the distal phalanx (fingertip) must rotate about its joint as the middle phalanx rotates. There are some papers also described the method to make it [17]. However, it is very difficult and unnatural to bend the finger at the proximal joint, while keeping the distal joint stiff. The motions of these two joints are linked and must move together. On the other hand, the knuckle joint is not linked to any other joints. The knuckle is able to move the entire finger with no motion in the proximal or distal joints. Moreover, it is difficult to make the suitable knuckle for our robot hand. Another method was shown [18]. Although it is an intelligent robot hand, it is very complex and requires excellent skills. Therefore, the purpose of this paper is to design a prosthetic hand with inexpensive materials that can be developed to an intelligent prosthetic hand,and can be easily used and controlled. And it will be applied for remote control in bilateral teleoperation.

The paper is organized as follow. Section 2 presents the background and methodology of designing a robotic hand. Section 3 shows the experiment results. Section 4 concludes the paper.

2. Methodology

2.1 Anatomy of hand

The anatomy of the hand is extremely complex, intricate, and fascinating, probably the most complex of all the joints in the body. Its structure is showed in the finger 1.

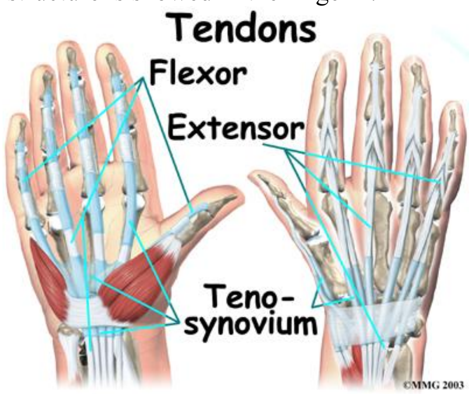

Figure 1: Anatomy of hand [19]

There are several important tendons that cross the wrist. Tendons connect muscles to bone. The tendons that cross the wrist begin as muscles that start in the forearm. Those that cross the palm side of the wrist are the flexor tendons. They curl the fingers and thumb, and they bend the wrist. The flexor tendons run beneath the transverse carpal ligament (mentioned earlier). This structure lies on the palm side of the wrist. This band of tissue keeps the flexor tendons from bowing outward when you curl your fingers, thumb, or wrist. The tendons that travel over the back of the wrist, the extensor tendons, run through a series of tunnels, called compartments. These compartments are lined with a slick substance called tenosynovium, which prevents friction as the extensor tendons glide inside their compartment.Its integrity is absolutely essential for our everyday functional living.

Our fingers are controlled by tendons attached to the muscles of the hand. Therefore, the paper introduces a simple way to make a prosthetic hand, that can be controlled by the human through the EEG or EMG signals; or the prosthetic hand can be used in dangerous environment where people can not reach.

2.2. Experimental design for robot hand

The prosthetic hand is designed by SolidWork software and is printed by 3D printer. The figure 2 shows the model of the prosthetic hand.

Figure 2: Model of the prosthetic hand

The Arduino Atmega8 is used as the controller. Arduino is a brand of open-source microcontrollers frequently used in at-home, do-it-yourself electronics projects. It can be programmed in a version of C, and the Arduino website contains software for programming the device. There are also a host of straightforward online tutorials that make it easy and quick to learn. A variety of electronic components can be connected via breadboard as inputs and outputs for the code, making Arduinos incredibly versatile. Arduino microcontrollers are intuitive, inexpensive, and readily available—three factors critical to accessible, easy-to-use prosthetics. The movement of robot fingers is controlled by Servo SG90. That is small and lightweight with high output power. Servo can rotate approximately 180 degrees (90 in each direction).

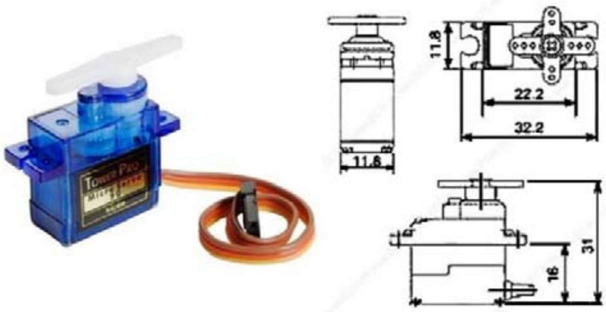

Figure 3: Servo SG90

That SG90 servo in Figure 3has specifications as table 1.

Table 1: Specifications of servo SG90

Weight	9 g
Dimension:	22.2 x 11.8 x 31 mm
Stall torque	1.8 kgf·cm
Operating speed	0.1 s/60 degree
Operating voltage	4.8 V (~5V)
Dead band width	10 µs
Temperature range	0 ºC – 55 ºC

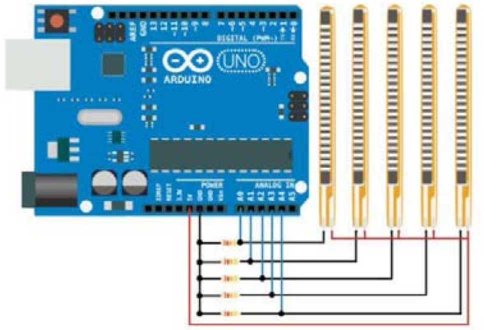

Figure 4: Model of the pros

The flex sensors are used to measure the bending of the fingers. When the sensor is flexed, the resistance across the sensor increases. The signals from the sensors are sent to Arduino to process and control the servo motor as showed in finger 4, that control the prosthetic hand. The flex sensor (R1) is connected in series with the resistor R2 (22k Ohm) as showed in figure 5, the output voltage on R2 will be:

$$V_{out} = V_{in} \frac{R_2}{R_1 + R_2}$$

In which V_{in} = 5V.

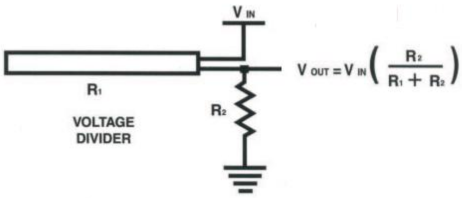

Figure 5: Connect the flex sensor

Table 2: The resistances of sensors when changing position from relax to hold tight

	Relax			Hold tight
Index finger	28k	35,76k	49k	58k
Middle finger	28k	30,88k	40k	53k
Ring finger	26k	28k	32k	42k
Baby finger	27k	30k	34k	42k

On the prosthetic hand, there are some tendon guide eyelets. For these, the fishing linesare put across the eyelets to help the prosthetic fingers move.Figure 6 shows five servos connected with fishing lines are used, one for each finger.

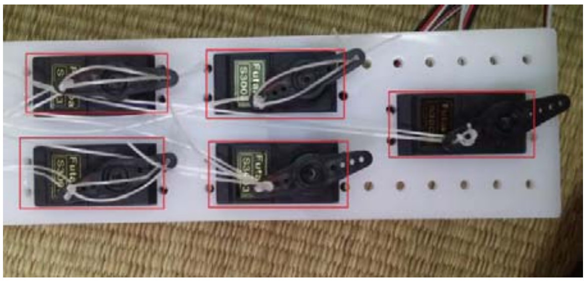

Figure 6: Fishing lines connected with motors

After attaching the ―tendon string” to the finger and threading it through all the narrow holes, the ‗opening‘ and ‗closing‘ finger positions are marked. The distance the string travelled can be measured, and therefore how far the servo needed to travel to open and close each finger. This measurement would be used to find the servo travel angle in the code for each finger. An Arduino Atmega8 is used to control the servo motor to control the movement of fingers.

Five servos are controlled by digital pins of Arduino:

```
myservo1.attach(9);
myservo2.attach(10);
myservo3.attach(11);
myservo4.attach(12);
myservo5.attach(13);
```

The void loop contains the variable pos (position). It is this one variable that is used to assess the condition to stay in or exit the loop, as well as incrementing/decrementing the counter. More importantly, this variable represents the servo position value for the myservo1.write(n) statement, where n is replaced with pos. As the loop runs, the pos value (which begin at 0) is incremented, and thus the position of the servo is changed one degree at a time by using the myservo1.write(pos) statement. The servo rotation is based on the code by using the time delay function delay() after each individual or group of write() position movements.

```
for(pos1 = 0; pos1 < 220; pos1 += 1)
  {
myservo1.write(pos1);  // Finger1(pinky)
delay(5);
  }
```

3. Experiment Results

The flex sensors 2.2” in length are attached to the glove as showed in figure 7 to identify the positions of fingers.

Figure 7: The controlling grove

The flexion and extension of each finger on prosthetic hand can be controlled by coding in Arduino through the fishing lines. Finger 8 shows the complete prosthetic system. The movement of fingers is likely the real one.

Figure 8: The complete prosthetic hand model and controlling grove

4. Conclusion

This paper presents a design of the prosthetic hand and glove for controlling the prosthetic hand. The servos, controlled by an Arduino, are used to control the movement of the finger through the cord. The finger can be moved likely the real finger. In the future, the feedback part would beimproved to realize the prosthetic hand.

References

[1] Ingall T, ―Stroke--incidence, mortality, morbidity and risk,” Journal of insurance medicine, 36(2),pp. 143-152, 2004.

[2] Prange GB, Jannink MJ, Groothuis-Oudshoorn CG, Hermens HJ, Ijzerman MJ, ―Systematic review of the effect of robot-aided therapy on recovery of the hemiparetic arm after stroke,” Journal of Rehabilitation Research & Development, 43 (2), pp. 171-184, 2006.

[3] Barreca S, Wolf SL, Fasoli S, Bohannon R, ―Treatment interventions for the paretic upper limb of stroke survivors: a critical review,”Neurorehabilitation and Neural Repair, 17(4); pp. 220-226, 2003.

[4] Feys HM, De Weerdt WJ, Selz BE, Cox Steck GA, Spichiger R, Vereeck CE, Putman KD, Van Hoydonck GA, ―Effect of a therapeutic intervention for the hemiplegic upper limb in the acute phase after stroke: a single-blind, randomized, controlled multicenter trial,” Stroke,29(4); pp. 785-792, 1998.

[5] Kwakkel G, Wagenaar RC, Twisk JW, Lankhorst GJ, Koetsier JC. ―Intensity of leg and arm training after primary middle-cerebral-artery stroke: a randomised trial,” Lancet, 354(9174), pp. 191-196, 1999.

[6] Krebs HI, Hogan N, Volpe BT, Aisen ML, Edelstein L, Diels C, ―Overview of clinical trials with MIT-

MANUS: a robot-aided neuro-rehabilitation facility," Technol Health Care, 7(6), pp. 419-23, 1999.

[7] Reinkensmeyer DJ, Kahn LE, Averbuch M, McKenna-Cole A, Schmit BD, Rymer WZ, ―Understanding and treating arm movement impairment after chronic brain injury: progress with the ARM guide," Journal of Rehabilitation Research & Development, 37(6), pp. 653-662, 2000.

[8] Burgar CG, Lum PS, Shor PC, Machiel Van der Loos HF,―Development of robots for rehabilitation therapy: the Palo Alto VA/Stanford experience,"Journal of Rehabilitation Research & Development, 37(6), pp. 663-73, 2000.

[9] Hesse S, Schulte-Tigges G, Konrad M, Bardeleben A, Werner C,―Robot-assisted arm trainer for the passive and active practice of bilateral forearm and wrist movements in hemiparetic subjects," Arch Phys Med Rehabil. 84(6), pp. 915-20, 2003.

[10] Susan C, Emma KS, ―Effect of robot-mediated therapy on upper extremity dysfunction post-stroke—a single case study," Physiotherapy, 91 (4), pp. 250–256, 2005.

[11] Panagiotis Polygerinos, Zheng Wang, Kevin C. Galloway, Robert J. Wood, Conor J. Walsh, ―Soft robotic glove for combined assistance and at-home rehabilitation," Robotics and Autonomous Systems, 73, pp. 135–143, 2015.

[12] Ueki S, Nishimoto Y, Abe M, Kawasaki H, Ito S, Ishigure Y, Mizumoto J, Ojika T,―Development of Virtual Reality Exercise of Hand Motion Assist Robot for Rehabilitation Therapy by Patient Self-Motion Control," in: 30th Annual International Conference of the IEEE Engineering in Medicine and Biology Society, 2008, EMBS 2008, 2008, pp. 4282–4285.

[13] N.G. Kutner, R. Zhang, A.J. Butler, S.L. Wolf, J.L. Alberts, ―Quality-of-life change associated with robotic-assisted therapy to improve hand motor function in patients with subacute stroke: a randomized clinical trial," Phys. Ther. 90, pp. 493–504, 2010.

[14] A. Polotto, F. Modulo, F. Flumian, Z.G. Xiao, P. Boscariol, C. Menon, ―Index finger rehabilitation/assistive device," in: 2012 4th IEEE RAS & EMBS International Conference on Biomedical Robotics and Biomechatronics, BioRob, pp. 1518–1523,2012.

[15] M. Takagi, K. Iwata, Y. Takahashi, S. Yamamoto, H. Koyama, T. Komeda, ―Development of a grip aid system using air cylinders," in: IEEE International Conference on Robotics and Automation, ICRA'09, pp. 2312-2317, 2009.

[16] K. Tadano, M. Akai, K. Kadota, K. Kawashima, Development of grip amplified glove using bi-articular mechanism with pneumatic artificial rubber muscle, in: 2010 IEEE International Conference on Robotics and Automation, ICRA, pp. 2363–2368, 2010.

[17] Peter Ohlmus, ―This Wooden Hand Can Teach You: Servo Control, Mechatronics, and Arduino Programming", online available at: http://www.servomagazine.com/index.php/magazine/issue/2015/08, August 2015

[18] EricoGuizzo, ―Building a Super Robust Robot Hand", <http://spectrum.ieee.org/automaton/robotics/humanoids/dlr-super-robust-robot-hand >, 25 Jan 2011.

[19] http://eorthopod.com/wrist-anatomy/