

Robust Controller Electromyogram Prosthetic Hand with Artificial Neural Network Control and Position

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Abstract

In this study, we proposed and designed a new control method for an electromyographically (EMG) controlled prosthetic hand. The objective is to increase the control efficiency of the human-machine interface and afford greater control of the prosthetic hand. The process works as follows: EMG biomedical signals acquired from Myoware sensors positioned on the relevant muscles are sent to the robot that consist of hand, Arduino and MATLAB program, which computes and controls the hand position in free space along with hand grasping operations. The Myoware device acquires muscle signals and sends them to the Arduino. The Arduino analyzes the received signals, based on which it controls the motor movement. In this design, the muscle signals are read and saved in a MATLAB system file. After program processing on the industrial hand which is applied by MATLAB simulation, the corresponding movement is transferred to the hand, enabling movements, such as, hand opening and closing according to the signal stored in the MATLAB system. In this study, hand and fingerprints were designed using a three-dimensional printer by separate recording finger and thumb signals. The muscle signals were then analyzed in order to obtain peak signal points and convert them into data. These results indicate the effectiveness of the proposed method and demonstrate the superiority of the method for amputees because of the improved controllability and perceptibility afforded by the design.

Keywords: *Arduino controller., Electromyography, Hand robot, Prosthetic hand.*

Introduction

Nowadays, the development of science and technology has led to prosthetic devices with promising functional capabilities and esthetic appearance in research domain in favor of commercialization¹.

The design of prosthetic hand is multidisciplinary, compelling knowledge of physiology, anatomy, electrical and electronics, mechanical design, software, and so on, depending on the nature of control. Robotic prosthetic hands have attracted considerable attention in terms of their practical use by amputees. Artificial neural network is used to classify the signal features and subsequently recognize the performed movement². Along this research line, Sumit et al. conducted real-

time identification of active hand-movement EMG signals based on wrist-hand mobility for simultaneous control of prosthetic robotic hands³. In another system, a fully wireless, mobile platform used for acquisition and communication of sEMG signals is embedded in a mobile control system, and Ottobock 13E200 EMG electrodes are used to acquire the EMG signals. The electrodes are attached to the patient's remaining forearm stump. In addition, a laptop is used to provide the required computational power for the control of the prosthetic robotic hand⁴. In the light of reducing costs, some studies have utilized an open-source design for the implementation of affordable, modular, compliant, under-actuated prosthetic fingers that can aid amputees who suffer from partial amputations (e.g., amputations of one or several fingers of the human hand, with the exception of the thumb) to regain lost dexterity⁵. In general, the control design of a robotic arm employs fuzzy algorithms to interpret EMG signals from the flexor carpi radialis, extensor carpi radialis, and biceps brachii

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muscles. In one type of control approach, the control and acquisition system consists of a microprocessor, analog filtering, digital filtering and frequency analysis, and a fuzzy control system, and electromyographic grasp recognition together with an 8-bit microcontroller is used to control a veneered robotic hand to emulate six grasp types that are used for over 70 % of daily activities^{6,7}. A new configuration of sEMG electrodes has been reported to reduce interference resulting from electrode shift depending on muscles movement⁸. The authors suggested that optimizing electrode configuration can improve the EMG pattern discrimination, wherein the proposed electrode configuration has a reference value.

Myoelectric prosthetic hands are primarily intended for adults but are also made by many companies for commercial purposes as prosthetic hand for children^{9,10}.

It is also noteworthy that almost all robotic hands designed in university research projects consist of numerous actuators and sensors, which makes them unsuitable for manufacturing along with being too expensive for the typical user. In general, the medical industry can greatly benefit from providing low-cost portable systems that allow visualization of patient data easily and remotely while also providing quick access to accurate data in real time, thereby enhancing the efficiency of doctors and specialists along with providing the patient with greater ability and care.

Today, robotics considered as one of the best technologies that deal with design, working and applications of robots, computer systems their control and information processing. These technologies help physiotherapists and robotics engineers to model and design robotic hands. We aim something more than material and physical. As a result, we want to create opportunities for people with no hands and ability to last their daily lives.

Aim and Objectives

In this study, hand and finger prints were designed using a three-dimensional printer by separate recording finger and thumb signals. The muscle signals were then analyzed in order to obtain peak signal points and convert them into data. These data are classified according to muscular positions and used for hand control

Materials and Method

Mechanical Hand Design

The prototype hand used in the study was a 3D printed version of the Flexy Hand¹¹. Therefore, the corresponding STL file was exported into the Makerbot platform and directly printed without any scaling or modification. Along with the separate parts of the hand, the printing of the entire hand took about 11 hours to be completed. The completed hand was strung with a fishing line and a stretched disposable pipette. The disposable pipette was used to clear any excess material from the 3D printing that would hinder the fishing line's path through the interior of the hand and fingers, and to aid in threading the line through the palm of the hand. Each finger was strung with about two feet of fishing line to ensure that there would be sufficient material to reach down the length of the arm and attach to the servos.

Motor Control

A servo motor with three wires, power wire, ground wire, and pulse-width modulation (PWM) wire, was used to drive the hand. The PWM wire was connected to one of the six PWM ports of an Arduino UNO board. The power and ground wires of each servo were connected to the horizontal positive and negative rows on the breadboard that was connected to a 6-V battery pack. The battery pack housed four 1.5-V D-size batteries. The PC module was plugged into the USB cable.

Hand Control

In this section, we used an Arduino UNO unit in this study to analyze the EMG signals acquired from the muscles. The signal is handled by the motor, and the UNO board is also used to send PWM information to the motor for hand control. By Using Myo arm band to provide the signal for MATLAB for recording it and simulating the signal after passing from equalization then the command which has been created by MATLAB will be pass to the microcontroller which has the all control to the hand by using servos.

Another benefit of having a simulation of the hand model is that it allows representing the results as functions of parameters (such as, the weight or type of material) to work on further improvements. Lastly, the grasp quality and optimization of the finger positions for different grasps are other crucial aspects that can be tested with a good model. The Simulink program is designed for multidomain simulation and model-based design. As mentioned previously, Simulink has the ability to simulate and generate automatic code, and allows conducting various tests along with verification

of the embedded systems. Further, Simulink enables users to incorporate their MATLAB algorithms into models and export the simulation results to MATLAB for additional analysis.. The Simulink program consists of the following commands: constant, Slider Gain, (Sum, Add, Subtract, and Sum of Elements), Sine Wave, and Arduino IO servo Write. The constant is used for generating a real or complex constant value. The Slider Gain is used for varying the scalar gain during the simulation by using the slider; this block has one input and one output. The sine wave is used for generating a sinusoidal waveform, thus indicating that the output of this block is sinusoidal. The sine wave and Slider Gain signals are directed to the mixer, whose output is the summation of the sine wave and Slider Gain signals. The output of the mixer forms the input of the servo Write.

EMG Signals

In this study, we used an EMG shield to obtain the signals from the arm muscles, and because the signals were not very clear, we used another high-sensitivity device to obtain clear signals.

$$y = \frac{1}{N} \sum_{i=1}^N |Xi| \dots\dots\dots(1)$$

Where N is the length of the signal and X_k represents the EMG signal in a segment. A simple way to measure the level of muscle activity is absolute value and this feature is common for use in myoelectric control. This feature is used for all classification in this project.

Root mean square:

$$y = \frac{1}{N} \sqrt{\sum_{i=1}^N X^2} \dots\dots\dots(2)$$

Slope sign change:

$$\dots\dots(3)$$

Waveform length:

$$y = \sum_{i=1}^{N-1} (|Xi+1 - Xi|) \dots\dots\dots(4)$$

Zero crossings:

$$y = \sum_{i_1}^{N-1} f(X) \dots\dots\dots(5)$$

Willson Amplitude:

$$y = \sum_{i_1}^{N-1} f(|Xi+1 - Xi|) \dots\dots\dots(6)$$

Variance:

$$y = \sum_{i_1}^{N-1} f(|Xi+1 - Xi|)$$

$$(7) \quad y = \frac{1}{N-1} \sum_{i=1}^N (X^2) \dots\dots\dots$$

Cost Analysis

Table 1 lists the cost breakdown of the entire system, including the price of 3D printing. The prices of electronic components (resistors, capacitors, wires, solder), and mechanical component (screws, nuts, bolts, crimps, silicone) are not listed since they can be acquired easily from campus laboratories and machine shop. The cost of the project stayed well within the estimated limit. Compared to the existing advanced robotic hands that are available on the market, which cost around 90,000 \$, a 350 \$ robotic hand solution seems more viable to the general population of users.

Results and Discussion

In this section, we compared the performances of our device and other existing devices in the market. Here, we remark that while our hand design is based on the ideas underlying the normally manufactured industrial robotic hand, we have also added a servo motor and EMG-based grip control in order to improve the device performance as well as ensure weight reduction relative to the weights of previously manufactured hands. The full weight of our device is 500 g, and the cost is as low as \$250. These benefits are possible due to the use of EMG and grip control. The table 2 compares our device

with certain other devices in the market. Comparison parameters include type, weight, and grip pattern along with other key parameters. From the table, it is obvious that our device is more feasible for practical application than other existing devices. In terms of device weight, our hand lies in the weight range of the myoelectrically controlled powered hand prosthetic and the BeBionic (RSL Stepper), whose weights are considered suitable for prosthetic hands. Overall, our findings indicate the proposed robotic hand delivers a satisfactory performance, particularly in terms of improved controllability and perceptibility over other devices. An added benefit is the fact our device is less expensive than other devices.

Due to an experimental limitation and difficulties problems or complications with reliably dependably performing each every gesture, different users had the latency check was solely done on one user. Every gesture was performed five times from an amount of rest and control till the motion completion time may well be determined resolute whereas the myogram activity and sophistication labels tags were unendingly recorded. Table 3 shows the results of testing the hand on 7 persons who were missing an arm. The data set is for two movements; namely, the closing and opening of the

hand. Some of the results have different rates of errors due to errors beyond the control of the designed system. One of common reason are the differences in the human muscles. In general, with regard to the design of robotic prosthesis, the primary challenge involves developing a flexible experimental setup for closed loop control of a prosthetic device with integrated augmented reality that allows changing the extent and type of provided visual and vibrotactile feedback. Several studies have focused on the control approach as well. In one study, thirteen volunteers participated in the experiments by controlling the Ottobock Sensor Hand Speed prosthesis¹². The results indicated that the recorded vibrotactile patterns were able to replace visual feedback. In another study, in a multi-sensory, five-fingered Bio-Mechatronic hand with an sEMG interface, each finger was integrated with torque and position sensors that offered the hand more grasping patterns and complex control methods¹³. Arduino code could be uploaded to an online repository and made freely available for download. This code would incorporate controller programming, and a Graphical UI (GUI) that would enable the client to tune the control calculation to their inclination. The client would then have the option to purchase modest diversion gadgets, transfer the product themselves to the controller, and introduce the controller into the Talonhand themselves¹⁴.

Table 1. Cost breakdown of all the materials used in the 3D printed robotic hand

.Item	Part No.	Price \$	Quantity	Total \$
Printing	Vero Blue	0.10	450 g	45.00
Printing	PLA White	0.10	40 g	4.00
Microcontroller	Arduino UNO	24.00	1	24.00
Servo	HK1529	15.00	5	75.00
Sensors	Myo Armband	200	1	200
Cables	50lb Fishing line	1.00	1	1.00
Battery	1000 mAh 5Volts	1.00	1	1.00
			Total \$	350

Table 2 . Comparison of existing commercial myoelectric prosthetics and our design

Name	Type	Weight	Grip pattern	EMG triggers	Grip control	Cosmetic cover	Adaptive grip	Price
Current design	sEMG	500 g	1	1	EMG	Yes		250 USD
Myoelectrically controlled powered hand prosthetic	sEMG	500 g	1	1	EMG	Yes	NO	300 USD
BeBionic (RSL Steeper)	sEMG	550 g	14	1	Smart-phone app	Yes	Yes	25000-35000 USD
i-Limb (Touch Bionics)	sEMG	460 g	14	1	Smart-phone app	Yes	Yes	20000-100000 USD
Deka Arm (DEKA)	TRI	-	6	4	EMG	No	No	100000 USD
Michelangelo (Ottobock)	sEMG	420 g	6	1	Remote control	Yes	No	100000 USD

Table 3. Results of testing the hand on 7 persons

Motion Gesture	PT1	PT2	PT3	PT4	PT5	PT6	PT7	Average
Open	80/100	90/100	85/100	80/100	95/100	75/100	90/100	85/100
Close	83/100	85/100	91/100	80/100	90/100	70/10	85/100	83/100

PT: Patients

Conclusion

From the results of this study, it is concluded that a simple and cost-effective prosthetic hand can significantly contribute to the development of robotic prosthesis and the results indicate the effectiveness of the proposed method and demonstrate the superiority of the method for amputees because of the improved controllability and perceptibility afforded by the design.

Ethical Clearance: The Research Ethical Committee at scientific research by ethical approval of both environmental and health and higher education and scientific research ministries in Iraq

Conflict of Interest: The authors declare that they have no conflict of interest.

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