

Development of Myoelectric Prosthetic Hand based on Arduino IDE and Visual

by Rifky Ismail

Submission date: 15-Oct-2020 07:26PM (UTC+0700)

Submission ID: 1415944189

File name: 7._proceeding.pdf (474.45K)

Word count: 2943

Character count: 15752

Development of Myoelectric Prosthetic Hand based on Arduino IDE and Visual C# for Trans-radial Amputee in Indonesia

² Rifky Ismail
Department of Mechanical Engineering
Diponegoro University
Semarang, Indonesia
ismail.rifky@gmail.com

Guntur D. Wijaya
Department of Mechanical Engineering
Diponegoro University
Semarang, Indonesia
gunturwijaya@gmail.com

Mochammad Ariyanto
Department of Mechanical Engineering
Diponegoro University
Semarang Indonesia
ari_janto5@yahoo.co.id

Adi Suriyanto
Orthopaedic Department
RSAL dr. Ramelan
Surabaya, Indonesia
adisuriyanto@gmail.com

² Wahyu Caesarendra
Department of Mechanical Engineering
Diponegoro University
Semarang Indonesia
w.caesarendra@gmail.com

Abstract— This paper presents a preliminary study on design and development of prosthetic hand controlled by electromyography (EMG) sensor for patients who suffered from trans-radial amputee. The system is made up of an embedded Arduino microcontroller equipped with Visual C# programming as graphical user interface (GUI). The prototype of the prosthetic hand has five grip modes i.e. hand open and close, hook finger movement, peace finger movement, pointing finger movement, and active thumb. The mechanism of prosthetic hand is designed with selected mode grip pattern, where each motion is triggered from muscle contraction that is acquired using EMG sensors. In addition, the input of EMG signal can be monitored from the graphs in GUI based on Visual C# programming. Each finger in the prosthetic hand prototype is driven by a linear actuator. The objective of this study is to design and develop a prototype of myoelectric hand based on EMG sensor and create a prosthetic hand grip pattern mode program.

Keywords—electromyography, Arduino, prosthetic, graphical user interface

I. INTRODUCTION

Currently, the development of the technology is growing rapidly in almost all aspects such as health, education, defense, security etc. Myoelectric prosthetic hand or often we call bionic hand is one example of the latest technological developments in the field of health, especially in the biomedical field. This technology comes as the development of pre-existing technology, namely passive prosthetic hand technology or artificial hand that is used for hand amputation patients. User / wearer can drive the passive prosthetic hand by powering it using his/her body such as shoulder. Prosthetic hand is aimed to replace the lost of upper body parts due to amputation.

Amputation is a medical act of cutting either part or all parts of the body, which can include the fingers, hands, arms, legs etc. Amputation on the hands of a person's body greatly affect the productivity or capacity of the person in handling a job or doing activity of daily living (ADL). Deformity of the hands can be caused by amputation due to the work accident. Injury, deformity, or handicap can affect the hand function and quality of life of a person [1].

Prosthetic hand (artificial hand) becomes the main alternative for replacing the lost hand. Prosthetic hand can be divided in two types; body-powered and electrical motor powered prosthesis. Body-powered prosthetic hand is manually operated by utilizing the movement of certain body parts that are connected through cables or ropes. The movement of certain body part such as shoulder is able to drive the prosthetic hand. While electric motor powered prosthetic hand is operated by the electric motor utilizing electricity signal from the remaining human hand in order to drive the prosthetic hand.

In this research, the myoelectric prosthetic hand technology is developed with the purpose as an option given besides passive prosthetic hand. The fundamental difference between myoelectric prosthetic hand and passive prosthetic hand technology is the inclusion of a series of programs that allow myoelectric prosthetic hand technology to perform movements that cannot be performed by passive prosthetic hand technology. The myoelectric prosthetic hand technology that is developed in this research will use Arduino microcontroller and C# programming. To control the myoelectric prosthetic hand, electromyography (EMG) sensor is employed in this research. Arduino microcontroller is utilized as a main computation for reading the muscle contraction via the EMG sensor and controlling the motion of linear actuators. The linear actuators are connected to the fingers by using four-bar linkage mechanism.

II. MYOELECTRIC PROSTHETIC HAND DESIGN

Prosthetic hand is an artificial human hand made with the aim to replace the lost of human hands for people who have upper limb amputations. Prosthetic hand basically has two functions that are as cosmetic tool and functional tool. Prosthetic hand as a cosmetic tool has a form resembling the original hand, but cannot function as the original hand [2]. While the prosthetic hand as a functional tool has the ability to perform basic human hand movements such as cylindrical, lateral, palmar, hook, tip, and spherical [3]. Anthropomorphic prosthetic hand has a high degree of resemblance with human hands and capable of performing activities such as human hands.

In this study, the prosthetic hand movement system was developed in the Arduino IDE software environment and the prosthetic hand control algorithm embedded on the Arduino Nano V3.0. This embedded system is developed to drive the prosthetic hand with the input from surface electromyography (sEMG) sensor. The sensor reads the muscle contraction of the user/wearer. The linear actuator used in this research is a linear motor Firgelli PQ12-R that was imported from Canada. The joint connection from linear actuator to the fingers is utilized four-bar linkage mechanism. The proposed myoelectric hand has five degrees of freedom (DOF). The design of the four-bar linkage mechanism has more challenging than the tendon-spring mechanism. Our previous research utilized tendon-spring mechanism for connecting the actuators and the fingers in the hand. Based on the previous research [4-6], the tendon spring mechanism can provide linear relationship from the actuator input to finger joint angle.

The design concept of the prosthetic hand prototype developed in this study is as an alternative device that can be used as a substitute for the hands of patients who have been amputated. The purposes of the proposed myoelectric hand are as follows:

- Develop a prosthetic hand that can be used with amputation under below elbow (transradial amputation)
- Input from the prosthetic hand movement comes from EMG sensor.
- Can perform five different grip pattern modes such as open-close, hook, peace, indicate, and active thumb.
- The resulted prosthetic hand weighs no more than 1 kg.
- Portable and convenient to use.

Fig. 1 shows the proposed of myoelectric prosthetic hand based on 3D printing technology. In the finger design, DIP joint is fixed at 15° . Index, middle, ring, and little fingers utilize four-bar linkage mechanism. The linkages are made of aluminum. The fingertips, and the palm of the hand are printed by using 3D printer. The other available prosthetic hands based on 3D print can be found in [7-13].

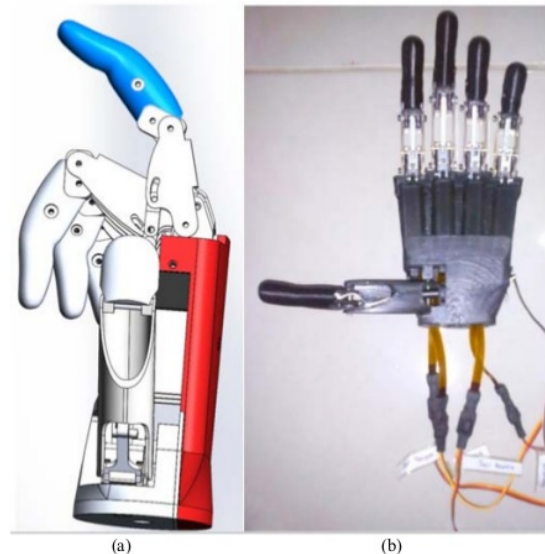


Fig. 1. Proposed myoelectric prosthetic hand. (a) 3D CAD design, (b) Result of the myoelectric hand prototype.

The myoelectric prosthetic hand prototype is designed to be driven by using sEMG sensor as an input control to drive the linear actuators. After the prototype of myoelectric prosthetic hand has been built, graphical user interface (GUI) was built for data acquisition, monitoring, and setting purposes. The developed GUI for the hand system is shown in Fig. 2. The GUI can be installed on the computer. The utilized toolbox and the character on the myoelectric hand system can be summarized as in Table I.

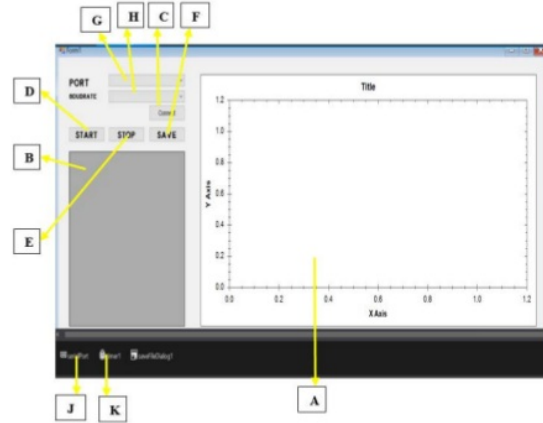


Fig. 2. Proposed graphical user interface in the myoelectric hand system.

TABLE I. DEVELOPED GUI TOOLBOX FOR WIRELESS EMG MONITORING SYSTEM.

Character	Toolbox	Function
A	Zedgraph	To create a realtime signal graph from the EMG sensor
B	DataGridView	To display the signal number from the EMG sensor being monitored
C	Button (Connect)	To enable graphics
D	Button (START)	To begin the monitoring process
E	Button (STOP)	To stop the monitoring process
F	Button (SAVE)	To store the monitoring results in richtextbox
G	Combobox (PORT)	To select a port
H	Combobox (BAUDRATE)	To select baudrate speed
J	Serial Port (Arduino)	To create a relationship between arduino Nano V3.0 microcontroller with C # programming language
K	Timer (Second)	To run the program work in realtime

The input used to drive the prosthetic hand comes from the EMG sensor signal. EMG sensor has an analog signal that is directly proportional to the muscle contraction of the human hand. The more the value of the muscle contraction is measured, the more the analog value outputs. This output voltage will go into the microcontroller and used to move the corresponding Firgelli linear actuator. Before developing the program of control algorithm on the myoelectric hand, the

measured analog value of the prosthetic hand user should be known. The analog value recorded on the Arduino monitor via serial communication will be used as the reference value to create a boundary value which will be used to control the linear actuator. The linear actuator can be extended or retracted for flexion and extension motion on the prosthetic hand fingers. EMG sensor used are able to read and convert muscle contractions on the human hand. Control algorithm program written in Arduino IDE is uploaded to the microcontroller and then the EMG is connected to Arduino Nano V3.0 using Analog input pin to move the prototype of the prosthetic hand.

III. RESULT AND DISCUSSIONS

A. Interface Hardware and Software

In this study, the developed hardware system is myoelectric prosthetic hand that can be moved with EMG sensor, where the EMG sensor is placed on the remaining arm/hand of the patient. The muscle contraction is read by EMG sensor and then sent the acquired signal to the microcontroller using analog to digital converter (ADC). The acquired signal is processed by the microcontroller and sent the processed signal to the actuators in the prosthetic hand in the form of the PWM signal. The acquired signal is sent to the developed GUI via serial communication by using Bluetooth. The proposed interface of the myoelectric hand system is shown in Fig. 3.

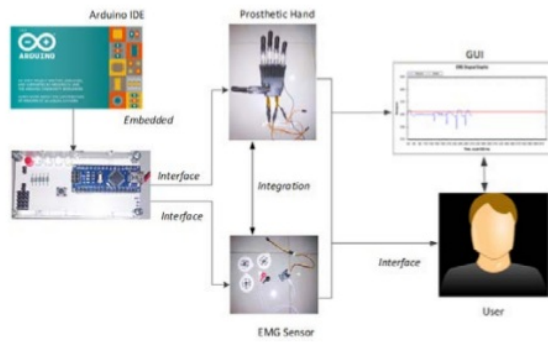


Fig. 3. Proposed interface in the myoelectric hand system

B. EMG signal acquisition

In this research, EMG data collection was recorded using electrodes attached to the skin surface. This surface electrode only allows for a maximum of three uses, which is using adhesive type EMG. This electrode acquires the voltage generated by the user's muscle contraction. The magnitude of the EMG signal depends on various factors, such as placement on the hand, the type of electrode used, and the strength of the muscle contraction. The electrodes were placed on the arms with hand movements and positions as shown in Fig. 4. This study is intended to find position and movement that produce the best muscle contraction response.

Data acquisition or data collection was carried out on five subjects or study participants. They were male (one of whom was a subject with hand amputation) and one subject was female. Subjects have varied ages, three subjects have ages from 20 to 24 years at the time of data collection, one subject with transradial amputation has an age of over 35 years,

while for female subject has an age of 22 years. Table II shows the list of subjects for EMG signal data acquisition.

In acquiring the muscle contraction signal, it used electromyography detector v1.1 and skin surface electrodes that use adhesive and cannot be reused or only one time usage. The data acquired by the microcontroller will be displayed on the monitoring GUI that was previously developed using Microsoft Visual Studio with C # language as shown in Fig. 2.

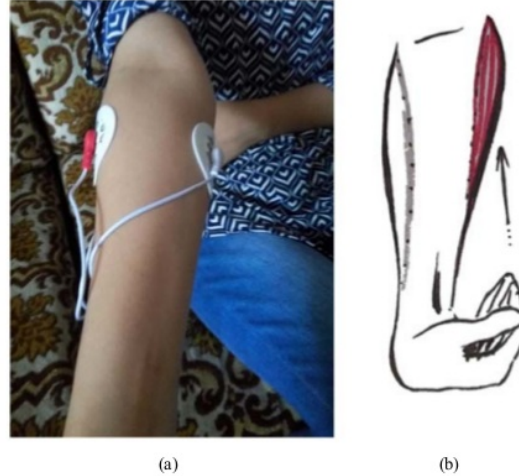


Fig. 4. Surface EMG placement. (a) on the arm below elbow, (b) flexion motion of the hand as a trigger to drive the myoelectric hand.

TABLE II. STUDY PARTICIPANTS INVOLVED IN THIS STUDY

Subject	Gender	Age	Hand condition
S1	Male	35	Transradial amputee
S2	Male	24	Healthy
S3	Male	21	Healthy
S4	Male	22	Healthy
S5	Female	22	Healthy

The results of the EMG acquisition signal with five study participants are displayed as shown in Fig. 5. The measurements start from subject 1 through subject 5 based on the position of the EMG electrode placement as shown in the Fig. 4. Flexion and extension movement on the user's hand is conducted with a measurement time of 20-40 seconds. The acquired sEMG signal is then sent to the GUI via serial communication by using Bluetooth. The acquired EMG signal that is sent to the GUI is in the form of analog to digital converter (ADC) value.

Based on the results of the measurements as shown in Fig. 5, the flexion and extension of the hand signal can be read by the sEMG sensor. The placement of the surface EMG electrodes on the arm as in Fig. 4 can detect flexion or extension movements in the user's hand. Based on the results in Fig. 5, study participant with transradial amputation gives the lowest amplitude of flexion and extension signal. Therefore, before the transradial amputee can utilize the myoelectric prosthetic hand perfectly, the remaining hand need to be trained and rehabilitated.

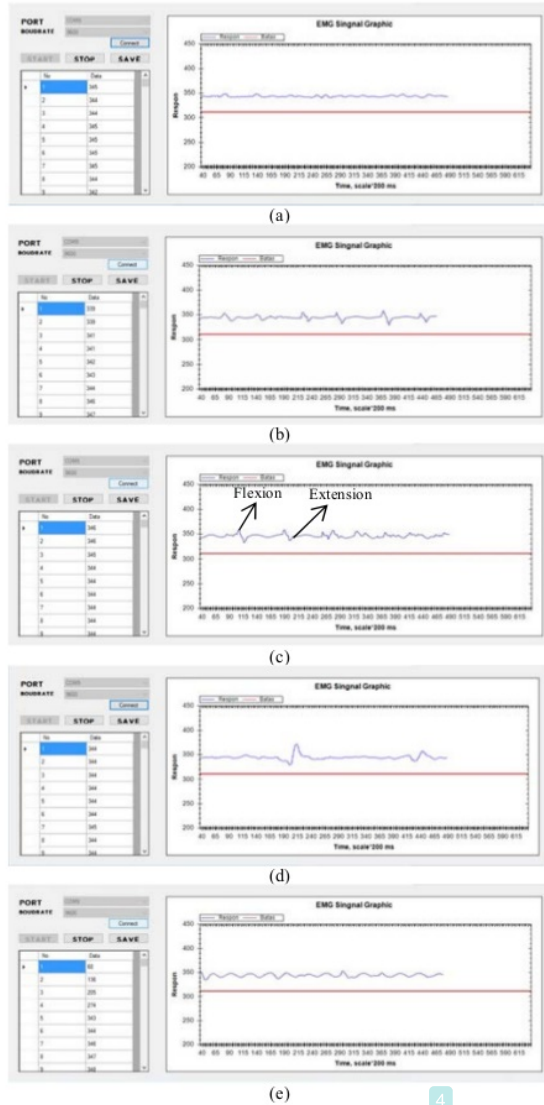


Fig. 5. Acquired EMG signals on five study participants. (a) Subject 1, (b) Subject 2, (c) Subject 3, (d) Subject 4, (e) Subject 5.



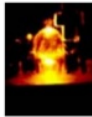

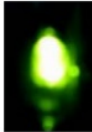





C. Experimental Results

Motion testing without grasping the object is conducted to find out the five motion modes can run according to the desired motion. There are five grip modes that have been developed on the proposed prosthetic hand, the movements that have been made are open - close, hook, peace, pointing, and active thumb. These modes will be explained in Table III as follows.

Table III shows the first mode with a red LED indicator that can move the hand open and hand close which is expected to replace the function of showing something or typing the keyboard, then the fifth mode with a white indicator with active thumb motion which is expected to replace the handshake function.

expected to replace the function of showing something or typing the keyboard, then the fifth mode with a white indicator with active thumb motion which is expected to replace the handshake function.

TABLE III. STUDY PARTICIPANTS INVOLVED IN THIS STUDY

Mode	LED colour	Hand posture
Open – Close		
Hook		
Peace		
Pointing		
Active thumb		

Object grasping motion test is conducted to find out the grip mode that has been developed can work properly and can withstand the given load. Table IV shows the objects that can be taken and held by myoelectric hand on grasping object test. Based on the test result, the proposed myoelectric hand can stably grasp objects such as cylinder, tennis ball, pliers, smartphone, and marker pen.

TABLE IV. OBJECT GRASPING TEST

Object	Grasping result
Cylinder	
Tennis ball	
Pliers	
Smartphone	
Marker pen	

IV. CONCLUSION

In this study, a myoelectric prosthetic hand has been developed using four-bar linkage mechanism. The GUI for monitoring, and setting the hand system has been built in visual C#. Five grip patterns that have been developed are open - close, hook, peace, pointing, and active thumb. Based on the test results using single channel surface EMG signal input, the proposed myoelectric hand can be stably grasp objects such as cylinder, tennis ball, pliers, smartphones, and marker pens.

REFERENCES

- [1] Brorsson, B., Gunnarsson, T., Hakanson, I., 2009. Transcranial magnetic stimulation in treating depression. SBU Report No. 192. Stockholm, Sweden: Swedish Council on Technology Assessment in Health Care (SBU).
- [2] Weir, R.F., 2004. Design of artificial arms and hands for prosthetic applications. Standard Handbook of Biomedical Engineering and Design, pp.1-61
- [3] Martel and Gini. "Robotic Hands: Design Review and Proposal of New Design Process", International Journal of Mechanical, Aerospace, Industrial, Mechatronic and Manufacturing Engineering Vol:1, No:2, 2007.
- [4] M. Ariyanto, R. Ismail, A. Nurmianto, W. Caesarendra, Paryanto and J. Franke, "Development of a low cost anthropomorphic robotic hand driven by modified glove sensor and integrated with 3D animation," 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES), Kuala Lumpur, 2016, pp. 341-346.
- [5] R. Ismail, M. Ariyanto, W. Caesarendra and A. Nurmianto, "Development of robotic hand integrated with SimMechanics 3D animation," 2016 International Seminar on Intelligent Technology and Its Applications (ISITIA), Lombok, 2016, pp. 629-634.
- [6] M. Ariyanto, Munadi, G. D. Haryadi, R. Ismail, J. A. Pakpahan and K. A. Mustaqim, "A low cost anthropomorphic prosthetic hand using DC micro metal gear motor," 2016 3rd International Conference on Information Technology, Computer, and Electrical Engineering (ICITACEE), Semarang, 2016, pp. 42-46.
- [7] J. Raines, Robotics Hand Development Kit-Ada V1.1 -Datasheet, United Kingdom, Open Bionics, May 2016.
- [8] Open Hand Project, Bristol (United Kingdom), Dextrus Hand, 2014.
- [9] J. Koprnicky, P. Najman and J. Šafka, "3D printed bionic prosthetic hands," 2017 IEEE International Workshop of Electronics, Control, Measurement, Signals and their Application to Mechatronics (ECMSM), Donostia-San Sebastian, 2017, pp. 1-6.
- [10] P. Slade, A. Akhtar, M. Nguyen and T. Bretl, "Tact: Design and performance of an open-source, affordable, myoelectric prosthetic hand," 2015 IEEE International Conference on Robotics and Automation (ICRA), Seattle, WA, 2015, pp. 6451-6456.
- [11] M. Yoshikawa, R. Sato, T. Higashihara, T. Ogasawara and N. Kawashima, "Rehand: Realistic electric prosthetic hand created with a 3D printer," 2015 37th Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC), Milan, 2015, pp. 2470-2473.
- [12] U. J. Pai, N. P. Sarath, R. Sidharth, A. P. Kumar, S. Pramod and G. Udupa, "Design and manufacture of 3D printed myoelectric multi-fingered hand for prosthetic application," 2016 International Conference on Robotics and Automation for Humanitarian Applications (RAHA), Kollam, 2016, pp. 1-6.
- [13] P. Wu and J. Shieh, "3D printed prosthetic hands," 2016 International Conference On Communication Problem-Solving (ICCP), Taipei, 2016, pp. 1-2.

Development of Myoelectric Prosthetic Hand based on Arduino IDE and Visual

ORIGINALITY REPORT

8%

SIMILARITY INDEX

%

INTERNET SOURCES

8%

PUBLICATIONS

%

STUDENT PAPERS

PRIMARY SOURCES

1

Y R Garda, W Caesarendra, T Tjahjowidodo, A Turnip, S Wahyudati, L Nurhasanah, D Sutopo. "Flex Sensor Based Biofeedback Monitoring for Post-Stroke Fingers Myopathy Patients", Journal of Physics: Conference Series, 2018

Publication

2%

2

Tarwaji Warsokusumo, Toni Prahasto, Wahyu Caesarendra, Achmad Widodo. "Optimization of Power Plant Operation Parameters for Efficiency Improvement through Data-Driven Relevance Vector Machine Regression Algorithm", 2018 International Conference on Applied Engineering (ICAE), 2018

Publication

2%

3

C. N. Savithri, E. Priya, J. Sudharsanan. "Chapter 13 Classification of sEMG Signal-Based Arm Action Using Convolutional Neural Network", Springer Science and Business Media LLC, 2021

Publication

1%

4

Panicker, Rajesh C, Sadasivan Puthusserypady, and Ying Sun. "Adaptation in P300 Brain–Computer Interfaces: A Two-Classifer Cotraining Approach", IEEE Transactions on Biomedical Engineering, 2010.

Publication

1%

5

Aggelos S. Bouhouras, Paschalis A. Gkaidatzis, Ioannis Panapakidis, Anastasios Tsiakalos et al. "A PSO based optimal EVs Charging utilizing BESSs and PVs in buildings", 2019 IEEE 13th International Conference on Compatibility, Power Electronics and Power Engineering (CPE-POWERENG), 2019

Publication

1%

6

Rifky Ismail, Mochammad Ariyanto, Kharisma A. Pambudi, Joshua W. Syafei, Gilar P. Ananto. "Extra robotic thumb and exoskeleton robotic fingers for patient with hand function disability", 2017 4th International Conference on Electrical Engineering, Computer Science and Informatics (EECSI), 2017

Publication

<1%

7

Rifky Ismail, Mochammad Ariyanto, Taufik Hidayat, Joga D. Setiawan. "Design of fabric-based soft robotic glove for hand function assistance", 2019 6th International Conference on Information Technology, Computer and

<1%

8

Mochamad Ariyanto, Rifky Ismail, Ahmad Nurmianto, Wahyu Caesarendra, Paryanto, Jorg Franke. "Development of a low cost anthropomorphic robotic hand driven by modified glove sensor and integrated with 3D animation", 2016 IEEE EMBS Conference on Biomedical Engineering and Sciences (IECBES), 2016

Publication

9

Matsumoto, Y.. "Mathematical models for the apparent masses of standing subjects exposed to vertical whole-body vibration", Journal of Sound and Vibration, 20030220

Publication

10

Sivapong Nilwong, Delowar Hossain, Eneo Petoku, Genci Capi. "Development of Myoelectric Robotic Hand using 3D Printer", 2019 1st International Conference on Advances in Science, Engineering and Robotics Technology (ICASERT), 2019

Publication

11

J.S. Artal-Sevil, F.J. Perez-Cebolla, A. Pascual-Acon, J.A. Dominguez. "Control of a Bionic Hand based on Neural Networks and improved Gesture Recognition Techniques using multiple

<1 %

<1 %

<1 %

<1 %

EMG sensors", 2020 XIV Technologies Applied to Electronics Teaching Conference (TAEE), 2020

Publication

12

"New Trends in Medical and Service Robots", Springer Science and Business Media LLC, 2014

Publication

<1%

13

Mohamad Aizat Abdul Wahit, Siti Anom Ahmad, Mohammad Hamiruce Marhaban, Chikamune Wada, Lila Iznita Izhar. "3D Printed Robot Hand Structure Using Four-Bar Linkage Mechanism for Prosthetic Application", Sensors, 2020

Publication

<1%

14

Mochammad Ariyanto, Gunawan D. Haryadi, M. Munadi, Rifky Ismail, Zulfa Hendra.

"Development of Low-Cost Autonomous Emergency Braking System (AEBS) for an Electric Car", 2018 5th International Conference on Electric Vehicular Technology (ICEVT), 2018

Publication

<1%

Exclude quotes

Off

Exclude matches

Off

Exclude bibliography

On

Development of Myoelectric Prosthetic Hand based on Arduino IDE and Visual

GRADEMARK REPORT

FINAL GRADE

/100

GENERAL COMMENTS

Instructor

PAGE 1

PAGE 2

PAGE 3

PAGE 4

PAGE 5