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DESIGN AND MANUFACTURING OF 3D PRINTERED PROSTHETIC HAND USING MUSCLE SIGNALS

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ABSTRACT: The person who has challenges not meeting needs due to the loss of his / her physical, mental and sensorial abilities to a certain extent on account of birth or any reason is defined as 'disabled' if any care or rehabilitation is required. These people have difficulty adapting to social life. Prostheses have been developed to ensure this compatibility. Today, by measuring directly from the patient, the production in place of the organ lost by the patient is carried out suitably. In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The movement of the fingers was performed by processing the signals received from the EMG sensor with a microcontroller and transmitting them to the servo motors in the form of meaningful values. Findings obtained were evaluated by comparison.

Keywords: Prosthetic, 3D printer, Microcontroller, EMG sensor.

1. INTRODUCTION

Today, with prostheses produced using light materials (plastic, composite, aluminum), a patient-oriented approach enables people who have lost organs to reach their old standards of life. The microchips and robotic systems used in the prosthesis minimize the adaptation and learning process provided by the mechanical movements of the prosthesis[1].The changes in living things occur as a result of the contraction of the muscles. Muscle fibres are transmitted through motor nerves. They can also respond to a warning such as electric current. The contraction of the muscle can take two forms: fixed neck swelling of the neck or both swelling and shortening of the neck. It is an EMG signal that we use for human-machine communication, with the contracted muscles being an electrical physiological signal representing the movements of the relevant motor unit. EMG signal amplitude varies between 0-10 mV or 0-1.5mV. The signal is in the 50-500Hz frequency range [2].

The devices used for rapid prototyping producing layer by layer according to the design to the finest detail are called 3D printers. Since the desired product is encountered in a short time, it is a great invention in technology. It can manufacture from hundreds of kinds of materials (plastic, metal, polymer, ceramic, etc.) [3-5]. 3D printing methods are FDM (Fused Deposition Modeling), SLS (Selective Laser Sintering), SLA (Stereolithography), PJ (Polyjet), LOM (Layered Object Manufacturing), Binder Jet (Binder Jet Technique). The most preferred type of 3D printing is FDM type 3D printing. FDM type printers are the technology that makes production by placing PLA and ABS thermoplastics as the raw material, on top of each other, in preferred layers.

In the literature, Cinal et al. [6], a virtual prosthesis was designed using single and dual-channel YEMG data. The virtual prosthesis is controlled in real-time by YEMG. With this processed data, the opening of the Virtual Prosthesis maintains its closing position. Kaya et al. [7] kinematic and dynamic analyzes of a hand prosthesis mechanism were performed. With the designed model, it used simulation outputs and motion analysis program to determine its dynamic behaviours accurately and successfully. Besides, it has been examined to provide supervision according to EMG signs. As a result of the experiments, it was revealed that three different hand movements were successful. İşler et al. [8] studied the EMG sensor, which senses the signals in the forearm muscles, with four classifiers for hand control, which can perform four separate movements, tightening, loosening, contraction and release. Here, in the machine learning algorithms, the k-nearest neighbour algorithm has been classified with MLP, RBF, and SWM. As a result of the tests and measurements, the classifier that showed the best performance was SWM.

İşler et al. [9] was drawn a hand prosthesis with Solidworks and printed on a 3D printer. In the design of the Electric-Electronic system, analog signals received from the SEMG were converted into digital signals, and precise movements were performed on the hand prosthesis together with the servo motor. Voltage values are compared and recorded personally. With the study, an inexpensive, lightweight, and easy-to-use application has been carried out for people with disabilities to reach. Taşar [10] was manufactured the prototype of the five-finger and fifteen-jointed prosthetic hand with a 3D printer, and this prosthetic hand was simulated with SimMechanics. The data and signals we received in real-time were compared with those obtained from the simulation, and a 70% success rate was achieved. Kate et al. [11] examined the ease of use, the benefits of living prostheses produced with 3D printing, and the advantages and disadvantages compared to traditional prosthetics. Cabibihan et al. [12] were scanned computed tomography images of the cut and non-cut arm of the sample person. The support structure and mold of the prosthetic arm are prepared with 3D printing with silicone material. This produced prosthetic arm was compared with the non-incision arm that was previously scanned in computed tomography. As a result of the comparison, a high accuracy rate was achieved. In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The movement of the fingers was performed by processing the signals received from the EMG sensor with a microcontroller and transmitting them to the servo motors in the form of meaningful values. Findings obtained were evaluated by comparison. Aksoy et al. [13] were created by pressing a five-finger robotic arm with a 3D printer. Six servo motors are mounted on the robot arm to move the fingers and wrists on the created robot arm. With the developed Python software, the microcontroller was communicated in series, and the sign language movements were detected by the robot arm.

2. MATERIAL AND METHODS

In the study, 3D printer, servo motors, rope line, EMG sensor, the microcontroller used as materials. In the method, design, manufacturing, assembly, and software of the prosthetic hand consists of stages.

2.1. Material

In the material section, the elements for the prosthetic hand designed .stl formats were manufactured by a 3D printer of TwoTreesBluer, such as shown in Figure 1. Processing parameters are printing speed 50mm/sec, nozzle diameter 0.4mm, layer thickness 0.2mm. PLA filament was preferred as the printing material.

Model	TwoTreesBluer
Nozzle diameter	0.4mm
Building table	235 * 235 * 280mm
Accuracy of printing	± 0.1-0.2mm
Layer thickness	0.1-0.4mm
Machine speed	10 ~ 300 mm / s
Printing speed	20-200mm / sn
Materials	PLA, ABS, PETG, wood filament
Dimensional of Machine	L410 * W400 * H520mm
Operating environment	Temperature: 5-40 ° C, humidity:%20-

Figure 1. Overview of the 3D printer

The electrical-electronic circuit system schema is given for the control of the prosthetic hand, as shown in Figure 2. Here, MG995 Servo motors are used to move the fingers of the prosthetic hand according to the signals from the microcontrollers. In the study, the rope line used replaces muscle fibers in the prosthetic hand. The thread line used is made of synthetic thermoplastic known as polyethylene. EMG sensors are a detect that helps in human-machine connection. It converts small electrical signals in muscle nerves to analog signals and allows them to be used in control processes to be performed in driver circuits. In the study, the EMG sensor was used to detect the user's movements in prosthetic hand-making and to control the hand in the prosthetic hand study. EMG sensors output are in the form of analog voltage output. Thus, it can be used with 5V and 3.3V systems. Arduino microcontroller with AtmelAtmega 328P was used as the microcontroller.

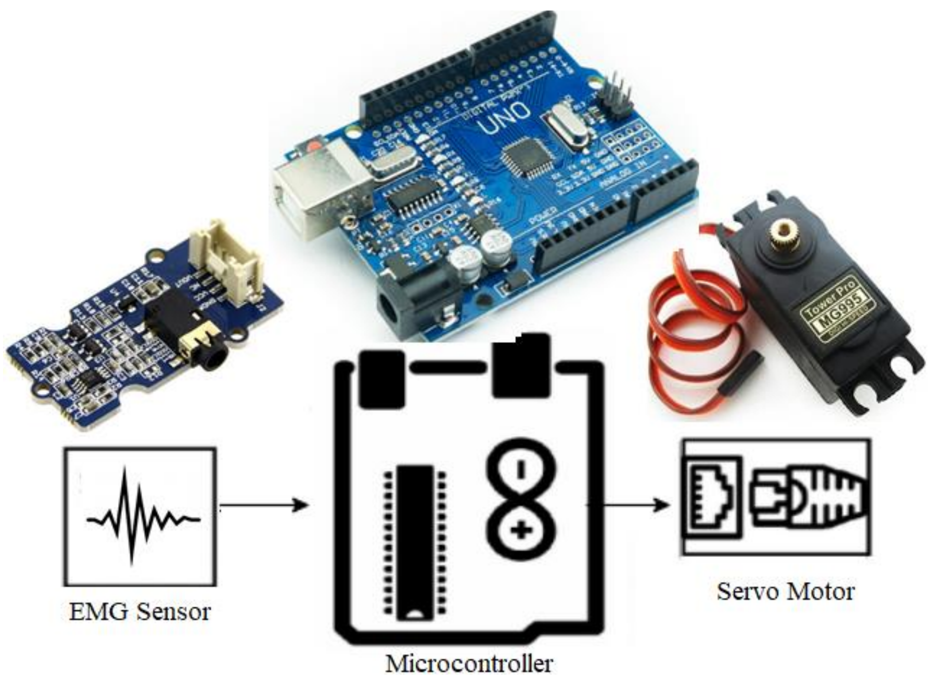


Figure 2. Electric-electronic system diagram

2.2. Method

2.2.1. Design of the prosthetic hand

The drawings of the fingers of the prosthetic hand .stl files with the SolidWorks program are given in Figure 3. The most important aspect of the design of the fingers was the connections of the fingers. Relationships form an essential part of freedom of movement.

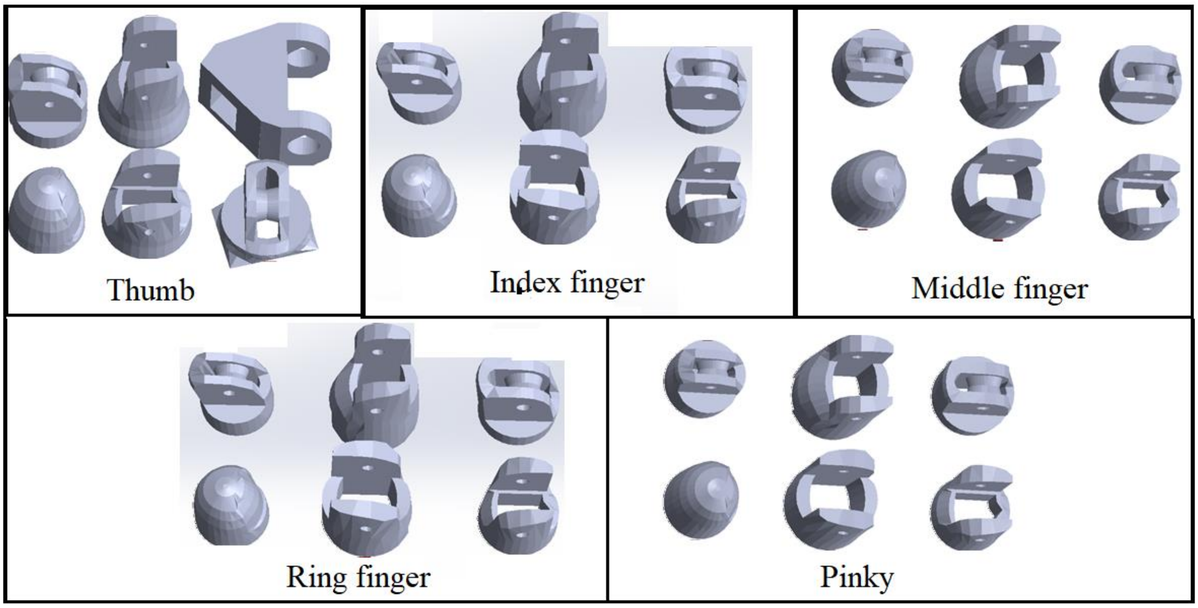


Figure 3. Overview of the fingers of the prosthetic hand [14]

Palm parts and connecting pins, wrist part arm part, and motor connection parts are given in Figure 4. The design of the prosthesis hand part is carefully drawn as it is the place where the rope lines that will replace the servo motor and muscle fibers are collected.

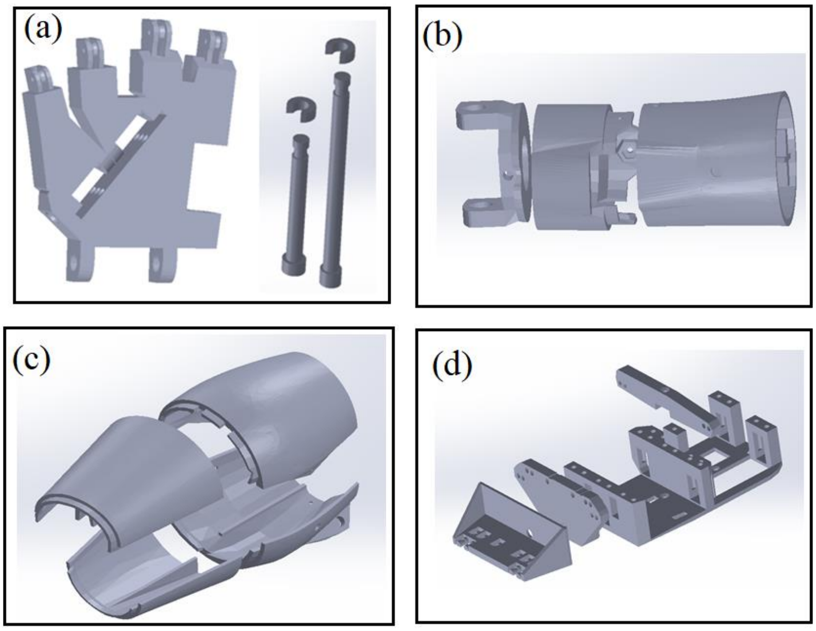


Figure 4. Overview of the other parts of the prosthetic hand [14]

2.2.2. Assembly and manufacturing of the prosthetic hand

The manufacturing mechanical parts of the prosthetic hand were printed with a 3D printer. Due to processing parameters, parts were manufactured with a 3D printer. The roughness and the points to be cleaned on the assembled components are sandpaper, etc. made ready for installation with operations. Its image is as shown in Figure 5 during manufacturing.

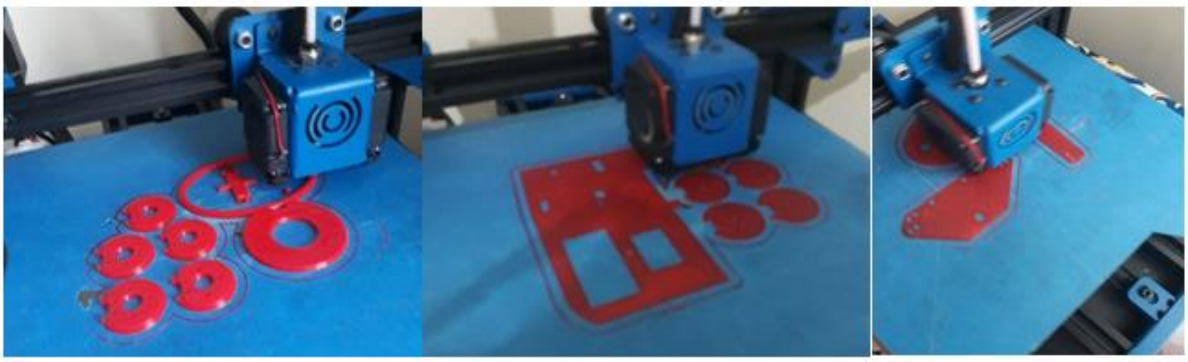


Figure 5. Overview of the manufacturing of the prosthetic hand

The palm section connections were carried out shafts printed by the 3D printer. Pre-assembled fingers were mounted on the prepared the palm with nails used as shafts. The links of harpoon threads have two ropes for opening and closing movements on each finger. The image of ropes palms and fingers, arm, and motor bearing mounted were shown as in Figure 6.

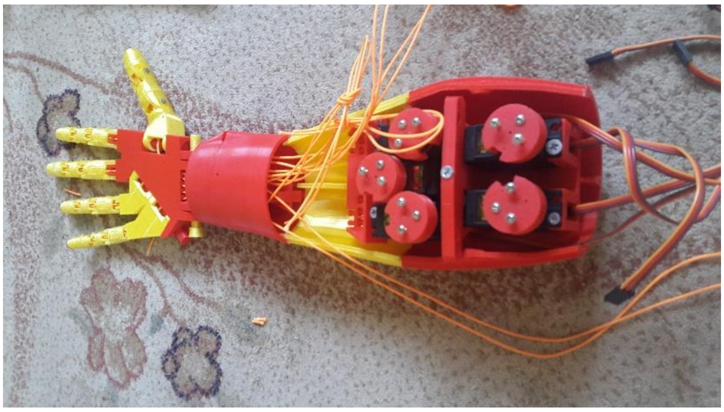
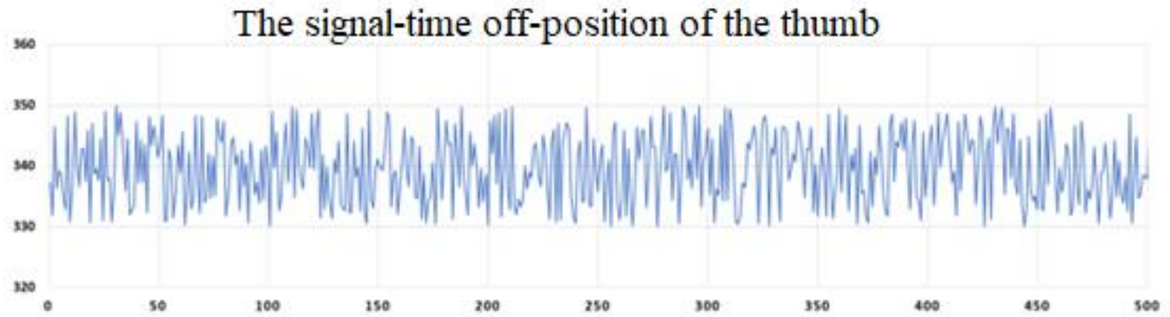


Figure 6. Overview of the assembly of the prosthetic hand and the other components

3. RESULTS AND DISCUSSION

To detect movements and regulate the operation of the prosthetic hand, signals from the arm muscles were obtained with the EMG sensor, and the control of the prosthetic arm was performed. The signals from the muscle signals were obtained with the Emg sensor. The movement of the fingers was achieved by processing the received signals with the microcontroller and transmitting them to the servo motors in the form of meaningful values. The muscle groups for which the signals will be taken for the received signal are accepted at the points where great test results and best results are determined. Different studies have shown that the electrodes of circuit boards and EMG sensors will have different values on different people. As shown in Figure 7, the signal time values determined for each finger are shown. These values indicate that the signals of EMG sensors in the most on and off position of each finger are recorded as a graph of time. In the thumb off-position signal time graph, the signal values vary between 330-350 Hz depending on the time. This value was obtained between 310-330 Hz on the index finger, 280-300 Hz on the middle finger, 380-400 Hz on the ring finger, and 250-280 Hz on the little finger. According to the values obtained, the off-position of the prosthetic hand with the movement of the ring finger muscle signals is felt more effectively. However, the signal was received in the case of fewer off-position in the little finger than the other fingers.



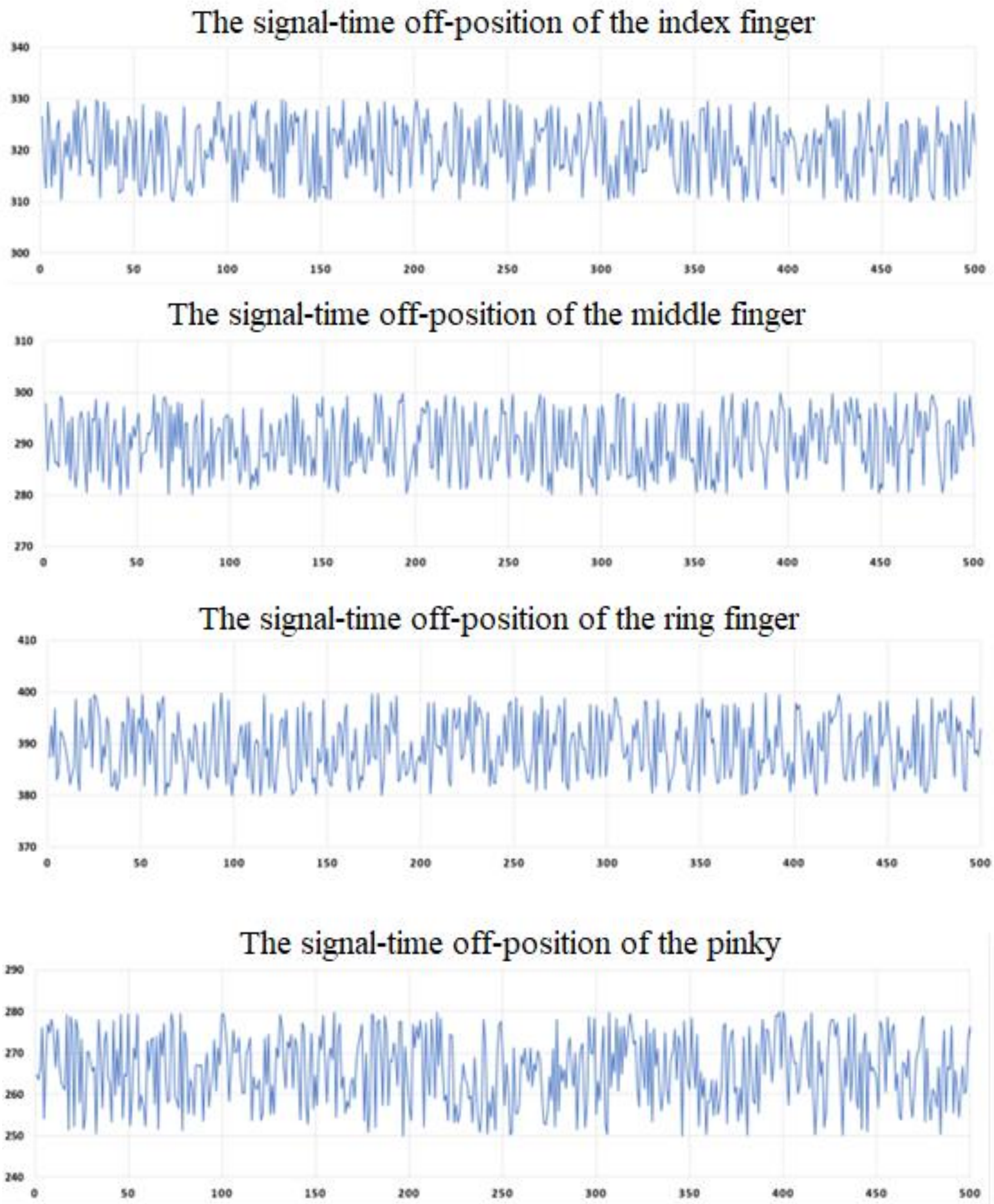
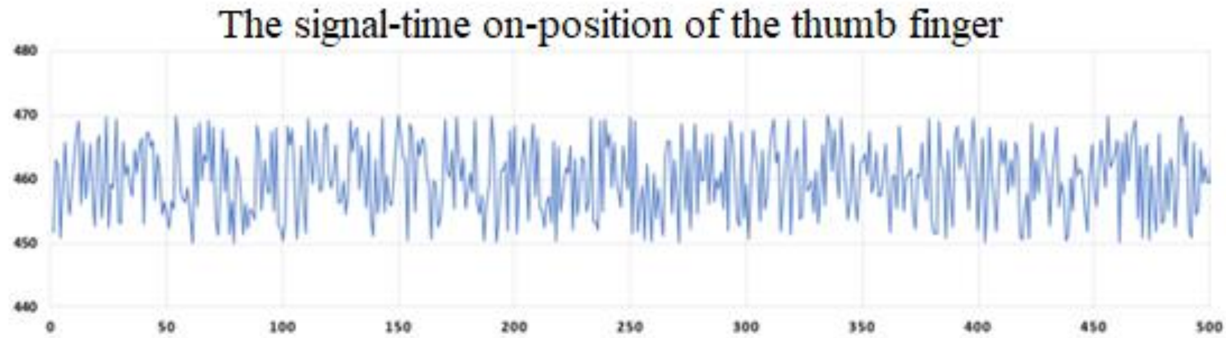
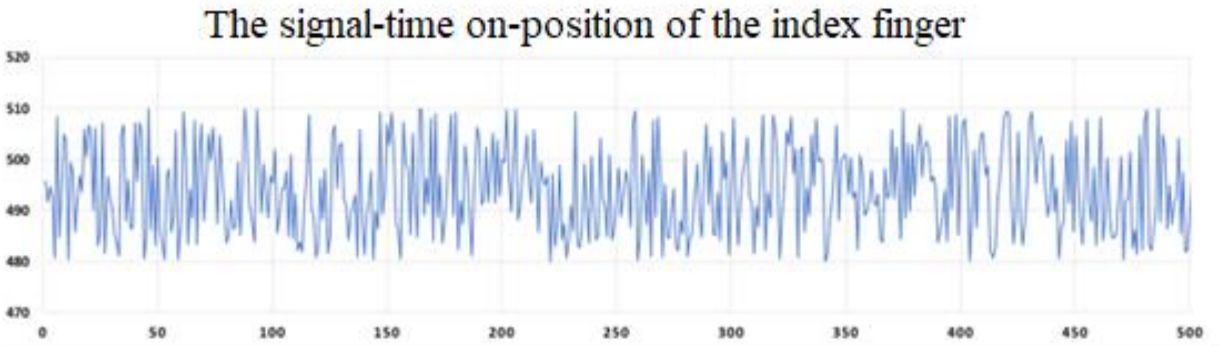
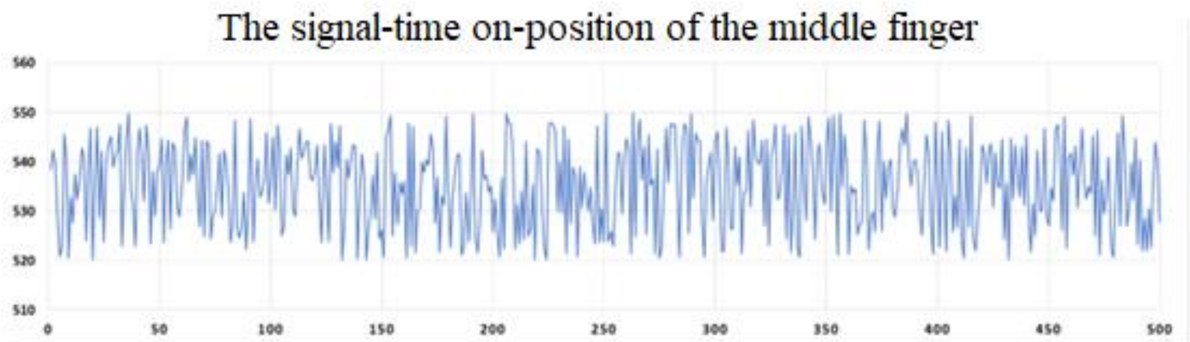


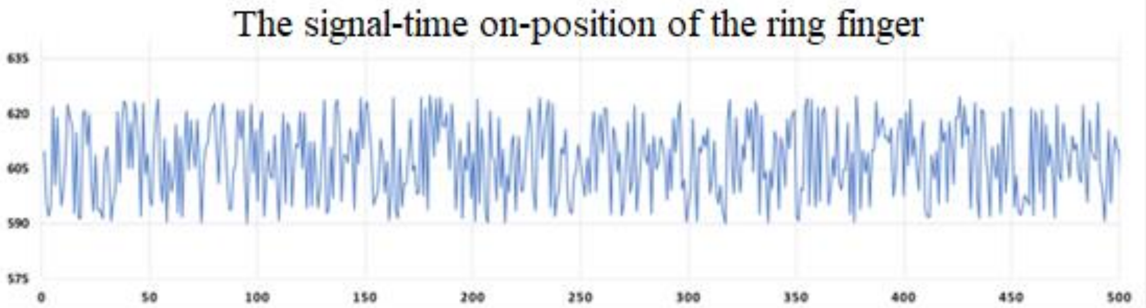
Figure 7. The signal -time off-position of the prosthetic hand

It is shown in Figure 8 that the signals of EMG sensors in the on-position state of the prosthetic hand are recorded as a graph depending on time. In the thumbs-up signal time graph, the signal values range from 450 to 470 Hz, depending on the time. Signal values between 480-510 Hz on the index finger, 520-550 Hz on the middle finger, 590-620 Hz on the ring finger, 565-580 Hz on the little finger were obtained. Depending on the values obtained, the opening of the ring finger muscle signals in the prosthetic hand is felt more effectively. However, the signal was received in case of less opportunity on the thumb than other fingers.


The signal-time on-position of the thumb finger
480
470
460
450
440
0 50 100 150 200 250 300 350 400 450 500


The signal-time on-position of the index finger
520
510
500
490
480
470
0 50 100 150 200 250 300 350 400 450 500


The signal-time on-position of the middle finger
560
550
540
530
520
510
0 50 100 150 200 250 300 350 400 450 500


The signal-time on-position of the ring finger
635
620
605
590
575
0 50 100 150 200 250 300 350 400 450 500

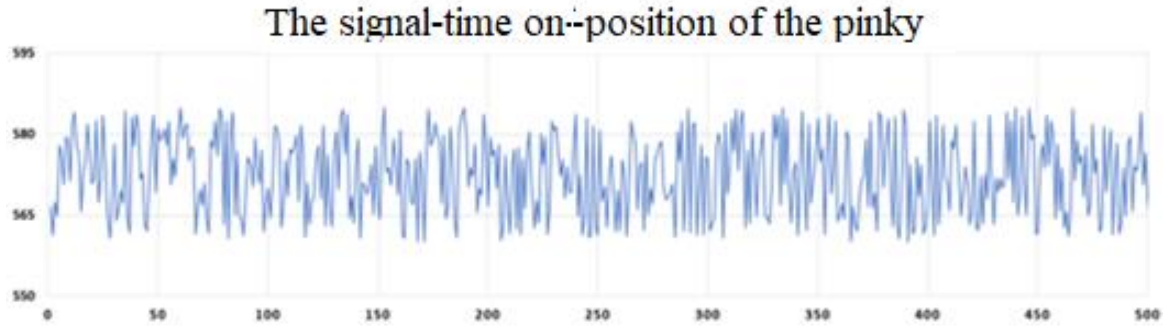


Figure 8. The signal-time on-position of the prosthetic hand

4. CONCLUSIONS

In this study, It was carried out to control muscle signals with EMG sensor prosthetic hand manufactured by a 3D printer. The motion of the servo motors is carried out by converting the analog signals received from the forearm muscle with electrodes to digital signals with a microcontroller. Finger movements were realized with the change of the servo motor. The conclusions are obtained below.

- It has been shown that the physiological signals obtained as a result of muscle and nerve activities in the human arm can be converted into electrical signals, and these signals can be processed and used in electronic circuits. Thus, with the developing technology, people with disabilities will be able to have a more comfortable life.
- In the study, an EMG sensor value was determined completely independent of the value of any EMG sensor.
- The on and off-position of the prosthetic hand with the movement of the ring finger muscle signals is felt more effectively as 380-400 Hz (off-position) and 565-580 Hz (on-position).
- The signal was received in case of less opportunity on the pinky than other fingers in off-position.
- The signal was received in case of less opportunity on the thumb than other fingers in on-position.
- The signal-time graphics obtained from the fingers of the prosthesis vary from custimized. It is recommended to experiment with more than one person to obtain an average value.

5. ACKNOWLEDGEMENTS

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