EMG Controlled Artificial Hand and Arm Design

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Abstract: - Today, there are many people who have lost their hands or arms for various reasons. This situation affects both psychology and daily life of people negatively. With the developing technology, prosthetic hand and arm studies are carried out to facilitate the life of disabled people and to eliminate this negativity. Thanks to the existing biopotentials in the body, it is possible to read the human body. In this context, it can explain our hand and arm movements with the existing biopotential signals and transfer these signals to a prosthesis, enabling people to make the desired movement. Since the biopotential signals in the body are of very low amplitude and frequency, the first goal is to obtain the EMG signal cleanly without noise. In this study, the obtained analog signal was converted into digital information by using software in the computer environment. Thus, each signal gained a meaning. As a result, the movement of the prosthesis was provided by transferring it to stepper motors with the help of Arduino.

Key-Words: EMG, Artificial hand and arm, MATLAB

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1 Introduction

With the development of technology, people have tried to produce robots that can replicate the movement they want to do. Today, robot movements are provided by using mostly EMG signals. After the Second World War, the first engineering studies were started with the encouragement of the US government to develop artificial limbs.

While the prostheses were controlled with simple cable-driven methods at the first stage, later on, prostheses that are suitable for human physiology and that can be automatically controlled by the electrical activity created by the muscles have begun to be made [1].

In recent years, many studies on anthropomorphic hand design have been reached. The hand prostheses that are emerging day by day are more similar to the functions of the human hand [2]. Commercial and easy-to-reach prostheses are generally simple in construction.

These simple structures are an important factor affecting the functionality of the hand, as in the Ottobock hand [3]. In addition to the disadvantages of commercial prostheses, prostheses known as FZK hand [4], RTRII hand [5], SDM hand [6], SmartHand [7], Vanderbilt University hand [8], which are much more functional as a result of academic studies, are also at the forefront today. The first EMG-controlled prostheses use the on-off method or simple proportional control methods.On the other hand, the working speed of prostheses is constant and slow. This makes it difficult for amputees to use prostheses as their own hands [9].

Since 1981, the Utah Arm Prosthesis has been the most widely used EMG-controlled arm prosthesis for people with amputated elbows [10]. First, Dr. It was developed by the University of Utah Engineering Design Center, led by Steve Jacobsen. In 1987, Motion Control, which made the Utah Arm Prosthesis the world's most durable and reliable EMG-controlled arm prosthesis available, launched the Utah-2 Arm Prosthesis with a completely redesigned electronic design [11].

In 2004, Motion Control Utah-3 introduced microprocessor technology to the Arm Prosthesis, which enables the prosthodontist or user to make necessary adjustments to achieve maximum performance. A wide variety of inputs are available, so more users have more options. Meanwhile, the U-3 still offers the same precise, proportional elbow, hand and wrist control that allows the user to move the arm and hand slowly or quickly in any position.

2 EMG Signal

Electromyogram is defined as the electrical activity that occurs on muscles during resting and contraction states. Electromyography (EMG) is the recording and interpretation of action potentials in muscles [12]. The EMG signal is a complex, non-stationary and noisy signal. The amplitude of the EMG signal is random and can usually be expressed as a Gaussian distribution. The amplitude range of the signal is 0-10 mV (peak to peak) or 0-1.5 mV (rms). While the usable energy of the EMG signal is in the frequency range of 0-500 Hz, the dominant energy is in the range of 50-150 Hz [13].

In medical applications, the characteristics of the signals produced by the muscles are used in the diagnosis of disorders in muscle or neural functions [14]. In this way, it is possible to attribute electrical meanings to people's movements. EMG signals that are loaded with meaning can be transferred to the prosthetic arm and can perform the movements of the arm depending on the human desire. In the light of this information, by using EMG signals from the body, the movements of the prosthetic hand or arm can be provided without any external influence. A classic EMG signal is given in Figure 1 below.

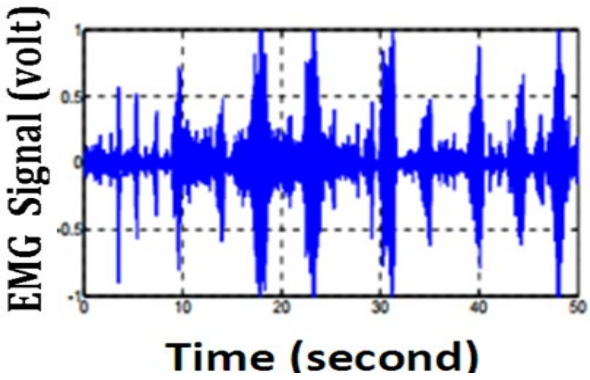

Figure 1. EMG signal

Needle and surface electrodes are used to record EMG signals. If a nerve damage is to be examined or a single muscle fiber is desired to be reached, needle EMG is preferred, while surface EMG is used for researches on electrical activity in a very large area or for examining the surface muscles.

3 Methods of Measuring EMG Signals

EMG measurement setups seen in clinics generally consist of electrodes for detecting EMG signals, stimulating, amplifier, oscilloscope, magnetic recorder and loudspeaker. In addition to these, some signal processing blocks, spectrum analyzers and computers can be found for research targeted studies.

By stimulating the motor nerve of the muscle to be examined with the stimulant, the EMG signals in the muscle fibers are transferred to the amplifier and from there to the relevant imaging unit with the help of receiving electrodes. EMG schemes are performed as a single compact unit for ease of application and transport, and sometimes for general purposes, capable of measuring biopotentials other than muscle signals [15].

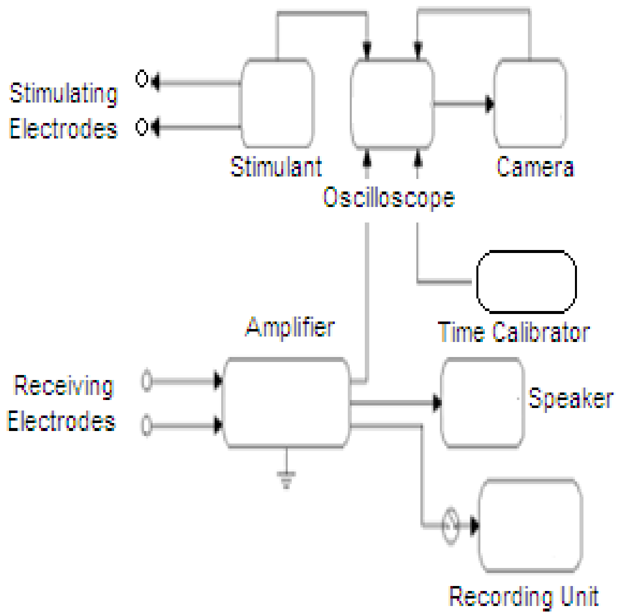

Figure 2. EMG scheme block diagram

The block diagram of the system used to obtain EMG signals is given in Figure 2 [15]. Many electrode shapes have been designed to collect biomedical signals. Bioelectrodes are tools for converting ionic conductivity to electronic conductivity and making it workable in electronic circuits. The general purpose of bioelectrodes is to collect medically important bioelectrical signals such as electrocardiogram, electroencephalogram, electromyogram. These electrodes are surface electrodes and internal electrodes [16].

4 Material and Method

The designed system consists of three main parts: (1) EMG signal processing circuit, (2) transferring the obtained analog signal to the computer environment and (3) transferring the digital signals to the servo motor.

4.1. EMG Signal Processing Circuit

Two signal processing circuits are implemented to provide the movement of the hand and wrist separately. To collect EMG signals, electrodes must be attached to the biceps muscles, which consist of skeletal fiber bundles. Three electrodes are required for each movement. Two of them were connected to the biceps muscles and applied to the input of the measurement biopotential.

The third one is connected to a different point on the arm and used as a reference point. Since EMG signals are too small to be processed by the microcontroller, they must be amplified before being fed to the microcontroller. A band-pass filter is used to increase the signal-to-noise ratio and suppress other physiological signals such as ECG. In the study; The band-pass filter is designed from high- and low-pass filters with cut-off frequencies of 50 and 500 Hz.

4.2. Transferring Obtained Analog Signal to the Computer

MATLAB and ARDUINO processors were used as software in the graphical and numerical acquisition of the EMG signal received from our body in the computer environment. The voltage supply, analog output and ground terminals of the EMG sensor circuit are connected to the ARDUINO processor as shown in Figure 3.

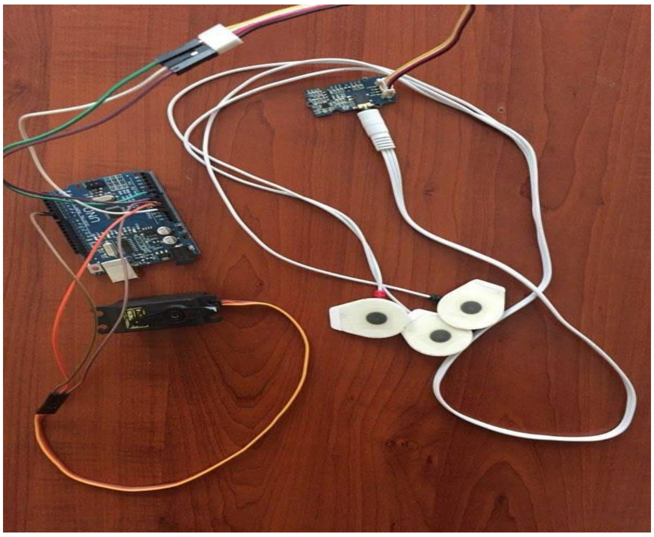

Figure 3. Connection of equipment with each other

With these connections, the graphical output of the signal is obtained in the MATLAB environment as seen in Figure 4.

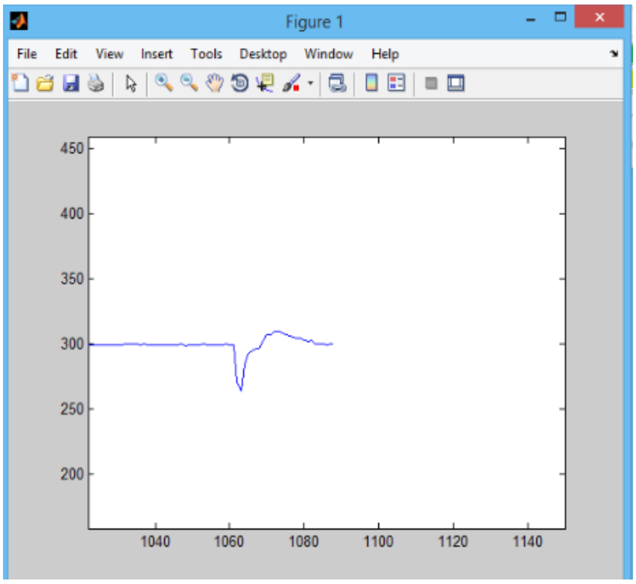

Figure 4. Example of the resulting graph

4.3. Transferring Digital Signals to Servo Motor

The movement of the motor was determined with the numerical data determined according to the opening and closing of the hand, accompanied by the numerical data obtained. In the light of these numerical data, the motor has been turned to 180 degrees when the hand is closed and 0 degrees when it is open. The numerical data obtained according to the opening and closing moment of the hand are given in Figure 5.

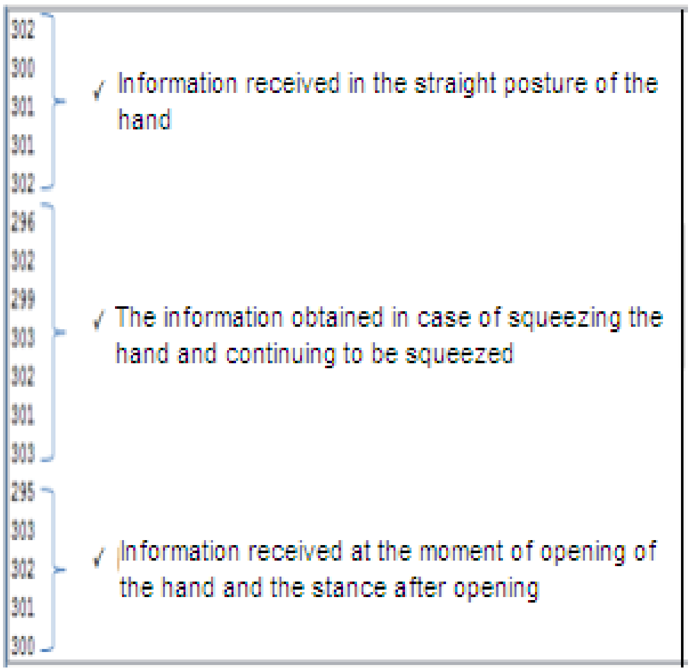

Figure 5. Numerical data obtained according to the opening and closing moment of the hand

5 Results

According to the movements of the hand and arm, the graphical outputs of the EMG signals were obtained with the help of MATLAB and their changes were observed. Graphics such as the opening and closing of the hand, the uncontracted state of the muscle, the left and right movements of the arm are given in Figure 6, Figure 7, Figure 8 and Figure 9.

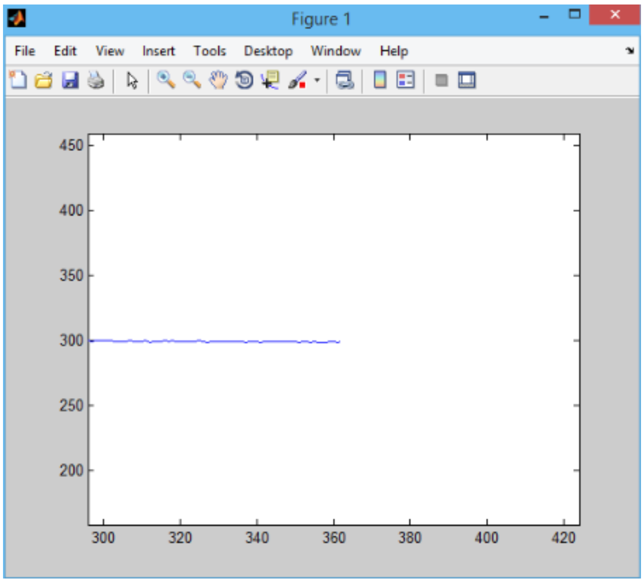

Figure 6. Muscle without contraction

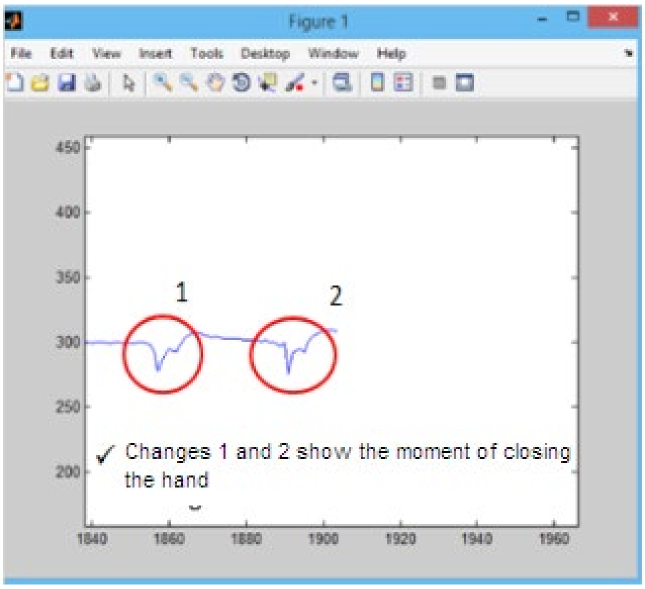

Figure 7. The moment of closing and opening of the hand

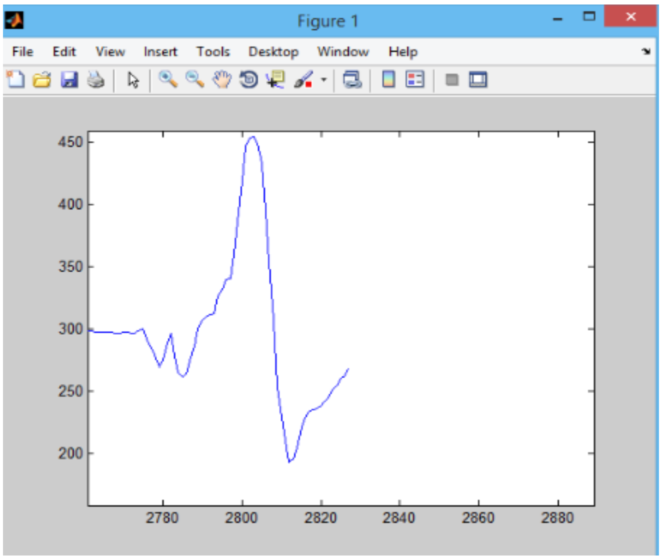

Figure 8. Graph showing arm movement to the left

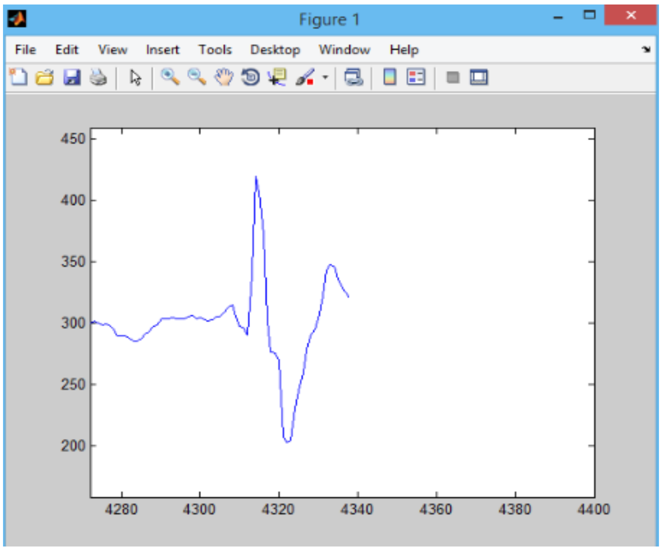

Figure 9. Graph showing arm movement to the right

6 Conclusions and Discussion

In recent years, the development and use of prosthetic devices has greatly changed and facilitated the lives of people with disabilities. The increasing number of disabled people and the fact that every healthy individual is a disabled candidate has increased the importance of prosthetic devices.

In this study, by obtaining EMG signals and using these signals, servo motors are driven, thus opening and closing of a hand is realized. The EMG signal best shows the muscle condition of the person receiving the signal. For this reason, it is very suitable as a source signal for the removable prosthesis in the use of prosthesis. On the other hand, the fact that the system is portable and its size is small within the possibilities has created an advantage for the user.

In addition to the difficulties that people who lost their limbs face in daily life, they also experience psychological disorders. The developed prostheses help to keep the difficulties experienced at a low level. Today, modern robotic prostheses, which are at the product level as well as being prototypes, are promising as new technologies that need to be studied. Unfortunately, EMG-based prosthesis studies are very limited in our country. It is hoped that these high-tech prostheses will reach the targeted points with the collaboration of different disciplines.

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