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Study on Virtual Control of a Robotic Arm via a Myo Armband for the Self-Manipulation of a Hand Amputee

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Abstract
This paper proposes a Myo device that has electromyography (EMG) sensors for detecting electrical activities from different parts of the forearm muscles; it also has a gyroscope and an accelerometer. EMG sensors detect and provide very clear and important data from muscles compared with other types of sensors. The Myo armband sends data from EMG, gyroscope, and accelerometer sensors to a computer via Bluetooth and uses these data to control a virtual robotic arm which was built in Unity 3D. Virtual robotic arms based on EMG, gyroscope, and accelerometer sensors have different features. A robotic arm based on EMG is controlled by using the tension and relaxation of muscles. Consequently, a virtual robotic arm based on EMG is preferred for a hand amputee to a virtual robotic arm based on a gyroscope and an accelerometer

Keywords: Myo armband, Electromyography, Controlling robotic arm, Hand amputee, Unity 3D

Introduction

The Myo armband detects electrical activity in forearm muscles. The human forearm has different types of muscles, each of which has a different arrangement, and these muscles control the movements of the wrist, such as moving fingers, making a fist, turning left or right, etc. The Myo armband has eight parts, each of which can detect these electrical activities in each part of the forearm.

The Myo armband has many advantages compared with other types of sensors, because it can be worn on the hand without cables, it connects with other devices or a computer via Bluetooth, and is very comfortable.

In addition, the electromyography (EMG) sensor of the Myo armband has a gyroscope sensor and an accelerometer [1]. Another advantage of this device is that, although the human hand size differs and human hand poses vary, we can adapt the Myo armband to anyone’s hand.

The remaining structure of this paper is outlined as follows. Section 'Motivation and Related Research' briefly introduces how virtual robotic arms (Myo armband and Unity 3D) are fabricated and describes the specifications of hand amputees and forearm muscles. Section 'Architecture design' shows the architectural design and Section 'Experimental results' discusses the experiment results obtained from virtual robotic arms. From these procedures, the design for a virtual robotic arm is proposed and experiments are carried out to demonstrate its features. In Section 'Conclusion,' we compare two different virtual robotic arms and determine which one is suitable for the hand amputee.

Motivation and Related Research

Data was obtained from EMG, the gyroscope, and the accelerometer and then analyzed to understand which parts of the forearm muscles electro activated in each wrist gestures.

The data obtained from the Myo armband sensors are used to control the robotic arm, which was built in Unity 3D. The robotic arm can move by using five distinct motions, including making a fist, spreading fingers, waving left, waving right, and double tapping fingers (to burst balloons the). The gyroscope data and accelerometer data are also used for moving the robotic arm in the X, Y, and Z directions.

EMG and MYO sensor

Most gesture-control systems still use cameras to detect movements, which can be incorrect due to poor lighting conditions, distance, and simple obstructions. By obtaining gesture information directly from the arm muscles rather than from a camera, the Myo circumvents these problems and works with devices that do not have a camera [2].

EMG is an electro-diagnostic technique for evaluating and recording the electrical activity produced by human skeletal muscles. EMG detects the electrical potential generated by muscle cells when these cells are electrically or neurologically activated. The signals can be analyzed to detect medical abnormalities, activation level, or recruitment order or to analyze the biomechanics of human movement [3]. EMG testing has a variety of clinical and biomedical applications. EMG is used as a diagnostics tool for identifying neuromuscular diseases, or as a research tool for studying kinesiology and disorders of motor control. EMG signals are sometimes used to guide botulinum toxin or phenol injections into muscles. EMG signals are also used as control signals for prosthetic devices such as prosthetic hands, arms, and lower limbs [4].

Figure 1: Using Myo armband

Figure 1 shows the Myo armband and controlling applications such as a shot gun game, an oculus game, controlling a remote control (RC) car, and drones.

Unity 3D

Unity 3D provides rendering of 3D objects, animations etc. in real time and has relatively easy-scripting, including the compatibility of various platforms. It is very popular for its intuitive interface application as shown in figures 2 and 3 [5]. It is also a game engine, similar to Unreal or Jupiter. However, Myo is the preferred device for interaction and visualizing using the virtual robotic arm. Therefore, Unity 3D is used to create virtual space and visualize experimental results.

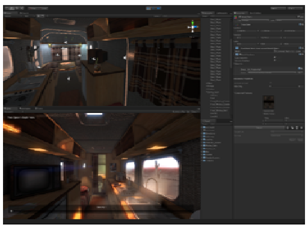

Figure 2: Interface of Unity 3D

Figure 3: Unity 3D providing multiple platforms

Hand amputee

A hand amputee is a person whose hand or arm has been severed, specifically the upper parts. Today, numerous assistance devices are available to help the movements of the hand amputee in practical life as shown in figures 4 and 5 [6][7], (e.g. synchronizing the amputated part with a robotic arm to insert a smart chip in the body [8]). However, the software or virtual devices available for hand amputees are insufficient. The virtual robotic arm is intended for the hand amputee. If their arm muscles are alive, the virtual robotic arm helps them. This means they can use EMG to contract and relax their muscles wearing EMG sensors such as those on the MYO armband. It is possible to control an object using their EMG in virtual space through the virtual robotic arm based on EMG.

Figure 4: Hand amputee

Figure 5: Device for amputee in practical life

Forearm muscles

The forearm refers to the region of the lower limb between the elbow and the wrist. The term ‘forearm’ is used in anatomy to distinguish it from the arm, a word which is most often used to describe the entire appendage of the upper and lower limbs, but which in anatomy, technically, means only the region of the upper arm, whereas the lower "arm" is called the forearm. It is homologous with the region of the leg that lies between the knee and the ankle joint, the crus. The forearm contains two long bones, the radius and the ulna, forming the radioulnar joint. The interosseous membrane connects these bones. Ultimately, the forearm is covered by skin, the anterior surface usually being less hairy than the posterior surface [9].

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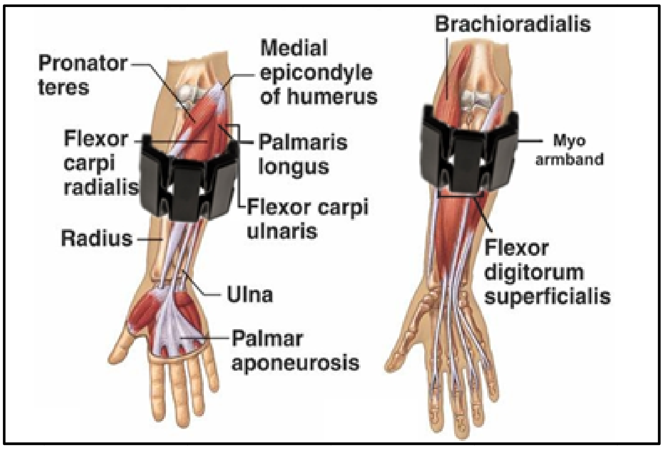

Figure 6: Forearm muscles

The forearm is divided into two compartments (a ventromedial or flexor compartment and a dorsolateral or extensor compartment), as can be seen in figure 6. The muscles of the forearm are segregated into these compartments, consisting of an anterior group (the flexors of the wrist and fingers and the pronators) and a posterior group (the extensors of the wrist and fingers and the supinator).

Architecture Design

A virtual robotic arm is composed of an EMG and robotic arm in virtual space. EMG is used for measurements made for the Myo armband, while the robotic arm in virtual space is produced by Unity 3D. They are connected to Bluetooth. The Myo armband has eight different parts, each of which contains a medical-grade EMG sensor. The armband also has a three-axis gyroscope and three-axis accelerometer. The Myo armband and the numbers of the sensors are shown in figure 7. These numbers are used in experimental results and are shown in figure 24.

Figure 7: Myo armband and numbers of the sensors

Design for virtual robotic arm

This section introduces the design for the virtual robotic arm [10]. Figure 8 shows the entire process of controlling the virtual robotic arm in Unity 3D. The first step involves creating space with targets and the virtual robotic arm in Unity 3D. The next step involves mapping the five functions of the robotic arm in virtual space to the five gestures measured by the Myo armband.

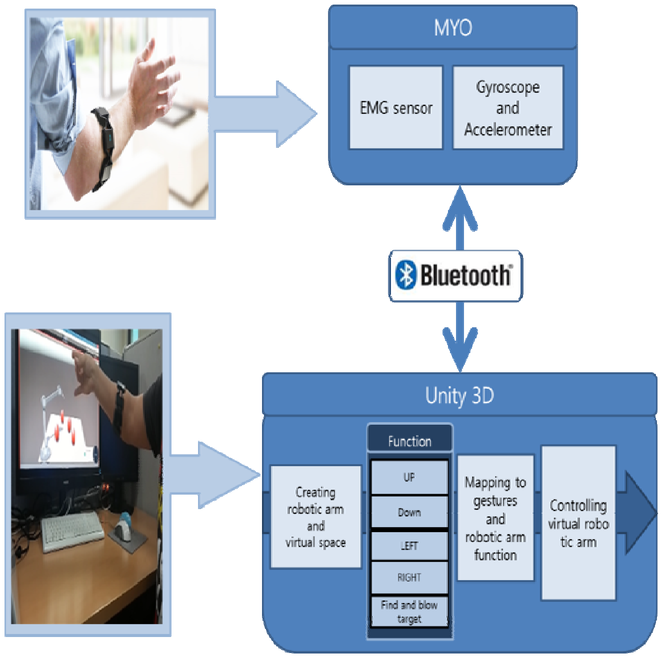

Figure 8: Architecture of the design for virtual robotic arm

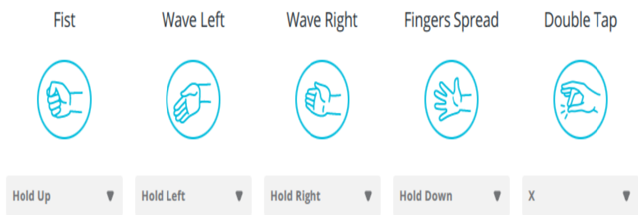

Figure 9: Five hand gestures and their functions

The mapping result is shown in figure 9. ‘Up’ is assigned to ‘Fist’, which has distinctly different activating rates than ‘Fingers spread’. Obviously, ‘Down’ is assigned to ‘Fingers spread’. These are the results from the activating rates of each EMG sensor part. Also, the mapped result can be changed by users. After these steps, the user can actually control the virtual robotic arm.

Experimental results

This section documents the experimental results. Figure 10 presents the results from eight EMG sensors in each gesture. It can be seen that in each gesture, different EMG sensors have different results. Subsection A shows the results from eight EMG sensors in five different gestures. In subsection B, graphs show data from the “Wave Right” gesture and show that part, of the eight parts of the forearm, that is electrically activated; the electrode voltage is shown in microvolts (μ V), which was obtained using the Myo data capture tool. Subsection E shows the EMG sensor controlling the virtual robotic arm.

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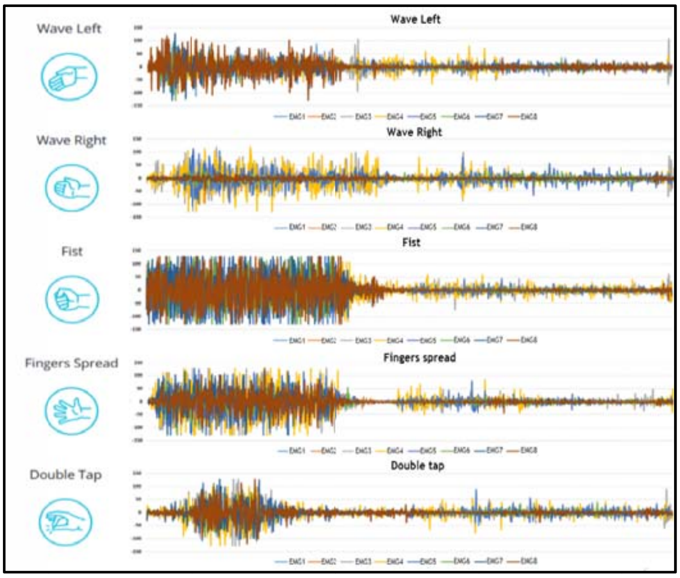

Figure 10: Data from eight EMG sensors in each gesture

In this case, five gestures were used: wave left for turning left robotic arm, wave right for turning right, fingers spread for raising up, fist placed down, and double tap with fingers automatically find balloons and burst them. Subsection F shows the gyroscope and accelerometer controlling the virtual robotic arm. In this case, the robotic arm moves in the X, Y, and Z directions.

Data from EMG sensors in each motion

In this section, the results from each EMG sensor in the five gestures are shown. Figures 11-15 show data from the EMG sensors and it can be seen that in different motions, the sensors are either active or not active [11].The Pod0 signal is matched with the Myo armband part number 1 in figure 7.

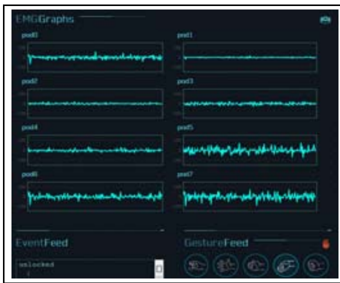

Figure 11: Wave in (left)

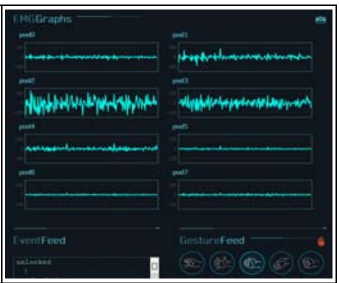

Figure 12: Wave out (right)

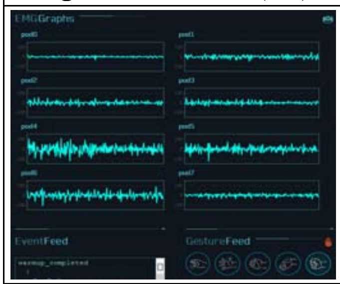

Figure 13: Fist

Figure 14: Fingers spread

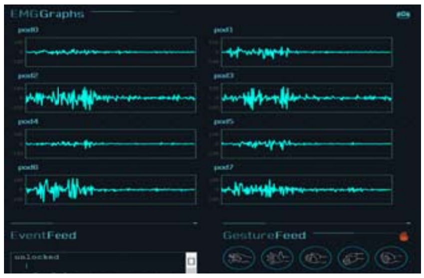

Figure 15: Double tap

Data from EMG sensors

Subsection A outlines the EMG for each motion. The EMG sensor is composed of eight parts with different data for each sensor as can be seen in figures 16-23. Subsection B shows graphs to check the activation rates for each part of the EMG sensor when making gestures such as 'Wave Right'. As a result, parts 3, 4, and 5 are electrically activating and parts 1, 2, 6, 7, and 8 are inactive.

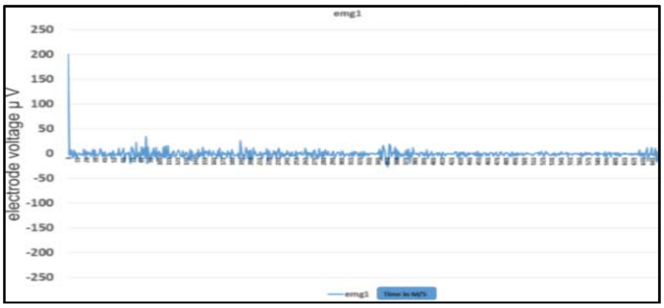

Figure 16: Data from EMG sensor1

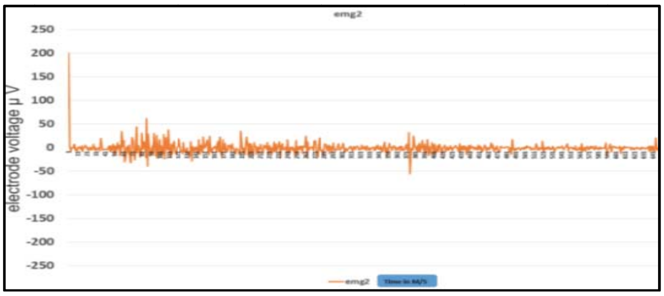

Figure 17: Data from EMG sensor2

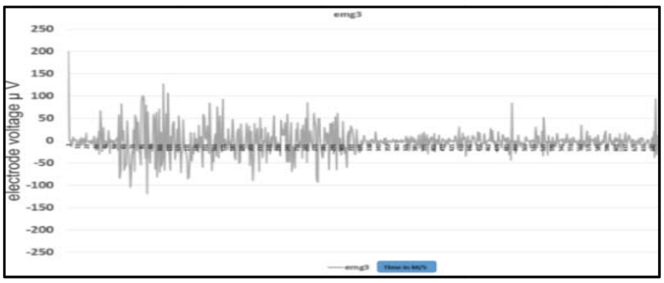

Figure 18: Data from EMG sensor3

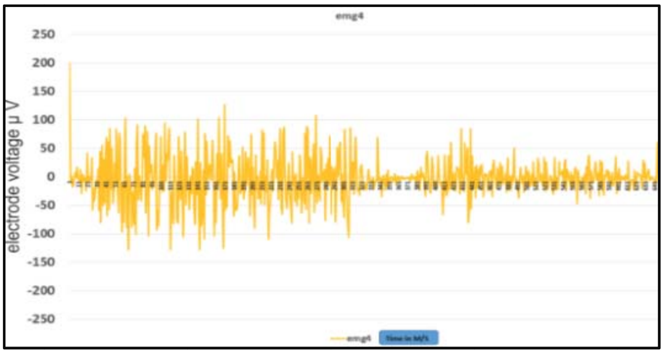

Figure 19: Data from EMG sensor4

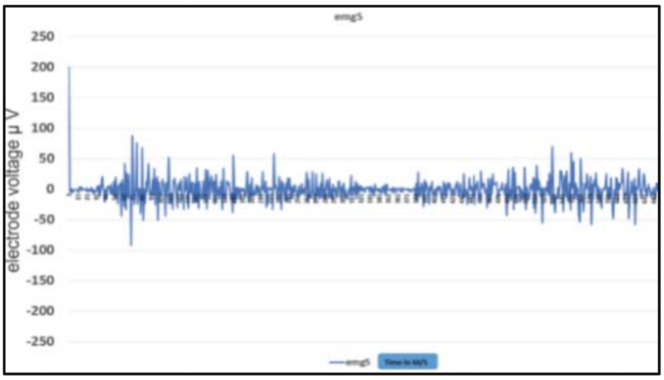

Figure 20: Data from EMG sensor5

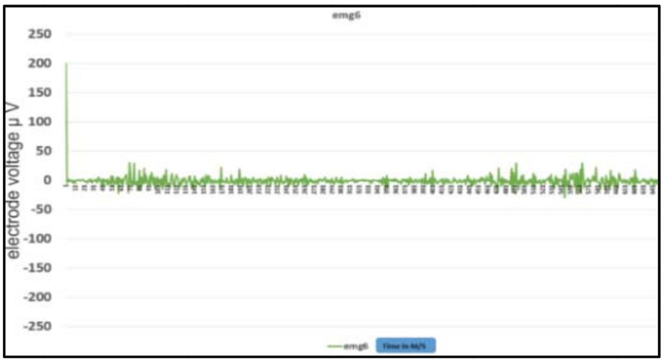

Figure 21: Data from EMG sensor6

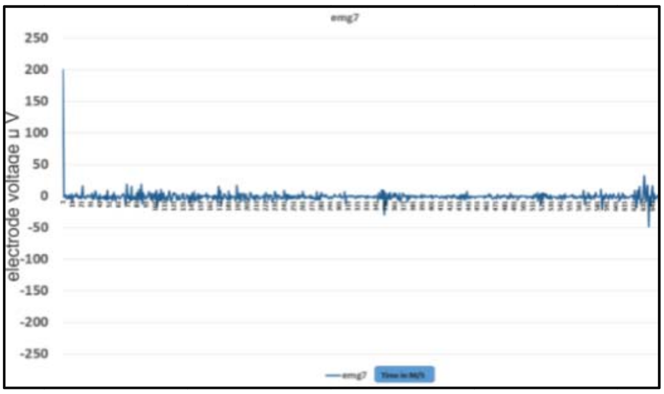

Figure 22: Data from EMG sensor7

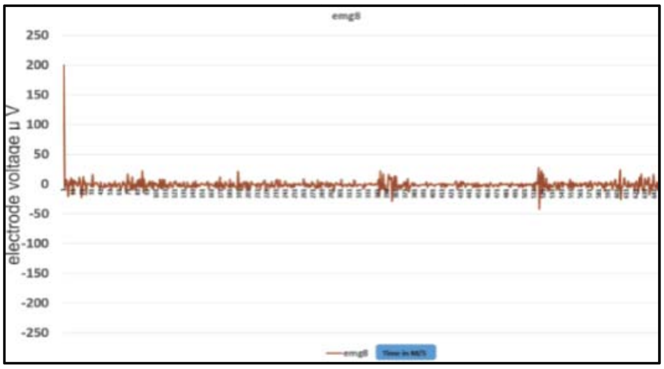

Figure 23: Data from EMG sensor8

Active sensors in each gesture

The eight sensor parts are composed of EMG sensors and each part has a different position, whereby each sensor measures the EMG in each position. The EMG sensor can thus check which parts are active and inactive. The EMG sensor can perceive each gesture and transmit information to the virtual robotic arm. The virtual robotic arm then implements the previously assigned function, as shown in figure 24, indicating the 'Wave left' and 'Wave right' of the five gestures. When performing these gestures, each part of the EMG sensor assumes a different aspect. Parts 1, 6, 7, and 8 are active in 'Wave left', while parts 3, 4, and 5 are active in 'Wave right'.

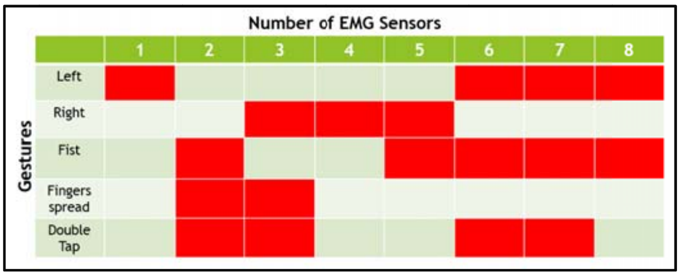

Figure 24: Dominance table showing which of the eight sensors are active in each motion

In [12], results were shown of the distinction of using muscles when making gestures, such as the brachioradialis muscle which affects the bending of the elbow, the pronator which is used to turn the wrist left and down, and the flexor digitorum superficialis which turns the wrist right and up.

In the case of 'Wave left', the pronator teres is more active than the flexor digitorum superficialis. The pronator teres is located in a relatively inner position. Therefore, the sensors located inside such as 1, 6, 7, and 8 show sensitive reaction. In the case of 'Wave right', the reaction of sensors distinctly changes as shown in figure 24. As shown in figure 25, the highlighted muscles are activated and the corresponding EMG sensors show oscillations.

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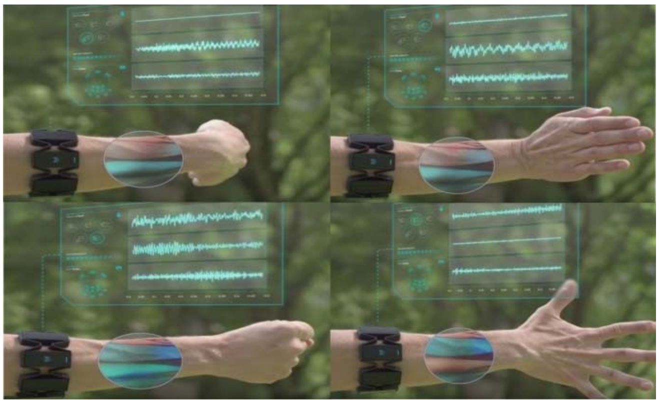

Figure 25: Muscle activities in gestures

Data from accelerometer and gyroscope

In our experiments, we used an accelerometer and gyroscope to control the robotic arm, and figures 26 and 27 illustrate data from the accelerometer and gyroscope in the X, Y, and Z directions.

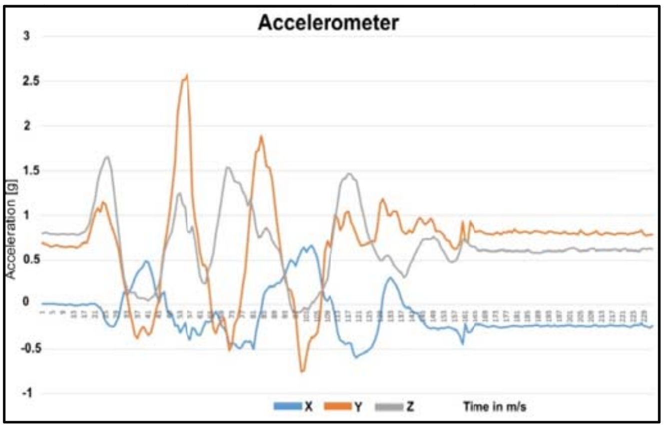

Figure 26: Data from accelerometer in random movements

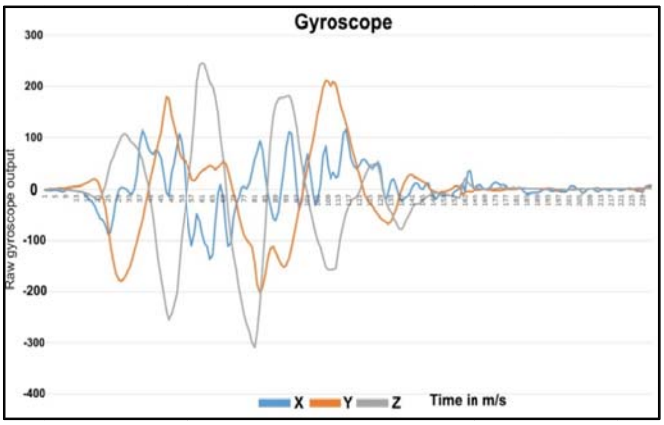

Figure 27: Data from gyroscope in random movements

The results from the accelerometer and gyroscope shown in figures 26 and 27 were obtained from random movements of the hand in the X, Y, and Z directions.

Controlling virtual robotic arm based on EMG

This section shows the results of controlling the virtual robotic arm using the EMG sensor, as shown in figures 28-32. Five gestures are used as follows: wave left for turning robotic arm left, wave right for turning right, fingers spread for raising up, fist facing down, and double tap of fingers for automatically finding balloons and bursting them.

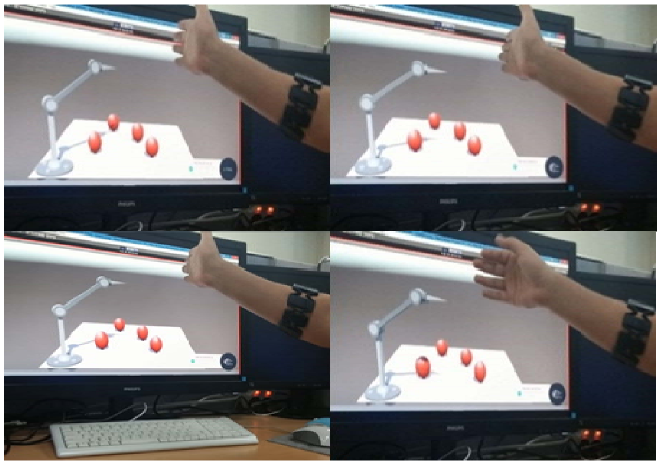

Figure 28: Wave Right-turns robotic arm right

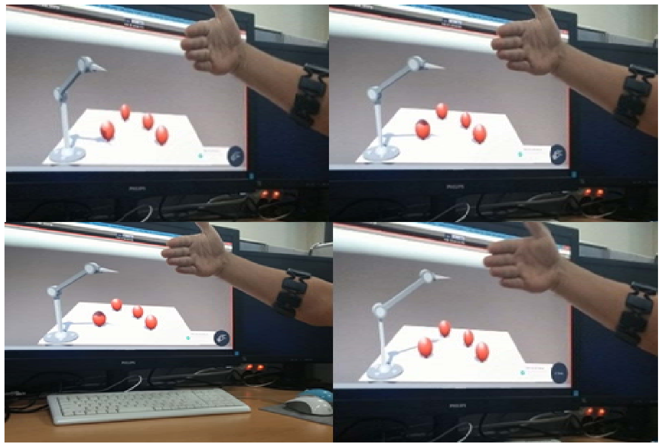

Figure 29: Wave Left-turns robotic arm left

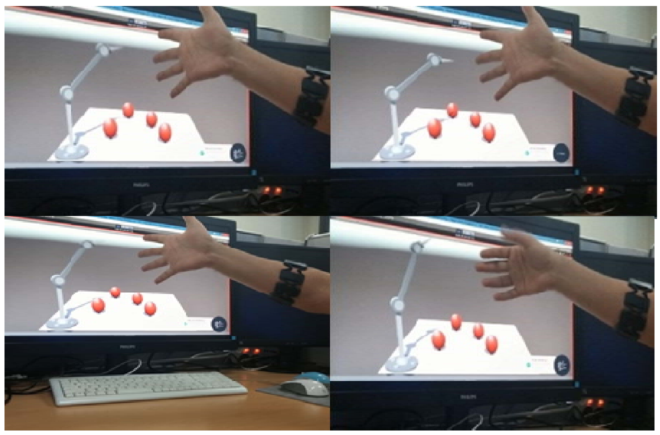

Figure 30: Fingers Spread –robotic arm rises up

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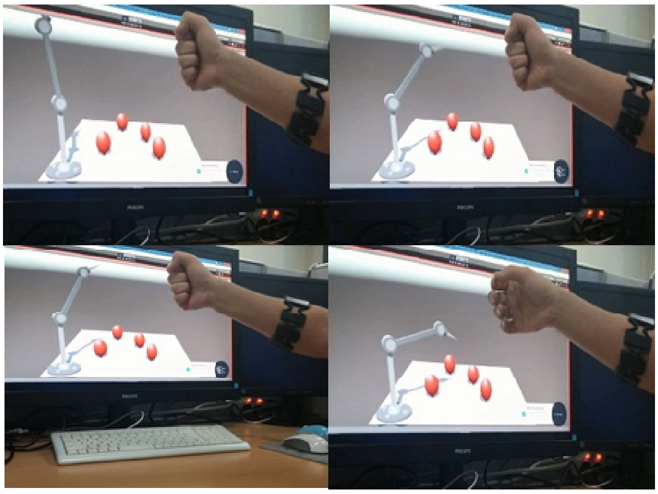

Figure 31: Fist –robotic arm is placed down

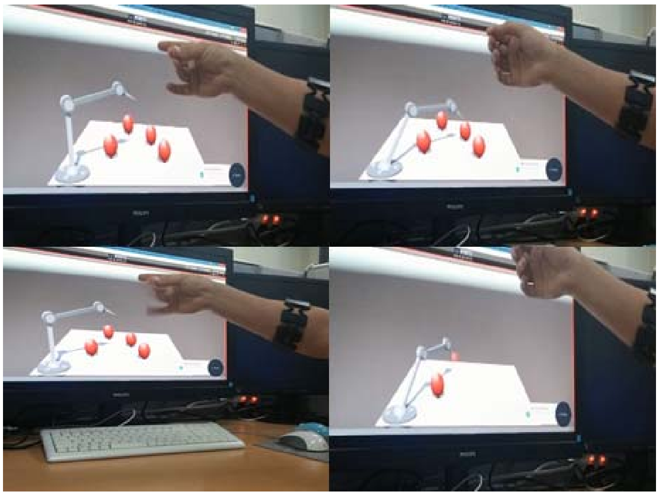

Figure 32: Double tap – robotic arm automatically finds balloons and bursts them

Controlling virtual robotic arm by gyroscope and accelerometers data in X, Y and Z directions

This virtual robotic arm is controlled by a gyroscope and an accelerometer. A gyroscope is inserted into the Myo device and can detect changes in orientation; this axis is unaffected by tilting or rotation of the mounting, according to the conservation of angular momentum. Because of this, gyroscopes are useful for measuring or maintaining orientation. Also, an accelerometer device is inserted in the Myo device and it measures proper acceleration ("g-force"). Proper acceleration is not the same as coordinate acceleration (rate of change of velocity) [13].

Figures 33-36 show the virtual robotic arm being controlled by using the gyroscope and accelerometer. In this case, the robotic arm moves in the X, Y, and Z directions.

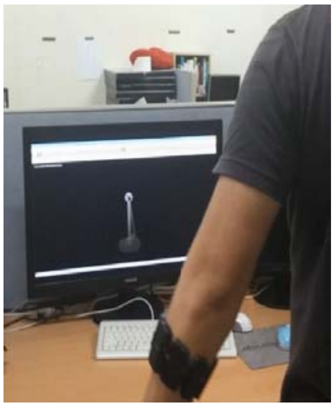

Figure 33: Putting arm down

Figure 34: Raising arm up

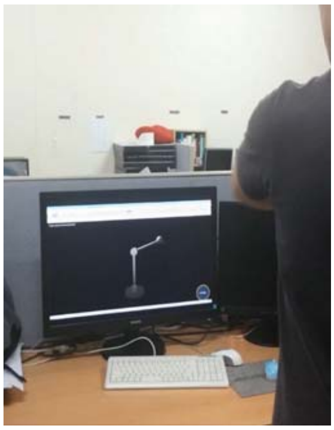

Figure 35: Turning Right

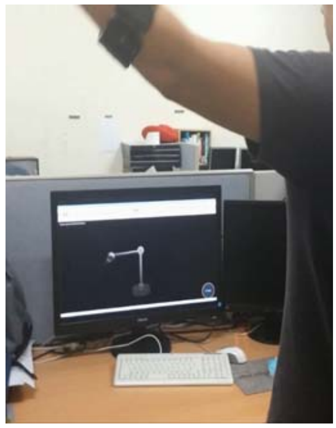

Figure 36: Turning Left

Without the need for the step of mapping gestures and functions, the virtual robotic arm controlled by the gyroscope and accelerometer makes it possible to coincide movements with the real arm. This is a strong advantage of the robotic arm based on the gyroscope and accelerometer. However, it is considered inappropriate for the case of hand amputee users because hand amputees find it difficult to perform the dynamic actions shown in figures 33-36. However, the virtual robotic arm based on EMG can be simply controlled by the tension and relaxation of muscles. This is the most significant advantage of the virtual robotic arm based on EMG and why the virtual robotic arm based on EMG is recommended for hand amputees rather than an arm based on a gyroscope and accelerometer.

Conclusion

In this paper, we showed how a virtual robotic arm, the prototype of which was built in Unity 3D, is controlled by using EMG, gyroscope, and accelerometer sensors. The best way to detect electro activities in muscles is to use the EMG sensor. The EMG sensor allowed us to obtain very clear and important data from forearm muscles and we used the data to control a virtual robotic arm. To verify the virtual robotic arm based on EMG, we compared it with another virtual robotic arm we made, which was controlled by a gyroscope and accelerometer.

Using the gyroscope and accelerometer to control the robotic arm showed that the dynamic movement of the entire arm is needed. On the other hand, the virtual robotic arm based on EMG needs specific muscle activities.

We view the work described in this paper as only the beginning of a large project. We intend to carry out the complete implementation of an EMG sensor and our aim is to use our knowledge and experimental results to make a bionic wrist for disabled people. The lives of hand amputees can be improved by using an artificial wrist for different purposes. In addition, it will be easy to remove the artificial wrist if the user does not need it at any time.

Acknowledgment

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