Electroencephalogram (EEG) Controlled Anatomical Robot Hand

H.M.K.K.M.B. Herath (kasunherathlive@gmail.com)
The Open University of Sri Lanka https://orcid.org/0000-0002-1873-768X
W.R. de Mel
The Open University of Sri Lanka

Short Report

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Abstract

Today, millions of peoples are suffering due to the lack of a functional arm preventing from doing things. In Sri Lanka there are about over thousands of people are suffering from disabilities. Sri Lanka Ministry of Health state that the number of disabled persons in Sri Lanka will be increased by 24.2% by 2025. Most of them will suffer from hand disabilities. Disabling a hand costs huge disadvantages to a human being. Living without a hand will be a major problem for those who having hand disabilities. The aim of this project is to give a solution to those who suffer from hand disabilities and make their life efficient and easy. The biosignal-based controlling system is the next step in order to achieve more accuracy. Bio-signals are referring as the Electroencephalography (EEG), Electromyogram (EMG) and Electrocardiogram (ECG) signals. The robot hand motions and movements of the fingers will be completely dependent on the brainwaves which human beings will produce. This project mainly focused on Electroencephalography (EEG) signals also known as the brain waves. The methodology of this project is based on the field of robotics, artificial intelligence (AI), anatomy, neuroanatomy, and biosignal.

1. Introduction

This project is about analyzing the human brain system and using brain waves extensively by performing some real-time activities implementing on the robotic hand model in order to address the common social issues such as medical and health care applications. Today, millions of peoples are suffering due to the lack of a functional arm preventing from doing things. In Sri Lanka there are about over thousands of people are suffering from disabilities. Sri Lanka Ministry of Health state that the number of disabled persons in Sri Lanka will be increased by 24.2% by 2025. Most of them will suffer from hand disabilities. Disabling a hand costs huge disadvantages to a human being. Living without a hand will be a major problem for those who having hand disabilities. The aim of this project is to give a solution to those who suffer from hand disabilities and make their life efficient and easy.

The field of robotics is growing fast in order to make people's life efficient and easy. There are various machines or robots designed are manufactured in this particular field to help handicapped people facing the problems like blindness, broken legs or arms, body part dislocation, etc. But design a robot for medicine is not that easy. There are some limitations in robotic works. One of the most important factors of robotic use in medicine is accuracy. Especially, the biomedical robotic designs are required very high accuracy when they taking the decisions. The biosignal-based controlling system is the next step in order to achieve more accuracy. Bio-signals are referring as the Electroencephalography (EEG), Electromyogram (EMG) and Electrocardiogram (ECG), etc. The robot hand motions and movements of the fingers will be completely dependent on the brainwaves which human beings produced. This project mainly focused on Electroencephalography (EEG) signals also known as the brain waves. However, according to concepts related to bio-medicine and engineering, we will hope to design and develop a three-finger robotics arm that will be controlled by the human brain. This robotic hand will be designed to pick and hold objects using the mind and also more useful for people who having hand disabilities.

Problem statement

1. Millions of people suffer from disabilities and reside in countries all over the world. The majority of them have problems with their arms, hands, and legs.
2. According to the Ministry of Health's annual report, the overall number of disabled persons in Sri Lanka is expected to rise by 24.2 percent by 2025. A large number of people will suffer from hand disabilities as a result.
3. Table 1 depicts the results of the 2012 Census of Population and Housing (Sri Lanka). According to the data, Sri Lanka has a significant number of persons with hand disabilities.

Table 1
The Census of Population and Housing Data of Sri Lanka (2012).

Major District in Sri Lanka	**Type of Disability (%)**			
	Seeing	**Hearing/Speaking**	**Hand**	**Legs**
Colombo	26.8	28.7	**21.7**	41.0
Gampaha	34.0	38.0	**25.2**	48.3
Kaluthara	44.2	47.5	**30.8**	58.5
Kandy	35.7	42.4	**25.9**	49.4
Kurunegala	45.0	49.2	**32.8**	63.5
Anuradhpura	52.3	49.9	**33.6**	67.1

Even now, these percentages are getting increasing. The disabling hand is costs huge disadvantages to a human being. Living without a hand is a major problem for those who have hand disabilities. This project gives a solution to those who suffer from the hand disabilities and make their life efficient and easy.

Anatomy of the Human Hand

The bones of the human hand (Fig. 1) and wrist give support and flexibility to the body, allowing it to move things in a variety of ways. Each hand has 27 different bones, which give it an amazing range of motion and accuracy. The thumb, index, middle, ring, and little fingers are the five fingers of a human hand. The fingers move in two main ways:

- Flexion
- Extension

We can flex our fingers to grab and hold onto objects and extend our fingers to reach out for things. Usually, each finger joint can be controlled individually and the human hand can bend the distal joint (at the fingertip) and the proximal joint (in the middle of the finger) separately. When all the finger flexor muscles and tendons pull together, humans make a tight fist.

Human fingers are compromising with 3 main joints,

- DIP – Distal Inter Phalange
- PIP – Proximal Inter Phalange
- MCP – Metacarpus Phalange

These joints have different relative motion angles (as shown in Table 2).

Table 2
Finger Motion Angle of MCP, PIP, DIP.

Finger Joint	Motion angle / degree (∘)
MCP	$0 < \theta < 100$
PIP	$0 < \theta < 105$
DIP	$0 < \theta < 85$

EEG Lead Systems

The internationally standardized 10–20 system is usually employed to record the spontaneous EEG. In this system 21 electrodes are located on the surface of the scalp, as shown in Fig. 2, A and B. Reference points are Nasion, which is the delve at the top of the nose, level with the eyes; and Inion, which is the bony lump at the base of the skull on the midline at the back of the head. From these points, the skull perimeters are measured in the transverse and median planes. Electrode locations are determined by dividing these perimeters into 10% and 20% intervals. Three other electrodes are placed on each side equidistant from the neighboring points, as shown in Fig. 2B. In addition to the 21 electrodes of the international 10–20 system, intermediate 10% electrode positions are also used. The locations and nomenclature of these electrodes are standardized by the American Electroencephalographic Society. In this recommendation, four electrodes have different names compared to the 10–20 system; these are T7, T8, P7, and P8.

Bipolar or unipolar electrodes can be used in EEG measurement. In the first method, the potential difference between a pair of electrodes were measured. In the latter method, the potential of each electrode is compared either to a neutral electrode or to the average of all electrodes.

2. Design And Development

The motor cortex is one of the most important regions of the brain for controlling voluntary movements. The mental execution of a movement without any overt movement or muscle activation is referred to as motor imagery. The motor cortex is found near the back of the frontal lobe, right before the central sulcus, which divides the frontal and parietal lobes.

The motor cortex is divided into two main areas, Area 4 and Area 6. Area 4, also known as the primary motor cortex, forms a thin band along the central sulcus. For this project, EEG electrodes are needed to place to cover the primary motor cortex. The primary motor cortex is mainly responsible for motor imagery which is very important for hand movements of the human body. By using the OpenBCI Toolkit, we used 8 channels (FC3, FC4, C1, C2, C3, C4, Cz, and CPZ) to cover the primary motor cortex of the human brain.

Design of the Logical Controller

The 8 EEG signal waves were captured using 8 electrode channels and then sent to the OpenBCI Module. The noise in the EEG wave signal was reduced by utilizing this module. The in-built signal amplification device of the OpenBCI module allowed recorded EEG signals to be amplified and sent to MATLAB.

With the aid of MATLAB Low pass filtering algorithms, 50 Hz signals were cut off from the original signal. And then the signals less than 1 Hz were filtered using a high-pass filtering algorithm. For the motor imagery, we were filtered mu rhythms. Therefore, by using the band-pass filtering algorithm mu range waves (7–13 Hz) were filtered. By using the SVM classifier, the signal was separated into two classes which in turn hand left and turn hand right. By using the decisions controller class left will give the signal to the SynGrasp toolbox to flexion for the fingers and the class right will give the signal to extension for the fingers.

3. Results

Figure 5 and 6 represents the raw EEG data and band-pass filtering results respectively. As shown in Figure 5, the wave was composed of artifacts. Therefore, band-pass filtering was applied with 13 Hz high pass, 7 Hz low pass, and 250 Hz sampling frequency.

The field of electrophysiological data analysis has been dominated by analysis of 1-dimensional event-related potential (ERP) averages. An event-related potential (ERP) is the measured brain response that is the direct result of a specific sensory, cognitive, or motor event. More formally, it is any stereotyped electrophysiological response to a stimulus. The study of the brain in this way provides a non-invasive means of evaluating brain functioning.

Latency is the time interval between stimulus presentation and the point of maximal value (peak) of a defined component. It is expressed in milliseconds and represents the time taken by the stimulus information to generate the component. Following scalp map (Figure 7) is representing for the 0 ms to 180 ms.

The following figure (Figure 8) shows the robot hand simulation for the EEG output signals. When the EEG grabs the commands for imagination for the hand left rotate movement, simulation was started to flexion and when the imagination for the hand rotates right, simulation was started to extend.

4. Discussion And Conclusion

In this project, we used the electrode touch to the motor cortex area of the head without using the gel. But in practice, this is not suitable because it will cause noise to the output signals. For good results, a gel is used in electrodes have multiple advantages such as,

- Provide contact with the skin when the electrode applied to an heir covered surface
- Provide an interface that allows minor movements without loss of contacts
- Keep the skin wet and conductive

As a solution to fulfill the above tasks following method is suggested,

In this project, we used the EEG signals to control the robotics hand, according to the objective and results in there is not possible to catch the class for individual hand movements. EEG signals release from the primary motor cortex are only responsible for hand movements. When we imagine grasping some object, it is possible to flexion all the fingers at once. But movements like real human hands are not possible with this practice. The flexion angle for the distal, intermediate, and proximal phalanges cannot be decided with this practice. But using EMG it is possible to identify the movements for the individual fingers. Power spectral analysis also provides the quantitative measure of the frequency distribution of the EEG.

Declarations

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Declarations

- The authors declare no competing interests.
- The authors affirm that human research participants provided informed consent for publication.

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Figures

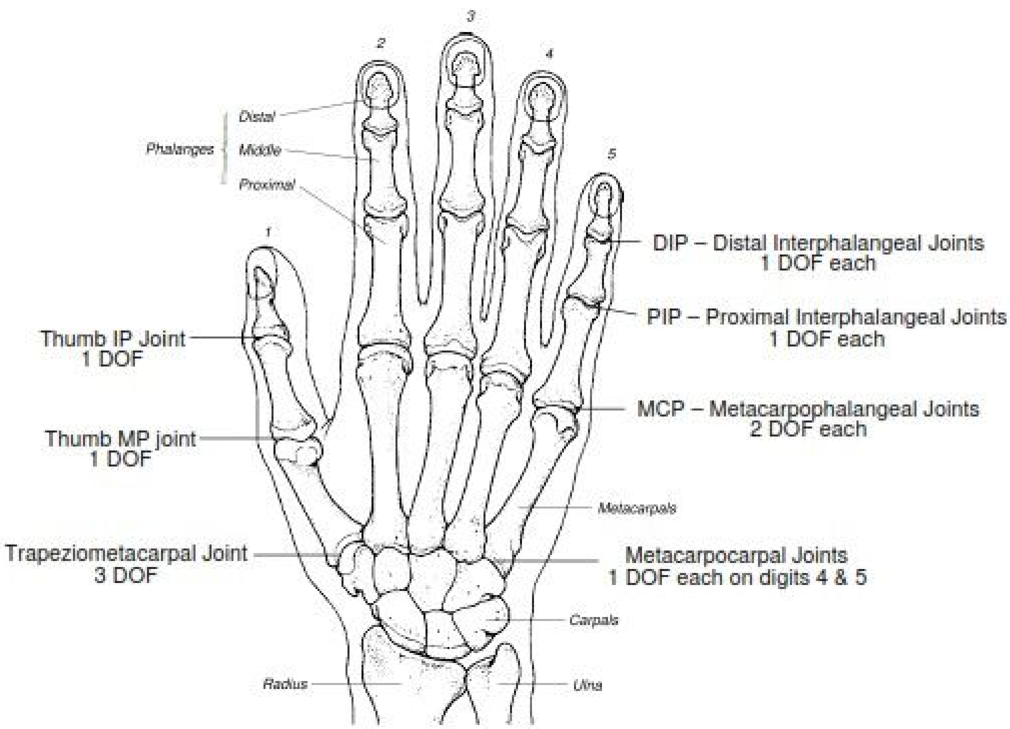

Figure 1

Anatomy of the Human Hand.

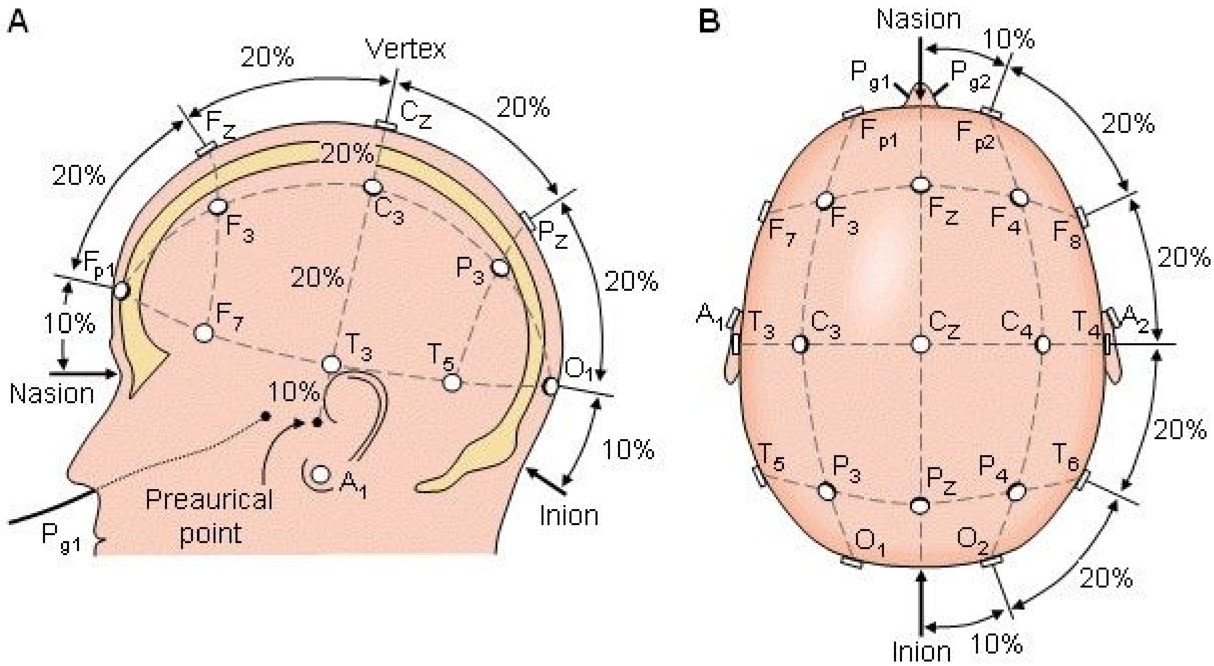

Figure 2

The International 10-20 System. Seen from (A) Left and (B) Above the Head.

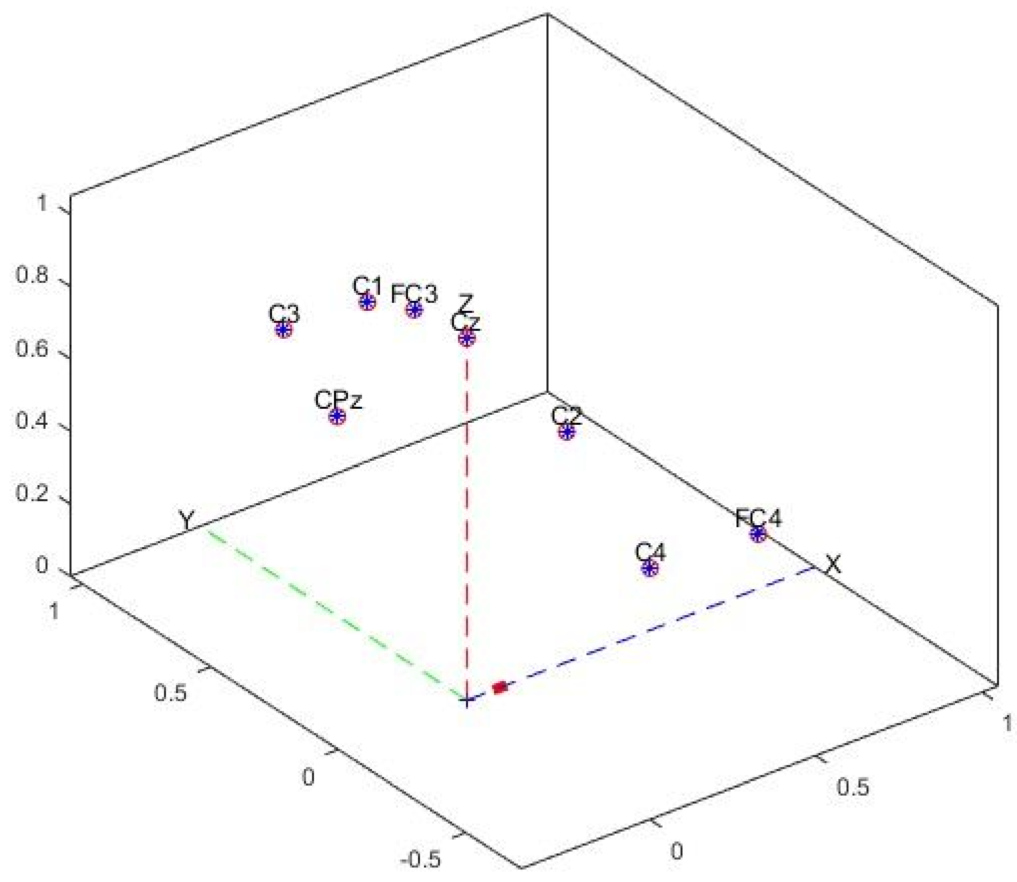

Figure 3

EEG Sensor Channel Location’s 3D-Plot (X, Y, Z).

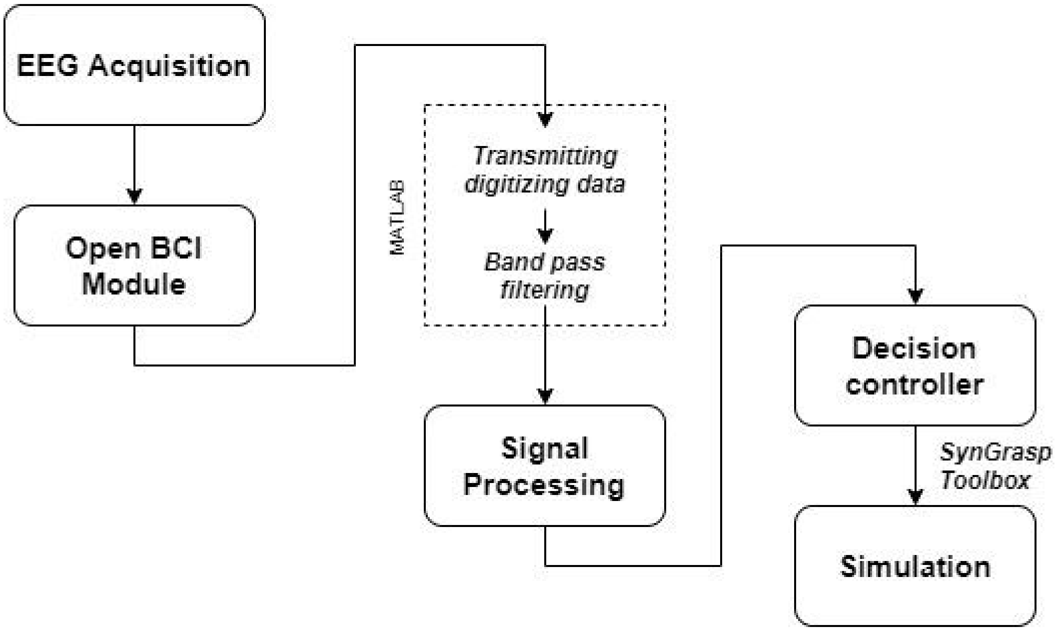

Figure 4

The architecture of the Proposed System.

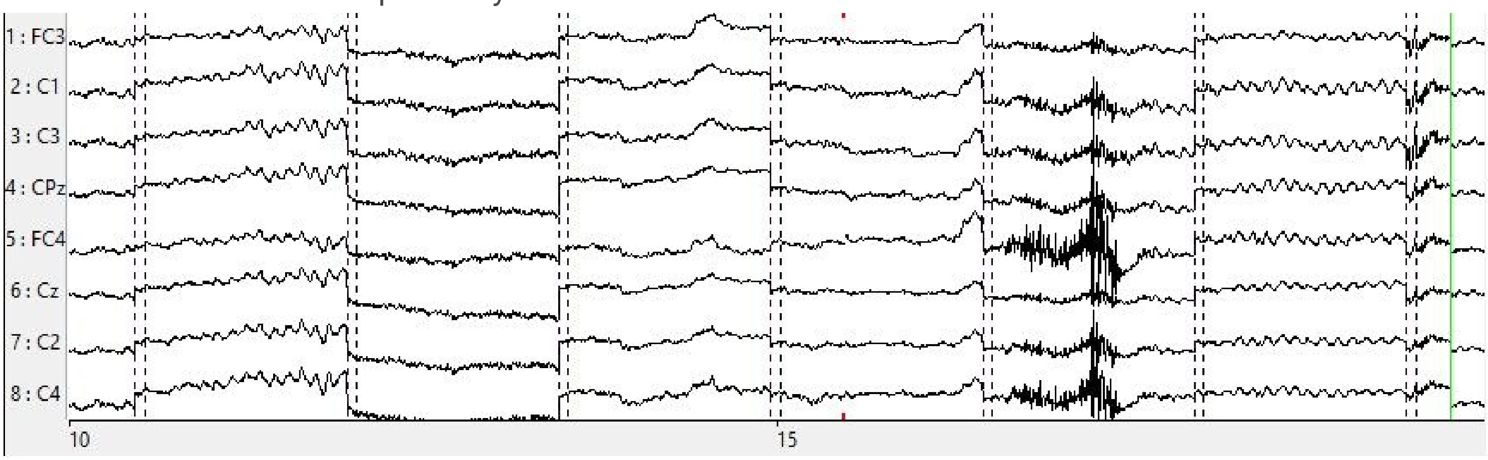

Figure 5

Raw EEG wave.

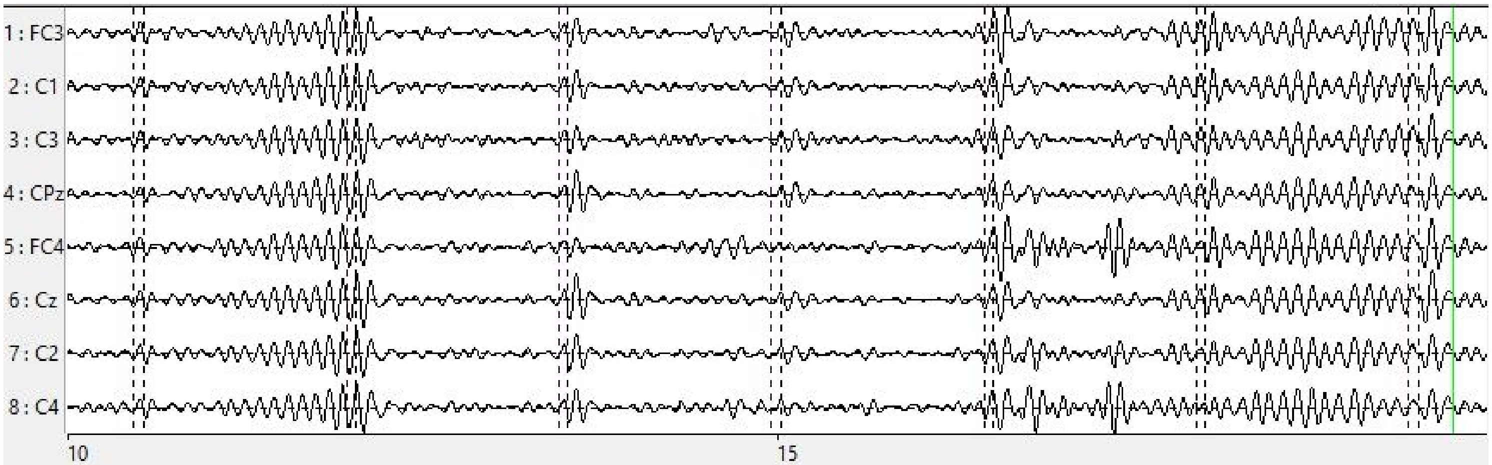

Figure 6

Band-pass Filtering Output.

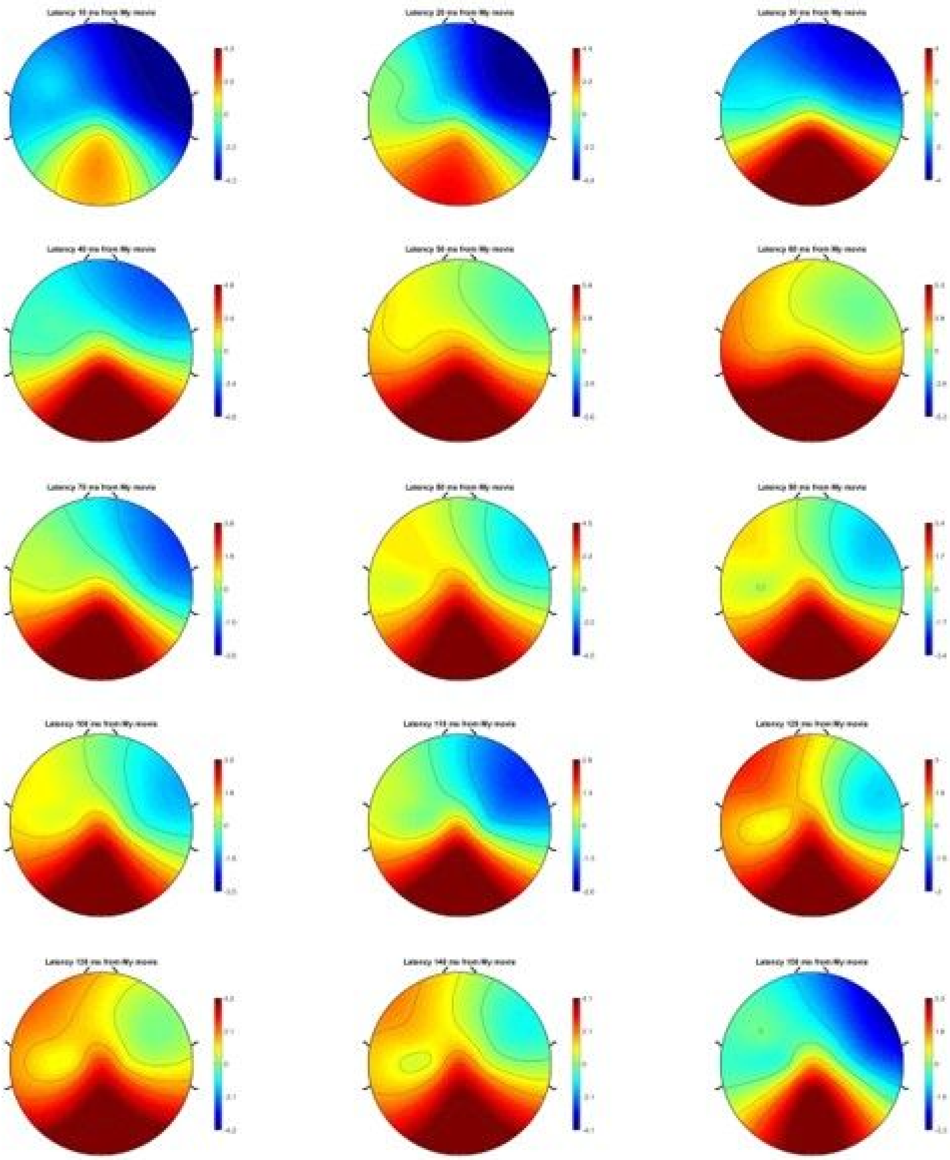

Figure 7

EEG Channel’s Scalp Map for Latency.

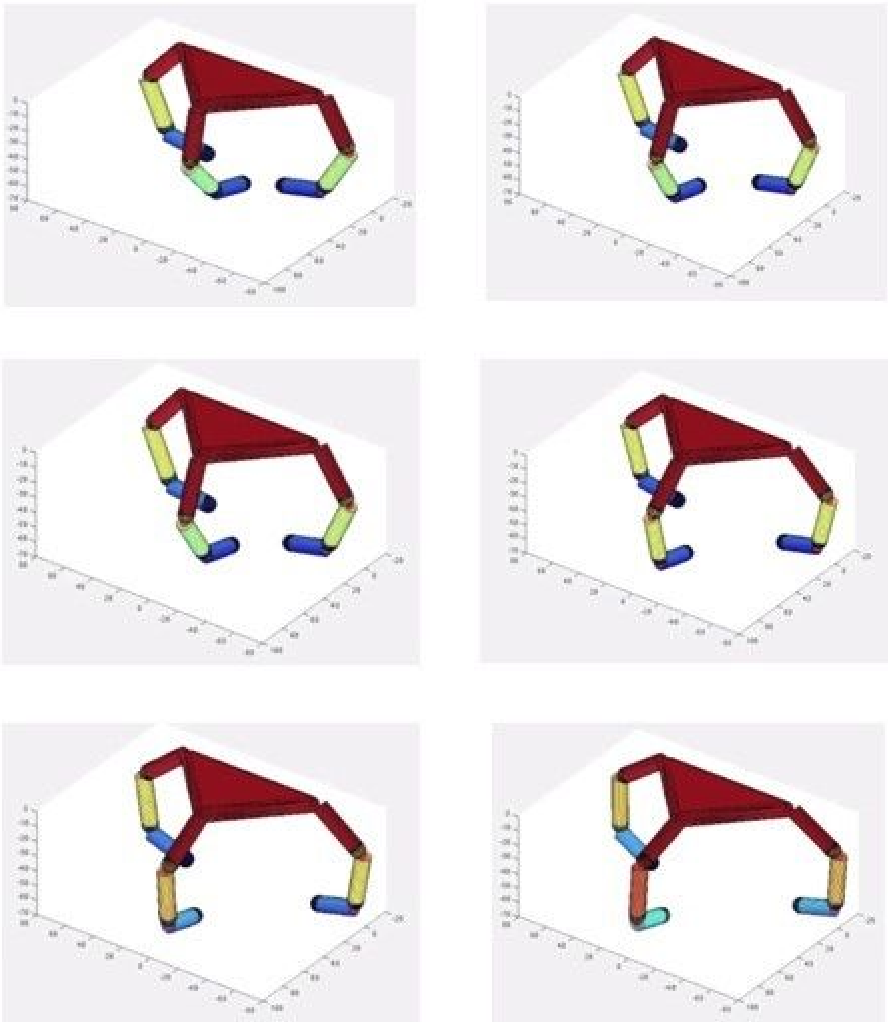

Figure 8

SynGrasp Hand Model Simulations Results for the EEG Response.