Viability of Controlling Prosthetic Hand Utilizing Electroencephalograph (EEG) Dataset Signal

Azizi Miskon*, Suresh A/L Thanakodi, Mohd Raihan Mazlan, Satria Mohd Haziq Azhar, and Siti Nooraya Mohd Tawil

Department of Electrical and Electronic Engineering, Faculty of Engineering, National Defence University of Malaysia, 57000 Kuala Lumpur, Malaysia.

azizimiskon@upnm.edu.my

Abstract. This project presents the development of an artificial hand controlled by Electroencephalograph (EEG) signal datasets for the prosthetic application. The EEG signal datasets were used as to improvise the way to control the prosthetic hand compared to the Electromyograph (EMG). The EMG has disadvantages to a person, who has not used the muscle for a long time and also to person with degenerative issues due to age factor. Thus, the EEG datasets found to be an alternative for EMG. The datasets used in this work were taken from Brain Computer Interface (BCI) Project. The datasets were already classified for open, close and combined movement operations. It served the purpose as an input to control the prosthetic hand by using an Interface system between Microsoft Visual Studio and Arduino. The obtained results reveal the prosthetic hand to be more efficient and faster in response to the EEG datasets with an additional LiPo (Lithium Polymer) battery attached to the prosthetic. Some limitations were also identified in terms of the hand movements, weight of the prosthetic, and the suggestions to improve were concluded in this paper. Overall, the objective of this paper were achieved when the prosthetic hand found to be feasible in operation utilizing the EEG datasets.

1. Introduction

In the late '40s, Malaya had faced a violent incident involving the Malayan Communist Party until a state of emergency were declared during the time. Establishing another communist country was the aim and many approach were done to win and influence the races in Malaya to support the establishment of communism in Malaya. Malayan troops were sent to ambush the Malayan Communist Party in order to resolve this critical terrorism and the mission accomplished successfully by mid of 1960.

However, during these period of counter communist, a substantial number of soldiers involved in the battle experienced some form of physical loss especially the loss of limbs mostly due to active landmines. This scenario considered to be common now not only limited to arm forces but limb amputations due to diabetes health conditions. Many researchers have worked on the artificial prosthetic in order to help disabled people due to health conditions, war, or even accident. It’s done to help physically challenged people to live a better life. The idea of giving the disabled people new perspective in life motivates the idea to develop an artificial hand controlled using Electroencephalograph (EEG). The main objectives of this research work were to develop the artificial hand using Electroencephalograph (EEG), the EEG datasets were used as an input to control the artificial hand and to evaluate the time lapse for the artificial hand to response.

1.1 Prosthetic hand

Prosthetics were designed to replace the lost parts of human body [1]. It’s a part of bio-mechatronic and science field that uses mechanical tools with human structure and nerve system to help or improve the ability of a lost body parts [2]. Moreover, the artificial hand considered to be one of the solutions that could be used for people who have lost hand as a result of unexpected incidences. It can be used even in myriad physical activity without experiencing any form of damage. Sports, load lifting, eating, typing, driving are just some of the examples in utilizing the device. Basically, prosthetics allow for the user to have the same practical functionality as a normal hand [3].

Many types of prosthetics for hands can be found such as mechanical hands, electrical hands, hybrid hands and myoelectric hands [1]. The mechanical hand functions when several movements were made in order to activate the power to control the prosthetic hand while the electrical hand uses external devices and receives power from an external source of electricity to the body. The hybrid hand uses both a motor and a battery to provide power to the prosthetic hand whereas the myoelectric detects signals by electrodes placed on the muscles known as Electromyography (EMG).

The user has own choice in choosing respective type of prosthetic hand according to personal preferences. Each type has its' own advantages and disadvantages. For instance, the mechanical hand is light, reasonably priced, and durable while the electrical hand expensive compared to others, heavy and not as durable as others. The hybrid system prosthetic hand has external devices that run on motor and battery, making it heavy. It's also expensive and dependent on the battery life. On the other hand, the myoelectric hand has to detect Electromyography (EMG) signals which can be lost due to muscular atrophy [4]. As to improvise the current features, a new development of artificial hand using an EEG signal datasets were applied to control the prosthetic hand for prosthetic application.

1.2 Electroencephalograph (EEG)

The brain is the center of all human body activity or in another words, the headquarters of human body. All the activity in the brain can be measured by electrical frequencies in the unit of Hertz (Hz) [5]. This organ considered as a very significant organ due to its functionality covering almost entire body functions including intelligence, emotions, and actions. The human brain has four types of brainwaves known as Delta, Theta, Alpha and Beta waves which make up the Electroencephalograph (EEG) [6].

Table I: Types of Brainwaves and Brain State

Beta (15Hz-30Hz)	Awake, normal alert consciousness
Alpha (9Hz-14Hz)	Relax, calm, meditation, creative visualization
Theta (4Hz-8HZ)	Deep relaxation and meditation, problem-solving
Delta (1Hz-3Hz)	Deep, dreamless sleep

Table I summarizes the brainwave categories with the respective brain state [7]. Alpha wave known to be more relaxing while Beta waves more into thoughts and excitements. Delta waves commonly experienced during sleep and Theta waves generated during deep relaxation. EEG is a tool that has ability to record all electrical activity in the brain from electrodes over the scalp [8].

EEG usually used in many applications [9] in medical field, for epilepsy, sleep disorder, brain death and migraine diagnosis. Figure 1 shows some of the examples of diagnosis performed using the EEG. Other than that, EEG also applied in gaming application for cursors control, control archery and moving objects.

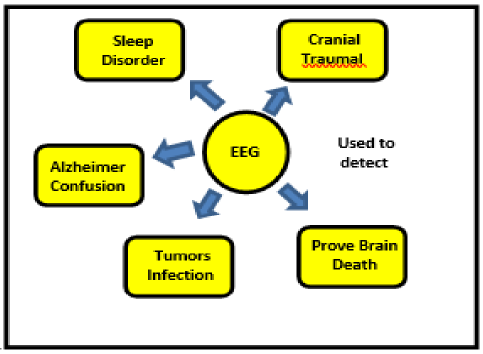

Fig 1. Diagnosis can be detected by EEG

1.3 Machine Interface (BMI)

This system includes the operation of the computer and the machines by thought as a control device. BMI systems work as a new communication channel to humans by measuring neurophysiological signals from the human, captured by the electroencephalograph (EEG) signals in particular. EEG-based BMI systems designed to decode the intention of the human user and generate commands to control external devices or computer applications. For initial study purposes, non-invasive technology applied using electrodes over the scalp [10]. The EEG method uses several electrodes to obtain the potential electrical signal over the scalp that causes brain action. The number of electrodes ranges from one to multiple, depending on the usage.

In this research work, the BMI system was used in controlling the artificial hand, through the EEG datasets, with some interface software such as Arduino software and Microsoft Visual Basic.

1.4 System Architecture

As illustrated in Figure 2, the proposed system architecture consists of two main subsystems: Datasets of the open, close, and combination of hand movement with Interface system. Prosthetic hand represented the machine. So, through this research work, the fundamentals of controlling the prosthetic hand using the EEG datasets were studied.

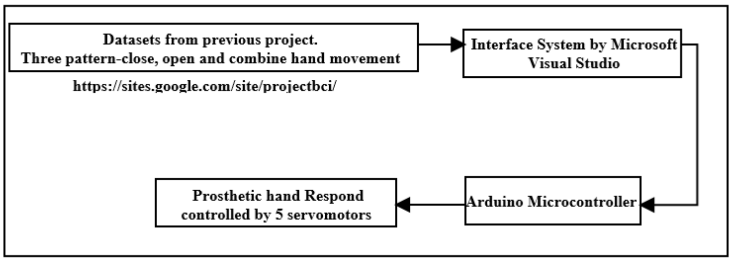

Fig 2. System Architecture

Figure 2 shows the overall process whereby the datasets were used to be an input to control the prosthetic hand. It was then read and loaded in Microsoft Visual Studio (as the Interface System) to the Arduino. The Arduino then, read the data and control the prosthetic hand accordingly. The response time taken recorded by the time lapse of the movement with and without an additional supply.

2. Methodology

2.1 EEG Datasets

The EEG datasets used in this research work were collected from the right-handed subject. The datasets used were from a healthy person aged 21 years old with no known medical conditions. Three signals were recorded in the process of obtaining brain signals and classified for hand movements including closing and opening all fingers, as well as with combination hand movements too. The EEG datasets were taken from the previous related works obtained at the following site: https://sites.google.com/site/projectbci/ . All datasets were recorded by using C3 electrode and the data were recorded in excel spreadsheet format file.

2.2 Hardware and Software Setup

The hardware consists of computer and the prosthetic hand with Arduino microcontroller equipped with servomotors. Figure 3 illustrates the hardware setup used in this research work.

2.3 System Description

The hydrogen sensor module prepared by coding the Arduino microcontroller, which being utilized to measure the hydrogen in parts per million (ppm). A hydrogen harvesting jar was built by attaching the MQ-8 Hydrogen H2 Sensor Module (Fig. 1) hydrogen sensor just below the cover and the Arduino Uno R3 (Fig.2) on the top. Then, all the holes of the cover were sealed with hot glue to ensure the most precise reading of hydrogen. This sensitive hydrogen sensor module which can measure from 10 to 1000 ppm is responsible to detect the hydrogen produced by the algae in the hydrogen jar. Arduino Uno R3 is the microcontroller programmed to be used as a medium of interaction by receiving input from the hydrogen sensor module and sending output to the laptop for data recording purposes. The coding commands the Arduino to display the hydrogen reading in ppm every second.

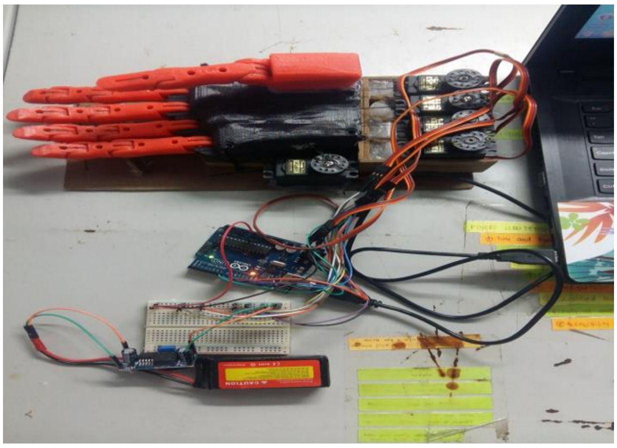

Fig 3. Overall Hardware Setup

In making sure minimal cost occurs for this research work, the artificial hand used for this work were from the previous research work done, and due to design limitations of the hand, this project focuses on the functionality responses of opening, closing and combination movements of the hand. The artificial hand controlled using five servo motors connected to the Arduino. Figure 4 illustrates the connection between the servo motors, Arduino and the input from Visual Studio.

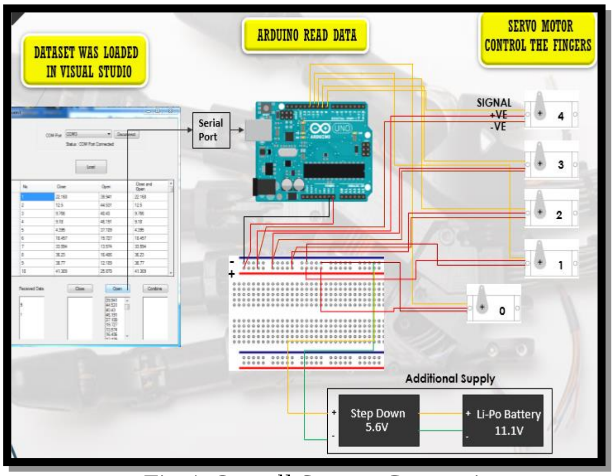

Fig 4. Overall System Connection

As for the software part, the Microsoft Visual Studio and Arduino software both involved in order to run this research work. Basically, the EEG datasets recorded in the excel spreadsheet format loaded to Microsoft Visual Studio then the datasets were interfaced with Arduino software to command the Arduino Uno microcontroller to control the prosthetic hand respective to the input data given from Microsoft Visual Studio.

2.4 System Description

The system development was carried out using an object-oriented programming language in Visual Studio 2010 and the application was manipulated to give commands to the artificial hand.

2.4.1 Arduino and Arduino Software

The microcontroller used in this work dedicated to one-task-and-run specific programs. It can execute tasks received from inputs via ports (read from external hardware), store data in file registers & arithmetic operations (added, subtracted, logic gates) and sent out data (control external hardware). The Arduino Uno has ATmega328 microcontroller and operates at 5V. The recommended input voltage ranges between 7-12V whereas the given input voltage ranges from 6-20V. The Arduino Uno illustrated in Figure 5. By connecting to the PC, Arduino board were programmed and the task to be executed were set by using Arduino software.

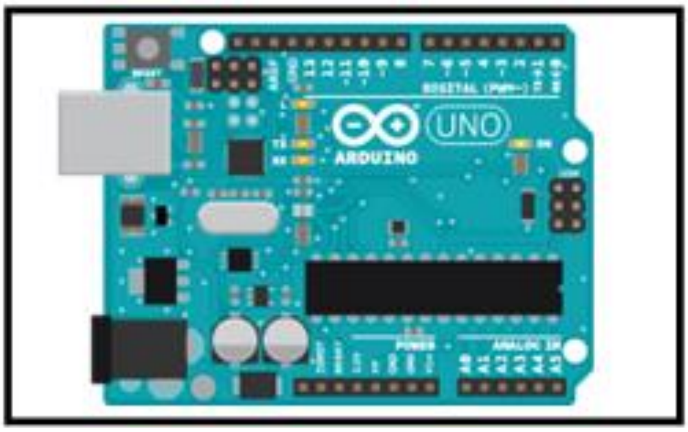

Fig 5. Arduino Uno Microcontroller

2.4.2 TowerPro MG995 Servomotor

Servomotors were used in this research work to move the fingers on the prosthetic hand. Higher voltage input results in a more rotational angle of the motor. The input signal for the motors were driven from Arduino which is at 5V. Due to the nature of Arduino's voltage suitability to suit one servomotor, additional supply, LiPo battery 11V with step down to 5.6V were used as an alternative too. The weight of each TowerPro MG995 is 55gram. With a dimension of 40.6mm x 19.8mm x 42.9mm (length x width x height) makes it bulky and heavy for the prosthetic hand. Since this research work focuses on the feasibility of operating the prosthetic hand using EEG, the dimensions and weight consider acceptable. All five fingers were able to open, close and execute combination functions.

2.5 Overall System Flow Chart

Figure 6 illustrates the flowchart of the overall process. Firstly, the computer and the prosthetic hand connected using the serial port, then, the datasets from the previous project were loaded to Microsoft Visual Studio. Next, the selection for first movement takes place either close, open or combined movement. Sample of input data for Microsoft Visual shown in Figure 7.

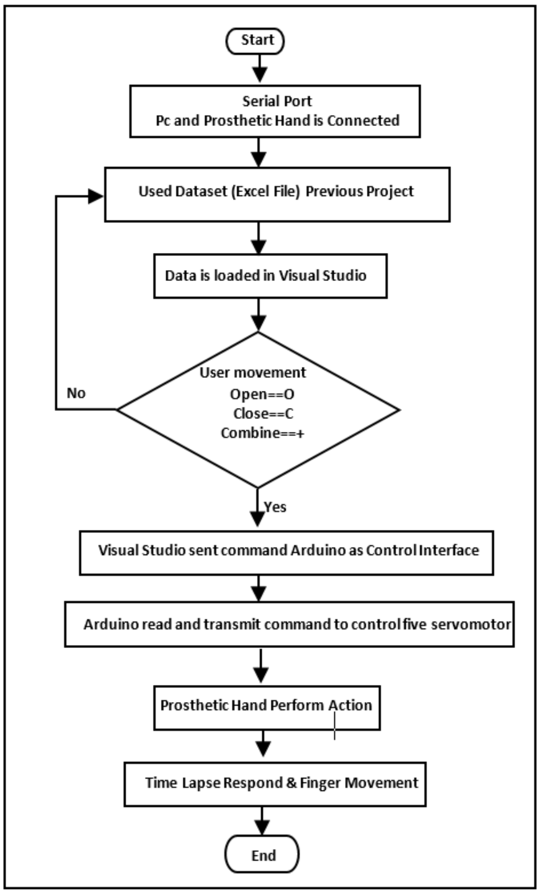

Fig 6. Flow Chart of Overall System

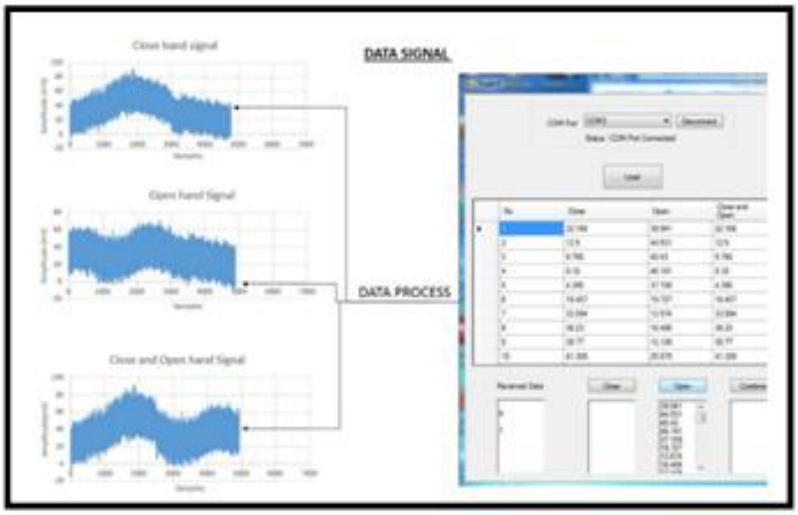

Fig 7. The Input Data for Microsoft Visual Studio

Once the input data received by the Microsoft Visual Studio, execution command to Arduino as Control Interface takes place whereby Arduino executes the commands and directly controls the five servomotors to act according to the selected movement. During this process, time lapse data recorded to measure the time taken for the prosthetic hand to respond.

2.6 Flow Chart of Arduino Works

Arduino work was connected by using serial port into the computer. All data can be transmitted and received through the serial port for communication with the devices or computer. In this project, the Arduino works as the control interface which received from the Microsoft Visual Basic and read the command then transmitted the command to the servomotors for the movement of the finger. The flow chart can be shown in Figure 8.

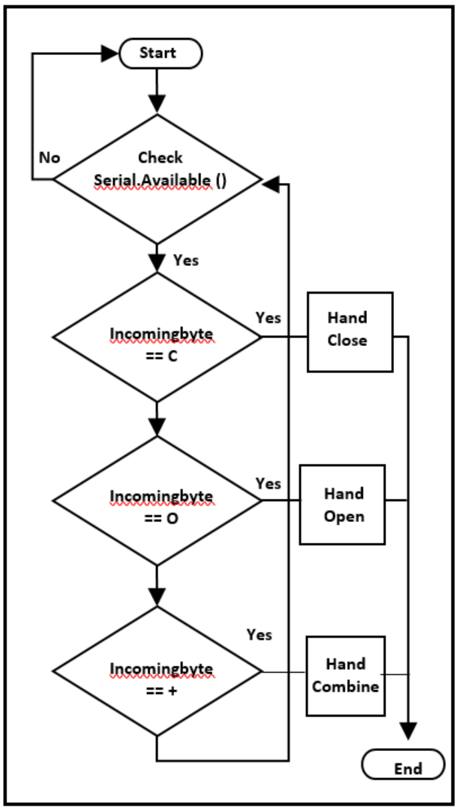

Fig 8. Arduino Operation Flow Chart

3. Results and Discussions

The prosthetic hand found to be successfully responded when triggered by the Arduino once the command executed from it. There were three responses recorded while running the work. The respective responses were closed hand, open hand, and the combination operation of both movements. The responded system shown in Figure 9, Figure 10 and Figure 11.

Fig 9. Close hand Operation

Fig 10. Open hand Operation

Fig 11 Combined hand Operation

Next, the time lapse and finger movement were recorded with and without the LiPo battery (additional supply) during the prosthetic hand operations. The time lapse of the prosthetic hand response shown in Table II and the response of finger movement shown in Table III.

Table II: Time Lapse during Prosthetic Hand Operation

Times Lapse of Movement (s) With Additional Supply	
Close hand	2. 37s
Open hand	3. 36s
Combine	4. 38s
Times Lapse of Movement (s) Without Additional Supply	
Close hand	5. 39s
Open hand	6. 37s
Combine	7. 40s

Table III: Time Lapse in Finger Movement during Prosthetic Hand Operation

	Finger Movements With Additional Supply			Finger Movements Without Additional Supply		
Respond of finger	Close	Open	Combine	Close	Open	Combine
Pinky	1s	/	/	2s	2s	2s
Ring	/	/	/	/	/	2s
Middle	/	/	/	/	/	/
Index	/	/	/	/	/	2s
Thumb	/	/	/	/	/	/

Obviously, the obtained EEG datasets can be utilized in executing the prosthetic hand operation. Table II summarizes the time lapse between the command execution and prosthetic hand response. By having an additional LiPo battery, the time lapse was reduced and the prosthetic movement observed to be much faster and efficient compared to operation without the additional battery. Mostly all the movements with the additional supply operates faster, more than 3% higher compared to without the additional supply.

In another test referring to Table III, the fingers' movement found to exhibit some lagging in the movement. The fingers movement lags more compared in the testing carried out without the additional supply. This is due to the Arduino can only supply 5V to the servomotor hence without the additional power supply, the power to control all the servo motors found to be insufficient. The servomotor voltage limit according to the datasheet known at 4-6V. This explains the efficiency, time taken much faster in response with the presence of an additional power supply. With extra battery, it's observed the motors able to perform well as the power supply found to be sufficient.

Although the work found to be successful, yet there's some limitation that can be improved in future. The datasets used limited to healthy human and could not be further investigated on real time on a physically challenged people due to the absence of the EEG emotive head set. Another challenge occurred during this work, the position of the prosthetic hand itself. Due to the horizontal position, the hand was not suitable for vertical (up and downwards movement) analysis. Since this work focuses on feasibility, the prosthetic hand's weight and structure not an ergonomic and user friendly design.

5. Conclusion

In conclusion, the development of artificial hand controlled using EEG datasets for prosthetic application achieved the objectives. The EEG datasets can be used as input for controlling the prosthetic hand. The time lapse found to be less using additional power supply of LiPo battery. Overall, it's feasible to operate a prosthetic hand using EEG set. This research work has high potential to use the EEG emotive device set to control the artificial hand in future. It's believed, with that the more accuracy in control according to each person can be characterized and analyzed further. Another suggestion for future work by utilizing a better prosthetic hand, this work can be extended to experiment on physically challenged people in real time analysis for higher accuracy results.

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