

LabVIEW GUI for Emotiv EPOC of Prosthetic Hand Control

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Abstract—The usual body-powered prosthetics is tiring and lead to compliance and restoration problems. Brain computer interface (BCI) prosthetic is one of the advanced technologies opening up new possibility in providing healthcare solutions for people with severe motor impairment. Generally, electroencephalography (EEG) is historically dominated by BCI researchers for prosthetics control. An issue with EEG user BCI researchers are tend to use invasive recording methods, posing surgical risks to generate control signals from brain activity patterns. This paper aims at reviewing the conceptual design for a non-invasive approach for controlling a prosthetic hand using an Emotiv EEG Headset integrated with a graphical user interface (GUI) designed in LabVIEW. EEG signals were recorded from healthy subjects through brain wave rhythm at F3 and FC5 of motor cortex area focusing on the artifact of upper limb movement; finger flexion-rest-extension. Five healthy subjects was selected for the conceptual proof and controlling a robot hand. The accuracies of data classification for the finger movement for all subjects exceeding the 50% for binary classification with average of 57.96%. This device can be used for paralyzed individuals with limited communication to control prosthetics using simple GUI.

Index Terms—electroencephalography, emotiv EPOC, LabVIEW, prosthetic hand

I. INTRODUCTION

People who are having difficulties in interacting with the community due to the long-term physical, mental, intellectual or sensory impairments are called amputees [1]. The lives of the amputees are very challenging in struggling with the disabilities and the self-esteem. The disabilities are divided into several groups such as Hearing Impairment, Lack of Vision, Physical Disabilities, Speech Disabilities, Learning Disabilities, Mental Disabilities and Cerebral Palsy. Amputees in Malaysia must be registered with the Ministry of National Unity and Social Development under the Ministry of Women and Family Development. From WHO data, 0.5% of the population of a developing country have a disability that require prosthetics/orthotics devices [1]. From this WHO prediction, it suggests that around 150,000 of Malaysia's current population of 30 million [2] need prosthetic or orthotic devices. This number shows that, an amputee in Malaysia is very high. Medical

allowances incentives were given to the registered disabled employer by the Malaysian government for them to purchase the prosthetics products through the government hospitals. Based on the development of modern technology now, various tools can help amputee to improve and increase the ability of human cognitive or sensory-motor functions [3].

One of the technologies, is known as brain computer interfaces (BCI); a modern technology and is explored in many different fields such as communication, neuro-prosthetics, robotics and mobility. The signals are collected whether using invasive, partial invasive or non-invasive method. There are four methods to record microvolt-level extracellular potentials generated by neurons in the cortical layers; electroencephalography (EEG), electrocorticography (ECoG), local field potentials (LFPs), and single-neuron action potential recordings (single units) [4]. Invasive method requires the patient undergo surgery of electrode implantation into their skull. Partial invasive method or called ECoG also required the implantation of electrode inside the skull but above the grey matter. The non-invasive method or EEG which is the most popular method used among researchers only placed on the scalp to obtain the signal [5]. These signals then will be processed and send as command to the output devices. BCI can be used to restore communication to people who suffer severe motor disabilities such as brainstem stroke, amyotrophic lateral sclerosis and spinal cord injury (quadriplegia) [6], [7].

The most challenging part in BCI researches is the features extraction process of random time-varying EEG signals and its classification according to the brain signal unique pattern. Thus, EEG based neuro-prosthetic devices is yet to be in the market and still undergoes demonstration. The aim of this study is to develop a concept of a neuro-prosthetics hand for amputee which includes the designing of a graphical user interface (GUI) using LabVIEW software to capture brain signal using Emotiv EEG Headset. An experimental evaluation to recognize brain wave pattern is conducted to evaluate the concept.

II. CONCEPT OF BCI-EEG SYSTEM

Apart from the neuro-prosthetics hand applications, BCI is also used to control Wheelchair [8], [9],

humanoid robot [10] and mobile robot [11]. There are several techniques to collect or mapping the brain which is through computational topography (CT), magnetic resonance imaging (MRI), functional magnetic resonance imaging (fMRI), positron emission tomography (PET), magnetoencephalography (MEG), EEG, and functional near infra-red (FNIR) Spectroscopy.

In this concept, we are focusing on implementation of BCI with EEG. EEG is an activity of recording the electric fields produced by brain by placing electrodes on the scalp. Local field potential (LFP) are generated as a result of the synaptic activities from hundreds of neurons over the integrated area at the electrode in a synchronized manner [12]. In 1924, according to Hans Berger who was the first to record the EEG, human brain waves called Berger or also known as the Alpha wave (8-12 Hz) have a very low signal. Electrodes are able to measure voltage differences on the skin in the microvolt (μV) range. By providing some amplification to the acquired signals will bring it up to the millivolt level and can make it available for digital signal processing. Electrodes used are usually made up of conductive materials such as gold or silver chloride. A conductive gel is applied to the electrodes to enhance its conductivity as well as maintain an acceptable signal to noise ratio [12].

Despite of instable signal, EEG have excellent temporal resolution of less than a millisecond. The signal can be analyzed according to its low frequency bands in Hertz [Hz]. The different waves of brain signals are delta, theta, alpha, beta and gamma as demonstrated in Fig. 1. Research has shown the advantages of deploying EEG technology to offer new solutions in prosthetic devices. Typically, most research using EEG for rapid communication with the equipment for easier and cheaper solution. Furthermore, the EEG has less procedures as well as more practical for patients and researchers [13]. In addition, the surface EEG does not require surgery.

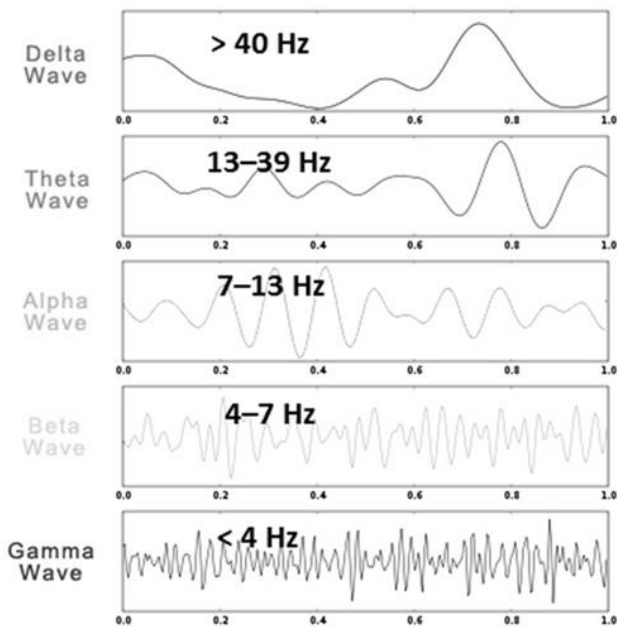


Figure 1. Brain waves classifications according to frequency [Hz].

A complex mechanical BCI system would allow a user to control an external system possibly a neuro-prosthetic device by creating an output of specific EEG frequency. The EEG records a signal by placing electrodes on the scalp with a conductive gel. Electrodes measure voltage differences at the skin in the microvolt (μV) range.

A BCI-EEG system is comprised of four different stages of signal acquisition, signal pre-processing, feature extraction and classification, and computer interaction, illustrated in Fig. 2. Signal Acquisition is acquired through the Emotiv EEG headset and two stages of signal pre-processing and feature extraction and classification is conducted using LabVIEW software. LabVIEW software is connected to the Arduino driver via USB serial data connection to completing the BCI four stages. The advantage of using LabVIEW is its ability to connect with other open source drivers. LabVIEW and Arduino is linked with specific palette called VISA in VI. Details of each stages is elaborated further in next sections.

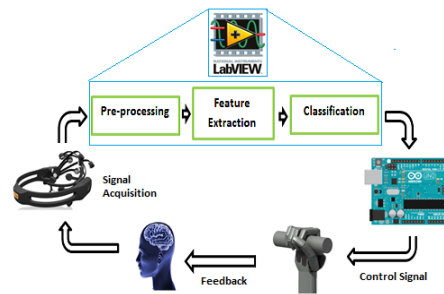


Figure 2. Concept of BCI – EEG for neuro-prosthetic hand.

III. DATA ACQUISITION

Data Acquisition is collected through Emotiv EEG headset. The working principle of EEG Emotiv headset is to capture the brain signal in microvolt (μV) produced during specific activities. Emotiv EEG headset, comes pre-configured with 14 electrodes located over 10-20 International System positions AF3, F7, F3, FC5, T7, P7, O1, O2, P8, T8, FC6, F4, F8, and AF4 using 2 reference electrodes show in Fig. 3. The concept of this study is to acquire signals from the motor cortex area, thus the arrangement of Emotiv Headset electrodes focusing on the pre-motor and frontal regions is found suitable for the development process at F3 and FC5 location. The headset aligns; band pass filters, and digitizes the signal at 128 Hz before transmitting wirelessly to a laptop.

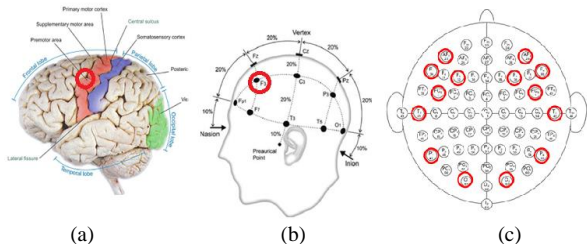


Figure 3. 10-20 System electrodes position: (a) functional areas of the cerebral cortex, (b) f3 electrodes placement on pre-motor area, part of motor cortex, and (c) Emotiv electrode positions.

IV. SIGNAL PRE-PROCESSING, FEATURE EXTRACTION & CLASSIFICATION

Signal pre-processing and feature extraction and classification stages are concluded in LabVIEW programming. LabVIEW program is one of the products of National Instrument (NI) in 1986 under the name Laboratory Virtual Instrument Engineering Workbench (LabVIEW). LabVIEW program is also referred to as virtual instrument (VI) because some operations in LabVIEW icon resembling instruments like oscilloscopes and multimeters. LabVIEW is a graphical programming language or Graphical Programming lined with a variety of virtual icons to replace the text programming in generating application. LabVIEW Software is different from other software compiler such as MATLAB and visual BASIC, which are using a text programming. Programming in LabVIEW is modular in which a complex program can be created in a number of other sub-programs.

In signal pre-processing phase, the EEG signal data is validated then loaded into the LabVIEW program to clean it from insignificant artifacts. It is required to clean the signal data before can be processed further to get higher classification rates [14]. Then, a cleaned signal data is sent to be extracted and classified. Classification is important to determine the pattern recognition of the brain waves signal of specific activities to control the neuro-prosthetic hand.

LabVIEW is comprised of three main components; the first is the front panel user interface. The second is the block diagram consisting of graphics resources that represent functions of the VI and the third component is intended as a connection panel to connector every function VI for perfect data flow. Each VI has the functions of each system and represents the specific information that is used to transfer data to the computer. The LabVIEW used in particular is connected to MATLAB for the data analysis. The LabVIEW for neuro-prosthetics hand is connected with MyRIO drivers. The advantage of using LabVIEW is that it has the virtual instrument package manager (VIPM) use toolkit that can be upgraded and can use a third party such as a toolkit that can be used in research such as VISA Toolkit, and Emotiv Toolkit and Arduino Toolkit. Arduino Toolkit is implemented in this development concept.

V. COMPUTER INTERACTION & FEEDBACK

Graphical user interface (GUI) is a monitoring system which is used in this project was developed by using LabVIEW software. The advantage of using LabVIEW software is to monitor the voltage on pin Arduino via data serial and controlling servo motor using LabVIEW GUI. Arduino has the ability to transmit data in serial form and display on a computer monitor, but only in the form of a digit number. But LabVIEW has the capability to process serial data which is sent to a chart or graphical graph for more details illustrated in Fig. 4.

This simple GUI template was developed using two consumers setting and simulation. Consumer setting is

used to determine the connection setting USB COM port and bit data. While the second consumer interface integration serves as a data graph. There is also the status of eye movement and status subject movement of prosthetic hand. It will also show error status if there are problems in this programming.

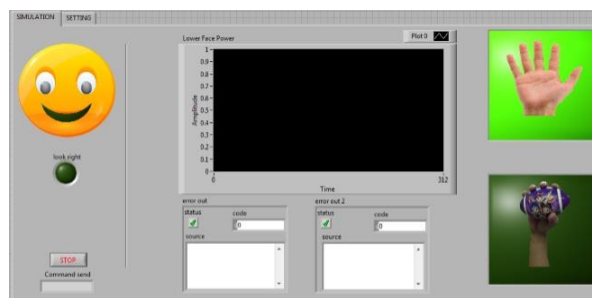


Figure 4. Front Panel neuro-prosthetic hand



Figure 5. Subject try to control the neuro-prosthetic hand.

The feedback of the brain waves is sent to the MechaTE LEFT Robot Hand, a completed five fingers hand with five degrees of freedom using micro servo motor. The MechaTE LEFT Robot Hand is improved by adding a prosthetic hand finger tips to get more friction for a better grasping movement. The fingertip is designed using CATIA software and printed using a 3D Printer Machine.

VI. EVALUATION & RESULTS

The inclusion criteria for the screening of subjects include the following; a) adult above 18 years old, b) healthy, c) right-handed, with d) no brain injuries history. The subjects are trained to control the prosthetic hand using finger flexion-rest-extension for brain wave pattern classifications. During the recording, the subjects were asked to sit in a comfortable armchair and a computer monitor was fixated in front of the subjects. The subject were asked to perform resting, isometric finger extension and flexion movements, based on a visual stimuli presented to the subjects via a computer monitor and to hold those positions against resistance. The visual stimuli presented last four seconds and is embedded into a 10 second cycle including two seconds for baseline correction, and four seconds for the subject to relax the hand, blink and swallow. The duration of the recording is 60 minutes for each subject. Subjects also need to minimize the body movement, eyes movement and eyes blinking during recording to decrease signal noise.

For classification of EEG data, ERD/ERS is referred for any energy changes of specific frequencies at motor cortex and increase or decrease in specific frequency bands. An algorithm to solve this is the spectrally-weighted common spatial pattern (Spec-CSP). It generates filter vectors that assign a weight to different locations and frequencies in order to maximize the difference between finger extension, flexion and rest.

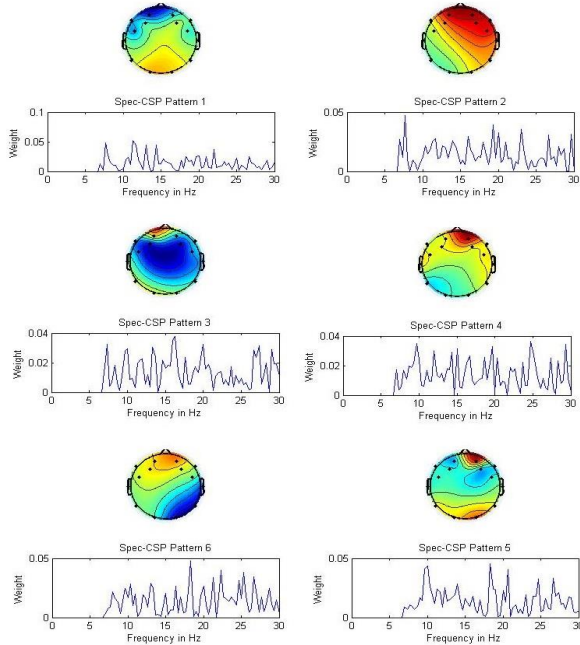


Figure 6. Spec-CSP filtered spatial projections from one subject.

Fig. 6, shows the sample of Spec-CSP data projections from one subject. The classification rates between extension versus rest, flexion versus rest and extension versus flexion are calculated using 5-fold cross validation. The interval providing the best classification result is used [15] in the analysis. This change of interval allows finding the part of data that holds the most relevant information for classification. In machine learning method, data with label will be trained in training function to calibrate a model. Then a new data with model calibration will be applied into a predict function to class a label.

To generalize the narrow-band ERD/ERS, the baseline or epoch-mean power spectrum and the event-related spectral perturbation (ERSP) of FC5 electrode at each subject were measured in time frequency analysis. Calculating an ERSP requires computing the power spectrum over a sliding latency window and averaging across data trials. The color at each image pixel indicates power (in dB) at a given frequency and latency relative to the time locking event. From Fig. 7, subject 1, 2, 3, 4 and 5 shows de-synchronization of beta rhythms (14-30 Hz) in the respective area (FC5) for right finger movement. Significant EEG changes were observed over FC5 since it is the closest to the primary sensorimotor area. In all five subjects, differentiation between isometric finger flexion and extension movement for right handed subject was possible within the beta band (14-30 Hz).

From the data classifications above, we are able to recognize finger flexion-rest-extension pattern through the EEG signals. The classification accuracies for finger flexion versus finger extension for subjects 1, 2, 3, 4 and 5 are 56.5%, 56.3%, 57.9%, 60.4%, and 58.7% respectively. Comparing to the random guessing level of 50% for binary classification [16], [17], the evaluation shows better classification.

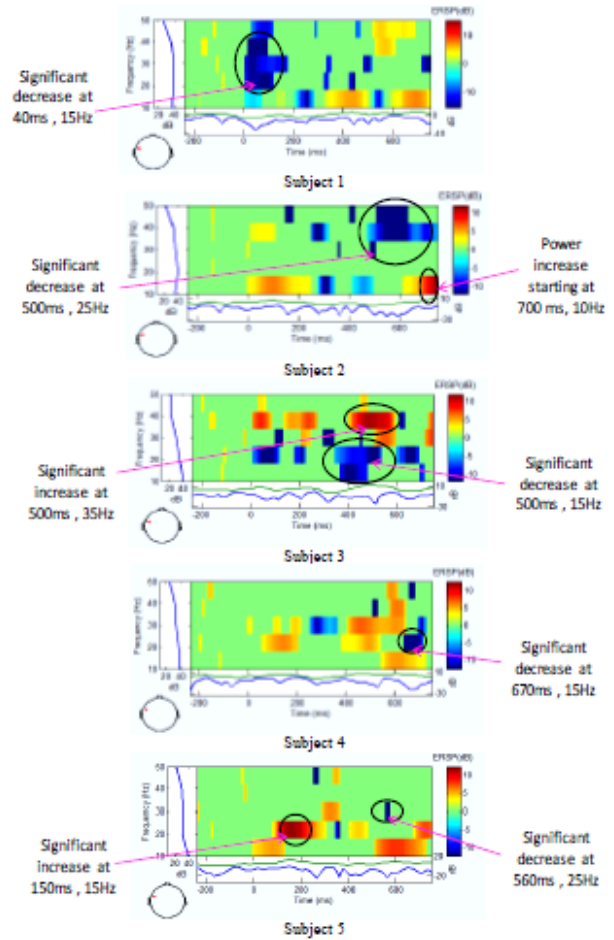


Figure 7. Time frequency decompositions of FC5 electrode activities for all subjects.

VII. CONCLUSION

The main objectives of this research are to develop a concept of neuro-prosthetic hand, acquiring the signal data from the EEG Emotiv Headset and develop a GUI using LabVIEW software based on the signal obtained from the Emotiv EEG headset. An EEG data classifications of finger flexion-rest-extension movement has been successfully conducted offline. A real-time evaluation with the LabVIEW control system using MechaTE Robot Hand shall proves the concept further. Towards development of neuro-prosthetic hand with BCI control, the classification accuracy is playing the main role in interpreting signal data. Based on review [18], classification of different movements of the same hand should increase the number of separable classes available for a BCI system.

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