ELECTROENCEPHALOGRAPH (EEG) BASED BRAIN COMPUTER INTERFACE (BCI) FOR CONTROLLING REAL TIME ROBOT ARM

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ABSTRACT

In this paper, development of non-invasive neural signals to drive a 2R robotic arm is presented. A brain computer interface based on steady state visual evoked potentials (SSVEP) is used. For stimulation stimuli arrow with different colours (red, black and violet) is used that flicker with different frequencies of 6.5 and 8.2 Hz respectively. PYTHON is used for online signal acquisition and MATLAB signal processing and analysis tool is used to analyse signals. Emotiv EPOC and Arduino are used as hardware devices to receive and transmit signals respectively. At last, signals are given as a commands through Arduino to a hardware experimental setup. The goal of our study is to control navigation of robot "turn right", "turn left" through neural signals acquired by EEG database.

KEYWORDS: Emotiv EPOC- A Brain Computer Interface, Python, MATLAB, ARDUINO, 2R Robotic Arm

The advancement of technologies in this era has great impacts on human life. Now, people are able to travel faster and communicate in a more convenient way than in the past. Assistive computers and machines provide conventional input devices such as a keyboard, a mouse, or a joystick to be operated by the users. These devices are, however, difficult to be used by elderly or disabled individuals. For this reason, special interfaces such as sip-and-puff systems, single switches, and eye-tracking systems have been proposed [1]. Nevertheless, these specials interfaces do not work for people suffering from severe neuromuscular diseases who cannot convey their intentions or operations to computers or machines with these interfaces. Consequently, even autonomous electric wheelchairs are unable to transport disabled people to their desired locations. Hence, there exists a growing demand and necessity for developing an alternative interface that can be used by the severely disabled population for communication with autonomous systems.

Brain-computer interface (BCI) system has been developed to address this challenge. BCIs are systems that can bypass conventional channels of communication, i.e. muscles and speech, to provide direct communication and control between the human brain and physical devices by translating different patterns of brain activity into commands in real-time [2].

A brain-computer interface (BCI) is a software and hardware system for establishing direct communication between human and computer, which enables people to send commands to the external world through brain activities, without depending on brain's normal output pathway of peripheral nerves and muscles activities [3].

LITERATURE REVIEW

Hovagim Bakardjian, et al. [4]'s work aimed to address directly the above problems by presenting and optimizing two new multi-command BCI designs based on Steady-State Visual Evoked Potential (SSVEP) brain responses. Hamzah S. Alzu'bi, et al. [8]'s thesis develops a set of prepossessing, feature extraction and classification methods that were implemented to help support and validate the proposed system and to benchmark it against the latest developed systems in BCI literature. Ruen Shan Leow, et al. [10]'s paper presents the development of the real-time brain computer interface (BCI) system based on the detection of steady-state visual evoked potential (SSVEP).R. Singla, A. Khosla, R. Jha, et al. [25] in their study of four different flickering frequencies in low frequency region were used to elicit the SSVEPs and were displayed on a Liquid Crystal Display (LCD) monitor using Lab- VIEW. Four stimuli colors, green, red, blue and violet were used to investigate the color influence in SSVEPs.

PROBLEM DEFINITION

This paper aims to develop a real-time SSVEP-based BCI system for command and control of a Robot Arm. For effective SSVEP response, which is dependent on colour and size of flickers and distance (form observer to subject), the dominating one of these is colour. three different colours like red, violet and black are used to check for the optimal colour which gave approximate frequency equal to the frequency of flickers. The scope of the work described in this paper includes:

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- Development of visual stimuli that give the best SSVEP response by using high timing precision software such as Psychophysics Toolbox from MATLAB
- Development and implementation of feature extraction and classification algorithms for real-time EEG signals processing and command recognition
- Development of a hardware interface between host laptop and the targeted Robot Arm
- Perform real-time evaluation on the constructed system

RESEARCH METHODOLOGY

Overview

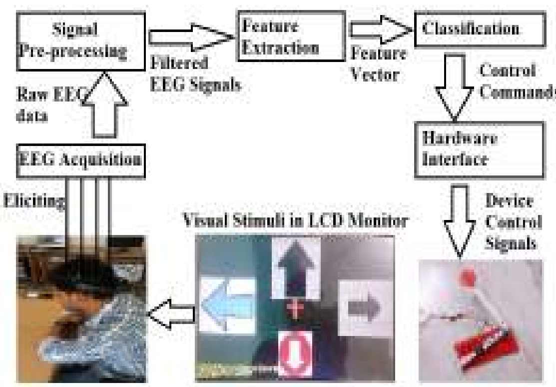

Figure 1: Conceptual block diagram of the proposed SSVEP-based Robot Arm control system

EEG Recording System

In this work, the acquisition of EEG signal is performed by using a 16-channel Emotiv EPOC EEG recording system with sintered Ag/AgCl active electrodes. This amplifier relies on the novel concept that high impedance provides stable and noise-insensitive signals. While it is supported by the 10-20 international electrode system, highest standard of EEG signal quality is always guaranteed.

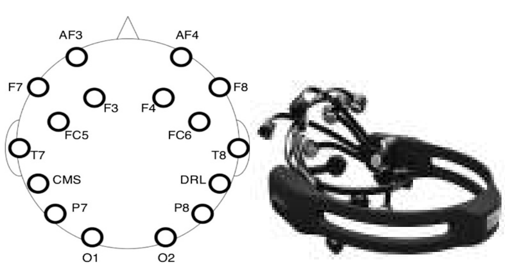

Figure 2: The 16-channel Emotiv EPOC EEG layout and the device

SSVEP Stimuli and Display

The visual stimuli consist of four arrows occupying a black background with one red fixation cross at the centre as shown in Fig. 3 The four arrows point to four different directions which represents the commands that subjects can generate to control the Robot Arm.

Figure 3: SSVEP visual stimuli generated by using Psychophysics Toolbox in MATLAB

Import Data in Matlab

After opening Matlab, import icon will appear on toolbar. Click on it, select the file to be imported, and then click on import selection button, which will import the file.

Figure 4: Shows import icon with blue circle

Bandpass Filtering of Raw EEG Signals

The isolation of raw EEG signals is to remove the unwanted artefact components. In this work, frequencies which do not fall within the alpha and beta bands are eliminated because they do not reflect visual processing in occipital region. This is achieved by constructing a 4th order Butterworth Infinite-Impulse Response (IIR) bandpass filter with a passband of 12 Hz to 30 Hz using the Signal Processing Toolbox in MATLAB.

The transfer function of IIR filters includes both numerator and denominator terms and are returned by the routine butter as row vectors ‘b’ and 'a' in the length of n+1, where n is the order of the filter, in descending powers of s, derived from this transfer function:

$$H(s) = \frac{B(s)}{A(s)} = \frac{b(1)s^n + b(2)s^{n-1} + \cdots + b(n+1)}{s^n + a(2)s^{n-1} + \cdots + a(n+1)}$$

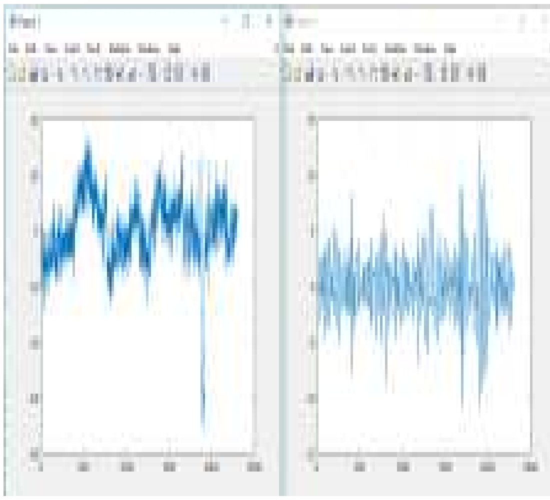

Figure 5: shows raw and filtered signal

Spectral Analysis and Feature Extraction Using Fourier Transform

To transform the discrete EEG data from time domain into frequency domain, the basic Fourier Transform routine fft(x,n) in MATLAB is implemented. The fft routine returns the discrete Fourier Transform (DFT) of any input vector x and computed with a high-speed Fourier Transform algorithm. In fact, DFT is applicable to windowed signal segments to perform a direct examination of information encoded in the frequency, phase, and amplitude of the component sinusoids. For n sample transform, the fft routine is implemented according to the formula:

$$X(k) = \sum_{n=1}^{N} x(n) e^{\frac{-j2\pi kn}{N}} \qquad k = 1,2,3,\ldots,N$$

where x(n) is the sample data at time index of n, X(k) is the vector of N values at frequency index of k corresponding to the magnitude of the sine waves as resulting from the decomposition of the time indexed signal.

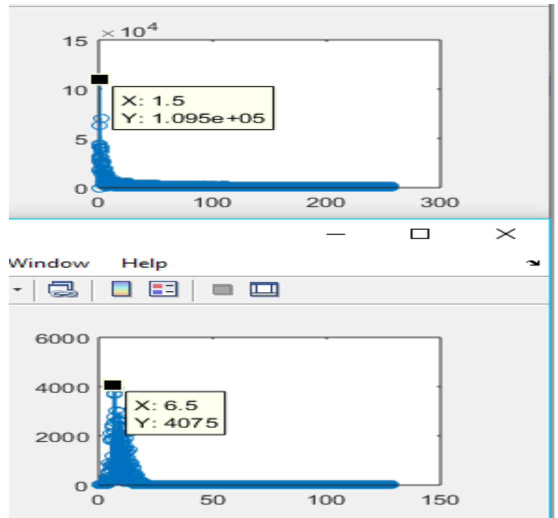

Figure 6: Frequency Analysis using FFT

Data Classification

FFT plot between frequency on x-axis and magnitude on y-axis. The thing here is, unwanted frequency components which are below 6 Hz, that's why set the threshold to 0.6 percentage of the magnitude, which altered the lower frequency.

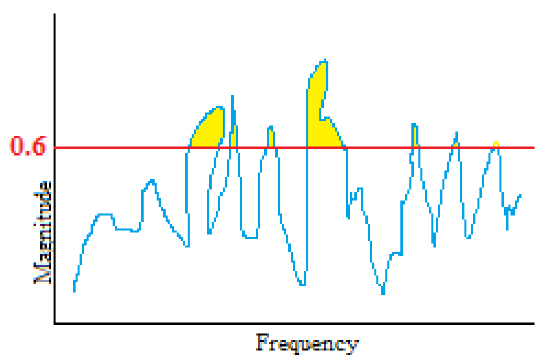

Figure 7: Classification by setting the Threshold Frequency

Hardware Implementation

Experimental setup is represented in the below figure. Two servo motors are used, motor 1 and motor 2 as indicated two joints of RR Manipulator.

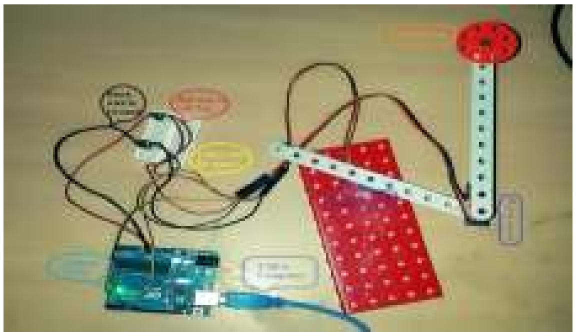

Figure 8: Experimental setup

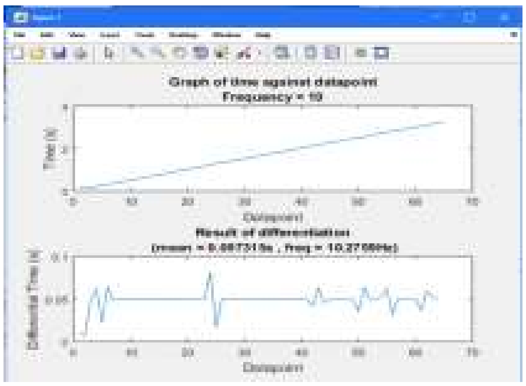

Figure 9: Time of actual flipping interval

RESULTS AND DISCUSSION

Fig 9 shows the time course of actual flipping interval for one of the flickering arrows (10 Hz) presented. Notice that one complete cycle to flick the arrow from white to black and back to white again consumes an average time of 0.097315 s, which approximately equals to 10.2759 Hz.

Table 1: Comparing of three colour and Average value

Frequency in Hz	Sl. No.	Colour			Average		
		Red	Black	Violet	Red	Black	Violet
6.5	1.	6.625	6.75	6.625	6.8125	6.73125	6.68125
	2.	6.875	6.8	6.5			
	3.	6.5	6.625	6.8			
	4.	7.25	6.75	6.8			
8.2	1.	7.5	12	7.625	7.8125	9.2625	7.9
	2.	7.625	7.5	7.75			
	3.	8.75	9.925	8.5			
	4.	7.375	7.625	7.725			

It is clear from the above table that the violet colour is giving nearly exact frequency to that of visual stimulus flickering. Violet colour with 6.5 Hz, and for four different samples, giving an average of 6.68125 Hz which is 0.18125 Hz greater than the flickering frequency. Violet colour with 8.2 Hz and for four different samples, giving an average of 7.9 Hz which is 0.3 Hz lesser than the flickering frequency.

CONCLUSION

- This paper provides an overview of the background theories on EEG-based BCI system. The explanations give an idea on the generation and transportation of electrical signals within the neural networks in the brain. Different cortical functions are mapped to different regions of the cerebral cortex. This enables us to correctly and effectively extract the information of interest for analysis purposes.
- Results of our work, have found Violet Colour is the efficient which gives the approximate frequency to the RVS, for 6.5 Hz, obtained 6.681 Hz and for 8.2 Hz, obtained 7.9 Hz which is far better than the other 2 colours.

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