BCI Based Home Automation System by Using SSVEP Signals

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Abstract. SSVEP based BCI system helps Tetraplegia patients to communicate and control devices based on Steady State Visual Evoked Potentials (SSVEP). Home automation systems are in huge need for the Tetraplegia patients to control home appliances like nurse calling system, lights, and Television sets by using visual cues from a stimulator. A visual stimulator is developed which flares at frequencies 7Hz, 8Hz, 9Hz and 10Hz to control nurse calling device at 7Hz, light at 8Hz, fan at 9Hz and thirsty buzzer at 10Hz. A brain signal acquisition device Emotive EPOC is used to acquire EEG signal under visual stimulus operates at different flickering frequencies. EEG signal is processed by Power spectrum to detect the flickering frequencies of the visual stimulator. These flickering frequencies are used to generate control signals from a microcontroller to control various appliances. Experiments were conducted on 40 subjects with 4 trials on every subject and obtain Maximum Power Frequency (MPF) from the EEG signal. it is found that the Maximum Power Frequency of all the trails across all the suubjects is significant in detection of the flickering frequencies of the visual stimulator with $p < 0.001$. It is found that the flickering frequencies are detected with the accuracy of 99.98% and specificity and sensitivity of 99.89 and 99.87 respectively.Hence MPF is used to generate control signals to actuate the devices.

Keywords: brain computer-interface (BCI) · Tetraplegia · steady state evoked potentials (SSVEP) · Maximum Power Frequency (MPF)

1 Introduction

According to the survey conducted by WHO in 2019, 533,172 individuals suffered from the neurological disorders and lost their lives, among them 213,129 (40%) are men, and 320,043 (60%) are women. About 1.9 percent of the population who are suffering from neuromuscular disorder roughly 1 among 50, approximately 35% of patients cannot control the domestic appliances. Advancement of technologies shows a greater promise for such patients to improve their quality of life. However, these technologies have no use for patients suffering from severe neuromuscular diseases or physically disabled persons. Tetraplegia patients suffer from the inability to perform voluntary movement of

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upper and lower limbs due to the disruption in the sensory and motor connectivity. It is essential for them to operate devices such as fans, light, nurse calling devices in hospitals or at home with the aid of technological advancements. The main objective of a BCI system is to assist disabled patients to reinstate their lost motor /sensory functionalities such as communication and mobility. These control devices enable wide range of usage for Tetraplegia patients, which are assisted by technology. BCI based system issues a communication track between the activities of nervous system and the external devices, namely, nurse calling device, fans, lights etc [1–2].

2 Litreature Review

Hui-Shyong Yeo et al. developed hand/finger (robust marker-less) tracking and gesture recognition system which can translate the hand gestures into functional inputs and using several methods it interfaces with other applications [3]. Jeong et al. used gesture recognition method for the television control system to operate TV. They captured hand gesture using a single camera and transform the gesture variants into control commands by a circuit [4]. Wenchang Zhang et al. examined neuro imaging modalities which are worn in wave step accession, each of brain waves observe a distinct brain effective pursuit like metabolic activity, energetic, discussed various signals that are generated in the brain pursuit ascertain user desire, and embrace few methods used in enhancement of signal step to accord with unwanted signals [5]. ETU podder et al. detected the event related desync/ sync of mu and beta rhythms during hand imagery movements by PSA (Power Spectral Analysis), ERP (Event Related Potential) plots, Time-Frequency Analysis, ERP comparison. Mainly, the EEG signals recorded at channels C4 and C3 are investigated [6]. Sujata R. et al. has used modern technological improvements based on EEG such as ML algorithms and recording signals with wireless based BCI model [7]. KaidoVärbu et al. conducetd a study on EEG-based BCI systems for medical purposes with the goal of aiding patients' return to a healthy life. The dispensation of the investigation in between the domain of medical and non-medical have been analyzed and additionally classify into fields of investigation within the evaluated province [8]. J. d. R. Millan et al. identified application areas where disabled people could get great benefits from advancements in Brain computer interface, include, "Communication & Control", "Motor Substitution", "Entertainment", and "Motor Recovery" [9–14].

The motivation for this study is to contribute towards improving the life of tetraplegic patients and disabled people by using BCI based method. In general, BCI system is classified into invasive BCI and non-invasive BCI emanate from placement of sensors.

3 Methodology

SSVEP-based BCI system uses a visual stimulator generates a stimulus flickering at specific frequencies and evoked SSVEP response is detected by EEG signal analysis to control the appliances. A Portable LED visual stimulator which can generate wide range of visual stimulus with different flickering frequencies is designed. EEG signal acquisition is done through an Emotive EPOC Emotive data acquisition system. The recorded signals are analysed/translated into commands to control the Nurse calling device and

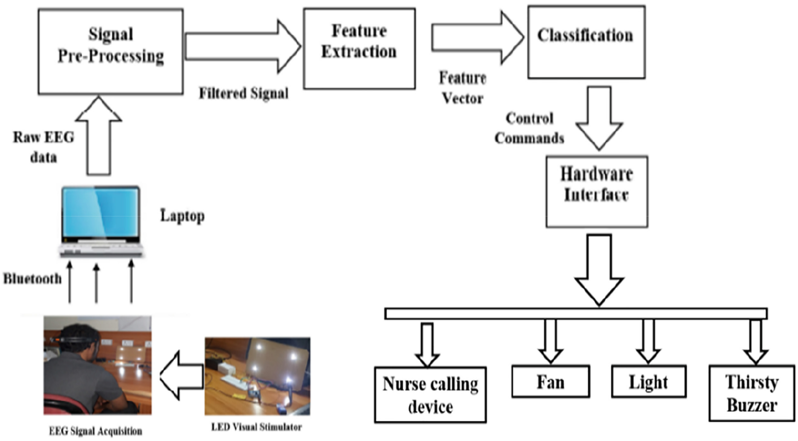

Fig. 1. Block diagram of SSVEP based BCI

other appliances. Finally, the developed system is tested to check its functionality and accuracy.

3.1 Materials

The block diagram shown in Fig. 1 comprises of the main functional units of the device. The hardware design for steady state evoked potentials optical emulator comprises of the following components 1. Arduino Uno, 2. Variable voltage to operate LEDs, 3. Control circuit board to control the high currents and 4. High power LEDS. The Arduino communicates with host by means of serial protocol to host by means of Universal serial Bus to chip place on PCB mount. The apparatus is energized by a 12 V supply of replenishable Lead battery, which form it mobile and attenuates EM interference from the electric cable. Arduino is supplied separately by 9V DC battery and software is carryout using a Universal serial Bus terminal which is affix to computer with Arduino (IDE). Arduino UNO has 14 digital input/output and six analog input ports. In this design, 4 digital outputs to control four LED's. Out of the 14 input/output lines, 6 can be cast-off for PWM. PWM can be cast-off to change the magnitude of sole colours combine of various colours from one to other color. Figure 2 shows the interfacing diagram of LED's with the Arduino with a LED driver IC. To test Arduino Uno board, Light Emitting Diodes are affix to 330 ΩR in sequence straight to the output ports. Each input/output pin delivers up to 40 milli amperes that might be sufficient if a one LED is used. Whereas high ability Light Emitting Diodes current requirements varies from 350 milli amperes to 1,500 milli amperes based on intensity. External 12V DC Lead battery was used to power the LEDs. The output voltage from the battery and current was controlled by Constant Current and voltage regulator Module which is further connected to the LED control circuit board which directly provides the controlled power to the LEDs. The use of Constant 37 Current Constant and voltage regulator Module in this design is its capacity to give output current up to 5A and a wide voltage of range 0.8V–36 V DC with an efficiency of 96%. The Arduino transmits the information to the host by means

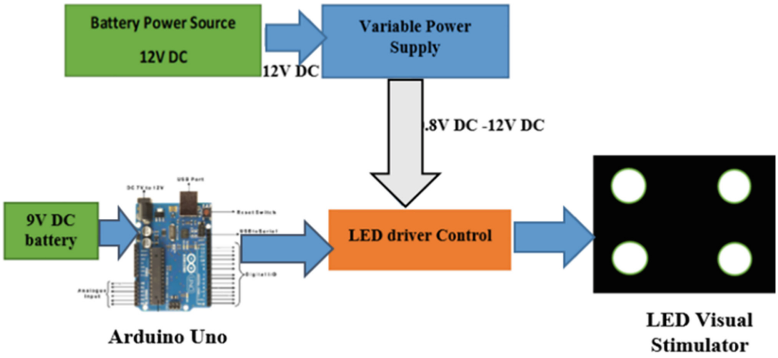

Fig. 2. Visual stimulus control block diagram

Table 1. Generation of Flickering frequencies by timing

Frequency in Hz	Time interval set (mSec)
7	70
8	61
9	54
10	49

of Universal serial port. The Arduino based program to flicker a LEDs is implemented based on time interval in Millis rather than using delay program which was not accurate and precise for this design. For the requirement of flickering the LED need to be powered off for each half cycle of the frequency, this requires the time interval which is calculated accordingly used in its implementation. The calculated time interval value is converted to Milliseconds because the software uses milliseconds and is shown in Table 1.

4 Results and Dıscussıons

Prototype and Setup: The developed prototype of portable LED Visual stimulator is shown in Fig. 3. It consists of the Arduino Uno and the basic computer platform, variable power supply (CC CV output regulator module), 4 LEDs, and 9V battery. Finally the generated flicker frequencies are measured by a Digital storage oscilloscope, and it is found that the stimulator is generating the flickering frequecnies at an accuracty of 99.99%. The experimentation involves acquisition of EEG signal from O1 & O2 electrodes of the subjects under the visual stimulus flares at different flickering frequencies. Each experiment is condcucted for 16 s, during the initial 4 secs subject are instructed to stay rest and start focusing at the visual stimulus on the 6th second. EEG signal acquired from a subject during the expermenttaion is shown in Fig. 4.

Four different colors of LED's (white, orange, green and blue) are used for the generation of flickering frequencies from the visual stimulus. EEG data is recorded

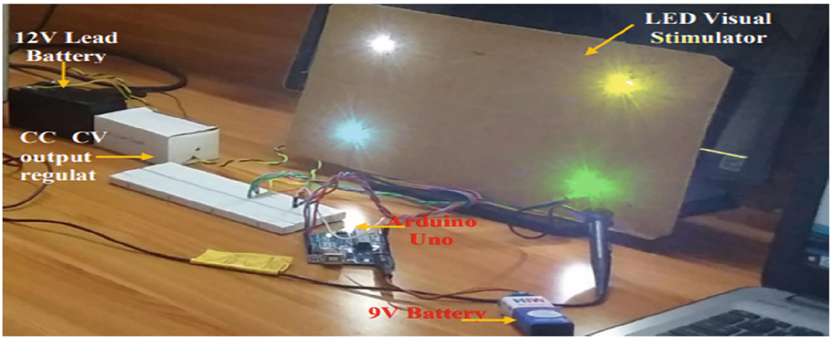

Fig. 3. Portable LED Visual Simulator

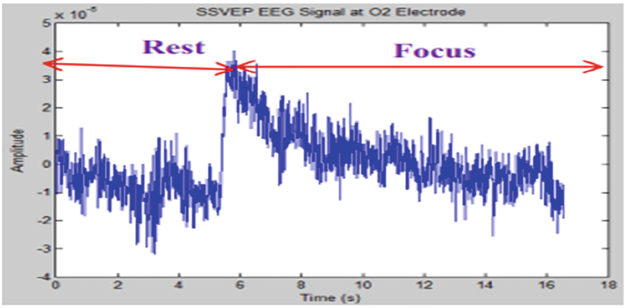

Fig. 4. Raw EEG signal acquired from a subject with visual stimulus of 7Hz

by using Emotive EPOC and analyzed to detect the elicited response from the power spectrum of EEG signal. For each color four flickering frequencies are used as the visual stimulus, and compared the response of the brain to different colors.

All the subjects are trained as per the visual stimulator is programmed to control four different devices. To call a nurse calling device should stare at the yellow LED fickers at 7Hz, to operate light need to observe the green LED flickers at 8Hz, to operate a fan stare at the blue LED flickers at 9Hz and to have water need to stare at white LED flickers at 10Hz. Sufficient training is required for the user to get used to the visual stimulator, however all the LED's are programmed in such way that they flickers at their respective frequencies continuously. The user whenever wants can stare at the corresponding LED that operates at a specific frequency. The visual stimulator is tested for its function by the digital storage oscilloscope, and it's found that the flickering frequencies are detected with 100% accuracy for all the four colors operated with multiple frequencies.Experiments were conducted on 40 student volunteers in the age group of 18–25 with a mean age of 22.5, a written consent is taken from all the participants. Before the experiment participants are informed about the procedure of EEG data collection. EEG signals are recorded from 40 subjects for 4 trails under four different flickering frequencies with different colors.

4.1 Visual Stimulus and Flickering Frequency Analysis

The EEG signal is acquired when the subjects are asked to stare at yellow colour LED flickering at 7 Hz, and the raw EEG signal is corrupted with the background noise. It is pre-processed by IIR Butter Worth filter with cut-off frequency of 0.5 Hz and further analysed by using Fast Fourier Transform (FFT). The magnitude spectrum of the EEG signal in Fig. 5 shows that a peak corresponding to 7 Hz, and hence maximum power frequency (MPF) is computed. The experiment is conducted on 40 subjects, 4 trails on each subject accounts to 160 EEG epochs. The MPF is detected for all the EEG epochs and the mean value is found as 7 with an accuracy of 100%. MPF is exactly matching with the visual stimulus that is used to generate the SVEP signal. After ensuring the

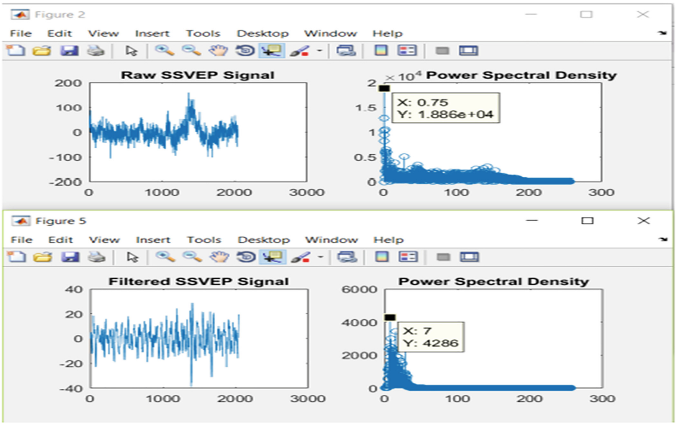

Fig. 5. Power spectrum of EEG signal under yellow color LED flickering at 7 Hz

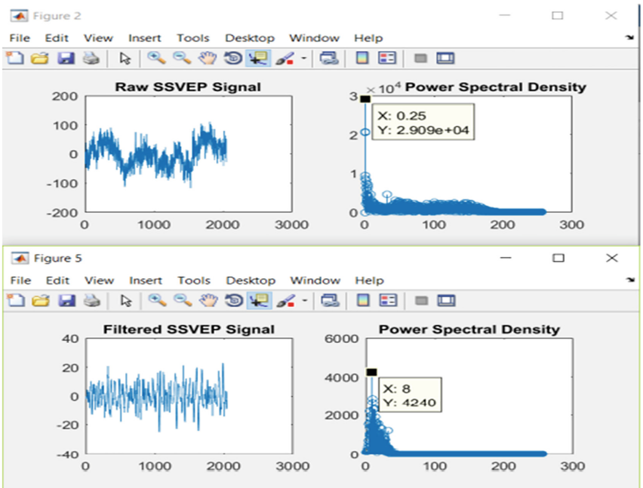

Fig. 6. Power spectrum of EEG signal under green color LED flickering at 8H

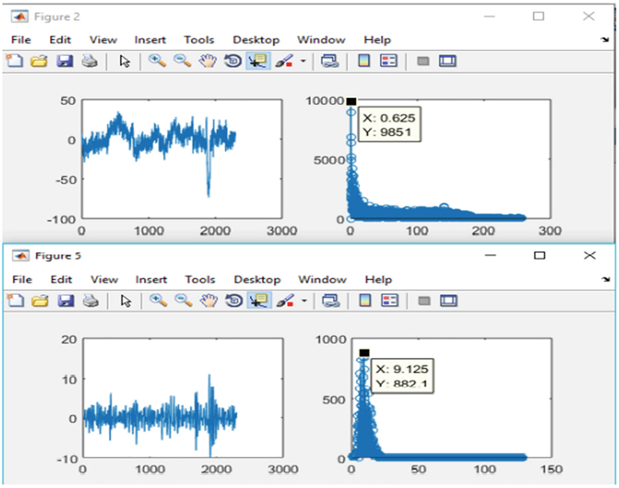

Fig. 7. Power spectrum of EEG signal under blue color LED flickering at 9 Hz

detection of visual stimulus through the SSVEP signals, it is used to generate the control signals to actuate a nurse calling device. The analysis is conducted similarly with the visual stimulus green color at 8 Hz, blue colour at 9 Hz, and white colour at 10 Hz. The power spectrum of the EEG under three different stimuli are shown in Figs. 6, 7, and 8. The MPF of the EEG signal is found to be significant with $p < 0.001$ in detection of visual stimulus frequency. Since the brain response to the visual stimuli is detected accurately microcontroller is programmed to generate the control signals based on the MPF of the EEG power spectrum. The device is tested on 40 subjects, and it is functioning accurately, and is immensely useful for tetraplegia patients to use in their daily life. It will certainly improve their quality of life and lead their life happily.

5 Conclusions

A Portable Visual stimulator is developed for BCI based home automation by using four LEDs operated at four different flickering frequencies is designed and developed. Power spectrum analysis of EEG data is carried out to detect the elicited response of the brain to the flickering frequencies. It is found that the Maximum Power Frequency (MPF) is found to be statistically significant ($p < 0.001$) in detection of the flickering frequency of the visual stimulus. This is immensely useful for Tetraplegia patients to operate the nurse emergency call devices and other accessories like fan, light and thirsty devices in the hospital room.. However, non-linear methods can be used such as ANN, SVM show significant improvements in terms of classification accuracy and usability when applied in the system.

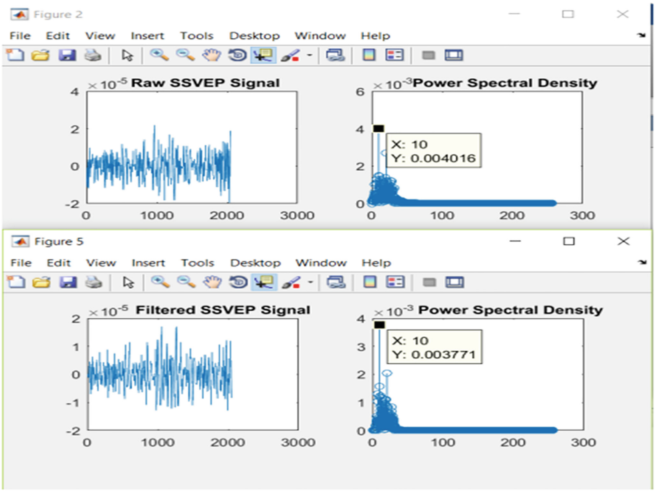

Fig. 8. Power spectrum of EEG signal under white color LED flickering at 10 Hz

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References

1. "Nurse Calling System | Welcome to Innovative Technologies , fire alarm panel, p a system,nurse calling system , power supply units." [Online]. Available: http://innovatech.co.in/products/nurse-calling-system/.
2. Q. P. Ha, T. H. Tran, and G. Dissanayake, "A wavelet- and neural network-based voice interface system for wheelchair control," Int. J. Intell. Syst. Technol. Appl., vol. 1, no. 1/2, p. 49, 2005.
3. H.-S. Yeo, B.-G. Lee, and H. Lim, "Hand tracking and gesture recognition system for human-computer interaction using low-cost hardware," Multimed. Tools Appl., vol. 74, no. 8, pp. 2687–2715, Apr. 2015.
4. S. Jeong, J. Jin, T. Song, K. Kwon, and J. Jeon, "Single-camera dedicated television control system using gesture drawing," IEEE Trans. Consum. Electron., vol. 58, no. 4, pp. 1129–1137, Nov. 2012.
5. Wenchang Zhang1,2 (*), Chuanqi Tan2, Fuchun Sun2, Hang Wu1, Bo Zhang2 2018. This article is published with open access at journals.sagepub.com/home/BSA
6. Etu Podder, Md. Maniruzzaman, Alok Sarkar: 1st International Conference on Advances in Science, Engineering and Robotics Technology 2019 (ICASERT 2019) 978-1-7281-3445-1/19/©2019 IEEE.
7. Sujata R. Kulkarni 1, Prakashgoud R. Patil2, Deepa Mulimani3 1KLE Technological University, Karnataka, Hubballi 2,3KLE Technological University, Karnataka, Hubballi : Survey on EEG based Brain Computer Interface for Emotion Detection
8. Past, Present, and Future of EEG-Based BCI Applications: Kaido Värbu 1, Naveed Muhammad 1 and Yar Muhammad 2, https://doi.org/10.3390/s22093331

9. J. D. R. Millán, R. Rupp, G. R. Müller-Putz, R. Murray-Smith, C. Giugliemma, M. Tangermann, C. Vidaurre, F. Cincotti, A. Kübler, R. Leeb, C. Neuper, K.-R. Müller, and D. Mattia, "Combining Brain-Computer Interfaces and Assistive Technologies: State-of-the-Art and Challenges.," Front. Neurosci., vol. 4, 2010.
10. Y. Liu, X. Jiang, T. Cao, F. Wan, P. U. Mak, P.-I. Mak, and M. I. Vai, "Implementation of SSVEP based BCI with Emotiv EPOC," in 2012 IEEE International Conference on Virtual Environments Human-Computer Interfaces and Measurement Systems (VECIMS) Proceedings, 2012, pp. 34–37.
11. R. J. Huster, S. Debener, T. Eichele, and C. S. Herrmann, "Methods for simultaneous EEG-fMRI: an introductory review.," J. Neurosci., vol. 32, no. 18, pp. 6053–60, May 2012.
12. J. L. Semmlow and B. Griffel, "Digital Filters" in BIOSIGNAL and MEDICAL IMAGE PROCESSING, 3rd ed. CRC Press, 2014. 16
13. G. R. Muller-Putz and G. Pfurtscheller, "Control of an Electrical Prosthesis With an SSVEP-Based BCI," IEEE Trans. Biomed. Eng., vol. 55, no. 1, pp. 361–364, Jan. 2008.
14. C. Guger, B. Z. Allison, B. Großwindhager, R. Prückl, C. Hintermüller, C. Kapeller, M. Bruckner, G. Krausz, and G. Edlinger, "How Many People Could Use an SSVEP BCI?," Front. Neurosci., vol. 6, p. 169, Nov. 2012

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