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RESEARCH ARTICLE

Development of Framework for Steady State Visually Evoked Potentials in Brain Computer Interface

Chetan Bondre[1], Deepak Kapgate[2]

[1] Department of Computer Science & Engineering, G.H.R.A.E.T, Nagpur University, India

[2] Department of Computer Science & Engineering, G.H.R.A.E.T, Nagpur University, India

[1] cbond21@gmail.com@gmail.com; [2] deepakkapgate32@gmail.com

Abstract— In this paper we discuss to development of the steady state evoked potentials (SSVEP) framework using electroencephalogram (EEG) signals. The main idea is to capture the signals from the brain for SSVEP application and after processing signals desired output can get. The information transfer rate(ITR) is to be increased using efficient filtering and classification algorithms such as Common spatial filter(CSP) and k-fold cross validation test. This study introduces a technique for classifying different frequencies separately so that accuracy is high. ITR is dependent upon accuracy, the more the accuracy more ITR can get.ITR can be calculated by the Wolpaw's Method. The focus of this paper is proposing the development of framework that can capture the EEG signals classify them in the SSVEP signals. These SSVEP signals then are used to train the user and application can be used by will of the user.

Keywords— Brain Computer Interface (BCI), Electroencephalogram (EEG), Steady state visually evoked Potentials(SSVEP), Information Transfer Rate(ITR).

I. INTRODUCTION

BCI uses very uncommon way of communication with the system and brain. Though it is uncommon it is the most direct way as the intentions are directly sent to the computer. With a BCI person such as subjects ideally do not need to use common output pathways of peripheral nerves or muscles, which is the main function of a BCI system. Cerebro-electrical brainwaves are measured with the electroencephalography (EEG), which is used to have primarily used for clinical purposes in the past, with amplification and fed into a system under certain circumstances and with proper algorithms able to process them satisfy application needs[19].

BCI can be classified in two categories by input system; those two categories are synchronous and asynchronous BCI. In synchronous BCI there is a predefined window is given in the system for a time variant. If there is any signal is generated outside that time window it is ignored by the system. This means that the user must use application in a specific time window which is specified by the BCI system. There are lots of advantages for the synchronous BCI, as only predefined signals are allowed in the system no other artifacts can be generated because of the user's fault. This makes the system more reliable and simple.

On the other hand asynchronous BCI is more complex and demanding. Asynchronous BCI needs continuous processing of the data even though the action of user is not a proper command system will continue the process[20]. This is the reason that asynchronous mode is a more natural way of interaction to the human with computers.

There are two types of headsets can be used for the collection of the data. They are 10-10 and 10-20. The difference between two headsets is according to their separation of the electrodes. Electrodes in 10-10 system are having distance among them as that of 10% of the total headset while 10-20 system is having distance between electrodes as 10% for boundary electrodes and 20% for other electrodes of the headset. There are total 18-21 electrodes in 10-20 system while 31-38 electrodes in 10-10 system. In 10-20 system we use less power than that of 10-10 system because of numbers of electrodes. Complexity in 10-10 system is more compared to 10-20 system and most of the electrodes in 10-10 systems are covered by electrodes of 10-20 system, because of these attributes generally most of the experiments are done with 10-20 system[6][8].

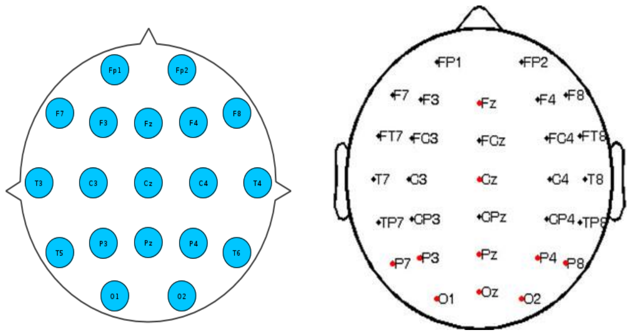

Fig.1 10-20 and 10-10 EEG headset

SSVEP-BCI offers the classification of a large number of symbols simultaneously and hence we can say that SSVEP BCI is multiclass in nature and provides high performance. Visual evoked potentials (VEPs) are electrical potential differences; those can be derived from the scalps after a visual stimulus, for example a flash-light[28].

There is a very high possibility of information transfer rate with minimal training time to the subject and very low requirements in SSVEP base BCI. Secondly if the system is carefully designed then it can be relatively robust with respect to noise and artifacts. The very important advantage is that we can easily extend the commands of the system because of the input process and short timing phase. The aim is to detect the reliably of frequency with the high accuracy. Furthermore the aim is to detect when the frequency do not appear, hence when the person or subject does not look at the stimulus.

OvenVibe is a software which is used to interface between the computer and EEG capturing device. We have used Openvibe to capture and store the EEG signals. These signals are processed by the framework and then final application can be run after the training is provided to the subject. We have used different modules to create the framework for example configuration of signals, training, classification and final application.

II. Theoretical Background

Information Transfer Rate: BCI performance might affected by two important task parameters. First is the number of targets. A large no. of targets may increase system performance, as more targets provide more information. Alternatively, a greater no. of targets may decrease system performance by decreasing its accuracy. The other is the rapidity of frequency change. Because of this user may feel tired after continuously watching at the screen.

Jonathon Wolpaw proposed a formula to calculate the ITR

$$ITR = s \cdot \left[\log_2 N + P \log_2 P + (1-P) \log_2 \left(\frac{1-P}{N-1}\right) \right]. \tag{1}$$

where N is the no. of possible targets. P is the probability that the target hit (accuracy). Bit rate can be calculated by dividing S by the trial .

In case of this project N=3. Accuracy and S is varying.

Electrode Positions: This is the important aspect in any BCI system. The position of the electrodes play an important role in the capturing the signals accurately. It means the quality of signals depend on the placement of electrodes. The positions used in this project are CPz, POz, Oz, Iz, O1,O2. The signals individually can be captured and then processed individually for each frequency.

K-fold Cross Validation Test : k-fold cross validation is a common technique for estimating the performance of a classifier. , a single run of k-fold cross validation proceeds as follows:
1. Arrange the training examples in a random order.
2. Divide the training examples into k folds. (k chunks of approximately m/k examples each.)
3. For i = 1, . . . , k:
• Train the classifier using all the examples that do not belong to Fold i.
• Test the classifier on all the examples in Fold i.
• Compute ni , the number of examples in Fold i that were wrongly classified.
4. Return the following estimate to the classifier error:

$$E = \frac{\sum_{i=1}^{k} n_i}{m}$$

III. PROPOSED SYSTEM

The Project is developed in OpenVibe software. The EEG signals are captured by the OpenBCI headset V-3 32 bit kit. There are different modules say scenarios are used in the system are Acquisition of signals, Training to user, CSP filtering and Classification, Online testing.

Acquisition of signals and configuration: Signals are tested in this module. Continuity of signals and quality of signals are checked using this module. We can check individual signals using this module.

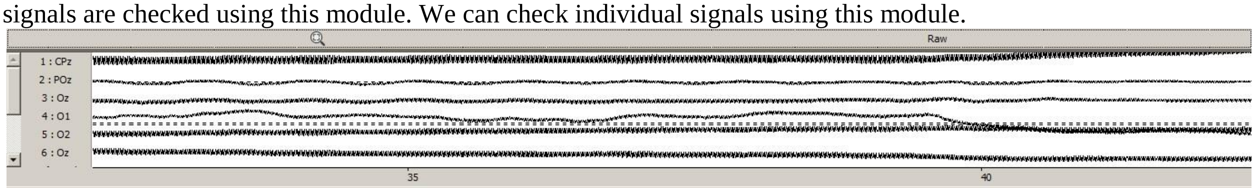

Figure 2. Signal Display of various electrode positions on brain.

This module contains FFT of average of all the signals and various boxes like acquisition client, temporal filter spatial filter for averaging, spectral analysis and signal display.

Configuration of the framework is can configure SSVEP experiment. There are two boxes of configuration parameters for peripheral and experimental settings. These settings are for stimulus and refresh rate of the screen.

Training of user: This SSVEP module uses Common Spatial Pattern (CSP) spatial filter which automatically selects the best characteristics. This means that user can place the electrodes on the occipital area's any part of the scalp. This module is used for acquisition of the training data necessary to train the SSVEP classifiers. In order to run correctly it has to be configured by the SSVEP Training Controller. Boxes used in this module are SSVEP training controller, stimulation control, acquisition client, and stream writer to write the data captured by the headset.

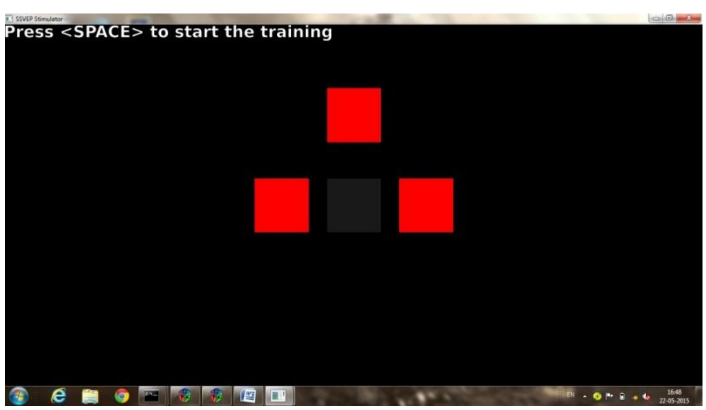

Figure 3. Flickering Stimuli for training the user.

CSP Training and Classification: CSP training is used for training of the Common Spatial Pattern filters. These enable user to use any set of electrodes and will automatically select the best combination of them for user. Signal processing is done on 3 different stimulation frequencies separately. Boxes used in the module are temporal filter, stimulation based epoching CSP spatial filter training, player controller and generic stream reader which loads the data written in previous module. Classification process contains boxes as generic stream reader, spatial filter, Target stimulator for different frequencies, time based epoching, DSP, Signal Average and classifier trainer. This module calculates the accuracy of the system which is useful for the calculation of ITR.

Online Testing: This module is used for the online testing of the framework. The trained data is used for scenario control of the system. This is in form of a game in which a ship is designed. It is having two wings which are flickering in two different frequencies which are used to rotate the ship in clockwise or anticlockwise. It also has a cannon which is used to fire the target. The cannon flicker with different frequency with respect to the two wings. The ship works in a way user concentrates on the flickering stimuli. This scenario contains boxes as SSVEP shooter controller, Scenario control, Button simplifier, player controller, Stimulator control, Spatial filter for three different frequencies, Time based epoching, Simple DSP, Signal average, Feature aggregator, classifier processor,SSVEp voter , VRPN ship control and Acquisition client.

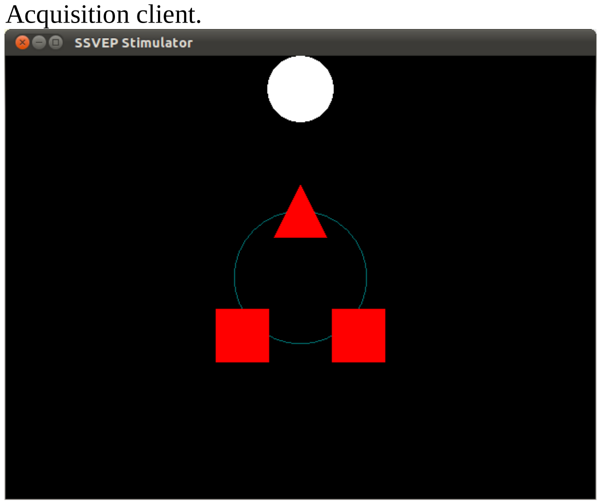

Figure 4. SSVEP stimulator online game

IV. RESULTS

After running all the modules explained above we get the accuracy ranging from 78% to 92%. Which leads to calculation of ITR.ITR is calculated manually and we get it from 24 bits/min to 40 bits/min with the feedback. The signals captured from the EEG headset are unstable with the software we used but most of the times signals captured were continuous and having great quality. The SSVEP stimulation is an online shoot game which is use for the testing of the system. It is running accurately with OpenBCI headsets. If user concentrates at right wing the ship rotates in clockwise direction. If user concentrates at right wing the ship rotates in anticlockwise direction. If user concentrates at cannon ship fires. After one target is vanished other target appears. There are total 8 targets to be vanish to finish the game.

V. CONCLUSIONS

In BCI mostly there is preference to the SSVEP system. As it is Exogenous BCI and it requires very low training to use, it is possible for user to perform actions on the system by their convenience. Furthermore SSVEP gives high information transfer rate so it is possible to use in real life also. Control signals can set up very easily so it is possible to use many options in one system using SSVEP. In this project ITR is increased then many of other frameworks used in past.

There are some disadvantages for the system; flickering visual stimuli may cause some tiredness or fatigue to the subject if used for a long time. If the subject is having some neurological disorders like color blindness or similar disorder, it is not appropriate for a person to identify the color, frequency or pattern in the system.. There is possibility of combining SSVEP signals with other Exogenous or Endogenous BCI signals. This can be done for the better performance, reliability of the system, robustness and more options to user.

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