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An alternate method for generation and usage of P300 EEG signal using image processing

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ABSTRACT

This paper presents a model for Developing a sustainable system for prolonged usage of Brain-computer interface for navigation and communication for the disabled, and the paralyzed with use of Electroencephalography (EEG) This model uses image recognition and classification of the video input from the camera for use in the P300 wave recognition. This model uses images instead of alphabets in oddball paradigm reducing the cognitive load on the brain and uses a different solution for the mental fatigue generated from the usage of the same visual stimulus over a long period of time

Keywords: *BCI, DWT, EEG, Event-related potentials, P300.*

1. INTRODUCTION

The brain EEG signals are captured by sensors placed on the brain scalp can be used in identifying the dominant frequency bands and analyzing brain activity. Among the signals extracted from the brain are event-related potential (ERP) which are generated after any cognitive process takes place after a visual, olfactory, auditory stimulus given to the subject. ERP's have been one of the most useful EEG Signals with a lot of practical application with disabled by using these signals to control and communication with the ERP's as input. Among the ERP's P300 has wide application lie detection, communication, and control of the vehicles with p300 signal.

The p300 traditionally have been used in spellers [1] [2] for communication with flashing words in rows and columns by the oddball paradigm which is mentally draining and most of the research done is done under 1 hour – 4 hours missing the practical effects of proposed systems over a long period of usage.

The system we propose replaces the use of speller with images acquired over real-time in the place of alphabets for communication and control making it easier and faster for the user relative to the 3.5- 4.0 word per minute cap by the P300 Speller.

There are three stages in this, the first step involves the acquisition and classification of the real-time video into images and set up to generate p300 signal for the user to select the category. The second stage involves the p300 recognition by discrete wavelet transform (DWT) for feature extraction and support vector machine (SVM) or convolution neural networks (CNN) or fisher's criteria for the p300 recognition. The third step involves in keeping the mental fatigue level of the user down so that it can be used over an extended period of time without the user getting strained by using the system.

2. DESIGN METHODOLOGY

A real-time control and communication for the user with least number of inputs from the user and lowering the cognitive load for the user is the main objective of this paper.

We choose to use DWT over other methods like short time Fourier transform and another transform to analyze the data. This is primarily because the frequency accuracy varies inversely with time accuracy and getting frequency and time accurately is really hard for example Fourier transform has no time component to it but has very high frequency accuracy and short time Fourier transform has time component but is very inefficient in time frequency localization when measuring non stationary EEG signal. The second part is recognition of p300 signal where various methods like SVM , and neural networks are employed as the recognition rate are usually accurate and change depending upon the subject's mental state, and the type of wavelet used in recognition and environment rather than the method employed after the DWT has been done.

The choice of usage of images instead of spellers is a critical one as the information conveyable by the subject by using images far outweighs that of a single word or letter.

The images are acquired by the camera and are classified into categories such as faces, objects, etc; to be selected by the user

With the help of P300 signal. The EEG signal passes through DWT and SVM (or any other equivalent method) for extracting the P300 signal as shown in fig 1.

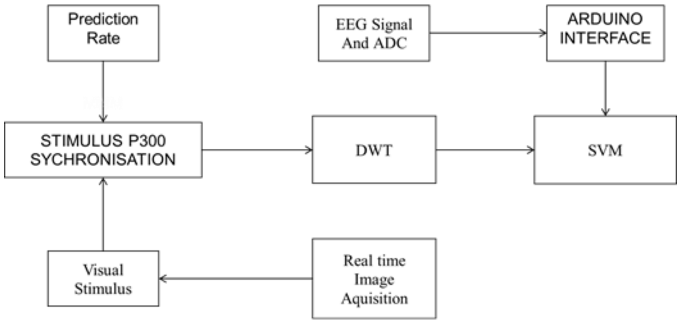

Fig 1 alternate to P300 speller

A. Discrete wavelet transform

Discrete wavelet transform can be seen as an extension of Discrete Fourier transform where sinusoidal waves are replaced by wavelets with specific shapes. In fact, feature extraction from DWT is conversation coefficients which indicate the similarity of the signal with components corresponding with its coefficients. The similarity of the EEG signal with the wavelet helps in identification of features better and so the mother-wavelet plays a crucial part in determining the accuracy. For the choice of mother wavelet, there have been many literatures about what kind of mother wavelet is suitable for P300.But db4 Fig 2 is used because of similarity between wave form and db4[3] and gives a pretty good performance.

Mother- Wavelet's contracting for high frequency and dilation for lower frequency. DWT works very well in EEG signals by giving both conversation coefficients and time-frequency localization with a relatively high degree of accuracy which is needed in real time application.

As filtration in frequency domain losses a lot of data. DWT is a great way to filter P300 signal. Mother wavelet plays a huge role in detecting the signal and different wavelets like db4, colf2, and sym4 are shown to better results when compared to others.

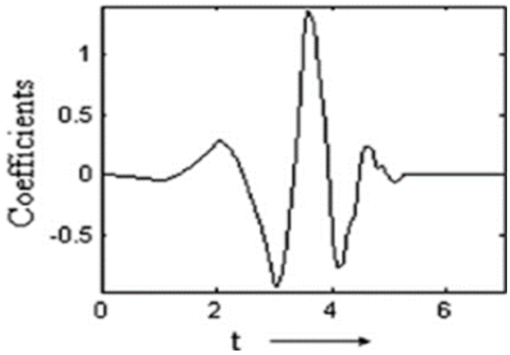

Fig 2 db4 wavelet

Doing layers of DWT is called multi-resolution decomposition. The multi-resolution decomposition Fig 3 separates the signal into details and approximation which is the coarse part.

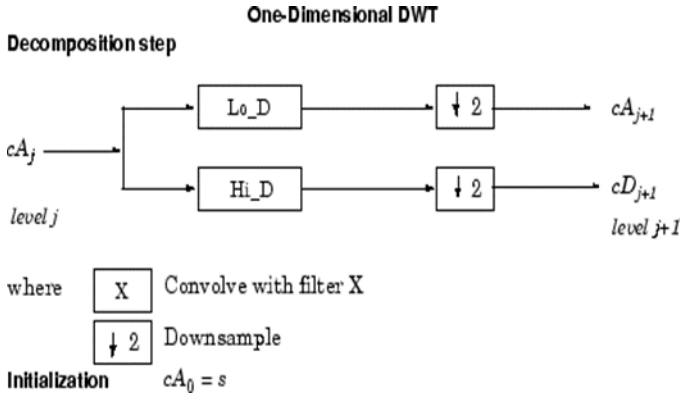

Fig 3 DWT level 1 decomposition

Mostly the P300 takes place in the delta frequency [4]. So we can concentrate more on analysis at the delta frequency.

B. P300 RECOGNITION

BCI was generally treated as a two-class classification problem. P300 signal and non P300 arbitrary EEG signal. Orthogonal least square (OLS) was boosted and used [5].

SVM has shown good results in P300 [6][7] recognition. SVM (ensemble) has shown better than single SVM [6] and SVM‘s are known for providing general ability than the traditional neural network trainer by error back propagation algorithm.

SVM make much more sense in using it as it takes fewer training time and the speed at which it responds to the P300 signal. Though the accuracy is very important it' SCs overall usability in a real-time system is determined by the above factors.

Contracted scales are used for high frequencies and dilated scale for lower frequencies. Mostly the p300 signals are observed in the delta frequency ranges

C. Acquisition and Application of Visual stimulus

The signals are extracted from the brain scalp using an electrode head gear with 12/16-bit analog to digital converter which samples each channel at 250hz. The electrode placements on the head gear are arranged in 20-10 format Fig 4 with the help of conductive solution such as KCL to reduce attenuation of EEG signal. These EEG signals are feed into the computer and processed by MATLAB real time. Generating ERP signals by P300 speller gives low information to work done ratio. Whereas usage of the images lets the user conveys more information in fewer trails. Live camera feed can be used to organize the real-time image into categories of faces, objects so that user can select the needed category , and the picture inside the categories can be selected by oddball paradigm. Makes a much better way for communication or navigation as it tries to reduce the amount to instruction needed to control. As human brains are used for processing huge amounts of visual information.

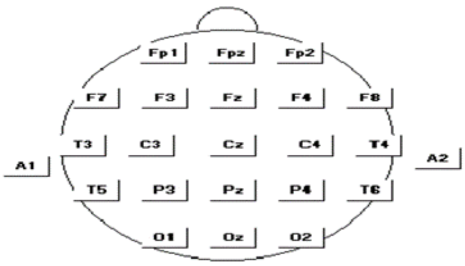

Fig 4 20-10 format arrangement on the scalp with A1 and A2 as ground

3. AN INTER-DISCIPLINARY APPROACH TO BRAIN FATIGUE

The number of trails required while training the SVM or CNN is around 5 to 6. There have many mentions of the user getting tired [9][10] during the trails so many of the methods developed for the usage of p300 signal in navigation have not taken into consideration the user tiredness or the necessity of prolonged usage as this is used by disabled paralyzed people. And the usage time cannot be reduced as it is the only way of communication for the disabled.

Various sensory input when given the same stimulation over and over again tend to either completely ignore that particular stimulus or get increasing difficult to process that repeating stimulus. One of the examples is olfactory fatigue when a single odor is applied as stimulus over a long time to the brain the nose cannot smell that particular odor.

The fatigue or tired from the neurological stand point is a decrease in reward chemicals like dopamine in brain.The dopamine level decreases as overtime after application of same stimulus.

There is a correlation between dopamine and the amount of p300 appears [11]. Calculating quantitatively measuring the mental fatigue. Mental fatigue scale [12] has measurable quantities such decreased processing speed and working memory.

The visual stimulus being given if its frequency is lowered by usage of images. Altering the visual input like changing the color filter makes the stimulus seem new in turn making the dopamine shoot up and this can be used in alteration when a particular stimulus starts to wear off reducing the drain on the user. A 3D p300 speller showed little better performance

Compared to the conventional p300 speller

We took a test group of 6 healthy subjects with no mental disorders or history of depression and divided into three segments where the First group is given the general p300 speller.

The second group is presented with the image as visual stimulation, and the third group is presented with modified images and repeated after a certain interval over a time span of three hours so that the visual stimulation does not feel redundant because of the small alterations to the original image. The readings of working memory and processing speed are taken every 15 min interval to measure the mental fatigue scale as its relative to the memory and processing time [12]. We observed that using one version of image modification as a stimulus for a limited and switching to another version decreases the fatigue as the dopamine is kept relatively high because it's perceived as new by the brain.

The scores of working memory and processing time are moderate while in the p300 speller it is a downward trend

Table 1 P300 Speller

WM 1	PT 1	WM 2	PT 2
14	17	13	16
12	12	9	13
7	15	10	17
8	11	6	12
6	8	8	10
11	10	9	9
9	12	8	13
8	9	6	12
10	7	10	9
12	10	12	11
8	11	9	10
5	13	8	8

Table 2 P300 with Images

WM 3	PT 3	WM 4	PT 4
14	17	15	16
12	12	7	13
7	15	10	17
8	11	6	12
6	8	8	10
11	10	7	11
9	12	11	13
6	11	13	12
10	7	10	9
12	10	12	11
8	11	9	10
5	13	8	8

Table 3 P300 switching Modified images

WM 5	PT 5	WM 6	PT 6
15	17	13	15
13	12	10	13
11	15	9	17
16	11	13	12
14	15	9	8
11	10	8	11
17	14	11	13
13	13	11	12
16	11	10	9
12	13	12	10
14	11	12	10

Working memory - WM (subject number)

Processing time – PT (subject number)

4. CONCLUSION

A model is developed for making it easier for the disabled using p300 signal based Brain-computer interface (BCI) for communication and control while considering the real world consideration like the amount of time a user spends and ease of use while using it by providing a real-time image classified for the user to pick. Varying the stimulus we provide so that the brain fatigue is reduced in user which might also be contributing to the error rate in recognizing the p300 signal.

It might be developed into providing stimulation in 3d form as most of the visuals are perceived 3 dimensionally.

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