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Design of EEG Based Wheel Chair by Using Color Stimuli and Rhythm Analysis

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***Abstract*—A novel methodology of brain controlled intelligent wheelchair by using color stimuli is proposed here. A general methodology is applied to find out most effective rhythm for color classification. Primary colors RGB and secondary color yellow were chosen for left, right, forward and stop command. Alpha, Beta, Theta, Delta rhythms were analyzed for three different subjects. Using dissimilar features of time and frequency domain twelve artificial neural network were built to decide the best rhythm. Principal component analysis was made for each EEG signal to remove the background effect of color stimuli. Comparing the findings it is visualized that beta rhythm is the most efficient rhythm with minimum mean square error of 4.845×10^{-9} among all designed ANN for color classification.**

Keywords— Electroencephalogram (EEG), Principal component analysis (PCA), Rhythm, Color stimuli, Artificial Neural Network (ANN).

I.INTRODUCTION

About hundred billion neurons are in human brain. Thoughts and emotional states makes interaction among these neurons. As a result different amplitude and frequency based EEG are produced. There are five rhythms namely alpha, beta, delta, theta and gamma [1]. Their frequency is eight to thirteen, thirteen to thirty, one to four, four to eight and thirty six to forty four Hz respectively.

Researches are going on to make an efficient and effective intelligent wheel chair for Quadriplegic and paralyzed patients. Most of recent works are based on eye blink such as described in [2]. Eye blinking is a natural phenomenon and uncomfortable command feature. By using one and two eye blink and attention level, a BCI was developed. Attention and eye blinks were also used in [3] but they have made it wireless and interfaced with RS-232C. SSVEP based wheelchair control is analyzed in [4]. Eye blink based another work is discussed in [5]. However an eye blinking pattern was used by them. An cost effective automated wheelchair with using conventional eye blinking feature is discussed in [6]. By recognizing eye movement such as blinking, glancing, eye opening a model is discussed in [7]. Researches on the basis of steady state visual evoked potential with different flickering frequency showed up good performance [8]. For classification support vector machine was used with satisfactory result.

In most of the cases either eye blinking feature or EEG raw signal was used. Some used internet of things. But there is lack of effectiveness. An innovative approach by using color stimuli is used here. To remove the background effect of the color stimuli the acquired EEG signals were gone through principal component analysis. Later band analysis was done. Though this work is depended on color stimuli but it can introduce more command features.

This paper presents a methodology to drive an EEG based wheelchair by using color stimuli with most effective rhythm. The primary colors red, green, blue were used for direction command (left/right/forward). A secondary color yellow was used to pause. The data acquisition was done by BIOPAC and Acqknowledge 4.1 software [9]. PCA and attribute extraction was done. Artificial neural network were built for classification in MATLAB 2014a.

The following portion of this article is designed as follows: part II describes about suggested method, section III describes about analyzing, section IV and V represents data analysis and classification. It ends with a opinion and coming up scope in portion VI.

II.PROPOSED MODEL

A. Projected Model

For designing EEG based wheel chair by color stimuli with PCA feature the model is described in Fig. 1. After getting the brain signal by BIOPAC and MP 36 , noise and artifact were removed. The rhythms were obtained by FIR band pass filter. To remove background effect of the color stimuli principal component analysis was done by Acqknowledge 4.1 software. The features were also extracted in this platform. Total twenty features were extracted in different frequency bands. Comparing the mean square error of artificial neural network which were based on extracted features a decision is taken about the proposed model efficiency and most effective rhythm.

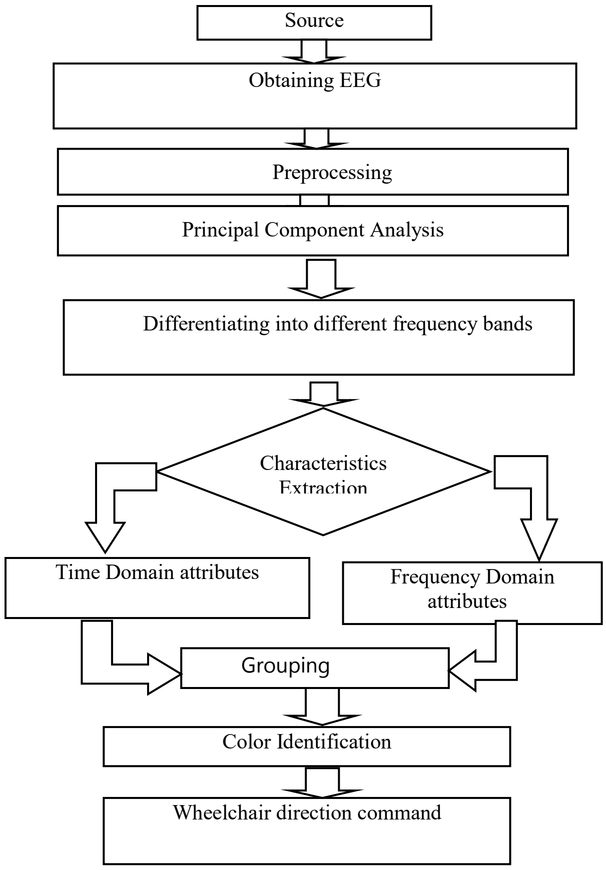

Fig. 1. Flow chart of suggested scheme

Fig. 2. Representational view while conducting experiment in BME lab, KUET

A. *Electroencephalography Determination and Exploratory Condition*

The test was conducted in Biomedical Engineering Lab of Khulna University of Engineering & Technology, Bangladesh. The test was conducted on three subjects, not suffering from any psychological disease or color blindness. The color stimuli was shown in personal computer monitor and instructed to focus on indefinite color. In real life patients may focus on monitor or colored board. Total ten trials were taken. First nine trials were used for training and validation purposes and the rest for test purpose.

B. *Experimental arrangement*

1) *Hardware description*: The BIOPAC data acquisition unit MP 36 was used in this experiment. Fig. 2 defines acquiring of EEG while conducting the experiment

2) *Diagonistic software*: Various softwares like BIOPAC student Lab Pro was used. For PCA and feature extractaion Acqknowledge 4.1 software was utilized. Principal component analysis was neceassry for removing background effect as the obtianed raw data was so much noisy. Artificial neural network was used in MATLAB 2014a platform.

III. PREPROCESSING AND ANALYSIS

A. *Filtering , Artifact seperating, smoothing*

The raw electroencephalogram was saved while experiment. There was noise may be due to EMG, EOG, hand movement, background effect of color stimuli. As 0.5 Hz to 44 Hz only necessary, band pass FIR filter was used. The line frequency (50 Hz) was removed. Smoothing was done for averaging the signal values.

B. *Principal Component Analysis*

Source is decomposed to a new signal by PCA. It is very effective as a data reduction tool. As the raw data was so much noisy although after removing artifact it was hard to classify individual color. So PCA was made for better color classification.

C. *Frequency bands analysis*

After filtering, smoothing, principal component analysis EEG was split up in different frequency bands by Acqknowledge 4.1 software. FIR band pass filter was used.

D. *Feature Extraction*

In time and frequency domain total twenty features were extracted. Maximum value, standard deviation, skew, kurtosis, Linear regression, moment of order from one to five, Lyapunov exponent, mutual information, correlate, Nonlinear model, power spectrum density mean , PSD max, PSD skew, fast Fourier transform mean, FFT max, FFT skew were extracted for three subjects in alpha, beta, delta, theta rhythms. All attributes were extracted in Acqknowledge 4.1 software.

IV. ATTAINED DATA

A. *Contrast of attributes of a individual rhythm for an individual color*

In time and frequency domain total twenty attributes were analyzed. In frequency domain PSD mean, PSD max, PSD skew , FFT mean , FFT max, FFT skew were analyzed. These attributes of subject 1 beta band for blue color is given in Table I.

TABLE I. RESPONSE OF BETA BAND IN FREQUENCY DOMAIN OF SUBJECT 1 FOR BLUE COLOR.

Trial	PSD (μV^2)/Hz			FFT(μV)		
	Mean	***Max.***	***Skew***	***Mean***	***Max***	***Skew***
1	0.038	0.748	4.085	0.016	0.341	4.024
2	0.038	0.769	4.185	0.017	-8.160	1.260
3	0.044	0.700	3.342	0.017	0.315	3.601
4	0.042	0.622	3.400	0.019	0.338	3.639
5	0.033	0.512	3.544	0.016	0.280	3.625
6	0.050	0.647	3.176	0.019	0.393	4.214
7	0.040	0.546	3.023	0.016	0.360	4.354
8	0.025	0.200	2.125	0.016	0.177	2.439
9	0.030	0.394	3.119	0.018	0.241	2.960
10	0.038	0.490	2.900	0.018	0.310	3.133

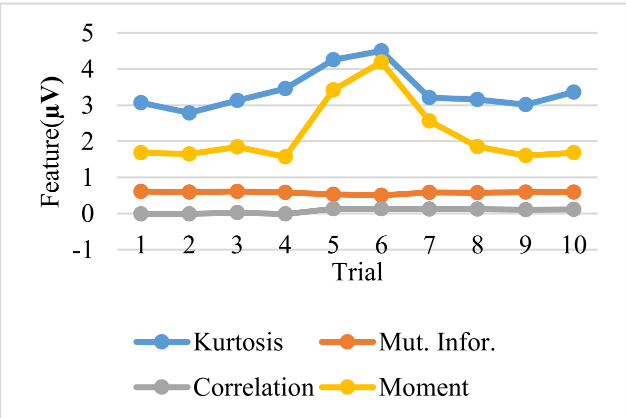

Fig. 3. Different attributes of beta band of subject 2 for red color.

Fig. 3 shows features of beta rhythm of subject 2 for red color. The kurtosis, mutual information, correlation, moment varied very small for same color and subject. Similarly twenty features were obtained for red, yellow, green, blue color and alpha, beta, delta, theta rhythm.

B. *Contrast of attributes of definite rhythm for various color*

There were three subjects and instructed at same condition. After PCA raw EEG was separated in frequency bands. Twenty features for each rhythm and every color were extracted. Fig. 4 shows PSD mean value of subject 1 of beta rhythm for different colors. For different colors the features varied greater comparatively.

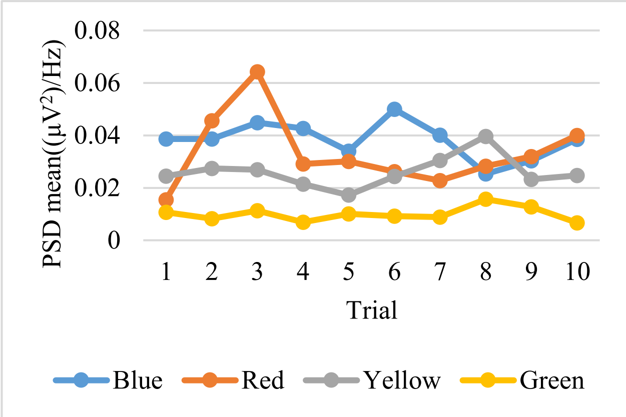

Fig. 4. Comaprison of PSD mean of subject 1 using beta rhythm for different colors

V. CLASSIFICATION RESULTS AND DISCUSSION

The categorization was required for analyzing the effectiveness of color classifying so that individual command can be identified. Moreover the effectiveness of rhythm also analyzed. By comparing the results of ANN most effective rhythm for color classification as well as command detection is determined. MATLAB built in nntool GUI was used. Feed forward backprob. , TRAINLM training function, LEARNGDM adaption learning function, two layer of Tan-Sigmoid transfer function, twenty neurons, Levenberg Marquardt learning algorithm were used. The target value was 10,20,30,40 for blue, red, yellow, green respectively.

A. *Scenario 1: Alpha Rhythm*

The ANN designed for alpha rhythm was successful to classify the colors having mean square error of 4.8125×10^{-6} , regression of 0.9898 , gradient of 0.0625. This ANN showed worst performance.

B. *Scenario 2: Theta Rhythm*

The ANN designed for theta rhythm was able to classify colors as well as command with mean square error of 1.1028×10^{-7}, regression of 0.996 , gradient of 1.10731×10^{-3} . It showed better performance than previous.

C. *Scenario 3: Delta Rhythm*

The ANN designed for delta rhythm was able to classify colors as well as command with mean square error of 3.56×10^{-9} , regression of 0.94164, gradient of 1.2478×10^{-5}. Relatively better performance obtained.

D. Scenario 4: Beta Rhythm

The ANN designed for beta rhythm was able to classify colors as well as command with mean square error of 4.845×10^{-9} , regression of 0.98157, gradient of 5.889×10^{-4}. It showed the best performance. Performance of the ANN designed for beta rhythm of subject 1 is shown in Fig. 5.

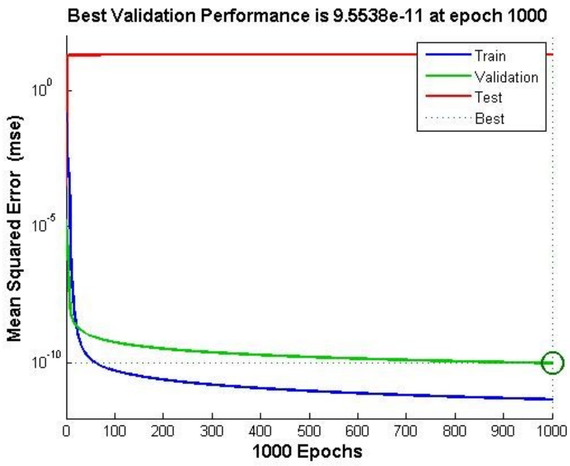

Fig. 5. Performance of ANN designed for Beta rhythm of subject 1

TABLE II . COMPARISON OF TWELVE DESIGNED NEURAL NETWORK.

Rhythm	Subject	Mean Square Error	Overall Regression	Gradient
Beta	1	9.5538×10^{-11}	0.9887	1.0290×10^{-6}
	2	1.4438×10^{-8}	0.9560	0.0017657
	3	1.5100×10^{-12}	1	4.1267×10^{-10}
	Average	4.8450×10^{-9}	0.9815	5.8890×10^{-4}
Delta	1	8.4434×10^{-9}	0.9997	2.0042×10^{-6}
	2	2.2354×10^{-9}	0.8260	1.2010×10^{-5}
	3	1.7720×10^{-12}	0.9991	2.3422×10^{-5}
	Average	3.5600×10^{-9}	0.9416	1.2478×10^{-5}
Theta	1	2.4561×10^{-7}	0.9999	0.0029
	2	5.9513×10^{-8}	0.9989	2.5050×10^{-5}
	3	2.5746×10^{-8}	0.9896	0.0003
	Average	1.1028×10^{-7}	0.9960	1.1073×10^{-3}
Alpha	1	5.6423×10^{-7}	0.9768	0.0518
	2	1.3553×10^{-5}	0.9938	0.1130
	3	3.2050×10^{-7}	0.9990	0.0227
	Average	4.8125×10^{-6}	0.9898	0.0625

All the findings of each designed neural network are showed in Table II. As total twelve ANN were built and there were three subjects so results of ANN for all subjects for same rhythm were calculated to an average value for generalization. The overall accuracy for color classification of Beta, Delta, Theta, Alpha rhythm based ANN were 100%, 99.8%,96.3% and 95% respectively. Data obtained in this work showed best accuracy for color classification as well as command for direction of wheel chair movement with Beta rhythm. Delta rhythms showed better performance and alpha rhythm showed worst performance.

VI. Conclusion

From this offline analysis of brain wave for the improvement of brain controlled wheel chair by using color stimuli, it is crystal clear that color stimuli can be used for this purpose effectively. The beta rhythm provided best performance for color classification of individual with minimum mean square error of 4.845×10^{-9} . Contradictory alpha rhythm showed worst performance with mean square error of 4.81257×10^{-6} .This method is more effective than conventional eye blinking based model because the command feature can be increased with increase in number of color stimuli. The feature of rotation at a certain angle, forward, backward, pause,left, right can be introduced through this proposed method. However there is a drawback of this proposed method is subject's visual weakness. The efficiency can be increased with increase in number of channels.

The future work can be implementation of this method with an increased number of color stimuli and channel. Making a fast online analysis system of EEG is under progress.

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