

# EEG Signal Based System to Control Home Appliances

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**Abstract** - This paper present a method of features extraction from an electroencephalograph (EEG) signal in real time based on common spatial pattern and utilize this into control command for home appliance. The determined goal of a BCI is the refurbishment of communication, effort and realization for patient and normal human. Due to successive research of electroencephalography based on single-sensor and spelling, now with the time they provide more detailed data about neurons communication. These data provides the patterns to regulate many devices such as cursor, prosthesis, wheel chairs, robotic arms etc. It promote an alternate to communication, behavior and control. It is an artificial machine interaction that bypasses the physical movement of human body. In that order an electroencephalogram constructed brain-computer interface is associated with a NeuroSky [1] Mindwave mobile headset to control home devices. The procured brain signals are transferred to the Arduino [2] using HC-05 Bluetooth module. In this context to control home devices we used an eye blinking and meditation with help of IOT. According to literature a CSP (Common Spatial Pattern) algorithms was utilized to study spatial pattern of envision hand and foot effort. Significant channel were chosen via looking through the greatest of spatial pattern in scalp mapping. The characterization precision with two ideal value for attention its 63 and eye blink were 127 and accuracy is 90% for five subject.

**Keywords:** Brain Computer Interface (BCI), Common Spatial Pattern (CSP), Electroencephalography (EEG), Internet of Things (IOT),

## I. INTRODUCTION

In current scenario, humans have invented to interact and communicate with devices through the brain signal and also create machines that work with human's brain. Modern science fiction stories and prehistoric myths are form of human brain thoughts. However, brain imaging technologies and cognitive neuroscience are attractive domain to provide interfacing with the human brain. Using sensors some of the action that strike within the brain that relates with forms of signal can be monitored. For the necessities of people, researchers have used this knowledge to develop BCIs, communication systems, such as a system that does not depend on peripheral muscles and nerves of the brains. This type of system can help two type of patient, first one who have physical disorder to recover their activities with a wheelchair, or a robot and so on. Second, for mentally disorder to monitor and restore their consciousness. It also help for healthy people to improve the efficiency and the productivity in extreme-throughput jobs. A BCI is an AI arrangement that can identify a definite set of arrangements of brain signals in further five consecutive stages: signal acquisition, preprocessing or signal enhancement, feature extraction, classification, and

the control interface [3]. Non-invasive methodologies have successfully been used by severely and partially paralyzed patients to reacquire basic forms of communication and to control neuroprosthetics and wheelchairs [4], [5], [6]. EEG signals are easily procured in a non-invasive manner through electrodes placed on the scalp, for which that reason it is by far the most widespread recording modality.

Table. 1 Various Neuroimaging Methods

Neuro-imaging Process	Movement Measured	Measurement Method	Possibility Measures	Portability Measures
ECoG	Electrical	Direct	Invasive	Portable
INR	Electrical	Direct	Invasive	Portable
EEG	Electrical	Direct	Non-invasive	Portable
MEG	Magnetic	Direct	Non-invasive	Non-Portable
fMRI	Metabolic	Indirect	Non-invasive	Non-portal
NIRS	Metabolic	Indirect	Non-invasive	Portable

EEG includes a set of signals which may be categorized on basis of their frequency. Well-known frequency ranges have been defined according to arrangement over the scalp. These frequency bands are discussed to as delta ( $\delta$ ), theta

( $\theta$ ), alpha ( $\alpha$ ), beta ( $\beta$ ), and gamma ( $\gamma$ ) from low to high, consequently. As explained above, EEG is recorded by electrodes. The electrodes placement methodology over the scalp are commonly based on the International 10–20 system [7] which has been standardized by the American Electroencephalographic Society. Still, some manufacturing companies, such as Emotiv[8] (San Francisco, CA, USA) and NeuroSky (San Jose, CA, USA) have released their wireless BCI headsets (Emotiv Epoc, NeuroSky Mindwave) for entertainment uses such as mind control gaming and brain signal monitoring with affordable prices for the clients. NeuroSky Mindwave Mobile Headset is low cost than the Emotiv Epoc, but it has only one electrode placed at the pre-frontal left position, Fp1. In figure 1[9].

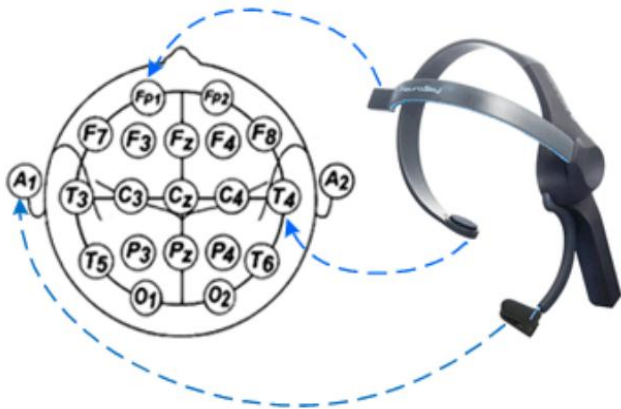


Fig.1 NeuroSky Mindwave Mobile headset electrode positioning based on 10-20 international system of electrode placement [8], as accessed on 2 Feb 2018.

NeuroSky devices have been used in scientific research, for example, as Home Automation by BCI [10], [11], [12], [13], [14] to controller robot by brainwave [15], [16] or for sensing or recognizing attentional [17], [18], [19] or relaxation [20], [21] states. NeuroSky Mindwave delivers various information but we used three classifier in three levels of processing in our framework: raw EEG signal, attention and eye blinking. This work looks into the feasibility of using cognitive skills, like attention, to control a system in a binary way (ON/OFF- attention\_threshold), such as a switch and eye blinking is used as a counter (3 bit) for device selection. Therefore, eye-blinking and attention signals are used as the management signals. These EEG signals are translated into instructions in PC. The experiment was performed first by normally developed people to calculate a CSP [22] analysis over collected data and then a mean value from this result is being utilized in Arduino sketch. Arduino is used to control home appliance.

In this paper EEG signals are collected from 14 subject for attention values and the eye blinking values are used to process the CSP algorithms for two condition on it and find an average values to control the model of home appliances such as different lights. There are a CSP mean techniques is implemented to find threshold values for eye blink and

attention and we used these values to control home appliance.

## II. PROBLEM STATEMENT

In medicinal perspective we found that stroke, epilepsy, brain injury, back bone injury and muscle injury are the leading causes of disability affecting many people. These are serious causes of injury as they are physically or mentally handicapped. In same manner aged people also need someone to complete their routine tasks. As per Census 2011, in India, out of the 121 Cr population, about 2.68 Cr individuals are ‘disabled’ which is 2.21% of the total population [Census, 2011]. In this figure when we talk about “development”. We could not achieve this 100% due to this human disability so we need right path to improve their life and efficiency. The non-invasive method is used for a most variety of the applications to simplify human life, therefore the NeuroSky Mindwave sensors for the non-invasive BCI technique are easy to wear on head and do not need any type of surgery as it is compulsory in the invasive and partially invasive methods.

## III. EXPERIMENTAL METHODOLOGY

We selected fourteen physically fit people for this investigation. Every individual was situated easily before a PC screen. A basic Graphical User Interface (GUI) that show video stimuli as bulb OFF for five second and ON for one second prompts to the all subject, According to bulb ON frequency participant’s will blink their eye’s (Twice). The NeuroSky Mindwave Mobile headset was wearied on the participant’s head. This device shown in Fig. 2.



Fig.2 NeuroSky Mindwave Mobile EEG

The NeuroSky Mobile Headset are having one frontal electrode and one non considerable referenceable electrode as ear clip. In this setup EEG were used for data acquisition signals.

Table. 2 NeuroSky EEG Rhythmic Activity Frequency Bands [1]

EEG Signal Type	Frequency Range ( in Hz)
Delta	0.1-3
Theta	4-7
Alpha1	8-9
Alpha2	10-12
Beta1	13-17
Beta2	18-30

Gamma1	31-40
Gamma2	41-50

So we targeted on acquiring the mind electrical activities for attention and more focused on capturing the muscle activities like an Eye blink. Generally, EEG indicators are characterized with the aid of rhythmic movement. Each band has a distinctive level of rhythmic movement. Table 2 offers the facts about the specific frequency bands and their rhythmic activities. These values have been procured with the help of the usage of the ThinkGear library function as eye blink by TG\_DATA\_BLINK\_STRENGTH=37 and attention through TG\_DATA\_ATTENTION=2. The interest or concentration can be controlled visually focusing on a specific point. During the focusing or concentration of the unique user, stage range from 1-100 [1]. The strength of discovered blink value range from 0-255 [1], (for small blink-zero and big blink-255) the attention variety in-between 40-50 at any given second is considered as "impartial or baseline". The EEG signal that is accrued can be analyzed by using offline processing method. However, a MATLAB [24] program has been written to collect the eye blink and attention from the EEG signal and a CSP algorithm is performed for further processing. The whole procedure is as described below:

- Establishment of a Bluetooth connection between the Laptop and the NeuroSky Mindwave Mobile Headset
- A calibration is setup for at least two minute
- Visual stimuli is start along with data acquisition with help of MATLAB
- Signal the start and end of each test with a 3-minute test timer.
- Display and record the attention and blink or raw data
- Create a dataset for two different class as Normal condition and Relaxed by repeating above steps.
- Process the CSP algorithms to find threshold value for attention and blink for both classes
- Calculate mean of CSP result to find a threshold values for eye blink and attention
- These values are used in Arduino's sketch to control home appliances.
- Setup a Bluetooth pairing of Neurosky Mindwave with Arduino Board using HC-05 module.
- Connect the Arduino with PC using UART cable and upload the Home\_Appliances sketch.
- Setup all the connection as per the Fig. 18, and then switch ON the Arduino Board.
- After that switch ON the Neurosky Mindwave headset, now the Mind wave device and Arduino Board (with HC-05) will pair automatically.
- Test subject's wear the Mind wave device on Head, and start blink eyes.
- For Neurosky Mindwave headset need calibration to detect the eye blink values in EEG signal? So far we

need to hold up couple of minutes (roughly 2 min) for calibration.

- After this calibration, every eye blink greater than blink\_threshold was counted (1 to 7). It's used for selection of home device.
- A particular device was selected and subject start concentration (attention) to change the state of particular device.
- If received averaged attention values is greater than attention\_threshold, then selected device will turn ON/ OFF.

#### IV. PROPOSED WORK

In The Proposed work, a NeuroSky Mindwave mobile headset is used to acquire brain EEG signal. A BCI is an alternate communication pathway between the human brain and an external interface. The system shown as figure 3. The patterns and frequencies of the brain electrical signals can be measured by placing a sensor on the scalp [23]. NeuroSky ThinkGear [1] technology, which measures the analog electrical signals, commonly referred to as brainwaves and processes them into digital signals.

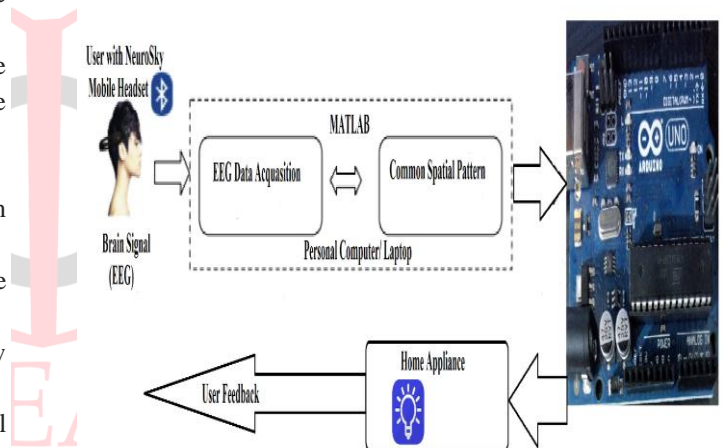


Fig.3 Proposed System Architecture

The NeuroSky device will receive the brain wave raw data and then it this data is collected through MATLAB platform by creating a program for data acquisition, which is further used as data processing unit to implement CSP over it. This analyzed data is being used in Arduino code transmitted to the controller section serially using UART cable. The control commands will be transmitted to the home appliance to change the state of the device as shown in the block diagram for further processing.

In controller section first, the Bluetooth pairing of the NeuroSky Mobile Headset sensor is done with the Arduino by HC-05. The Bluetooth MAC address of NeuroSky Mindwave is bind with HC-05 using command mode. The blink\_threshold and attention\_threshold value is defined in Arduino sketch to control home appliance. By Neurosky Mindwave headset measure the eye blink and attention values are detected and the corresponding home appliance

is selected and according to the eye blink and attention values, the home appliance is switched ON/OFF.

The flow diagram Fig. 4 shows how home appliances are controlled using attention and eye blinking signals from the human brain. It works as follow; the first step is to initialize the NeuroSky mobile handset and then capture the EEG eye blink signals. Then around 2 minutes is needed to calibrate NeuroSky Mobile Headset with Arduino by HC-05 Bluetooth module. The eye blink signal values range from 0 to 255.

Initially, Threshold\_eyeblink will be maintained, if Eyeblink signals values are greater than 127(Mean eye blink value from CSP algorithms) then the counter (device selection) will become starters, and each Threshold\_eyeblink change the device selection. After that, an attention signal value is going to use to control device state by mean attention value. This attention value range from 0 to 100 and if attention value is greater than 63 (Mean eye blink value from CSP algorithms), it'll change the status of LED. i.e. if LED lights on will turn off, and LED lights off will turn on.

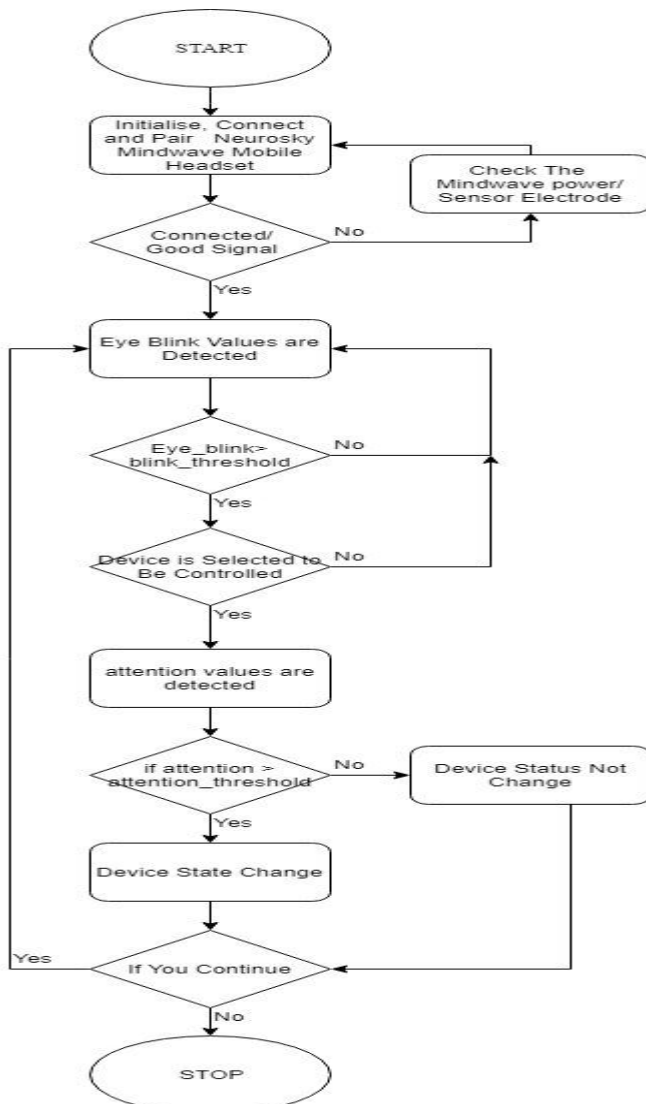


Fig.4Flow chart of Home Appliance Control

### A. Experiment Requirement Specification

#### 1) Participant

Seven young adult subjects (A1...A7) aged  $20.0 \pm 3$  formed group and seven adult subjects with (B1...B8) aged  $35.0 \pm 5$  made up group B, who participated in test.

#### 2) Environment

Experimentation was carried out in a quiet room with normal lighting. The experiment was considered correct if there were no interruptions. Participants belonging to group A and B were told to set the environmental conditions (temperature, lighting) so that they were comfortable during the experiment.

#### 3) Stages in Testing

Testing consisted of two situations. As described below, in the first phase, the participants had to find the strategies to control their attention and hard blink (twice) their eye according to a visual display (bulb on) in a video. Those who would not have been able to control their mental state properly did not perform the following phase. The Second phase was similar to the first with the difference that we recorded the information sent by the sensor with some relax music and suggest user to sit back properly to achieve clam condition to their own.

#### 4) Experiment Timeline for Signal Acquisition

Since the duration of each test was three minutes as shown in Fig. 5, each subject took in approx. total between 7 to 15 minutes to complete all 2 stages, the survey, and the briefing. After the test, the subjects were asked to continue the survey to gather information about the comfort of the NeuroSky Mobile Headset as well as the different relaxation techniques the subjects used for the second task. Most of the subjects mentioned that they sat back deeper in the chair while listening to the relaxation music played.

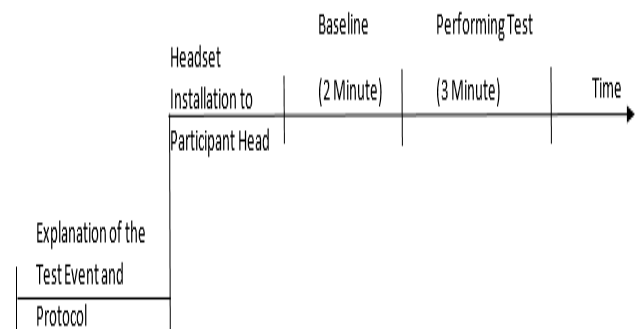


Fig.5 Timeline for the Experiment.

#### 5) Visual Stimulation

The graphical stimuli were offered to the subject on a 15.6" display screen. EEG data were collected from each subject while performing the experimental task. Each workload level session lasted approximately 5 min. The experiment lasted for approximately 15 min including subject preparation, testing, and breaks. Relaxing breaks were given between different workload phases. If the subject fell

asleep, the test was dismissed and a new appointment was planned. In this we explain user to press hard eye blink (double) when a visual of a bulb on is evoked (1 sec) in video and rest of time (5 sec) they need to alertness for the video. This process is collected from the subject data according to their value sense by Mindwave. The structure of visual stimulation is shown in fig.6.

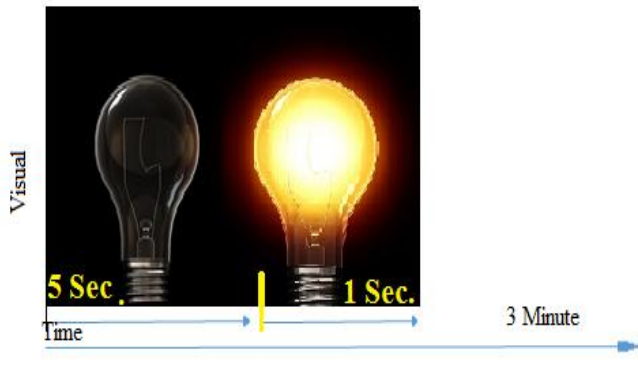


Fig.6 Structure of Visual Stimuli

## V. SIGNAL ACQUISITION

Data acquisition was done through developing a MATLAB program on a Laptop running the Windows operating system. The MATLAB program was designed for two main reasons: To experiment with the NeuroSky headset to collect data, and evaluate CSP on it. Communication between the NeuroSky mobile Headset and the Laptop was done via a wireless Bluetooth connection and according to the ThinkGear proprietary communication procedure developed by NeuroSky. The program was built using ThinkGear functions on the MATLAB using the ThinkGear library provided freely on the NeuroSky website. It was presented examples of recorded EEG signal in time domain. On the basis, two situations we collect attention and eye blink signals for all subject and signal waves are presented. The Bluetooth communications protocol is used by the system of visual stimuli framework for message exchanges between MATLAB and the EEG device.

## VI. FEATURES EXTRACTION

The attention and eye blink information gathered from each test contains of two mental states: NORMAL and REST. The EEG information was handled by a signal preparing unit that performs signal preprocessing, feature extraction, and characterization tasks. The valid features were extricated and meant helpful to control signal that could be utilized in device control. In a two-class characterization issue, the yield of the classifier had one of the two discrete states variations. Signal feature extraction comprises of two methodologies: spatial filtering and temporal filtering as shown in Fig. 7. In this examination, a MATLAB tool used to collect user data and this data used

to process the spatial filtering on EEG information by CSP algorithms [24].

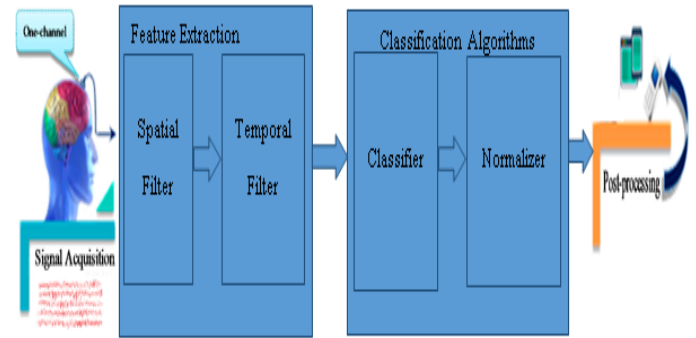


Fig.7 EEG Signal Processing Framework

### A. Common Spatial Patterns (CSP)

Common Spatial Pattern (CSP) method was first suggested for classification of multi-channel EEG during imagined hand movement by H.Romoser [24]. Details of the algorithms are described as follows with the example of classifying single-trial EEG during normal and relaxed state.  $X_F$  and  $X_S$  denote the preprocessed EEG metrics under two conditions (First and Second) with dimension  $N \times T$ , where  $N$  is the number of channel and  $T$  is the number of trial per channel. The normalized Spatial Covariance of the EEG can be represented as:

$$R_F = \frac{X_F X_F^T}{\text{trace}(X_F X_F^T)} \quad 1$$

$$R_S = \frac{X_S X_S^T}{\text{trace}(X_S X_S^T)} \quad 2$$

$X^T$  is the transpose of  $X$  and  $\text{trace}(A)$  compute the sum of a diagonal element of  $A$ . The averaged normalized covariance  $\bar{R}_F$  and  $\bar{R}_S$  are calculated by average over all the trails of each group. The composite spatial covariance can be factorized as

$$R = \bar{R}_F + \bar{R}_S = U_0 \Sigma U_0^T \quad 3$$

Where  $U_0$  the matrix of eigenvectors and  $\Sigma$  is the diagonal matrix of eigenvalue. The whitening transformation matrix

$$P = \Sigma^{-1/2} U_0^T \quad 4$$

Now we can transform the average covariance matrices as

$$S_F = P \bar{R}_F P^T$$

$$S_S = P \bar{R}_S P^T \quad 5$$

$S_F$  and  $S_S$  share common eigenvectors and the sum of corresponding eigenvalues for the two metrics will always be one,

$$S_F = U \Sigma_F U^T \text{ and } S_S = U \Sigma_S U^T \quad 6$$

$$\Sigma_F + \Sigma_S = I \quad 7$$

With help of equation 6 and 7, general eigenvectors (U) and eigenvalues for  $S_F$  and  $S_S$  can be calculated. By apply a norm (MATLAB) function over eigenvectors to change complex values into normal value.

The eigenvectors with the largest eigenvalues for  $S_F$  have the smallest eigenvalues for  $S_S$  and vice versa. The transformation of whitened EEG onto the eigenvectors corresponding to the largest eigenvalues in  $\Sigma_F$  and  $\Sigma_S$  is optimal for separating variance in two signal matrices. The projection matrix W denoted as

$$W = (U^T P) \tag{8}$$

The decomposition (mapping) of a trial E is given as

$$Z = WE \tag{9}$$

$$E = W^{-1}Z \tag{10}$$

Where  $W^{-1}$  is the inverse matrix of W. Hereby applying abs function over  $W^{-1}$  to find absolute value from it. The column of  $W^{-1}$  are spatial patterns, which can be considered as EEG source distribution vectors. The First and last columns of  $W^{-1}$  are the most important spatial pattern that explains the smallest variance of one task and the largest variance of another task.

## VII. RESULTS

### A. Result Data by EEG Signal Acquisition

In Experimental setup user's brain signal as eye blink and attention using MATLAB code. In this code, 14 user's data is saved for 30 trails in CSV file format that have one field (column) space separated values which are eye blink and attention. We manually convert this data in two column. The first column shows the values of eye blink and second column represent the attention value. Further, this data is separated into two excel file for both situation as one for attention values of 14 subject and another on is blink value for these 14 subject.

Fig. 8 show the blink strength graph in between strength amplitude and 30 trial of 14 subject. In graph a minimum value is 31 found for subject 5, subject 7 and subject 11 and maximum value 255 for subject 12 and subject 13.

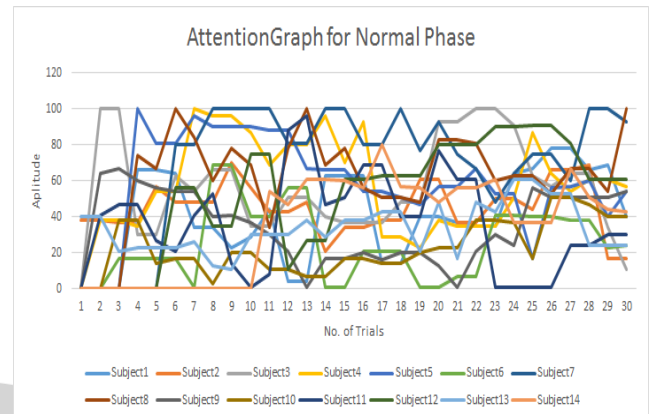


Fig.9 Attention Graph of Subject for Normal Task

Fig. 9 show the attention strength graph in between attention amplitude and 30 trial of 14 subject. In graph a minimum value is 1 (except 0) found for subject 9 and subject 14 and maximum value 100 for subject 3, subject 4 and subject 7.

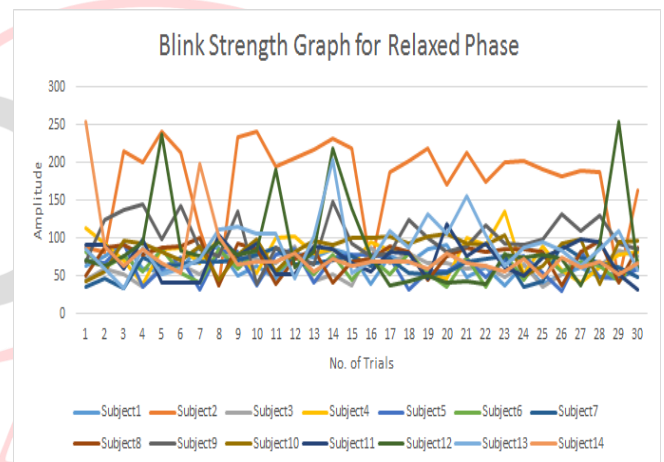


Fig.10 Blink Strength Graph of Subjects for Relaxation

Fig. 10 show the blink strength graph for Relaxed phase. This graph show a blink strength of 14 subject for 30 trials. In graph a minimum value is 31 found for subject 5 and maximum value 255 for subject 12 and subject 14.

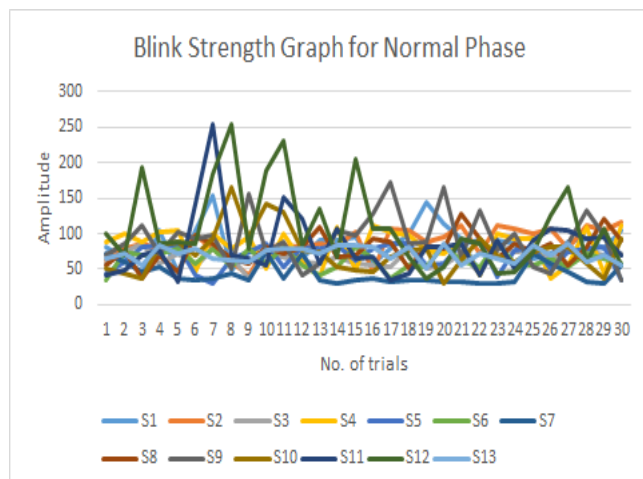


Fig.8 Blink Strength Graph of Subject for Normal Task

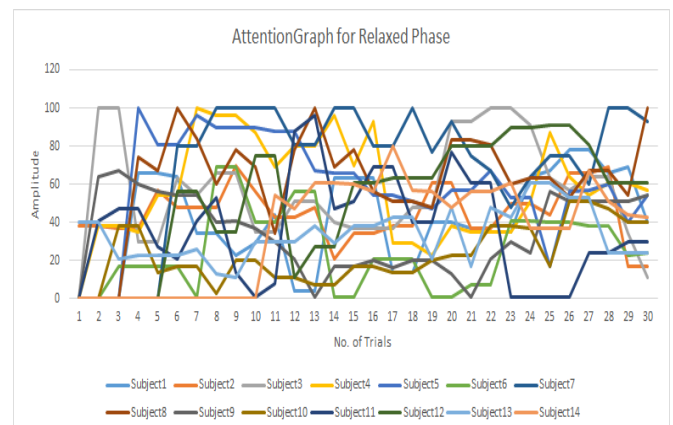


Fig.11 Attention Graph of Subjects for Relaxation

Fig. 11 show the attention strength graph for Relaxed situation. This graph show attention values of 14 subject for 30 trial. In graph a minimum value is 1 (except 0) found subject 9 and subject 14 and maximum value 100 for subject 3, subject 4 and subject 7.

By above graph representation show that different data is found for the attention values and eye blink for all subject, which is variable in nature for each user and each situation. These graph show no relative constraint in between user for all trials. So this data is used as raw information not used for experimental setup for generalize threshold value for attention and eye blink.

**B. Result Data by CSP Algorithms**

In this section, the MATLAB process the subject data by CSP algorithms code and find test result for a Normal and Relaxed situation of attention and eye blink with CSP for 14 subject that is shown by figure 12, 13, 14, 15. By using CSP algorithms we find different classes data for every subject. In this, some function performs as abs function (MATLAB) for absolute value and round function (Excel) to convert this values in real values.

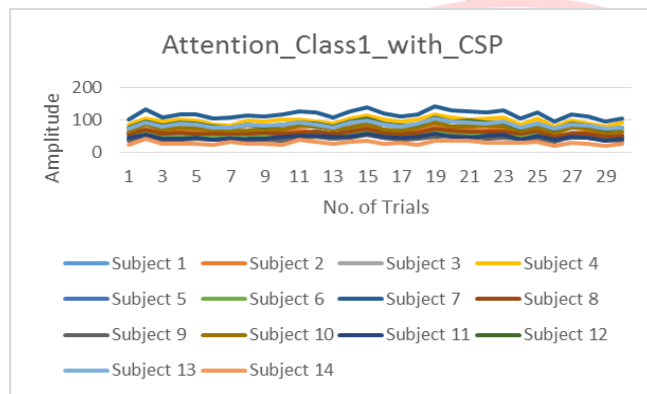


Fig.12 14 Subject Data Attention Values with CSP for Class1

With help of MATLAB CSP program attention data is processed for Normal situation as graph shown in Fig 12. In this graph on vertical axes amplitude value of attention is shown for 14 subject and on horizontal axes no of trials is taken place for these. This graph show that on each trial for each subject having similarity, as trial have a hike for all subject and same side down for all subject.

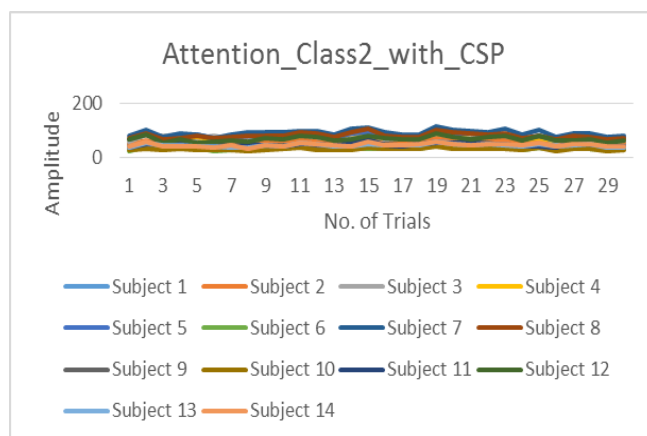


Fig.13 14 Subject Data Attention Values with CSP for Class2

A graph is plotted for attention data is processed for relaxed situation as shown in Fig 13. In this graph on vertical axes amplitude value of attention is shown for 14 subject and on horizontal axes no of trials is taken place for these.

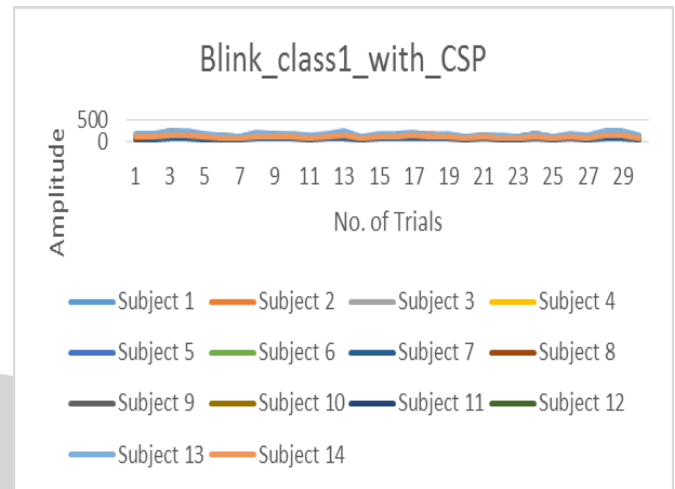


Fig.14 14 Subject Data Blink Values with CSP for Class1

By using MATLAB CSP program eye blink data is processed for Normal situation as graph shown in Fig 14. In this graph on vertical axes amplitude value of blink strength is shown for 14 subject and on horizontal axes no of trials is taken place for these.

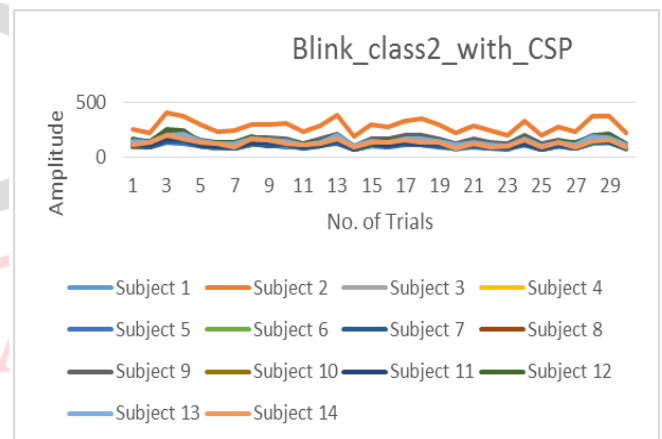


Fig.15 14 Subject Data Blink Values with CSP for Class2

A graph is plotted for eye blink values by CSP for Relaxed situation is shown in Fig 12. This graph show that on each trial for each subject having similarity, as a trial value have a hike for all subject and same side down for all subject.

By looking up these values, a calculation can be done to find the mean value of attention and eye blink for both classes. So an analysis table 3 is prepared for Normal Situation and table 4 is create for Relaxed class and here a common average value for attention and eye blink with CSP and Without CSP is being calculated.

**1) Normal Situation:**

Table. 3 Data of Normal Situation

Subject	Attention without CSP (Mean)	Blink without CSP (Mean)	Attention With CSP (Mean)	Blink with CSP (Mean)

S1	45	84	58	133
S2	50	88	64	139
S3	63	66	81	105
S4	75	82	97	129
S5	35	69	45	109
S6	42	63	53	100
S7	43	91	68	116
S8	47	70	60	111
S9	33	76	42	124
S10	57	94	73	146
S11	36	75	46	121
S12	67	83	86	133
S13	66	110	85	172
S14	22	71	28	112
Mean	52	77	67	122

With help of table 3, a decision is taken that optimal mean value of the Normal test for attention is 52 and 77 for eye Blink Strength. And with CSP algorithm this value is improved as 67 for attention and eye blink values as 122. These mean values are amplitude values in a time domain. In the below, tables data is plotted in Fig. 16. Blue color line show the Mean values of attention of Normal situation for 14 subject are taken before CSP and after processing CSP are shown by brown color line. Eye blink mean value of 14 subject are display by orange color for without CSP and yellow color show CSP processed values.

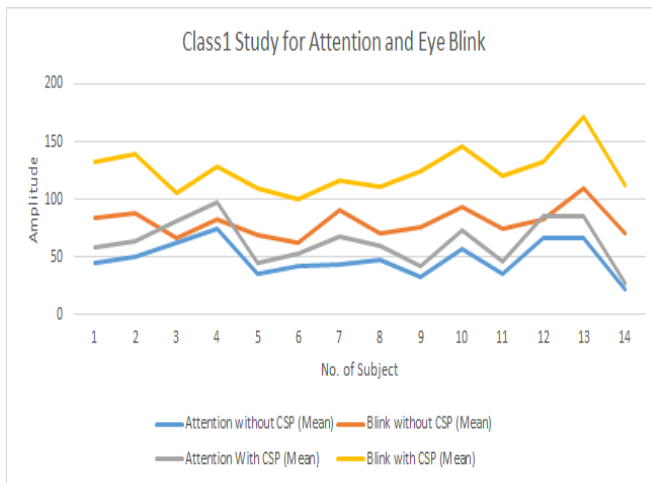


Fig.16 Mean graph of attention and eye blink for Phase1 (Normal)

2) **Relaxed Situation:**

Table 4 shows the values in a Relaxed test, by examining above data an optimal mean value of attention is 45 and value of eye blink strength is 84 shown. And these value show improved result with CSP algorithms for attention value as 58 and for eye blink 132. These mean values are amplitude values in a time domain. In the below, there are some sample figures of blink and attention values in time domain graphics.

Table. 4 Data of Relaxed Situation

Subject	Attention without CSP (Mean)	Blink without CSP (Mean)	Attention With CSP (Mean)	Blink with CSP (Mean)
S1	41	65	52	103

S2	45	178	58	282
S3	57	63	73	100
S4	58	79	74	123
S5	59	63	76	97
S6	26	64	33	101
S7	70	64	90	101
S8	62	75	80	120
S9	35	101	44	161
S10	23	84	29	133
S11	37	73	47	114
S12	52	91	67	148
S13	34	90	44	142
S14	36	79	45	126
Mean	45	84	58	132

In the Fig. 16 a graph represent the study for Relaxed situation. Blue color line show the Mean values of attention of Normal situation for 14 subject are taken before CSP and after processing CSP are shown by brown color line. Eye blink mean value of 14 subject are display by orange color for without CSP and yellow color show CSP processed values. By examining the graph a subject2 having exceptional hike for blink other all values lines showing an almost similar way of amplitude increasing and decreasing.

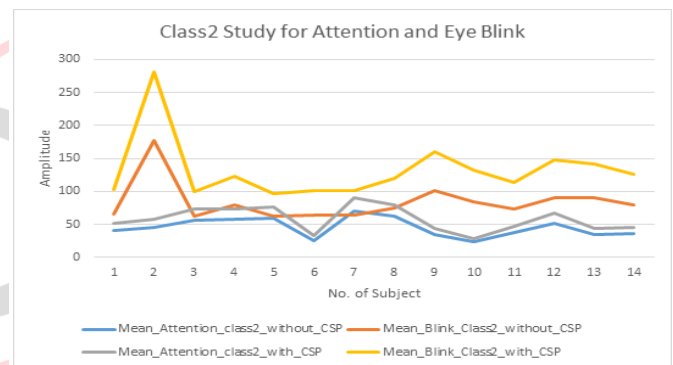


Fig.17 Mean graph of attention and eye blink for Phase1 (Relaxed)

C. **Data Analysis**

When user's data were examined two different phase reports which are; Normal condition and Relaxed condition. This calculation and results accuracy is 90%, in light of the fact that both NeuroSky Mindwave Mobile Headset and our framework setup have an error rate, so we qualities our result with  $\pm 5\%$  and we utilize this correction in our experiment. We observed to changes about mean values of attention and eye blink in 3 minute.

- 1) **Normal situation**, mean value of attention is equivalent to approx. 52. Likewise, we can see on the attention graph which has amplitude values and all values from 22 to 75. In addition, in a Normal situation, mean values of hard eye blink rate is around 77. And with CSP these values are calculated as 67 for attention and 122 for an eye blink. These values are variable in nature for each individual yet this values is a mean of 14 subjects. So it is important to detection for in this situation.
- 2) **Relaxed situation**, by calculation mean value of attention is 45 and eye blink rate is approximately 84. And with CSP these mean value of attention is



calculated as 58 and for an eye blink it's 132. These values are also subject dependent and varying in nature for each subject for different session and condition.

Table. 5 Data Analysis for Attention and Eye Blink

	Attention without CSP (Mean)	Blink without CSP (Mean)	Attention With CSP (Mean)	Blink with CSP (Mean)
Mean (Normal Situation)	52	77	67	122
Mean (Relaxed Situation)	45	84	58	132
	49	81	63	127


We have assigned these value as 63 for threshold\_attention and threshold\_Eyeblick to control of device state and selection of devices in home controller section.

#### D. Home Appliance Control Result

In this section, we implement a home appliance section with help of Arduino and LED (Green and Red). The red LED is used as home appliance and green LED are used to select device numbering. Our results show the average blink threshold value is 127 and attention threshold value is 63. In the experiment we test our CSP values by Arduino sketch for home appliance controller. In setup, a calibration time is needed to synchronize user eye blink value and attention values with the system. In this process a user's need to do hard eye blink twice with a normal rate of hardness, because this eye blinking is used to a selection of device.

If an eye blink greater than threshold\_Eyeblick then a device selection is changed and we select any device by eye blink as shown in the table 6. There are three display LED's, which demonstrates the selection, device in 3-bit representation (as appeared in shown table). For Example, in the event that we try to control the sixth device means, initially, we can do the gadget selection as '110' by eye blink. After that we can give the attention levels and control the status of the chose (sixth) device. Each high attention the chosen device status will be changed.



Table. 6 Device Selection Table

	Device Selected for Control
001	1
010	2
011	3
100	4
101	5
110	6
111	7

There are individual appliance display LED's, which demonstrates the household appliance state means that a LED is glow show appliance is otherwise it's in off condition. This status can be changed by attention value as

shown in table 7, if attention value is higher than the threshold value it turn ON the state of LED otherwise no change.

Table. 7 Device Status Table

Device LED	Device Status
	Device OFF
	Device ON

### VIII. EXPERIMENT SETUP

Connect the Bluetooth HC-05 module with Arduino and LED's appear in a figure below. Note the Bluetooth RX isn't associated. We write the sketch in the Arduino IDE. Verify the outline and transfer to the Arduino. Turn on the Mindwave Mobile Headset. Once associated, the Mindwave will have a strong blue light and the HC-05 Bluetooth will have a flicker (when flag got) red light.

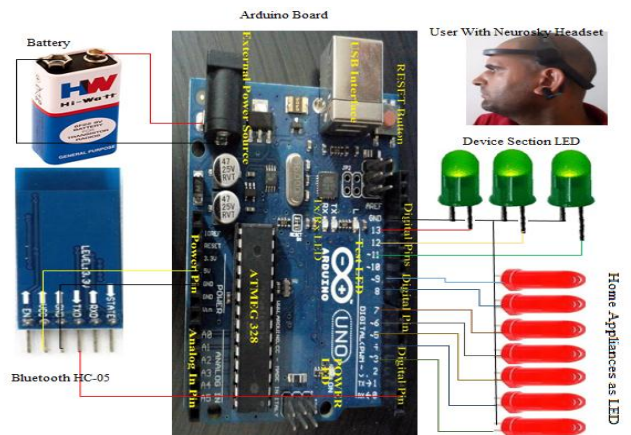


Fig.18 Complete Setup with Connection Diagram and User with NeuroSky Headset

First, wear the NeuroSky Mindwave headset at subject's Head, and blink our eyes. For Mind wave gadget require Calibration to distinguish the eye blink qualities in EEG data. So far we need to hold up a couple of minutes (around 2 min) for adjustment. After calibration, each eye blink was checked (1 to 7). It's used for selection of the home devices. If a device was chosen implies we will offer regard to change the condition of specific gadget. For each high attention, the selected device state will be changed.

### IX. CONCLUSION

We have implement a features extraction method by using CSP on EEG Signal as eye blink and attention. The values of eye blink and attention from CSP are used to setup a BCI in Home Appliance Controlling. The system consists mainly of a NeuroSky Mindwave headset and an Arduino module. This experiment setup allows home appliances to be controlled successfully through the subject's EEG signal in real-time scenario.

NeuroSky Mindwave headset was used to record EEG signal and transmits that data to the computer via a



Bluetooth module. A Graphical User Interface (GUI) was developed to detect user eye blink and attention for two situations, and the received EEG data was procured by the MATLAB. The framework was prepared with help of 14 people to data collection and process CSP algorithms. CSP mean results show the average blink threshold value is 127 and attention threshold value is 63 were used in Arduino sketch. This sketch transmitted to the Arduino system to control the appliances through a UART cable.

An experimental model is created for Home appliance with Arduino, Bluetooth module HC-05 and LED's. To test the setup NeuroSky Mindwave headset is paired with Arduino using BC-05. The experiment has been tested with help of 5 people and accuracy of controlling is found as 90%. A single component i.e. eye blink is used as selection of appliances and attention signal are utilized to control a virtual home appliance state. This will help people with serious illness as they need not depend on others for doing their day to day activities. It will bring about an exceptional change in the sort and personal satisfaction of people and debilitated and elderly individuals

X. FUTURE SCOPE

The procedure we have grown up until this point is very great taking check of the many-sided quality of calculation and number of electrode it utilizes, we will build up a model demonstrating the home automation by the help of created CSP, and we mean to assemble a completely home setup to controlling appliance by EEG signals. In future, we expect to construct additional time proficient, expedient and more exact strategy utilizing more brain signal handling techniques and by utilizing DSP processors. We expect to advance current methods and to influence numerous new age to help the contrastingly abled individuals.

APPENDIX

Table with 14 columns (A-N) and 34 rows of numerical data. Includes a 'blink\_class1\_with\_CSP' label at the bottom.

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