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To Correlate RAW EEG Signals and Attention Levels of BCI using KNN Technique

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Abstract: It is not impossible to read the human brain and to predict the state of mind. In this work, we are using MindWave Headsets to read the signals from human mind and to conclude the mental state of the person. A large number of studies has been conducted in this domain but an issue was faced that is related to the delay. This study performs KNN classification for classifying the data set of 300 mind wave samples. Three types of mind states are considered in this work i.e. Attention, Meditation and Normal. The results are simulated in the terms of time taken to train and test the signals. The results prove the efficiency of proposed research work.

Keywords: Brain Signals, Mental State, MindWave, Attention, Meditation.

I. INTRODUCTION

Various patterns of neural interaction in human brain leads to the various brain states. On the basis of these patterns the signal waves are characterized by various amplitudes and frequency. The neural interaction takes place among large number of neurons. During interaction among the neurons, a minuscule electric discharge is generated [1].

This study deals with the brain signals and in order to do so it is mandatory to capture the signals. Thus the electronic devices are used for capturing the mind wave signals. The electroencephalogram is a device that is specifically used for capturing the brain activities. The amplitude of brain waves is random and small. EEG signals are affected by multiple variables, health, activities, mental predicament, surroundings, and electrical involvement from other organs of the body and other exterior impetus. The EEG signals are non-stationary and random in nature thus it became complex to process these signals [2]. Classification of EEG waves is done to capture the variations in brain activities. There is a requirement to apply transformation on EEG signals in order to make classification less complex.EEG signals are classified in following types:

1. Alpha Waves
2. Beta Waves
3. Theta Waves
4. Delta Waves

Alpha Waves comprised of 8-13 Hz, conscious, relaxed state with closed eyes.

Beta Waves comprised of 14-26 Hz and occur when the mind is in state of thinking or any other activity.

Theta Waves are of 4 to 7.5 Hz and generated when mind is in state of light sleep, naps or emotional state [3].

Delta Waves are of 0.5 to 4 Hz and is generated when human is sleeping. It has been noticed that most of the research works use the EEG signals in frequency domain due to its various features like average amplitude and are level signals. Figure below represents the sample of EEG signals with respect to the different state of mind.

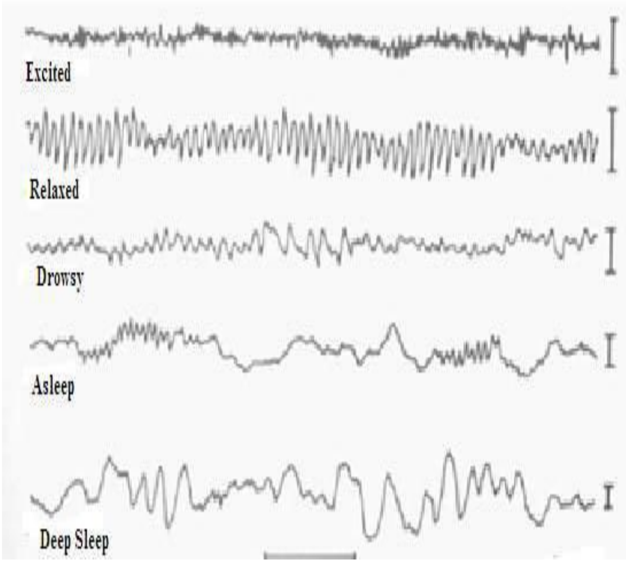

Figure 1 Sample Brain Waves [4]

II. MINDWAVE

The hardware that has vital role in this research work is Neuro Sky MindWave headsets. This is a specific device used for gathering the EEG signals of brain. It is officially available EEG neuron device that is modeled to evaluate the brain signals and then evaluated signals are used to monitor the states of mind. In this, the headset sensor is deployed at the left side of the forehead. Along with this, the sensor is located as per the FP1 position with respect to the 10-20 system of electrodes placements. These sensors transmit the signals by using electrode that is deployed on left ear lobe. After obtaining the data, the gathered data is sampled at the rate of 512 Hz. Neuro Sky MindWave is a device that operates on the basis of the single electrode and hence generate single EEG wave at a time. The feature of this device is that it can communicate with other devices such as laptops, computers, microcontroller by using wireless network such as Bluetooth. The structure of MindWave device is represented in figure 2 [4].

Figure 2 MindWave NeuroSky

Three types of state of mind is considered under this research work.

a. Attention
b. Meditation
c. Normal

Attention eSense

This is used to evaluate the intensity of mental focus and attention like which one occur during the intense concentration and direct stable mental activities performed by brain. It lies with in 0 and 100. The attention mental level can goes down due to distraction, anxiety, wandering and lack of focus [5]

Meditation eSense

This sensor is used to evaluate the calmness and relaxation level of brain. It ranges from 0 to 100. Meditation is used to evaluate the mental state of a being instead of physical state, thus do not get confused with physical meditation level because the simple relaxation of muscles of body does not leads to the sudden hike in mental meditation level. Whereas, in case of the most of the human beings, to relaxing body helps to relax the mind as well. Meditation level is linked to the decrement in the mental activities by the active mental process of the mind [6]. Closing eyes is also a way to increase the meditation level as while one closes his eyes, the mental activities in the brain gets turned off correspondingly. The activities such as disturbance, wondering thoughts and sensory stimuli can reduce the mental meditation level of brain.

Normal eSense

Normal signal waves from mind depict the state when the person is doing nothing and is sitting or moving freely here and there.

Table 1:- Specification of MindWave device:

S.No	Parameter	Value
1.	Weigh	90g
2.	Sensor arm up	Height: 225mm x Width:155mm x Depth: 92mm
3.	Sensor Arm down	height: 225mm x width:155mm x depth:165mm
4.	rate power	30mW
5.	max power	50mW
6.	RF frequency	2.420 - 2.471GHz
7.	RF max power	6dBm
8.	RF Data Rate	250kbit/s
9.	RF range	10m
10.	packet loss	5% via wireless
11.	UART Baudrate	57,600 Baud
12.	EEG maximum signal input range	0.1mV pk-pk
13.	hardware filter range	3Hz – 100Hz
14.	ADC resultion	12 bits
15.	sampling rate	512Hz
16.	eSense calculation rate	1Hz

III. PROPOSED WORK

Mind waves or signals are used to evaluate the mental state of human being. From last few years, this is established as a major research domain for scholars. The MindWave signals are gathered first of all and then transmitted to a processing device for evaluating the mind state on the basis of the observed mind waves. The process of gathering the signal is done by using sensor device. But while signal transmission a delay has been notified due to which the system's efficiency is reduced. Thus major objective of this work is to reduce the delay for signal transmission and gathering. In order to do so, a dataset of waves is created. After then, this dataset is further used for the purpose of signal matching. To perform the signal matching, a small signal is acquired and then pattern matching and classification is performed by the signals that are stored in the dataset. The KNN classification mechanism is used to perform signal matching. Then on the basis of the matched signals, the mental state of the human being is concluded

IV. METHODOLOGY

The system model or methodology for proposed work is defined as follows:

1. The process starts by acquiring the dataset or signals by using the headsets of MindWave. The acquired signals are in the form of waves.
2. The collected raw signals or waves are transmitted to the laptop or any other connected device such as desktop etc. the signal transmission is done by using the wireless mean of communication i.e. Bluetooth.
3. In Laptop, the KNN classification is done by using the code that is developed in Python. The KNN classifier is designed in Python for the purpose of classification. From Laptop, the signals are transmitted to the microcontroller by using a serial cable. The Arduino microcontroller is used for the proposed research work. The mathematical model for KNN classification is as follows:

To perform the classification by using KNN classifier first we need to develop a data set. The data set comprised of certain attributes. After creating the data set, the data set is divided into two parts i.e. one for training purpose and other for testing purpose. The data set for training is passed as an input to the classifier whereas the testing data set is used for testing purpose on the basis of the trained dataset. The mathematical model for KNN depicts that it only utilizes the local prior possibilities for classification purpose [12]. For given query the classifier works as follows:

$$y_t = \underset{c \in (c1, c2, \ldots\ldots cm)}{argmax} \sum x_i \in N(x_t, k)^{E(y_i, c)} \ldots\ldots (1)$$

Where denotes the predicted class corresponding to the , m depicts the classes that are included in data. Also,

$$E(a,b) = \begin{cases} 1 \text{ if } a = b \\ 0 \quad else \end{cases} \ldots\ldots\ldots\ldots\ldots (2)$$

$$N(x,k) = set\ of\ k\ nearest\ neighbor\ of\ x.$$

The above defined equation (1) can also be formulated as follows:

$$argmax\left\{\sum x_i \in N(x_i,k)^{E(y_i,c1)}, \sum x_i \in N(x_i,k)^{E(y_i,c2)}, \ldots\ldots \sum x_i \in N(x_i,k)^{E(y_i,cm)}\right\} \ldots..(3)$$

$$y_t = argmax\left\{\sum x_i \in N(x_i,k)^{E\frac{(y_i,c1)}{k}}, \sum x_i \in N(x_i,k)^{E\frac{(y_i,c2)}{k}}, \ldots\ldots \sum x_i \in N(x_i,k)^{E\frac{(y_i,cm)}{k}}\right\} \ldots..(4)$$

It is known that

$$p(c_j)_{(x_t,k)} = \sum x_i \in N(x_t,k)^{\frac{E(y_i,c_j)}{k}} \ldots\ldots\ldots (5)$$

Denotes the probability of occurrence of jth class in neighbor

Thus the equation (4) turns to be equation (6)

$$y_t = argmax\{p(c_1)_{(x_t,k)}, p(c_2)_{(x_t,k)}, \ldots\ldots, p(c_m)_{(x_t,k)}\} \ldots\ldots (6)$$

On the basis of above formulation it is defined that the KNN performs the classification on the basis of the local possibilities. Following is the process for KNN that is implemented in proposed work:

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1. *Evaluate* $d(x,x_i) i = 1,2,\ldots,n$
2. *d refers to the Euclidean Distance among the points. It is evaluated as follows:*

$$d = \sqrt{(y1 - x1)^2 + (y2 - x2)^2} \ldots\ldots (7)$$

3. *Let k a positive integer; consider the first k distance from d.*
4. *Evaluate k point corresponding to k distances.*
5. *Assume* k_i *to define the number of points related to the* i^{th} *class among k.* $k \geq 0$
6. *If* $K_i > k_j \forall i \neq j$ *then put x in class i.*

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4. In the microcontroller process the obtained signals are displayed in the form of message on connected LCD. The LCD shows the state of mind of the user.

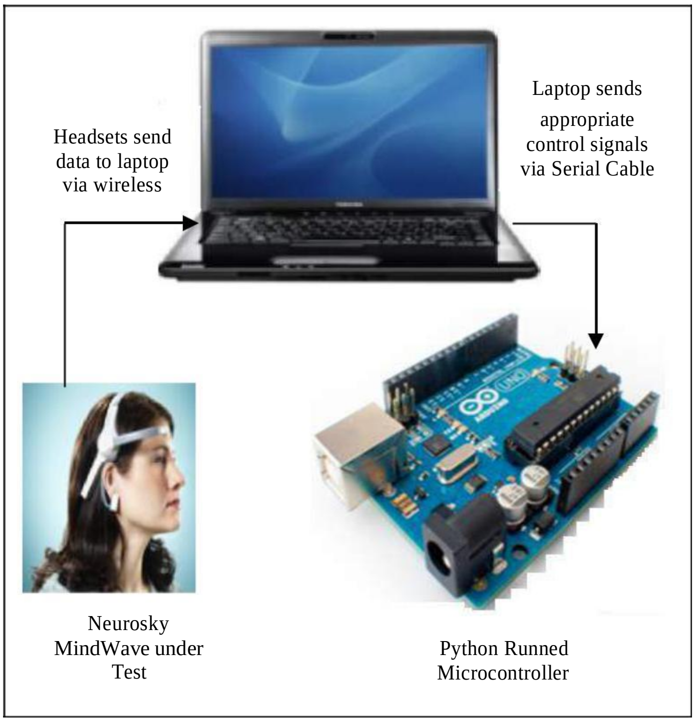

Figure 3 Framework for proposed research work

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In this work the K-Mean classification is used for classifying and matching the signals. The dataset of 6 persons i.e. 3 males and 3 females is used for simulation. The objective behind using the k mean classifier is to reducing the delay that occurs during matching and signal gathering process.

V. RESULTS

This section depicts the results that are obtained after implementing the KNN technique and by using Python programming language. For the purpose of simulation, first of all a dataset corresponding to the mind signals with respect to various persons are gathered. The figure 4, 5, 6 represent the dataset corresponding to the attention level of persons. The x axis in the graphs depicts the number of data samples and y axis in graph represents the attention level that ranges from 0 to 100. Total 300 data samples are used for the purpose of training.

The figure 7, 8 and 9 delineate the gathered data sample for meditation level of human brain. The number of data samples and level for meditation level is same as the attention level.

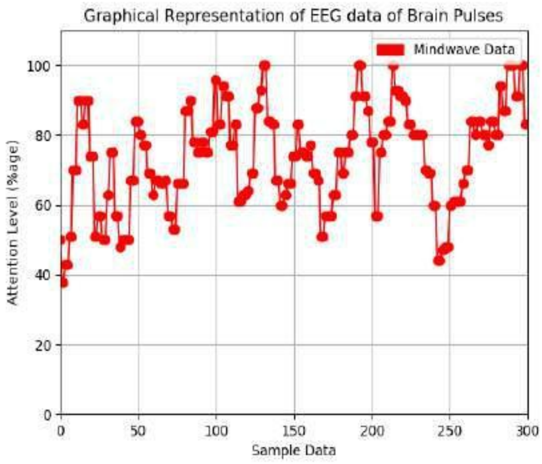

Figure 4 Sample 1 for Attention

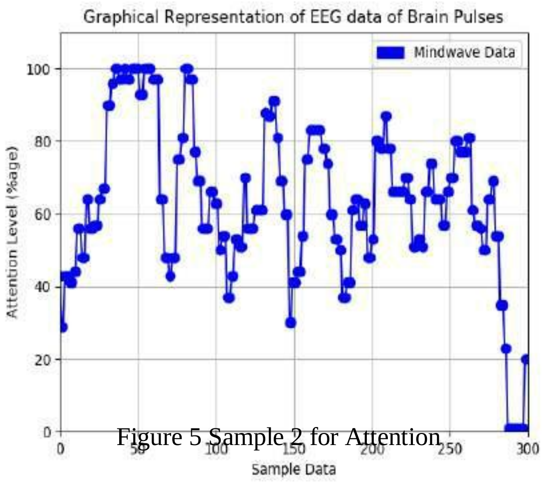

Figure 5 Sample 2 for Attention

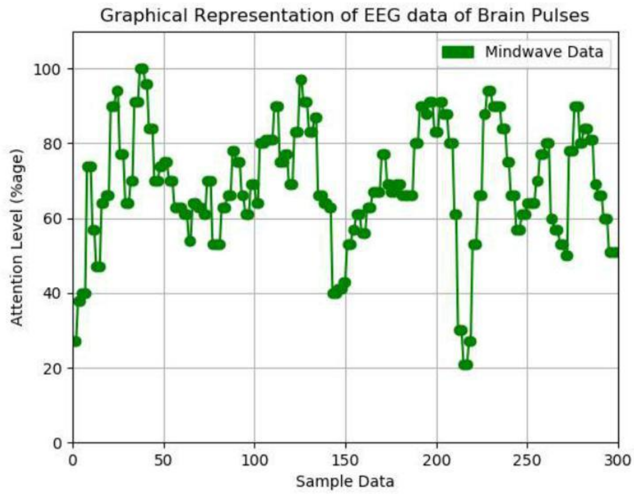

Figure 6 Sample 3 for Attention

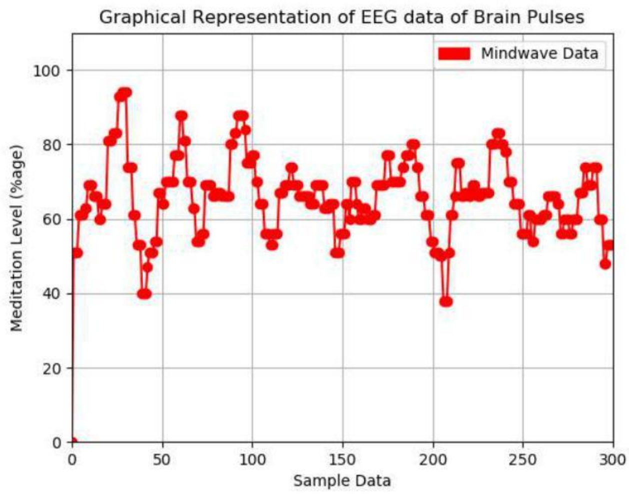

Figure 7 Sample 1 for Meditation

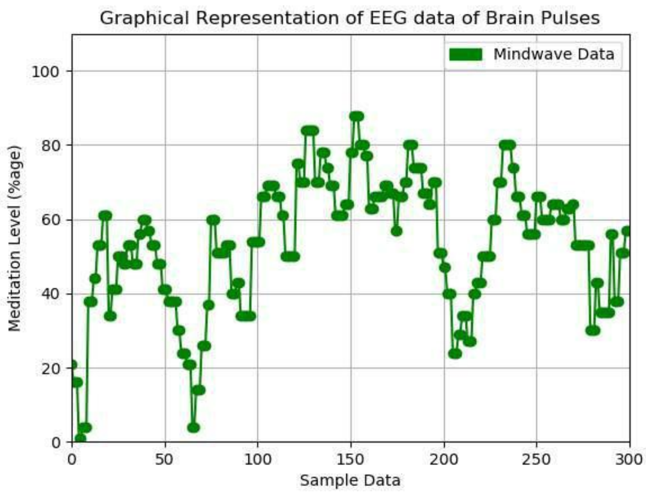

Figure 8 Sample 2 for Meditation

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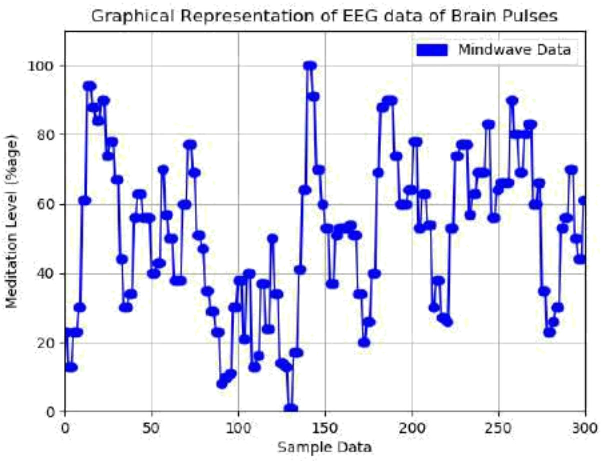

Figure 9 Sample 3 for Meditation

The graph in figure 10, 11, 12, 13 represents the tested data samples. In this work, total 300 data samples are used for training and 50 data samples are used for the purpose of testing. The reason behind considering 50 samples for testing is to reduce the delay in sample processing. The KNN classifier somewhere proves to consume a lot of time for classification but it is much efficient than the traditional classification procedure. In traditional work, total 300 samples were used for the purpose of training as well as testing. Thus the matching of acquired samples was performed with total 300 trained samples which consumes a lot of time and also led to the delay in result generation. Whereas the proposed KNN classifier perform training over 300 data samples and testing on approx. 50 datasets so that the processing time can be reduced to eliminate the delay in result generation. If the KNN classifier finds the matching pattern once in the tested signals and did not goes over whole sample for pattern matching. The pattern matching is done by using a threshold value. For brief understanding of proposed delay reduction mechanism let us consider the following scenario.

$$Time\ required = Number\ of\ Samples * time\ taken\ for\ one\ sample \ldots (8)$$

Total samples taken in the data set is 300 and time taken each sample is 0.3 sec. Thus as per (8)

$$Time\ required = 300 * 0.3 \ldots (9)$$

The time required for 300 samples is evaluated to be 90 sec. For purpose of testing in proposed work, nearby 50 or 60 data samples are considered thus time taken by this data sample is

$$Time\ required = approx\ 55 * 0.3 \ldots (10)$$

This proves that the testing data sample considers approximately 16.5 seconds. Therefore the proposed work leads to the reduction in delay.

In figure 10, graph explains that the attention level of user is higher as it reaches to 100. The attention level less than 40 is considered as normal whereas if it goes above 40 than it is referred as high attention level. Similarly, in figure 11, the graph shows the low attention level for tested data samples.

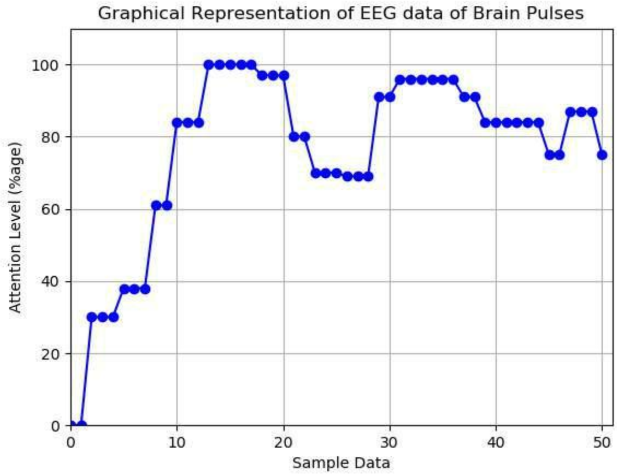

Figure 10 Tested Data sample 1 for Attention Level

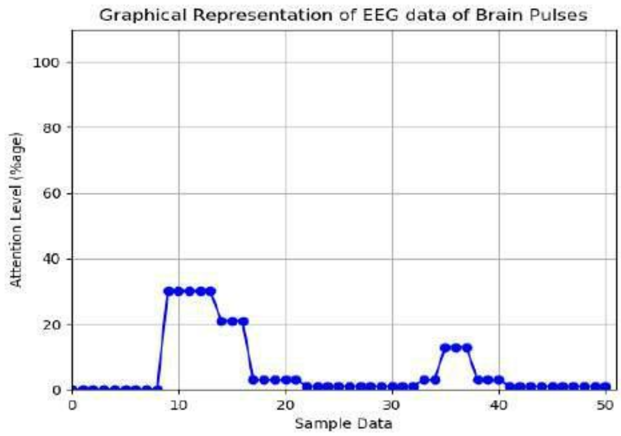

Figure 11 Tested data sample 2 for Attention level

The graph in figure 12 and 13 depicts the tested data samples for evaluating the meditation level of human brain on the basis of tested and trained signals. The meditation level presented in figure 12 is average and the mediation level depicted by figure 13 is higher.

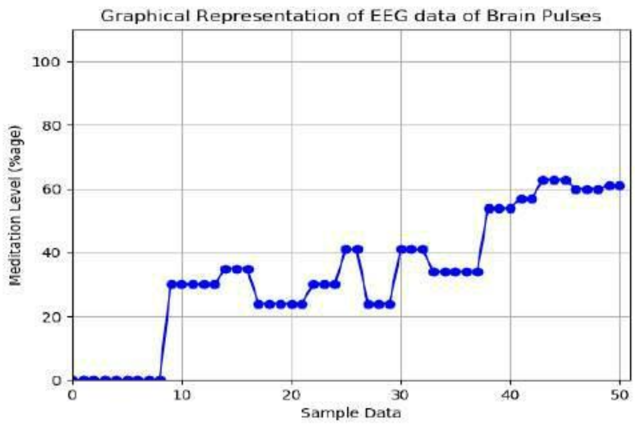

Figure 12 Tested data sample 1 for Mediation level

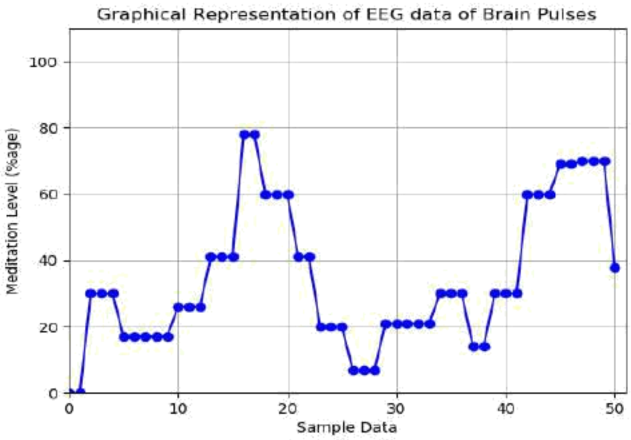

Figure 13 Tested data sample 2 for Mediation level

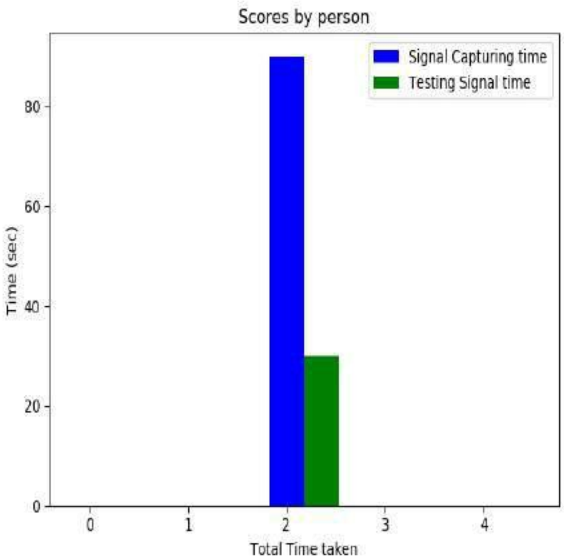

Figure 14 Time taken by Proposed Work

Graph in figure 14 delineates the time taken by the proposed research work to acquire and process the signals. The x axis in the graph shows the time taken for capturing the signals in blue color and time taken for testing the signal in green color. The y axis shows the time from 0 to 80 seconds. The graph proves that the proposed work consumes approximately 90 seconds to process the data set and 30 seconds for testing the data samples which is quite efficient and better than the traditional ones.

VI. Conclusion & Future Scope

This study deals with the mind waves in order to extract the mental state of the person. It deals with the three type mental states i.e. Attention, Meditation and Normal. The MindWave headset is used for acquiring the mind waves. The Arduino Microcontroller is used to control and display the results on the connected LCD. Along with this the KNN classifier is used for classification of the signals. The results depicts that the proposed technique leads to the less delay for result generation and the short term memory for different condition tested. Now this can lead to provide the same data to the smartphone app for complex span test. During this work we found the good correlation between attention levels and RAW EEG signals but the complex span test need to be tested on more conditions specially to deal with the neurological disordered patients.

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