Review of Open-Source BCI approach using OpenViBE

N.K. Jadhav[1*], B.F. Momin[2]

[1*]Department of Computer Science and Engineering, Walchand College of Engineering, Sangli, India

[2] Department of Computer Science and Engineering, Walchand College of Engineering, Sangli, India

E-mail: mtech.nkjadhav@gmail.com, bfmomin@yahoo.com

[*]*Corresponding Author: mtech.nkjadhav@gmail.com, Tel.: +91-8087082261*

***Abstract* —** Brain-Computer Interface (BCI) is a communication method that allows users to pass on information to computers by means of human brain activity. This paper reviews the analysis and measurement of Electroencephalography (EEG) signal using a BCI software system – OpenViBE. This software allows neurological researchers to construct, experiment and simulate Brain-Computer Interface. Although, there exists various hardware equipment in the market for recording brain activity and software platforms for analyzing those signals. Here, Neurosky Mindwave EEG headband is used for measuring EEG signals for certain human brain activity and OpenViBE is used for analysis of these signals. The OpenViBE software is offered for free and can be distributed under an open-source license. Primarily, connecting EEG devices with OpenViBE BCI software and storing the recorded values in the form of files requires certain procedures to be followed which are highlighted here. OpenViBE software comprises an Acquisition Server, which takes care of establishing a connection with various types of EEG devices and Designer part is essentially required to simulate scenarios using various EEG processing modules. OpenViBE uses an integrated approach for online as well as offline analysis of EEG data. Secondarily, simple processing modules of OpenViBE and the techniques to adjust parameters of these modules are reviewed here. Learning to analyze and measure signals from EEG sensors using OpenViBE, allow researchers and BCI enthusiast to explore in a numerous areas of BCI.

***Keywords*—** Bio-signals, BCI, EEG, OpenViBE, Neurosky Mindwave

I. INTRODUCTION

Information signals are the key elements of an automated system. In a human body, Bio-signals are generated by different organs which can serve as an information signal. Signals of eyes, muscles, heart, brain, etc. can be recorded and measured to operate several applications [1]. Bio-signals, performs a vital role for persons with a certain lack of ability. A disabled person who is incapable to use an application as a normal person does, such person's bio-signals can help to operate the same [2]. These Bio-signals are analog, its analysis is a tough task since internal organs of a Human body works independently and nobody can have control over them. On the other hand, thoughts generated by the Human brain are controllable to some extent. Besides the normal operation of the brain a person can control thoughts to achieve a desired mental state.

To record bio-signals from the brain in the form of electrical signals various low-cost wearable EEG devices are available in the market [3]. In recent years, wearable EEG sensor devices have been emerging from different vendors and have a different number of channels for placing electrodes along the scalp. Some popular wearable brainwave sensors are Emotive insight, Emotive Epoch, Neurosky Mindwave, etc. each of them has a slightly different EEG data techniques and output protocol. Amongst these devices, Neurosky Mindwave EEG headband is a single channel inexpensive wearable EEG device which is used to record signals for brain activities.

Also for analysis purpose various software platforms like a statistical analyzer-MINITAB, Python Module-PyEEG, EEGLAB-a MATLAB toolbox, OpenViBE, etc. are available. Every wearable EEG device and software has a unique way of establishing a connection and signal measuring style. Here, for the analysis of EEG signal data, Neurosky Mindwave EEG headband and OpenViBE software are reviewed.

The remainder of this paper is arranged in following order, Section II provides EEG fundamentals in brief. Section III introduces popular and inexpensive EEG headband Neurosky Mindwave. Connection setup steps for an EEG headband with OpenViBE are discussed in Section IV. Section V highlights basics for OpenViBE usage. Section VI focuses on OpenViBE Designer scenarios for analysis and measuring of EEG data. At the end Section VII, gives conclusion of this paper.

II. FUNDAMENTALS OF EEG

A. Neurons

Most vital part in human body is the brain which acts as the command center of the human nervous system and along with the spinal cord, it makes up the central nervous system. Cerebral cortex (human brain) is built up of dense layers of neural tissue, consisting of millions of nerve cells or neurons. Human brain is mainly separated into four lobes known as – (a) Occipital lobe accountable for visual abilities (b) Temporal lobe for memory, speech and sound (c) Parietal lobe for external sensations such as pain, touch, and so on. (d) Frontal lobe for knowledgeable activities carried out by humans. Neurons have the ability to carry "messages" through an electrochemical process. Neurons have fundamental cell parts known as dendrites and axons. Dendrites carry electrical signals into the cell body and axons pass information out from the cell body as depicted in "Figure 1". Neurons interact with one another by means of an electrochemical process. Neurons contain some special chemicals like neurotransmitters and

structures like synapses to connect each neuron with many others to form neural networks. Every communication between neurons creates a microscopic electrical discharge, the activity created by millions of simultaneous discharges aggregates into waves which can be measured.

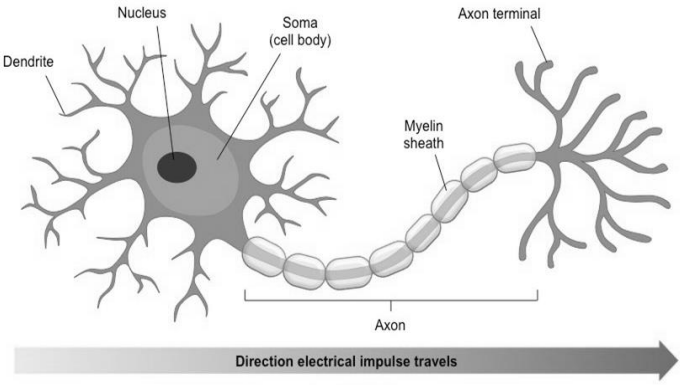

Figure 1. Neuron's fundamental cell parts

B. EEG Signals

By means of EEG electrodes placed on the scalp, a spontaneous brain activity can be measured which is known as an electroencephalogram (EEG). The amplitude of the measured signals on the scalp is about 100 µV. The bandwidth of such EEG signal ranges around below 1 Hz to 50 Hz. These EEG signals are categorized in different bands as tabulated in Table 1 [4].

International 10–20 system is an internationally acknowledged method to define and derive unique placement of EEG electrodes on the scalp in perspective of an EEG test or experiment [5]. This method was developed to ensure consistent reproducibility of tests so that a result of study could be compared over time and could be compared with other researchers from the same field.

Table 1. Frequency bands of EEG Signal

Band	*Frequency*
Delta (δ)	< 4 Hz
Theta (θ)	≥ 4 Hz and < 8 Hz
Alpha (α)	≥ 8 Hz and < 14 Hz
Beta (β)	≥ 14 Hz

III. EEG HEADBAND – NEUROSKY MINDWAVE

NeuroSky, Inc. is one of the well-known manufacturers of Brain-Computer Interface (BCI) equipment for consumer product and applications. NeuroSky Mindwave shown in "Figure 2" is an EEG headband technology, which is low cost and having an inexpensive dry sensor. The headband also incorporates built-in electrical noise reduction software/hardware, and use the embedded technique for signal measurement and output. Such wearable EEG devices have advantages over older EEG hardware setups as there is no need for the application of a conductive gel between the number of electrodes and the scalp.

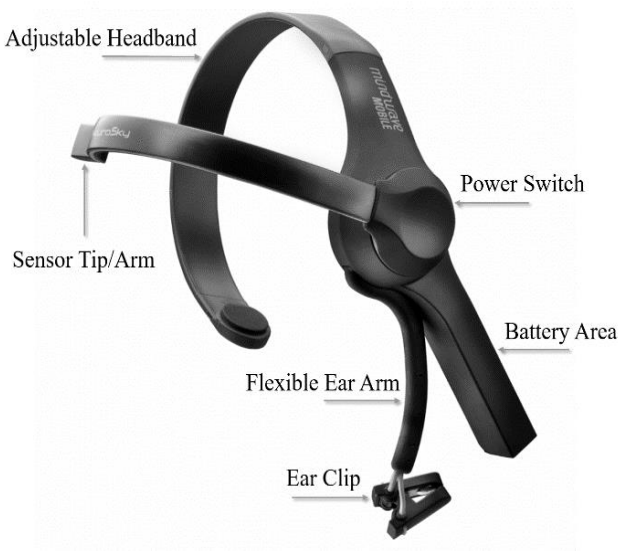

Figure 2. Neurosky Mindwave EEG Headband

IV. CONNECTING NEUROSKY MINDWAVE - OPENVIBE

In order to establish a successful connection between Neurosky Mindwave EEG Headband and OpenViBE following main steps should be followed [6].

- Download and install the latest OpenViBE executable setup from the official site. Here, OpenViBE 2.0.0 was installed on Windows 10 system.
- Also, it is required to install Mindwave Mobile software setup provided along with Neurosky Mindwave EEG Headband. This will install "ThinkGear Connector' on a system which will enable communication between EEG Headband and the computer system over Bluetooth.
- After successful pairing with Bluetooth "ThinkGear Connector Preferences" window will show the COM Port on which EEG Headband is connected as highlighted in Figure 3. If multiple COM Ports are available for Bluetooth then one should take care of selecting correct COM port in ThinkGear preferences.

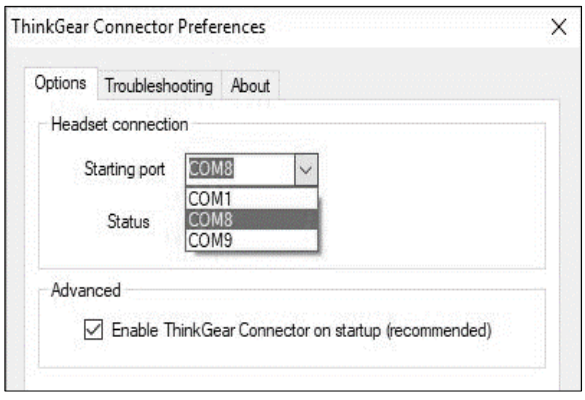

Figure 3. Headset Connection Preferences

V. OpenViBE Softeware Platform

OpenViBE is a community driven program which is free and available as open-source to construct, experiment and simulate BCI scenarios [7]. Broadly, it has two components: (A) Acquisition Server - This server is responsible for acquiring EEG data from external devices such as wearable EEG Headband. (B) OpenViBE Designer – provides GUI to construct the anticipated BCI scenarios from preconfigured processing modules. OpenViBE server grabs EEG signal from connected EEG peripheral and then it sends this data to one or more acquisition clients. In many of the BCI experimentations OpenViBE designer acts as a client. On same system OpenViBE can run Acquisition Server as well as the clients or in another case on different systems of the same network, or it can be a combination of both cases.

A. OpenViBE Acquisition Server

- Launch OpenViBE Acquisition Server installed on system from the Windows Start button which will populate the GUI for Server. Select Neurosky Mindset from enlisted driver dropdown options. Open Driver Properties and choose appropriate values of Age and Gender for the person wearing EEG Band as captured in "Figure 4". Select the correct COM port for Bluetooth connection and apply settings.
- Click on Connect. Once it gets connected with EEG Headband over Bluetooth, hit the Play button. OpenViBE server will switch to acquiring data mode and will start receiving EEG data from the connected headband as captured in "Figure 5".

B. OpenViBE Designer

- OpenViBE Designer is a GUI based tool dedicated to building and implementing OpenViBE scenarios. It relies on a GUI to offer signal processing tools in easy way, and doesn't require any programming skills. Signal processing 'box algorithms' are available in the Designer. These algorithms develop over time by a community of researchers and users. Users may organize any number of such boxes in a very convenient manner, fundamentally there is no limit on the number of boxes that may be included in a desired BCI scenario.

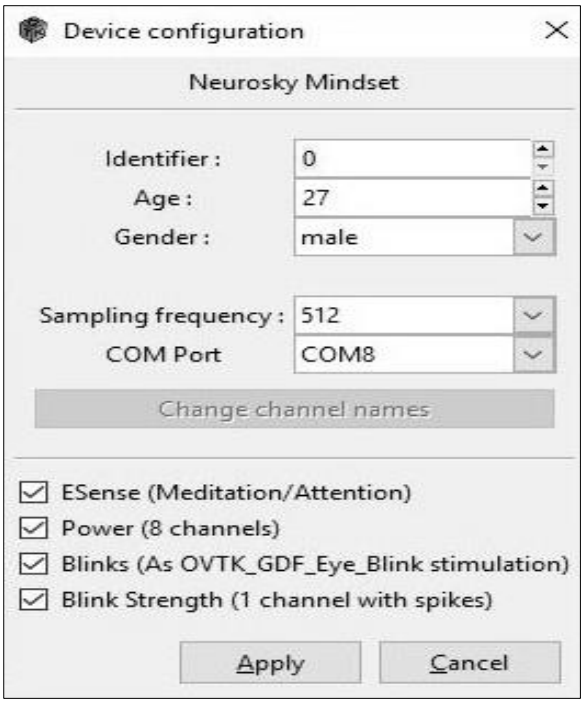

Figure 4. OpenViBE Acquisition Server Configuration

- "Figure 6" shows a typical layout of OpenViBE Designer covering the main functionalities. On the right-hand side of the Designer window, existing box algorithms are available. These boxes are the fundamental part of OpenViBE scenario. Box algorithms can be added to the scenario simply by drag and drop operation from the tree view into the scenario editor window. In Designer one can create a custom reusable box from combination of available boxes, known Metabox.

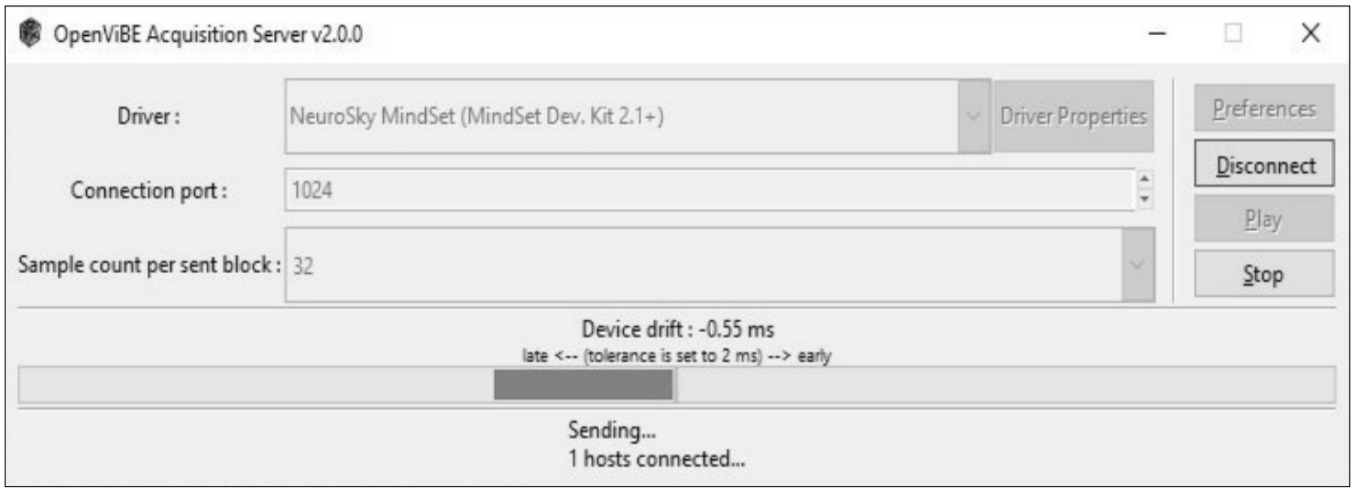

Figure 5. OpenViBE Acquiring Signal

VI. ANALYSING AND MEASURING EEG SIGNALS

OpenViBE Designer offers different processing modules also known as "Boxes" like Advanced Visualisation, Data Generation, Acquisition and Network IO, Signal Processing and several other as seen in "Figure 6" in right half of Designer. Any number of such boxes may be linked to generate a scenario and can be used to measure EEG data according to application needs. The only essential requirement is that the inputs, outputs of linked blocks must comply in data types otherwise the simulation will generate an error.

Analysing and measuring of EEG data received from EEG headband can be accomplished by creating a desired scenario in OpenViBE Designer while Acquisition Server running in background. EEG signals captured by Acquisition server are transferred to acquisition client. In most of the cases a scenario running in the OpenViBE Designer contains acquisition client.

To perform offline analysis of EEG signals, data served to Acquisition client should be saved in a file. This can be achieved by using File reading and writing box having CSV File writer - Comma Separated Values. This block can capture live EEG Headband data on joining with acquisition client in designer and can save data into .csv file format at preferred directory selected by the scenario creator.

Here, two of such basic scenarios are presented to validate the OpenViBE software with Neurosky Mindwave EEG Headband to analyse and measure EEG Data.

A. Analysis of EEG Data

Live EEG data can be visualised by constructing a simple scenario in an OpenViBE Designer as captured in "Figure 7". In scenario Acquisition client box is joined with Signal Display box by drawing connections between "In | Out | Set" labels appropriately. By clicking the triangle marked button which will start/pause the constructed scenario, gets into running mode. Live EEG data can be visualized similar to observed live signals in "Figure 8".

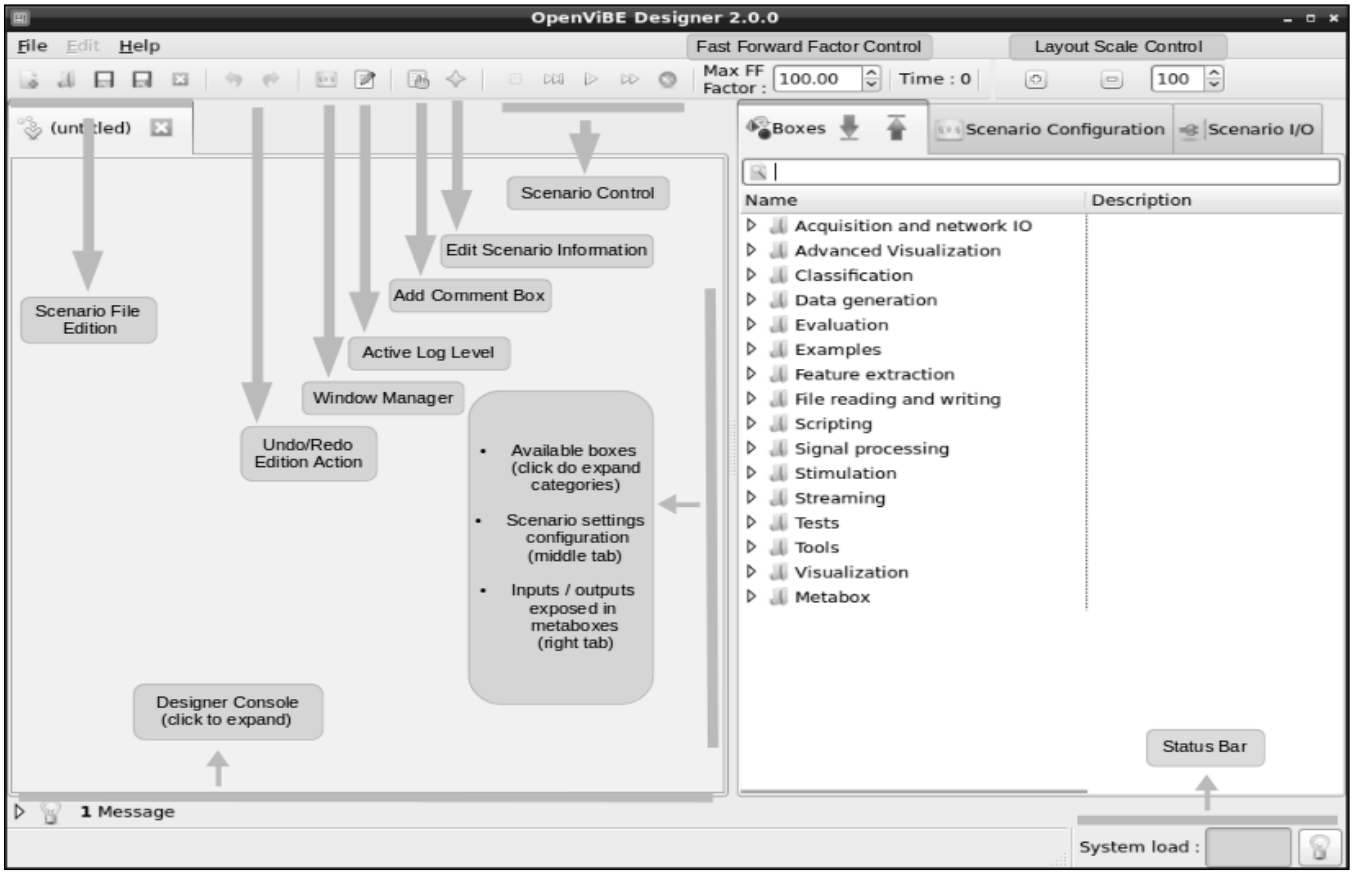

Figure 6. Typical layout of OpenViBE Designer

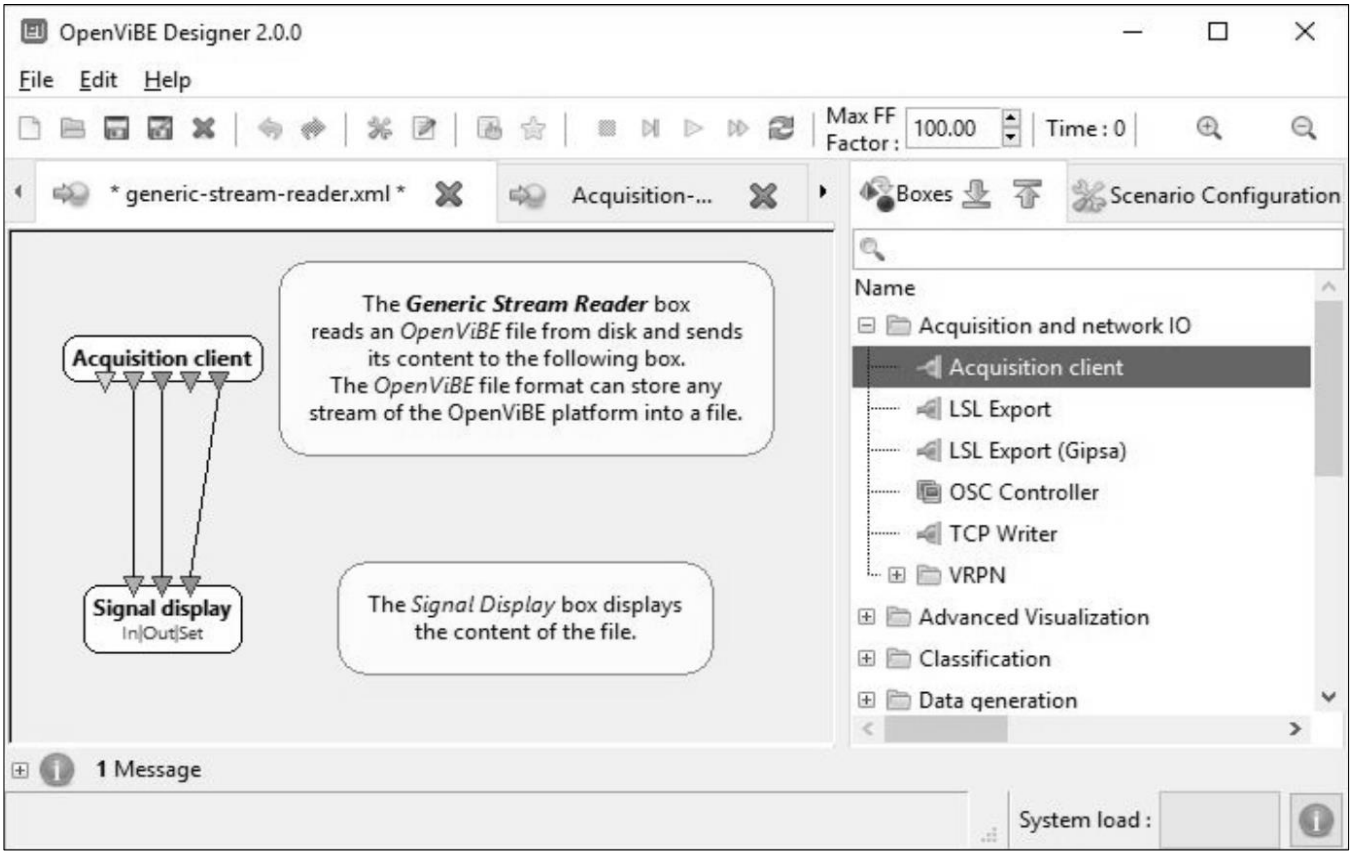

Figure 7. Scenario to analyze EEG Data

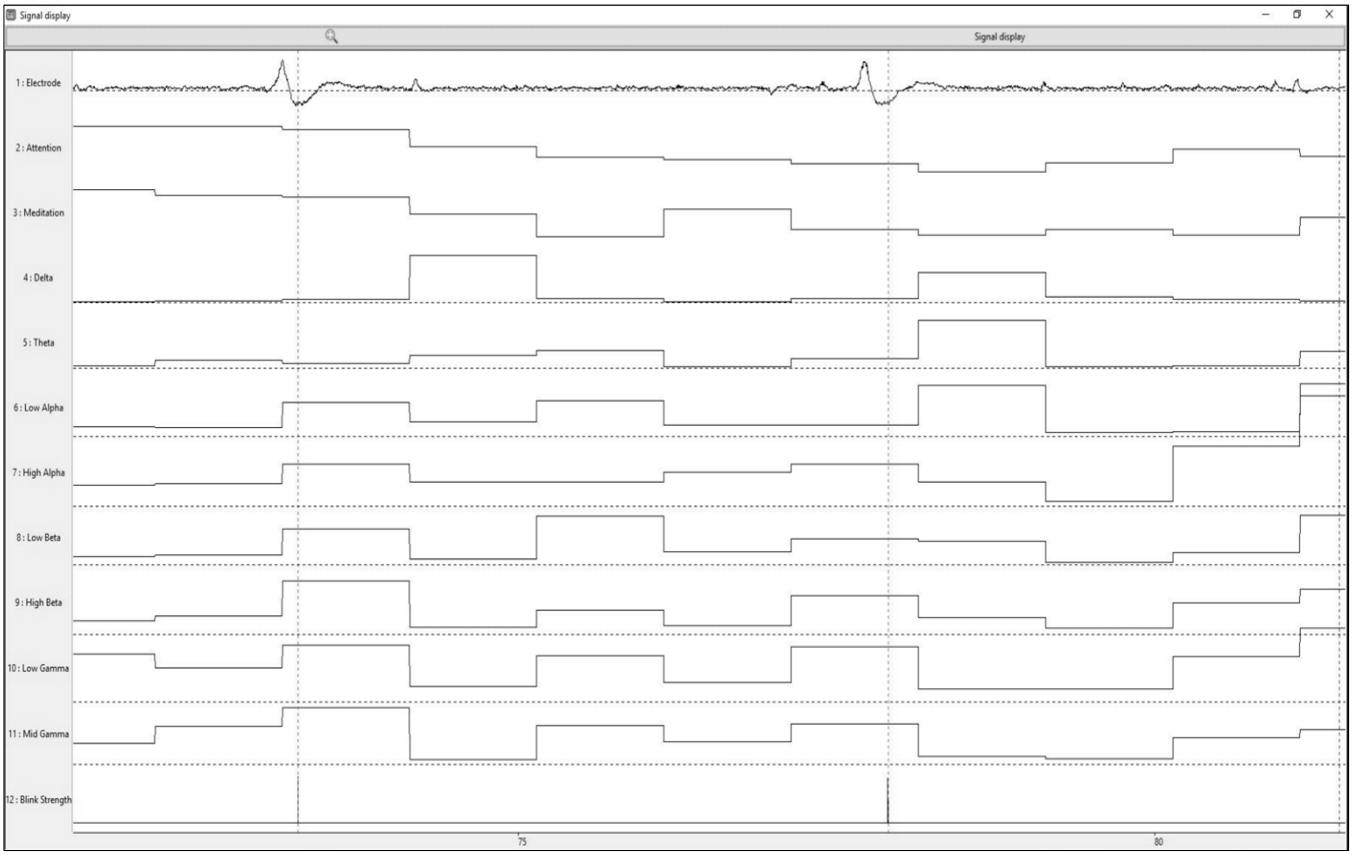

Figure 8. Live signal display of analyzed EEG data

B. Measuring EEG Data

In many of cases it is necessary to capture and store EEG data results of an experiment for later study and reference purpose. Data of a particular historical session can be then accessed by files that were generated and stored onto disk. Here, in this scenario, EEG data acquired for user's brain activities could be saved on system by joining using acquisition client with CSV file writer box as captured in "Figure 9". To set the path for storage location one can double-click the CSV writer box and provide a desired directory path. Generated CSV can be read using Microsoft Excel like programs and it can be analyzed further by plotting desired graphs using stored values. CSV file generated by recording normal mental state of a person looks similar to contents as shown in "Table 2". Generated file contains the timestamp, Raw EEG values, Blink strength value, and various EEG Spectrum bands in the form of integers.

VII. CONCLUSION

The significance of treating Bio-signals equally like information signals and principally EEG signals produced by brain activities are highlighted in this paper. It emphasizes the Neurosky Mindwave EEG headband and connection steps involved with OpenViBE tool. The OpenViBE software has a numerous features to allow researchers to explore EEG signals to a greater extent. The GUI of OpenViBE is simple to interact and easy to understand. It is a great platform for creating BCI scenarios and saving them for later use. OpenViBE can be given preference over expensive BCI softwares available in the market. This is only possible due to open-source and free availability of OpenViBE for study and research purpose. This paper can also provide information of basic concepts used for EEG data acquisition and measurement using OpenViBE. This paper can provide an outline for naive BCI researchers who are keen to explore easy yet effective experimental techniques.

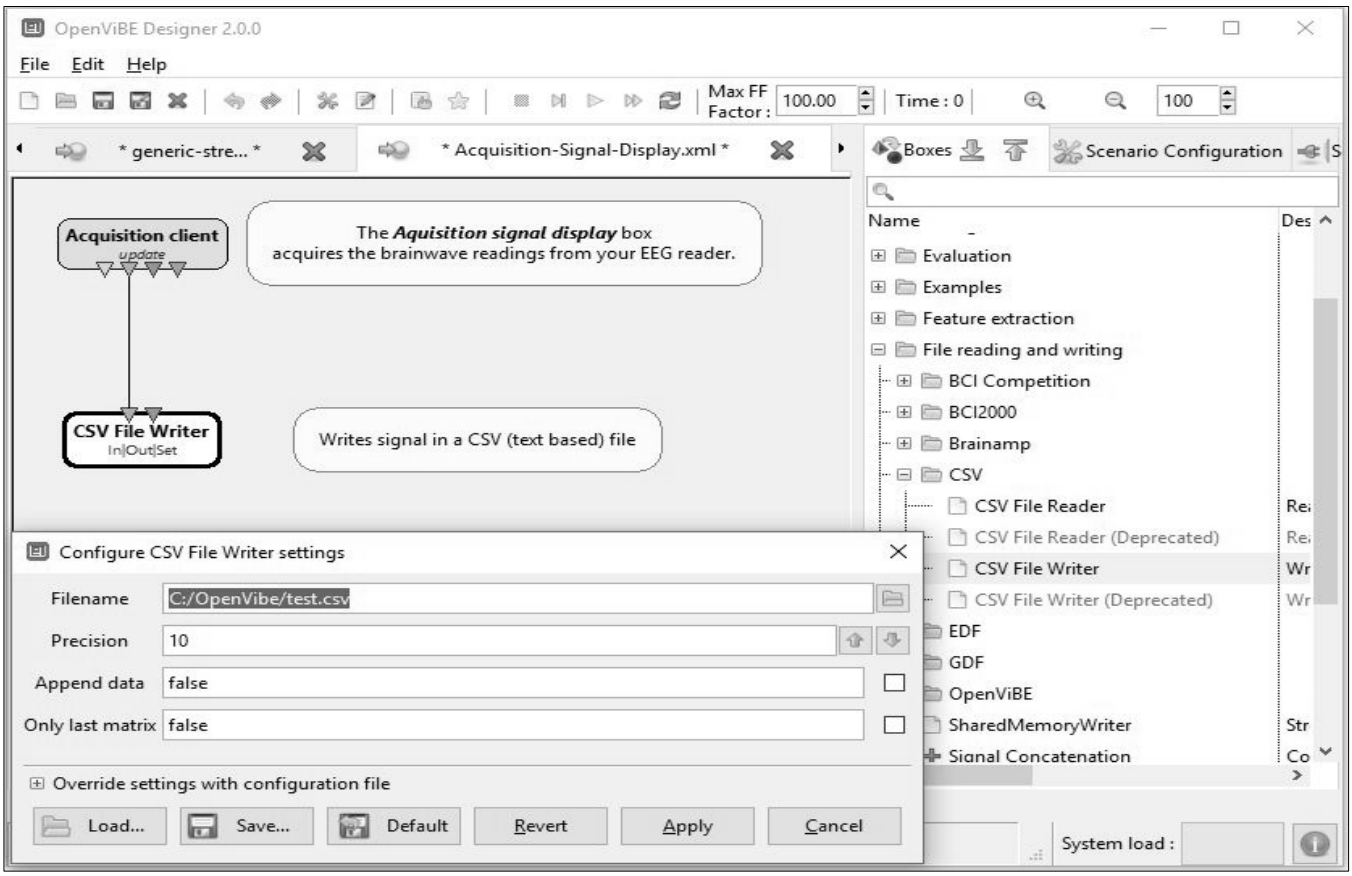

Figure 9. Scenario to measure and store EEG Data to CSV

Table 2. Generated CSV file from EEG Data

	A	B	C	D	E	F	G	H	I	J	K	L	M	N
1	Time (s)	Electrode	Attention	Meditation	Delta	Theta	Low Alpha	High Alpha	Low Beta	High Beta	Low Gamma	Mid Gamma	Blink Strength	Sampling Rate
2	0.00E+00	2.30E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	512
3	1.95E-03	2.40E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
4	3.91E-03	3.70E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
5	5.86E-03	4.00E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
6	7.81E-03	3.90E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
7	9.77E-03	4.30E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
8	1.17E-02	5.80E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
9	1.37E-02	7.10E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
10	1.56E-02	7.50E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
11	1.76E-02	7.10E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
12	1.95E-02	6.10E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
13	2.15E-02	5.70E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
14	2.34E-02	5.90E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
15	2.54E-02	5.90E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
16	2.73E-02	5.50E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
17	2.93E-02	5.20E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
18	3.13E-02	5.50E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
19	3.32E-02	4.90E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
20	3.52E-02	1.90E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
21	3.71E-02	3.00E+00	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
22	3.91E-02	1.70E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
23	4.10E-02	3.70E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
24	4.30E-02	6.50E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	
25	4.49E-02	8.20E+01	4.10E+01	5.40E+01	4.61E+04	1.56E+04	1.56E+04	4.06E+04	7.49E+03	6.07E+03	4.39E+03	2.54E+03	0.00E+00	

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Author Profile

Mr. N K Jadhav pursed Bachelor of Technology in Computer Science and Engineering from SGGSIE&T, Nanded, Maharashtra, India in 2012. He is currently pursuing Master of Technology in Computer Science and Engineering from Walchand College of Engineering, Sangli, Maharashtra, India. His main research work focuses on biometrics, IoT Technologies and Sensor Data Aqusition. He has 2.5 years of industrial experience in the field of IT.

Dr. B F Momin pursed Ph.D. from Jadavpur University and currently working as Associate Professor in Department of Computer Science and Engineering, Walchand College of Engineering, Sangli, India since 1996. He is a life member of Indian Society for Technical Education (ISTE) and Advanced Computing & Communication Society (ACS). His main research work focuses on Database Management Systems, Pattern Recognition and its applications, Soft Computing Techniques, Data Mining, Bioinformatics, Embedded Technology and Internet of Things (IoT). He has 24 years of teaching experience and 4 years of Industrial Experience.