Advancements in Open Source Software Vitality for EEG Signal Processing

[1]Sanjeev Nara, [2]Kundan Lal Verma, [3]Saurav Dutta
[1,2]Postgraduate Student, [3] Head of Department
[1]Department of Biomedical Engineering, Deenbandhu Chhotu Ram University of Science & Technology, Murthal, Haryana, India
[2] Department of Electronics, DDU Gorakhpur University, Gorakhpur, Uttar Pradesh, India
[3] Department of Biomedical Engineering, PDM College of Engineering, Bahadurgarh, Haryana, India
[1]sanjeevnara91@gmail.com , [2] klv.elect@gmail.com , [3] sauravmom@gmail.com

***Abstract*— Electroencephalography (EEG) signal processing has become one of the most commonly used technique for brain analysis such as neurological disorders, neuro-cognition and brain activity. There are numerous softwares available for EEG analysis in the market both open source and paid categories so choosing an appropriate software not only helps in utilizing maximum efficiency of the user but also saves time. Open source bio-cybernetic solutions plays an important role in research, development and business sectors compare to other software. This paper illustrates a brief idea about optimum usefulness of different bio-cybernetics software in research of EEG signal processing so that it can be utilized in further studies for enhancement and improvement on end user level application with increased feasibility.**

***Index Terms*— EEG, Open source, GPL, Bio-cybernetics.**

I. Introduction & Background

Electroencephalography (EEG) signal measures electrical activity of the brain. The raw EEG signal contains clinically important information that may serve as a first objective information and documentation of the neural activity taking placing in the brain under normal conditions and in various other circumstances. Apart from using EEG to characterize activity of the brain researchers also rely on techniques such as functional resonance imaging (fMRI), Electro-corticography (EcoG) and near-infrared spectroscopy (NIRS). Among all these, EEG is the most common as it is noninvasive, and portable as well as can be used in almost any environment, with excellent time resolution. With the advancement in the technology, different software methodologies have evolved that has generated a new value in various kinds of studies involving clinical and non-clinical applications in the EEG signal analysis.

Encephalogram has gone through enormous advancement in more than 100 years of its history. This all started when Richard Caton discovered the existence of the electrical currents in human brain in the year 1875. In 1924, German neurologist Hans Berger with his standard radio equipment enhanced human brain's electrical activity. He also discovered the variation in the rhythm with the individual's condition of consciousness and that various regions of the brain do not discharge the same brain wave frequency at the same time [5]. Later in year 1934, Adrian and Matthews had proven the concept of "human brain waves" and identify regular oscillations around 10 Hz to 12 Hz which they name it "alpha rhythm" [5]. About 1970, EEG interpretation was largely heuristic and of a descriptive nature. From last decade onwards, applications of EEG to numerous research areas have increased drastically. Some of these clinical applications are such as characterization of sleep phenomena, prediction of epileptic seizures, encephalopathy and monitoring of anaesthesia depth. All these experiments are associated with a technology which is based on software tools that are useful to give end results on their own basis. The main aim of this study is to investigate the vital status of open source software for better enhancement in EEG signal research and development procedures.

II. Open Source Softwares

Open Source Software (OSS) is a computer software in which the source code is made available under a license with certain terms and conditions that allows the study, change and distribution to anyone for any purpose [13]. Free of cost availability and right to modify and redistribute with modifications make it popular for end user applications. When users can alter and change the original software as much as they like this will result in development of higher quality software with improved features. To ensure that the software can appropriately utilized, the copyright holder releases the code under some license while making the source code available to the user.

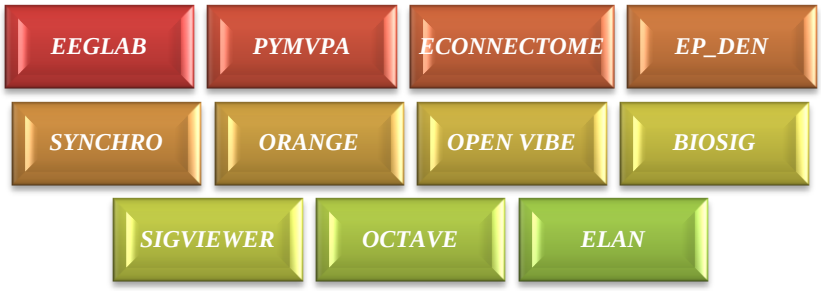

Fig-1: Different GPL based Open Source Softwares for EEG Signal Processing

There are many open source compatible licenses available but GNU General Public License(GPL) and BSD license are most commonly used. BSD license allows unlimited redistribution for any purpose as long as the legal copyright notices are maintained while GPL restricts the users in some way to use the derived works to prevent redistribution of derived versions without source code and ensuring free distribution at the same time. In this paper, different GPL based open source softwares available for EEG analysis are described as shown diagrammatically in Figure-1.

III. COMPUTING ENVIRONMENTS

The main consideration in these different kinds of computing environments is limited to potential benefits on their application level and are shown diagrammatically in Figure-2 below. Most commonly used computing platform for EEG signal processing is MATLAB. MATLAB is a numerical computing programming language that provides polished and integrated interactive development environment to develop algorithms, manipulate & visualize data and perform analyses. It is a commercial product but student licenses are also available. Collection of various toolboxes providing specialized functionality along with debugging and profiling capabilities are some of its advantages that make it a user friendly platform. Along with this platform some open source clones such as Octave are also available that maintain compatibility with MATLAB allowing access to analysis tools for users without a MATLAB license.

Another Environment that is used by researchers in free and compiled from several years is C++. It is an intermediate language that consists of both the features of high and low level language. It provides imperative and object oriented driven programming features implemented on a wide variety of hardware and operating system platforms.

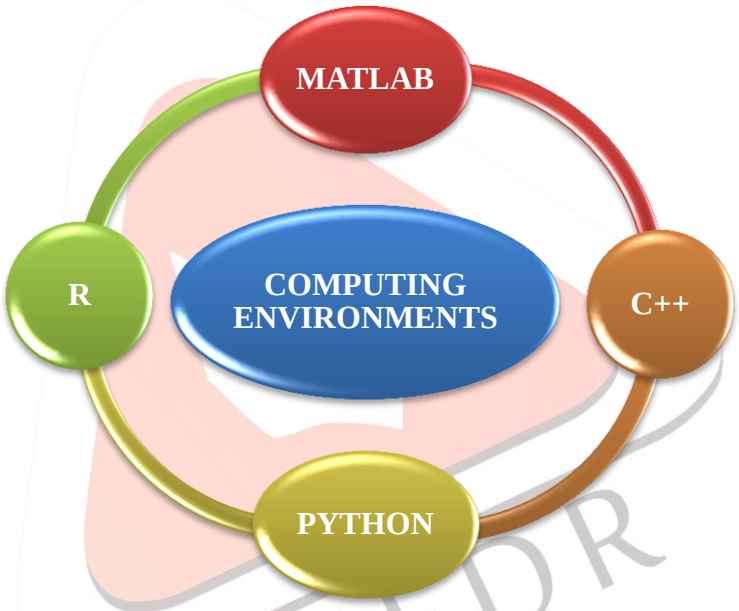

Fig-2: Different Computing Environments for EEG Signal Processing

Another programming language that is gaining popularity in recent years among the researchers is Python. It is a general purpose, well designed object oriented language which is easy to use and learn and is freely available at the same time. NumPy, Scipy are some of its excellent numerical and scientific components that makes it suitable to be used for scientific computation interactive data analysis and visualization [11]. In addition to the numerical and scientific computing tools, a large range of libraries are also freely available for general computing tasks.

Finally, R is a open source and freely available environment for statistical computing and graphics. Flexible data types and a comprehensive archive of an extremely wide range of statistical techniques are making it popular among researchers community.

IV. SOFTWARES FOR EEG ANALYSIS

In recent years there are many advancements that took place for the development of efficient open source analysis softwares for EEG signals in terms of dealing with the quantities of neurophysiological data available. By using these sensitive and more powerful softwares researchers can derive the maximum benefit from the collected data by performing quantitative investigation of neural coding on it. Development of these kind of novel techniques can breathe new life into archived data that allows new questions to be addressed with results from old experiments. Some of these popular and most commonly used efficient softwares in the area of EEG signal processing with their additional applications can be described as follows:

1. Octave

http://www.gnu.org/software/octave/

GNU Octave was developed by John W. Eaton and released on January 4, 1993 [8]. It is named after Octave Levenspiel, a professor at Oregon State University. It is based on high-level interpreted language that is primarily designed to solve issues related to numerical computations. Due to complexity of other softwares and Octave's interactive interface, it was redeveloped to enable

its usage beyond solving chemical reactor design problems. It is capable to solve problems of linear and nonlinear numerical computations and facilitates graphics module for data visualization and manipulation.

2. EEGLAB

http://sccn.ucsd.edu/eeglab/

EEGLAB is an interactive and widely used open source MATLAB toolbox for analysis and processing of physiological data as shown in Figure-4. It is a project of the Swartz Center for Computational Neuroscience (SCCN) of the University of California San Diego (UCSD) and the tools were made available for public use in 1997 by Scott Makeig [2]. In this, users are allowed to handle various data formats and can apply several preprocessing operations such as filter, resample, average, epoch. Users can also visualize signal browser, event-related potentials, power spectra and can perform independent component analysis (ICA). Event related spectral perturbation (ERSP) and inter-trial coherence(ITC) are some of the time and frequency analysis methods that can be implemented with its help. Most useful and impressive feature is extensible plug-in architecture that enables the third parties to contribute additional functionality such as source localization and designing of online brain-computer interfaces [2].

3. EP_den

http://www.vis.caltech.edu/rodri/EP_den/EP_den_home.htm

EP_den is a MATLAB package for denoising single trial evoked potentials from the background EEG [6]. It is developed by Rodrigo Quian Quiroga in 2003 and is based on a wavelet multi-resolution decomposition that introduces an automatic selection of wavelet coefficients based on the inter- and intra-scale correlation of neighboring wavelet coefficients. It provides an interactive graphical interface for denoising the evoked potentials and visualizing the single trial responses.

4. BioSig

http://biosig.sourceforge.net/

Biosig is an open source software that was developed in 2003 for analysis and processing of biomedical signals such as Electrocardiogram(ECG), Electroencephalogram (EEG), Electromyogram (EMG), Electrooculogram (EOG) etc. It can be utilized for data acquisition, artifact removal, feature extraction, classification and data visualization [4]. It consists of some coherent parts which can be depicted as shown in Figure-3. Neuro-physiology, psychology Neuroinformatics, brain-computer interfaces, , cardiovascular systems and sleep research are the major application areas of its implementation.

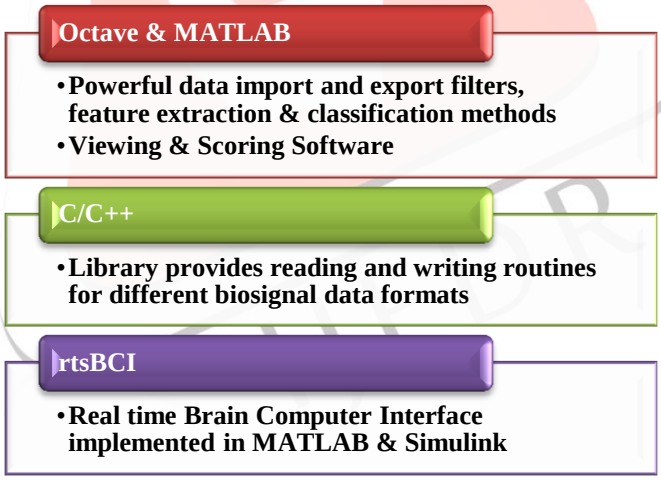

Fig-3: Coherent Parts of BioSig

5. pyMVPA

http://www.pymvpa.org/

PyMVPA stands for MultiVariate Pattern Analysis (MVPA) in Python. It is steadily increasing in popularity as the language of choice for scientific computing and was developed inside Debian Experimental Psychology Project in 2005. It is a package that is used for statistical learning analyses of large datasets. It has high level language interface with extendable framework ranging from algorithms for classification, regression, feature selection to data import and export [7]. It has been most popularly used for analyzing fMRI neuroimaging datasets, EEG, MEG and extracellular recordings.

6. Synchro

http://www.vis.caltech.edu/~rodri/Syncoehro/Synchro_home.htm

Synchro is developed by Rodrigo Quian Quiroga & Chee Seng Koh in 2006. It is a MATLAB package for evaluating linear and non-linear synchronization measures between two signals. The nonlinear synchronization measures are based on a phase space reconstruction of the signal, which is sensitive to non-linear interactions and can in principle disclose driver-response relationships [12]. It provides an interactive graphical interface for visualizing the data and synchronization.

7. eConnectome

http://econnectome.umn.edu/

eConnectome is a MATLAB package for imaging connectivity of brain functionality with physiological signals as shown in Figure-4. It is developed under the supervision of Dr. Bin He at Functional Imaging and Neuro-Engineering Laboratory of University of Minnesota. The first beta version was released on March 12, 2010 while the full version was released on August 19, 2010. Major functions include EEG/ECoG preprocessing, scalp spatial mapping, cortical source estimation, connectivity analysis, and visualization [1]. Its graphical user interfaces allow users to analyze EEG/ECoG data interactively without employing MATLAB programming. It also allows users to run modules in command line and write customized modules with available functions and interfaces. This uniform structure 'ECOM' is designed to store EEG/ECoG data including acquisition information such as sampling rate, electrodes locations, time series and event information.

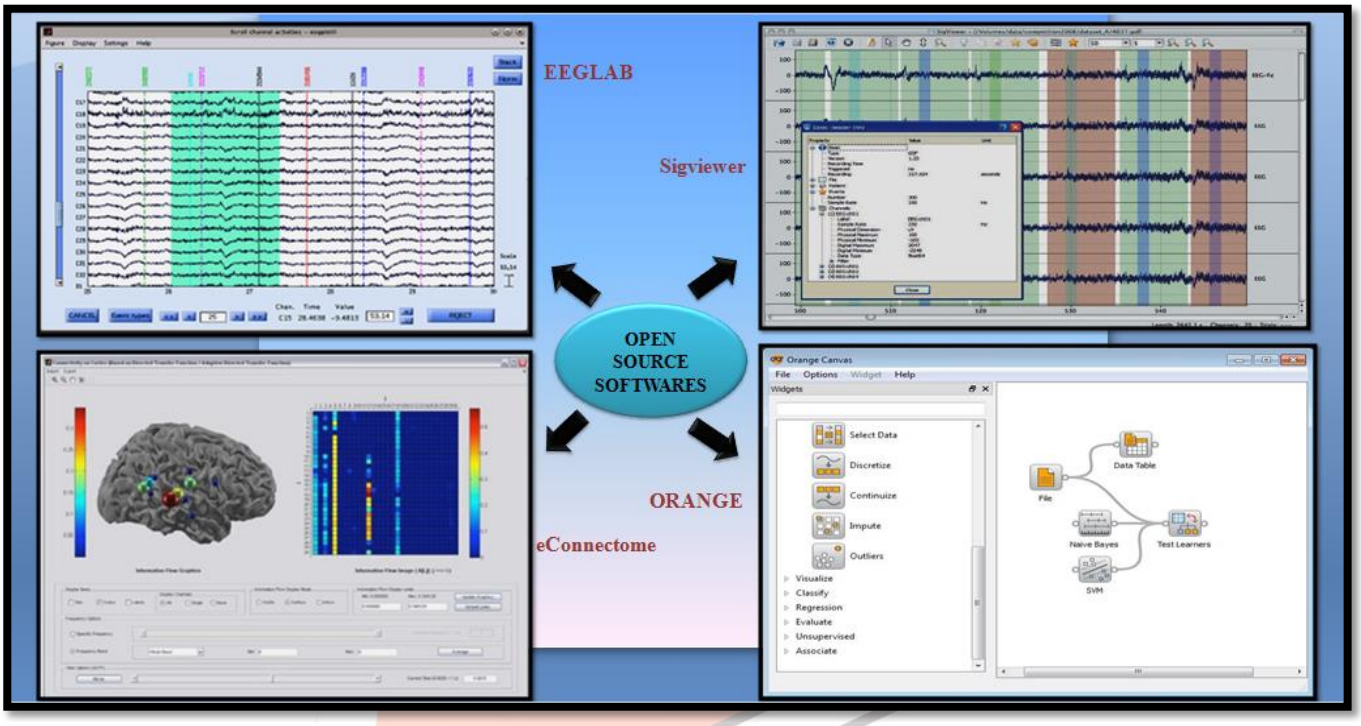

Fig-4: Overview of some Open Source Softwares

8. Open ViBE

http://openvibe.inria.fr

OpenViBE is first library of functions written in C++ and is developed by INRIA - French Institute for Research in Computer Science and Automation [14]. The development of OpenViBE actually involved contribution from six academic and industrial French partners INRIA, INSERM, FRANCE TELECOM R&D, CEA, GIPSA-LAB and AFM. It was first published in 15 April, 2010. It is free and open source software that works on Windows and Linux operating systems. It can be utilized for real time analysis of brain signals that includes acquisition, filtering, processing, classification and visualization techniques. It is highly modular and is a embedded visualization and feedback based software that provides easiest solution on VR and 3D displays of BCI design.

9. ORANGE

http://orange.biolab.si/

Bioinformatics Laboratory of the Faculty of Computer and Information Science, University of Ljubljana, Slovenia developed component-based data mining and machine learning software suite called ORANGE for explorative data analysis and visualization in which Python bindings and libraries are used for scripting. It includes techniques for data preprocessing, filtering, modeling, feature scoring and model evaluation that are easily implemented with the help of C++ and Python. It has a very simple graphical user interface (GUI) for users with limited knowledge in data mining. Its strength is its interactive visualization function, which enables users to set visualization parameters and choose data points or nodes directly from a graph compared to the other data mining tools [10].

10. SigViewer

http://sigviewer.sourceforge.net/

SigViewer was developed at the Graz University of Technology by Clemens Brunner. It is one of the most powerful application for visualization of biosignals especially EEG. It supports several biosignal data formats through libbiosig such as GDF, EDF, CNT, EEG etc. It is written in standard C++ using graphical user interface (GUI) toolkit Qt 4 which is cross platform with availability in all three major platforms-Windows, Mac OS X, and Linux. It is a free open-source program that is independent of

proprietary tools such as MATLAB. Apart from visualization, it also helps in creating markers for the selection of particular artifacts and specific events. It also features signal processing modules such as power spectrum of selected signals and average of selected epochs [3].

11. ELAN

http://elan.lyon.inserm.fr/

ELAN is a software bundle for electrophysiology data analysis (EEG, MEG, iEEG, LFP) developed at INSERM Brain Dynamics & Cognition team of the Lyon Neuroscience Research Centre. It is mainly used for data visualization and informatics collection. ELAN consists of compiled C programs that make up a bundle of data analysis and visualization functions for various electrophysiological data including EEG, MEG, iEEG, LFP, reconstructed source time series, or any type of continuous signals [9]. All ELAN functions can be run in command-line or batch-mode.

V. CONCLUSION

Artifact contamination, low signal-to-noise ratios, different data formats, classification, and statistical evaluation are some of the challenges that EEG signal processing has to deal with. A large number of different data processing methods for different applications are now being developed to sort out these problems. Software development is an important part of biomedical signal processing. Earlier, the field of software development was characterized by providers that offered proprietary solutions that caused incompatibilities, and the same algorithms were implemented again and again. Another problem associated with it was that each equipment provider defined its own data format for storing bio-signals. These data could then be analyzed only with the proprietary software of the vendor. Data export at the same time was also difficult and resulted usually in loss of important information. These facts lead to the development of Open source softwares. The success of free and open source software in the field of operating systems and server software encouraged the development of a free software library for biomedical signal processing. This study gives useful information of software and application specific vital status of different softwares available to perform EEG processing. In future, information may be used to develop open source software for good quality research in EEG signal processing.

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