Review on bio-signal processing software packages

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ABSTRACT

Bio-signal processing and analysis holds great significance in present day medical practice. In recent years, many processing techniques and different algorithms have been developed to help doctors to find new information added in bio- signals which is not easily noticeable in the raw data and hence aid in diagnosis of any ailments. Bio-signal processing is a rapidly evolving field with new processing technique coming out every other day which in turn makes it more and more difficult to be up to date. Signals format, algorithms implementation and comparison, artifacts and various other aspects make the learning of this field a long-drawn process, and in many situations plenty of software components are required to process or visualize bio-signals. In this paper we discuss open sourced, bio signal processing software packages that offer a variety of bio-signal processing algorithms: domain transforms, filtering, wave detection, basic operators, exchange signals format readily in their modules. The objective of this paper is to become an easily referable tool shed that discusses various options of software packages in brief for medical practice or biomedical educational purposes and to evaluate its compatibility with any architecture.

*Keywords***:** *Bio-signal Processing; Software Packages; BioSPPy; Ecgkit; Kubios HRV; WFDB Package; BioSig*

1. INTRODUCTION

Biomedical signals are used for monitoring of physiological actions of organisms, ranging from growth to differentiation, to neural cardiac rhythms, to tissue and organ images. Biomedical signals give useful information by means of biomedical signal processing. Biologists can find new patterns in or a whole new biology and physicians can identify or monitor illnesses with the help of biomedical signal processing [1]. This paper demonstrates the implementation of different software packages namely on physiological signal like ECG, heart rate and skin temperature which are some common physiological reference signal. In recent years, a variety of signal processing software packages are available, which can easily be integrated with any architecture to help the caretakers make decisions. In view of this, different software packages with varying forms of bio-signal analysis methodologies and algorithms for signal processing are discussed and tested. For this study large collections of recorded physiologic signals from Physio Net were used.

1.1 BioSPPy

BioSPPy is a bio signal processing toolbox written in Python whose Attractiveness is in part based on the accessibility of a wide variety of open-source software libraries. Each one is adjusted for precise types of signals and files which further leads to ideal time consumption in any kind of signal processing [2]. The BioSPPy toolbox specifically, brings together numerous pattern recognition and signal processing algorithms dedicated for the analysis of biomedical signals like BVP, ECG, EDA, EEG, EMG, Respiration and is able to do filtering and frequency analysis.

1.2 BioSPPy LIBRARY

The library, like mentioned earlier, is open-source and it is handy both for non-profitable and profitable usages. It covers a variety of functions required for biomedical signal processing. The syntax of these functions is noticeably simplified with respect to ideal use of biomedical signals. The library, using command "import" can be called from the Python environment.

Toolbox is further defined into modules namely: biometrics, plotting, clustering, metrics, signals.bvp, signals.ecg, signals.tools, signals.eeg, signals.emg, signals.eda, signals.resp, storage and utilse.

Module "biosppy.biometrics" provides classifier interfaces for identity recognition i.e. biometrics applications. The module "biosppy.clustering" provides various unsupervised machine learning (clustering) algorithms. Module "biosppy.metrics" provides pairwise distance computation methods. Module "signals.ecg" offers electrocardio- gram processing, while "signals.resp" offers

respiratory signal processing tools, "plotting" is used to obtain graphical representation, "signals.tools" module extends functions for filtering and frequency analysis. Lastly, the module "signals.ecg" incorporates methods for ECG signal importing, pre-processing, estimation of Instantaneous Heart Rate and algorithms for detection of QRS complex [3].

A Sample ECG signal collected from PhysioNet waveform data base is analyzed by bioSPPy which is shown in Figure 1, here the sampling frequency is taken as 1500Hz. This python based open source package can easily be integrated into any architecture [4].
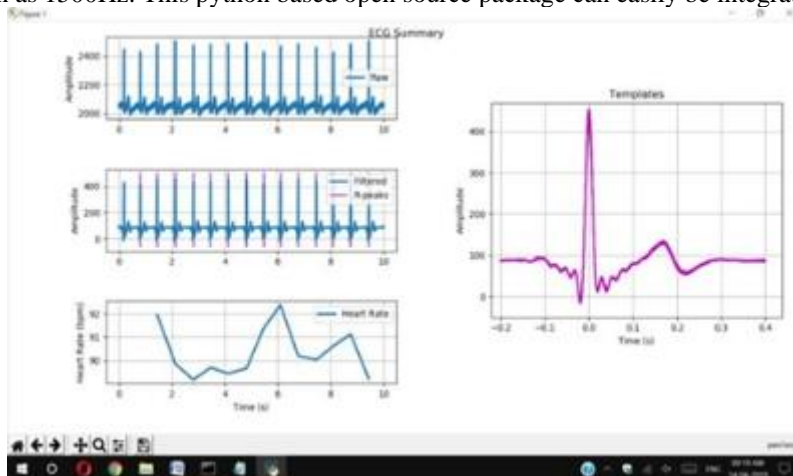

Fig. 1: Sample ECG signal Analysis by BioSPPy [4].

2. AVAILABILITY OF THE SOFTWARE
Recent version of BioSPPy steps on the installation can be easily found at https://biosppy.readthedocs.io/en/stable/#installation

3. ECG KIT
The ECG-kit for MATLAB gives a construct level for acquirement, examination and processing of cardiovascular signals. This open-source application-programming interface (API) is a collection of several, frequently used tools.
The main feature of these tools is to use various well-known algorithms for ECG-processing, such as:
• Physionet's WFDB software package Algorithms.
• QRS detectors, like Pan & Tompkins, gqrs, wqrs, wavedet, EP limited,ecgpuwave.
• Pulse wave detectors as wabp and wave-PPG
• a2hbc and EP limited heartbeat classifiers.
• Wavedet ECG delineator
• And scripts that involve inspecting correcting and reporting all these results.
Seven TB of data in community databases accommodated in Physionet and THEW can easily be accessed by this toolbox.

3.1.ECG-KIT Modules
The fundamental of this toolbox is ECG wrapper. This class makes it possible to define recording format and length, hence provides the probability of processing and recordings of long or short intervals. The wrapper also extends an interface to QRS detectors and classifiers, two pulse wave detectors, a heartbeat delineation, and various other tasks. These tasks are routines in cardiovascular bio-signal processing, which provides both, detection of the heartbeat or pulse as well as the per-beat wave segmentation. ECG-task, an abstract class which gives an abstraction level from the algorithm to the ECG-wrapper is used to implement each task. ECG-task class furnishes a base interface that can be further improved and defined by higher hierarchy ECG-task classes, such as ECG-task_ECG_delineation or ECG-task_QRS_detection. Each task can execute various algorithms that can be used simultaneously, with a common configuration. The toolbox also includes several functions that offer visualization and the results achieved are offered with an option to be stored either with Mat. MAT (Matlab) file for backup or by creating a PDF report.

Fig. 2: Sample report from Ecg-kit for a multimodal recording
 This toolbox gives a good outset for researchers learning new or already implemented cardiovascular signal processing algorithms, for either comparison or further development[5].

3.2. Availability of the software
Ecg-kit for Linux and Windows operating systems is easily available at http://marianux.github.io/ecg-kit/.[5]

4. KUBIOS HRV
Kubios HRV software is an easily operable HRV analysis tool which extends a variety of frequency-domain, time- domain and nonlinear analysis options. Heart rate variability analysis generally sees its application in evaluation of autonomic nervous system functioning and in various human fitness allied applications. HRV is generally known to be influenced by some cardiac diseases, stress and other pathological states. [6]

4.1. Algorithms For the Processing of Signals
Kubios HRV uses various algorithms for pre-processing and analysis of bio-signals. Kubios HRV is available as freeware as well as premium. The freeware software is available for noncommercial and personal use with most frequently used time and frequency domain analysis, HRV parameters. The premium version in the other hand designed for scientific research and professional use with extensive range of ECG, PPG and HR data analysis with commonly used time and frequency domain analysis and nonlinear HRV data analysis. In addition, Premium version comprises enhanced pre-processing, ECG derived respiration, time-varying analysis and exporting options. Analysis results can be saved as illustrative CSV text file, PDF reports, MATLAB file and likewise in a "SPSS friendly" batch file.

In standard version Threshold based beat correction and removing low frequency components in HRV analysis are possible. In addition to that detecting PPG data and tools for noise handling and beat correction methods are available in premium version. Kubios developed their own algorithm for beat detection based on the Pan–Tompkins algorithm, which provides accurate results in pulse wave detection. The Threshold based artefact correction is followed in both the versions. Also, various time-domain, frequency-domain and nonlinear analysis were used in both standard and premium versions.

Kubios HRV is one of the commonly used HRV analysis softwares for scientific research and is scientifically validated. Which is developed using MATLAB, and it can able to perform as a standalone application with the MATLAB compiler. The software is appropriate for professionals working on human well-being, clinical and public health researchers, or sports persons for anybody who need to perform complete analyses on heart rate variation, e.g. to inspect autonomic nervous system function [10].

4.2. Availability of the Software
Kubios HRV is available at https://www.kubios.com/ For support on using Kubios HRV the User's Guide and FAQ are available at https://www.kubios.com/support/.

5.THE WFDB PACKAGE
WFDB (WaveForm DataBase) Software Package is a Software to view, analys and create recordings of physiologic signals. The software package was created by Physionet to allow a robust usage of PhysioBank information. The collection of records created, each consists of, one header file, any number of signal files and any number of annotation files.

The major parts of the WFDB software system Package square measure the WFDB library, concerning seventy-five WFDB applications for signal process and automatic analysis, and therefore, the WAVE software system for viewing, annotation, and interactive analysis of wave information. A comprehensive assortment of documentation, as well as tutorials and reference manuals, is additionally enclosed within the package. The WFDB library allows applications linked with it, with an optional feature to view or analyse data those are accessible from PhysioBank. The compilation of WFDB library files can be done by using a web browser, which gives the freedom to use the software.
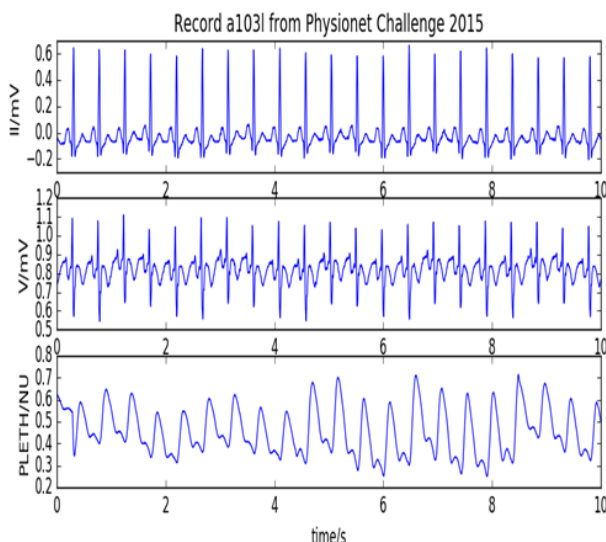

Fig. 3: Sample ECG signal Analysis by The WFDB

The WFDB packages are also available in Native python scripts (modules:wfdb.io, wfdb.plot, wfdb.processing) (for reading and writing WFDB signals and annotation), Matlab toolbox and in other different programming languages which is compatible with

various signal formats. The WFDB packages are able to provide a variety of analysis functions by being one of the most powerful software packages that can be implemented in any architecture [12].

5.1. Availability of the software
The package is on pypi at: https://pypi.python.org/pypi/wfdb/ . To install the package straight away from pypi without wanting to download content, run on terminal: $ pip install wfdb

6. BIOSIG
BioSig software library is an open source which aims to promote study in biomedical signal processing by providing, freeware tools ranging various application areas. BioSig can be employed in the analysis of bio-signals such as the electrocardiogram (ECG), electroencephalogram (EEG), electromyogram (EMG), electrocorticogram (ECoG), electrooculogram (EOG), or respiration signals. BioSig includes some coherent portions that are potted as follows.

I.   (biosig4octmat) BioSig for Matlab, Octave and Scilab: A toolbox for Matlab, Octave and Scilab with strong data import and export filters, classification methods, feature extraction algorithms, a powerful software for viewing and scoring.
II. (biosig4c++) BioSig for C and C++: A C and C++ library that gives reading as well as writing procedures for various formats of bio-signal data.
III. rtsBCI : A Realtime Brain Computer Interface system employed in MATLAB and Simulink [14]
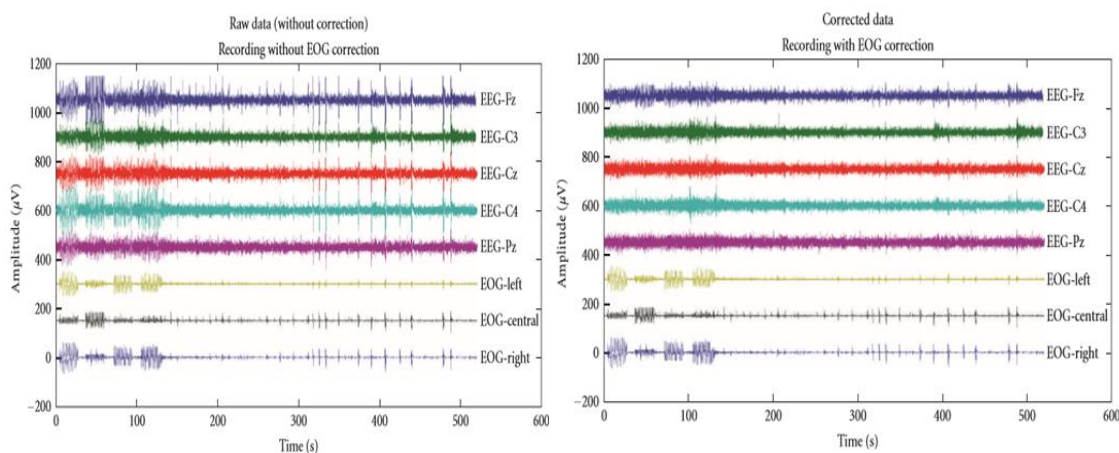
Fig. 4: (a) Raw EEG data, contaminated with ocular artifacts (b) Corrected data obtained from BioSig using regression analysis.

Figure 4 shows the regression technique to correct EOG artefacts in EEG. The above figure is the raw EEG data, and the below the corrected ECG. [[12]]

6.1. Toolbox Components
All functions of BioSig are tested for their compatibility with scilab, MATLAB and Octave platforms. Though BioSig supports other computer programming languages of programming which may be primarily C/C++, Python, constitutes the core module of BioSig. BioSig provides an extensive range of biomedical signal processing. Therefore, based on the working of the algorithm's toolbox is selected and is divided into several subcategories. The "data input and output" module is an interface which is common for accessing different formats including an automated format detection, which supports reading (around 40) and writing (around 10) audio formats and different data formats. The pre-processing module gives a tool for segmenting (triggering) signal data, for artefact reduction, artefact detection, and quality control.

The signal processing element comprises various speciate bio-signal processing functions, but for more complex analyses, interfaces to standard wrapper and signal processing functions. The functions help to support various classification procedures. A number of classifiers like regularized discriminant analysis, Naive Bayes Classifiers, Perceptron Learning, Regression analysis linear/ Partial Least Squares, quadratic and, numerous methods of Support Vector Machines as well as some light classifiers are supported; cross-validation events are supported to stop overfitting. The visualization module has an easy viewer for biomedical data additionally a wrapper role is performed to check the results of many normal analysis procedures. Ddifferent important modules are the Time Series Analysis (TSA) toolbox and the NaN-toolbox. The TSA toolbox gives a distinct number of coupling measures founded on a multi- variate auto regressive modelling routine. The data with missing values will be handled by the NaN toolbox, that normally generates artefacts and determined by not-a-number (NaN).

The Biosig is a one stop destinations for solutions on data acquisition, feature extraction, quality control, artifact processing, modeling, classification, data visualization, and so on. Several helpful algorithms such as algorithms for stochastic model parameters (multivariate, autoregressive, time-varying, etc.) in the TSA toolbox, QRS detection is also part of this project. The BioSig toolbox provides a unique interface that supports reading and writing of several file formats. A powerful viewing and scoring program called SViewer is included, Based on this interface. Most functions can be used with Scilab, Octave and Matlab, due to its easy usability it can be easily integrated in to any proposed architecture [14].

6.2. Availability of the software
Various versions BioSig is available free of charge at http://biosig.sourceforge.net/download.html and documentation on use of BioSig is also available.

The comparison of all the discussed bio-signal software packages is listed in the table-1.

Table 1: Properties of all the discussed bio-signal processing software packages

Software package	OS supported	Programming languages and Software tools used	Algorithms used	Functions offered	Various bio-signals supported
BioSPPy	Windows, Linux	Python	QRS complex detection (Gamboa, Hamilton, Slope Sum Function)	Cclassifier interfaces for identity recognition (biometrics) applications, pairwise distance computation methods, filtering, frequency analysis, electrocardiogram signal importing, signal pre-processing, estimation of Instantaneous Heart Rate and algorithms for complex QRS detection, electrocardiogram processing, data storage methods	BVP, ECG, EDA, EEG, EMG, Respiration
ECG-Kit	Linux	MATLAB	WFDB-software package-Physionet's Algorithms.	Aalgorithms often used in pulse detectors for pulsate signals, processing of cardiovascular signals, such as heartbeat detectors and classifiers, and an ECG delineator. Aadditionally, a tool for manual assess and correction the outcome given by automated algorithms. The results achieved are saved as a MATLAB file for process later, or to create a PDF report.	cardiovascular signal, ECG.
Kubios HRV	windows Linux	MATLAB	It comprises an Adaptive QRS detection algorithm and correction of artifact, analysis sample selection and trend removal tools.	Computation of all commonly used methods and various non-linear parameters along with the ECG derived respiratory frequency. Different data analysis can be improved by the adjustable analysis settings. The analysis results are saved as an ASCII text, MATLAB file, or as a PDF report.	ECG data and RR interval data.
The WFDB Package	Linux	MATLAB, Python	Sspecialized algorithms such as QRS (beat) detectors in addition to general-purpose tools for sampling frequency conversion.	Vviewing, analysing, and creating recordings of physiologic signals. WFDB record and returns the signal and record descriptors as attributes in a Record or Multi Record object.	All physiologic signals in Physionet database
BioSig	Windows, Linux	Octave and MATLAB C/C++, Python	Algorithms used in QRS detection, algorithms for stochastic model parameters in the TSA toolbox.	Data Acquisition, Feature Extraction, quality control, artifact process, classification, modelling and visualization.	EEG, ECoG, ECG, EOG, EMG, or respiration signals.

7. CONCLUSION
In this paper, freeware software packages for bio-signal processing, visualization and editing have been discussed and presented. The features offered by each of the modules are briefly discussed. Moreover, these software packages can be utilized each in education and in medicine, suggests that to perform a rapid study and test of the algorithms, and additionally analysis of physiologic signals. The bio-signal processing software packages are generally seen using python, C++, C, Octave or MATLAB for their execution under Windows and Linux operating systems and can be easily integrated with any architecture.

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