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PSGMiner: A modular software for polysomnographic analysis

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ABSTRACT

Purpose: Sleep disorders affect a great percentage of the population. The diagnosis of these disorders is usually made by polysomnography. This paper details the development of new software to carry out feature extraction in order to perform robust analysis and classification of sleep events using polysomnographic data. The software, called PSGMiner, is a tool, which visualizes, processes and classifies bioelectrical data. The purpose of this program is to provide researchers with a platform with which to test new hypotheses by creating tests to check for correlations that are not available in commercially available software. The software is freely available under the GPL3 License.
Method: PSGMiner is composed of a number of diverse modules such as feature extraction, annotation, and machine learning modules, all of which are accessible from the main module. Using the software, it is possible to extract features of polysomnography using digital signal processing and statistical methods and to perform different analyses. The features can be classified through the use of five classification algorithms. PSGMiner offers an architecture designed for integrating new methods.
Comparison with existing methods: Automatic scoring, which is available in almost all commercial PSG software, is not inherently available in this program, though it can be implemented by two different methodologies (machine learning and algorithms). While similar software focuses on a certain signal or event composed of a small number of modules with no expansion possibility, the software introduced here can handle all polysomnographic signals and events.
Conclusions: The software simplifies the processing of polysomnographic signals for researchers and physicians that are not experts in computer programming. It can find correlations between different events which could help predict an oncoming event such as sleep apnea. The software could also be used for educational purposes.

1. Introduction

Polysomnography (PSG) is a standard test that is applied in sleep laboratories and is used in diagnosing patients with sleep problems. During the night, continuous and real time recordings of the bioelectric signals produced by the body during sleep are made [1]. At present, sleep disorder research has become a specialised area of expertize in which approximately 90 different diseases are defined. Among the various methods used, PSG is the leading method used in sleep disorder studies [2].

PSG montage may have a different number of channels depending on the problem to be solved in a specific patient. Following acquisition, the signals are amplified and filtered in order to remove noise and artifacts. There are various software and hardware solutions for PSG recording and analysis. Some of them are as follows: Cadwell Laboratories Inc. (Easy III Software), CareFusion (SomnoStar Software), CleveMed (Crystal PSG Software), Compumedics U.S.A. Inc. (ProFusion PSG 3 Software), Natus Medical Inc. (Sandman software), Natus neurology Grass Technologies (TWin PSG Clinical Software), Nihon Kohden (PSG-1100 Sleep System), Philips Respironics (Sleepware G3), Signature Sleep Services (Galaxy PSG Diagnostic Platform), Sleepvirtual (Sleepvirtual BWIII), SOMNOmedics America Inc. (DOMINO Software). These commercial software have four functions in computer-based PSG: recording, documentation, scoring and report generation.

Various academic groups that deal with digital signal processing (DSP) and machine learning (ML) techniques have software that is used for analysis of physiological signals [3–17]. However, these software focus on certain signals and disorders. The examples of these can be given as ANYWAVE (visualizing and processing electrophysiological signals), KUBIOS HRV [4] (heart rate variability analysis software), POTENCOR [5] (calculate power and correlation spectra of electroencephalography (EEG) signals), RESP-24 [6] (the investigation of 24-h breathing abnormalities in heart failure patients by using Respiratory Signal (RS)), EEGLAB [7] (processing continuous and event-related EEG and magneto-

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Table 1
The characteristics of software packages.

	Development environment				Extendible modular structure	Software dependency		Parallel processing support	Target signal	Machine learning support	Web site
	Matlab	C++	LabVIEW	Delphi		Matlab	LabVIEW				
AnyWave [3]		√			√	√			PSG		√
Kubios HRV [4]	√					√			ECG		√
POTENCOR [5]				√					EEG		
RESP-24 [6]	√					√			RS		
EEGLAB [7]	√				√	√			EEG		√
FieldTrip [8]	√				√	√		√	EEG, MEG		√
MEA-Tools [9]	√				√	√			ECG		√
BSMART [10]	√					√			EEG		√
EPILAB [11]	√					√		√	EEG, ECG	√	√
ERPWAVELAB [12]	√					√			EEG		√
EMEGS [13]	√				√	√			EEG, MEG		√
LIMO EEG [14]	√					√			EEG		√
Craniux [15]			√				√	√	EEG		√
OpenMEEG [16]		√			√	√		√	EEG, MEG		√
mfERG_LAB [17]	√					√			EEG	√	
PSGMiner				√	√			√	PSG	√	√

encephalogram (MEG) signals), FIELDTRIP [8] (MEG and EEG analysis), MEA-TOOLS [9] (spike analysis), BSMART [10] (analysis of multichannel neural time series), EPILAB [11] (studies on the prediction of epileptic seizures), ERPWAVELAB [12] (multi-channel time-frequency analysis of event-related activity of EEG and MEG data), EMEGS [13] (analysis of EEG and MEG data), LIMO EEG [14] (statistical analysis of physiological data), CRANIUX [15] (brain-machine interface research), OPENMEEG [16] and MFERG_LAB [17] (software for quasi-static bio-electromagnetics). The detailed characteristics of these software packages are listed in Table 1.

As seen in Table 1, the majority of software packages are created based on MATLAB™, which would require some level of programming knowledge. However, these software packages fail to provide an interface that is effective and easy to use in clinical works, which highly require a thorough visualization of signals and delicate marking events. Therefore, a common platform is strongly needed in order to allow a rapid interaction between clinical researchers and methodologists.

Here, the aim is to develop a tool at the interface between methodologists and researchers in the field of physiology. For this purpose, modular software (PSGMiner) that has marking tools and data import/export functionality was developed, which could make basic visualizations, analysis and classification of data. This software also makes it possible to incorporate any feature extraction module so that methodologists could use the newly developed algorithms properly.

With its expandable modular structure, parallel processing and machine learning support, PSGminer is capable of analyzing all of the PSG signals.

PSGminer is not limited to default parameters. It is easy to add a new data type, an analysis type, or a new ML method; users can even modify an existing feature. Any number of different data can be obtained through the calculation of the features of each PSG channel. Following that, the data obtained are stored in different tables in the database according to the type of the analysis.

Although some academic software contains DSP and ML, there is no commercial software that has these features. PSGMiner contains DSP and ML techniques at the same time and it uses the parameters obtained from the PSG signals, which are required to classify different sleep disorders or user-defined events. It can use the results of manual or automated analysis performed by the recording device.

PSGMiner creates a database, which is specific to the files and the analysis, by reading the raw PSG files with different channels and features. In the feature extraction module, it extracts features from the raw data in the form of epochs (desired time) in time, frequency, and entropy domains and stores them in the database created. In the annotation module, PSG data can be scored visually or necessary changes can be made on existing scoring data. In the artifact module, the epochs with dense artifacts are excluded from the classification. In the ML module, the classification operation is conducted through the use of five algorithms. All of these operations are managed within a single piece of software. The program can also be used to analyze signals to detect correlations and changes in a particular parameter, which could have useful applications. For example, this could give researchers an opportunity to predict an event in advance by means of established correlations, which would be an important advantage for the researchers or technicians conducting the sleep experiments, as they could be alerted to an oncoming critical event such as sleep apnea.

This study presents the architecture of the PSG miner software, which emphasizes the feature plug-ins that can be developed in any programming language. This process is described in the help menu of the software and online (http://www.psgminer.com/). It is possible to use the developed software free under GNU Lesser General Public License v3.0, with full documentation and examples at http://sourceforge.net/projects/psgminer/.

2. Materials and methods

2.1. PSG data

PSG data that are used at the designing stage of the study were taken from 153 patients (M/F, 112/41; mean age, 61,48 ± 11.54 years, age range, 32–94). The study protocol was approved by a local ethics committee. These patients were actual patients from the archive of a sleep laboratory. Recordings were used in a retrospective manner. All patients were diagnosed with periodic leg movement disorder and underwent a one-night PSG for diagnosis. These PSG records were recorded with a 44-channel polygraph (Compumedics 44E series, Australia) and these archive records were obtained through the use of complete PSG techniques in the sleep Laboratory of the Faculty of Medicine, Trakya University. PSG assembly involves 6-channel EEG (F3-A2, F4-A1, O1-A2, O2-A1, C3-A2 and C4-A1), right and left electrooculography (EOG) (LOC-A2 and ROC-A1), leg electromyography (EMG), chin EMG, electrocardiography (ECG), oxygen saturation with fingertip pulse