Software tool using different methods for analysis and processing EEG signals in Biomedical and Medicine studies

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Abstract *— Electroencephalography is the recording and evaluation of electrical potentials generated by the brain and obtained through electrodes placed on the scalp surface. The signal monitoring is a basic tool for some applications in clinical medicine. Specifically, quantitative analysis of the electroencephalogram (EEG) to understand brain function in order to aid in the diagnosis of dysfunctional states in disciplines such as Neurology, Neurosurgery, Psychiatry, Psychology and Pharmacology. "Deustotech EEG Digital Processing Toolbox" provides an interactive graphical user interface (GUI) allowing users to flexibly process various brain signals. This software integrates different filtering options, including a range of analytical methods used in functional connectivity.*

Index Terms — Electroencephalography, EEG signals, Digital signal processing, connectivity methods.

INTRODUCTION

The use of technology is vital to the education of XXI century students regardless their field of study. Therefore, in this paper we present a training proposal for students in engineering and medicine, with an ad hoc tool designed for educational purposes.

The software described in this document, provides an easy way to learn more about digital processing EEG signals and brain connectivity problems. This tool is associated with a hardware that enables the collection EEG data synchronized.

The electroencephalogram (EEG) is the recording of the electrical activity of neurons in the brain. The EEG, like all biomedical signals, is very susceptible to a variety of large signal artifacts or contaminations which reduces its clinical usefulness. For example, blinking or moving the eyes produces large electrical potentials around the eyes called the electrooculogram (EOG).

The EEG can detect alterations in the whole brain or in some areas, ie, it can serve to detect diffuse lesions or located lesions. Measurements in the scalp can detect internal electrical configurations, but with attenuation and blurring introduced by the passage through the skull. Unfortunately, electrical signals from the brain resist control. What is usually done, is to measure a plurality of EEG signals and filter out unwanted components.

In this sense, we have developed an EEG signal-processing toolbox written in Matlab and running under Microsoft Windows. Offering a variety of filters to explore the possibilities of digital signal processing in encephalographic recordings.

In this article, we briefly introduce, a toolbox composed of a multitude of signal-processing modules which are all controlled through a single user-interface. It is also focused on teaching how sophisticated methods can be accessible for students with background of digital signal processing.

METHODS

In general, neurological disorders often manifest themselves in the EEG as slow waves which unfortunately not only have appearance similar to EOGs but they also share the same frequency bands as EOGs. The problem then, is remove the EOGs while preserving the signals of clinical interest.

Several methods have been proposed for processing EOGs. However, factors such as the requirements of the clinical laboratory, constraints of real-time applications, costs, the random nature of EOGs and the spectral overlap between EOGs and some signals of brain origin force the application of different mathematical methods.

Digital Filters

In order to reduce the brain activity suppression, it has been proposed low-pass filtering of EOG signals before making any other filtering in the time domain. Specifically, it is estimated that the eye activity is almost negligible from 7.5Hz [1].

However, a recent study claims that the effects of ocular artifacts in EEG signals are present not only in the delta [1-4Hz.] and theta [4-8Hz.] frequency ranges.

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Linear Regression

Procedures based on linear regression consist of estimating propagation factors of ocular activity signal bypass, and reconstruction of the EEG signal corrected by subtracting the portion of the eye component present in the recorded signal. They assume the condition that the recorded signals are not correlated at any instant of time [2].

However, the most important limitation which presents the linear regression is the impossibility of acquiring records from ocular activity only because of the bidirectional contamination between brain and ocular activity.

Thus, this method not only reduces the ocular artifacts but it also eliminates the brain activity recorded by the electrodes in common.

Adaptative Filter

This is a classical digital filter, with the particularity that its parameters can vary over time. The charge to change these parameters is an optimization algorithm that, in order to minimize some criterion, constantly calculating the best settings.

The estimated coefficients (parameters) of the model are made from the signal samples. As a general rule, if we have N samples of the signal, usually a half of them are used to estimate the coefficients and the remainder to validate the model.

Various algorithms have been developed to obtain the coefficients of the model:

- RLS (Recursive Least Squares).
- Yule-Walker [3].
- Burg.
- MLE (Maximum Likelihood).
- Kalman [4].

It is noteworthy that these five methods consider the signal as stationary, and that all data need to be present to do the calculation.

Blind Source Separation (BSS)

In recent years, many algorithms have been developed which allow the obtaining of the original source signals in a mixing process for the many applications which can occur at the level of biomedicine, audio, cancelling noise and interference, telecommunications, etc.

The reduction of artifacts which contaminate the EEG signals by BSS methodology was initiated by Vigario and Makeig [5, 6]. This application was created with the objective of resolving the need for a reference channel where the activity is recorded by the artifact.

There are a variety of algorithms to solving the problem of the BSS, and therefore various processes for decomposing the signals recorded in source signals. These are implemented in our application:

- Based on second order statistics[7]: algorithm SOBI (Second Order Blind Identification).
- Based on higher order statistics [8]: algorithm JADE [9] (Joint Approximate Diagonalization of Eigenmatrices) and Infomax algorithm [10] (maximization of information flow).

SYSTEM DESIGN

The system design is intended to provide a complete idea of what the software functional domains focusing the data and behavior from the point of view of implementation. A set of facts, principles and rules classified, showing a logical plan. Thus, the tool can be grouped into three main processes:

- Hardware synchronization.
- Digital signal processing.
- Futher Processing.
- Results Viewer.

Hardware synchronization

The development of synchronization is to synchronize, in an efficient and effective way, the software which is responsible for the acquisition and storage of electroencephalographic signals and the software responsible for the presentation of the stimuli. The software responsible for carrying out the capture of the signal is a software acquired while the hardware itself g.tec Company (Austria).

The synchronization is performed by means of the mouse position and event producing at the same time. So when the mouse is pressed to start recording in the commercial application, it runs on both the video recording and the corresponding stimulus presentation. The high-level diagram of the synchronization is shown below as a module of the global system (Figure 1).

Digital signal processing

As a second option, digital filtering is displayed. At this point we have developed algorithms of different kinds. Ocular artifacts filtering born with the dilemma of how to apply filtering method. Depending on the choice considered we are channeling towards one direction or another.

For executing the desired method, the user will choose one or some of the tests available on the toolbox, as can be seen in Figure 1. The methods the user choose will depend on what the researcher is looking.

Results Viewer

Once one of the mathematical methods has been resolved to the new system, it allows Matlab users interact with data visualization window by selecting items organized in the main menu window.

It also adds a large margin of alternative graphical representation of the required signals, see Figure 1.

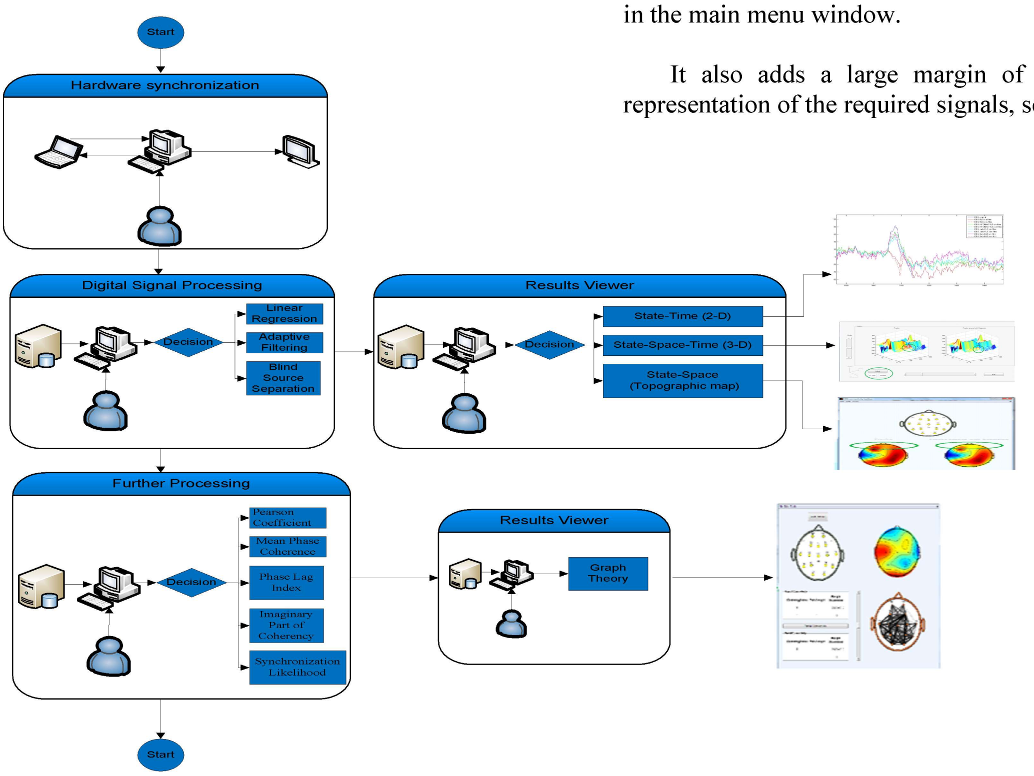

FIGURE. 1.
MODULES FORMING THE TOOLBOX SYSTEM DESIGN AS WORKFLOW CHART

Further Processing

Aside the functions mentioned above, the toolbox also provides other supporting functions for further EEG processing:

- Power Spectrum.
- Pearson Coefficient.
- Mean Phase Coherence [11].
- Phase Lag Index.
- Imaginary Part of Coherency.
- Synchronization Likelihood [12,13].
- Graph Theory [14].

RESULTS

"Deustotech EEG Digital Processing Toolbox" operates in the very rich Matlab environment. This system was originally developed in the frame of author's own research. The structure of DEDPT functions makes it easy to combine them in new ways in original Matlab scripts, which may use any of the wide variety of processing tools and methods available in Matlab. That is something many or most Matlab users do routinely.

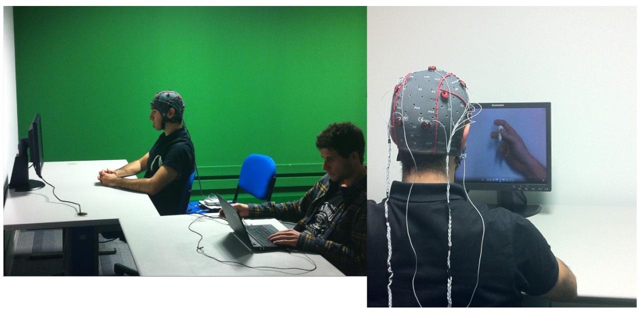

FIGURE. 2. SCREENSHOT OF ONE RECORDING SESSION

DEDPT can be called directly in the Matlab command window. It comes as a fully functional graphical user interface (GUI). Profitable since users do not have to call functions or type anything in the command window, everything can be obtained via interface.

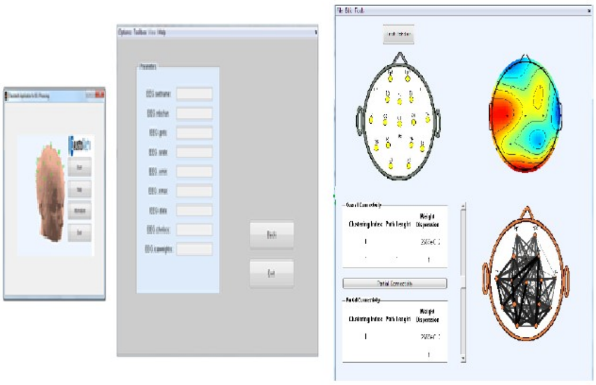

FIGURE. 3.
SCREENSHOT OF ONE OF THE INTERFACE PARAMETERS SELECTION MENUS

Compared to other EEG toolboxes, students do not have to face huge amount of Matlab code and still obtain already debugged and running code which is simple to extend.The whole toolbox has also a pedagogic dimension as students can have a look at the functions and see how are the algorithms implemented. In addition to this, it is easily possible to introduce new modules to the system and distribute them amongst students.

CONCLUSION

The contamination of a signal of interest by other unwanted, mostly larger, signals or noise is a problem often encountered in many applications. Where, the signal and noise occupy fixed and separate frequency bands, conventional linear filters with fixed coefficients are normally used to extract the signal. However, there are many instance when it is necessary for the filters characteristics to be variable, adapted to changing signal characteristics, or to be altered intelligently. In such cases, the coefficients of the filter must vary and cannot be specified in advance.

Our contribution is this very useful toolbox, directed for those who want to learn about digital processing. Indeed, it is important to keep in mind that signal processing can be and have been used for other purposes.

In general, the meaning of this software tool provides an interactive Matlab toolbox for new users, checking the effectiveness of some analysis methods. These improvements enhance the students to make their own proofs on the algorithms and data.

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