Development of an EEG signal processing program based on EEGLAB

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Abstract— **Brain Computer Interface development requires different disciplines from the engineering area. The amounts of information generated by a project like this are huge and need to be processed with the assistance of specialized software. EEGLAB is software that allows signal processing with graphing capabilities regardless the dataset amount. EEGLAB is open source, multiplatform and with a user friendly interface that allows inexperienced users to be able to use the software. This open source software is useful as a reference point for the development of a LabView based program.**

Keywords—**BCI, EEG, EEGLAB, FastICA**

I. Introduction

Brain computer interface (BCI) development is a task that requires different engineering disciplines. Since the signal intensity is low, in the microvolts order [1], special filtering is required. Nevertheless filtering is not the only problem a designer has when trying to develop a BCI, signal processing is also an important task in this type of projects.

It is common that brain signals appear with certain undesired artifacts such as heart beating, breathing, and blinking [1-2] and removing these signals cannot be done efficiently with active filters. In order to solve this problem there are some methods that allow component separation such as Blind Source Separation (BSS) or Independent Component Analysis (ICA) [1].

On the other hand, Electroencephalography (EEG) tests represent large amounts of data [2], if the user would repeat such tests several times it would be necessary a tool that eases organization and data handling.

Computational tools (software) have been created to provide analysis and handling of EEG datasets, also they serve as an aid for signal visualizing which is crucial for this kind of projects. An example of these tools is EEGLAB, which was developed by the Swartz Center for Computational Neuroscience and the actual chief developers are Arnaud Delorme and Scott Makeig.

EEGLAB's easy-to-use graphical user interface and its free distribution make this software a useful tool for BCI development. It makes easier certain stages during the signal analysis; it is capable of identifying artifacts that may be distorting the brain signal with its ICA algorithm [3]. Also this software is not limited to just providing certain solutions and algorithms for EEG signal analysis, it also allows the implementation of self-made algorithms in order to have greater functionality.

This paper describes the capabilities of EEGLAB and its use as a starting point for the comprehension of processing algorithms such as ICA and the development of a similar program in LabView for a BCI application.

II. Software Development and EEGLAB Description

EEGLAB is a program designed for EEG signal processing. Event related potentials and other types of brain responses can be analyzed with this software. It also provides methods such as ICA and different types of signal visualization in frequency and time domain.

This software is free distributed and open source protected by GNU license. There are distributions for different operative systems such as Linux, Windows or MAC OS X. It is developed in Matlab and there are two types of this software, the compiled version and the un-compiled version.

The compiled version is designed for users who do not own Matlab. Such version requires more memory than its counterpart, the un-compiled version, because it contains a compiler that builds the EEGLAB code.

The un-compiled version contains all the codes for each command and it is designed for those users who possess Matlab.

EEGLAB works analyzing datasets obtained from BCI tests or any other device based on EEG. This data can have different types of formats depending on which amplifier was used. EEGLAB has importing properties in order to be able to read several types of format. At the software's webpage there is a table that contains the different formats that EEGLAB support.

This importing capability allows the user to analyze self-made datasets because it supports ASCII or MAT datasets which can be generated using MATLAB or LabView.

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It is important to point that this tool only reads datasets that were previously processed; this means that EEGLAB cannot read data directly of an acquisition card like other software tools such as LabView.

Based on the fact that LabView was able to register signals directly from a DAQ, the program that is being developed is able to register the signals coming from the EEG amplifier and registering them to an ASCII dataset.

Two screens showing the capture in real time show the conversion of the dataset reading or generation, one screen is used for displaying the signals when reading from a dataset and the other is used for showing the signals that are going to be written in the dataset.

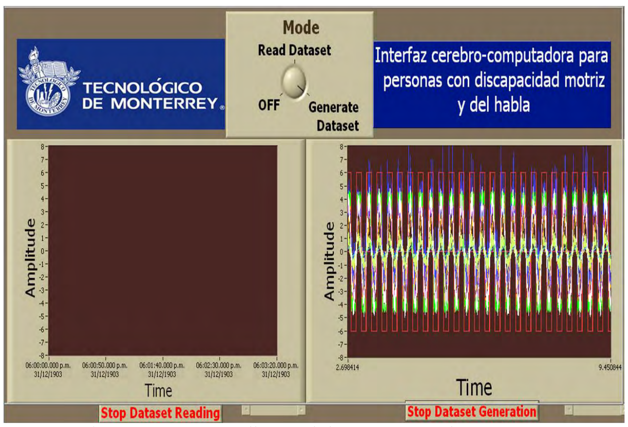

Fig. 1.- Dataset reading and dataset generation screens.

Another capability of EEGLAB is channel location association, i.e. this software is able to associate certain signal to a channel using the international 10-20 convention [2].

In order to make this association it is necessary to have another file that contains a scalp map that is all the channel locations that are or will be used, this can be done considering commercial devices that already contain predetermined channel locations; EEGLAB contains a default channel location file.

Each channel location file may vary depending on which kind of commercial amplifier is used, EEGLAB is also able to import these files and if there are no files available this tool provides the chance to specify the electrode locations [2].

There is no channel association feature for the program developed in LabView since the channel locations are well known and they are manually assigned and also the EEG amplifier that it is used is not commercial i.e. a self-made amplifier and filtering device is being used.

It is possible to plot each signal in the time domain, channel by channel. This allows the user to get familiarized with the signal form and to understand the behavior of such signal in the time domain, in figure 1 a time domain plot is shown.

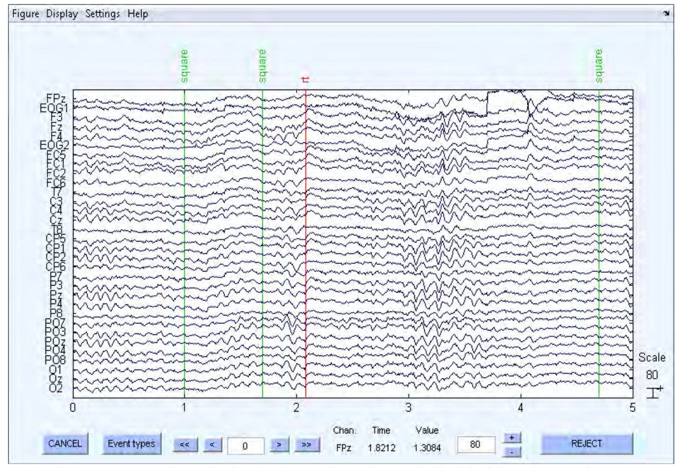

Fig. 2.- EEG signal plot in time domain and divided by channel [1].

Based on this feature the developers of the LabView software implemented a real time signal plotting capability. As seen in figure 1 each signal is displayed in time and arranged by channel, a similar plot was designed to show in time domain all the signals that are being recorded. Since the channel locations are well known and as mentioned before they are manually assigned this plots are shown in a GUI that indicates which channel is being seen, in figure 2 appears this GUI.

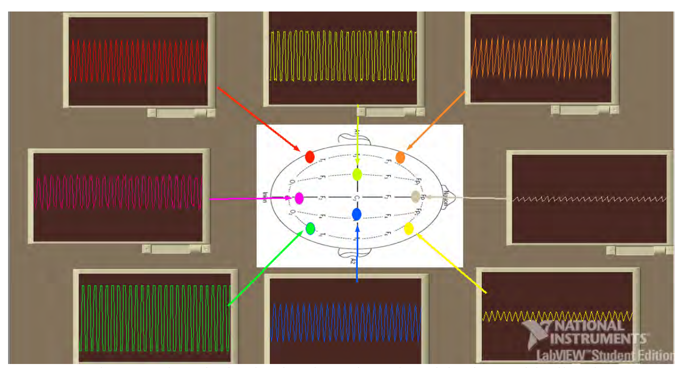

Fig. 3.- Signal plot in the time domain with channel indication.

In EEGLAB when a dataset is loaded to the software is possible to plot the data. Visualization options go from time domain plots to frequency domain plots and they can be displayed all together or channel by channel. Also, this program allows plotting the data considering topographic distribution of the signals and signal intensity just as showed in Fig. 4.

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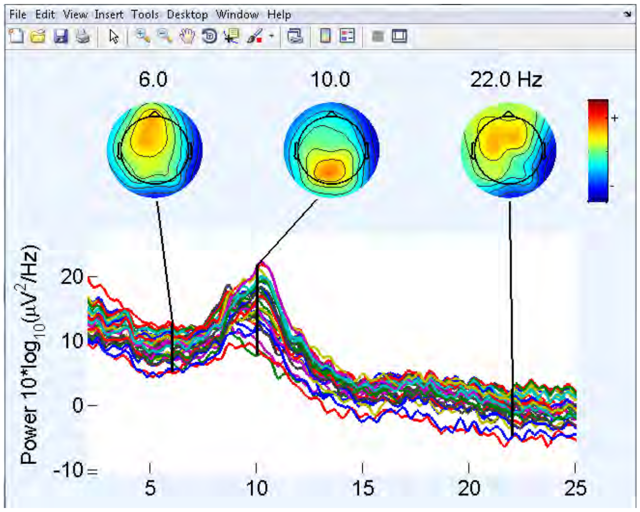

Fig. 4.- Intensity and Signal spectra plot.

With this kind of information the user can be able to know at which frequency the signal behaves or in which part of the brain the signal is stronger, this is important in certain applications such as spellers.

Plots with topographic distributions can be generated in 2 o 3 dimensions. In contrast to EEGLAB, the software under development in LabView is able to plot frequency responses and topographic intensities in different windows.

A 3D model with the 10-20 channel locations assigned is used for showing signal intensities. In figure 3 an image showing the frequency graph and the head model can be seen.

The way this works, is sampling and measuring the amplitude of brain signals and mapping them into a 3d model, where different color set combinations can be configured; for example: an amplitude of 0 volts is painted with purple and an amplitude of N volts if painted with red.

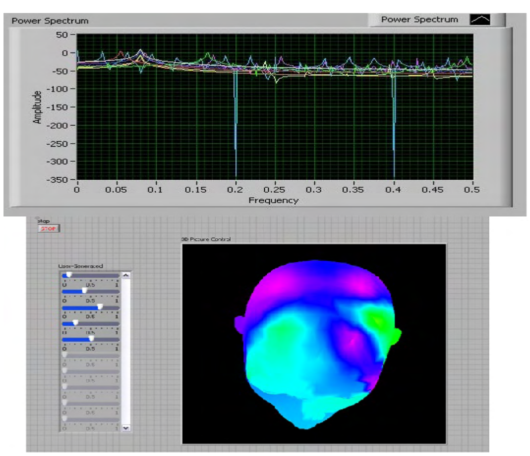

Fig. 5.- Frequency signal graph and 3D head model with intensities.

EEGLAB is a useful tool when working with BCI's because it allows the user to divide the dataset in epochs. Dividing a dataset in epochs lowers the amount of memory required for the dataset because it allows selecting only those parts which are important for analysis.

In order to achieve epoch separation successfully is important to relate the epoch with the target stimuli. The correct relation is achieved by manually configuring the event stimulus with its latency.

It is known that when processing EEG signals is important to repeat the stimulus several times if a reliable signal is needed [2] [4]. That's why datasets are able to save several signals of the same event.

Just like epoch extracting, it is possible to select desired events and extract them for later comparison, i. e. when selecting an event it is only being clustered together with other events of the same type.

With this new group of events each event can be extracted from its group in order to compare them among other events, in other words extracting an event isolates it from that group which allows comparison with other extracted events.

EEGLAB is capable of comparing 2 or more signals by averaging them and displaying their variance and standard deviation. This operation provides a clearer form of an ERP3 given certain stimulus. A plot of averaged ERP's is shown in figure 6; this type of plot is generated per channel.

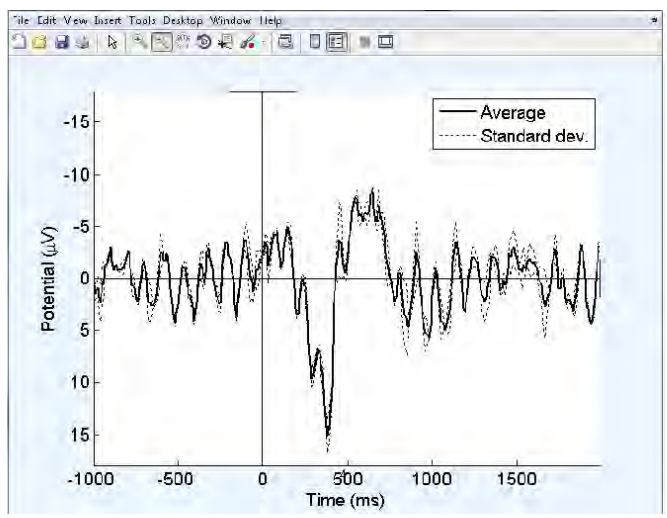

Fig. 6.- ERP average and standard deviation plot.

A similar approach was taken when developing the LabView software, signal averaging is possible with this software, unlike EEGLAB this LabView program has a control that allows the user to decide the amount of trials that will be averaged.

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It is important to mention that EEGLAB has de capability of letting the user to decide the amount of signals to be averaged but the difference between EEGLAB and the LabView program is that the last one has a control that affects the signal averaging automatically; such control can be seen in Fig. 7.

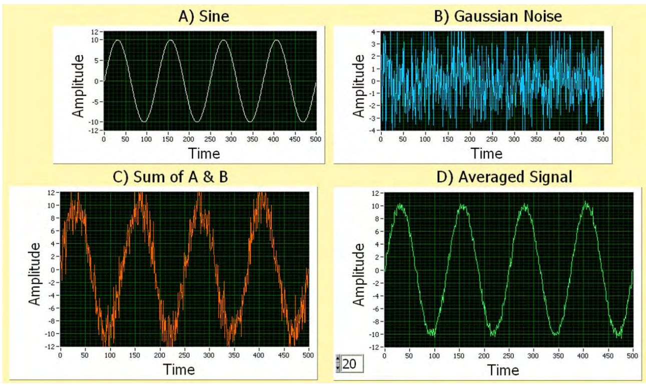

Fig. 7.- Signal averaging control.

This program is planned to be used with a P300 speller also under development by the authors of this text therefore it also contains a letter matrix used for patient stimulation.

The program has the capability of flashing the rows and columns of this matrix during certain time amounts configurable by the user. In figure 8 this matrix can be seen.

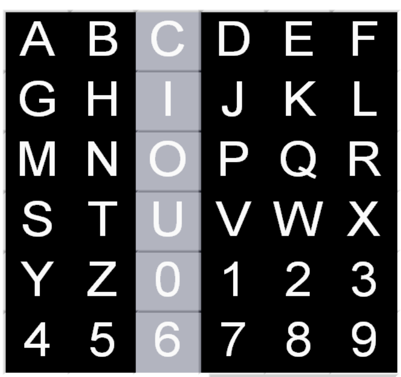

Fig. 8. – Matrix used for patient stimulation.

IV. Conclusion

EEGLAB is a program that provides an accessible solution to the EEG signal processing problem, its free distribution and great service variety allows inexperienced users to be able to acquire some knowledge experimenting with EEGLAB.

In BCI development is necessary to be able to visualize brain signals in one way or another. EEGLAB provides visualization, analysis and processing for those signals. EEGLAB can be used both by experienced users and new users from the electrophysiological field. Its flexibility allows experienced users to develop their own functions and use them in the program.

In case of BCI development EEGLAB works as a useful tool for signal visualization and signal analysis, its user friendly menu and different plotting capabilities are useful for BCI designers.

For the authors of this text it worked as a starting point for EEG signal processing comprehension. The wide variety of plots that EEGLAB is capable of displaying allowed a better understanding of the impact of some algorithms used in BCI.

It also worked as a reference point for the development of a program designed in LabView. The reason LabView was selected as a designing platform is that is easy to program since is a graphical environment, unlike EEGLAB LabView has the capability of recording signals directly from a DAQ. An advantage of reading signals from a DAQ is that greater portability can be achieved if fewer programs for signal recording and processing are used. This program is under development and there are some missing capabilities required such as ICA analysis and component graphing.

EEGLAB has the capabilities for ICA processing, component separation and component elimination. For these reasons EEGLAB can be used as a potential solution for those students or professionals who wish to learn or perform EEG signal analysis and processing.

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