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BioSigPlot : An opensource tool for the visualization of multi-channel biomedical signals with Matlab

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Abstract— **This paper presents a Matlab-based software (MathWorks inc.) called BioSigPlot for the visualization of multi-channel biomedical signals, particularly for the EEG. This tool is designed for researchers on both engineering and medicine who have to collaborate to visualize and analyze signals. It aims to provide a highly customizable interface for signal processing experimentation in order to plot several kinds of signals while integrating the common tools for physician. The main advantages compared to other existing programs are the multi-dataset displaying, the synchronization with video and the online processing. On top of that, this program uses object oriented programming, so that the interface can be controlled by both graphic controls and command lines. It can be used as EEGlab plug-in but, since it is not limited to EEG, it would be distributed separately. BioSigPlot is distributed free of charge (http://biosigplot.sourceforge.net), under the terms of GNU Public License for non-commercial use and open source development.**

I. Introduction

Research on biomedical signal processing is an important area to improve healthcare diagnostic and treatment. It results from the collaboration of physicians who have the knowledge of the human physiology and engineers who have to program new analysis processing. It is important that they both communicate by visualizing efficiently the results of process and correlate them with eventual clinical events. For that, researchers on biomedical signal spend considerable time to customs interfaces for the signals they want to analyze. To simplify this process, we propose a generic and customizable interface to plot all kinds of long duration biomedical signals which is called BioSigPlot.

This project was originally developed to compare various methods of artifact filtering on EEG [1]. We needed an efficient tool to plot and compare raw EEG and filtered EEG for a recording of several hours. We have then decided to extend it to a general tool useful for all our projects. BioSigPlot can now be used to plot most of biomedical signals (eg. electrocardiography (ECG), electroencephalography (EEG), electromyography (EMG), the fetal heart rate (FHR), various biological measure etc.).

BioSigPlot is a free and open source project hosted by sourceforge (http://biosigplot.sourceforge.net), which means that it is subjected to continuous development by an increasing number of researchers. There is a limited amount of open source tool for biomedical signals particularly for other signals than EEG [2] and ECG [3]. BioSig [4] is a rich library for biomedical signal analysis with tools developed for Matlab and other language. For EEG, there is also EEGlab [5] [6], a most widely used Matlab application and library for EEG signal processing. BioSigPlot aims to propose an alternative to their signal plotting functions which would be more convenient for physician interpretation and more controllable and customizable by programmers.

Here is below the list of main features added by BioSigPlot:

- Plotting biomedical signals with the commonly used disposition (for now, particularly EEG, and FHR);
- Viewing multiple datasets of the same duration simultaneously on different modes;
- Scrolling and auto-scrolling over the time;
- Exporting to PDF for possible printing;
- Standard signal preprocessing (set montage and data prefiltering);
- Viewing video synchronously with signals (On 32bit Matlab Version);
- Plotting and Browsing event marks;
- Both graphics and command line controls.

This paper first presents the general concepts used to create this program and then the program specifications are described.

II. General concepts

A. Conception

BioSigPlot aims to give a friendly-user interface, in order that various physicians can analyze signals in the same way as they do with the softwares provided by the devices manufactuers.

For this purpose, some specific classes can be created for each kind of signal which requires specific disposition and/or tools. For now, there are two specilalized classes: one is BioSigPlotEEG for EEG (Fig. 1), and the other is BioSigPlotFHR for FHR (Fig. 2)

Those two classes inherit from the main class BioSigPlot which can display any kind of signal even if the disposition may have some small differences compared to specific manufacturer softwares.

The Fig. 3 shows the simplified UML class diagram of this project. The classes VideoWindow, EventWindow and ConfigWindow are three windows which can interact with the main window as explained on Secs II.D and II.E.

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Fig. 1. Example of visualization of EEG with BioSigPlotEEG with video synchronization and event window

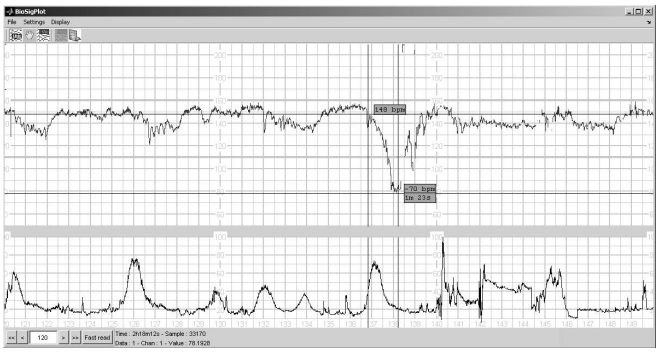


Fig. 2. Example of visualization of FHR with BioSigPlotFHR.

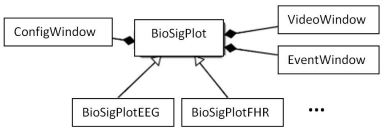


Fig. 3. UML diagram of BioSigPlot project.

B. Multi-dataset

As BioSigPlot aims to help researcher to visualize the results of various possible signal processing, it is useful to be able to plot several datasets at the same time, one containing the original signal, and the other containing the result of the signal processing.

BioSigPlot has integrated this general feature which eases the plot in various situations. It has to be noticed that all the datasets must have the same duration and sampling rate, but it's not compulsory that they have the same channels. If the channels are the same, the datasets are called ChanLink. The behavior of the program is then slightly different: the modification of the properties of one dataset modify also those properties of other datasets.

Here are some examples of visualization of multi-channel signal features:

1) EEG channels and ICA sources;
2) EEG before and after filtering (ChanLink) (Fig. 4);
3) EEG channels and indices computed on each period of time of each channel (ChanLink);
4) 1 to 9 realisation of ERPs (ChanLink);
5) EEG, ECG or other signals like BCI stimulation;
6) X and Y (and Z) signals for posturography;
7) Various signals which are monitored in reanimation.

Depending on the problem, there is the choice to plot them on various modes (Fig. 4):

- Superimposed (Fig. 4(a)): Each dataset is on different colors one in front of the others;
- Alternated (Fig. 4(b)): For each channel, the various datasets are plotted one after others;
- Horizontal (Fig. 4(c)): Each Dataset is plotted on horizontally positionned axes;
- Vertical (Fig. 4(d)): Each Dataset is plotted on vertically positionned axes;
- Single: Only one dataset is plotted at a time and it is possible to switch.

C. Processing inside the current window

One of the BioSigPlot concepts is that the preprocessing of data is done directly in the current Window. Consequently, you don't have to wait a preprocessing of all the data before viewing them, and you can test the different pre-process parameters without restarting the program.

The two preprocessing features for now are filtering (high pass, low pass and Stop band) and montages (e.g. raw, mean reference, longitudinal, transverse). The filtering is common on each dataset but the montages can be different depending on the dataset.

Two kinds of filters can be set :

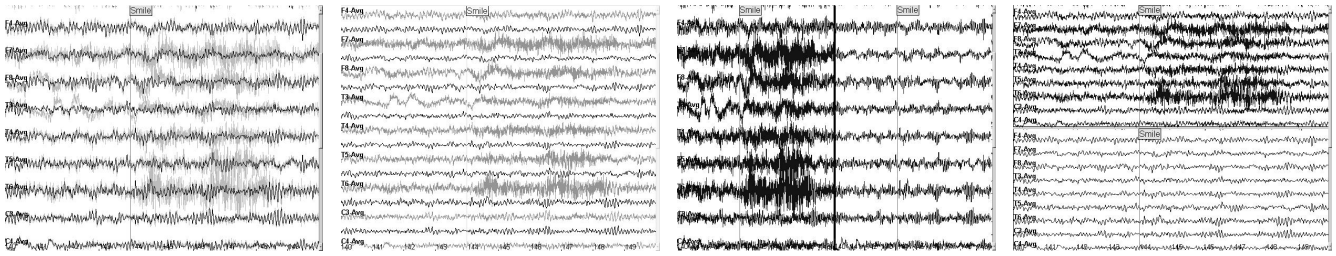
- 1st order Butterworth filter (2nd for band-stop), it's often this type of filter which is implemented on reading Software of manufacturer devices;
- 4th order Butterworth Filter (8th for band-stop) with forward-backward process (better filters). The forward-backward filter function 'filtfilt', implemented in Matlab has been redeveloped by the authors on C++. It is now four time faster, thus making the navigation fluent.

D. BioSigPlot control and communication between windows

The programming of BioSigPlot as a class enables researcher to control it from other programs. All the actions which are done graphically can be done with command line by setting one or several properties (see sec. III.C).

On top of that, when a property is modified, an event notification is sent and can be listened. For example, it is possible to define two instances of BioSigPlot object with different data but when an action is carried out in the first instance, it is also carried out on the second instance.

This kind of communication is used to synchronize the BioSigPlot window with video or events. When the event window is opened and an event is clicked, BioSigPlot goes directly to the time of the Event. Furthermore, when the video window is opened, a video cursor is plotted in the BioSigPlot window and when scrolling on the time of BioSigPlot, the video time is also changed.



(a) Superimposed mode (b) Alternated mode (c) Horizontal mode (d) Vertical mode

Fig. 4. The Mutli-dataset view modes

A function has also been developed to manually select continued or discontinued period of time on the recording. The selected period can then be accessed by the "Selection" property. It can be useful, for example, to select a training period for algorithm or you want to save some period of interrest on a database.

E. Configuration files and command observer

To help knowing the effect of a property, BioSigPlot proposes a command observer to see the various commands the interface has done. This feature is a kind of macro recorder like in Word or Excel. Consequently, it is not required to read the help carefully to understand what kind of argument must be put on keys.

On top of that, due to the variety of signals that can be plotted with this interface, there is a possibility to record various default parameter set for each type of signals. Those default parameters are stored on a CFG file which can be open with the constructor or with 'set' methods. There is also the ConfigWindow which enable to edit the properties, load/save CFG File, and import/export the properties to the current BioSigPlot window.

F. EEGlab integration

BioSigPlot is a generic tool to plot all biomedical signals, but one of the main applications is EEG signals. This project does not aim to open or save data files and to do a process on the entire recording (e.g. compute the ICA on the entire recording). In this purpose, there is the EEGlab project [5] [6] which is perfectly suited for that. EEGLab permits easily to add new plug-in, and consequently BioSigPlot can be launched from EEGlab. Then, it permits to plot both the EEG and the ICA sources in the same window and it adds some new features compared to the original 'eegplot' function of EEGLab even if some of the functions are not yet developed.

G. Professional tools

In order to enable physician and engineers to analyze signals efficiently, several features have been developed on top of the previously cited:

- The auto time scroll which is very useful to examine very long duration recordings;
- Zoom on some specific channels;
- Possibility to show grid to better see the time unit;
- Possibility to change the scales of signals;
- Possibility to change signal colors;
- Possibility to view the signal on full screen by plotting the channels names and the time inside the graph, or to put them outside in order to not hide the signal;
- A line measurer which show the synchronization of signals and their value at a given time;
- The possibility to export as PDF for eventual printing;
- A complete Help and a "How to Start" video.

H. Future evolution

BioSigPlot is still in development and some new features may appears soon. This is the list of the main features which will be developed on priority :

- Reading directly from the file avoiding to load the entire recording into memory;
- Create separate classes for axes and figures which will give more flexibility on the disposition of windows;
- Synchronization with time-frequency image of a one channel (e.g. O1 and use it navigate through time);
- Fourier Spectra on selection of a channel and a time period;
- Preparing specialized interface for other biomedical signals (particularly ECG);
- Copying and editing the plotted figures (for word, latex, etc.).

Obviously, there will be other improvements according to the needs of future users.

III. Program specification

A. System requirements

BioSigPlot has been tested on Matlab R2009b and on Matlab R2012b (32bits and 64bits versions) on OS windows XP and 7. There is only the VideoLan VLC ActiveX which does not work on 64 bits version. Noted that it is still possible to install 32bits version on Windows 64bits. Looking at the most recent function it is required, it can be supposed that this program works from version R2008a. The program should work on Mac and Linux but some source files must be re-compiled and the video will not work.

B. Installation procedure, and how to start

The only thing to do to install BioSigPlot, is to unzip the package and set the current directory of Matlab on the BioSigPlot folder. On Matlab R2012b, you just have to click on the application file.

There is then a HowToStart video which shows the main features of BioSigPlot and there are data samples (Raw EEG and filtered EEG with AFOP method [1]) which can be loaded and plotted by launching 'biosigdemo'.

To use it as EEGLab plug-in, it must be unzipped on the subfolder 'plugins' of EEGLab and then it is possible to use the demonstration data of EEGLab.

C. Syntax

This is precisely the permitted syntax. The list of keys is described on next section.

- You can set some properties directly with the constructor: >> a=biosigplot(DATA, 'key1', value1 ...);
- Then, to modify properties :
  >>a.key1=value1
  OR >>set(a,'key1',value1,'key2',value2,...) (Faster if there are more than one key)
- And to get property values :
  >>val=a.key1
  OR >>val=get('key1',value1)
- The modification of key is allowed
  >>a.key1(i)=val
  >>a.key1.subkey=val)
- You can receive a notification when each key is modified:
  >>listener=addlistener(a,'key1','PostSet',@Callback)

The system of classes in Matlab has changed and consequently the two kinds of class still exists on Matlab. There are advantages on both systems. The old one, used for graphic classes (figure, axes, ...), use "get" and "set" functions to access properties and thus, it is possible to set several properties at the same time and call only one 'redraw' at the end when all properties are set. The other advantage is that you can set the properties directly with the constructor of the class. The new one used '.' (dot) syntax and has the advantage to simplify the notation, permit modification of properties (and not only replacement), and notify with event when a property is set. The BioSigPlot class uses an original coding which is based on the new system and adds the possibilities of the old one.

The table I gives the most important keys that can be "get" and "set". The complete list and syntax is given by typing 'help biosigplot' in Command Window or in a help documentation.

TABLE I
LIST OF PROPERTIES

Properties	Description
ChanLink	true if all dataset have the same channels
ChanNames	Cell with channel names corresponding to raw data
Config	Default config file. Contains all default states values
NormalModeColors	Colors for views Horizontal, Vertical, or single
AlternatedModeColors	Colors for alternated view
SuperimposedModeColors	Colors for superimposed view
DataView	View mode for Multi datasets
DispChans	Number of channels to display on each dataset
FirstDispChans	First channel to display for each data set (used for channel scrolling)
Evts	List of events
Montage	Path for a system file which contains info on Montage or structure with those informations
MontageRef	Montage number
ReadSpeedTime	The time between pages during fast reading
SRate	Sampling rate
Selection	Begining and end times of the selected period
Spacing	Spacing between 2 channels (in Y-unit)
Time	Current time (in TimeUnit) of the current
Video	File path of the video
VideoTime	Time for video cursor
WinLength	Time length of windows (in Time Unit)

IV. CONCLUSION

Biosigplot is a tool which tends to be both user-friendly and permissive in order to save time for analysis of biomedical signals and processing results. It has been tested by specialists on EEG and FHR for study on several hours of recordings (e.g. [1]). They have found this program useful and very convenient to realise their interpretations.

The fact that it is developed on Matlab will allow a great community of researchers to use it. Matlab enables users to program some experiment fastly and BioSigPlot enables them to easily visualize the results. A limitation however could be for real time processing since Matlab is not always optimized. For this purpose, it is often better to use C/C++.

We will try to devolop on future version the standard tools used for other biomedical signals than EEG and FHR (e.g. ECG). We think however it would be mostly useful for long duration signals which require time scrolling. BioSigPlot will aim to stay simple and to keep specialising in the displaying. It should not relase global signal processing. We let this latter to over project like EEGLab and BioSig and we do the interface between those projects and BioSigPlot. We hope encouraging, the development of such library into Open Source thus accelerating the research on those fields.

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