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LivBioSig: Development of a Toolbox for Online Bio-Signals processing and experimentation.

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Abstract— **Various research fields, such as brain computer interface, requires online acquisition and analysis of biological data to validate assumptions or to help obtaining insights into the physiological processes of the human body. In this paper we introduce the LivBioSig toolbox for online bio-signals processing and experimentation. This open source and modularized MATLAB toolbox allows performing various experiment paradigms involving online signal processing. These currently include synchronous and asynchronous BCI experiments, and event related stimulation experiments. The use of Graphic User Interfaces (GUI) makes the system suitable even for beginner Matlab users, and the experiments easily configurable. The modularized structure allows advanced users to develop the toolbox further to adapt it to the needs of the research fields.**

Index Terms—**Toolbox, Online, Signal processing, BCI.**

I. Introduction

Bio-Signals, such as Electromyographic (EMG) or Electroencephalographic (EEG) signals are extensively used in both research and clinical applications [1]. They provide information to monitor the activities in the human body, and to assist in gaining insights into the physiological processes underlying the bio-signals. Thanks to this information, various studies [2, 3] analyze the impact of some external factor (e.g. electrical stimulation, visual feedback, etc.) on the human body mechanisms (e.g. training, rehabilitation, etc.).

One field of great interest in the past decades is brain-computer interface (BCI), sometimes called a direct neural interface or a brain-machine interface (BMI). It consists of a direct communication between a brain and an external device, such as computer. BCI's are often aimed at assessing, augmenting or repairing human cognitive or sensory-motor function [4]. BCI experiments can be carried in two modes: synchronous or asynchronous (also called self-paced). Each mode is application specific. The majority of BCI experiments work with synchronous paradigms. However, such paradigm is an unnatural and discomforting mode of interaction for most typical applications. In contrast, in asynchronous BCI, the user intends a specific mental activity whenever he/she wishes to. Studies performed in asynchronous target the ultimate goal of BCI systems, which is to allow the user to have interaction with his/her external environment just through mental activities

In order to perform such type of research activities, an online recording and processing system is necessary. This system must be flexible enough to allow different experiment protocols. It can be achieved by using a modularized design.

Various programing languages exist to program such a toolbox, amongst them, C++ (BCI 2000 [5]), LABVIEW, or MATLAB. However, the modularized approach requires modification on the system to adapt it to various experiments. Thus, the language selected for programing must be as widely used as possible in the biomedical engineering field. It should also provide a nice balance between the execution efficiency and the ability for fast-prototyping. For these reasons, we selected MATLAB (The Mathworks, Inc., Natick, MA, USA) as the development platform for LivBioSig.

The focus of the present paper is to introduce the LivBioSig toolbox and its potential, not to describe any specific protocol or analysis method. In the following, we describe the main features of the toolbox which was initially developed for BCI experiments.

II. Methods

LivBioSig is a MATLAB open source toolbox for online bio-signal processing and experiments.

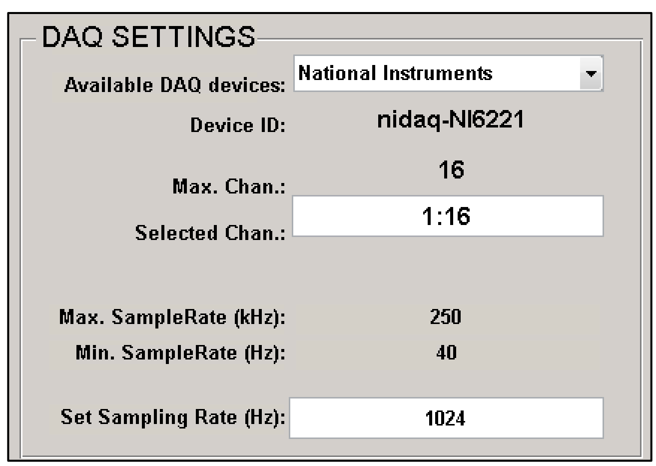

Fig.1: The settings section of the analog module GUI. This interface allows defining the general settings of the analog acquisition operated by the acquisition toolbox of MATLAB

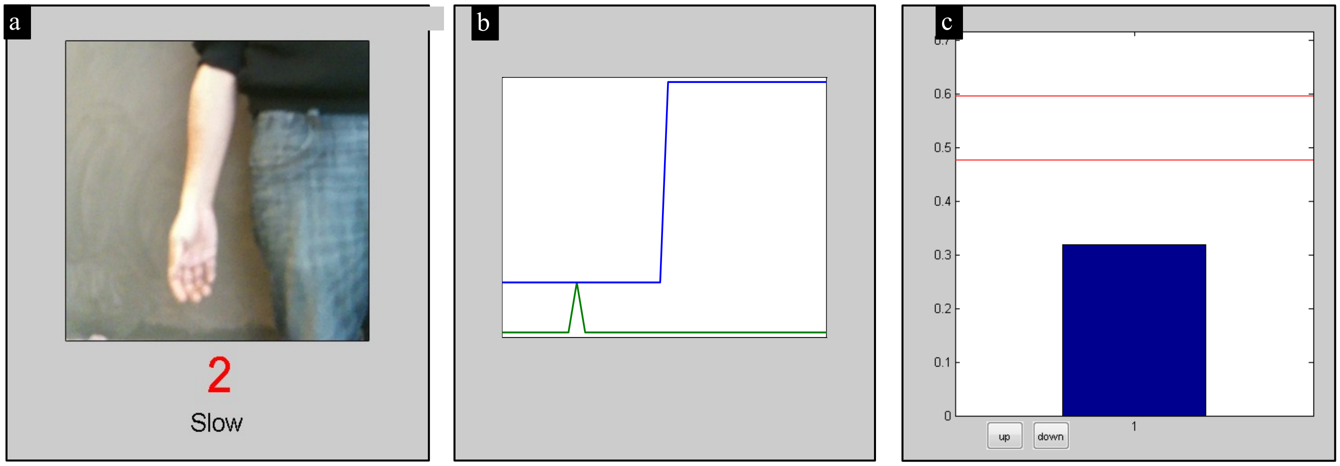

Fig.2: Three example of subject display GUI, from left to right: (a) analog feedback bar with target selection, (b) synchronous BCI instructions with countdown, (c) cue display for synchronous BCI experiment with stimulation

It was designed as a modularized program to perform BCI experiments with various protocols, but can also be used for any kind of bio-signal recordings by creating the experiment specific module.

The modularized structure is divided in two main groups, the resource modules, and the experiment specific modules.

A. Resource modules

The resource modules are meant to be used during the development of experiment modules. They manage all the functions required by multiple protocol programs, such as acquisition, processing, or feedback display.

The following list describes the currently available resource modules. This list will evolve as new environments and requirements appear.

1) Analog module (Fig.1): This module provides a GUI to manage the settings of the acquisition toolbox of Matlab. These settings include analog input and output systems (e.g. source selection, channel selection, sample rate…). It allows saving these settings into a configuration file in order facilitating experimentation in multiple sessions and days.

2) Neuroscan module: This module provides the interface using Tcp-IP with the neuroscan software (Acquire v.4.5). It allows using the data recorded with NuAmps amplifiers for online BCI experiments.

3) Subject Display module (Fig.2): This module manages the display to the subject during the experiments. As BCI experiments are sensitive to external perturbations, the display presented to the subject has to be carefully prepared. Thus, this module regroups all the information to be displayed (on a separated screen) to the subject. It mainly consists of a GUI with various components to be accessed and updated during the experiment according to the protocol (i.e. Text and pictured instructions, visual feedback, etc.).

4) Processing module: This module includes various widely used bio-signals algorithm, particularly oriented for online processing. This processing module is based on two steps. First, all the processing parameters are determined offline and a series of function handles are generated for online processing. Then, online, these function handles are called to process the data, minimizing the computation time. The processing algorithms currently available are divided in 3 steps: pre-processing, feature extraction, post-processing. The pre-processing step includes usual algorithms such as frequency filtering and spatial filtering (linear combination, i.e. Principal component analysis (PCA) [6], Common spatial pattern (CSP) [7], etc.). The feature extraction step provides characterization functions, often used for feedback or classification of bio-signals, such as slow cortical potentials and ERD/ERS. This includes Fast Fourier Transform [8], Time Domain coefficients [9], Autoregressive coefficients [6], Discrete Wavelet Transform (DWT) coefficients [10] and DWT marginals [11]. The last step, post-processing, allows the outcome to be suitable for online systems, by providing comparison and classification algorithms, such as matched filter [12], linear discriminant analysis [6] and support vector machines [13]. The processing module was also developed as a modular program, making the addition of new algorithms very fast and intuitive.

B. Experiment modules

The experiment module is the core of the software related to a specific experiment design. An experiment module consists of an ensemble of functions and GUIs which are designed to manage an online experiment. Two elements are mandatory in the design of an experiment module: the graphic user interface for the experimenter, and the online callback function. The toolbox includes guidelines and models to facilitate the development of new experiment modules as well as a default visualization module. As the toolbox was first designed for BCI experiments, the three existing experiment modules are related to different BCI experiment design:

- Visualization module: This module provides an online display of the recorded signals in both time and frequency domain, with channel selection. The elements of the visualization module are displayed in Fig.3. They consist of the plot as well as the display parameters (Freq. controls,

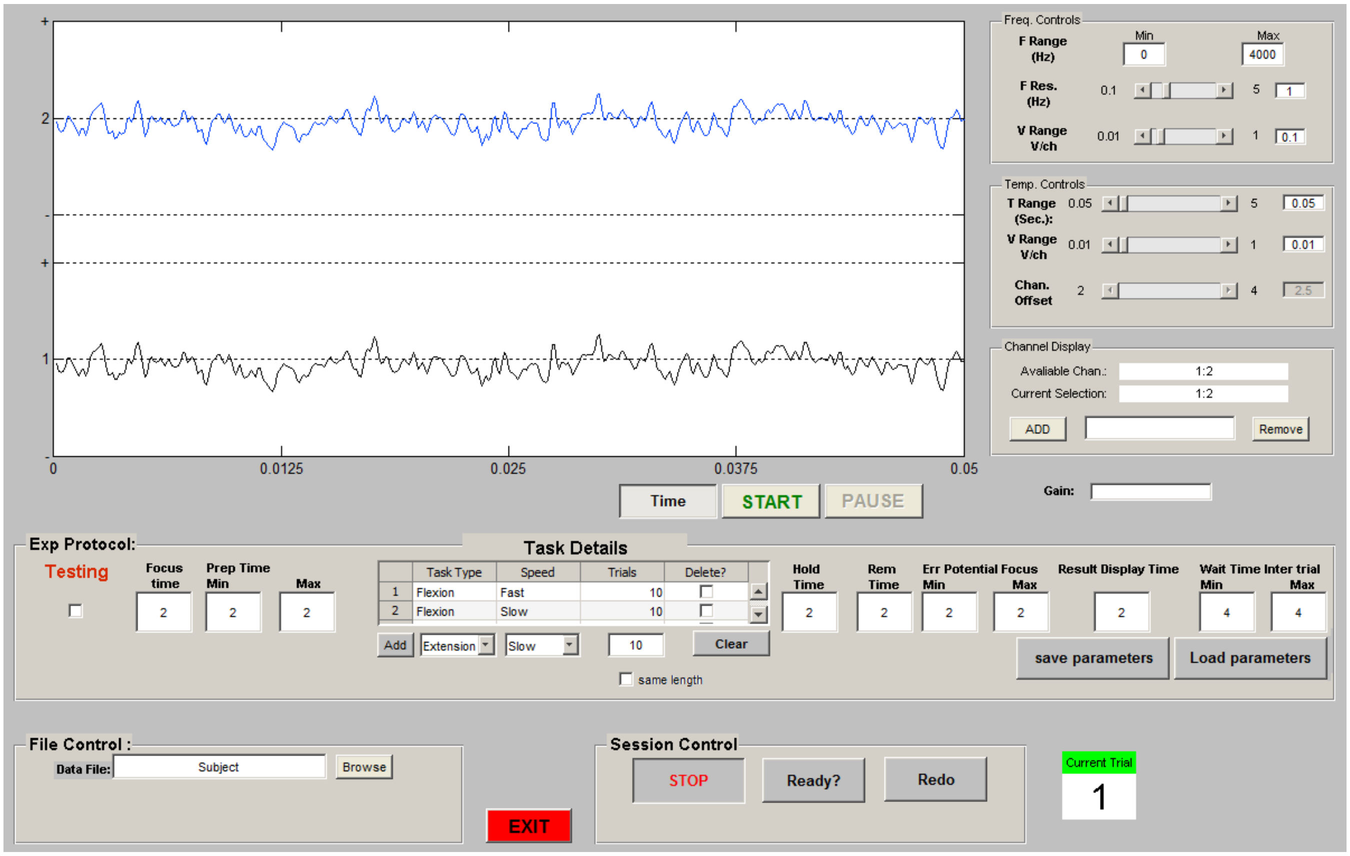

Fig. 3: GUI for experimenter from the Synchronous BCI module.

Temp. controls, channel display). It allows in addition saving in a file selected portions of the recorded data displayed.

- Synchronous BCI module: This module was developed to perform synchronous BCI experiment involving both voluntary potentials, and evoked potentials. Various experiments can be conducted using this module, including BCI classification with online feedback, as well as Error Potential recordings. This interface can be used in bothalgorithm training and testing condition, and allows to adapt all the characteristics of the experiment (i.e. focus time, preparation time, etc.) in order to optimize the protocol for each study. Fig.3 shows the experimenter's GUI of the module and Fig.2a a show one example of subject display interface. The graphic controls of the experimenter interface are divided in two main sections: the experiment parameters which have to be defined prior to the experiment (Exp. Protocol and File control), and the display options (Freq. controls, Temp. controls, channel display) which determines, in real time, the displayed elements on the experimenter's screen. The data recorded are saved in files for further offline processing, trial by trial in order to minimize memory usage

- Event Synchronized Stimulation module: The event synchronized module uses a similar interface as the synchronous BCI module but provides a simplified display to the subject (Fig.2b). In addition, it offers an option to trigger an external element (e.g. peripheral electrical stimulation) at any selected time during the experiment. This module can be used beyond the BCI field as an synchronized human machine interface, such as EMG driven Functional electrical stimulation (FES)

- Asynchronous BCI module: The asynchronous module was built for self-paced BCI experiments, where subjects determine themselves when they want to perform a task. The experimenter's GUI displays simultaneously the targeted muscle activity and the EEG. In addition, it provides the controls to manage the session as well as the parameters for the online processing and feedback. The subject display of the asynchronous BCI is very simple and only shows a feedback bar (Fig.2c), related to the output of the online processing of EEG and/or EMG. In addition, the module provides an option to trigger an external element whenever a task is detected in EEG.

III. Discussion

We have introduced the LivBioSig toolbox for online bio-signals experimentation using MATLAB. The proprietary software MATLAB was used for the development of this open-source toolbox as it is an accessible, yet powerful and widely used programing language for research and signal processing. The GUI based experiment modules makes it usable for beginner MATLAB users Its modulatory structure, guidelines, and resource modules allow advanced users to develop it further according to the evolution of the needs in the research fields.

The online display of the recorded signals is a major requirement for online experiments. It allows the experimenter to identify instrumentation errors and to optimize the signals during the experiment. In the LivBioSig toolbox, the visualization module is a part of the guideline for experiment module programing, as it fulfills this need of online display of the recorded signals.

The separate GUIs for subject and experimenter prevent the subject from modifying the response signal due to the online display. In addition, the subject display as resource module in the toolbox allows controlling very precisely the focus of the subject during the experiment, minimizing the data variability in BCI recordings.

Finally, the online oriented signal processing module provides the experimenter the online tools for experiment requiring feedback, such as Error potentials [14].

These features give the LivBioSig toolbox the potential to be used in various research fields involving bio-signal processing and experiments.

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