EOGSTUDIO
A Software Platform for Processing Electrooculography Recordings

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Abstract: Analysis of saccadic eye movements is a fundamental task for the study of different neurological disorders. The Center of Research and Rehabilitation of Hereditary Ataxias (CIRAH) located in Holguín, Cuba; uses this technique in order to study the evolution of many different ataxias. Nevertheless, current available software applications do not fill the requirements needed by the CIRAH's staff to complete their processing protocol, as they do not run in modern operating systems or are poorly usable. EogStudio was created with the objective of filling the gap left by these applications. It is signal processing platform based on extensible plugins that meet the requirements made by CIRAH's researchers. For the processing and determination of the significative points of the saccadic eye movements, soft computing techniques, such as independent component analysis, were applied.

1 INTRODUCTION

The study of eye movements has been proved to be a useful tool to diagnose and evaluate the patient condition in many neurological disorders. In particular, saccadic tests for clinical proposals are usually applied in researches related to several diseases, like ataxia, Parkinson, schizophrenia, amongst many others (Jones and DeJong, 1971); (Rivaud-Pechoux et al., 1998); (Schulze et al., 2006).

Available embedded software in dedicated equipment that records and analyzes eye movements, behaves as a 'black box', since manufacturers do not usually give information related to the algorithms and mathematical methods involved in the computing of variables concerning the evaluation of the eye movements. Furthermore, these systems in general terms lack of the necessary extensibility, and very often the reports do not accomplish the researchers' requirements.

In this work, a software developed in the University of Holguin, in Cuba, named EogStudio, is described, together with its algorithms for saccade detection and characterization.

All the experiments were carried out by the medical staff of CIRAH. Each patient was placed in a chair, with a head fixation device to avoid head movements, the variables were collected by a two channel electronystagmograph (Otoscreen, Jaeger-Toennies, D-97204 Höchberg, Germany). Recording conditions were set as follows: electrodes of silver chloride placed in the external borders of right eye (active electrode) and left eye (reference electrode), high pass filtering 0.002 Hz, low pass filtering 20 Hz, sensitivity 200 μV/division, and sampling frequency 200 Hz. For stimulus generation a black screen CRT display showing a white circular target with an angular size of 0.7º was used. The stimulus and patient response data are automatically stored in ASCII files by Otoscreen electronystagmograph.

This software reads the saccadic records from the files generated by the electronystagmograph and computes a set of significant variables, in order to study neurological disorders. A main goal of the developers of this software was the potential for extension and upgrading adapting to researchers' requirements. This goals was achieved through the use of a plugin-based architecture model.

The software is intended for ataxia SCA-2 computer-aided diagnosis. SCA-2 is a disease that

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presents the international highest levels of prevalence in Holguín, Cuba, where the Center of Research and Rehabilitation of Hereditary Ataxias (CIRAH for its Spanish acronym) is entirely dedicated to study and treat this disease (García Bermúdez, 2007, Velázquez-Pérez, 2001).

Medical staff of CIRAH contributed in the process of selecting the variables to be studied, collecting patient records and validating tests to the software. CIRAH has been also the main user of the software, which has been used in this centre in the last two years.

2 DESIGN

Although there is some available software for performing some of the tasks for which EogStudio is intended, these programs are generally old and very specific for the machine where they get the data from. For instance, the equipment used at CIRAH to make EOG recordings is the Otoscreen electronystagmograph, which provides its own software designed to run on machines with MS-Windows 95 operating system. This software makes very difficult to do certain tasks like saccadic point editing and its usability is poor when running in modern operating systems.

More modern software packages like EyeLink Matlab Toolbox (Cornelissen and Peters, 2002) or ILab (Gitelman, 2002) depends on other frameworks like Matlab and are focused in a very specialized audience.

The main intention of EogStudio is providing medical staff with less computing background with a tool were they are capable to manage and edit data from EOG recordings as if they were using an office suite application like Writer, Calc or MS-Word. Thereby, the development team focuses in creating a desktop application that helps users to detect saccades automatically and to make corrections on these data in a fast and easy way.

Other non-functional but not less important requirements was that the software application must be fast and run in all major platforms nowadays like MS-Windows, Mac OS X and GNU/Linux. For this requirement, the use of Qt Toolkit Libraries and the C++ programming language was necessary.

EogStudio was created to be extensible through plugins in order to support various file formats, reports and processing algorithms. Its structure is based on several libraries and plugins which separate and organize the functionalities. Figure 1 illustrates the overall system design.

3 WORKFLOW

EogStudio is centered in studies, where a study is the document where all signals data and events are stored.

The workflow steps to use EogStudio are straightforward, and they can be split in the four following steps:

1. Create a study from an existing recording like Otoscreen CSV files.

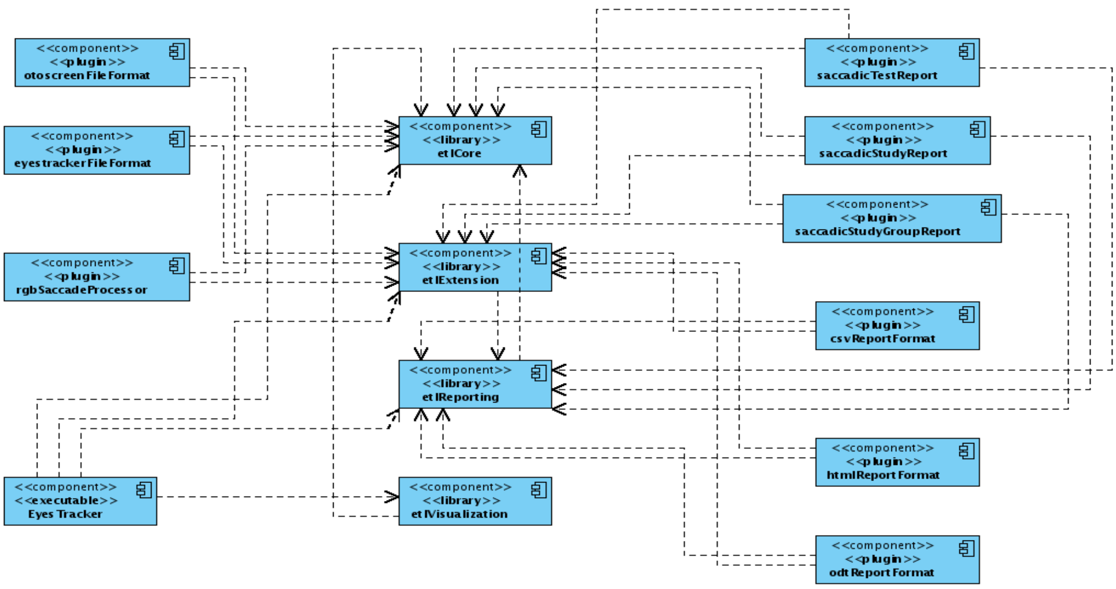

Figure 1: EogStudio components design and dependencies.

2. Detect saccades using the automatic saccade detector.
3. Correct saccadic points using the saccadic editor.
4. Report study saccadic results for further analysis.

The first step consists of creating an study starting from a recording file from Otoscreen or other supported equipment. In the application, this stage comprises a wizard that guides the user through the process. After this, the study will be opened and the application will show the saccade editor for the first test.

The second step of this process allows us to get an initial approximation of the saccades present in the study. A detection algorithm proposed by (García Bermúdez, 2007) was used to fulfill this task.

The algorithm for saccade detection works as follows:

1. Locate the stimulus transition points.
2. Find the middle point of each saccade.
3. Determine the start and end point of each saccade.

The algorithm uses local polynomials to adjust the saccade start and end points according to Equation 1.

$$T_{Start} = T_{MiddlePoint} - \frac{T_{MaxSac}}{2}$$
$$T_{End} = T_{MiddlePoint} + \frac{T_{MaxSac}}{2} \qquad (1)$$

Where T_{Start} and T_{End} are the saccade start and end points, respectively; and T_{MaxSac} is the maximum duration of a saccade.

Once we have the first approximation of saccadic points, we proceed to fix the saccades whose points were not set well in the signal using a simple visual editor provided in the application with facilities for adding, removing and editing saccadic points (Figure 2).

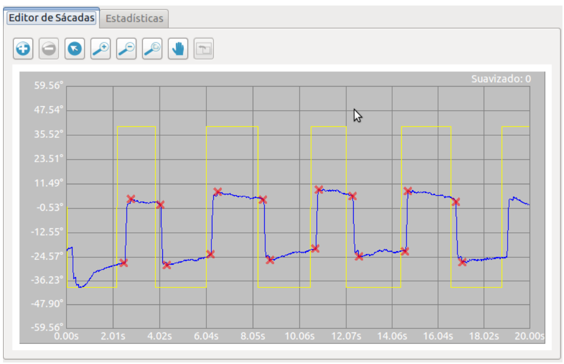

Figure 2: Saccades editor.

Once all saccades were corrected, study reports can be generated to different formats like: tabulated text (csv), Hypertext Markup Language (html) and Open Document Format (odf). This report contains all relevant data that the medical team may use for their studies.

4 APPLICATION EXTENSION THROUGH PLUGINS

Nowadays, software applications must include an easy extension mechanism in order to simplify the task of adding new functionalities. As it was shown in the design section, EogStudio was built using a plug-in based architecture, which facilitates the previously mentioned task.

This architecture enables independency between the application author and third parties developers. The application provides four types of plugins (Figure 3):

- *File Format Plugins:* This module allows the support of new type of equipment and storage formats.
- *Report Format Plugins:* It provides a simple interface which supports new report presentation formats.
- *Report Plugins:* It brings the possibility of creating new reports and not only the default formats provided by the application.
- *Processing Plugins:* It gives the chance to implement new processing algorithms, for instance detect other ocular events and not only saccades.

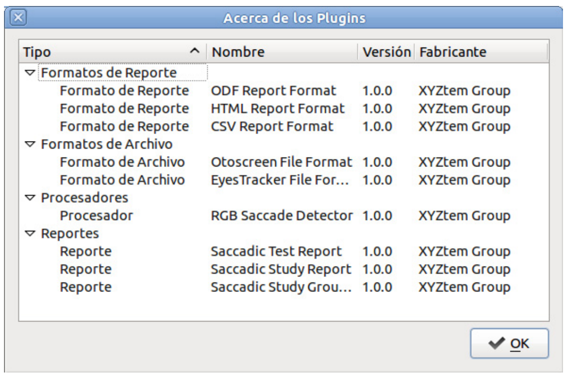

Figure 3: Installed plugins dialog window.

It is planned to release a Software Development Kit (SDK) which facilitates the work of developers who wants to extend the application. This kit would consist of a set of well documented libraries used in the development of EogStudio, and a set of plugins for QtCreator, which it is the integrated development environment (IDE) that was used to create the application.

5 CONCLUSIONS

EogStudy has already been used at CIRAH for more than one year, processing hundreds of records of sick and control subjects in several drug clinical experiments performed during this period. It was also used in order to follow the evolution of many patients.

This tool was conceived having in mind the current status of neurophysiology, in relation with characterization and evaluation of saccadic eye movements, and it was adapted to fit CIRAH's requirements.

EogStudio answered the expectations and needs of CIRAH's researchers and it also can be used in other medical institutions with similar needs due to its plugin-based architecture model which facilitates the extension and adaptation of the application.

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