Automatic recording and processing of saccadic electrooculograms

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This work presents the development of a technology that processes human eye movement records in a fully automatic way. Since it is part of a collaboration with the Center for Rehabilitation and Research of Hereditary Ataxias (CIRAH) of Cuba, we focus on records of subjects suffering Spinocerebellar Ataxia type 2 (SCA2). The SCA2 is a neurodegenerative disease which has a very high prevalence in Cuba.

Our research has two complementary objectives: (i) design a fully automatic method to extract the relevant medical data from saccadic eye movement recordings; (ii) design and testing a low-cost device to record eye movements for clinical purposes.

To accomplish the first goal, we have defined a processing pipeline (Fig 1) which comprises the following blocks: filtering, differentiation, segmentation and biomarkers extraction.

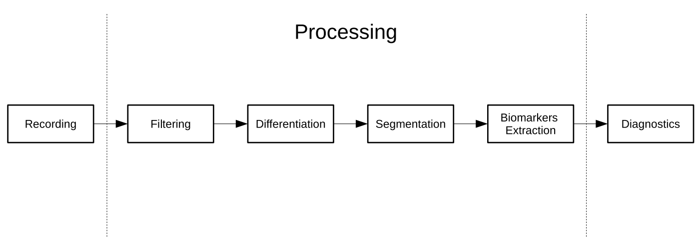

Fig. 1. Electrooculogram processing pipeline

For each one of these blocks, we have analyzed the current methodology employed and obtained a set of methods and algorithms that fit best for our kind of signals. For **Filtering** we have used median filters, which are mostly recommended in the literature on saccadic signals. Numerical **Differentiation** is used to obtain the velocity profile of the saccadic signals; we have evaluated 16 methods, selecting the Lanczos with 11 points as the best fit for this task [1]. **Segmentation** is the operation where we identify induced saccades (those provoked by the stimulus). First, we separate all saccades (induced and spontaneous) from the rest of spurious events present in the signal by using both Multilayer Perceptron and Random Forest [2] with similar results. Second, we separate induced saccades from spontaneous ones. For this specific task we also evaluate four supervised machine learning techniques: Support Vector Machines (SVM), K-Nearest Neighbors (KNN), Classification and Regression Trees (CART) and Naive Bayes. Among these, we recommends to use CART because its high performance and explainability [3]. Induced saccades are clinically useful because they follow a visual stimulus that allows us to calculate biomarkers which are not computable from spontaneous saccades. Thus, **Biomarker Extraction** is finally carried out obtaining the following relevant clinical biomarkers: peak velocity, latency, duration, amplitude.

To fulfill the second goal, we present the development of a low-cost equipment that uses electrooculography to record eye movements. The hardware part of this equipment is based on the OpenBCI Cyton board, but with our own custom firmware that we named *OpenEOG*. To record and visualize the signals obtained by the *OpenEOG* we developed our own software. In order to use it in clinical environments, this software includes a visual stimulator that allows us to record saccadic eye movements in a controlled way. The system was tested by analyzing the data recorded to 10 healthy volunteers and comparing them against data from professional equipment and results in literature [4].

Our work shows how a fully automatic method can extract the saccadic information required by professional medical doctors to help them study neurological diseases such as SCA2. Also, we have shown that implementing a low-cost eye movement recording system is possible.

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