Development of a Biosignals Framework for Usability Analysis

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ABSTRACT
The understanding of human physical and physiological signals and expressions, together with a growing processing and control capacity allows for new approaches in interactive systems design. In this poster, we introduce constitutive elements and steps towards the integration of EEG (Electroencephalography) signals in a system to analyze reading activities.

The poster presents system design choices that include the software architecture and the feature extraction and classification techniques used in the first prototypes.

Categories and Subject Descriptors
H.5.2 [Information Interfaces and Presentation]: User Interfaces – user centered design, evaluation/methodology.

General Terms
Design, Experimentation, Human Factors.

Keywords
EEG signals, Usability Analysis

1 INTRODUCTION
Neurophysiological signals have become an important, and a usable source of information. The recent research field of neuroergonomics relates the disciplines of neurosciences and ergonomics, and studies the behavior of the brain in the context of the usage of real world artifacts and situations, i.e. the brain at work [6]. The integration of this discipline with system design has an impact on the methods for usability analysis [6].

The effectiveness of a usability study may benefit from the consideration of the human physiological signals. [1][2]. The paper describes the experience in the integration of electroencephalography (EEG) signals in a preliminary usability analysis setting. The goal is to design experiments dealing with the analysis of “reading” situations and this poster focuses on the required system architecture and feature extraction solutions.

2 SYSTEM ARCHITECTURE
Our EEG-based applications are built upon a software framework (EEGLib) that encapsulates the critical issues of EEG processing.

The EEGLib components extract relevant features from EEG data and can be reused in different applications. The object model includes components for EEG data modeling and tools for EEG data processing. The core concepts are: EEGFrame represents a frame data, a numerical matrix with rows for samples and columns for electrodes. Each frame is synchronized with a time server. EEGStream models a time continuous stream of frames, and EEGOperator abstracts the EEG processing operations in frames and streams, and encapsulates feature extraction and classification. Each concept is represented by a (C++) class and integrated in a systematic hierarchy. All the processing operations are based on a MatLab Engine [5].

EEGLib includes tools that can be classified in the following categories: (a) Basic operations (Electrode, Sample and Windowing); (b) Feature extraction; and (c) Classification operations to categorize a feature vector. EEGLib currently exploits the following recognition algorithms, based in MatLab neural network and SPRTOOL [4] toolboxes: (1) Multi-layer perceptrons, (2) Bayesian classifiers, (3) Linear classifiers, (4) K-Nearest-Neighbors, (5) K-Means, (6) Support Vector Machines, and (7) Expectation-Maximization.

The software framework provides the building blocks to program EEG-based applications and to compose the right (feature extraction * feature classification). The experiences use a simple 16-channel EEG device, (MindSet-1000) represented below in Figure 1 (10-20 International System).

Figure 1. 16-channel EEG device electrode map
3 EXPERIENCE AND RESULTS

Some very simple tools built with EEGLib were applied in test experiments related with specific aspects of user interaction, with a restricted number of subjects. The understanding and observation of the “reading” task was the goal at this stage.

3.1 Reading or Not Reading

The initial experiments on “reading detection” were based in the presentation of alternate blank and text screens containing a few lines of news text. The text was never repeated was presented in such a way that no particular visual effort was required.

Features vectors were based on the mean PSD (Power Spectral Density) in $\alpha$, $\beta$, $\theta$, and $\delta$ rhythms obtained in the 16-channel signal. A full vector is therefore composed of 64 individual 16-bit samples (1kHz). The feature vectors were reduced using PCA or a minimal variance (Var) threshold. This threshold eliminates features without changing the original signal. The thresholds of both preprocessing methods were tuned for several classification tools based on the average error rate in 100 trials. In each trial, the training and test sets were randomly selected from the reading and non-reading sets.

Figure 2 shows the best average results obtained. As the figure shows, K-nn, AdaBoost with MV preprocessing and SVM with PCA achieved precision and recall rates above 90%.

![Figure 2. READING : Best average results with PCA and MV preprocessing](image)

After selection of different bands and electrodes, theoretically more correlated with the reading task, the results were refined and re-obtained and showed better quality.

The selection of the best (band * channel) combination requires further test and integration of previous results which provide initial filtering options for the reading status information. Reading tasks, as demonstrated in [3] activate different brain areas (hemispheres for example), rhythms and also include a spectrum of tasks like visual, orthographic, phonetic and semantic).

4 DISCUSSION

This experience shows that EEG-based systems for usability are feasible. A number of issues require further discussion.

The tests mentioned above were made with a very limited number of subjects (2-3), so results cannot be generalized. The focus has been the development and optimization of the framework. Ideally, a significant number of tests and samples should produce a robust identification of the channel*band thresholds associated with a given cognitive process (i.e. reading). We know however that variance is to be expected due to task constraints, user differences or brain plasticity.

The effective exploitation use of biosignals such as EEG requires the capacity for real time processing. The simplest devices are usually isolated and generate sample files to be processed off-line. In the experiments, real time processing requires direct access to the device bus connections.

Our results provide a positive hint that EEG signals can be of use in evaluating usability. In particular, the results of the reading state detection open a door to the study of legibility via EEG processing, provided that appropriate experiments are designed. The next step will be to exploit these tools in the analysis of known factors that influence legibility (such as font size, font or background color). An important goal is to objectively confirm some usability rules and heuristics.

A further development of the application of this framework is the extension towards multimodality evaluation [8], an area of advanced interfaces that requires innovative evaluation techniques, and is closely coupled with the management of the awareness and attention mechanisms.

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6 REFERENCES