Software platform for managing the classification of error-related potentials of observers

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Abstract. Human learning is partly based on observation. Electroencephalographic recordings of subjects who perform acts (actors) or observe actors (observers), contain a negative waveform in the Evoked Potentials (EPs) of the actors that commit errors and of observers who observe the error-committing actors. This waveform is called the Error-Related Negativity (ERN). Its detection has applications in the context of Brain-Computer Interfaces. The present work describes a software system developed for managing EPs of observers, with the aim of classifying them into observations of either correct or incorrect actions. It consists of an integrated platform for the storage, management, processing and classification of EPs recorded during error-observation experiments. The system was developed using C# and the following development tools and frameworks: MySQL, .NET Framework, Entity Framework and Emgu CV, for interfacing with the machine learning library of OpenCV. Up to six features can be computed per EP recording per electrode. The user can select among various feature selection algorithms and then proceed to train one of three types of classifiers: Artificial Neural Networks, Support Vector Machines, k-nearest neighbour. Next the classifier can be used for classifying any EP curve that has been inputted to the database.

1. Introduction

A significant part of human learning takes place through observation. Studies in observational learning suggest that the mechanisms through which observation contributes to learning are similar to the mechanisms contributing to learning through self-action. A significant role in such mechanisms is error processing, an aspect of performance monitoring necessary for detecting errors, as fast as possible, and for optimizing future response behavior. Previous research has shown that, when errors are committed, a negative deflection appears in electroencephalographic Evoked Potentials (EPs), the Error-Related Negativity (ERN) [1]. Such a deflection has also been recorded when persons observed other committing errors or observed the performance of an external agent, in the context of Brain-Computer Interfaces (BCIs).

There are several software platforms for acquisition and processing continuous and event-related EEG, such as the EEGLab [2]. These platforms can be used for general purpose tasks, but they do not provide tools for the classification of EPs. This paper presents the development of a dedicated, integrated software system for the classification of EPs of subjects who observe the execution of

correct or incorrect responses of other people or agents. The system comprise data collection, feature extraction and classification sub-systems.

2. System Architecture

The proposed system is an integrated platform for the storage, management, processing and classification of the EPs recorded during error-observation experiments. The system is comprised of the data acquisition sub-system, the feature extraction sub-system and the classification sub-system.
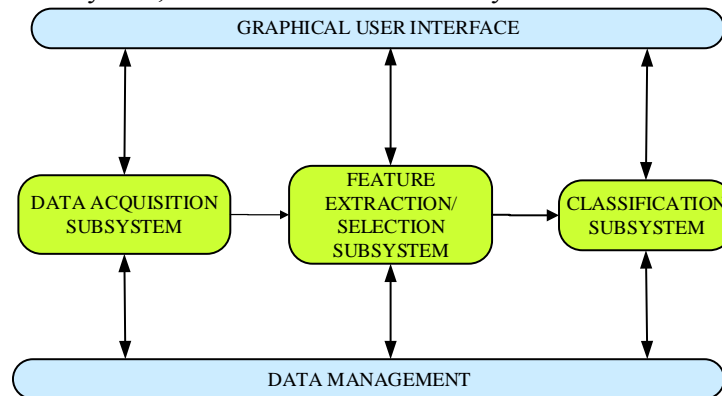

Figure 1. Architecture of the proposed system.

The data acquisition subsystem allows the acquisition of EPs from people who observe correct or incorrect actions of other subjects. The data are incorporated into a database along with various supporting data (demographics, date of recording, comments etc.).

The feature extraction/selection sub-system is responsible for the selection of features that are used for the description of EP recordings. Due to the relatively large amount of data obtained from EP recordings in modern electroencephalography (several tens of electrodes per person), appropriate signal processing techniques are available in the system for extraction and selection of a reduced set of quantitative indicators (features) to form a full description of the original data. Three methods for selecting features have been incorporated in the system: the Sequential Forward Search (SFS), the Sequential Backward Search (SBS) and the Sequential Floating Forward Search (SFFS) [3].

The classification subsystem categorizes vectors of features in one of the two categories of interest (observation of correct action and observation of incorrect actions). This subsystem can be regarded as implementing a function of many variables (classification function). The variables of this function are the components of each feature vector and the value of the function is the category of the feature vector. The classification system implements the k-Nearest Neighbor, the Support Vector Machine and the Artificial Neural Network techniques [3].

The system supports three different categories of users:
- simple users: psychologists or others without further technical knowledge who want to simply use the system to classify EP
- engineers: researchers with technical knowledge in signal processing and analysis, who have access to more advanced aspects of the system, such as feature selection and training of classifiers
- Administrators: users with full rights and access to each and every potential aspect of the system.

The system was developed using C# and the following development tools and frameworks:
- MySQL: database management system.
- .NET Framework: development platform for building graphical user interface and algorithms of signal processing and analysis using the C# programming language.
- Entity Framework: mapping tool of database tools to C# classes.
- Emgu CV: library machine learning algorithms.

3. Results

The initial screen of the application is shown in Figure 2. It contains two fields of entering the user name and password. A new user can be registered by selecting the link named Register. In this case, a registration form becomes visible (Figure 3). The user fills in the necessary information and submits the form.

Figure 2. Access control form.

Figure 3. Registration form.

The main screen of the application is shown in Figure 4. It includes the following tabs: Data Management, Feature Extraction, Feature Selection, Classification, User Management and Settings. The Data Management tab displays the stored data in hierarchical order. The hierarchy consists of 3 levels. The first level includes subjects, the second level includes sessions and third level includes recordings (Figure 4). The next tab enables the extraction of various features (mean value, standard deviation etc.) from the available recordings (Figure 5). Optionally, smoothing filters (mean or median) and/or detrending can be applied before the feature extraction.
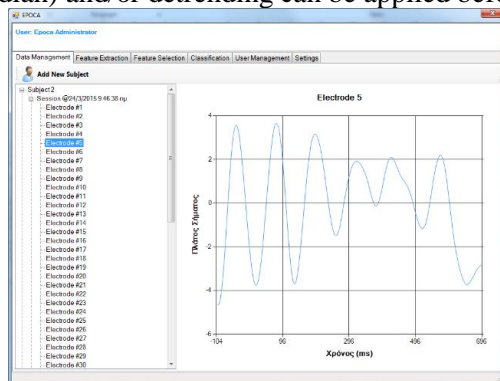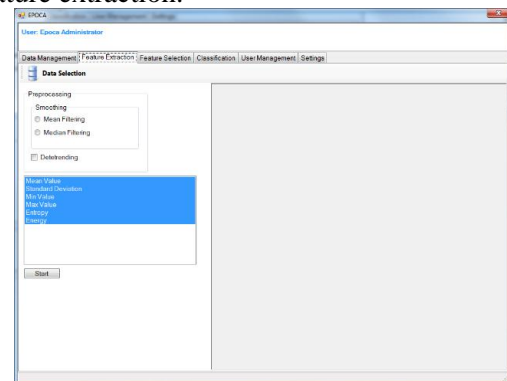

Figure 4. Data management tab.

Figure 5. Feature extraction tab.

The third and fourth tabs include options for feature selection (Figure 6) and classification (Figure 7), respectively. The user management tab displays the registered users and provides reset password, update and delete capabilities (Figure 8). Finally, the last tab provides settings regarding the connection with the database server (Figure 9).

The evaluation of the performance of the classification subsystem has been presented in previous publications of the research team [4], [5].
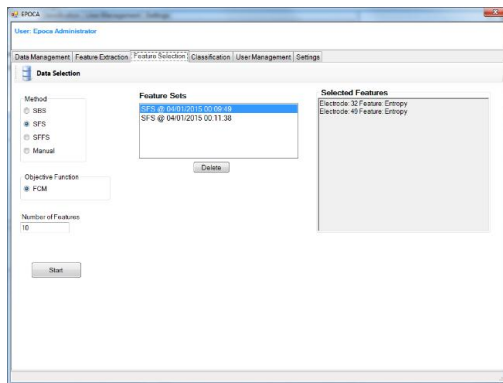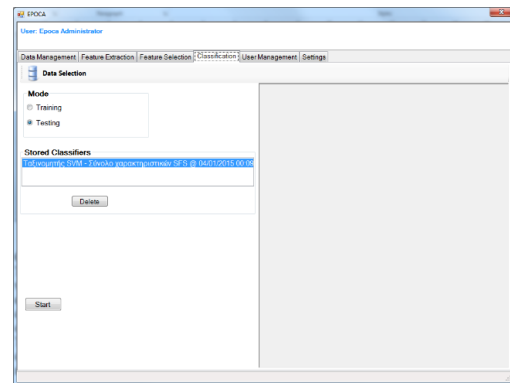
Figure 6. Feature selection tab.
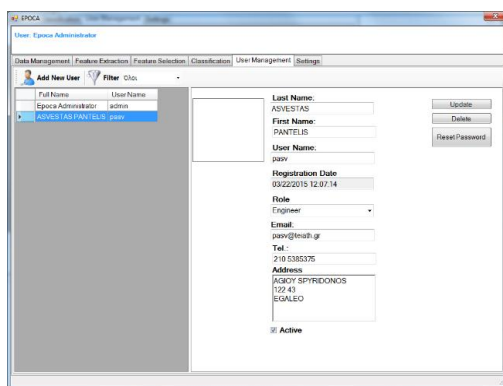

Figure 7.Classification tab.

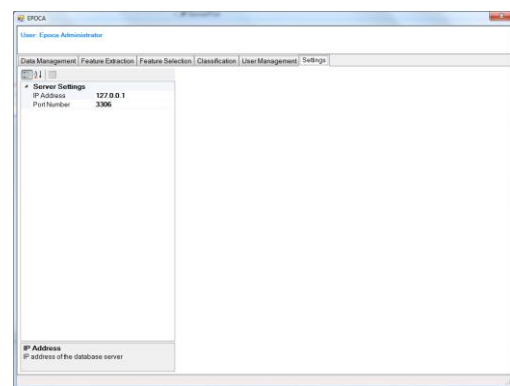**Figure 8**. User management tab.

Figure 9. Settings tab.

Conclusion

Through the use of the proposed system, indications could be provided in real time concerning whether or not an observer, who oversees the actions of another person, perceives the existence of errors in the actions of the supervised person. Indications of critical parameters in display screens could also be the focus of observation, enabling the automatic evaluation of the performance of observers, which is significant for the selection of airplane pilots or operators of critical installations. The system might also contribute to the improvement of BCI performance, by enabling the automatic correction of wrong actions of the BCI, based on the EPs of the person using the BCI. In the future, it might also detect errors in joint actions, either between two persons, or between a person and a robot.

References

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