Implementation of a Brain-Computer Interface Based on Motor Imagery

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Abstract
In this work, a Brain-Computer Interface based on motor imagery was implemented focusing on the signal processing stage. Methods based on machine learning were used along with feature selection techniques on the treatment and classification of data.

Key words:
Brain-Computer Interface, Motor Imagery, Machine learning.

Introduction

A Brain-Computer Interface (BCI) represents an alternative form of communication between the individual and the external environment without using conventional pathways such as speaking, gestures, keyboards etc. Since BCIs do not use the conventional physiological pathways, they can constitute important assistive technologies for people with lesions that compromise their interaction with the external environment [1]. Among the different types of BCIs, this work focuses on the motor imagery (MI) paradigm, in which the user attempts to communicate by thinking of a specific movement of his body. The implementation of an MI-BCI includes neural signal acquisition, feature extraction and classification. This project was especially dedicated to the last two, using the software MATLAB. Therefore, the data used were previously collected by the research group and approved by the UNICAMP Ethics Committee. The objective of the project was the implementation of an MI-BCI using different classification algorithms (e.g. SVMs, neural networks, linear and logistic regression) and feature selection techniques (e.g. wrapper, Pearson correlation coefficients), which allows a comparative analysis of the impacts each method has on the interface.

Results and Discussion

The neural signals were collected by asking the user to imagine the movement of either his left or right hand. These signals were filtered and passed through feature extraction by applying the Welch's method. Subsequently, the resulting characteristic matrix was divided in a training set (70%) and a test set (30%). After that, the classifier was trained using the training set and then applied in both sets. These steps were repeated in 1000 iterations and each one generated and error when compared to the labels. The final results for each classification method are displayed in Chart 1.

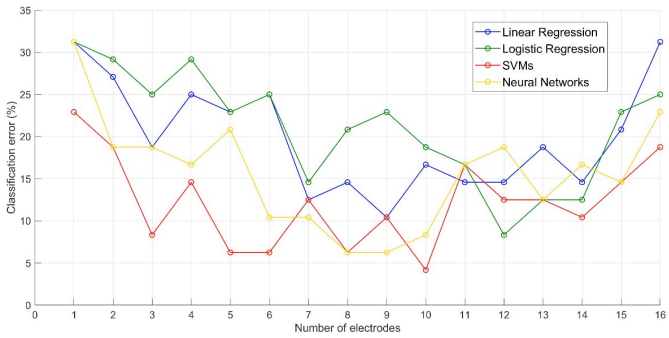
After a quick analysis of the chart, the SVMs seems to be the best option among the classifiers used in the MI-BCI. Furthermore, it can be observed that logistic regression has a slightly better performance than the linear regression in regard to the error obtained in both classifiers. It is valid to notice that the neural networks didn't show desirable results in all iterations due to the limited amount of data available for training the network.

When a variable selection was applied by using a wrapper, the classification results had considerable improvements. In its most general formulation, the wrapper methodology consists in using the prediction performance of a given learning machine to assess the relative usefulness of subsets of variables [2]. In this work, the wrapper was employed in order to select the most useful electrodes to be used in the classification. As shown in the Image 1, the error dropped by 10% to 20% in each classifier for the optimum combination of electrodes.

Chart 1. Classification errors in training and test sets for distinct algorithms

	Training			Test		
	Mean	**Min.**	**Max.**	**Mean**	**Min.**	**Max.**
Linear Regression	5.56%	0.00%	11.61%	24.76%	8.33%	45.83%
Logistic Regression	4.78%	0.00%	10.71%	22.71%	6.25%	37.50%
SVMs	1.69%	0.00%	4.46%	14.42%	0.00%	35.42%
Neural Networks	12.33%	0.00%	59.82%	23.62%	2.08%	54.17%

Image 1. Variation of the classification errors in the test set for distinct quantities of used electrodes



Conclusions

A MI-BCI can be of great use to help people with physical disabilities. However, lot of work is still necessary to achieve the public assistance. In this work, an offline solution for the implementation of a MI-BCI was presented along with several types of data classification. Moreover, the electrodes selection using the wrapper shown some good results and has potential to be object of study of future work.

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