Classification of Fine Hand Movements of The Same Limb Through EEG Signals

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Objetive:

This research presents the performance evaluation of different strategies of classification using Linear Discriminant Analysis (LDA) method and power spectral density (PSD) features for three tasks: make a fist, open the hand, and keep the anatomical position of the hand.

Material & Methods:

The present research evaluates different classifiers based on power spectral density (PSD) characteristics and linear discrimination analysis (LDA) to basically determine two things: first, if it is possible to determine the beginning of a fine movement of the hand, and second if it is possible to discretize between the movements of the hand. This analysis is done on electroencephalography signals acquired from 10 test subjects (4 females and 6 males with an average age of 23).

To collect the EEG signals, an experimental protocol was executed that required an isolated space for visual and sound stimuli. For this protocol, the test subjects that participated in this experiment sat in front of a screen that showed them the path of data collection that allowed acquire information of 90 trails per subject, that is, 30 trails per class. The information given to each test subject was presented in three stages and is described below:

- **fixing cross:** At the start of a test, a fixation cross is placed on the screen indicating to the test subject that they should be aware of the type of movement that has to do after this cross. This visual stimulus is presented for 3 seconds and the subject is asked to try not to blink or make sudden movements while the screen presents this image.
- **Movement image:** After presenting the fixation cross, a visual stimulus is presented for 5 seconds that indicates the movement that must be executed. This image can instruct the test subject to make a fist, extend the hand, or simply do nothing. During this stage of motor execution, the subject is asked to execute the requested movement with the greatest possible force and to hold it until rest advice appears.

- **Rest screen:** The final step in the recording process of a trial is the resting stage that cover lasts 5 seconds. During this stage, an image is presented with the word "descanso" that indicates to the test subjects that they can blink, adjust their position to be more comfortable, and prepare for the next trial that will start with the next fixation cross.

This experiment aims to evaluate the difference in brain activity during the fixation cross attention task, which is the first stage of the instruction given to the test subject, and the different motor tasks (including holding anatomical position) and evaluate de differences between the performed tasks.

Data Collection:

To collect the data analyzed in this research, a high-performance neuroscience research system was used, the g.HIamp by g.Tec. With this device, 32 EEG channels were recorded simultaneously with a sampling frequency of 1200 Hz. for this measurement, a notch filter of 60 Hz is used to avoid electrical artifacts.

Pre-processing:

In the pre-processing stage of this research, the first step is to resample the frequency to 256 Hz, then a band-pass Butterworth filter was applied from 2 to 30 Hz. This frequency range is sufficient for the feature extraction needs that are used to train and test the classifiers. In addition to this bandpass filter, a notch filter was applied to reject the noise that the electrical network could apply to the analyzed signal.

Once these filters were applied, the signals obtained were analyzed with the intention of eliminating noisy data from channels and entire trials that, due to artifacts, movements, or any other situation, generate noise and can generate bad classifications or a malfunction in the implemented classifiers.

feature extraction:

After the preprocessing step, the signal was divided into two 1-second analysis windows. The first data section was the last second of fixation cross time, and the second data window was determined from 0.2 seconds of movement execution time. Once the signals were separated in the analysis windows, the characteristics with which the classifiers were implemented were obtained, although it was expected that the result of this research would show a great influence of the sensorimotor band as the relevant characteristics for the classification of this type of task, the power spectral density (PSD) of the entire frequency band within the bandpass filter implemented in the preprocess step was calculated in the process for both fixation cross and motor execution data. At the end of this stage, an array of features was obtained where each feature is related to the amplitude for each frequency value.

Classification:

For the evaluation of the classification models implemented in this research, two cross-validation methods were used: the first one was done with the intention of analyzing the offline behavior of a classifier. For this, the Monte Carlo method was implemented where 80% of the trials were used to train LDA classifiers and 20% were used to test it. This training and testing process was executed for 1000 times due to the low amount of data.

The other type of analysis carried out in this work was done with the intention of evaluating the possibility of implementing an Online classification system. For this, the leave-one-out cross-validation method was used where all the trials except one are used to train the LDA based classifier and then, the data that was not part of the training process is used to test the behavior of the classifier. This was done until all trials were used as test data.

Results & Discussion:

One of the questions that this research addresses is whether it is possible to implement a human-machine interface based on electroencephalography. The results show that for the offline analysis the start of the movement can be predicted with approximately 78% accuracy and in a pseudo-online analysis with an average of 76%. Regarding the classification between movements, the offline analysis shows an average precision of approximately 46% and in the online analysis of 55%. These results reveal the first topic of discussion in this research. It is about the role that electroencephalography would play in the eventual implementation of a human-machine interface to predict motor execution. As can be seen, the start of movement has a good performance with LDA classifiers and PSD features. however, when determining what type of movement, the subject wants to make, it is necessary to add other types of technologies to implement a hybrid interface that improves system performance.

The other topic that needs to be discussed and perhaps implemented in new methods to clarify in future work is the type of task that is being classified when detecting the start of each one evaluated in this work. On the part of the offline classifier, an accuracy of approximately 76% was obtained to classify each task and evaluating only the task of maintaining the anatomical position of the hand, the result was approximately 77%. On the other hand, when the same things were classified with the pseudo-online strategy, it was obtained that on average 77% and 80% respectively. These results raise doubts as to which is the participation of the motor task and which of the attention task when the intention of the movement is classified through the methodology proposed. In future works, it will be necessary to implement different protocols to verify how it affects the attention task to the results obtained.