CLASSIFICATION OF FINE HAND MOVEMENTS OF THE SAME LIMB THROUGH EEG SIGNALS

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COULD A COMPUTER KNOW WHEN AND HOW YOU WANT TO MOVE YOUR HAND?

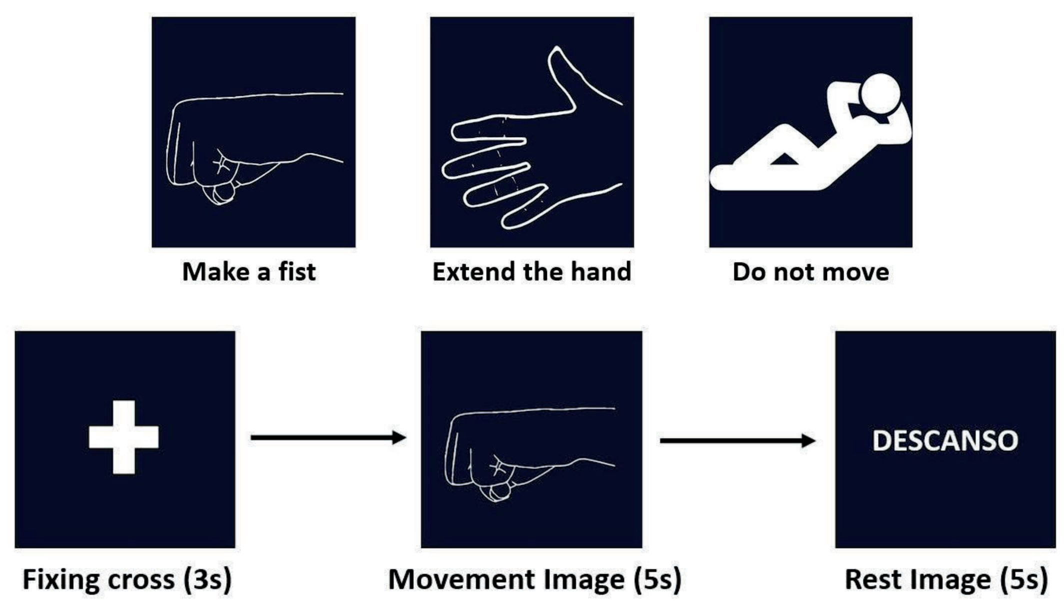
ABSTRACT:

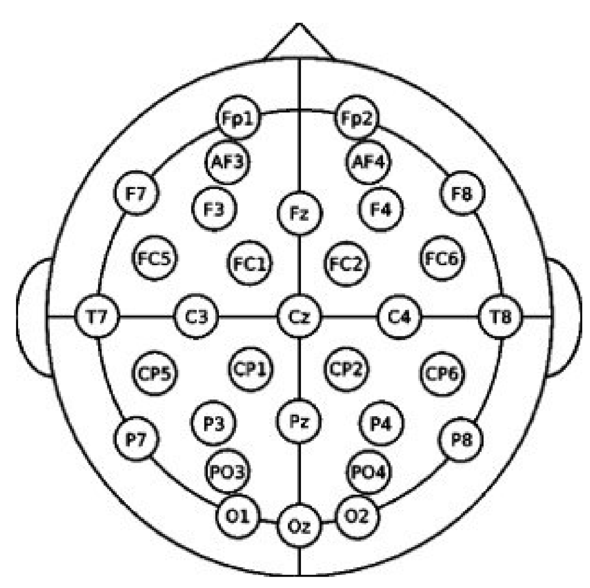
Discriminating fine movements within the same limb using electroencephalography (EEG) signals is a current challenge to non-invasive BCIs systems due to the close spatial representations on the motor cortex area of the brain, the signal-to-noise ratio, and the stochastic nature of this kind of signal. This research presents the performance evaluation of different strategies of classification using the 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. For this, EEG signals were collected from 10 healthy subjects and evaluated with different cross-validation methods: Monte Carlo, to implement an Offline Analysis And Leave-one-out for a pseudo-online implementation. The results show that the average accuracy for classifying the start of each task is approximately 76% for offline and Pseudo-online Analysis, classifying just the start of the movement is 54% and 62% respectively for same both methods and 45% for and 32% for classifying between classes. Based on these results, it can be said that the implementation of a BCI based on PSD features and the LDA method could work to detect the start of one of the proposed tasks but to discriminate the movement it is necessary to implement a different strategy for increase accuracy in the classification problem.

MATERIAL & METHODOLOGY:

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).

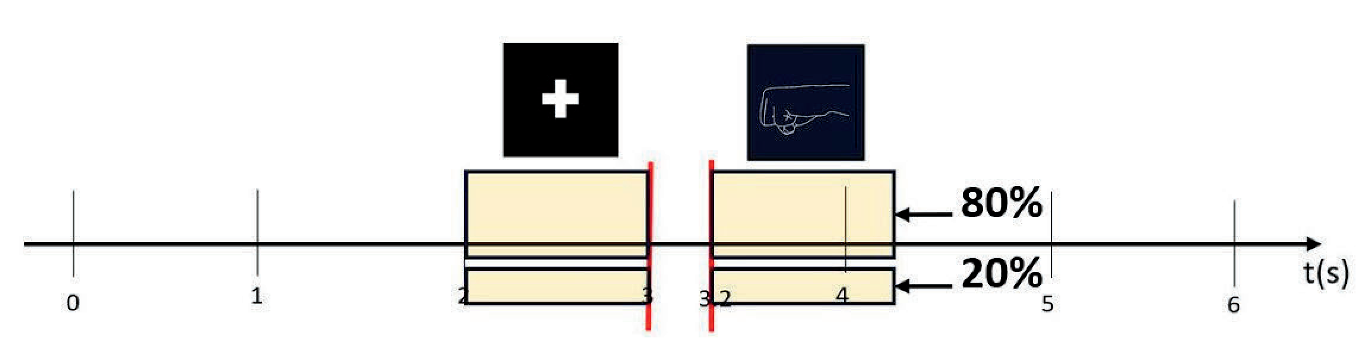
To collect the EEG signals, an experimental protocol was executed that required an isolated space for visual and sound stimuli. For this protocol, the test subjects that participated in this experiment sat in front of a screen that showed them the path of data collection that allowed acquire information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

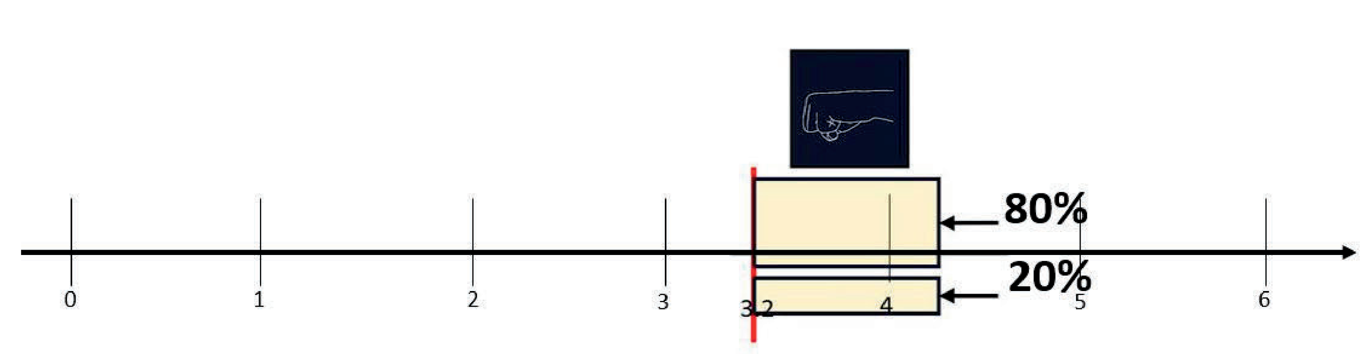




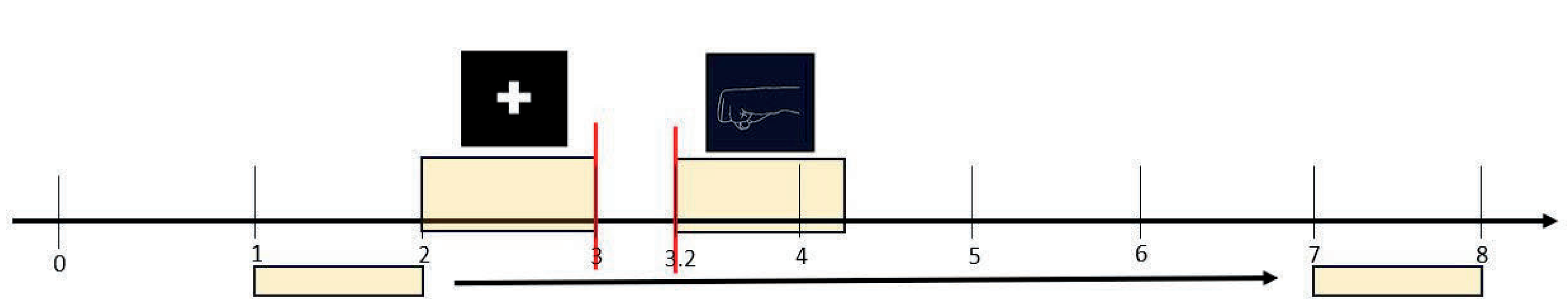
Two analysis scenarios were implemented for this study, the first was an offline analysis to evaluate the theoretical performance of an LDA-based classifier with PSD features. The second scenario allows evaluating the performance of an eventual implementation of an online classifier in which each data set was classified as it arrived at the classification instance. Both scenarios are shown graphically below:

OFFLINE ANALYSIS: MONTE CARLO CROSS-VALIDATION





PSEUDO-ONLINE ANALYSIS: LEAVE-ONE-OUT CROSS-VALIDATION



RESULTS & DISCUSSION:

Offline Analysis

Task	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Make a fist	0.66	0.60	0.74	0.92	0.68	0.82	0.84	0.59	0.80	0.71
Extend the hand	0.64	0.60	0.82	0.94	0.67	0.81	0.73	0.58	0.77	0.77
Do not move	0.87	0.56	0.71	0.87	0.63	0.79	0.81	0.68	0.79	0.81

Table 2: Average accuracy for the classification of each of the tasks

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mean accuracy	0.77	0.61	0.79	0.93	0.62	0.83	0.84	0.61	0.82	0.82

Table 3: Average accuracy for classification of movement start for each of the subjects

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Accuracy of classifier	0.44	0.38	0.48	0.43	0.39	0.53	0.49	0.33	0.59	0.43
Recall for make a fist	0.37	0.40	0.46	0.36	0.36	0.42	0.39	0.32	0.59	0.44
Recall for extend the hand	0.29	0.43	0.45	0.50	0.43	0.47	0.52	0.31	0.58	0.37
Recall for do not move	0.68	0.32	0.56	0.47	0.40	0.72	0.58	0.40	0.62	0.52

Table 4: Average accuracy for classification of movement start for each of the subjects

Pseudo-Online Analysis

Task	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Make a fist	0.75	0.68	0.89	0.87	0.62	0.76	0.89	0.63	0.81	0.67
Extend the hand	0.74	0.66	0.88	0.95	0.63	0.79	0.85	0.73	0.70	0.82
do not move	0.86	0.69	0.76	0.85	0.65	0.83	0.86	0.71	0.91	0.89

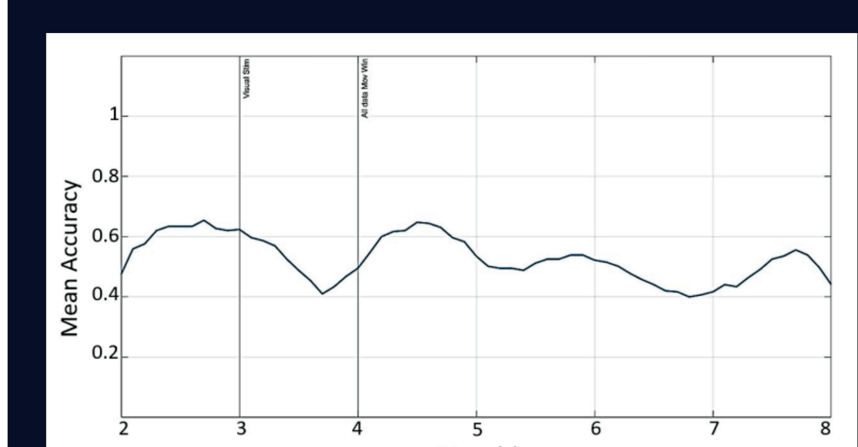
Table 5: Average accuracy for classification of movement start for each of the subjects

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mean Accuracy	0.59	0.54	0.54	0.80	0.49	0.63	0.75	0.53	0.58	0.55

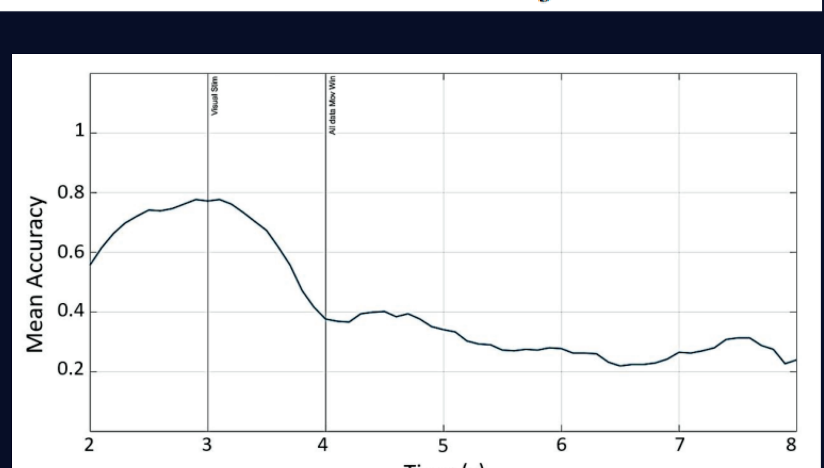
Table 6: Maximum accuracy for classification of movement onset for each subject

	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
Mean Accuracy	0.34	0.25	0.31	0.42	0.25	0.33	0.39	0.25	0.33	0.33

Table 7: Mean accuracy for classification of each task for each subjects



Accuracy curve for Pseudo-online Analysis for movement onset. subject 8



Accuracy curve for Pseudo-online Analysis for classifying each task. subject 4

The main concern in developing this work is whether it is possible to perform a BCI based on EEG to classify fine movements of the hand. The results of this research generate a discussion about the role of electroencephalographic signals when it comes to predicting the onset and type of fine movement of the hand that is executed: 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.

In the future, this type of BCI will be evaluated in patients diagnosed with neurodegenerative diseases to try to use this technology to improve their mobility. However, there is another discussion that needs to be resolved and it is referring to the kind of task that is classified in this research: the 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.