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On the pursuit of classification of EEG recorded during imagined speech

A. A. Torres-García[1*], E. F. González-Castañeda[1], C. A. Reyes-García[1], L. Villaseñor-Pineda
[1]*Instituto Nacional de Astrofísica Óptica y electrónica, Puebla, Mexico*

*Instituto Nacional de Astrofísica Óptica y Electrónica. Luis Enrique Erro 1, Tonantzintla, Puebla, México.
e-mail: alejandro.torres@ccc.inaoep.mx

Introduction: Allowing direct communication is one of the main purposes of BCIs. This was firstly focused on handicapped persons but nowadays its scope has increased to healthy persons, due to the necessity of a private channel of communication, to be used even in public spaces; with less effort than voice and free of audible noise. Nevertheless, common EEG-based BCIs use 4 broad neuroparadigms (SCPs, motor imagery, p300 signals and SSVEPs) that need translation to language domain. Consequently, we are exploring a alternative neuroparadigm called imagined speech, which refers to the internal pronunciation of words without emitting sounds or doing facial movements [1]. Specifically, we used a dataset composed of EEG signals recorded using an EPOC headset from 27 subjects (S1-S27) while internally pronouncing five Spanish words ("arriba," "abajo," "izquierda," "derecha" and "seleccionar") corresponding to ("up," "down," "left," "right" and "select").
Material Methods and Results: We are facing this issue following three approaches developed in a parallel way. They are; multi-objective channel selection, fuzzy classification and EEG textification approaches. The first of them searches for a minimal subset of channels to accomplish the task of recognizing imagined speech. The second approach consists on the assessing of fuzzy classifiers over the EEG classification problem. Finally, the third approach looks for assessing if EEG signals from unspoken words can be better recognized in the text domain through the textual representation of sequences of high energy brain activations.
A) Multi-objective channel selection: A method for channel selection based on a multi-objective approach was implemented, to minimize the error rate using random forest classifier and the number of channels used. This method is based, different from previous works, on a fuzzy inference system (FIS) for automatically selecting a single solution (combination of channels) from the Pareto front. The FIS was composed by three membership functions for each variable (error rate, number of channels and selection level). The method performance was assessed using this channel combination and an unused test set during the exploration of the possible channel combinations. The reduction of channels applying the proposed method achieved similar performance to the method using all the channels; the average accuracies were 68.18% and 70.33%, respectively.
B) Fuzzy classification approach: We assessed two neuro-fuzzy classifiers never applied to the imagined speech classification problem: Adaptive Neuro-Fuzzy Classifier with Linguistic Hedges (ANFCLH) and an ensemble of them based on random subspace (RS), called Fuzzy Random Electrode selection for ensemble (FRESE). FRESE handles all features of each channel as a unique entity unlike RS. For each subject's data, we applied instance selection guided by artefact removal detected by both independent components and gyroscope signals. Later, discrete wavelet transform and instantaneous energy were computed to create feature vectors of each instance of subject's data. Later, we classified using ANFCLH and FRESE whose best performances were 66.88% and 71.45%, respectively.
C) EEG textification: In this approach we first obtain sparse time-frequency maps applying the bump modeling algorithm. This technique allows us to transform the brain signal into a map of high energy events. Then we codified every bump modeling map of events as a document of textual sentences. From this document, we obtain the sequence of events applying an N-gram technique. The extracted signal N-grams are reduced applying attribute selection and then classified using a Support Vector Machine (SVM). We obtained an average classification accuracy of 72.63 ±11.92%. Specifically, S8 was the best classified with 81.75 ±11.35% whereas S25 was the worst with 48.31±12.73%.
Discussion: Fuzzy classification obtained similar performance compared to random forest using all channels with 71.45% and 70.33%, respectively. Also, the performance could be statistically kept using around 7 channels selected by the M.O. channel selection method. Finally, the classification results applying EEG textification showed that the consideration of the sequence of events improves the classification of the unspoken words compared with previous works [1]. On the other hand, to provide evidence for the validity of the results gotten during the classification of imagined speech we applied a permutation test ($N = 1000$, $\alpha = 0.05$). Results showed that dependence exists between EEG data and imagined words (p-value≈0.0009).
Significance: Our study provides evidence of the utility of the application of novel techniques as multi-objective channel selection, fuzzy classifiers and EEG textification on imagined speech classification problem.
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References
[1] Wester, M., & Schultz, T. (2006). Unspoken Speech - Speech Recognition Based On Electroencephalography. Master's thesis Institut für Theoretische Informatik Universität Karlsruhe (TH), Karlsruhe, Germany.