Neural networks for artifact reduction and vowel speech imagery classification in EEG data

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This work describes an EEG-based software system for brain-computer interfacing, having the long-term goal of creating an alternative speech tool for people with severe communication handicaps. The system is capable of recognizing with a high success rate, in the recorded EEG traces of the subjects, the imagined production of the Italian vowels /a/ and /i/.

Twelve subjects were asked to perform one of two tasks: imagine to produce the /a/ vowel, or imagine to produce the /i/ vowel. Each task was triggered by an auditory stimulus (listening to recorded /a/ or /i/) presented 80 times to each subject (40 times for /a/, 40 for /i/, random order). The presentation tool was BCI2000. The brain activities of the subjects were recorded (at 250 Hz sampling rate) by an EEG system with 64 active scalp electrodes embedded in an electro cap (actiCAP, Brain Products). The recording software was Brain Vision Recorder. Data processing was performed by MATLAB, EEGLAB being used for preprocessing (down-sampling to 100 Hz; 2 to 30 Hz band-pass filtering; subdivision into labeled epochs).

The software system can be divided into two parts: artifact reduction, and imagined speech classification (Figure 1).

In the first part, in order to reduce the ocular and muscular artifacts, we performed independent component analysis (ICA) on the EEG data. The spectra of the independent components (ICs) were examined: artifacts were visually identified in accordance with spectral power content, and labeled as such. A 2-layer, 3-hidden-neuron, feed-forward back-propagation ANN (Artificial Neural Network) was trained and tested for the recognition of the artifacts by LOO (Leave One Out) cross-validation, and the classification accuracy was assessed by the area under the ROC (Receiver Operating Characteristic) curve (AUC). We chose discriminating features in each epoch and for each EEG independent component as the average signal power in diverse spectral ranges, calculated as an approximation of the definite integral of the estimated signal Power Spectral Density (PSD) within each frequency interval. ICs identified as artifacts were rejected, and the corrected data were recalculated.

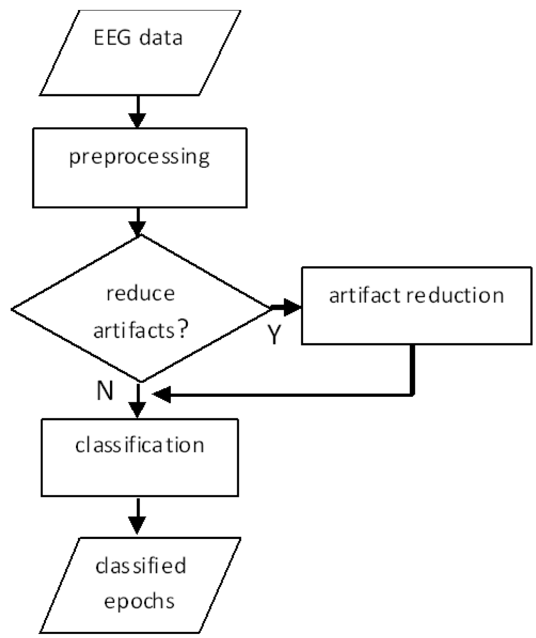

Figure 1. The overall flow of the processing pipeline.

In the second part, EEG epochs were processed by time-frequency analysis in the ambiguity plane [1]. Values of the ambiguity function:

$$A_x(\tau,\nu) = \int_{\Re} x\left(u+\frac{\tau}{2}\right) x^*\left(u-\frac{\tau}{2}\right) e^{-2\pi i \nu u}\, du$$

in the plane were chosen as features for vowel recognition. The 100 most discriminant points were identified by maximizing the Fisher contrast of the two classes, and formed the feature vector. A 3-hidden-neuron ANN was trained and tested for the recognition of the imagined speech, this time on single subjects. AUCs were calculated both with and without artifact removal. Overall vowel classification accuracies as measured by the AUCs ranged from 0.80 to 0.90 (for the different subjects) without artifact reduction, while the insertion of the artifact remover had in many subjects a beneficial influence on accuracy.

REFERENCES

1. Saeid Sanei, J. A. Chambers, EEG Signal Processing, John Wiley & Sons, July 2007, ISBN: 978-0-470-02581-9