

Inverse solutions for classifying Event Related Potentials

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Abstract. In this paper we want to show the use of inverse solutions—in particular cortical current density (CCD)—with respect to the current surface electroencephalogram (EEG) in classifying event related potentials. We construct feature vector from selected channels which had highest discriminant power for a two class problem. We present the results for 6 subjects, where in general, the CCD based method performs significantly better in comparison to the surface EEG methods.

Keywords: Inverse solutions, surface EEG, error related potentials, discriminant power

1. Introduction

Inverse solutions are methods that estimate localized neuronal activity from surface EEG potentials. This localized activity has recently been used to classify motor imagery data in the context of Brain Computer Interaction (BCI). In this paper we analyze the classification performance of inverse methods to event related potentials, in particular we will implement our methods on error-related potentials (ErrP).

ErrPs are generated in humans while the monitored system (e.g. external agent or BCI) commits an error. This signal is characterized on grand averages by two fronto-central positive peaks appearing at 200 ms and 320 ms as well as fronto-central negativity near 250 ms and 450 ms after receiving error feedback from the agent [Chavarriaga and Millán, 2010].

In this paper we use cortical current density (CCD) based inverse method [Cincotti et al., 2008] to classify ErrPs and compare its performance with surface EEG features. A potential limitation of the CCD method is the large number of possible input channels to the classifier, which poses challenge to feature selection. However, we overcome this problem by choosing features from selected channels based on their discriminant power.

2. Material and Methods

The protocol and experimental set up for measuring ErrPs is well documented in [Chavarriaga and Millán, 2010]. EEG recordings were performed on 6 healthy subjects on two different days with 64 electrodes according to the 10/20 international system. Estimation of intra-cranial source activity using CCD method resulted in 3013 channels, each corresponding to a source. Features for classification were time points in the window [0.2 0.45]s after feedback following previous studies. A discriminant power (DP) was computed for each channel using the mean of the Fisher score for each time point in the specified window computed for 2-class problem (erroneous vs. correct trial). The feature vector for classification was created by concatenating features from channels whose DP value was in the range $[DP_{\max} \text{ and } (100 - P)\% \text{ of } DP_{\max}]$ where P is a variable threshold between 0 and 25. A LDA classifier was trained using data of day 1 and was tested on data from day 2. Feature independence was assumed by using diagonal covariance matrices to avoid problems of over-fitting.

The above method for feature selection was used in the 64-channel scalp EEG and the 3013 channel CCD inverse space. The classification accuracies obtained for different values of threshold P is compared with a baseline accuracy computed using a classifier based on FCz and Cz channels as in previously reported studies on these signals [Chavarriaga and Millán, 2010; and ref. therein].

3. Results

Classification of the features in inverse space yields an overall increase in accuracy compared to surface EEG. Fig. 1 shows the comparison of accuracies for baseline, EEG channels and CCD channels for 6 subjects. Firstly, it was found that with varying threshold P , the accuracy for selected EEG channels improved significantly for subjects 3,4,6 over baseline (wilcoxon, $p < 0.05$). Secondly, the accuracy for selected CCD channels was significantly higher than baseline for all subjects except subject 1 where the accuracies were comparable. It should be noticed that the baseline accuracy for this subject was rather high. Thirdly, the selected CCD channels yielded significant improvements compared to selected EEG channels over all subjects except subject 3 (wilcoxon, $p < 0.05$). Nevertheless, for this subject CCD resulted in higher accuracies for larger values of threshold P . Overall, the accuracies with CCD were best for four subjects (2, 4, 5, 6) and yielded similar results compared to baseline for subject 1 and to EEG for subject 3. Fig. 1, right panel, also shows localization of the selected discriminant channels. It can be noticed that they are located in a compact cluster over the Anterior Cingulate Cortex, thus being consistent with the reported neurophysiological substrates of this type of signals.

4. Discussion

We presented the use of CCD based inverse solutions in classifying ERPs. The encouraging results obtained with this method have shown that it could be used in detecting ErrPs and may lead to a performance increase when compared to scalp EEG. Further work would be aimed to select the CCD channels relevant to the mental task with added neurophysiological knowledge in constraining the location of selected channels.

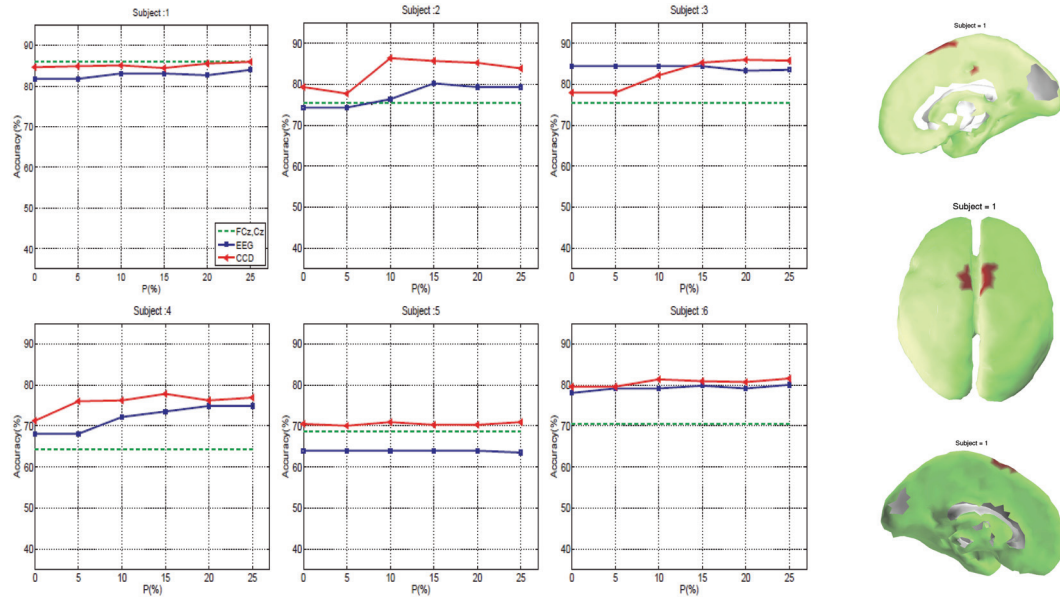


Figure 1. (Left) Comparison of classification accuracies for ErrP of six subjects. Baseline accuracies computed using features of FCz and Cz channels are shown in dotted line. Line with square dots represent accuracies for selected EEG channels and line with triangular dots represent accuracies for selected CCD channels. (Right) The selected channels on the CCD inverse head model for subject 1 with $P = 25\%$.

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References

- Chavarriaga R, Millán J del R. Learning from EEG error-related potentials in noninvasive brain-computer interfaces. *IEEE Transactions on Neural Systems and Rehabilitation.*, 18(4):381-388, 2010.
- Cincotti F, Mattia D, Aloise F, Bufalari S, Astolfi L, Falani FDV, Tocci A, Bianchi L, Marciani MG, Gao S, Millán J del R, Babiloni F. High-resolution EEG techniques for brain-computer interface applications. *Journal of Neuroscience Methods.* 167(1):31-42, 2008.