Combining Feature Extraction Methods
in Brain-Computer Interface

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`https://github.com/kahvel/VEP-BCI`

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INTRODUCTION

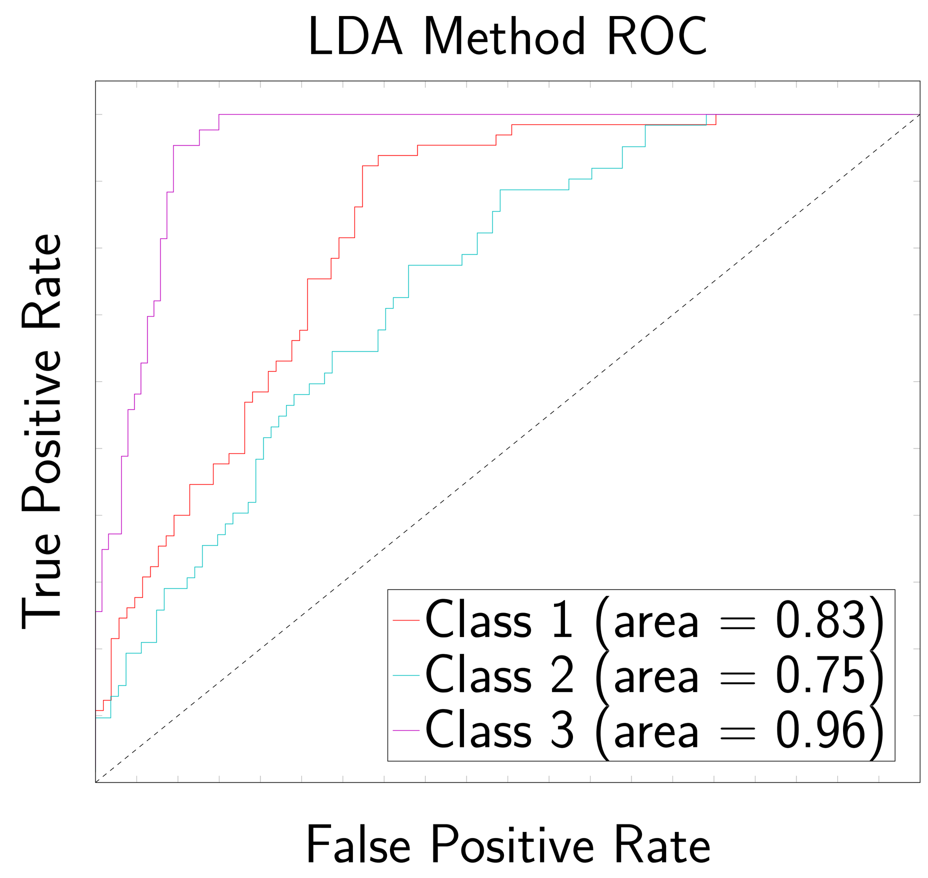
Direct communication channel between the brain and an external device is called a brain-computer interface (BCI). Developing a BCI is a well-known problem in neuroscience and many different types of BCIs have been developed over the years. The uses of BCIs include controlling electric wheelchairs and other devices that can increase the quality of life of disabled people and it has been shown that BCIs can be used to assess cognitive functions in coma patients.

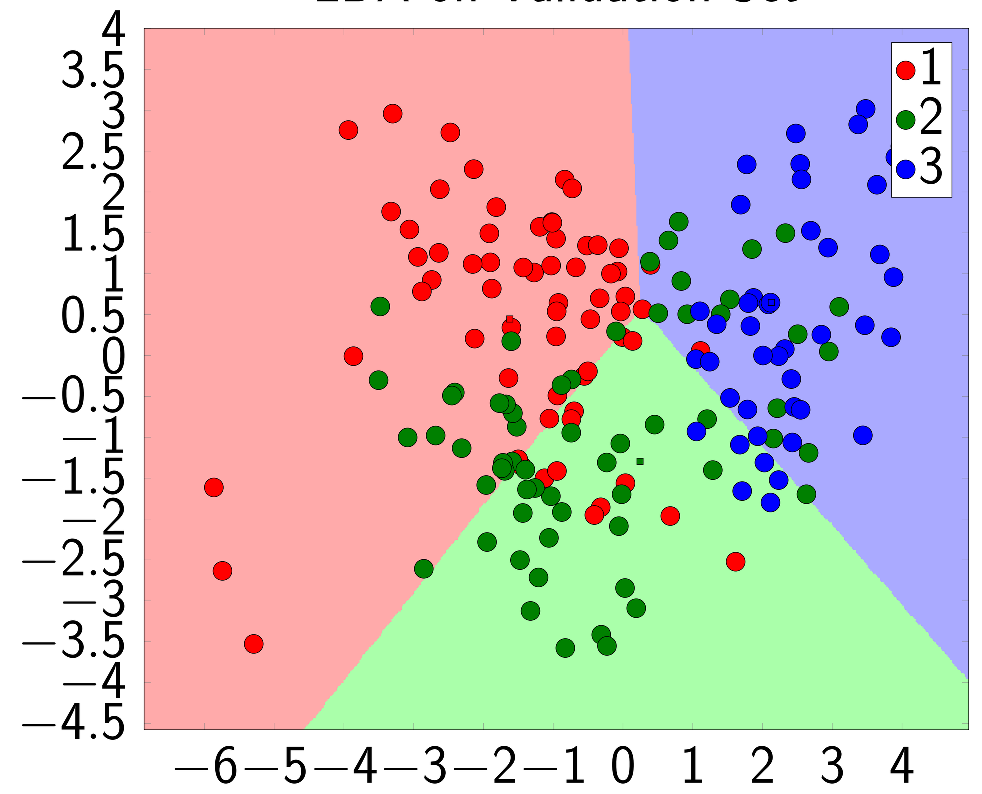
One method to implement a BCI is to evoke brain potential called steady-state visual evoked potential (SSVEP) in a user while recording his brain activity with electroencephalography (EEG) device and then use a feature extraction method to extract information related to the potential from the EEG recording. Then classification is made based on extracted features. In this project an SSVEP-based BCI which is authors previous work is improved.

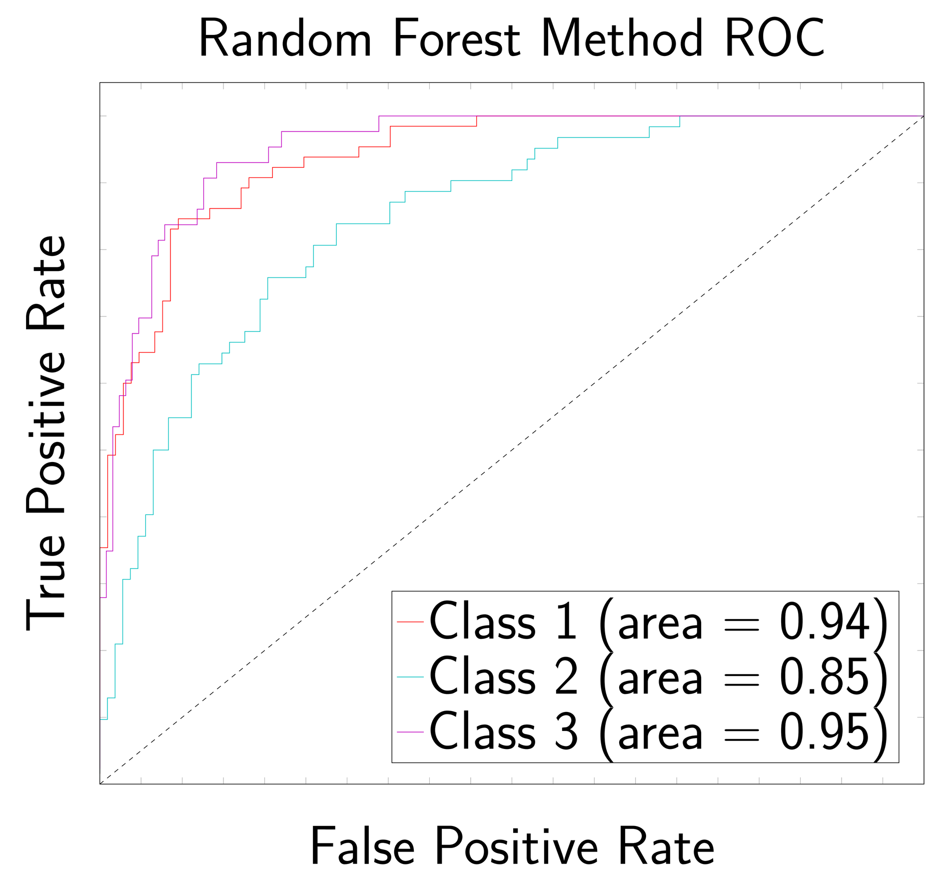
COMBINING FEATURE EXTRACTION METHODS

The most common approach to implement SSVEP-based BCI is to use one feature extraction method and then to define a set of rules according to which the final decision about which command the user wishes to send. There have also been attempts to use machine learning for classification with one or multiple feature extraction method but in these articles either online experiment was not performed or the BCI had low performance. The aim of this project is to test further the online performance of a SSVEP-based BCI with multiple feature extraction methods.

In this project two feature extraction methods are combined in a BCI—power spectral density analysis (PSDA) and canonical correlation analysis (CCA). These methods are combined using linear discriminant analysis (LDA) in attempt to improve the performance of the BCI. Also, random forest with Platts probability calibration is slightly tested as classifier. Using multiple feature extraction methods should provide more information about the brain signal and thus make it possible to implement more accurate communication channel







CLASSIFICATION METHOD

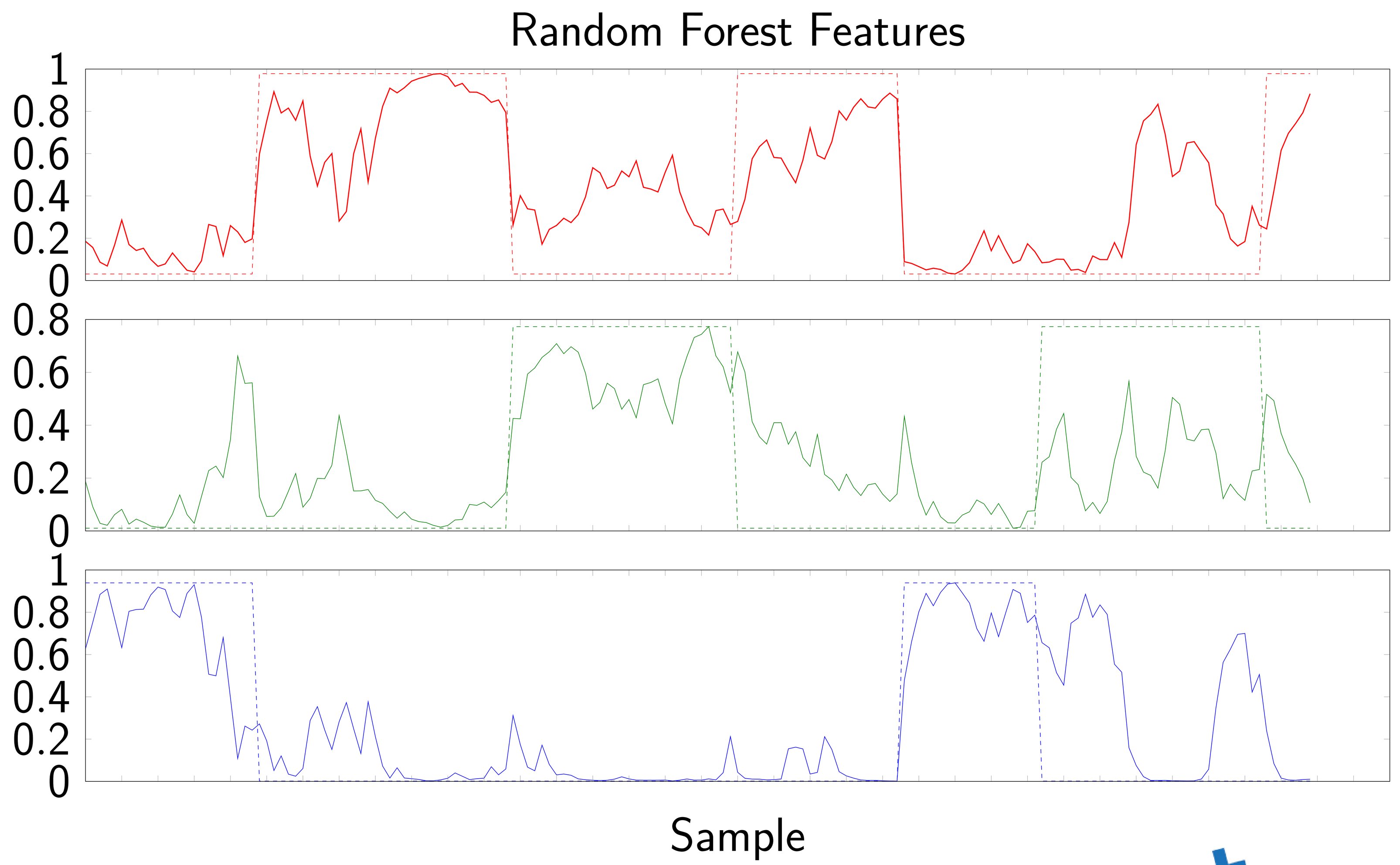
Since the traditional multiclass LDA prediction did not work very well for the task of classifying users chosen targets, a different approach was used in this work. First, a training dataset is used to find a dimensionality reduction transformation. Then a threshold d_h is found for each class h which is used as a cutoff for lower-dimensional features. If for one class h^* the distance to decision border is smaller than its cutoff d_{h^*} and for each other class the distance is larger, only then classification is made.

Another approach that was briefly tested was using probability calibration on random forest. Method called Platts scaling was used for the calibration.

RESULTS AND CONCLUSION

ROC curves of the classifiers and LDA dimensionality reduction can be seen above. The figures below show how the LDA lower-dimensional features and random forest's calibrated probability changes over time for each class. The dashed line shows what is the expected class—when the dashed line is up, then the corresponding class is expected. With 3 targets the BCI obtains a very good accuracy of 90 but due to the fact that the classifiers require information about 10 previous samples, the target detection time is around 4.5 seconds. The results from this project indicate that random forest with Platt's probability calibration outperforms LDA classifier.

In order to use BCIs in real-world applications, they still need improvements. The high accuracy obtained in this project, however, is one of the most important properties that a BCI should have in order to use it in everyday life. But since the results presented here were obtained from one subject only, the BCI definitely needs more testing, most importantly to see how well it performs on other subjects.



The code repository also contains detailed report of the project.
Thesis on the BCI under consideration: A. Ingel. Control a Robot via VEP Using Emotiv EPOC. Bachelor's thesis, University of Tartu, 2015.
Other attempts of combining feature extraction methods:
H. L. Jian and K. T. Tang. Improving classification accuracy of ssvep based bci using rbf svm with signal quality evaluation. In Intelligent Signal Processing and Communication Systems (ISPACS), 2014 International Symposium on, pages 302306, Dec 2014.
I. Martiius and R. Damaeviius. A Prototype SSVEP Based Real Time BCI Gaming System. Computational Intelligence and Neuroscience, 2016.

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