Parameter Optimisation for Brain-Computer Interface

Author: Anti Ingel[1]
https://github.com/kahvel/VEP-BCI

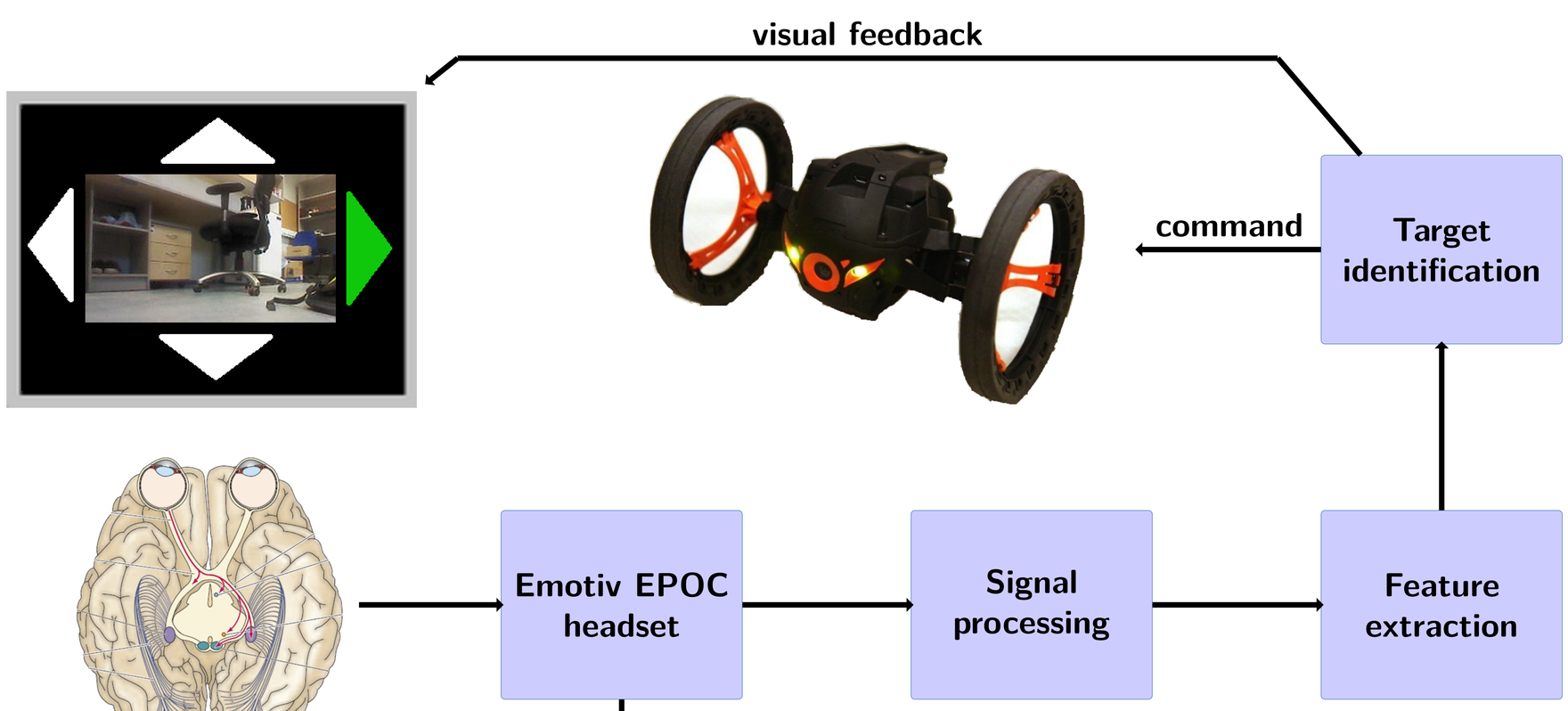
[1]Computer Science, 1st year of MSc,
University of Tartu faculty of Science and Technology,
Institute of Computer Science

INTRODUCTION

In this project different optimisation algorithms were tested for finding good parameters for a visual evoked potential based brain-computer interface (BCI). The BCI which was used in this project is author's previous work and its main weakness is that it has not been thoroughly tested. The aim of this project is to add the functionality of automatically optimising parameters to the BCI and to find out whether this approach gives better performance than previously used method of choosing parameters manually.

In the course of the project, there were improvements made to the BCI. Most notably, the false positives filtering was improved and more flexibility was added for choosing options for different feature extraction methods. Furthermore, now the BCI can be used to control Parrot MiniDrone Jumping Sumo.

The main idea of the BCI is that user looks at one of four blinking targets on the screen and the BCI tries to identify, which target is the user looking. Overview of the BCI pipeline can be seen below.

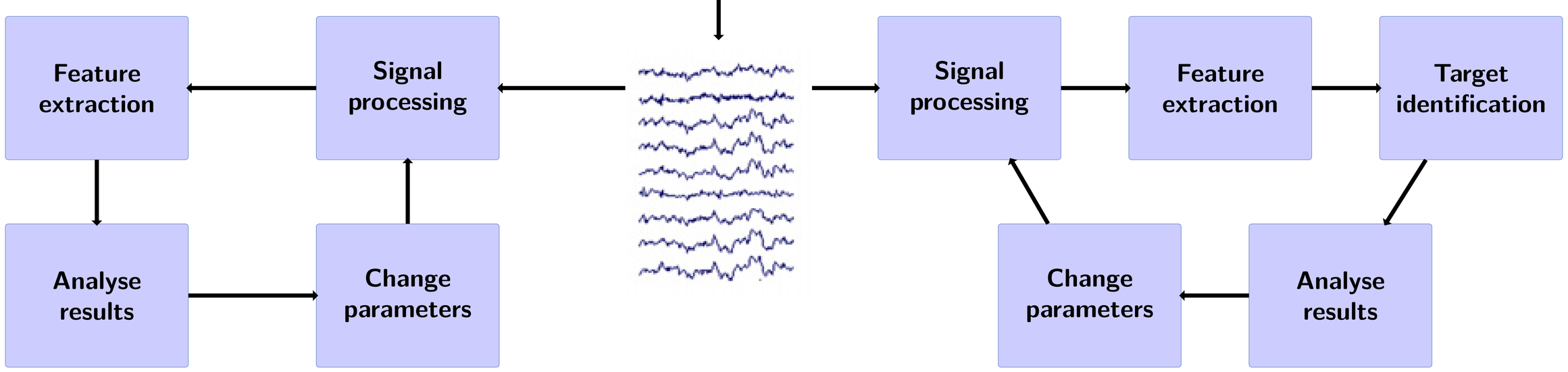


BCI PIPELINE STEPS ⬈

1. EEG device Emotiv EPOC measures user's brain activity.
2. Digital signal processing techniques are applied to prepare the signal for feature extraction.
3. Power spectral density analysis and canonical correlation analysis feature extraction methods are applied.
4. The final decision is made by analysing the outputs of different feature extraction methods.

OPTIMISING PARAMETERS FOR TARGET IDENTFICATION ⬇

Finding parameters for signal processing should be done before finding parameters for target identification, because the signal processing affects the target identification. Unlike signal processing, the target identification step has mostly continuous and some binary parameters. The continuous parameters are the weights for different feature extraction methods and the amounts how much best results have to be better than other results for it to be considered the correct result. Optimising parameters with traditional differential evolution was implemented, because it is good at handling multivariate functions about which we cannot make many assumptions.



OPTIMISING PARAMETERS FOR SIGNAL PROCESSING ⬉

The signal processing step in this BCI has only discrete and non-numerical parameters. Two different optimising methods were implemented for optimising these parameters—brute force and differential evolution suitable for discrete values. These methods were chosen, because they are suitable for multivariate global optimisation. Two cost functions for these methods were implemented, one that penalises only if the best result from feature extraction is not the expected result and the other that also takes into account how much better is the best result from others.

CONCLUSION

The code of the BCI was greatly improved in the course of the project and different methods for optimising parameters of signal processing and target identification were implemented. Unfortunately the most interesting part—finding how much the performance actually increased thanks to the new method—did not fit into the scope of this project. But this will be definitely done in the future.

If it turns out, that the parameter finding works very good, then the next step would be to completely automate the process and also make it dynamically improve the parameters during the usage of the BCI if possible.

BCI and pipeline figure from: A. Ingel. Control a Robot via VEP Using Emotiv EPOC. Bachelor's thesis, University of Tartu, 2015.
Brain picture from: D. Purves, G. J. Augustine, D. Fitzpatrick, W. C. Hall, A.-S. Lamantia, J. O. McNamara, and S. M. Williams, editors. Neuroscience. Sinauer Associates Inc, 3 edition, 2004.
EEG picture from: G. Bin, X. Gao, Z. Yan, B. Hong, and S. Gao. An online multi-channel SSVEP-based brain-computer interface using a canonical correlation analysis method. Journal of Neural Engineering, 6(4), 2009.
Drone picture: http://ipvideo-box.com/wp-content/uploads/2014/04/1389535539__parrot-jumping-sumo-05.jpg

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