Parameter Optimisation
for Brain-Computer Interface

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

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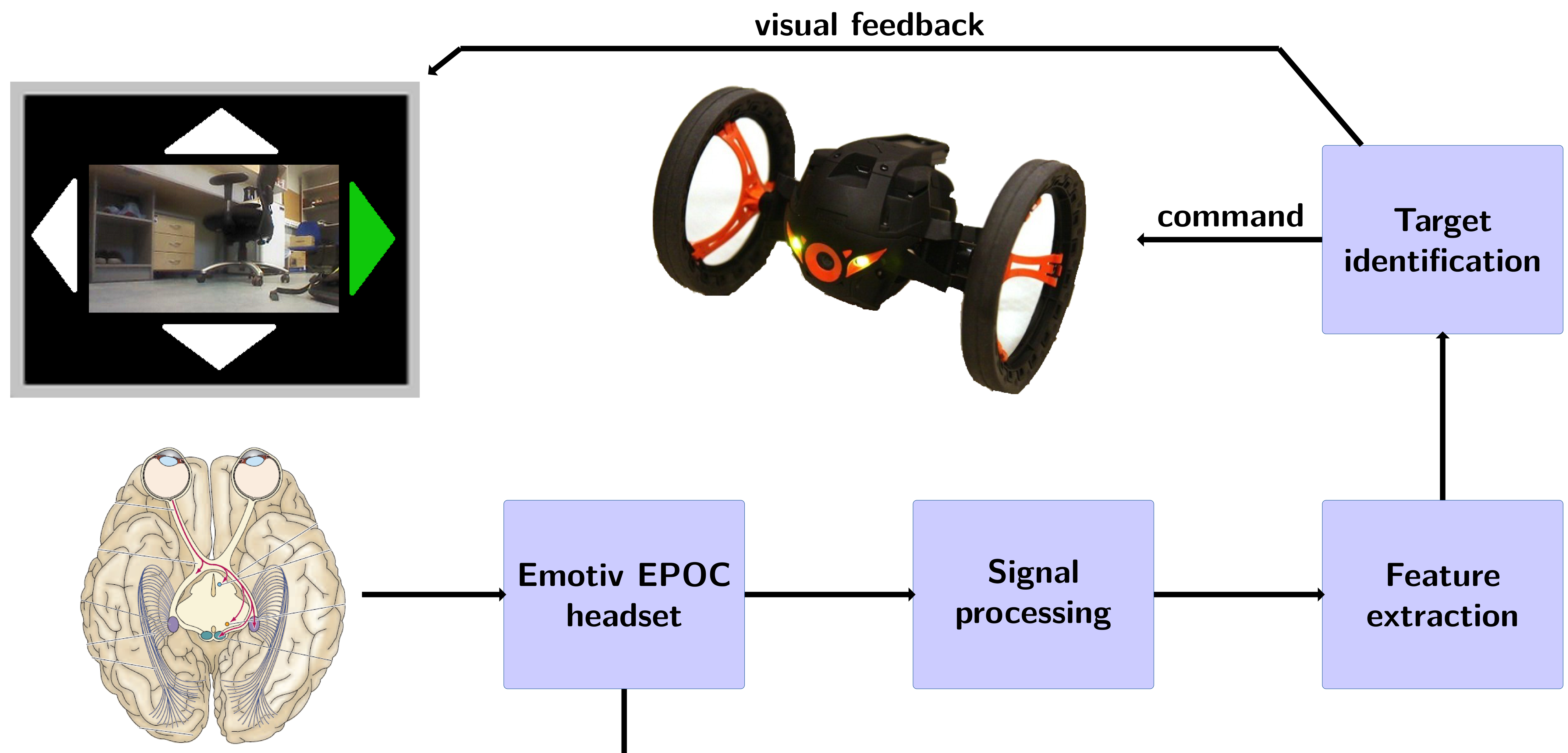
INTRODUCTION

This project laid the foundation on automatically finding good parameters for a visual evoked potential based brain-computer interface (BCI). The BCI for which the parameter optimisation was implemented is author's previous work and its main weakness is that it has not been thoroughly tested. This project aims to make testing of the BCI easier by automating the parameter finding step and hopefully helps to reveal the true potential of the BCI.

In the course of the project several improvements were 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.

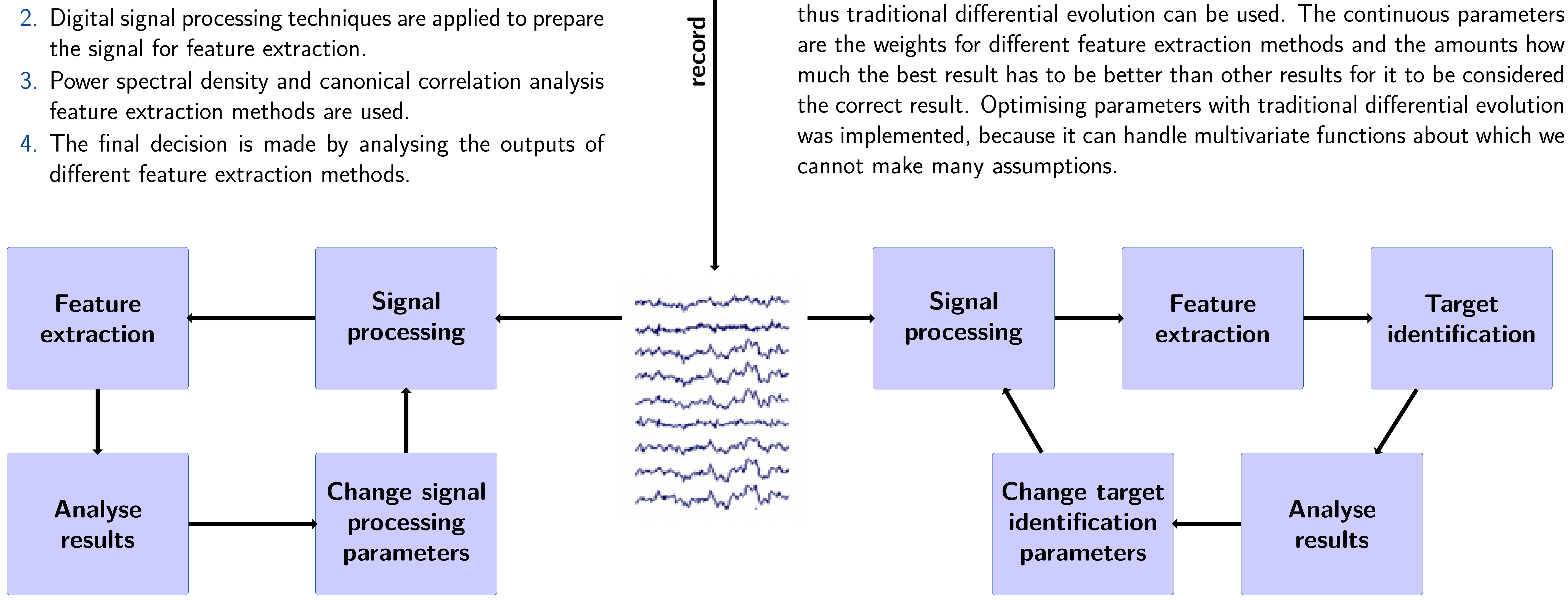


BCI PIPELINE STEPS ⬈

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 and canonical correlation analysis feature extraction methods are used.
4. The final decision is made by analysing the outputs of different feature extraction methods.

OPTIMISING PARAMETERS FOR TARGET IDENTFICATION ⬇

Unlike signal processing, the parameters of this step are mostly continuous and thus traditional differential evolution can be used. The continuous parameters are the weights for different feature extraction methods and the amounts how much the best result has to be better than other results for it to be considered the correct result. Optimising parameters with traditional differential evolution was implemented, because it can handle 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 new method increased the performance—did not fit into the scope of this project. But this will be definitely done in the future.

Furthermore, if the parameter optimisation works very well, then the next step would be to completely automate the process and make it dynamically improve the parameters during the usage of the BCI.

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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