Design and Implementation of a modular EEG-Based Real-Time Brain-Computer Interface

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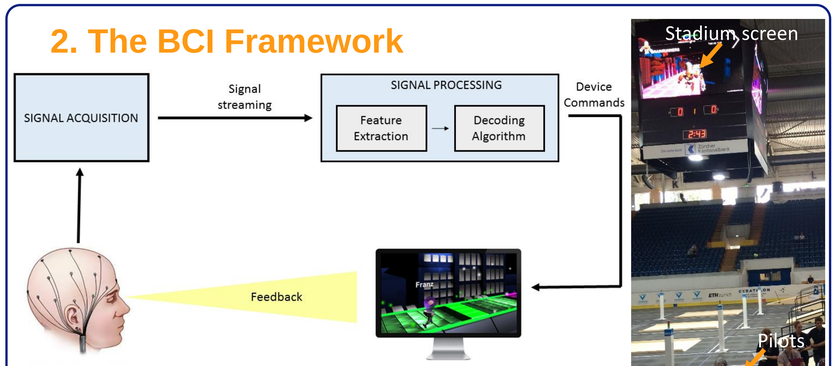
1. Introduction

Neuromotor diseases affect millions of people throughout the globe obstructing their ability to move and interact with the world. Brain-Computer Interfaces (BCIs) hold the premise of allowing to re-rout movement related neural pathways around the damaged parts of the nervous system and re-gain control over the environment. However, the field still faces open challenges in system design, training and real-time implementation. This work proposes a flexible BCI framework designed to facilitate simple, intuitive and reliable prototyping and implementation of real-time BCIs.

2. The BCI Framework

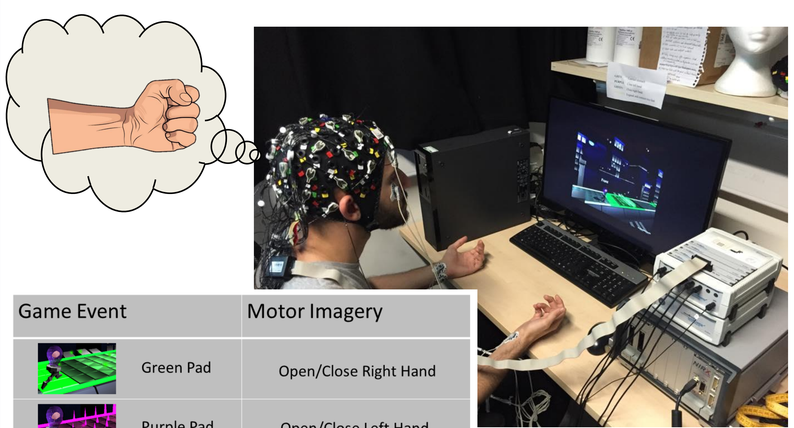


Design of our online BCI framework.

- **Stream signal**
- **Decode thought**
- **Send game command**

The system is intended to compete at 2016 Cybathlon's BCI Race, in which neurologically impaired pilots compete on a racing video game controlled using strictly brain activity.

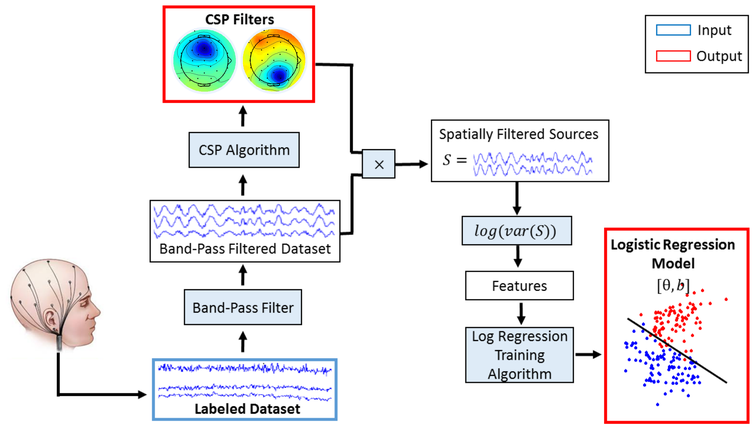
3. Training Data Acquisition



Game Event		Motor Imagery
	Green Pad	Open/Close Right Hand
	Purple Pad	Open/Close Left Hand
	Yellow Pad	Contract/Expand Feet
	Grey Pad	Contract Abdominal Muscles

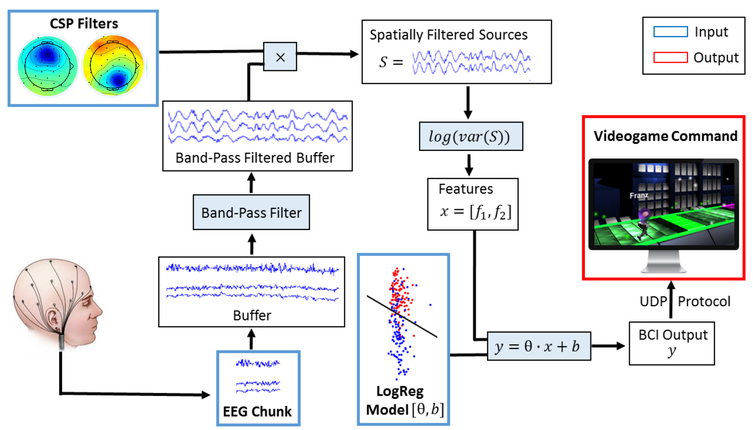
The user watches a video of the gameplay of the video game he will compete on and thinks about performing a specific motor action (motor imagery), whenever a certain event happens in the video.

4. BCI System Calibration / Training



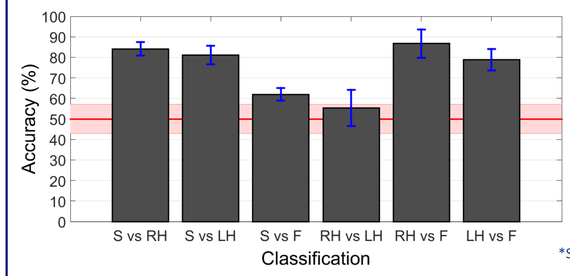
- EEG signal trials from each motor imagery are band-pass filtered in the frequency range of the mu and beta rhythms, associated with motor planning [1].
- Common Spatial Patterns (CSPs), spatial filters that maximize differences in variance between the EEG signals associated to pairs of different motor imageries, are computed.
- The log-variance of the spatially filtered signals are used as features.
- A classifier (Logistic Regression or Linear Discriminant Analysis) is trained to classify the feature space composed of features from different motor imageries.

5. Real Time Decoding



- The EEG data is continuously streamed into a buffer in real-time.
- The decoding thread, reads the buffer and applies temporal (band-pass filter) and spatial (CSP filters obtained on the training phase) filtering.
- A log-variance feature vector is computed.
- The feature vector is classified using the Logistic Regression or LDA model computed during the training phase.
- A specific command is sent to the videogame depending on the classification outcome.

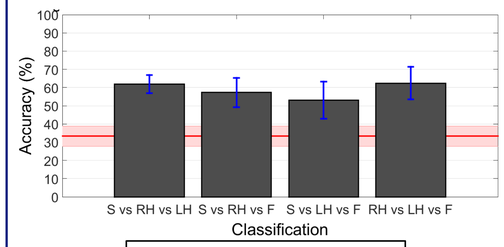
6. Results



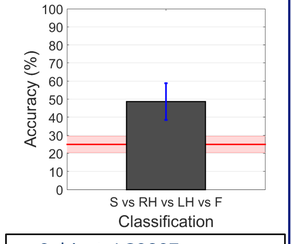
- Subject: LG2807
- Algorithm: Spec-CSP
- Classification task: 2 classes

RH = Right Hand
LH = Left Hand
S = Stomach
F = Feet

*Spec-CSP: Spectrally weighted CSP [2]



- Subject: LG2807
- Algorithm: Spec-CSP
- Classification task: 3 classes



- Subject: LG2807
- Algorithm: Spec-CSP
- Classification task: 4 classes

Results of the prediction in a 5-fold cross validation on training data. The red line indicates the probability to decode correctly purely by chance (chance level) for each classification task and the pink area represents a 95% confidence interval for the chance level.

7. Towards the Cybathlon

This work is aimed at Imperial College participation at the 2016 Cybathlon Championship, empowering the development of assistive technologies [3]. This project is focused particularly on the BCI Race discipline in which athletes with severe motor impairments compete on a virtual race using Brain-Computer Interface technologies.

Photography: ETH Zurich / Alessandro Della Bella

8. Summary and Conclusions

We have developed a modular Brain-Computer interface framework that allows real-time BCI control and testing of different algorithmic approaches.

The algorithms we have implemented on our framework are focused on the identification of sensorimotor rhythms to decode motor imageries, obtaining accuracies of up to 87%, allowing fluent control of the videogame in real-time. The main importance of this work is providing a platform for intuitive and flexible BCI prototyping allowing to move from offline decoding studies to real-time BCI applications in a fast and robust manner.

References

[1] Pfurtscheller G, Neuper C. Motor imagery activates primary sensorimotor area in humans. Neuroscience letters 1997;239(2) 65-68.

[2] Tomioka R, Dornhege G, Nolte G, Blankertz B, Aihara K, Müller K. Spectrally weighted common spatial pattern algorithm for single trial EEG classification. Dept.Math.Eng., Univ.Tokyo, Tokyo, Japan, Tech.Rep 2006;40.

[3] Riener R, Seward LJ. Cybathlon 2016. Systems, Man and Cybernetics (SMC), 2014 IEEE International Conference on, : IEEE; 2014. pp. 2792-2794.