MSc in Computational Cognitive Neuroscience

braincontrol human technology

Goldsmiths UNIVERSITY OF LONDON

Real-time Processing and Decoding of Visual Imagery (VI) for an EEG-Based BCI System Prototype

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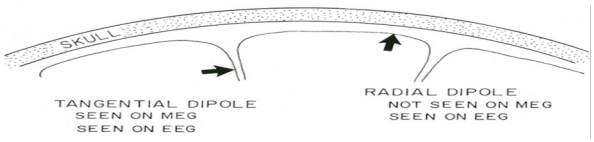
Introduction & Rationale

A brain-computer interface (BCI) is a type of neurotechnology that employs algorithms within a processing pipeline to facilitate communication between the brain and electronic devices.

- **Offline BCI** - analysing EEG recordings from multiple pre-recorded trials
- **Real-time BCI** - short time windows of data are selected and processed in a dynamic pipeline for real world application

Electroencephalography (EEG)



Source of EEG [1, Fig. 1].

Research has revealed associations between neural oscillations and VI tasks, specifically, a complex association between alpha and beta band-power has been linked to cognitive load management through inhibitory processes [2,3]. These results highlight the potential for EEG-based BCIs to decode and classify these neural oscillations.

Aims

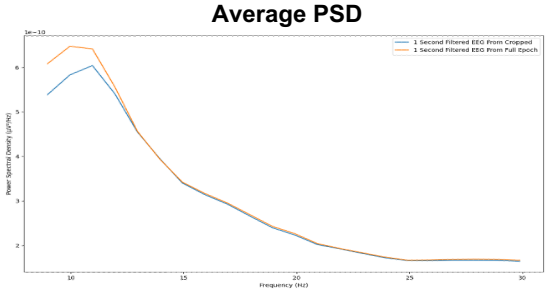
This study aims to investigate the optimal parameters needed for real-time processing, in order to achieve optimal model performance.

Hypothesis

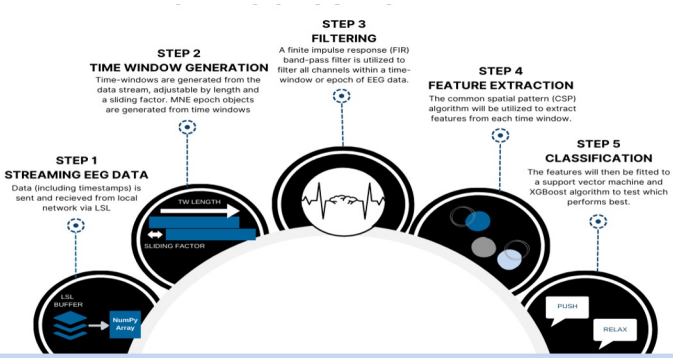
Successfully decode EEG signals in real-time based on two VI conditions:

- Relax - where participants will visualize a static object
- Push - where participants will visualize pushing an object far into space

Average PSD



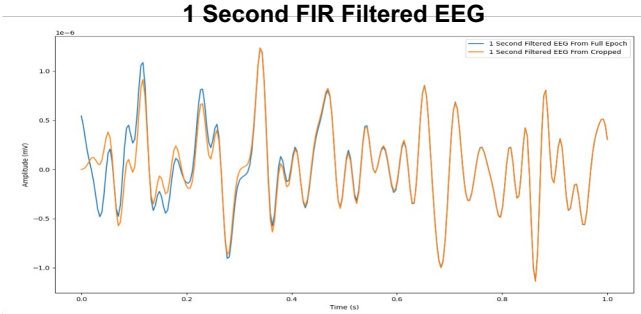
Methods



Preliminary Results - FIR Filter

- FIR filter applied with overlap-add method and minimum phase response between 8 and 30 Hz
- Filter optimized to achieve maximum performance for the application under consideration
- Performance on short-duration data evaluated
- Cropped segment and full EEG data filtered, averaged and compared
- Average power spectral decomposition (PSD) also compared
- Time windows will be cropped and padded by 0.1s

1 Second FIR Filtered EEG



Common Spatial Pattern (CSP)

- Commonly used in BCI applications
- Identify and enhance discriminative spatial patterns while attenuating common or uninformative spatial patterns [4]
- Achieved through the maximization and minimization of variances, proportional to band-power when applied to band-pass filtered signals

Future Directions

We will train and test a model using a pre-recorded dataset, exploring different techniques and epoch lengths to achieve optimal performance. The majority of the dataset will be used for this phase. In the next step, we will simulate real-time data arrival using the remaining portion of the dataset. The saved model, including CSP weights, will be deployed in real-time, applying them to time-windows of the same length. This will allow us to assess the model's performance in real-time scenarios.

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[2] M. Villena-González, I. Palacios-García, E. Rodríguez, and V. López, "Beta oscillations distinguish between two forms of mental imagery while gamma and Theta activity reflects auditory attention," *Frontiers in Human Neuroscience*, vol. 12, 2018. doi:10.3389/fnhum.2018.00389

[3] N. Kosmyna, J. T. Lindgren, and A. Lécuyer, "Attending to Visual Stimuli versus Performing Visual Imagery as a Control Strategy for EEG-based Brain-Computer Interfaces," Scientific Reports, vol. 8, no. 1, Sep. 2018, doi: 10.1038/s41598-018-31472-9.

[4] B. Blankertz, R. Tomioka, S. Lemm, M. Kawanabe, and K. Muller, "Optimizing spatial filters for robust EEG single-trial analysis," *IEEE Signal Processing Magazine*, vol. 25, no. 1, pp. 41–56, 2008. doi:10.1109/msp.2008.4408441