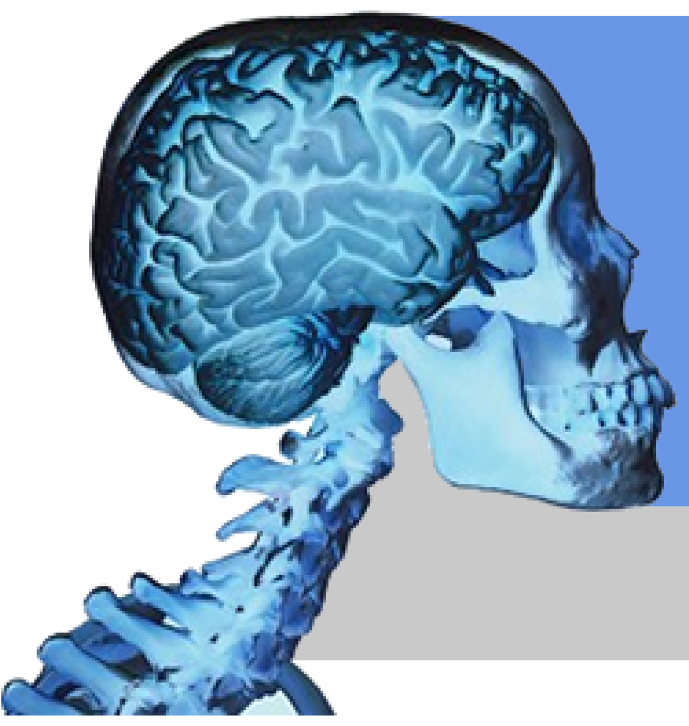

Nature-Inspired Dimensionality Reduction and Feature Selection For Brain-Computer Interfaces

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Introduction

Human methods of interaction with each other, the environment and machines rely heavily on effective motor skills. Conditions such as Parkinson's Disease and Muscular Dystrophy have devastating effects on the motor control and quality of life of sufferers. Brain-computer interfaces could provide significant enhancements to the daily lives of such people by utilising an untapped communication channel between brain and machine.

Electroencephalography (EEG) is the primary means of accessing the signals being transmitted along the neural pathways of the brain. This non-invasive method requires subjects to wear a cap (figure 1) embedded with up to 256 electrodes depending on clinical or system requirements. As the electrodes are measuring potentials through the natural barrier of the skull, EEG signals are very noisy and contain spatial distortions.

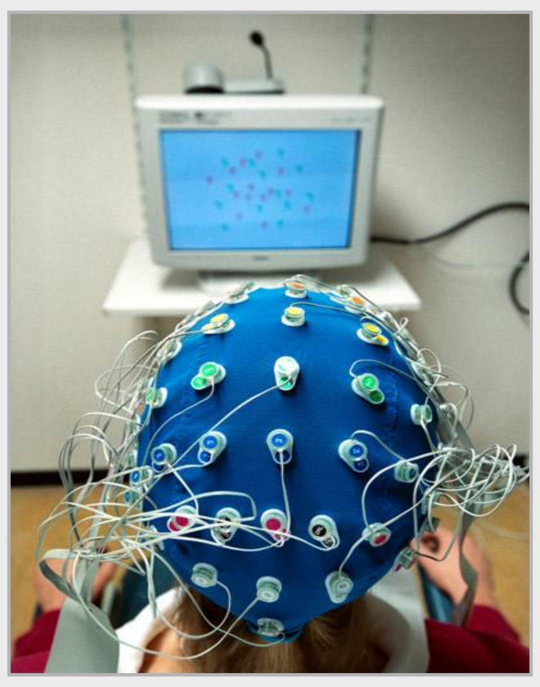


Figure 1. EEG Cap.

The aim of this project was to classify EEG data associated with four motor tasks, namely the movement of the left hand, right hand, foot and tongue. The data was obtained from the publicly available BCI Competition III dataset. EEG signals from two different subjects were used.

ERD and ERS

Event-related desynchronisation (ERD) and event-related synchronisation (ERS) are localised fluctuations in the measurable neural activity within certain frequency bands of the EEG signal. ERD and ERS characteristics can be detected in the primary motor cortex of the brain immediately before and after motor tasks, such as finger motion, are carried out as shown in figures 2 and 3. Crucially, the mere planning of a movement produces a similar effect even if the motion itself is stopped through conscious control or due to physical dysfunction or amputation [1].

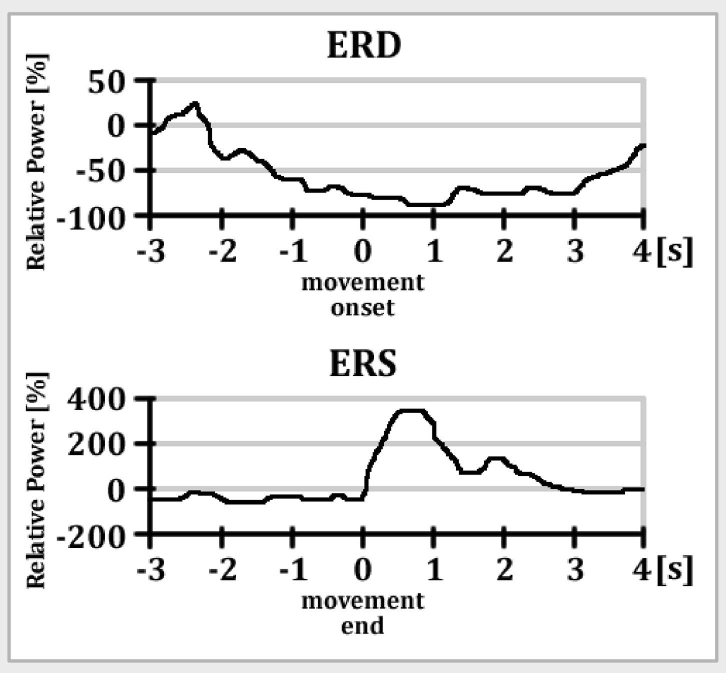


Figure 2. Signal power changes of ERD and ERS. Adapted from [1].

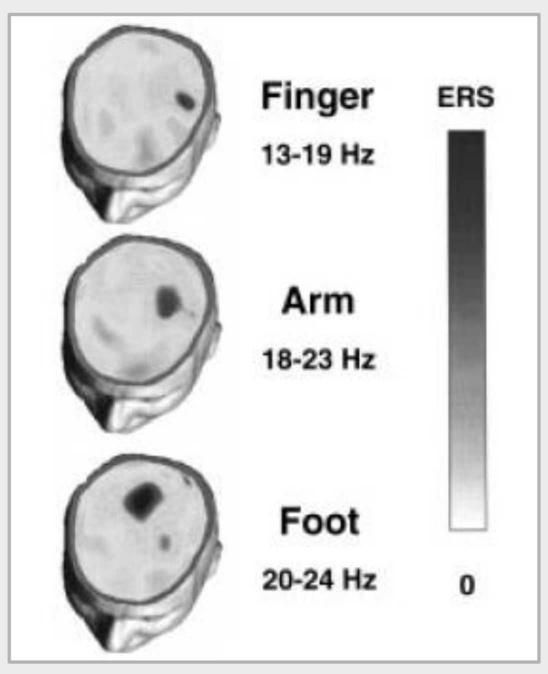


Figure 3. Frequency and spatial localisation of ERS. [1]

Self-Organising Maps

Kohonen's self-organising maps (SOMs) are a type of artificial neural network that undergo unsupervised learning to produce a low dimensional topological representation of the training data. Newly presented data is then mapped onto the most closely matched nodes of the SOM.

In this project, series' of samples of EEG data associated with four motor tasks were spectrally decomposed using the Fourier transform. The SOMs were then trained to represent the high dimensional spectral data as a two-dimensional grid. This produced a simplified representation of the ERD and ERS fluctuations of different frequency bands linked to the four motor tasks. One SOM is used per EEG channel so that the spatial localisation of the EEG signals can be used to influence the classification of the subject's intentions.

System Design

Seven channels of data obtained from locations close to the primary motor cortex were chosen for analysis from the sixty channels available. The SOM mappings for each of the seven EEG channels are then presented to an arrangement of neural network classifiers trained using a 1-vs-all schema. The class of a single experimental trial is decided by a majority vote over all signal samples in a one second period after the subject was instructed to imagine the motion.

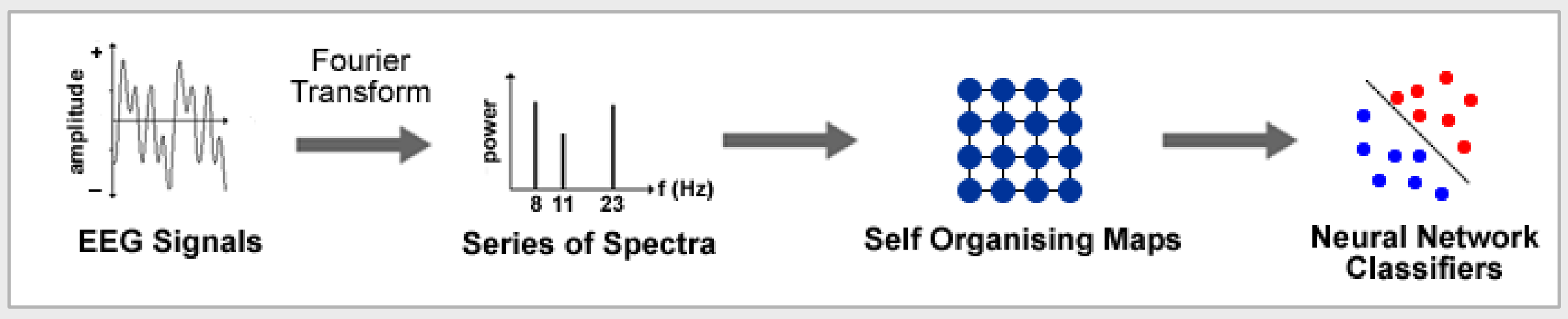
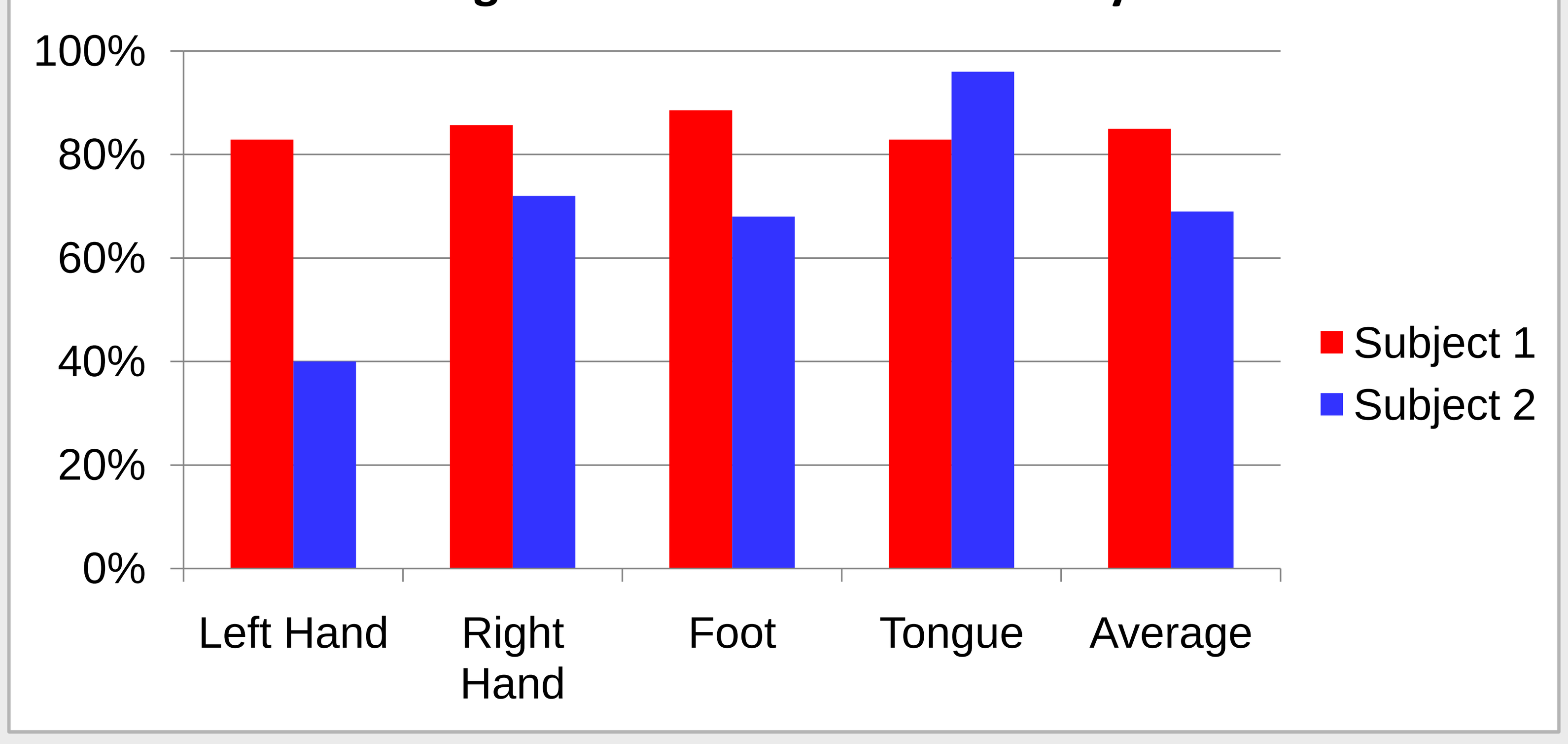


Figure 4. Illustration of System Design

Results

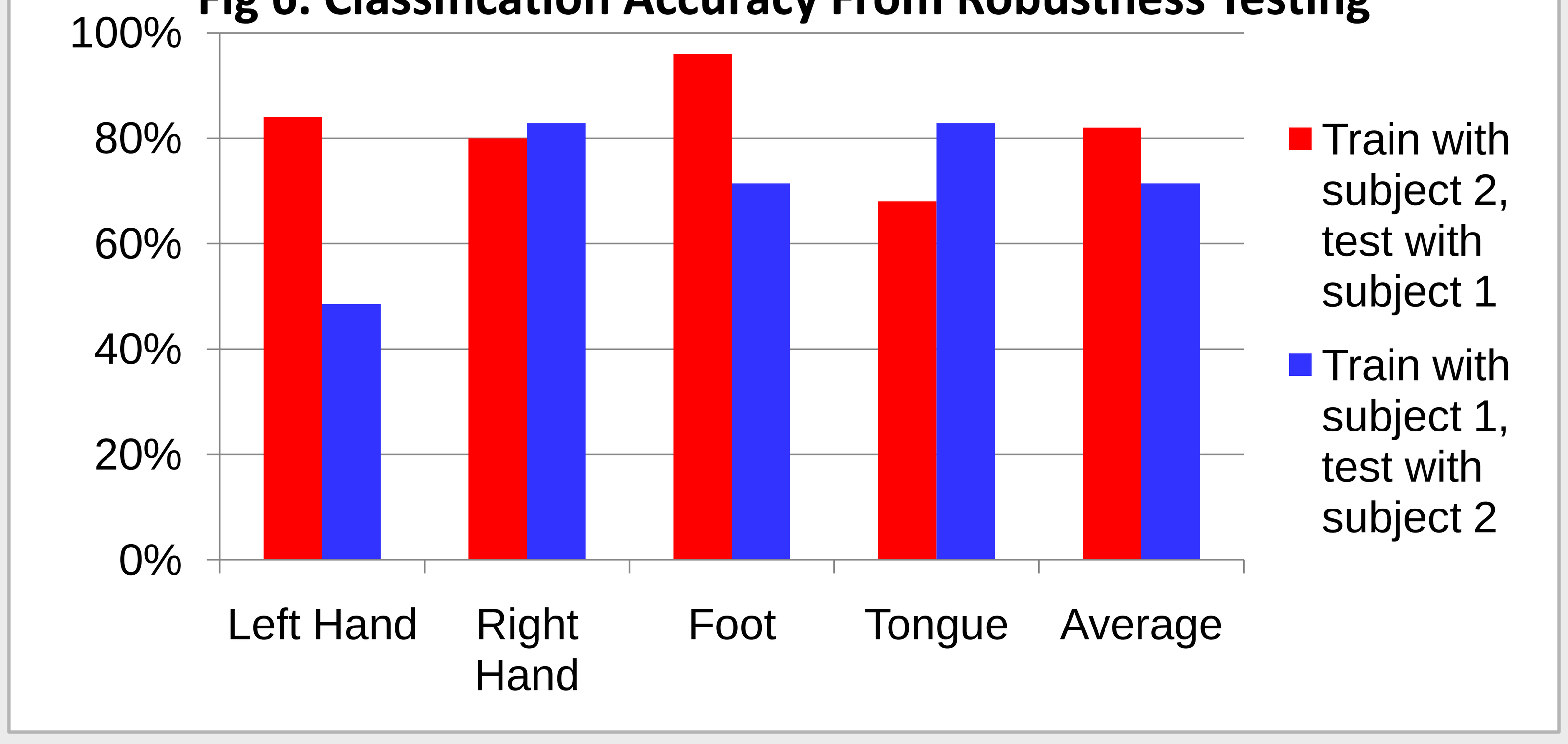
Figure 5 shows the classification accuracy obtained by the system for the four motor tasks and an overall average for each of the subjects.

Figure 5. Classification Accuracy



A good brain-computer interface should be robust enough to successfully classify the intentions of a different user to the provider of the training data. Figure 6 illustrates this system's capabilities.

Fig 6. Classification Accuracy From Robustness Testing



Discussion

It has been shown that SOMs can successfully represent the spectral construction of EEG data in a manner that allows accurate classification of user intentions. Further, the robustness of this system has been proven by training and testing the system with data from different subjects. The results suggest that training a BCI system with data from a subject showing pronounced ERD and ERS may allow weaker subjects to control a BCI more effectively. Further research should be conducted to test this tentative hypothesis over a larger sample of subjects.

References

[1] G Pfurtscheller & F Lopes da Silva. Event-related EEG/MEG synchronization and desynchronization: basic principles. Clinical Neurophysiology 110, 1842--1857(1999).

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