P300 Speller Performance With added Interaction Features Using Frontal and Posterior Electrode Placement

Experiment Setup

Subjects

The OpenVibe P300-Speller experiment is conducted for 3 subjects. For each subject, we have considered varied skills background (For Example: Arts, Games, Meditation etc). The assumption here is, these skills give them an edge to focus towards the task at hand, as well as they should have developed their own stress management techniques. First subject is 47 year old male candidate and is actively involved in meditation practices for last 1 year. The second subject is 19 year old college going student who developed expertise in playing Piano for 6 years and a male candidate. The third subject is 18 year old college going student who is also a Rubik Cube player and participates in various competitions of playing Rubik Cube - also a male candidate. The first subject is given three characters during training phase and 3 characters during online phase. The second subject is given 5 characters during training phase and 5 characters during online phase. The third subject is given 3 characters during training phase and 3 characters during online phase. The vision of all the three subjects is normal or corrected to normal. The number of characters offered to them is different, which gives them varied level of focussing stress as well as it gives us varied amount of training data.

Muse - 2

This experiment uses Muse – 2 as EEG device to capture the raw data. Muse – 2 has total 7 electrodes. Three of them are reference electrodes on the forehead. Other 4 electrodes are placed at locations TP9, AF7, AF8, TP10 according to 10-20 electrode positioning system. TP9 and TP10 are posterior electrodes which are behind the ears. AF7 and AF8 are frontal electrodes placed on the forehead. The sampling rate of Muse – 2 is 256Hz.

Feature Extraction and Classification

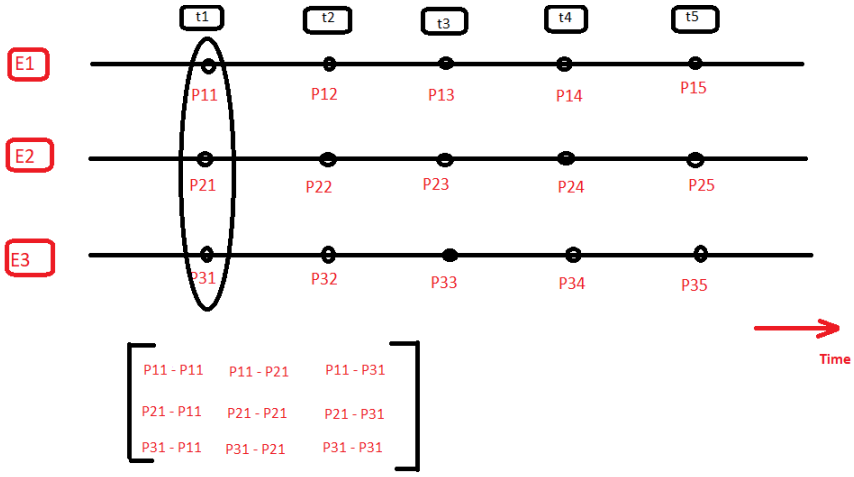
We decimate the signals acquired by the Muse – 2 by 2 and then subject it for epoching. There are two kinds of epochs in this experiment - Target and Non-Target. “Target” epochs are the epochs around the focussed character and “Non-Target” epochs are around the non-focussed characters. There are totally 24 epochs around target character and 120 epochs around non-target character for single trial (single character). We then filter each epoch for two different purposes. The first purpose is to extract P300 *temporal features* and the second purpose is to *calculate synchrony*. To extract the temporal features of P300, we need to filter the epoch in the frequency range 1Hz to 15Hz. Whereas to calculate Gamma band synchrony we need to filter the epoch for Gamma band frequency range which is 25Hz to 45Hz. We incorporated a 6^{th} order Butterworth bandpass filter to filter out the expected frequencies. We further normalize the temporal features [Appendix B] to have values between -1 to +1. Phase synchrony [Appendix A] has values anywhere between 0 to 1. We feed both temporal and synchrony features to SVM classifier with polynomial kernel of degree 4. The *training accuracy* is found to be 100% for all the three subjects. The 5-fold *testing accuracy* was around 93 to 97% for different subjects, as displayed by the confusion matrix. After offline training and testing, the classifier output was fed to *Online* workflow. (No re-tuning of algorithm is done for any of the subjects.)

Results

The interaction feature algorithm is trained with *individual training*. The average Online accuracy was found to be 53% (Subject – 1 : 66%, Subject – 2 : 60%, Subject – 3 : 33%). Out of total 11 characters presented to the three subjects online, 3 characters were found to be Green, 6 were Orange and 2 were Red. Here, *Green* indicates a correctly predicted character. Orange is a character that is predicted close to the focussed character. (“Close” here indicates a character which falls either in the same row or in the same column of the focussed character.) The epoch duration needs to be tweaked for every subject differently, in order to get correct prediction of the characters during the training phase.

Appendix – A

Calculate Synchrony Matrix As A Feature For The Classifier:



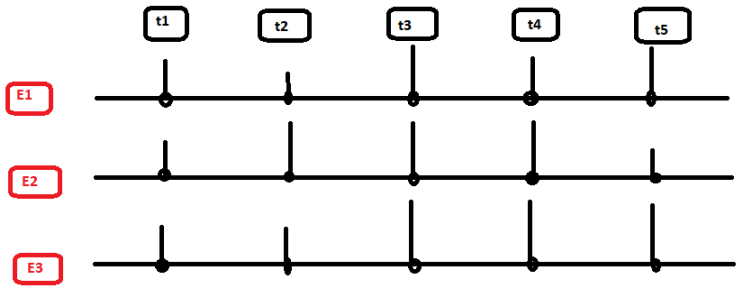
Phase difference matrix for t1

Steps for Classification:

- Hilbert Transform (exists in OpenVibe) gives me instantaneous phase for each electrode
- I choose a few equi-distant samples of instantaneous phase for the epoch (as shown in the figure)
- For each sample, I calculate the phase difference across all electrodes and create a matrix
- I flatten the phase difference matrices "for each epoch" and feed them to SVM
- Get the cofusion matrix with the accuracy results for two classes "Target" and "Non-Target"

Appendix – B

Calculate Temporal Vector As A Feature For The Classifier



- E1, E2 and E3 denote the electrodes
- The standing lines on the electrode denote the amplitude of the signal at a given time
- t1, t2, t3, t4 and t5 denote the time samples of the electrodes
- As "Temporal Features", we normalize the amplitude at each time instance, store all the samples in a Vector across all electrodes and pass the feature vector to the SVM

Future Work:

- Comparison results are not included. The results with P300 temporal features alone. Also the results with Synchrony alone are not included yet
- Higher order interaction features need to incorporated to check if it improves the online accuracy from 53% to 80%