Evaluation of SSVEP Stimulation Pattern using Canonical Coherence Analysis

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Steady State Visually Evoked EEG potentials (SSVEP) is a type of brain machine interface (BMI) that enable direct communication pathway between the brain and an external device. The basic principle of this operation is that the electric signal from brain activity, called electroencephalography (EEG), obtained using electrodes placed on the scalp, can be amplified, analyzed and decoded to determine the intention of the user based on the user's visual fixation target. The objective of this project is to evaluate the performance of two different LED flashing patterns, and compare the performance of two analysis techniques: a simple averaging method, and canonical coherence analysis(CCA) method.

Objectives

- Build and implement the hardware stimulation device and software analysis tools for Steady State Visually Evoked EEG potentials (SSVEP)
- Perform preliminary frequency analysis to understand the brain signal
- Compare the effect of lighting pattern on SSVEP using Canonical Coherence Analysis (CCA)

Major Steps of Experiment

- Connect EEG device to subject
- Clear up the environment in order to perform the experiment
- Perform experiment 1: Checkerboard lighting pattern (delays: 73, 100, 125, 165ms)
- Perform experiment 2: All On/Off lighting pattern (delays: 73, 100, 125, 165ms)
- Determine flash pattern that generates strongest SSVEP
- Implement CCA to evaluate optimal location of recording to decode LED flash frequency.

Equipment

- LED panel was placed 40 cm in front of the subject. The flashing frequency and lighting pattern are controlled using Arduino.
- The EEG signal is detected using a non-invasive approach with existing device in Dr. Chiu's lab (g.LabyBird active electrodes, g.GAMMAcap EEG cap, and g.MOBIlab+ amplifier and wireless transmission system for up to 8 EEG channels.).

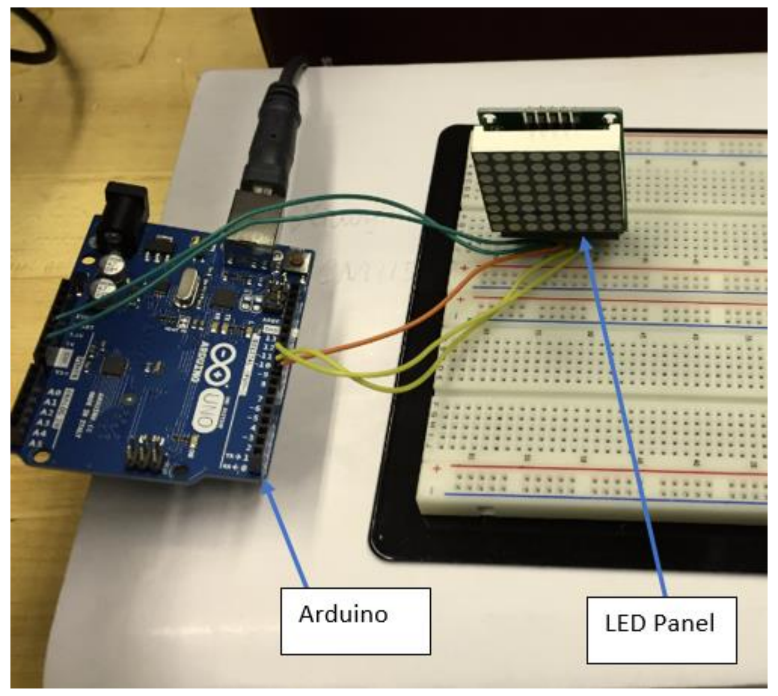
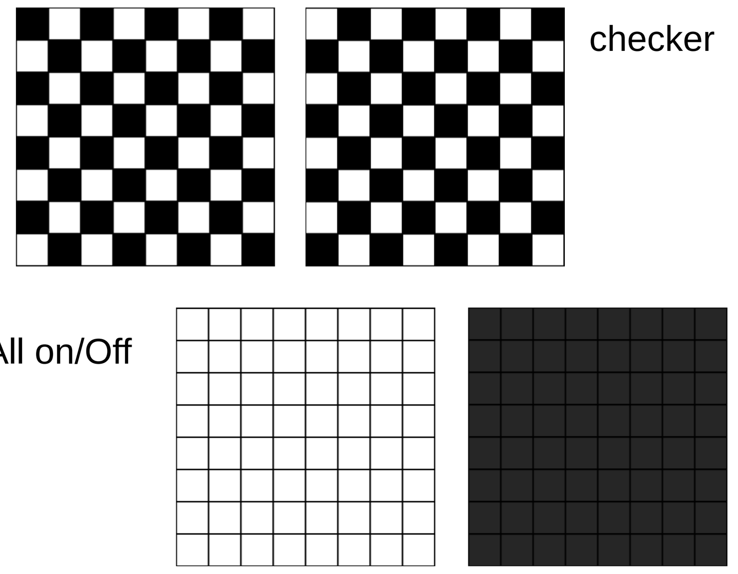


Figure 1. A picture of the lighting device that is used to conduct the experiment.



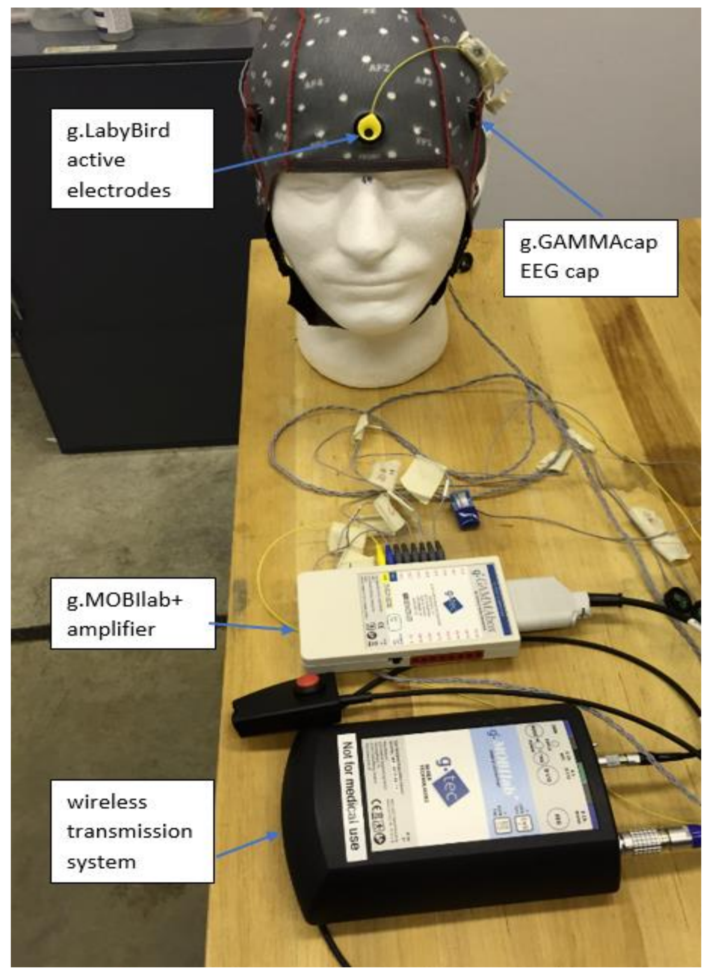


Figure 2. A picture of the EEG device. Signal is obtained from the electrodes on the cap and then transmitted through wireless system into Matlab interface.

EEG analysis

- The EEG signal was reshaped into rectangular matrices with the widths equal to the periods of the LED flashing periods.
- The amplitude of the averaged SSVEP signal in each matrix was calculated. Average SSVEP with largest amplitude should correspond to the flash rate of interest.
- CCA was implemented (Bin et al, 2009) to evaluate which EEG recording location gives highest accuracy.

Results

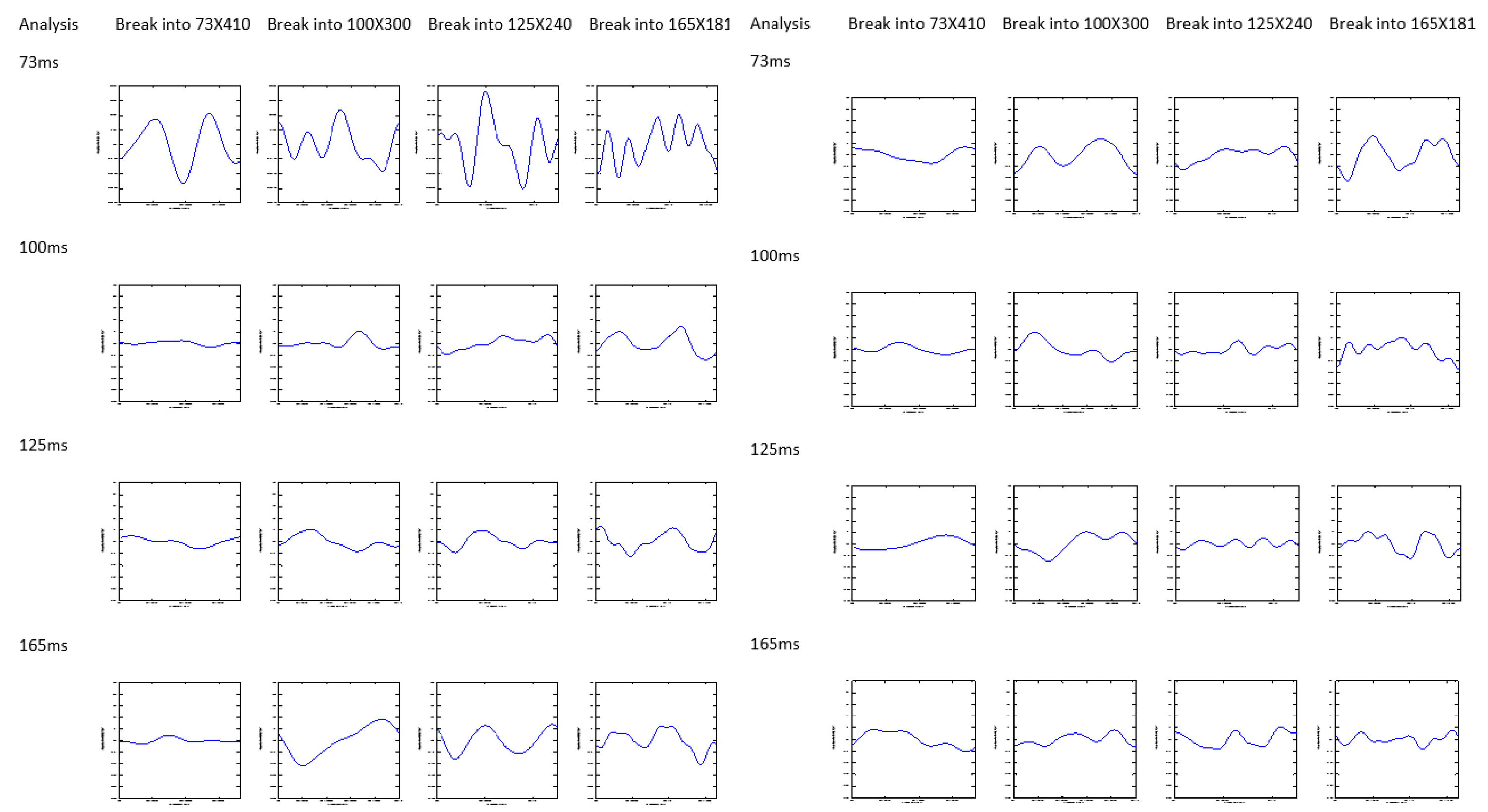


Figure 3. The analysis of SSVEP patterns by breaking each signal into different dimensions of matrix according to the different possible LED flash pattern. On the left is the signal from trial one, checkerboard lighting pattern. On the right is the signal from trial two, all On/Off panel lighting. Each trail of signal have four different frequency component with delay time of 73ms, 100ms, 125ms and 165ms.

Results

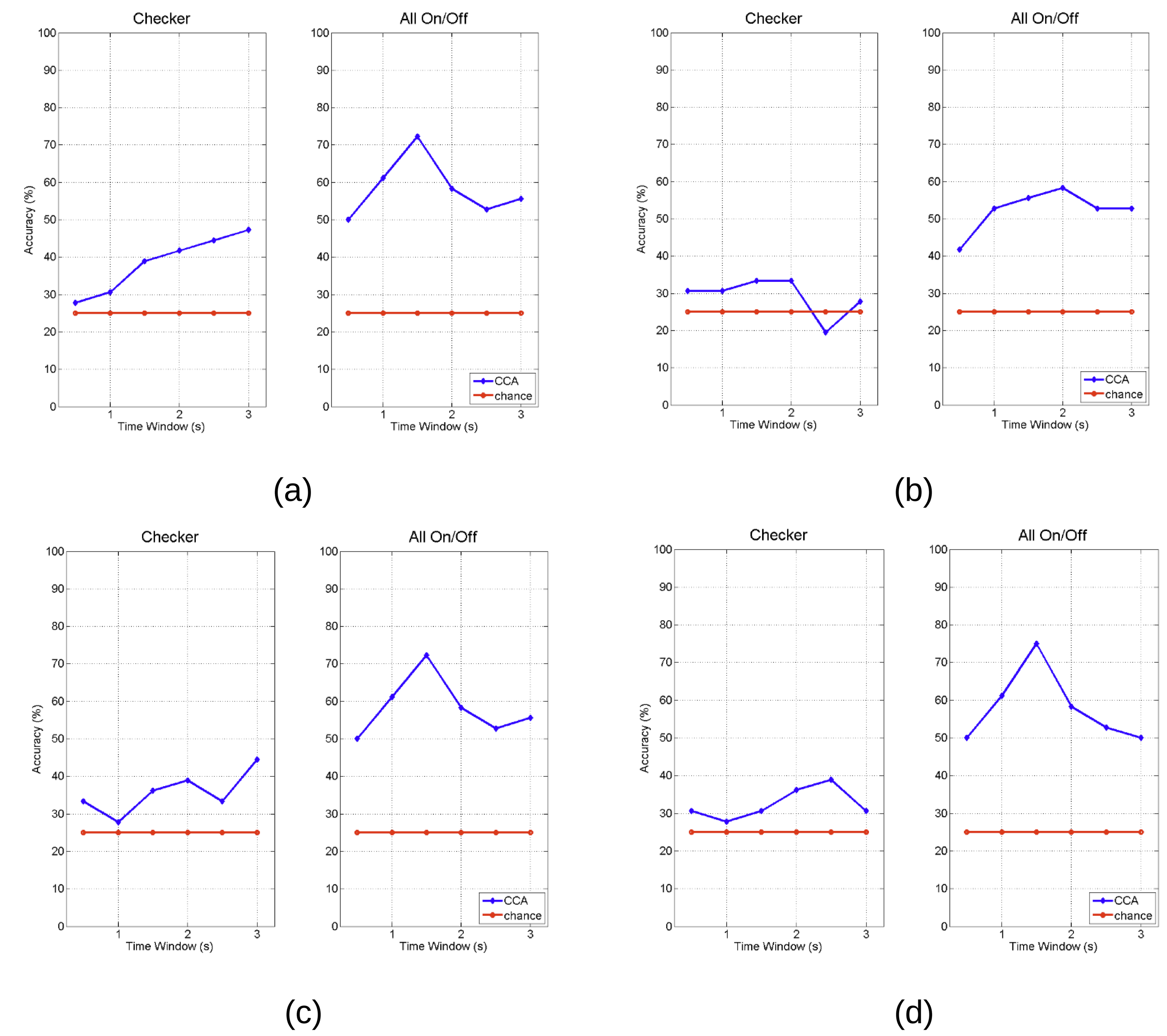


Figure 4. The accuracy of the signal pattern recognition using CCA method for both checkerboard pattern and full lighting pattern. Graph(a) use the signal from Oz, where graph (b) use the signal from Oz and Pz, graph (c) uses the signal from Oz, PO7 and PO8 and graph (d) use the signal from Oz, Pz, PO7 and PO8. The graphs show that the pattern recognition result using CCA is statistically higher than random. The All On/Off flashing patterns also appear to elicit stronger SSVEP responses leading better classification result. The use of EEG waveform from Oz location seems to be the most important factor for good SSVEP classifier.

Future Work

- Complete construction of four portable LED panels.
- Utilize SSVEP data to incorporate into existing video games
- Modify the flashing periods of LED panels so that they are not integer multiples of the periods of 60Hz noise.

References

G. Y. Bin, X. R. Gao, Z. Yan, B. Hong, and S. K. Gao, "An online multi-channel SSVEP-based brain-computer interface using a canonical correlation analysis method," Journal of Neural Engineering, vol. 6, p. 046002 (6pp), 2009.

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