Playing checkers with your mind: An application of a SSVEP-based Brain-Computer Interface

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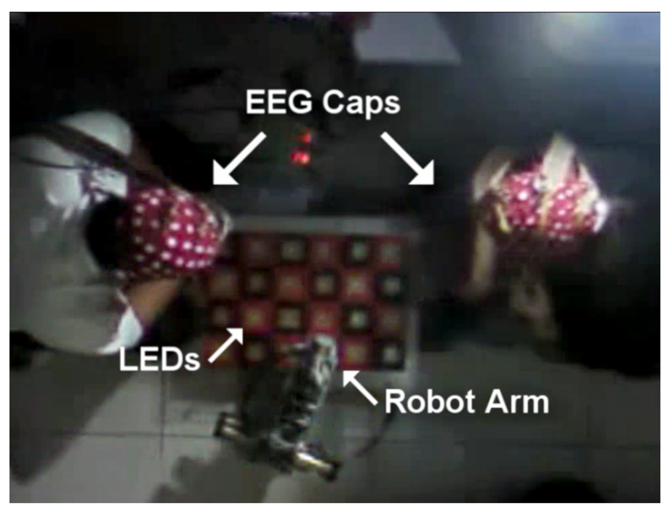
Abstract

There are many Brain-Computer Interfaces (BCIs) today that rely on a user's gaze and visual focus as inputs. However, most of these BCIs have been limited in scope to single users and stimuli in fixed positions. To make BCIs more practical, they should account for dynamic spatial configurations of stimuli whose positions correspond to an area in the physical environment where users would like to interact. In this project we present an application for using a BCI based on Steady-State Visually Evoked Potentials (SSVEP) to play a game of checkers. We light squares on a checkerboard with flickering LEDs to elicit SSVEP responses in the players. When a player takes an action, he focuses his gaze on a particular square. We then classify the resulting SSVEP and a robot arm picks or places selected pieces on the board. We show how to coordinate BCI inputs from multiple users to control a robot arm in a physical environment with stimuli whose spatial configurations can change.



Overhead view of the SSVEP checkers system with two subjects sitting on either side of the LED stimulus checkerboard. The robot arm is used to pick and place pieces.

Introduction

Brain-Computer Interfaces (BCIs)

- BCIs allow users to communicate by measuring biological activity produced from the brain
- Allow people who are severely paralyzed or locked-in to communicate and perform necessary tasks
- Commonly uses electroencephalography (EEG) as interface.

Steady-State Visually Evoked Potentials (SSVEP)

- SSVEPs are neural responses elicited in the visual cortex of the brain when focusing on a visual stimulus appearing at a frequency between 1-100Hz.
- Stimuli can be flickering LEDs or inverting checkerboard patterns
- High signal-to-noise ratio (SNR).

SSVEP has been shown to achieve good control over various tasks including:

- Robotic arms for rehabilitation (University of Bremen)
- Computer cursor control (NASA)
- Mobile robotic control (e.g. an RC car) (g.tec)

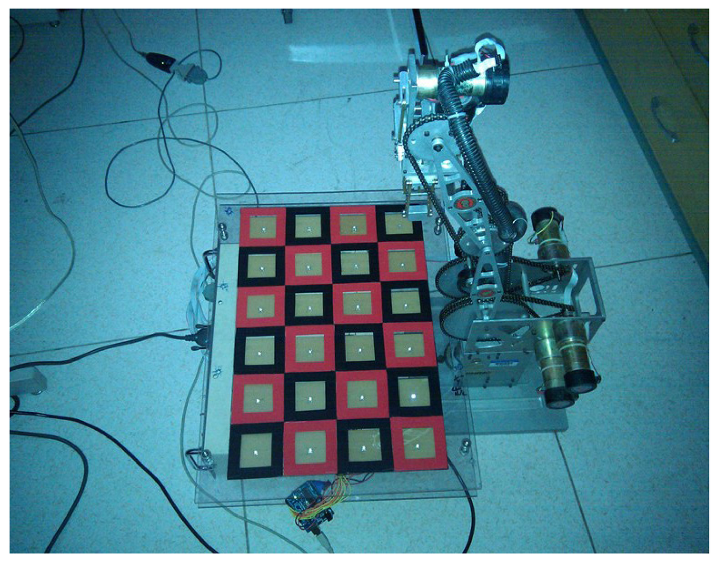
Our Aims

- Interface with the physical world by exploiting a signal generated from the brain
- Allow for multiple user interaction
- Change the positions of stimuli based on user-input
- Intuitively control using SSVEP
- Use the system without training data

Methods

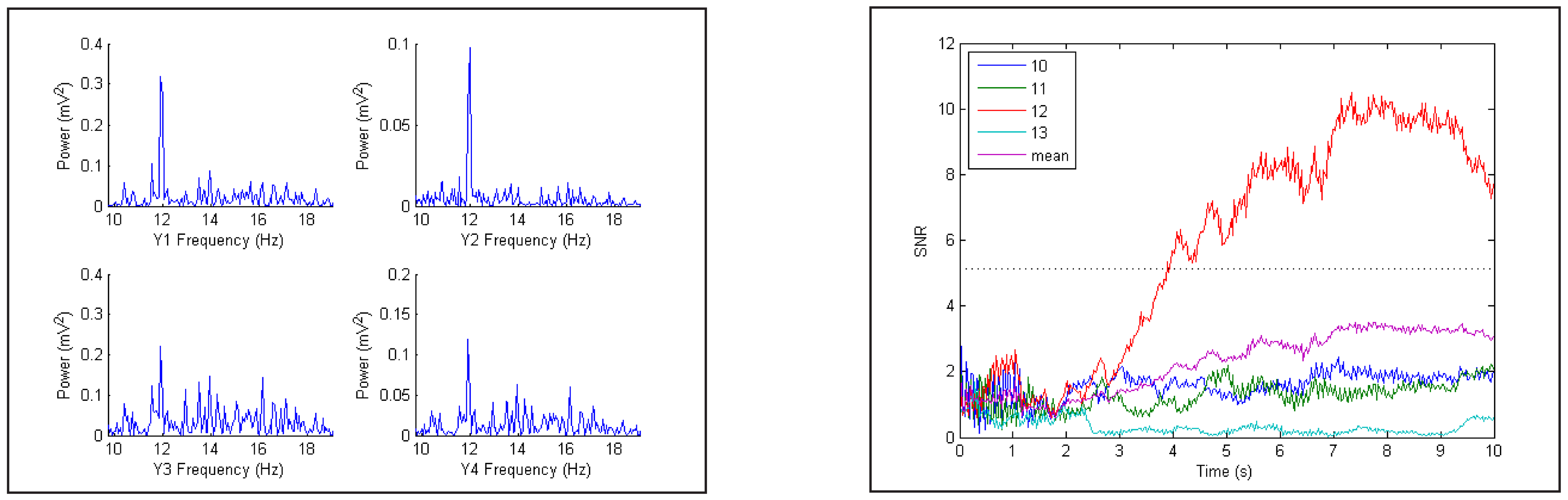
A 6x4 checkerboard with each square housing a single white LED was used for stimuli. The Plexiglas layer over the LEDs was divided into 24 squares. Eight Plexiglas pieces, 5.5cm^3 each with edges painted red or black, were positioned over squares on the board.

White LEDs flickering at 10, 11, 12, and 13Hz were used as stimuli, lighting the available moves on a player's turn. Anywhere from 2-4 LEDs were lit at a time. Electrodes on an EEG cap measured electrical potentials from each subject's scalp over the visual cortex. The available squares are lit for 2 seconds before signal processing and classification began to give enough time for the subject to select a stimulus. Data were collected using BCI2000 software and processed with MATLAB.



The 6x4 LED checkerboard and robot arm used in the experiment

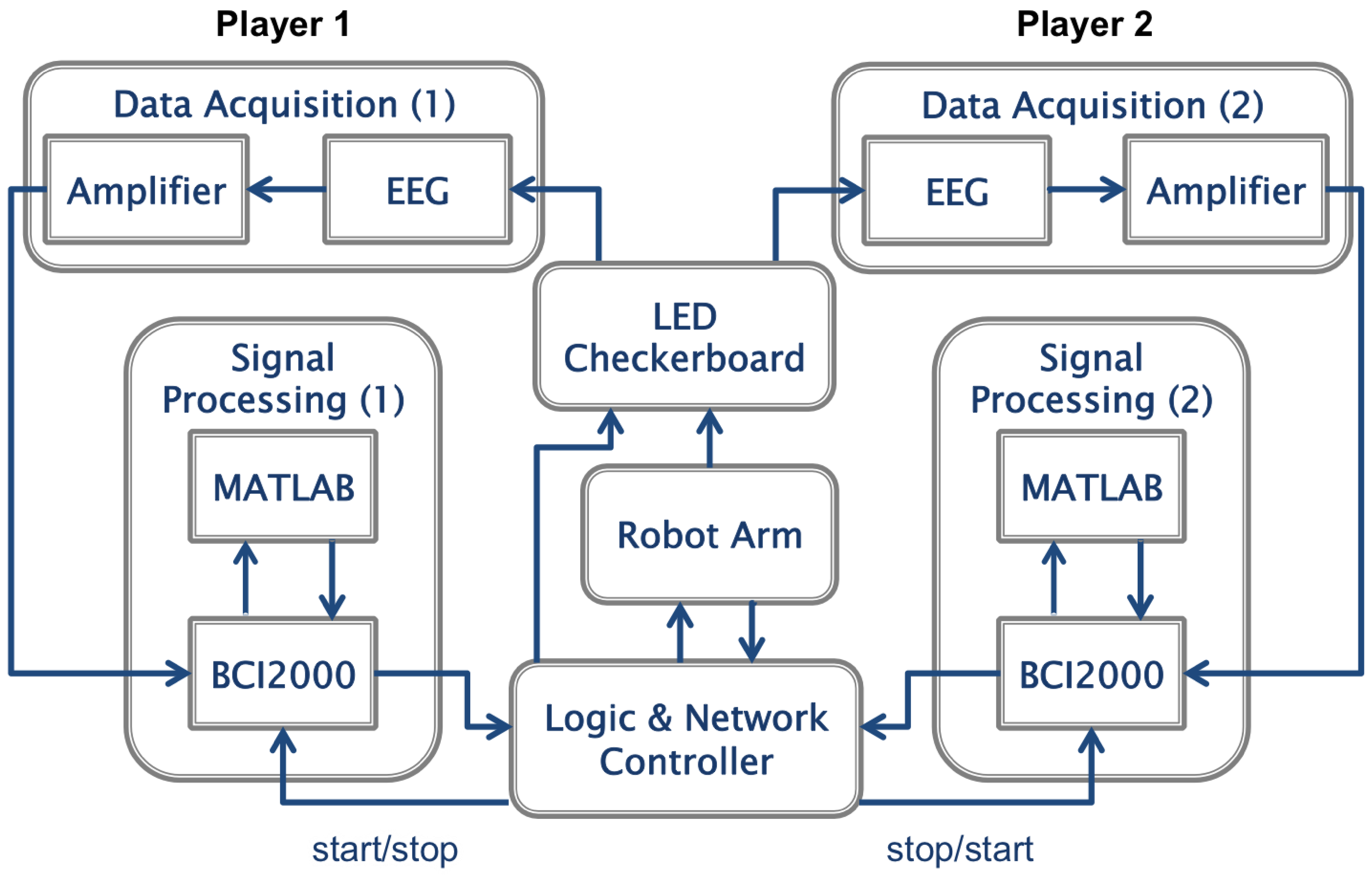
Four linear combinations of the EEG channels were used to maximize the SSVEP SNR over all the EEG channels. If, on average, the signal peaks were 5 times greater than the noise, a classification was made. If none of the averaged ratios for the four frequencies reach the threshold within 20 seconds, the signal processing and classification restarts for a new set of 20 seconds.



(a) (b)

(a) Sample FFTs per channel combination of a subject observing a single 12Hz stimulus ratio after 10 seconds. Scales for each plot are adjusted to view the signal relative to its noise level. (b) The SNR averaged over each channel combination for the four stimulus frequencies. The red line is the SNR for 12Hz. The dotted line at 5 represents the threshold for classification.

Upon classification, when the threshold is reached, the signal is sent to the logic and network controlling program. This program coordinates the checkers logic, the available moves to light, the players turns, and the robot arm (Rhino XR-3, Mark III Controller) used to physically move the piece to or from the square of interest. For each move, we recorded the result of the classification, the time it took to classify, and the spatial configuration of stimuli with respect to the target stimulus.



A flowchart depicting the stimulus presentation, data acquisition, signal processing, classification, and end effector (robot arm) processes for 2 players.

Results

The performance results for two subjects. The subjects completed four games with a varying number of selections per game and per person. Both subjects performed with generally high accuracy. Errors are defined when the classifier did not correclty select the target stimulus.

	Subject 1	Subject 2
Num. Selections	43	42
Num. Errors	8	3
Accuracy	81.0%	93.0%
Avg. Time to Classification	18.0 s	8.43 s

Conclusion

We show that we can use an SSVEP-based BCI to allow multiple users to interact with the physical world with by just focusing on a stimulus. The applications of this research extend to rehabilitation engineering, which would allow patients with paralysis to still communicate with others and perform activities of daily living. Furthermore, since SSVEP is modulated by attention, it could help patients with problems related to focus and concentration. Finally, this work also relates to the area of human-computer interaction by giving users an extra modality with which to interact with their environment.

Future work involves computational modeling of the SSVEP response with respect to the distance to and brightness of the stimuli. We also plan to include both auditory and tactile feedback to strengthen focus and increase accuracy.

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