Demonstration Paper: A 16-channel Bluetooth Enabled Wearable EEG Platform with Dry-contact Electrodes for Brain Computer Interface

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ABSTRACT
A mobile, easy to use, wireless dry contact EEG acquisition system is presented in this work. This system can potentially facilitate continuous in-home monitoring of electroencephalography (EEG) to diagnose ailments such as epilepsy. The system has also been validated with brain computer interface (BCI) paradigms that would enable physically disabled users to communicate.

Keywords
Wearable EEG; Dry Electrodes; Brain computer interface

1. INTRODUCTION
Dry EEG electrodes have garnered significant interest as a favorable alternative to wet/gel-based electrodes for electroencephalography (EEG). As Figure 1 illustrates, the convenience of a dry system can enable continuous in-home monitoring of EEG. Moreover, this system can also be used to implement BCIs such as steady state visually evoked potentials (SSVEP), P300 and motor imagery. These BCIs can be crucial for patient care, such as in the case of patients with amyotrophic lateral sclerosis (ALS) [1] who could regain the ability to communicate.

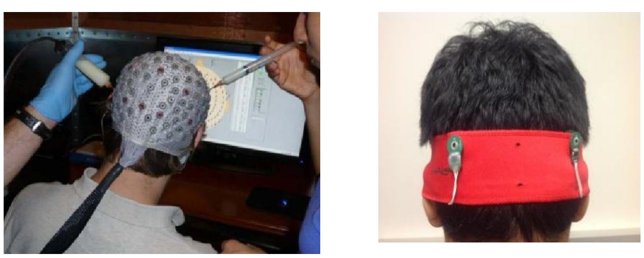

Figure 1 – (left) Wet electrode systems[2] are inconvenient and require regular application of gel. (right) Dry electrode systems provide added comfort, convenience and enhanced wearability.

2. HARDWARE DESCRIPTION
The platform used is a custom board designed by our lab, shown in Figure 2, which incorporates two daisy-chained TI ADS1299 analog front ends for 16-channel EEG, the TI MSP430 microcontroller and a BlueRadios dual mode Bluetooth radio for wireless communication of the data to a PC. A gain of 1 is used on the ADS1299 differential amplifiers so as not to saturate them. Additional gain is not necessary as the 24-bit ADC has a resolution of roughly 0.4 μV. The board is battery powered and can recharge the battery using a micro-USB interface. The board also incorporates an active driven right leg (DRL) circuit for better common mode rejection based on the design in [3]. We assembled our own custom dry electrodes which consist of two pieces that snap together as shown in Figure 3. The first piece shown to the left in Figure 3 has an LMP7721 low-noise buffer that receives the measured signals through the snap and then transmits them through the wires. Consequently these buffered signals are not affected by motion artifacts or other external noise affecting the cables carrying the signals to the board. This interfaces with the piece that actually makes contact with a scalp: a spring loaded finger surface, previously verified in [4].

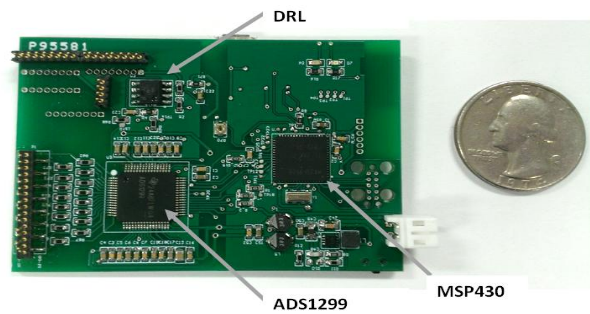

Figure 2 - 16-channel EEG platform designed by our lab

Figure 3 – (left) Electrode snap with buffer circuit (right) attached to finger based dry electrode

3. BCI PARADIGMS
3.1 SSVEP Task
In the proposed BCI system, eight dry electrodes are placed at locations O1, O2, PO3, PO4, PO7, PO8, Oz, and POz according to the 10-20 system and all of them are referenced to the right mastoid. The EEG recording system transfers the collected EEG signals to a PC where the signal processing procedure is performed. In the SSVEP-based system, an LCD monitor is used to display the stimulus. There are four targets in the BCI task, with flickering frequencies of 6 Hz, 7.5 Hz, 8.6 Hz and 10Hz located on the four corners of the screen as shown in Figure 4. The experiments were designed using the Psychophysics Toolbox [5]. The canonical correlation analysis (CCA) method is employed for the SSVEP-based BCI as in [6]. The multi-channel

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EEG signals and each of the reference signals are used as an input of the CCA method. The output canonical correlation is used for frequency recognition.

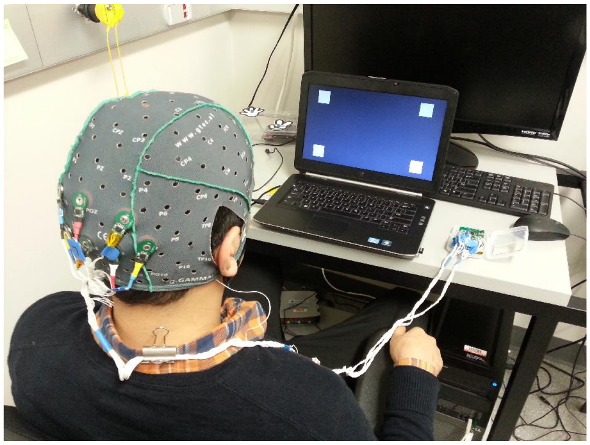

Figure 4 - The distribution of four targets on the monitor

3.2 P300 Speller

The P300 BCI application enables users to spell a word from a 6×6 matrix that includes all the alphabet letters as well as other useful symbols (Figure 5). Certain groups of letters presented on a screen intensify periodically as implemented in [7]. To spell a word, the subjects are instructed to focus on the letter and the EEG signals recorded at scalp locations Fz, Cz, Pz, P3, P4, PO7, PO8, Oz and referenced at right mastoid are used to pick up the P300 potential and infer the intended letter. For each letter, the intensification lasts for 250 ms followed by a 125 ms blank interval. Twelve intensifications make up one epoch which covers all the letters and 15 epochs are carried out for each letter. Thus for one letter, there are 15×12 =180 intensifications. The task of the P300 speller is to identify the subject's desired letter based on the EEG data collected during the 180 intensifications.

Figure 5 - P300 speller matrix with one row intensified

3.3 Motor Imagery Task

The motor imagery BCI application requires 2 dry electrodes placed over the left and right motor cortex areas, C3 and C4, and a reference electrode at Cz Additionally, 6 other next-nearest neighbor electrodes (according to the 10-20 system) placed at F3, F4, P3, P4, T7, T8, are used to perform a surface Laplacian around the electrode sites of interest [8]. This application is similar to the one in [9], and allows the user to move a cursor to the active target (see Figure 6) by controlling the frequencies elicited from the motor cortex. A learning algorithm takes the frequency information from the two electrode locations over motor cortex and interprets that information into a series of vertical and horizontal movements that are applied to the cursor in real time.

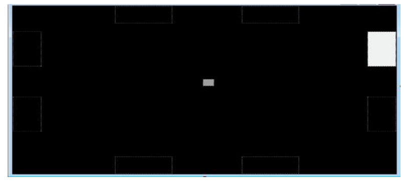

Figure 6 – Motor Imagery Task: the cursor is at the center of the screen, the current active target is at the top right with the other possible targets (total of 8) shown with dashed lines.

4. CONCLUSION

In this work we have presented a 16-channel EEG acquisition system that could potentially be used for daily in-home monitoring of EEG as well as in conjunction with BCIs to enable patients to communicate. The platform uses dry electrodes for comfort, is Bluetooth enabled to wirelessly transfer the data and is battery powered in a small form factor to enhance wearability. We are currently in the process of validating this system in terms of BCI performance for various subjects for tasks such as Motor Imagery, SSVEP and P300.

5. ACKNOWLEDGMENT

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6. REFERENCES

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