Brain and Visual Controlled Mobility Scooter

Bei Cong Zheng, Qiushi Li, Yi Xin Xiang, Jesse Hernandez, Steve Mann
MannLab Canada, 330 Dundas Street West, Toronto, Ontario, M5T 1G5

***Abstract*—A steady-state visual evoked potential (SSVEP) based brain-computer interface (BCI) is developed for use in controlling electric mobility scooters. The BCI is implemented via the Muse brain-sensing headband. For SSVEP, a custom electrode is added to collect EEG data at the Oz position of the occipital lobe. The system is able to operate in real-time and achieve latencies of under a second.**

I. Introduction

Mobility scooters are a pivotal device for helping those with accessibility requirements to move around and otherwise regain their independence to a degree. However for those with severe disabilities operating such devices on their own can be exceedingly difficult, such as when the user does not have the necessary hand dexterity. Fortunately, advances in brain-computer interfaces (BCI) has made it possible for users to control machinery without the need for any bodily motor capabilities. These technological advances have already been used in controlling robotic arms, robots, and wheelchairs [1], [2], [3]. Furthering this field, this reproducibility paper documents the development of a steady-state visual evoked potential (SSVEP) based BCI system for controlling four-wheeled mobility scooters. This system combines recommendations from various state-of-the-art studies to create a single unified solution.

II. System Architecture

The system begins with a visual stimulus, displayed on a LED screen mounted on the front of the mobility scooter. The visual stimulus will evoke signals in the user's occipital lobe, which is detected by the BCI. The BCI then transmits EEG data to the mobility scooter's on-board computer. The on-board computer used was the Jetson AGX Xavier by Nvidia. The Jetson processes the EEG data and then sends serial commands to an on-board Arduino Nano via USB. An optional ESP32 module by Espressif Systems is inserted at this point to facilitate WiFi communication with the Arduino. The ESP32 receives commands via UDP and forwards them to the Arduino via serial communication. This is useful when it is necessary to communicate with the system remotely. After receiving commands from the Jetson, the Arduino generates Pulse Width Modulation (PWM) signals to control the Motor Driver. Finally, the Motor Driver will drive the stepper motors in the mobility scooter. Fig. 1 shows the system diagram. Fig. 2 shows the physical setup of the system.

III. Data Acquisition

For the stimulus, 4 flashing checkerboard patterns were displayed on screen on the top, bottom, left, and right positions (Fig. 3). These positions correspond to moving forward, moving backward, turning left, and turning right. Each checkerboard flashes at frequencies of 7Hz, 8.6Hz, 10Hz, and 12Hz respectively. These frequencies and the checkerboard pattern was chosen among other designs due to their effectiveness in past studies. [4], [5], [6]

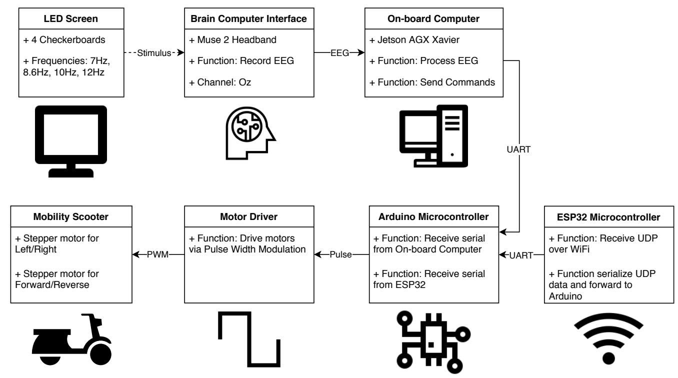

Fig. 1. Diagram of the system architecture

Fig. 2. Left: Side view of mobility scooter. Right: Front view of mobility scooter with participant wearing a Muse 2 Headband

To get the raw EEG signals, the BCI is implemented by InteraXon's Muse 2 Headband (Fig. 4). The Muse is able to provide raw data from 4 EEG channels TP9, AF7, AF8, TP10 (using the 10/20 system) [7]. Additionally, the Muse is able to record measurements on a 5th custom electrode which can be placed anywhere as necessary. Decisively, the 5th electrode is placed in the Oz position because it is the closest location to

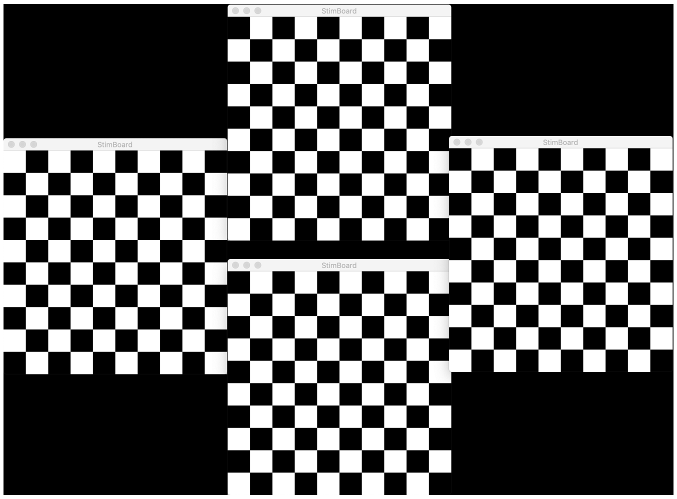

Fig. 3. Visual stimulus for SSVEP

Fig. 4. Left: Side view of Muse 2. Middle: Rear view of Muse 2 and custom electrode band. Right: Front view of custom electrode band.

the occipital lobe. The electrodes used are dry electrodes by OpenBCI shown in Fig. 4, Right.

IV. Data Analysis

EEG Measurements from the Muse are buffered into a rolling window with a length of 2.5 seconds. Because the Muse samples at 256Hz [8], this window contains 640 samples. A second thread repeatedly computes the power spectral density of this window via the Fast Fourier Transform. Then the total power is inspected near each of the target frequencies of 7Hz, 8.6Hz, 10Hz, and 12Hz. If the total power is over the threshold, then it can be considered that the user is focusing on the corresponding checkerboard stimulus. The power spectral density in Fig. 5 shows a noticeable peak at 7Hz when the user's gaze is focused on the 7Hz checkerboard stimulus. Similar results can be seen in the spectrogram in Fig. 6.

V. Control Scheme

Following the analysis of the EEG's power spectral density, the control scheme consists of two subsystems. Code for the first subsystem runs on the Jetson, and code for the second subsystem runs on the Arduino Nano. The Jetson in the first subsystem connects to the Muse and performs the data acquisition and analysis as previously mentioned. However, the acquisition and analysis routines are run on separate threads to minimize latency. Once this subsystem detects that the user's gaze has focused on one of the target frequencies, the Jetson

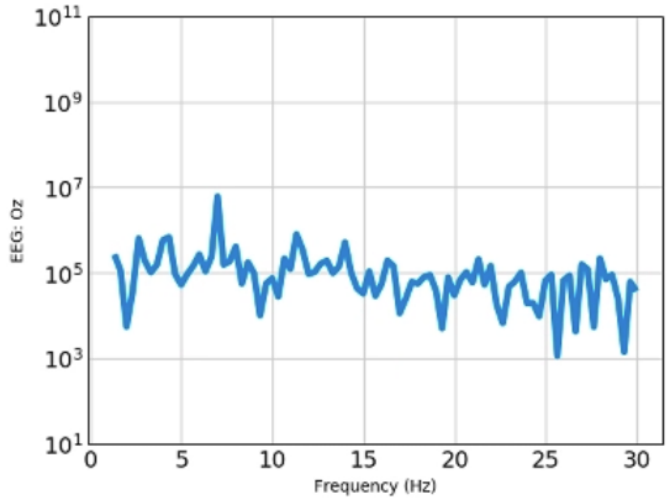

Fig. 5. Power spectral density with peak at 7Hz

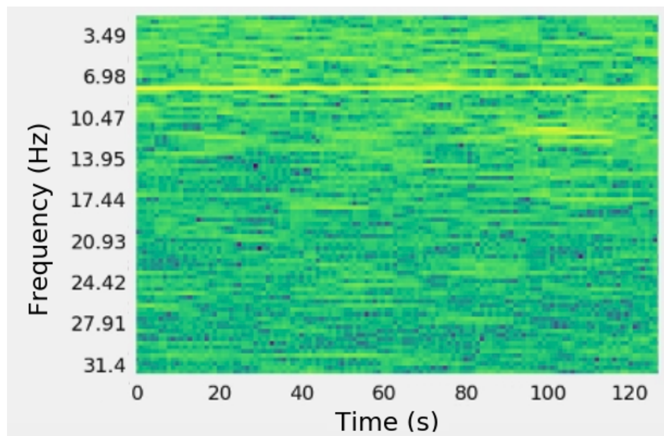

Fig. 6. Spectrogram with high intensity around 7Hz

sends serial commands to the Arduino Nano in the second subsystem via UART. From there, the Arduino Nano parses the commands and sends the corresponding PWM signals to the motor driver. Finally, the motor driver will turn the stepper motors in the mobility scooter. The use of these two subsystems allows communication from the high-level Muse and Jetson, to the low-level Arduino Nano and motor driver. Flowcharts for these two sets of code is shown in Fig. 7.

VI. Conclusion

A real-time SSVEP-based BCI system for controlling mobility scooters was successfully developed. By using the Muse 2 Headband, cost for the BCI system could be kept low in comparison to other alternatives on the market. Through optimizations in software, the system is able to achieve fast response rates with latency under a second. In future iterations, techniques such as sensor fusion and the use of convolutional neural networks can be explored to improve accuracy of the EEG data analysis. While this system was developed for a

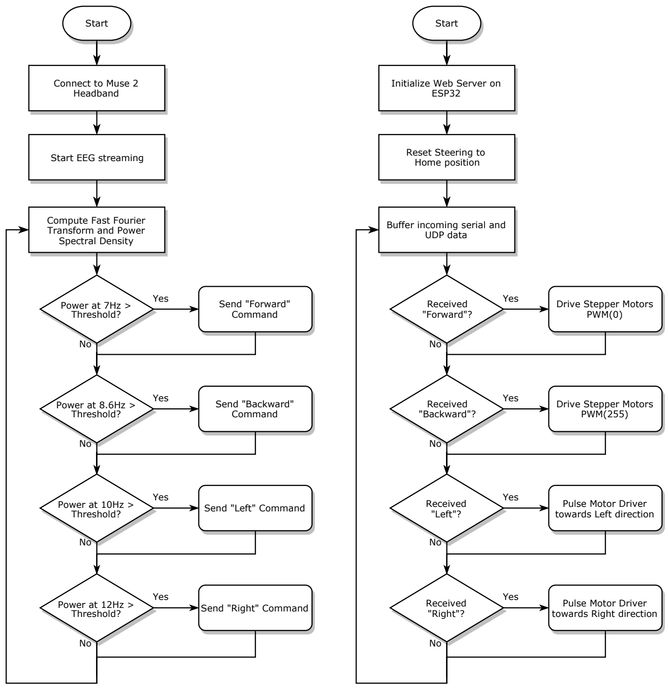

Fig. 7. Left: Flowchart for the Muse interface code on Jetson. Right: Flowchart for the motor control code on Arduino. Their mirrored design is a bridge between the digital Controller and analog Motor Driver

mobility scooter as a preliminary trial, it can be adapted to other accessibility solutions in the future.

ACKNOWLEDGEMENTS

The authors thank the many advisors, affiliates, and students of MannLab and MannLab Canada who helped with the project, including Jeremy and Kyle.

REFERENCES

[1] W. A. Jang, S. M. Lee, and D. H. Lee, "Development bci for individuals with severely disability using emotiv eeg headset and robot," in *2014 International Winter Workshop on Brain-Computer Interface (BCI)*, Feb 2014, pp. 1–3.

[2] G. R. Müller-Putz, P. Ofner, A. Schwarz, J. Pereira, A. Pinegger, C. L. Dias, L. Hehenberger, R. Kobler, and A. I. Sburlea, "Towards non-invasive eeg-based arm/hand-control in users with spinal cord injury," in *2017 5th International Winter Conference on Brain-Computer Interface (BCI)*, Jan 2017, pp. 63–65.

[3] N. Qin and W. Mei, "Wheelchair control method based on combination of ssvep and intention," in *2018 International Symposium on Computer, Consumer and Control (IS3C)*, Dec 2018, pp. 274–277.

[4] E. C. Lalor, S. P. Kelly, C. Finucane, R. Burke, R. Smith, R. B. Reilly, and G. McDarby, "Steady-state vep-based brain-computer interface control in an immersive 3d gaming environment," *EURASIP Journal on Advances in Signal Processing*, vol. 2005, no. 19, p. 706906, Nov 2005. [Online]. Available: https://doi.org/10.1155/ASP.2005.3156

[5] A. Turnip, A. I. Simbolon, M. F. Amri, and M. A. Suhendra, "Utilization of eeg-ssvep method and anfis classifier for controlling electronic wheelchair," in *2015 International Conference on Technology, Informatics, Management, Engineering Environment (TIME-E)*, Sep. 2015, pp. 143–146.

[6] M. M. Ben Khelifa, H. A. Lamti, and J. Grillasca, "A gaze/ssvep based wheelchair command," in *2018 IEEE/ACS 15th International Conference on Computer Systems and Applications (AICCSA)*, Oct 2018, pp. 1–2.

[7] J. Pascau, M. Desco, P. Rojo, A. Santos, J. Lopez, and M. A. Pozo, "Spatial localisation of eeg dipoles in mri using the 10-20 international system anatomical references," in *IWISPA 2000. Proceedings of the First International Workshop on Image and Signal Processing and Analysis. in conjunction with 22nd International Conference on Information Technology Interfaces. (IEEE*, June 2000, pp. 151–156.

[8] A. Mehreen, S. M. Anwar, M. Haseeb, M. Majid, and M. O. Ullah, "A hybrid scheme for drowsiness detection using wearable sensors," *IEEE Sensors Journal*, vol. 19, no. 13, pp. 5119–5126, July 2019.