BCI-based EEG Signal Processing and Application

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***Abstract*— Electroencephalography (EEG) is an efficient means of brain signals acquisition corresponding to motor and sensory states which reflect human behavior. This recording of EEG signals is used for monitoring brain activities, wherein researchers have discussed methods for non-invasive methods of extraction and analysis for faster interpretation of results. In this paper, we set up a prototype integrating brain computer interface (BCI) technology with non-invasive EEG signal extraction processed in real-time integrated on an edge AI device. This extracted data may then be used for behavioral analysis such as emotion recognition, cognitive response, and biomedical applications.**

Keywords—brain computer interface, emotion recognition, electroencephalography, signal processing

I. Introduction

The brain is a significant part of a human which controls the other parts of the human body. It is made up of neurons which release electrical signals of the brain. The use of electroencephalography (EEG) has been utilized for detection of these signals by recording the electrical activity of the brain. EEG is a modality which helps to analyze the brain and its behaviors based on respective frequency of a signal. Significant characteristics of EEG include non-destructive while accurate interpretations, diagnosis, and analysis of brain diseases such as epilepsy, memory loss, Alzheimer's and autism. The classification of EEG signals may be done based on different signal frequencies caused by states or decisions made by the brain, such as eyeball movement, opening or closing of the eyes, hand and finger movement [1].

Brain-computer interface (BCI) technology has been on the rise for the last few decades, especially in clinical applications. Notable usage of this technology is enabling severely disable people to interact with their environment. However, recent studies emphasize the use of non-invasive EEG devices, indicating that BCI may be used outside of a controlled laboratory system [2]. Other uses of EEG-enabled technology focusing on the emotion recognition from the state at which EEG signals were extracted allowing researchers to determine current states. However, the scalability of such research is one of the major challenges that is experienced in this field [3].

The main objective of this paper is to implement real-time EEG signal extraction and integrate with BCI technology for end-user application. The following sections discuss on the prototype configuration, real-time signal processing, and its application, testing, and deployment on the experimental set-up.

II. Prototype Configuration

For the project implementation, combination of the hardware configuration alongside the software algorithm for signal processing was done. The OpenBCI Cyton Board coupled with a OpenBCI Daisy Shield on top of it which is integrated to an edge AI device which is the NVIDIA Jetson NX. The OpenBCI can handle a total of 16 EEG signal channels (CH1-CH16) through the OpenBCI Cyton (N1P – N8P) + Daisy biosensing (N9P – N16P) board. The interfaced cEEGrid technology are lightweight and flexible C-shaped ear-EEG. Each cEEGrid have 10 electrodes represented by right cEEGrid electrode (R1-R10) and left cEEGrid electrode (L1-L10) whereas for this implementation, 8 electrodes is utilized for the left and right ear application. The right and left ears have these EEG channels and pins configuration: (CH1-R1, CH2-R2, CH3-R4, CH4-R5, CH5-R7, CH6-R8, CH7-R9, CH8-R10) and (CH9-L1, CH10-L2, CH11-L4, CH-12-L5, CH13-L7, CH14-L8, CH15-L9, CH16-L10) respectively. OpenBCI + cEEGrid interfaced to NVIDIA Jetson NX prototype can acquire and process signals in real-time. Linux is the main platform of the NVIDIA Jetson NX which is utilized for this implementation.

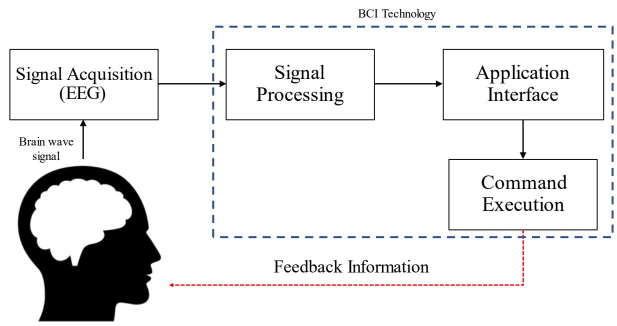

Fig. 1. Brain-Computer Interface Flow Diagram

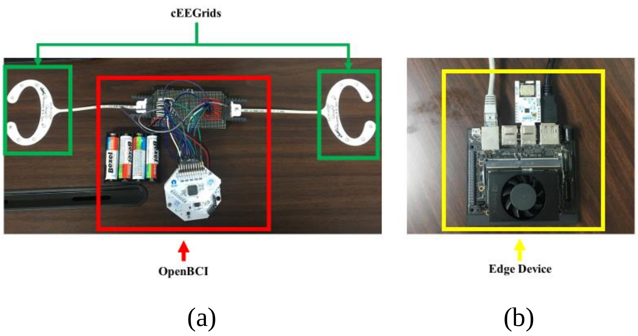

Fig. 2. Actual Prototype Set-up: (a) OpenBCI Cyton + Daisy integrated with cEEGrids (b) edge device (NVIDIA Jetson NX).

III. Results and Discussion

With the main intention of applying the non-invasive EEG signal extraction in real-time, we attach the 8-electrode cEEGrid around both ears of the person by use of conductive adhesive gel. The implementation of the prototype was performed having extractions for two states: eyes are open, and eyes are closed. The data streaming is done five times for each state for a generation of the data set. The extracted EEG signals from the brain is detected by the terminals of the cEEGrid which is processed by use of the integrated BrainFlow algorithms in the OpenBCI hardware.

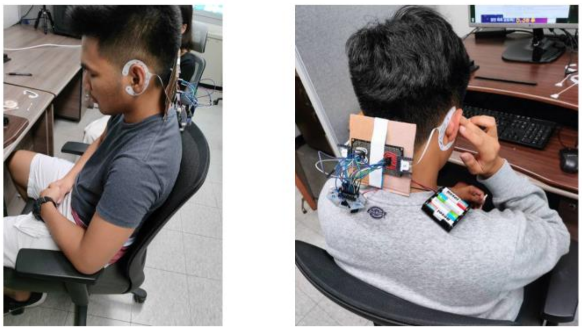

Fig. 3. Actual EEG Signal Extraction and Dataset Creation

For the real-time data acquisition, the sampling rate set is 125Hz at a 15s time interval. Each of the test interval has an expected dataset output of 1,875 EEG signal reading for the 16 channels (8 channels for the right ear, 8 channels for the left ear). Furthermore, the signal resolution used for the EEG signals is 0.02235μV with a gain amplifier equivalent to 24. This leads to a signal range of -187500μV to 187500μV. The EEG signal resolution range and signal range have a directly proportional relationship whereas both have inversely proportional relationship with the gain amplifier. This proposed convergence approach of OpenBCI + cEEGrid integrated to an edge AI device enables state-of-the-art BCI computing. The implementation is utilized for data collection, de-noising, down sampling, band power configuration, EEG signals real-time plotting and EEG metric analysis. The local processing capability of the edge AI device and its computing capability maximizes the potential of BCI computing.

IV. Conclusion

We proposed to implement real-time EEG signal extraction integrated with BCI technology. This was performed by configuring the openBCI hardware with non-invasive ear-EEG signal receptors for the data streaming on both left and right ears. With the intention of analyzing the signal in real-time, the algorithm is implemented on the hardware device. In addition to that, the real-time signal processing extracted the data with purpose, for future use of emotion recognition. From this, we have created a dataset by using this prototype. Furthermore, we also classified the data set of when eyes are in open or closed state.

Acknowledgment

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