Technical Review Paper Evaluation Form

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Team Name: A novel detection method for mTBI

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- Implementation of the technology
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Team Name: A novel detection method for mTBI

Electroencephalogram Sensors for Event-Related Potentials

Introduction

Traumatic brain injuries are both difficult to detect and diagnose due to the current qualitative methods of diagnosis and expensive barriers to entry for quantitative results. With the advancements in biomedical sensing, electroencephalograms (EEGs) have become a vital tool in the detection and classification of human brain activities for relatively low costs. This technical review briefly summarizes some commercially available EEGs in the market today, explains the development of the technology, and examines the building blocks for implementation.

Commercially Available EEGs In the Market Today

EEGs are separated by cost and precision. Single channel EEGs are utilized mostly for their low cost in comparison to multi-channel (up to 256 channels) sensors. An example of this is the Neurosky Mindwave headset. The product features a single channel option with dry electrodes as well as an Analog to Digital Converter (ADC) bit count of 12. The single channel and modest ADC bit count indicate a mid-tier level of accuracy in sacrifice for a low cost of $100. In comparison, the Emotiv Epoc headset consists of 14 channels with 14 bits in the ADC. Along with this, the sensor has a sampling rate 4 times that of the Neurosky at 2048Hz. The improved specifications in performance are priced at $799, almost 8 times the price of the Neurosky. The two products differ in both performance and price with the Emotiv Epoc headset prioritizing accuracy while the Neruosky aims at a lower cost [1].

Unlike the two products, the OpenBCI headset is an open source platform rather than a proprietary product. The headset features 16 channels with a 26 hour battery life (in comparison to 8 hours on the Neruosky and 6 hours on the Epoc) for a cost of $500 for the 8 channel option and up to $949 for the 16 channel option. The benefit of the OpenBCI platform is the ability for free open source development including a 3D printed cap [1].

The Bitalino EEG provides a large bandwidth from 0.8 to 48 Hz [2]. This benefit of performance provides the capability of detecting a diversity of stimuli that could be used for sleep studies (utilizing a low frequency) and evoked potentials (such as from an image or music). The product features a low power consumption of approximately 3mA with a large gain of 4000 [2]. These features allow for a robust use of the sensors for reasons beyond clinical applications.

Technology Behind the EEG

Biological

The EEG is based off the electrical impulses in the brain. The brain tends to produce 5 different bands of frequencies depending on the activity and state of the subject. The 5 bands are the Theta (4–7 Hz), Delta (up to 4 Hz), Alpha (7–13 Hz), and Beta waves (14–30 Hz) [3]. Alpha and Theta waves are associated with calm and relaxed states, Delta waves with deep stages of sleep or infants, and Beta waves with awake and alert consciousness. By classifying these signals, diagnosis of diseases and trauma is possible by monitoring activity levels for the different frequency bands [3].

EEG Sensors

EEG sensors are noninvasive metal discs, called electrodes, that rest on the scalp of the user. The electrodes measure the electrical activity caused from brain cells emitting signals in a non-linear pattern [3]. Electrodes either rest on the scalp with a dry sensor or are placed after the location is coated with an adhesive gel to promote better data accuracy. Because of the low amplitude brainwaves and the added impedance of the scalp, the sensors utilize an amplifier with large gain (usually in the order of magnitude of 1000) to boost the raw data for further processing [2]. The Fast Fourier Transform is then implemented to classify the input into distinct waves with an associated frequency. The resulting processed signals are classified into one of the 5 frequency bands [4].

Typically, the quantity of electrodes and location relative to the scalp result in varying levels of precision. The minimum number of required electrodes to identify sections of the brain experiencing normal and abnormal EEG patterns is 16 with additional channels recommended for monitoring physiological activities and highlighting specific regions. Along with this, electrode placements should align with the 10-20 System indicating electrodes should be separated by 10% or 20% the total distance of the skull [5]. A greater quantity of channels allows a special mapping of the brain that would be impossible with a single channel; however, single channels are utilized for low cost and compact form factors, such as a headband. The performance of single channels depends heavily on the placement of the electrode with performance as low as 23.1% up to 100% depending on where the recording electrode is relative to the source of interest [6].

Building Blocks for Implementation

EEGs are dependent heavily on both the acquisition of raw data in the form of brain waves and the processing of signals for analysis. For the acquisition, an electrode cap containing a varying number of electrodes (depending on if it is a single or multichannel EEG) outputs to a front-end conditioning module. This typically contains an amplifier and filter combination to both boost the signal's amplitude and reduce noise associated with it. This is followed by an Analog to Digital (ADC) converter to provide a digital version of the signal available for processing. From there, tools such as LabVIEW and OpenBCI are popular software used for post processing. OpenBCI is popular in the open source community because it is a free interface in comparison to many proprietary options offered by companies such as Emotiv and Neruosky whose software is exclusive to the respective product [4]. For CPU considerations, processing in clinical settings is typically done on computers, but FPGAs are commonly utilized when mobility is a priority. A popular option for an EEG tailored FPGA is the Cyton Biosensing Board that costs $500. It contains an RFArduino radio module and is Bluetooth compatibile to send data remotely to a host computer. Along with this it is a portable device that is powered by a 6V AA battery pack [1].

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[4] Q. Ai, Q. Liu, W. Meng, and S. Q. Xie, *Advanced Rehabilitative Technology.* San Diego, CA: Elsevier, 2018.

[5] S. R. Sinha, L. Sullivan, D. Sabau, D. San-Juan, K. E. Dombrowski, J. J. Halford, A. J. Hani, F. W. Drislane, M. M. Stecker, “American Clinical Neurophysiology Society Guideline 1: Minimum Technical Requirements for Performing Clinical Electroencephalography,” vol. 33, no. 4, Aug., pp. 303 – 307, 2016

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