The Electroencephalography System

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***Abstract*—The Electroencephalography system (EEG) was developed as an invaluable system to help physicians in distinguishing among the various causes of unconsciousness or comas. EEG is a testing method used to diagnose the disorders related to electrical activities of the brain. The EEG is used for measuring neuronal electrical activities such as the action potentials, which are discretely produced voltage spikes travelling along the axon of neurons towards the terminals in order to release neurotransmitters.**

***Index Terms*—EEG; signal acquisition; signal processing; BCI(brain computer interface); wearable and wireless system; neurons**

I. Introduction

Various technological advances on electronic and information have been made over the past few decades thusly propelling the recent developments concerning biomedical signal monitoring systems to help in evaluating neurological disorders. According to the World Health Organization, neurological disorders are rapidly becoming a threat to public health as such disorders and their outcomes have affected approximately one billion people across the world. As a result, the electroencephalography system (EEG) was developed as an invaluable system to help physicians in distinguishing among the various causes of unconsciousness or comas. EEG is a testing method used to diagnose the disorders related to electrical activities of the brain.

II. THE PARTS OF THE SYSTEM

A. Part 1

One of the most significant branches of research today is the brain-computer interface (BCI), which is increasingly becoming a heated topic in the study of brain science and neural engineering as well as rehabilitation. Such debates arise from the rapid advancements that have recently been made towards biomedical signal monitoring systems. This field of research is relatively new yet has rapidly grown over the past few decades. Furthermore, the most convenient BCI systems that freely moving individuals can adopt using without constraints need not to be invasive or intrusive. Besides, it should be light in weight and able to process online signals. This type of monitoring system comprises of three main parts, the first part is the signal acquisition stage where neural signals are captured as well as noise reduction and artifact processing. This part also comprises of electrodes including both analog and digital circuit systems that help in recording and transmitting neurophysiological signals.

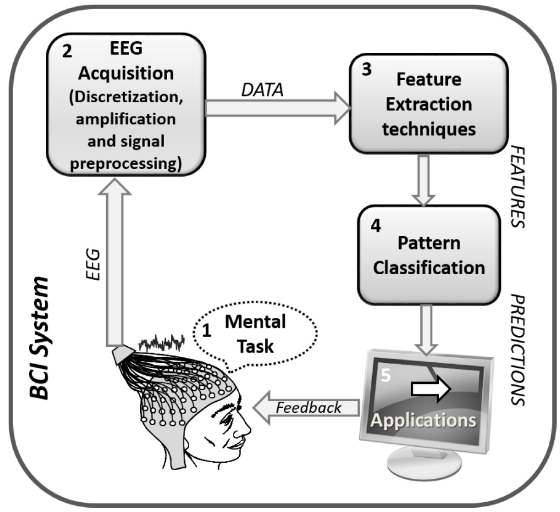

Fig. 1. Parts of System

B. Part 2

The second stage of the BCI system is the preprocessing part where signals are prepared in a suitable form to be processed further. This stage also contains the feature extraction part which helps with the identification of discriminative information presented by the recorded neural signals. Furthermore, the stage comprised of some components for sensing and signal processing to help with the acquisition and brain activity analysis for the purpose of establishing a direct and reliable channel for communication between the brain and external devices such as neuro-prosthesis systems.The figure below shows the basic design and functioning blocks of a typical BCI system (Lin et al. 2010).

C. Part3

The third stage of the system comprises of the translation part where computing devices such as laptops, smart phones, and PDAs are mainly used to perform high-quality processing. After measuring the brain signals, they are mapped onto vectors that contain effective and discriminative features from the signals that have been observed. Therefore, this part adopts the use of an application program for algorithmic processing such as feature extraction and classification for the purpose of converting the recorded neurophysiological signals into information that a computer can read. Moreover, the implanted electrodes in the brain or on the scalp surface often serve the purpose of recording brain signals that are generally obscured by noise and other artificial interference from power lines or displacements of electrodes. Other physiological interference may result from ocular and respiratory activities, including cardiovascular and muscular activities.

D. *Part4*

The brain-computer interface has a computer-based system for acquiring and analyzing neural signals and translating them into commands that get relayed to an output device for the purpose of carrying out the desired action. A single neuron often generates very little electrical potential that the EEG monitoring system cannot easily pick up. The EEG is used for measuring neuronal electrical activities such as the action potentials, which are discretely produced voltage spikes travelling along the axon of neurons towards the terminals in order to release neurotransmitters. However, action potentials cannot be detected easily by surface electrodes as a result of the physical arrangements of the axons as well as their timing. Therefore, the activities of the system often reflect on all the synchronous activities of millions of neurons that exhibit the same spatial orientation. Hence, the ions for cells that lack similar spatial orientations cannot be detected easily because they do not line up to develop detectable wave fronts. Furthermore, most EEG signals are produced by pyramidal neurons found in the cortex due to the effective alignment of the ions. What is happening at cellular level can be understood from figure 2. Firstly, action potential reaches axon terminal and neurotransmitter released diffuses across synaptic cleft with binding post-synaptic receptors. Then, influx of positive(Na, Ca) or negative(Cl) ions happens and generates EPSP.

III. Discussion

Initially, the BCI systems that were traditionally used were bulky and wired. Furthermore, the sensing equipment for measuring the activities of the brain under well-controlled conditions could only be accessed in laboratories, thus making it quite uncomfortable and unreliable for users by impeding their ability to perform other daily routine tasks in their operational environments (Xiao et al. 2019). Besides, the signal processing for BCI systems is associated with large volumes of data, hence prompting an off-line processing method by use of high-ended personal computers. As a result, the processing method hinders the real-world applications of the brain-computer interface system. Therefore, it is important to focus on online BCI systems that are wireless and wearable to be used practically by freely moving individuals to reduce constrains of routine practices in operational environments.

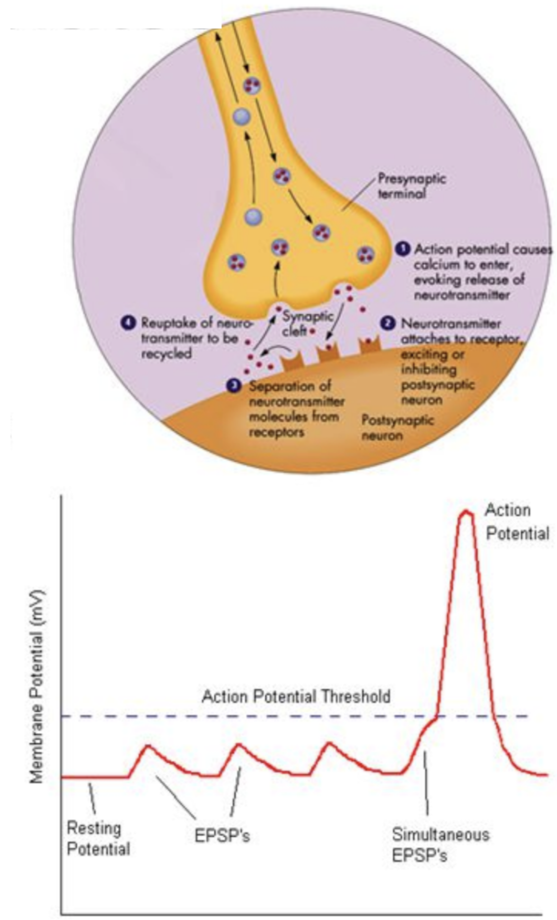

Fig. 2. Parts of System

A. *Cost and Manufacturers*

Despite the limited capabilities of the current BCI systems, they have potential benefits mainly towards individuals with severe disabilities. Besides, the cost of acquiring an invasive BCI system is estimated to be approximately $5,000to$10,000. Such systems can be acquired from various manufacturers across the world such as NextMind, Emotiv, and Neuralink among other manufacturers.

B. *Limitations Of The Biomedical System*

According to the recent research on the impacts of neurological disorders, encephalopathy was acknowledged as one of the most dangerous diseases that continue to threaten human health today. Consequently various monitoring systems and other modern advances such as near-infrared spectroscopy (NIRS) and magneto-encephalography (MEG) have been used alongside electroencephalography to conduct medical diagnosis and promote effective rehabilitation in the affected patients (Consul-Pacareu, Mahajan, Morshed, 2017). Moreover, EEG is the only non-invasive system used for evaluating the neuronal brain functions as well as diagnosing other types of encephalopathy. Even though, the current EEG monitoring devices are generally huge in volume, as such, it is mostly convenient for inpatients. As a result, it becomes quite difficult to monitor outpatient rehabilitation conditions in real timing. Fortunately, several researchers have proposed the adoption of wearable electroencephalography systems to help physicians conduct ambulatory monitoring on patients away from the hospital. Furthermore, physicians will be able to obtain outpatient continuous recordings from these wearable devices, thus becoming a future potential diagnostic tool for monitoring and rehabilitation. Wearable EEG monitoring devices for outpatients are significant in complementary recordings and also important in providing various benefits especially during long-term monitoring. However, these newly developed systems undergo several limitations by inconveniencing patients towards the retrieval of recorded information and provision of timely and accurate classification. Besides, most patients are uncomfortable wearing such EEG monitoring devices.

C. Propose a modification in the system

Therefore, a wireless wearable electroencephalography system is recommended for the daily monitoring of encephalopathy. Such a monitoring device will help by integrating with the electroencephalography sensors for signal acquisition and processing such as Bluetooth. Other major contributions include a mobile terminal with a dedicated monitoring application to display continuous monitoring in real time, including the application of a classified algorithm towards clinical encephalopathy to warn patients before experiencing adverse effects of neurological disorders (Wang et al. 2017).

IV. Conclusion

The brain-computer interface system has rapidly gained much attention in recent years with much focus being put on wearable wireless systems that are operational in real time. The main objective towards the development of such systems aims at maximizing the usability, portability as well as the reliability of such wearable and wireless systems in operational environments. Furthermore, various BCI systems capable of obtaining high-fidelity data are likely to be developed in the near future aimed at explaining the complex functions of the brain in a natural and operational environment.

References

[1] Consul-Pacareu, S., Mahajan, R., Morshed, B. I. (2017).NeuroMonitor: a low-power, wireless, wearable EEG device with DRL-less AFE. IET Circuits, Devices Systems, 11(5), 471-477.

[2] Lin, C. T., Ko, L. W., Chang, M. H., Duann, J. R., Chen, J. Y., Su, T. P., Jung, T. P. (2010). Review of wireless and wearable electroencephalogram systems and brain-computer interfaces–a mini-review. Gerontology, 56(1), 112-119.

[3] Wang, D., Chen, J., Zhao, D., Dai, F., Zheng, C., Wu, X. (2017).Monitoring workers' attention and vigilance in construction activities through a wireless and wearable electroencephalography system. Automation in Construction, 82, 122-137.

[4] Xiao, Y., Jia, Y., Cheng, X., Yu, J., Liang, Z., Tian, Z. (2019). I can see your brain: Investigating home-use electroencephalography system security. IEEE Internet of Things Journal, 6(4), 6681-6691.

[5] Zhang, Q., Wang, P., Liu, Y., Peng, B., Zhou, Y., Zhou, Z., Dai, Y. (2018). A real-time wireless wearable electroencephalography system based on Support Vector Machine for encephalopathy daily monitoring. International Journal of Distributed Sensor Networks, 14(5), 1550147718779562.