EEG and EMG based BCI System - A Review

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Abstract - **The analysis of Electromyography (EMG) signal is one of the effective determinants for the valuable prosthetic devices. Now a day various techniques have been proposed by the researchers for detecting the different hand movements and postures. Ideally, one would observe neural activity, extract signatures of movement intention, and use that as a trigger to provide assisted movement, the contingent feedback, and reward. This is the rationale behind any neuro-rehabilitation approach using restorative BCI (Brain Computer Interface). Recent researches combines Electroencephalogram (EEG) and EMG signals using the spectral power correlation (SPC) to create a hybrid BCI device for controlling a hand exoskeleton. This paper portrays the layout of various physiological signals and reviews the Electromyography (EMG) and Electroencephalography involvement in brain computer interfaces. This paper reviews various research challenges in EMG that booms in the medical era.**

Keywords: EEG, EMG, Amputees, BCI and Rhythms.

I. INTRODUCTION

BCI [1] is an innovative technology that can directly transforms the human thoughts into the machine command. Using this new invention, one can interrelate with the external devices in mind, without the involvement of traditional peripheral neuromuscular pathway. Fig. 1 shows the representation of BCI system applications. The studies related to the realization of BCI shows that people can interconnect through the controlling of the certain components of their electroencephalography (EEG).

The signal originates from postsynaptic potentials, aggregates at the cortex, and transfers through the skull to the scalp are accounted by the EEG as an electrical signal [2]. This creates the space for the development of research areas, to determine the specific status of the electrical signal and the use of that signal as a BCI controller. Several BCI systems are already available in the market such as P300-based brain computer interface using event-related potential (ERP), a 3-state self-paced BCI system, and mental task based BCI system [3].

The task-based BCI system is one of the coolest solutions for implementing BCI computer which can acquire specific state from the electrical brain signal. In general, there are five distinct tasks in mental test such as baseline measurements, complex problem solving, geometric Fig. rotation, mental letter composing, and visual counting. This task was implemented under both eyes closed conditions. So that totally ten different experimental conditions were examined [4]. This mental task-based BCI system is very beneficial to the handicapped person who couldn't use their hand and foot easily because of accident or getting old. By using this system, the communication between those handicapped person and other people become easy and they can operate the home automation system using computer. Though, there is a problem in this BCI system that the implementation of that brain signal inclines to be continuous.

Since brain signal sustains, it is very difficult to control it. Due to that, they tend to be continuous. So that it is necessary that, the BCI system should distinguish the status between try to use and try not to use the control. Though, traditional EEG-based BCIs functioned in a synchronous style, pretentious that the user is forever in the control state.

The key in asynchronous control in an EEG-based BCI system is an efficient computational process to distinguishing between the control state and non-control state of EEG signals. This paper effectively reviews all the available BCI systems and discusses its performance in a comprehensive manner.

II. DIFFERENT TYPES OF BCI SYSTEMS

BCI systems help the disabled persons by serving as assistive tools to sustain and reinstate their lost motor function. There are different types of physiological signals used in BCI such as EEG, EMG and ECG etc. These both signals plays major role in developing BCI systems. Majority of the BCI systems are based on non-invasive techniques called electroencephalograms (EEG) that takes the readings from the scalp. Though this EEG based BCI serves as potential assistive tools, the usability of such system still needs unbroken improvement. The major limitation of such system is the low spatial resolution and the signal-to-noise ratio (SNR) of EEG.
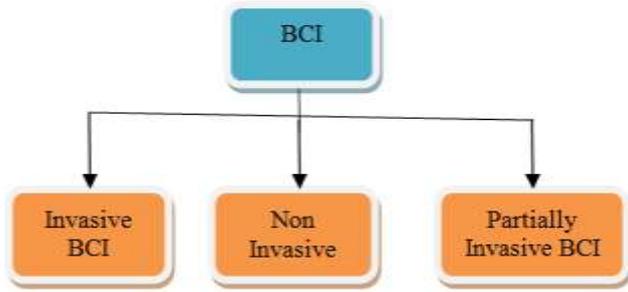
Figure 1: Types of BCI systems

The current trend in BCI is the development of hybrid BCI which is developed by combining the EEG signal with other physiological signals. This will increase the overall performance of traditional single modal BCI systems. In general, there are three different types of BCI systems which is shown in Fig.1. The invasive Brain Computer Interface devices are directly implanted to the brain and record the most quality signals. The partially invasive BCI systems can be implanted inside the skull. The signals obtained by using this type of BCI are weak when compared to the invasive BCI systems. Resolution of this type of system is higher compared to the non-invasive. It also has less chance of scar tissue formation compared to Invasive BCI. As already mentioned, the non-invasive brain computer interface produces signals with less resolution. This type of non-invasive method is very safest than other methods. This type of technique is the one that has mounted medical scanning devices on headbands.

In the literature, various types of BCI systems such as EEG based BCI, EMG based BCI and hybrid BCI is presented. This chapter reviews some of the available BCI systems. The representation of BCI application is shown in Fig.2. The basic process involved in BCI is shown in Fig. 3. First the EEG signal is acquired from the sources and then the noises are removed using some filtering techniques. Then the features are extracted using conventional feature extraction methods. Based on the extracted features, the signals are classified using novel classifiers.

Jose Rouillard et al [1], proposed a hybrid Brain-Computer Interfaces (BCI) that linked the joystick data, EEG of brain and EMG of brain activities to monitor the severe motor disabilities. They focused on the muscular activity which acts as control modality to interconnect with an application. For detecting right movement and left movement, they used some novel data processing and classification techniques. Then the EEG signal processing is done. Sivakumar et al [2] used an EMG detector which detects the possibility of using EMG for detecting hand/wrist extension which in turn triggered the robot assisted training. They compared the result of EMG detector with the sensory motor rhythm based EEG-BCI. This

study showed that the large proportion of severely affected stroke patients will have residual EMG. Andre Ferreira et al [3], developed two dissimilar BCI which are based on electro-biological signals i.e., one is based on the EMG signal and the other is based on the EEG signal.
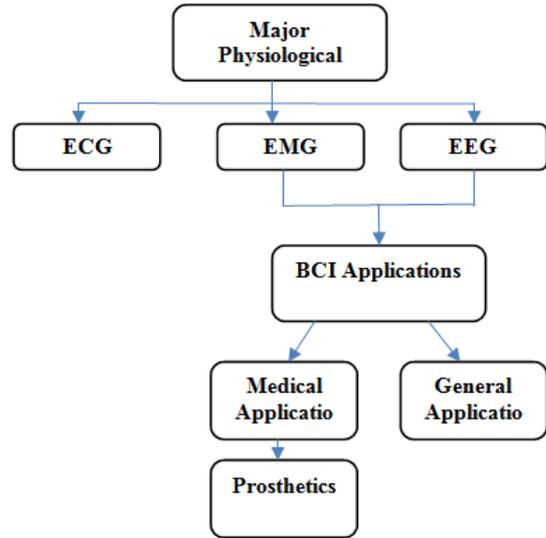

Figure 2: Representation of BCI application

Lin Kat.al., [4], designed the hybrid brain-computer interface which is linked with at least one of the other communication system. They combined the electromyogram (EMG) and steady-state visual evoked potential (SSVEP) to increases the number of targets and the information transfer rate (ITR). They developed the multi-choice selection method for enhancing the system performance. In the paper [5], they concluded that, neurological phenomena are the only source of control for BCI system. They also proposed new mouse control system for solving the problem which was designed from EEG (electroencephalogram) and EMG signals. The experimental result shows that the proposed method has an accuracy of 88%.

Electromyography arte facts are a renowned problem in EEG studies. Although there are some conventional methods to remove this arte facts, some of the EEG source information are also gets removed. To avoid this issue, the author [6] proposed a new technique to select the particular EEG channels which are tainted with the class-dependent EMG. This proposed method showed improvement in class separation. In the paper [7], they used the feature extraction and artificial neural network and achieved 82% of offline classification accuracy for 8 hand motions and 91% accuracy for 6 hand motions based on 200 ms of EMG signal. They also developed the motion detection algorithm and tested it successfully. They also suggested that implementation of

hardware band-pass filter and software optimization will improves the results further.

The completely paralyzed patients cannot move their muscles conferring to their intentions. But the partially paralyzed patients can move some of their muscles and eyes voluntarily. The monitoring of electrical activity produced due to eye blinks and eye movements are known as an electrooculography (EOG). Hence it is convenient to have a BCI system that operates on EMG and EOG activities in addition to EEG.

Figure 3: Basic process in BCI system

The author [8] investigated a variety of signals produce by EMG and EOG activities and thus utilizing them for making an effective BCI system which works according to the user purpose. They have investigated three types of EMG/EOG signals. They are single eye blink, double eye blink and mouth clenching. In [9], D Seth et.al proposed a novel method of inferring the health status based on the power analysis of neurophysiological signals. In [10], a novel method is proposed to identify the human hand movements using EMG-EMG correlation analysis. In order to analyze the ordinary pattern of surface EMG signals, Mutual information (MI) measure is employed. Their comparative experimental results show that autoregressive coefficients (AR) + MI have an improved performance. It is necessary that the signal acquisition hardware should be upgraded to extend the functional nonmedical BCI applications. Choi et.al [11] reviewed and analyzed the current strategy of BCI system. They suggested that this BCI could be characterized using following three important factors such as, source of brain signal, characteristics of brain signal and the characteristics of each system in BCI [12]. This paper proposed a solution to extract the features of EG and EMG quantitative description method to extract instantaneous feature of the EEG and EMG based on local mean decomposition and multi scale entropy.

III. CHALLENGES AND APPLICATIONS IN BCI

The statistics of worldwide brain monitoring devices suggested that the value of $1.08 billion in 2012 grew at a CAGR (compound annual growth rate) of 8.6% and will reach $1.63 billion by 2017. Diverse of brain monitoring devices are offered by commercial market to monitor the brain death and Traumatic Brain Injury (TBI). BCI replaces the use of EEG devices as an investigative tool. BCI was used in various applications. It is mainly used for communication and control such as spelling devices, environmental control and Functional Electric Stimulation (FES) or prosthetic devices. It is also used in neuro physical regulation and rehabilitation. BCI has exciting applications in healthcare field which could consider the advantage of brain signals in every connected phase including prevention, detection and diagnosis, rehabilitation and restoration which are shown in Fig. 4. BCI researchers should employ themselves to undertake three critical problems such as signal acquisition hardware, reliability and training process. These are challenges faced in this particular field. The researchers should concentrate towards this and make a simple solution by applying complex statistical methods.

IV. DISCUSSION AND CONCLUSION

The best operative hybrid BCI system should achieve the following factors. Such that it should have superior classification accuracy, enlarged amount of brain commands for control application, and it should require minimum brain-command recognition time. Some of the hybrid BCI systems for various control applications are shown in table 1.

Figure 4: BCI medical applications

TABLE 1
Hybrid BCI Studies with Various Applications

| Reference	Modality	Classifiers	Accuracy	Applications
Li, Y. Q et.al [13]	EEG+EOG	SVM	92.8%	Cursor control in 2D
Hortal et al. [14]	EEG + EOG	SVM	71.13%	Robotic arm control for pick and place task
Buccino et al. [15]	EEG + fNIRS	LDA	94.2% (for rest-task classification)	Hand movement discrimination
Zimmermann et al.[16]	fNIRS + bio-signals (ECG)	Hidden Markov model (HMM)	88.5%	Feasibility for BCI
Leeb et al.[17]	EEG + EMG	Bayesian	87%	Application to patient motor training
Lin et al.[18]	EEG + EMG	CCA	81%	Choice selection
Aziz et al.[19]	EEG + EOG	SVM, HMM	98%	Automated wheelchair navigation
Shishkin et al[20]	EEG + EOG	LDA	90%	Game control
Zhang et al.[21]	EEG + EOG + EMG	FDA with Mahalanobis distance	75.3%	Application to devices control
Wang et al.[22]	EEG + EOG	SVM	93%	Asynchronous wheelchair control
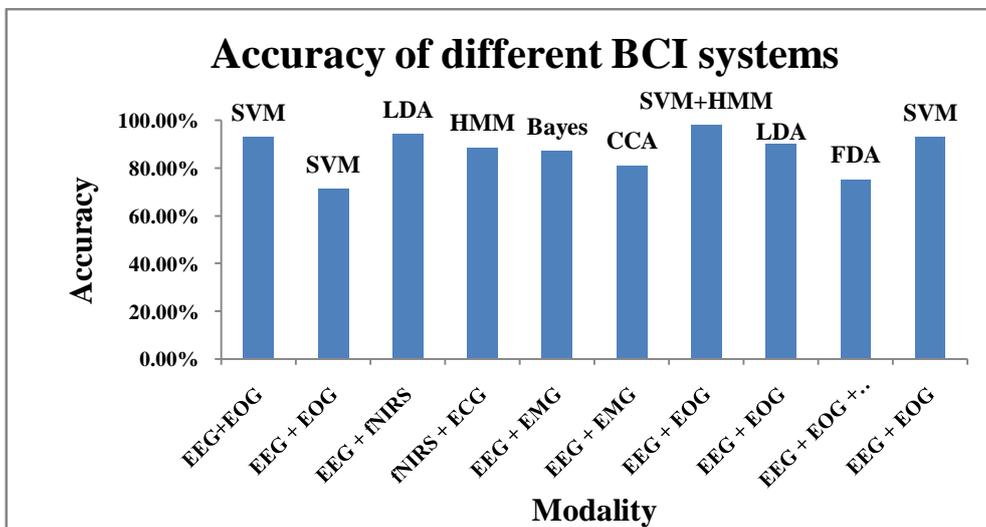
Figure 5: Accuracy of various BCI systems

This table shows that, in the majority of BCI applications the signals can be classified using Support Vector Machine (SVM). This technique is one of the most important machines learning approach for the classification problems. It shows higher accuracy when compared to the other classifiers. In most of these BCI systems the EEG and EOG signals are combined together and provide improved results. The functional near infrared spectroscopy (fNIRS) modalities also combined with EEG for control application which shows 94.2 % of accuracy. Accuracy of various BCI device applications is shown in Fig. 5. In this paper, we methodically go over and analyzed the current state-of-the-art hybrid BCI system. Overall, EEG, EMG and hybrid BCI systems are currently a very energetic and dynamic research topic with countless promising latent outcomes in the near future. The BCI still needs improvement with more secure and sensible EEG caps and electrodes, increased support of operating and short calibration. In order to bring the modern BCI outside laboratories to the users, consumer and to market, it needs many research efforts. The reliability of the BCI can be

improved by a) improving the machine learning based algorithms b) exploring the new developments in machine learning and signal processing and c) improving the BCI user training protocols with human learning theories. Research in the BCI area could be boost up with the adaption of new applications.

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Citation of this Article:

Seeni Mohamed Aliar Maraikkayar S M, Tamilselvi R, Parisa beham M, Sabah Afroze A, "EEG and EMG based BCI System - A Review" Published in *International Research Journal of Innovations in Engineering and Technology (IRJIET)*, Volume 3, Issue 9, pp 17-22, September 2019.

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