ABSTRACT

Augmentative and Alternative Communication (AAC) devices have been developed to assist people who are unable to communicate through speech, hand gestures or eye gaze. AAC devices such as joy stick, communication boards, etc. enhance communication in speech impaired people and thus, help people to interact with the environment. But, people who are undergoing stroke rehabilitation or having neuromuscular disorder such as Amyotrophic Lateral Sclerosis (ALS), and Guillian Barre Syndrome (GBS) express difficulty and discomfort in using these devices, as their limb muscles become paralysed. This condition referred to as Locked-In-Syndrome (LIS), is where people cannot use their normal muscular pathway for communication though their cognition abilities remain intact. So they communicate either through eye movements or eye blinks which sometimes lead to misinterpretation. In those situations, Brain Computer Interface (BCI) provides an alternative and promising solution by addressing the above mentioned limitations of AAC devices, to improve the quality of life in LIS patients.

BCI refers to the interface that manipulates an external device using brain signals or vice versa. The electrical activity of the brain is monitored and analysed for certain features or patterns which are leveraged to manipulate or control a BCI system. P300 is an endogenous potential generated in response to a rare or infrequent visual or auditory stimulus and is referred to as Event Related Potential (ERP). The challenge lies in the interpretation of this underlying information that presents itself as specific patterns in the scalp EEG signal. Thus, one of the translational research areas of BCI, is the development of various signal processing approaches to extract this significant information from EEG signals.

The objective of the proposed research work is to develop and implement signal processing methods that eliminate artefacts from EEG signal and improve detection of endogenous ERP-P300 with better accuracy.

In this research work two preprocessing methods are proposed to improve the signal to noise ratio for better event detection. Signals obtained from 3 standard mid line electrode positions are used to reduce data dimension and computational complexity. Here, the signals recorded from parietal (Pz), central (Cz) and frontal (Fz) positions in response to a stimuli are used for detection of ERP-P300. This will help in designing simple, affordable and portable subject independent BCI system.

Since, EEG is a non-stationary signal, two wavelet based preprocessing approaches, Discrete Wavelet Transform (DWT) and DWT combined Recursive Least Square Adaptive Noise Canceller (RLS-ANC) are proposed and their performance is compared with respect to artefact suppression. This is followed by event detection which is based on the time-domain approaches: ensemble and temporal averaging that result in detection of ERP-P300. The detected events are then template matched and classified using the extracted time domain features. Performances of four different supervised classifiers are compared and the efficacy of proposed methodology is evaluated.

The main findings from this study are

- The proposed pre-processing methods outperforms the state of art approaches like K-Singular Value Decomposition (K-SVD) and Morphological component analysis (MCA)in terms of coherence, root mean square error, signal to artefact ratio and correlation, thereby preserving the EEG content and maintaining the signal quality. The novelty lies in the fact that this method requires no separate baseline correction procedures for P300 detection and reference channel for artefact elimination.

- Time domain averaging in sequence with the proposed pre-processing approaches reduces the computation complexity in P300 detection from single trial. Moreover, this method preserves the morphology of detected P300, which is more important for studies like attention assessment.

- The proposed methods localise P300 events, and the time domain markers, namely, peak and latency, extracted from detected events help in achieving better classification accuracy, by identifying target and non target events in a single trial EEG signal.

- The method also reduces the data dimensionality and computational complexity when compared with approaches that uses channel selection procedures and feature optimization techniques to achieve improved classification accuracy.

On comparing the two proposed methods, DWT method outperforms the DWT combined RLS-ANC as well as the existing approaches that use signals obtained from 3 channels. Classification accuracy of 90.9% and region of convergence area of 0.957 is achieved using Random Forest (RF) classifier. Hence the proposed DWT method is the best of all existing preprocessing methods, and its combination with time domain averaging, makes it suitable for implementation in portable applications used to enhance the quality of life of people who were in need.