ABSTRACT

The disability in stroke patients caused due to their inability to lift the foot during the swing phase of the gait cycle is known as ‘foot drop’. Rehabilitation of the stroke patients with major objective of gait recovery is highly important as soon as their medical condition gets stabilised. Traditional physiotherapy techniques provide limited neurological and motor function recovery leaving the stroke survivors dependent on caregivers to perform activities of daily living. Noninvasive Electroencephalogram (EEG) based brain-computer interface (BCI) technology is increasingly being explored by many researchers as a potential tool for rehabilitation of upper extremity. In spite of large number of EEG based BCI studies on stroke recovery which focuses on rehabilitation of the upper limbs, especially that of hand movements, this option has been explored by very few groups for applications in lower limb rehabilitation. Some of the main challenges in the design of EEG based BCI are due to random, non-stationary and noisy characteristics of EEG signals. Another important drawback in BCI research is the difficulty of reproducing the results of different BCI studies and hence comparing the different algorithms at present is very difficult.

The main objective of the thesis is analysis and detection of lower limb motor activity from EEG signals. Standard estimation procedure was used to compare the maximum amplitude and latency values of the event related desynchronization (ERD) and event related synchronization (ERS) patterns in EEG produced as a result foot dorsiflexion movement in healthy subjects and stroke affected foot drop subjects. Changes in peak amplitude and latency of ERD/ERS patterns in two frequency bands was studied pre and post 12 weeks of Functional Electrical Stimulation (FES) treatment in a group of stroke affected foot drop subjects while they performed foot dorsiflexion movement . Walking is a crucial part of daily physical activity. Feature transformation (FT) based dimensionality reduction techniques, namely, Principal Component Analysis (PCA), Locality Preserving Projections (LPP) and Local Fisher Discriminant Analysis (LFDA) were evaluated for their efficacy in improving the detection of brisk walking (BW) and idle motor imagery (MI) from non-stationary, noise prone EEG signals. EEG signals are highly non stationary signals and pick up a lot of physiological and non-physiological artifacts thereby reducing the signal to noise ratio. Time-frequency (TF)

based analysis ,namely, Short Time Fourier Transform (STFT), Continuous Wavelet Transform (CWT), Multitaper (MT) and Weighted Power Spectral Density (WPSD) methods were also evaluated for classifying the Brisk walking (BW) and Standing Idle (SI) MI tasks. Support Vector Machine (SVM), Shrinkage Linear Discriminant Analysis (sLDA), Random Forest (RF) and Logistic Regression (LR) classifiers performances were compared for classifying the most discriminant TF feature.

Most of the stroke affected foot drop subjects are able to produce ERD/ERS pattern during the foot dorsiflexion movement but at a reduced amplitude and higher latency values compared to the healthy subjects. The effect of FES therapy on the ERD/ERS pattern is different for six stroke subjects studied. It is observed that the peak amplitude and latency values improved, degraded or showed no good patterns post therapy. On applying FT techniques, that transformed complete set of features into a reduced dimension, the classification accuracy of the detection of MI BW and Idle state from EEG signals significantly improved. Among various FT techniques, LFDA performs best in improving the detection of BW MI compared to other FT techniques or without using any FT technique. Among the three techniques, LFDA performed the best showing an average increase in classification accuracy (26.9%), sensitivity (37.6%) and specificity (26.2%) over the average values obtained when no FT technique are used for the group of five subjects. Hence LFDA can be used as a potential dimensionality reduction method in the design of feature based BCI system for detection of BW MI from idle condition. On group level, combination of Common spatial patterns (CSP) with STFT, CWT and MT provided an average increase of classification accuracy of 18.40%, 19.94% and 22.72% over applying STFT, CWT and MT methods directly on the 35 channel data. Therefore CSP spatial filtering prior to TF based feature extraction (FE) improves the detection of BW and SI MI from multichannel EEG signals. WPSD using STFT TF method improves the detection of BW and SI MI tasks by locating the most discriminating channel couple (CC) pair based TF features. Among different classifiers used, optimized SVM-RBF kernel gives the maximum accuracy for all the subjects using WPSD STFT TF features. WPSD with SVM as classifier significantly improves the mean classification accuracy by 28.94% and 8.90% compared to STFT and CSP+STFT with sLDA as classifier respectively. Hence, the effectiveness of feature transformation techniques and nonstationary time frequency methods can be employed in the design of

an EEG BCI system which can be used as a virtual navigation based seated lower limb neurorehabilitation therapy for stroke affected foot drop subjects.

Keyword- Foot Drop, Electroencephalogram (EEG), Brain-Computer Interface (BCI), Lower Limb, Feature Transformation (FT), Time-Frequency (TF)