Improved Feature Set for Mental Task EEG Based BCI

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The traditional feature extraction methods for characterisation of EEG signals, especially in Brain Computer-Interface (BCI) designs, are mostly dependent on time-frequency based methods . Therefore, there is little to no literature on the use of nonlinear features on the characterisation of EEG signals for mental task classification. In this study we set out to investigate the characterisation ability of three conventional linear features namely the band power (BP), autoregressive (AR) model coefficients, AR reflection coefficients and a nonlinear complexity measure namely the approximate entropy (APEN) for classification of multi-channel electroencephalogram (EEG). Furthermore we propose to combine these features in order to improve the classification accuracy of EEG signals which were recorded during motor imagery and cognitive tasks. The EEG data used in this study is the Data set V of BCI Competition III. In this data set, the EEG signals were recorded from three subjects, during imaginary left hand movement, imaginary right hand movement and imaginary word generation starting with same random letter. For testing the separability of features, initially the raw EEG data was high-pass filtered with a cut-off frequency of 0.5Hz and pre-processed with common average referencing. Next, the signals were band pass filtered using eight distinct frequency bands corresponding to delta (0.1-5Hz), theta (5-8Hz), alpha (8-12Hz), sigma (12-15Hz), beta (15-25Hz) bands along with three gamma bands (25-35, 35-45, 45-55 Hz). Finally the data from each frequency band has been spatially filtered using common spatial patterns (CSP) method. Features were estimated from spatially filtered EEG segments. Class separability of individual features was investigated using linear discriminant analysis (LDA) method. The combined feature sets were created by using sequential floating forward search algorithm with LDA classifier (SFFS-LDA) where a subset of 15 features were selected from the feature space. The results have demonstrated that, based on the comparison among features, band power feature provided the highest classification accuracies of 80.02%, 62.07% and 61.65% for subjects 1, 2 and 3 respectively. Combining linear features and nonlinear complexity measure demonstrated a significant improvement in the classification accuracy for all of the subjects where an accuracy of 86.96%, 84.35% and 85.16% was obtained for subjects 1, 2 and 3. These findings demonstrate that the linear and nonlinear features are complimentary to each other where these features represent distinct properties of EEG signals. Hence the linear and nonlinear features provide an enhanced representation and class discrimination when used in combination.

Keywords: Electroencephalogram, Common Spatial Patterns, Band Power, Autoregressive Model, Approximate Entropy