A new feature fusion based technique for classifying multi-class motor imagery problems

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ABSTRACT

The benefit of a Motor Imagery-Based Brain Computer Interface (MI-BCI) is its great independence, which may rely on the user's spontaneous brain activity to run external equipment. However, MI-BCI still suffers from a lack of control effect, which necessitates the use of more efficient feature extraction techniques and classification approaches to extract distinctively separable features from Electroencephalogram (EEG) data. This study suggests a new framework based on bispectrum, entropy, and a similar spatial pattern. We extract MI-EEG signal characteristics using three methods: bispectrum in higher order spectra, entropy, and CSP, and then pick the most contributing features using a tree-based feature selection algorithm. SVM, Random Forest, Naive Bayes, LDA, KNN, Xgboost, and Adaboost classification results were compared, finally, we decided to employ the SVM technique based on the RBF kernel function, which produced the best classification results among them. The proposed approach is used to the BCI competition IV data sets 2a and IVa. The maximum accuracy on the evaluation data set is 85% on data set 2a. The experiment on data set IVa can also yield promising results. Our algorithm's performance has also increased when compared to other algorithms that employ the same data set.

Key Words: *Neuroimaging*

OPINION

Brain–Computer Interface (BCI) is a cutting-edge communication technology that allows for direct data transmission between the human brain and a computer. A typical BCI system procedure is to collect and analyze electrical brain signals, extract their significant aspects after processing, and then identify and categorize mental processes. Electroencephalography (EEG), Functional Magnetic Resonance Imaging (fMRI), Functional Near-Infrared Spectroscopy (fNIRS), and Magnetoencephalography (MEG) are some of the current techniques for measuring brain activity.

Electroencephalography (EEG), a brain mapping and neuroimaging technique commonly utilised in the clinical area, is one of the techniques mentioned above. It is a method for measuring the electric fields created by the active brain.

When compared to alternative brain activity monitoring technologies, EEG is used in the majority of existing BCI systems due to its low cost, non-invasive nature, high temporal resolution, and relatively straightforward recording of brain signals. The Brain–Computer Interface (BCI) is a promising technology that uses informative brain response patterns to correlate to specific mental activities. MI-BCI, for example, enables impaired persons to interact with the world only through brain signals, without the need for real movement. These technologies are built on the idea of recognizing the patients' goals by analyzing brain signals. The basic idea behind the MI-BCI system is to develop a model and utilize specific training scenarios to separate brain signals into several primary motions. The BCI system has recently gotten a lot of interest.

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Controlling a wheelchair, text input, or a lower-limb exoskeleton are some examples of applications that can be utilised to demonstrate its practicality. Motor imagery has been found to contain brain processes that are equivalent to doing real motions. It is anticipated to be utilised as an alternate exercise or to minimize impairment in the absence of exercise capability.

Simultaneously, various feature extraction and classification approaches have played a key role in the advancement of BCI. The majority of brain–computer interfaces based on Electroencephalogram (EEG) rely on machine learning techniques for assistance. On the Graz dataset, Oikonomou et al. employed SVM to categorize EEG characteristics based on Power Spectral Density (PSD) approaches and obtained 79.33% accuracy. B. Kim et al. suggested a frequency-band optimization approach based on a Common Spatial Pattern (CSP). On BCI Competition III dataset IVa, they utilised a Regularized Linear Discriminant Analysis (RLDA) classifier and obtained 68.07% accuracy.

Wang et al. suggested a Shallow Convolutional Neural Network (SCNN). To mine the intrinsic properties of EEG recordings, the network employed a single feature layer. On BCI Competition IV dataset 2b, it achieved 73.0% accuracy. SVM was used by Miah et al. to categorize two kinds of EEG data. Their experimental results demonstrated that averaging covariance matrices with small dimension data using Riemannian geometry can enhance classification outcomes. To extract features and categorize 4-class MI-EEG data, Tang et al. coupled the One-Versus Rest Common Spatial Pattern (OVR-CSP) technique and a unique Convolution Neural Networks (CNN) algorithm. Finally, on datasets IIIa of the BCI2005 competition, it obtained 91.9% accuracy.

Jin et al. suggested a Correlation-Based Channel Selection (CCS) technique for channel selection and extracted useful features using a unique Regularized Common Spatial Pattern (RCSP) method. Finally, on the BCI competition IV dataset 1, the Support Vector Machine (SVM) classifier with the Radial Basis Function (RBF) kernel obtained 81.6% accuracy. Tanga et al. introduced a novel semi-supervised model known as the KNN-based Smooth Auto-Encoder (k-SAE). It searched for the samples' nearest neighbor values to create a new input, achieving 82.86% accuracy on BCI competition IV data set 2b. Li et al. established a system that integrates CSP and rWPLI, and the SVM classifier obtained 70.18% accuracy on the BCI competition IV dataset.

Despite the fact that numerous researchers have advanced many good ideas and methodologies in this discipline and achieved impressive results. However, the derived characteristics and the accuracy of motor imagery EEG signals must be enhanced further. The MI-BCI system's algorithms are classified into three types. The first is based on frequency domain analysis. The second strategy employs temporal analysis. The third classification is based on geographical analysis. In terms of information expression, the single feature extraction approach is not broad and may overlook several various types of features. This research presents a unique hybrid framework, Bispectrum-Entropy-CSP (BECSP), to identify multi-class motor imagery EEG data in order to overcome these constraints. Among them, bispectrum has the benefit of limiting the effect of Gaussian noise and describing nonlinear process features based on time and frequency fluctuation. Entropy is a simple and effective statistical metric for minor changes in non-stationary signals and noise reduction. Furthermore, by maximizing the variance differences of distinct signals in the same projection matrix, the CSP approach may provide feature vectors with greater discrimination. When compared to certain single feature extraction approaches, our method has the benefit of including more detailed information.

Frequency characteristics are represented by bispectrum. The degree of chaos in a signal is represented by entropy. CSP denotes spatial properties. In terms of information content, the suggested technique can contain more discriminative information and aid in boosting usability by offsetting the flaws of one modality with the benefits of another. We initially preprocess the EEG signals with band-pass filtering before extracting the bispectrum features, entropy features, and CSP features. The retrieved characteristics are then fused together in the following stage, such that they contain a range of information. Then we utilize the tree-based feature selection approach to choose features before sending them to the SVM for classification.

This study examines a number of feature extraction and categorization algorithms. We take into account the temporal, frequency, and spatial aspects of EEG signals. Finally, the BECSP framework is proposed in this study, and it achieves good classification performance when compared to certain current approaches.

Because of the extremely restricted information transmission that the two types of BCI systems can achieve, the investigation of EEG signals has steadily evolved from a two-class model to a multi-class model with the development of MI-BCI technology. As a result, research into signal processing and pattern recognition approaches for multi-class EEG classification is required. A unique BECSP framework for recognizing multi-class EEG signals was suggested in this article.