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Enhancing Typing Speed of P300 Speller Using Ensemble of Support Vector Machines with Dataset Manipulation for Increased Diversity

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Abstract

The P300 speller is a valuable brain-computer interface system that allows typing by analyzing electroencephalogram (EEG) signals generated in response to visual stimuli. Among the classification methods employed for the P300 speller, the ensemble of support vector machines (eSVM) is renowned for achieving high accuracy. However, existing eSVM approaches primarily focus on individual classifier accuracy, overlooking the importance of diversity among the classifiers. To address this limitation, we propose a dataset manipulation method that divides the training dataset into distinct groups based on the characteristics of EEG signals generated at different distances between the target letter and the visual keyboard. By training each individual SVM classifier on these diverse groups, we enhance the ensemble's diversity. Experimental results demonstrate that the proposed eSVM approach with increased diversity significantly improves the typing speed of the P300 speller, achieving an average accuracy of 70% with only four repetitions per letter, enabling verbal communication via the Language Support Program.

Keywords: P300 speller, brain-computer interface, electroencephalogram, ensemble of support vector machines, classification accuracy, typing speed, dataset manipulation, diversity.

I. Introduction

The P300 speller is a widely adopted brain-computer interface (BCI) system enabling individuals to spell text on a computer through visual stimulation [1-2]. This system relies on the detection of the P300 component, a positive peak in the electroencephalogram (EEG) occurring approximately 300 ms after the stimulus, which reflects a heightened response compared to other components. To detect P300 signals accurately, various classification methods, including artificial neural networks, linear discriminant analysis, and support vector machines (SVM), have been employed [3-5]. Among these methods, the ensemble of SVMs (eSVM) has demonstrated superior performance in estimating correct letters without true letter information [6]. To foster advancements in signal processing and classification methods for BCIs, the BCI Competition III included P300 speller data, prompting competitors to propose innovative algorithms for accurate letter estimation using training and test data. The eSVM algorithm emerged as the top performer, surpassing single SVM approaches with fewer iterations of training data [7]. By employing an ensemble of classifiers, the eSVM reduces the impact of signal variability by averaging classifier outputs [5]. However, conventional eSVM techniques primarily consider dataset homogeneity in terms of noisy components, neglecting the potential benefits of diversity among classifiers.

Efforts to improve the performance of the P300 speller through ensemble methods have focused on training time and accuracy. Previous attempts employed wavelets and an ensemble of Fisher's linear discriminant (FLD) to reduce training time but resulted in decreased accuracy [8]. Similar outcomes were observed when event-related potential (ERP) signals and FLD were utilized [9]. While clustering training datasets was proposed as a means to reduce training time, only minor improvements were achieved [10]. Additionally, typing speed, an important factor affecting user convenience and the feasibility of real BCI systems, has not significantly improved in previous eSVM studies [8-10]. his paper aims to enhance the typing speed of the P300 speller by modifying the conventional eSVM algorithm. Reducing the number of repetitions in data acquisition enhances typing speed but introduces increased signal variability. To mitigate this issue, we focus on improving the ensemble method by considering both individual classifier accuracy and diversity. Diversity refers to the production of distinct outputs when the same data is fed into multiple classifiers. Higher ensemble diversity, achieved through

address the computational complexity associated with the eSVM. This complexity arises due to the involvement of multiple SVMs, which require solving constrained quadratic programming problems and recursive channel selection in each classifier. One potential solution to this problem is to explore methods that reduce training data since SVM training is known to have a time complexity of O(n^3), where n represents the number of samples in the training data. Another avenue for research is to investigate alternative classifiers with lower computational complexity and high accuracy for further improvements in the P300 speller.

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