JOURNAL OF SOUTHERN COMMUNICATION ENGINEERING
ISLAMIC AZAD UNIVERSITY BUSHEHR BRANCH

E-ISSN: 2980-9231
https://jce.bushehr.iau.ir

https://doi.org/10.30495/jce.2023.1981368.1196

Vol. 14/ No. 54/Winter 2025

Research Article

Imagined Movement Recognition in People with Disabilities Using Common Sparse Spatio Spectral Pattern (CSSSP) and Sequential Features Selection (SFS)

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Received: 7 March 2023
Revised: 1 May 2023
Accepted: 8 June 2023

Abstract

Motor Imagery is a mental process that includes preparation for movement. The brain interface system intends to prepare direct connectivity between the brain and the computer to be aware of the requests of an individual and use them as a control signal for external devices. Motion imaging events occur in the three main frequency bands: beta, mu, and gamma. After preprocessing the EEG data, the next step is to apply various types of filters in order to reduce any residual noise present in the signal. Numerous functional imaging studies showed that motion-imaging results from the specific activation of neural circuits involved in the early stages of motor control. Studies have shown that the CSP algorithm performs better than other algorithms. Due to the lack of a suitable frequency band, the results of the frequency-dependent CSP method are not satisfactory, so the CSSP is similar to the FIR filter, but since this filter does not have all the coefficients of an FIR filter, the presence of noise in the EEG signal can lead to suboptimal definition of the frequency filter. The CSSSP algorithm was used to solve this problem. With using sequential feature selection for feature extraction, it was revealed that CSSSP performance has been better compared to the CSP and CSSP in most cases and the average accuracy was 92.55%.

Keywords: EEG Signal Processing, CSP, CSSP, CSSSP, SFS, Features Extraction, Motor Imagery.

Highlights

- Use a new method based on CSP, but with the aim of decrease drawbacks, so the CSSSP method was used.
- CSSSP performs both spatial optimization and frequency optimization.
- CSSSP simultaneously optimizes a flexible FIR filter with CSP analysis.

Citation: A. Pirasteh, M. Shamseini Ghiyasvand, and M. Pouladian "Imagined Movement Recognition in People with Disabilities Using Common Sparse Spatio Spectral Pattern (CSSSP) and Sequential Features Selection (SFS)," *Journal of Southern Communication Engineering*, vol. 14, no. 54, pp. 83–92, 2025, doi: 10.30495/jce.2023.1981368.1196, [in Persian].

1. Introduction

In order to help people with disabilities, understanding the presence of the coronavirus (COVID-19) pandemic increasingly highlights the need for emerging technologies. As we know, BCI[1] systems were hired to resolve the important challenges on the quality of life of people with disabilities and improve disabled person independence in performing daily activities [1]. Problems that occur after spinal cord complications lead to movement limitations in people even for the rest of the patient's life. Advances in the connection between the human brain and the computer make it possible to classify brain activity and turn it into a control command for a computer or a special device such as a wheelchair or mechatronic arm. The goal is to use the BCI system in general or to create a lost ability in the individual with the help of mechatronic structures and artificial intelligence. When using EEG data, the time dimensions can be analyzed gradually and one by one, and different behaviors in different time frames or frequencies can be examined. The oscillating signals received from the brain are one-dimensional and change with time. When a person is in a normal state and is not engaged in any particular activity, brain signals can be received continuously and uniformly. In 2006, Guido Dornhege introduce a novel approach that allows the concurrent nonlinear optimization of a spatial and a spectral filter improving differentiability rates of single-trial EEG channels [2]. In 2019, Feng introduced an optimized channel draft method based on the CSP algorithm for the BCI system based on motion imaging. Channel selection methods can eliminate these task-independent signals and ameliorate BCI system efficiency. Nevertheless, in different frequency bands, the brain regions related to motor mental imagery are not the same, leading to the incapability of common channel selection approaches to extract effective EEG features. To deal with the above problem, he proposes a new method based on the common spatial pattern or CSP and selecting the channel rank for the multi-frequency EEG band. It uses a combination of signal analysis filter and CSP channel selection method to select meaningful channels and then uses LDA for classification. The accuracy of this method is much better than CSP [3]. In 2019 Javeria presented a way to classify multi-class EEG signals from motion imaging with sub-band spatial patterns. The output of these filters is used to apply features by applying CSP and LDA algorithms. Then, three methods of SVM, NBPW and, KNN were used for classification. An accuracy of 86.5% was obtained for this project [4]. In a 2019 study, Mr. Kurhan classified EEG signals from motion imaging using CSP and convolutional neural networks. The results of this method were very interesting and while the CNN method alone had an accuracy of 43.12%, CNN and CSP together achieved an accuracy of 93.75% [5]. In a 2019 study by Zhang et al., Brain network features were used to increase classification accuracy in BCI systems. According to this paper, CSP has been used to extract features in most studies [6]. In a 2020 study by Yau Guo et al., The FCCP method and the LDA classification were used, with an average accuracy of 82% [7]. In a study in 2021 by Jun Yang, he presents a Multi-Time and Frequency Band Common Space Pattern (MTF-CSP)-based on the EEG approach. As a result, the average accuracy was 78.7% [8]. In another study in June 2022 , Xiaozhong Geng presented that EEG signals are nonlinear and weak signals. The CSP method is an effective and good method for extracting suitable features. The results of this method show that the EEG signals processed in this method have an optimal performance in identifying and removing EOG and ECG artifacts [9]. In another study by Alireza Pirasteh in February 2022, we used the CSSP method and the SFS features algorithm. His approach attains high accuracy compared with the CSP method [10].

The introduction section may provide an overview of the importance of motor imagery in brain-computer interface applications and the challenges associated with using EEG signals for this purpose.

2. Innovation and contributions

In this paper, we use a new method based on CSP, but with the aim of decreasing drawbacks, so the CSSSP method was used. CSSSP performs both spatial optimization and frequency optimization.

Among the innovations of this paper, the following can be stated:

- CSSSP simultaneously optimizes a flexible FIR filter with CSP analysis.
- The CSSSP method with sequential feature selection (SFS) has shown better performance than CSP and CSSP.
- Considering that studies have shown that the CSP method is better than other algorithms in EEG processing for motion tasks and imaging, so we use a new method based on CSP, but with the aim of decreasing drawbacks, so the CSSSP method was used.
- One of the drawbacks of CSP is the selection of a frequency band, and another drawback is related to spatial optimization. CSSSP performs both spatial optimization and frequency optimization.
- CSSSP simultaneously optimizes a flexible FIR filter with CSP analysis and uses a sparsity constraint to avoid the risk of overfitting.
- The CSSSP method with sequential feature selection (SFS) has shown better performance than CSP and CSSP in most cases.

3. Materials and Methods

In the Motor imagery BCI system, a person is asked to imagine body movement. Hence motor imagery, it activates the nervous system, as a result of which events occur in the brain. The task of the BCI system is to extract these events from the sampled EEG signals and to detect the type of motion based on them. The preprocessing step is done for two reasons. The first reason is that since the EEG signal is motor imagery in the beta and mu bands, it is necessary to filter the EEG signal so that only the band information related to the motor imagery stays in the EEG signal. To do this, we use a Butterworth filter. After applying the filters, the reconstructed EEG signal will contain information about the 8 to 30 Hz band (mu and beta band). The second reason for filtering the EEG signal using spatial filters is to increase the localization property of the electrodes. Since each electrode is affected by other parts of the brain when recording, the information that an electrode records is not specific to one area of the brain, thus reducing the performance of our model in the analysis. To solve this problem, a series of spatial filters such as car,

[1] brain computer interface

large and small Laplace is applied. Then CSP, CSSP, and CSSSP were applied to the data to extract the properties and the results were analyzed. As shown in Figure 1, the overall structure of the system under our investigation is as follows.

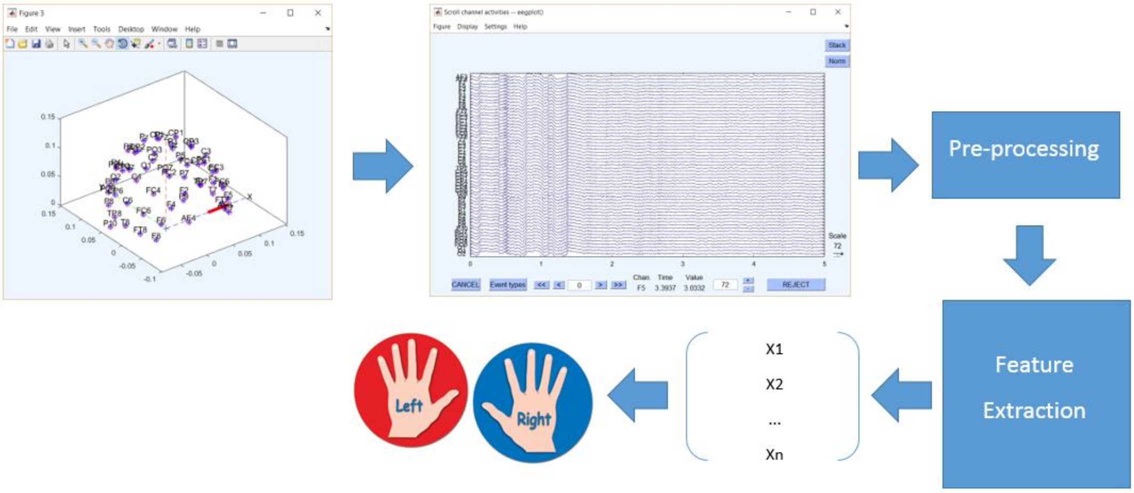

Figure 1. General structure of BCI system, A. Pirasteh et al 2022

The Common Spatial Patterns (CSP) method was initially used to separate abnormal from normal signals in two-class motion imaging systems. It was then generalized to multi-class structures. In this method, using spatial filters, maximize variance in first grade and minimum in second grade. Then extracts first class features from the filtered signals [11]. After applying the CSP algorithm to the data, the number of channels is reduced to two channels and variance is extracted from each channel as features and finally used in classification parts of projects to detect each class.
We derive the cost to weight function from this function and calculate the Common Spatial Pattern. After applying the CSP algorithm to the data, the number of channels is reduced to two channels and data variance is extracted as a feature. This happens due to the use of CSP-based methods, namely CSSP and CSSSP, and the reason is due to the existence of the cost function. After applying CSP-based algorithms to the data, the number of channels is reduced to two channels, and data variance is extracted from each channel as a feature and presented to the class band algorithm to recognize the data class. Selecting the appropriate frequency range plays an important role in the results of the CSP method [12]. The materials and method section may describe the details of the experimental setup, including participant recruitment, EEG recording and preprocessing, and the procedure for motor imagery tasks. The feature extraction section may explain the CSSSP algorithm and its implementation for extracting discriminative features from the EEG signals. The results section may present the experimental results, including the performance of the CSSSP features in classifying different motor imagery tasks and the comparison with other feature extraction methods. The discussion section may provide a critical analysis of the results, highlighting the strengths and limitations of the CSSSP method and suggesting directions for future research.

4. Results and Discussion

In this study, we want to compare corrected common Spatial Patterns such as CSP, CSSP, and CSSSP and improve the computational efficiency and reduce the error of the method by removing irrelevant features or noise. We use sequential features selection (SFS) for features selection. Finally, it is found that from the proposed CSSSP method. By using of sequential features selection for feature extraction, it was revealed that CSSSP performance has been better compared to the CSP and CSSP in most cases and the average accuracy was 92.55%.

5. Conclusion

The results of experiments on different people showed that method CSSSP was s better than methods CSP and CSSP, but this conclusion does not apply to all people, and there have been cases where the performance and accuracy of method CSSSP is less than CSSP and CSP accuracy. Indeed, CSSSP Simultaneously optimizes a flexible FIR filter with CSP analysis and uses a sparsity constraint to avoid the risk of overfitting. But there are some drawbacks to CSSSP method. CSSP method requires a suitable frequency band at the beginning of the work, while CSSSP method depends on an initial optimal starting point. In CSSSP method, due to computational costs and the selection of different parameters in method CSSSP, computational costs will increase and it will be difficult to adjust the parameters.

6. Acknowledgement

This article was extracted from the thesis prepared by Alireza Pirasteh. The authors acknowledge the Department of Biomedical Engineering of South Tehran Branch Azad University, and the Research Deputy for the support of the research.

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Appendix

Table 1: Classification accuracies (%) for motor imagery by CSSSP (C is a regularization constant .This was done to evaluate the impact of the regularization constant on the results.T is a constant that control to avoid over fitting and τ denote to delayed signal)

band	m	τ	T	C	Subject1	Subject2	Subject3	Ave
5-35	1	5	3	0.1	78	96	89	87
5-35	10	5	3	0.1	89.6	96.8	94.6	93.6
5-35	1	10	3	0.1	98.1	94,8	89.6	94.16
5-35	10	10	3	0.1	98,2	90.1	86,2	91.5
7-30	1				98.8	93.2	90	94
7-30	10				98.7	96,1	89.8	94.8
Average					92.64	94.02	90.6	92.55

Declaration of Competing Interest: Authors do not have conflict of interest. The content of the paper is approved by the authors.

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Author Contributions: All authors reviewed the manuscript.

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