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Collective Almost Synchronization Modeling Used for Motor Imagery EEG Classification

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***Abstract*— The purpose of this study is to investigate the performance of the specified dynamical system model called Collective Almost Synchronization (CAS) features in the classification of Motor Imagery (MI) states. A methodology for pattern recognition of EEG signals was established based on the coefficient parameters of the CAS-based linear regression model. Compared with state-of-the-art methods, our proposed method achieved better performance on two-class MI classification.**

I. Introduction

Feature extraction is a crucial part to achieve reliable results of Brain-Computer Interface (BCI) systems. Classification performance can be improved if the features are extracted in a proper way. Traditional methods of feature extraction for MI-EEG, such as the time-domain method, frequency domain, and their combination yield a good description of the characteristics of EEG. However, linear transform methods usually fail to address the non-linear characteristic of EEG signals [1] Human brain can be considered a dynamic network and EEG signals can be modeled by oscillators [2], [3]. By exploring the dynamical nature of EEG, our new approach of feature extraction method addresses to improve the classification accuracy.

II. Methods

The CAS phenomenon shows a specific pattern that can appear in a complex network for weak coupling strength. Some studies aspect of CAS method has been considered in EEG modeling. This phenomenon can be studied using computational models of dynamical systems such as the Hindmarsh-Rose model [2], [3].

Our method includes three steps. Firstly, a complex network of chaotic Hindmarsh–Rose neurons is configured to be a weakly connected network that behave in the so-called CAS state. Secondly, the EEG signals are modelled by linear mixing of these HR neurons. The outcome of linear coefficient is calculated by Pseudo-inverse method. Finally, these coefficients are fed into Convolutional Neural Network (CNN) classifier as input. The CNN are designed simply, as shown in Fig. 1, to avoid overfitting problem.

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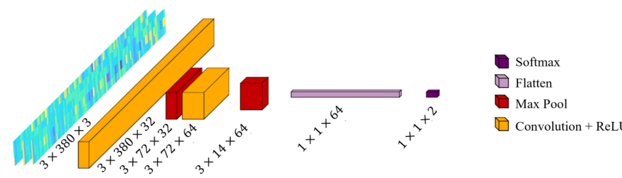

Fig. 1. Architecture of the CNN for the proposed model.

III. Experiments and Results

Our proposed method is evaluated on MI-EEG dataset 2b from BCI IV. The results demonstrate that two main points. Firstly, the CAS-based method significantly improves the classification accuracy between ours (78.2%) and a common method (fast-Fourier transform, 75.0%). The significant differences between those methods were evaluated by a two-sided paired t-test ($p = 0.002189$). Secondly, classification accuracy of our approach (74.0%) is superior to that of CNN hybrid convolution scale (65.3%) and Deep Belief Network (70.0%) for cross-subject classification [4].

IV. Discussion

The performance of proposed feature extraction method was compared with CNN-based methods for both two approaches: inter-subject and across-subjects MI-EEG classification. Through the results of experiments, we found that CAS-based method successfully maintains important features of EEG signals, thereby improving performance. In conclusion, our method demonstrates the superior performance and promising potential of the proposed feature using fewer assumptions. It could pave the way for the practical implementation of an across-subjects BCI.

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