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Motor Imagery EEG Recognition using Deep Generative Adversarial Network with EMD for BCI Applications

Stephan STEPHE, Thangaiyan JAYASANKAR*, Kalimuthu VINOTH KUMAR

Abstract: The activities for motor imagery (MI) movements in Electroencephalography (EEG) are still interesting and challenging. BCI (Brain Computer Interface) allows the brain signals to control the external devices and also helps a disabled person suffering from neuromuscular disorders. In any BCI system, the two most essential steps are feature extraction and classification method. However, in this paper, the MI classification is improved by the performance of Deep Learning (DL) concept. In this proposed system two-moment imagination of right hand and right foot from the BCI competition three datasets IVA has been taken and classification methods utilizing Conventional neural network (CNN) and Generative Adversarial Network (GAN) are developed. The training time is reduced and non-stationary problem is managed by applying Empirical mode decomposition (EMD) and mixing their intrinsic mode functions (IMFs) in feature extraction technique. The experimental result indicates the proposed GAN classification technique achieves better classification accuracy in terms of 95.29% than the CNN of 89.38%. The proposed GAN method achieves an average positive rate of 62% and average false positive rate of 3.4% on BCI competition three datasets IVA whose EEG facts were resulting from the similar C3, C4, and *Cz* channels of the motor cortex.

Keywords: convolutional neural network (CNN); electroencephalogram (EEG); empirical mode decomposition (EMD); generative adversarial network (GAN); intrinsic mode function (IMF); motor imagery (MI)

1 INTRODUCTION

BCI converts the brain doings documented by the human scalp into PC control instructions to regulate the external strategies and thereby assisting incapacitated people in regaining their moto skills [1]. The use of EEGs to control intelligent wheelchairs has been investigated [2], as well as other external equipments. In the brain-computer interface (BCI), the characterization of EEG signals is formed as a significant component. Generally used EEG data contains event-associated SSVEP capabilities [3], and motor image (MI) [4]. The EEG signal has few different features compared to other types of signals. The gathered EEG signs vary according to the subject of the mental state [5]. Therefore, the EEG signs of each subject are different. EEG signs are non-stationary and non-linear, meaning the change of EEG data features over the period of time [6]. Furthermore, the EEG signals analysis is challenging since the composed EEG signals are normally combined with noise. Operative processes should, therefore, be in use to develop the SNR of the EEG data.

The EEG characteristics are controlled by the methods for assessing the frequency and the signal energy delivered in the Time-frequency or Time signal range. As far as the best authors, however, no comprehensive comparative analysis of these methods has been carried out using sophisticated linear and non-linear BCI classifiers in the BCI framework. Most of the comparative values given in the literature are limited to few techniques or only one classification [7]. Wavelet transform (WT) is basically used in the feature extraction process [8], normal spatial patterns (CSP) [9], and Principal Component Analysis (PCA) [10], EMD [11, 12] and so on. Since EMD algorithm is able to optimally split the signal, it has been proven to be a suitable candidate for the examination of non-linear and unsteady EEG signals. For example, [13] uses the EMD algorithm to filter the motor imagery EEG signal. However, common EMD algorithms typically select Intrinsic Mode Functions (IMFs) based on the researcher's experience so that some EEG samples can mix unnecessary information or lose useful data. Additionally, features created using these existing schemes are usually designed by hand, which requires high level of expertise. Therefore, it is very significant to extract the EEG signal active features robotically.

In current period, particular DL methods have been used to categorize EEG signals, among which CNN is the special representative's model for classification. The greater advantage of the DL is that it can deal with non-linear and transient data energetically to extract the feature representations from the unique data. In a study by Amin et al. [14], a multilayer CNN feature fusion model for classifying EEG signals is proposed, and this model extracts the spatial and temporal structures from EEG facts. To match the non-linear and transient features of the EEG signal, CNN features are applied to the autoencoder and the EEG signals are classified. The outcome expresses that the EEG signal detection accuracy has been enhanced. There are some approaches to join traditional feature removal methods with DL techniques [15]. For illustration, Xu et al. [16] used Wavelet transform to change 1-D EEG signals into 2-D time-frequency imageries and it was created as a CNN classifier. The main limitations of CNN for avoiding local optima depends on class imbalances over the data capacity, and initial parameter tuning. Compared with physical analysis of the classification task by using Convolutional Neural Network (CNN), it is found much more convenient, but it needs a certain volume of annotated training instance which cannot be acquired easily. Hence to overcome this issue, Generative Adversarial Network (GAN) is used for classification. In this regard, GAN has achieved satisfactory results. It is believed that GAN can be used to optimize feature information networks, confirm the efficiency of the features used, and improve the ability to select features.

2 RELATED WORKS

Lu et al. [17] has developed a deep learning technique based on a constrained Boltzmann and an FFT to classify the motor imaginary images. Extensive and systematic experiments were carried out with publicly available

Dr.D.SENTHIL KUMARAN, M.E., Ph.D., (NUS)
Principal
SSM Institute of Engineering and Technology
Kuttathupatti Village, Sindalagundu (Po),
Palani Road, Dindigul - 624 002.