Guest Editorial: Advanced Machine-Learning Methods for Brain-Machine Interfacing or Brain-Computer Interfacing

Kaijian Xia, Yizhang Jiang, Yudong Zhang, and Wen Si

This special section of the *IEEE/ACM Transactions on Computational Biology and Bioinformatics* is a selection of 7 papers presented as a special section on Advanced Machine-Learning Methods for Brain-Machine Interfacing or Brain-Computer Interfacing. This special section focuses primarily on novel theories and methods using transfer learning and deep learning proposed for Brain-Machine Interfacing (BMI) or Brain-Computer Interfacing (BCI). Our purpose is to review the new progress and achievements on transfer learning, deep learning, and their applications in BMI or BCI in recent years.

We received 17 submissions to the special issue, based on the review comments from peer reviewers, finally 7 papers (which contains 6 regular papers and 1 survey paper) were accepted. We provide a brief summary of these papers as follows.

In the survey article entitled "EEG-Based Brain-Computer Interfaces (BCIs): A Survey of Recent Studies on Signal Sensing Technologies and Computational Intelligence Approaches and Their Applications," Xiaotong Gu, Zehong Cao, Alireza Jolfaei, Peng Xu, Dongrui Wu, Tzyy-Ping Jung, and Chin-Teng Lin survey the recent literature on EEG signal sensing technologies and computational intelligence approaches in BCI applications, compensating for the gaps in the systematic summary of the past five years. Specifically, they first review the current status of BCI and signal sensing technologies for collecting reliable EEG signals. Then, they demonstrate state-of-the-art computational intelligence techniques, including fuzzy models and transfer learning in machine learning and deep learning algorithms, to detect, monitor, and maintain human cognitive states and task performance in prevalent applications. Finally, they present a couple of innovative BCI-inspired healthcare applications and discuss future research directions in EEG-based BCI research.

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In the article "Epilepsy Signal Recognition Using Online Transfer TSK Fuzzy Classifier Underlying Classification Error and Joint Distribution Consensus Regularization," Yuanpeng Zhang, Ziyuan Zhou, Wenjie Pan, Heming Bai, Wei Liu, Li Wang, and Chuang Lin present an online transfer TSK fuzzy classifier O-T-TSK-FC for epilepsy signals recognition. Compared with most of the existing transfer learning models, O-T-TSK-FC enjoys its merits from the following three aspects: 1) Since different patients often have different neural responses to the same neuronal firing stimulation, the auxiliary data from the source domain cannot accurately represent the primary EEG data in the target domain. Therefore, they design an objective function which can integrate with subject-specific data in the target domain to induce the target predictive function. 2) A new classification error consensus regularization used for knowledge transfer is proposed, and its rationality is explained from the perspective of probability density estimation. 3) Clustering techniques are used to select source domains so as to reduce the computation of O-T-TSK-FC without affecting its performance. They construct 6 transfer scenarios based on the original EEG signals provided by the Bonn University to verify the performance of the proposed O-T-TSK-FC and introduce some baselines for a benchmarking study. Experimental results show that O-T-TSK-FC performs better than baselines and is robust to its parameters.

In the article "A Hierarchical Discriminative Sparse Representation Classifier for EEG Signal Detection," Xiaoqing Gu, Cong Zhang, and TongGuang Ni present a hierarchical discriminative sparse representation classification model (called HD-SRC) for EEG signal detection. Based on the framework of neural network, HD-SRC learns the hierarchical nonlinear transformation and maps the signal data into the nonlinear transformed space. Through incorporating this idea into label consistent K singular value decomposition (LC-KSVD) at the top layer of neural network, HD-SRC seeks discriminative representation together with dictionary, while minimizing errors of classification, reconstruction and discriminative sparse-code for pattern classification. By learning the hierarchical feature mapping and discriminative dictionary simultaneously, more discriminative information of data can be exploited. In the experiment the proposed model is evaluated on the Bonn EEG database, and the results show it obtains satisfactory classification performance in multiple EEG signal detection tasks.

In the article "Advanced Machine-Learning Methods for Brain-Computer Interfacing," Zhihan Lv, Liang Qiao, Qingjun Wang, and Francesco Piccialli present a data classification model by integrating transfer learning algorithm and the improved Common Spatial Pattern (CSP) algorithm. Finally, the effectiveness of the proposed algorithm is verified. The results show that in actual and imagined movements, the accuracy of the left- and right-hand movements at different speeds is higher than when the speeds are the same. The proposed Adaptive Composite Common Spatial Pattern (ACCSP) and Self Adaptive Common Spatial Pattern (SACSP) algorithms have good classification effects on 5 subjects, with an average classification accuracy rate of 83.58 percent, which is an increase of 6.96 percent compared with traditional algorithms. When the training sample size is 10, the classification accuracy of the ACCSP algorithm is higher than that of the traditional CSP algorithm.

In the article "A Multi-Scale Activity Transition Network for Data Translation in EEG Signals Decoding," Bo Lin, Shuiguang Deng, Honghao Gao, and Jianwei Yin present a multi-scale activity transition network (MSATNet) to alleviate the influence of the translation problem in convolution-based models. MSATNet provides an activity state pyramid consisting of multi-scale recurrent neural networks to capture the relationship between brain activities, which is a translation-invariant feature. In the experiment, KullbackLeibler divergence is applied to measure the degree of translation. The comprehensive results demonstrate that their method surpasses the AUC of 0.0080, 0.0254, 0.0393 in 1, 5, and 10 KL divergence compared to competitors with various convolution structures.

In the article "Subject-Independent Emotion Recognition of EEG Signals Based on Dynamic Empirical Convolutional Neural Network," Shuaiqi Liu, Xu Wang, Ling Zhao, Jie Zhao, Qi Xin, and Shui-Hua Wang present a subject-independent emotion recognition algorithm based on dynamic empirical convolutional neural network (DECNN) in view of the challenges. Combining the advantages of empirical mode decomposition (EMD) and differential entropy (DE), they proposed a dynamic differential entropy (DDE) algorithm to extract the features of EEG signals. After that, the extracted DDE features were classified by convolutional neural networks (CNN). Finally, the proposed algorithm is verified on SJTU Emotion EEG Dataset (SEED). In addition, they discuss the brain area closely related to emotion and design the best profile of electrode placements to reduce the calculation and complexity. Experimental results show that the accuracy of this algorithm is 3.53 percent higher than that of the state-of-the-art emotion recognition methods. What's more, they studied the key electrodes for EEG emotion recognition, which is of guiding significance for the development of wearable EEG devices.

In the article "Predicting Human Intention-Behavior Through EEG Signal Analysis Using Multi-Scale CNN," Chenxi Huang, Yutian Xiao, and Gaowei Xu present a multi-scale CNN model-based EEG signal classification method. In this method, first, the EEG signals are preprocessed and converted to time-frequency images using the short-time Fourier Transform (STFT) technique. Then, a multi-scale CNN model is designed for EEG signal classification, which takes the converted time-frequency image as the input. Especially, in the designed multi-scale CNN model, both the local and global information is taken into consideration. The performance of the proposed method is verified on the benchmark data set 2b used in the BCI contest IV.

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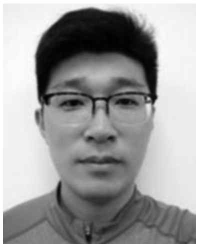

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