ABSTRACT

The urgent need for accurate emotion recognition, combined with the rapid growth of mental health problems, necessitates the development of appropriate techniques for EEG-based emotion recognition systems. Conventional EEG signal feature analysis methods extract features for classifier models and utilize multiple feature representations to enrich the EEG signal analysis by providing diverse perspectives. However, this multifaceted feature engineering introduces challenges, such as the curse of dimensionality leading to overfitting and the need to identify redundant or irrelevant features. Additionally, EEG data are complex, high-dimensional, nonstationary, and nonlinear, making emotion recognition tasks even more challenging.

To address these challenges, in this study, EEG signals were transformed into advanced input image representations, enabling direct processing with CNN-based classifiers without conventional feature extraction. These advanced input formulations aim to enhance the EEG-based emotion recognition. An innovative multirepresentation (MR) input formulation mitigates the curse of dimensionality associated with multifaceted feature engineering. Furthermore, the inherent complexity of EEG signals is managed through an asymmetric windowing recurrence plot (AWRP) input formulation.

The proposed methods include the introduction of a multi-representation convolutional neural network (MrCNN) model designed to classify EEG signal image representations derived from the MR input formulation for recognizing complex emotional states. By integrating multiple EEG signal image representations, MrCNN can classify complex emotional states and improve emotion recognition performance. Additionally, to enrich the input data texture and enhance the CNN-based classifier performance, an AWRP input formulation was developed. The DEAP and SEED datasets were used to validate the proposed methods, and the performance was evaluated using the accuracy, F1 score, and Kappa metrics.

Empirical evaluations using the DEAP and SEED datasets demonstrated that the MrCNN model outperformed single-representation input techniques, achieving an accuracy of 0.9663, F1 score of 0.9656, and Kappa of 0.9511 on the DEAP dataset and an accuracy of 0.9695, F1 score of 0.9695, and Kappa of 0.9543 on the SEED dataset. The AWRP input formulation significantly improved the classification performance by considering the nonlinearity and nonstationarity of EEG signals compared to conventional recurrence plot input formulations, achieving an accuracy of 0.9984, F1 score of 0.9984, and Kappa of 0.9977 on the DEAP dataset and an accuracy of 0.9969, F1 score of 0.9969, and Kappa of 0.9953 on the SEED dataset.

This study demonstrates how strategic input formulation, combining an image representation of EEG data with CNN-based classifiers, can enhance the model performance in distinguishing between different emotional states. Thus, the present study lays the groundwork for subsequent research on practical applications of the proposed methodology.

Keywords—EEG, Emotion Recognition, Image Representation, Input Formulation, Multi-Representation, Multi-Representation Convolutional Neural Networks, Asymmetric Windowing Recurrence Plots.