EEG-Based Cognitive State Assessment Using Deep Ensemble Model and Filter Bank Common Spatial Pattern

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Abstract

Electroencephalography (EEG) is the most used physiological measure to evaluate the cognitive state of a user efficiently. As EEG inherently suffers from a poor spatial resolution, features extracted from each EEG channel may not be efficiently used for the cognitive state assessment. In this paper, the EEG-based cognitive state assessment has been performed during the mental arithmetic experiment, which includes two cognitive states (task and rest) of a user. To obtain the temporal as well as the spatial resolution of the EEG signal, we combined the Filter Bank Common Spatial Pattern (FBCSP) method and Long Short-Term Memory (LSTM)-based deep ensemble model for classifying the cognitive state of a user. The proposed deep ensemble model consists of multiple similar structured LSTM networks that work in parallel. The output of the ensemble model (i.e., the cognitive state of a user) is computed using the average weighted combination of the individual model prediction. This proposed model achieves 87% classification accuracy, and it can also effectively estimate the cognitive state of a user in a low computing environment.

1. Motivation

1. In CSP, classification result is highly influenced by the selection of subject-specific EEG band. To overcome this issue, we use the Filter Bank Common Spatial Patterns (FBCSP) method that used all the frequency bands of EEG for each subject.
2. The proposed deep ensemble classifier consists of multiple deep models that efficiently predict the unseen data by combining the prediction of each classifier using some voting system.

2. Framework

1. Subject-wise data distribution has been performed due to the execution of a large volume of data in a low computing environment.
2. Filter bank is created by decomposing the EEG signal into eight equal-sized frequency bands.
3. CSP algorithm has been applied to extract the spatial features from each of those bands.
4. Most discriminate CSP features from each filter bank have been identified using the Mutual Information-based Best Individual Feature (MIBIF) method.
5. Subject-specific optimum CSP features have been fed into the LSTM model for cognitive state classification.

The framework of this proposed model is shown in Fig.1(a). The working procedure of the deep ensemble model is depicted in Fig.1(b).

6. Conclusion and Future Work

Conclusion:

1. The proposed deep ensemble model can efficiently identify the cognitive state of a subject with 87% classification accuracy.
2. The model can be effectively utilized for the execution of a deep model over a large volume of data in the low computing environment.
3. Due to low computational resources, we experimented on fourteen subjects among the total thirty subjects. The proposed model achieves the maximum accuracy with ten subjects (Fig.3 (b)).

In the near future, we will revise the proposed model by adding multimodal functionality (EEG and NIRS) for more number of subjects.

3. Proposed Methodology

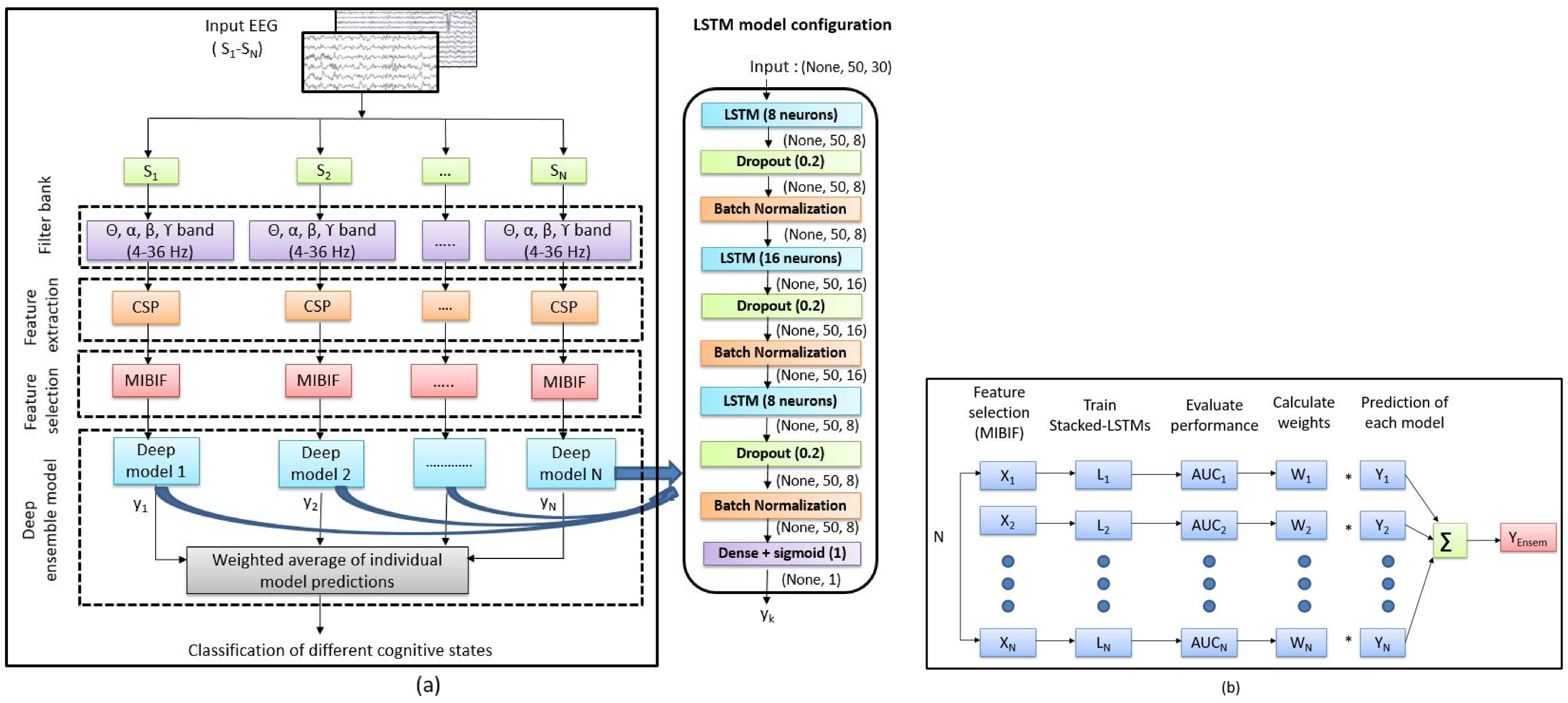

Fig.1.: (a) Framework of the proposed model & individual deep LSTM network, (b) Working procedure of the proposed ensemble model

4. Results

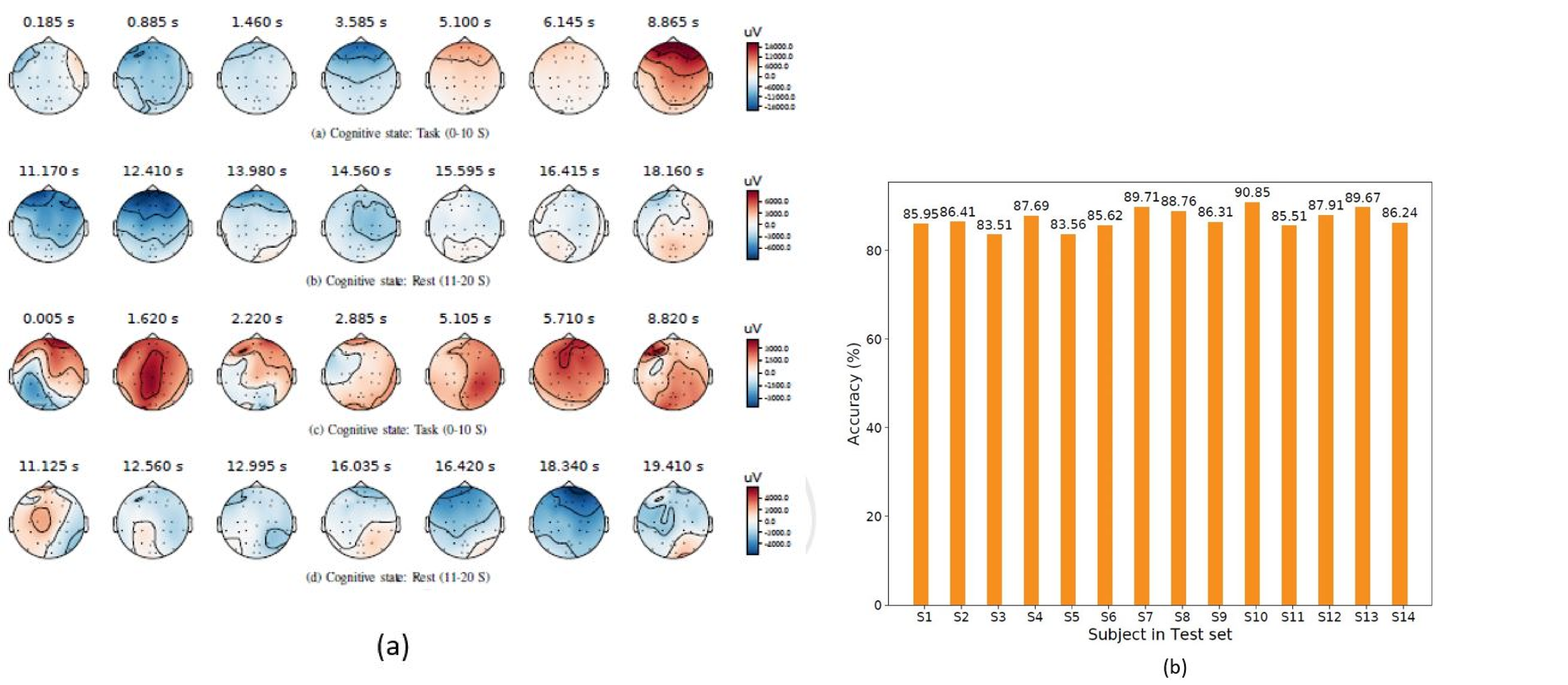

Fig.2.: (a): CSP filters (topographic map) of EEG bands for cognitive state task and rest: theta band (1^{st} and 2^{nd} row), alpha band (3^{rd} and 4^{th} row), (b) Subject-wise performance analysis: Result of Leave-subject-out experiment.

From Fig.2 (a), it can be observed that the CSP filter of alpha-band (3^{rd} filter of the 3^{rd} row) can effectively distinguish the two cognitive states of a subject.

5. Performance Analysis

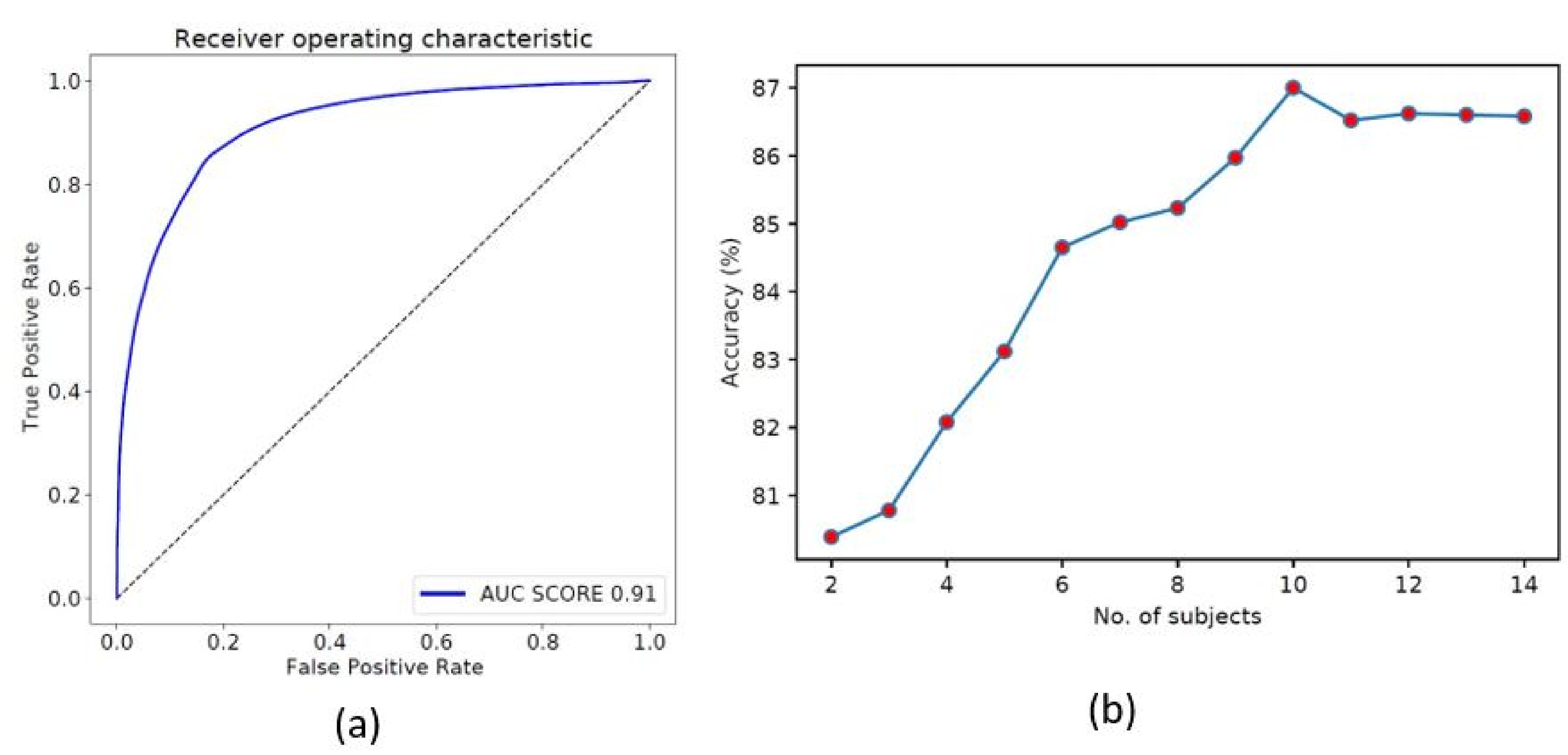

Fig. 3: (a) ROC Curve of the model, (b) Result of scalability test.