CNN LSTM Combined Network for Artifact Identification in Multi-channel EEG data

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Abstract. A diverse range of physiological data is nowadays recorded continuously for a wide range of cognitive and health monitoring applications. Electroencephalogram (EEG) signals are important physiological data for a variety of brain monitoring and computer interfacing devices. However, there are also some contaminating signals mixed with EEG signals which are not originated from cerebral activities. Such contaminating signals, termed as artifacts, require efficient methods for identification and analysis.

Deep learning algorithms have shown tremendous success in extracting useful knowledge and features from multi-modal time-series data. However deep learning models are computationally and memory intensive, making them very challenging to deploy in embedded systems with limited hardware resources and power budgets. This paper proposes an efficient machine learning classifier that can identify multiple artifacts on continuous multi-channel EEG data. The EEG data were recorded using a 64 channel BioSemi Active Two System with a sampling rate of 512 Hz. Participants were required to perform 10 different ocular or muscular artifacts. Additionally, each participant performed a baseline recording session where they were not doing any ocular or muscular movements and that baseline session was used as 'clean' (or artifact-free) data. We considered 10 different artifacts including clenching jaw, move jaw, blink eyes, move eyes leftwards, move eyes rightward, raise eye-brows, rotate head, shrugging shoulders and rotate torso. EEG epochs of size 64*512 are extracted both from artifact and artifact-free signals with different step sizes. In the proposed classifier, one dimensional separable convolutional neural network (CNN) is used to extract features and then Long Short-Term Memory (LSTM) followed by dense layer are used to identify the EEG artifacts according to the extracted features. Our proposed model consists of one 1-dimensional separable convolution layer with 16 filters and each of size 4, one 1-dimensional max-pooling layer of size 16, one LSTM layer having 16 units, one dense layer having 20 neurons and one output layer for identifying 10 artifacts. ReLU was used as activation function for separable convolution and dense layer whereas, tanh and sigmoid are used for the LSTM layer. Softmax is used as activation function for the output layer. All the layers of the network have their weights initialized from a normal distribution. Adam optimization with a learning rate of 0.001 was used while training the network. Categorical cross-entropy was used as the loss function. Separable convolution is used instead of traditional convolution to reduce the number of operations required. The experimental results show that the proposed classifier achieves 93.25% average accuracy which outperforms both standalone CNN and standalone LSTM, in terms of identification accuracy, memory requirements and required number of operations which determines the power efficiency on embedded hardware design. The trained model was also implemented on an Artix FPGA as well as an embedded NVIDIA Jetson TX2 platform for evaluating the energy-latency trade-off. From the experimental results, the lowest power consumption was achieved with only one core of the CPUs running at its minimum clock frequency of 345 MHz. On the other hand, the lowest energy per classification was obtained with the single-core CPU running at its maximum frequency of 2035 MHz.

Keywords: Deep Learning, CNN, LSTM, EEG, Artifacts, Low Power Embedded