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Master's thesis

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Automatic detection of sleep spindles by deep learning me-

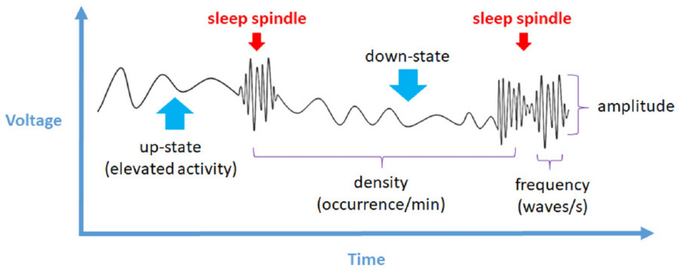
Abstract

Sleep is an integral part of human life, and the average person sleeps about one-third of their life. Therefore, it is important to understand sleep and analyze it correctly. The goal of this master thesis is to propose, design, implement, and test various machine/deep learning methods suitable for EEG signal processing to identify sleep spindles. The learning algorithms were trained on well-annotated data provided by the Montreal Archive of Sleep Studies (MASS) data center.

Introduction

The goal of this master thesis is to propose, design, implement and test various machine/deep learning methods suitable for EEG signal processing. The research is focused on the use of neural networks such as CNN, LSTM, and Dense and their combinations. The success of the network is evaluated by the classification of sleep spindles.

Analysis



The figure shows sleep spindles in comparison with other EEG signals.

Data

The data are provided by the Montreal Archive of Sleep Studies (MASS). The study includes eight males and eleven females. More information is in the table below.

Number of sleep records	19
Number of sleep spindles	11204
Maximum duration of spindle	2.21 sec
Minimum duration of spindle	0.33 sec
Average age of subjects	24.3 years

The basic information about provided data

Methods

Neural networks

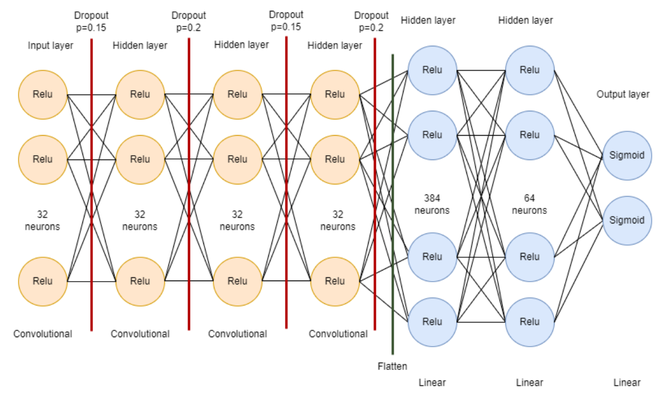
An artificial neural network (ANN) is one of the computational models used in artificial intelligence. An artificial neural network is a structure designed for data processing and exists in various types. LSTM, CNN, and Dense neural networks were chosen as promising models for classifying sleep spindles.

Value-based method

The principle of this method is that it sums the measured values and compares the resulting values with each other. For the technique, it is critical to interpolate the set of values by the border correctly. Everything below the border is marked as a non-spindle, and everything above the border is marked as a spindle.

Results

The worst results were provided by the LSTM and a variety of LSTM-CNN neural networks. These networks reached an accuracy of 52.81%, corresponding to the ratio between the number of spindles and non-spindles sets.
Slightly better results were reached using the Dense and CNN networks from the Keras packages. Their classification accuracy was around 60-65%. The best result was provided by the CNN neural network implemented in the Torch package. This neural network that contains four CNN layers and three linear layers is shown in the figure below. It reached an accuracy of over 67%.



The neural network with the best accuracy (67%)

The value-based method correctly classifies over 64% of spindles and non-spindles based on the input part of the EEG signal.

Conclusion

The best classification accuracy was reached by the CNN neural network (over 67%). Binary cross-entropy is used as the loss function; the network needs 2000 epochs to train. The process of learning is shown in the table below.

Number of input neurons	Number of output neurons	Time to process	Accuracy	The number of epochs
64	2	732 sec	57.29%	500
64	2	1023 sec	63.89%	1000
64	2	1455 sec	65.96%	1500
64	2	2836 sec	67.15%	2000
64	2	3637 sec	67.15%	2500

The learning process of the CNN neural network with the best classification accuracy.

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