Work-in-Progress: Sleep Stage Prediction via Deep Learning using Actigraphy Data to Detect Disorders by Modeling Sleep.

Omar Barazanji & Dr. SueAnne Griffith

Dept. of Electrical and Computer Engineering, Auburn University

Introduction

Sleep is one of the most important functions in the human body. It is also very predictable and has expected patterns that we can model. Sleep activity can be either quiet, non-rapid eye movement (NREM) or active, rapid eye movement (REM) sleep. To capture sleep data, high sensitivity accelerometers can be attached to the wrist and other parts of the body during sleep to capture the predictable movements during NREM/REM. This data is referred to as actigraphy. There are existing models that can automatically label actigraphy data, but there is a lack of models that can accurately predict disorders that affect sleep.

Objective / Mission

In this study, we used datasets on regular sleep activity to train a model that can accurately predict and label sleep/wake from actigraphy. We then will create a custom dataset on patients with known disorders that affect sleep. Through a mix of public datasets and sleep studies, we can add labels for each person's known disorder. With the disorder labels on the actigraphy data, our trained model will be able to predict if a person might have certain disorders or not, such as Sleep Apnea.

Datasets

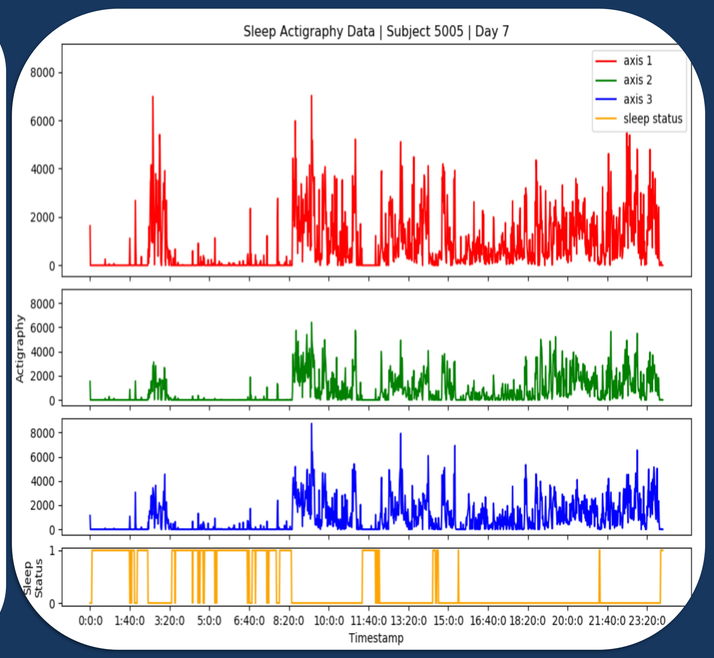
1. Sleep Actigraphy from the Urban Poor in India
   - Contains 3-axis accelerometer data from 30 participants.
   - Data is labeled with sleep status, either a 1 or a 0 for asleep or awake, respectively.

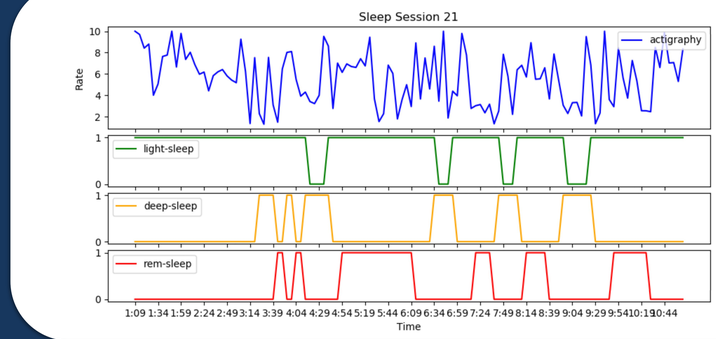
2. Sleep as Android Watch Actigraphy
   - This dataset contains labels for sleep stages as well as lux, snoring, bpm, and more.
   - Data is collected from a compatible Wear OS device during sleep and is converted into a single actigraphy curve for sleep stage prediction.

Methods

Time-Series Forecasting: RNNs and the LSTM Neural Network.

- Recurrent Neural Networks (RNNs):
  - RNNs are a special type of neural network that are designed to process long sequences of data and predict how data should continue per time step based on its training data.
- Long Short-Term Memory (LSTM):
  - The LSTM network is a refined version of the vanilla RNN that can "forget" useless information in training data. This prevents the network from overfitting, which is a big problem in the vanilla RNN.
- Data Windowing and Preprocessing for Time-Series Prediction:
  - Data must be segmented by iterating through input data X with window size N and per iteration (iter_num) we save data points X[iter_num : N] and X[N+1] until iteration count len(X) - N.

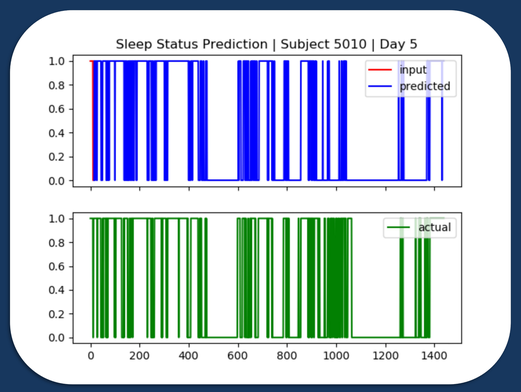




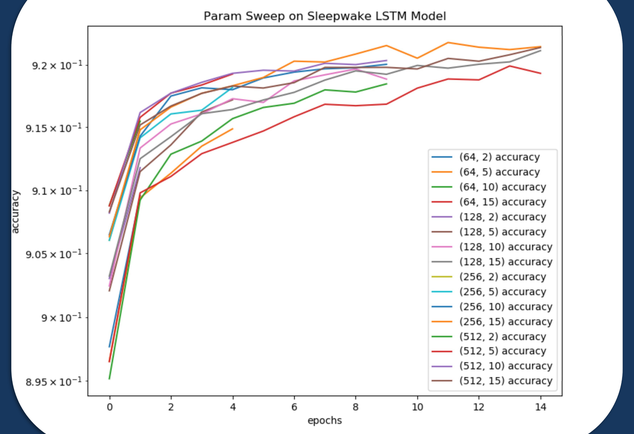
Multivariate Time-Series Forecasting with the LSTM Network:

1. Single dataset of normalized actigraphy containing lux (light in lumens), 3-axis accelerometer, and bpm.
2. Predict 4 key sleep stages: awake, light sleep, deep sleep, and REM.

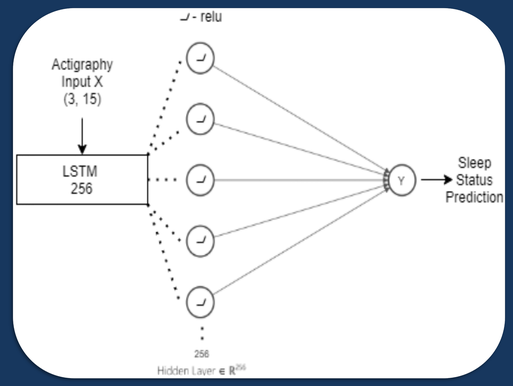
Results



256-unit LSTM Model Prediction Results with 92% accuracy.



Diagram



256-unit LSTM Model for Time-Series Sleep Status Prediction.

Future Directions

1. Create multivariate LSTM model for predicting 4 key sleep stages.
2. Create actigraphy from accelerometer and other sensors to create a model that can use the device to label sleep stages.
3. Extend the dataset to contain a participant's disorders, if any, that can directly affect sleep. Then, use this dataset to predict sleep stages and disorder labels.
4. Evaluate the model's performance and accuracy on real-world data.

References

[1] A. Sano, W. Chen, D. Lopez-Martinez, S. Taylor and R. W. Picard, "Multimodal Ambulatory Sleep Detection Using LSTM Recurrent Neural Networks," in IEEE Journal of Biomedical and Health Informatics, vol. 23, no. 4, pp. 1607-1617, July 2019, doi: 10.1109/JBHI.2018.2867619.

[2] Sathyanarayana, Aarti et al. "Sleep Quality Prediction From Wearable Data Using Deep Learning." JMIR mHealth and uHealth vol. 4,4 e125. 4 Nov. 2016, doi:10.2196/mhealth.6562