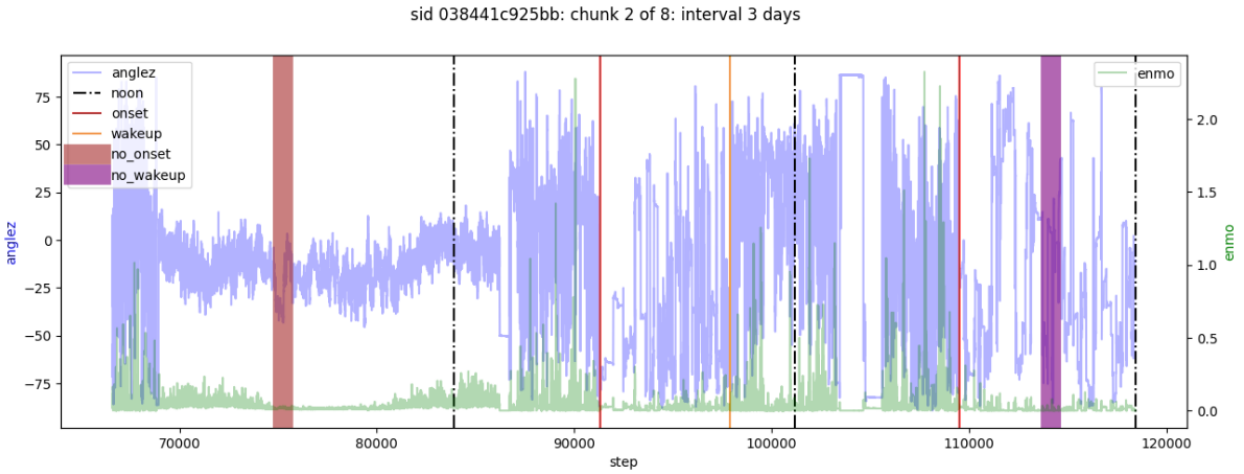
Efficient Sleep State Tracking

Leveraging Data Science for Health



Problem: Efficiently Tracking Sleep States

Sleep is essential for human health, and accurate sleep monitoring is crucial for researchers and individuals. However, research in this field has faced challenges "due to the lack of naturalistic data capture alongside accurate annotation" (Esper et al., 2023). Data science can significantly aid sleep experts and consumers in better understanding and monitoring sleep.

Deliverables

- Develop a model that predicts sleep onset and wakeup times from wrist-worn accelerometer data.
- Create a comprehensive report and presentation outlining the process, outcomes, and recommendations.

Stakeholders

Researchers studying sleep and companies interested in using accelerometer data for health-related sleep tracking.

Proposed Solution

We propose a deep learning model that takes accelerometer data as input and predicts "onset" and "wakeup" events, along with confidence scores ranging from 0 to 1. This problem is treated as a segmentation task, where we segment sleep and awake periods while predicting transition times.

Recommendations

1. Utilize the model's predictions to automatically annotate sleep onset and wake-up times.
2. Incorporate these annotations into sleep research to study its overall health effects.

3. Apply the annotations in a business context to help individuals understand their sleep patterns' impact on health.

Methodology Overview

Model Description

- **Model Inputs:** Multi-day accelerometer data with 5-second intervals.
- **Model Outputs:** A list of time steps and probabilities indicating "onset" or "wakeup" events.

Metric

Submissions are evaluated based on the average precision of detected events, considering timestamp error tolerance thresholds and event classes.

Detailed Description

1. **Assignment:** Predicted events are matched with ground-truth events.
2. **Scoring:** Each group of predictions is scored against corresponding ground-truth events using Average Precision.
3. **Reduction:** Multiple AP scores are averaged to produce an overall score.

Data

The dataset contains around 500 multi-day wrist-worn accelerometer recordings annotated with "onset" and "wakeup" events. Data may have gaps where the accelerometer was removed.

Files and Field Descriptions

- **train_series.parquet:** Contains continuous accelerometer data with unique series IDs.
- **train_events.csv:** Sleep logs with series IDs, night enumeration, event types, and timestamps.

Exploratory Data Analysis

- No missing values for **enmo** and **anglez** columns.
- Some nights lack "onset" or "wakeup" annotations, likely due to accelerometer removal.
- A few nights have only one event annotated.
- During sleep, **enmo** and **anglez** values exhibit distinct patterns.

Preprocessing

Features

- Shape: (n_features, **cfg.duration**) - (10, 5760) in the best model.
- Sine and cosine components for various time aspects.
- Differences between consecutive values for anglez and ENMO.

- Rolling medians for differences (window size: 5 * 12).
- Reverse rolling medians for differences (window size: 5 * 12).

Labels

- Shape: (**cfg.duration** / **cfg.downsample_rate**, 3) - (1920, 3) in the best model.
- Three values: is_asleep (0 or 1), onset, wakeup.
- Labels may include onset, wakeup, or background (no label).
- Gaussian labels for onset and wakeup with soft labels around the annotated time step.

Final Model Description

- Segmentation model with encoder and decoder.
- LSTM feature extractor.
- UNet decoder.

Post-processing

Select peak predictions for onset and wakeup events.

Validation

- 20% validation set (valid_set 1).
- Kaggle public leaderboard (valid_set 2).
- Kaggle private leaderboard (final test set).

Notable Experiments

Model	Brief Description	Valid_1 Score
Baseline	Config defaults	0.74
v1_ds3	Downsample_rate 2 to 3	0.7546
v2_ds3	Added rolling median features	0.7565
v2_ds3_fe_LSTMFeatureExtractor	Chosen Model	0.7598

Manual Post-processing

Techniques for improving the metric:

- Lower threshold (threshold == 0.005, valid_1 score: 0.765).

- Filter_by_min_max_th (Remove predictions if min(max of onset and wakeup score) < 0.03, valid_1 score: 0.767).
- Filter_(onset of wakeup)_threshold (Keep max prediction if above 0.82, valid_1 score: 0.768).
- Filter_max_score_by_night (Eliminate predictions if max is not above 0.03, valid_1 score: 0.769).
- Inflate_max_wakeup (Inflate max wakeup score by a multiplier of 3.2, valid_1 score: 0.771).
- Inflate_max_onset (Inflate max onset score by a multiplier of 13.4, valid_1 score: 0.774).

Test Score

0.758

References

Nathalia Esper, Maggie Demkin, Ryan Hoolbrok, Yuki Kotani, Larissa Hunt, Andrew Leroux, Vincent van Hees, Vadim Zipunnikov, Kathleen Merikangas, Michael Milham, Alexandre Franco, Gregory Kiar. (2023). Child Mind Institute - Detect Sleep States. Kaggle. Link