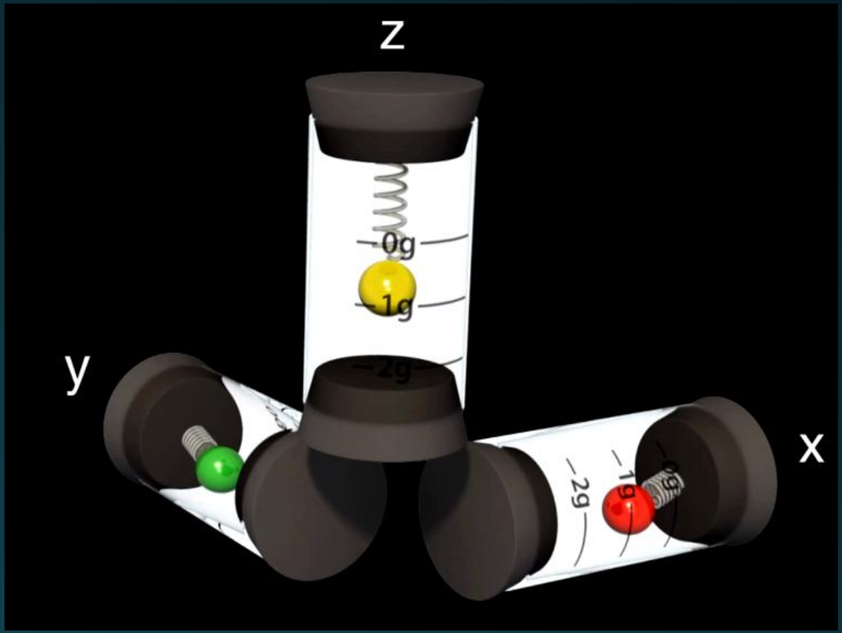
Sleep Detection with Wrist-worn Accelerometer

Viktor Overko
Dmytro Kasiianenko
Anastasiia Bobyr

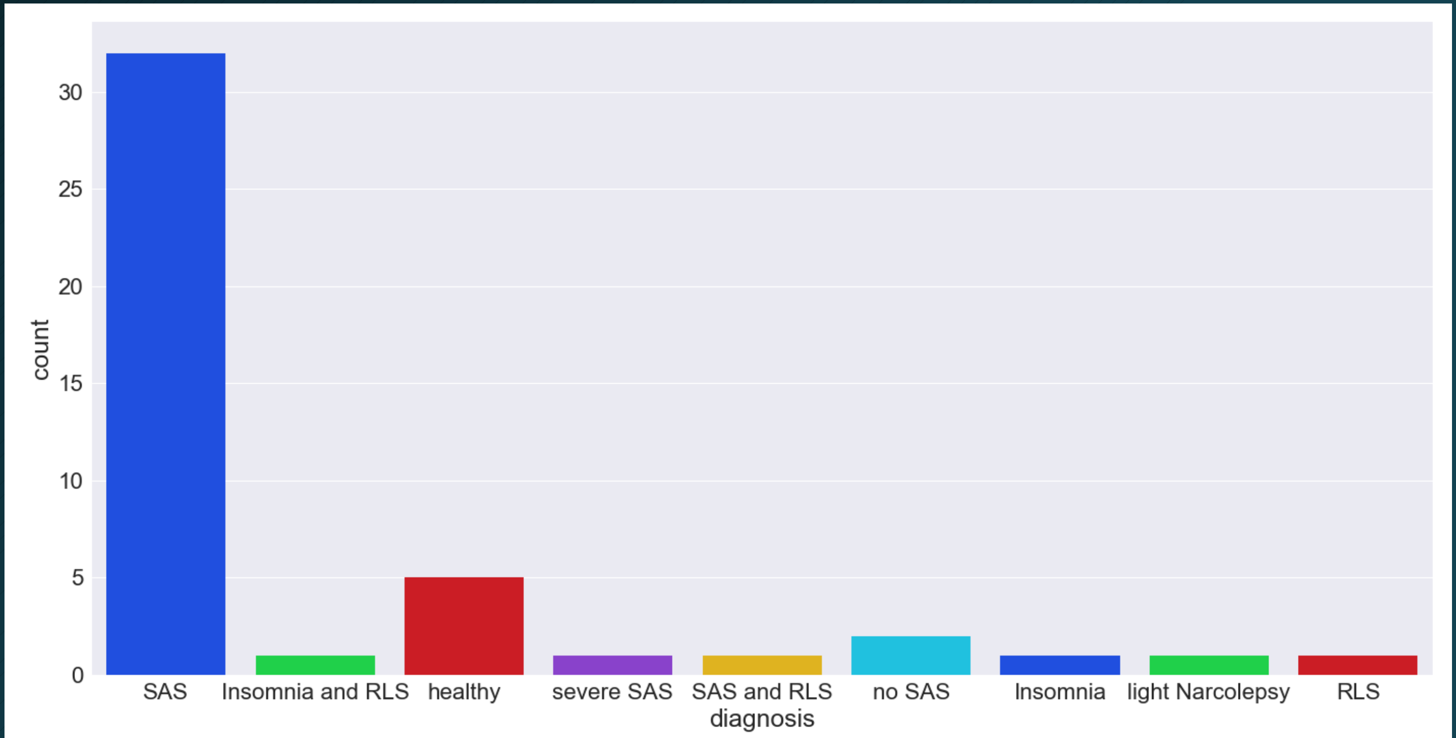
Contents

- Dataset overview
- Existing solutions
- 2 ways to classification
- Statistical features
- Raw data and neural networks
- Deployment to the device
- Plans for improving the model



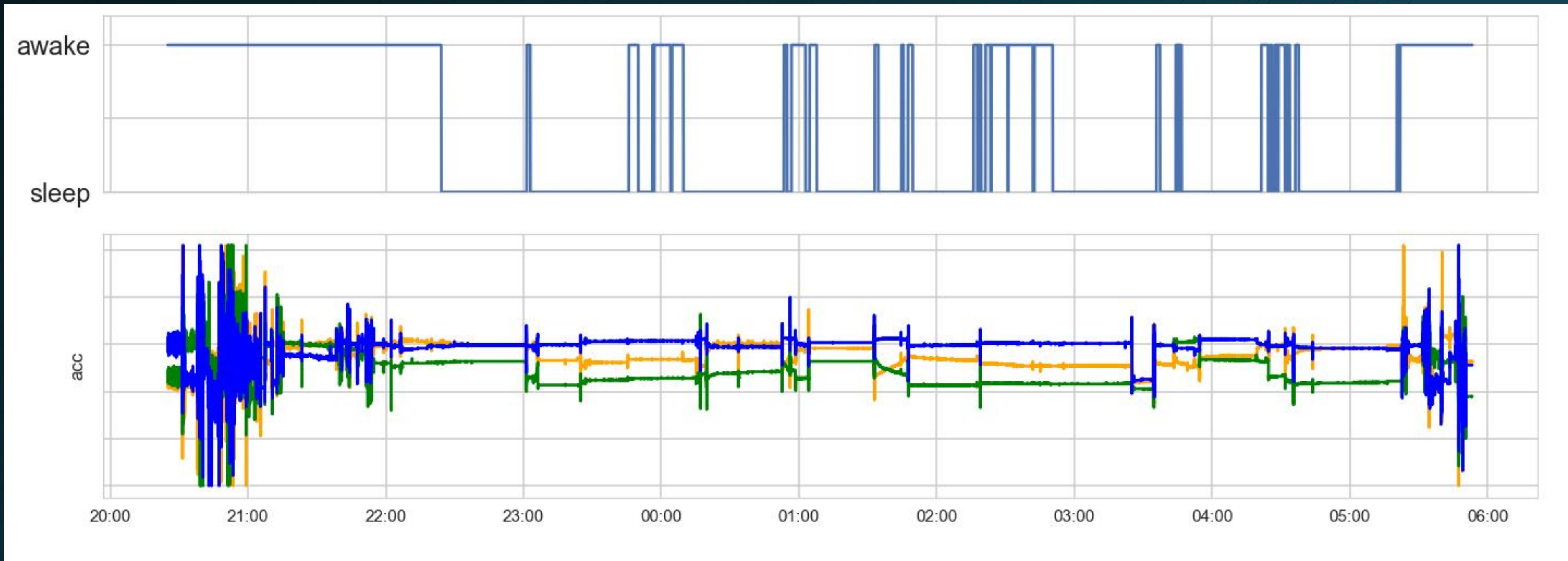
Dataset overview

- 42 patients with different sleeping disorders
- 45 records at all (1 or 2 records per patient)



distribution of patients by sleep disorders

Dataset overview



Records for one patient

Existing solutions

<u>Estimation of Stationary Sleep-segments (ESS)</u>

Detects long periods of idleness

Steps:

1. Identify the segments in which there are no movement patterns present due to the formula (std threshold = 6)

$$S_\delta = \begin{cases} 1, & \text{if } \sqrt{\frac{1}{99}\sum_{i=1}^{100}(z_i - \overline{z})^2} > \delta, \\ 0, & \text{otherwise.} \end{cases}$$

2. Identify entire segments and collect their start, stop times and length in sec (interval threshold = 600)

2 ways to solve the classification problem

Feed raw data to neural network

Takes ages for training

Extracting statistical features

Fast & more accurate

Dealing with time-series

1. **Split** continuous data of each patient separately into windows of the length of 60 seconds

2. **Aggregate** data of each window with statistical function (**std**/mean/max/**ptp**)

3. **Take** into consideration 15 previous and 15 next aggregated with statistical function windows

-4 min	-3 min	-2 min	-1 min	Current minute	+ 1 min	+ 2 min	+ 3 min	+ 4 min
STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z	STD for X, Y, Z

=

Feature-vector of shape (9, 3) for classification current window

Machine Learning Classifiers

	Features	Accuracy	F1-score	Training time
Logistic Regression	std	0.7425	0.6857	<1 sec
XGBoost	std	0.7332	0.6652	<1 min
RNN	std	0.7407	0.6866	<10 min
CNN	std	0.7417	0.6467	<10 min

Convolutional NN Architecture

```
cnn = Sequential()
cnn.add(Conv1D(filters=32, kernel_size=2, activation='relu'))
cnn.add(Conv1D(filters=64, kernel_size=2, activation='relu'))
cnn.add(MaxPooling1D(pool_size=2, strides=2, padding="same"))

cnn.add(Dropout(0.2))
cnn.add(Flatten())

cnn.add(Dense(8, activation='relu', kernel_regularizer=regularizers.l2(0.02)))
cnn.add(Dense(1, activation='sigmoid', kernel_regularizer=regularizers.l2(0.02)))
```

Recurrent NN Architecture

```
RNN = Sequential()
RNN.add(LSTM(10, dropout=0.2, recurrent_dropout=0.2, input_shape=(31, 3) ))
RNN.add(Dense(1, activation="sigmoid", kernel_initializer="glorot_uniform", kernel_regularizer=l2(0.01)))
```

Neural Networks with Raw Data

	Accuracy	Training time
CNN	0.7269	>30 min
CNN+RNN	0.7256	>30 min

Deployment to the device

There are many different accelerometers. So to use our classifier with them you need:

1. Scale training dataset to get data similar to your accelerometer data. Standardization, for example.
2. Extract statistical features.
3. Train the model.
4. Evaluate the model on your data (optional).

For example, the model shows such results on MAWI dataset:

Accuracy = 0.904, F1-score = 0.9

STD vs PTP

Model	Axes	Features	Accuracy	F1-score
Logistic regression	All 3 axes	std	0.7425	0.6857
		ptp	0.7431	0.6830
	Only 1 axis	std	0.7413	0.6813
	Only 1 axis	ptp	0.7425	0.6813

Conclusion

1. Best models: Logistic regression, RNN.
2. To maximize quality use STD for each of 3 axes.
3. To optimize calculations use PTP for one axis.

Plans for improving the classifier

1. Try using other RNN with statistical features.
2. Add age and gender to each feature-vector.
3. Add sleep disorder of the patient to each feature-vector.

References

- Towards Benchmarked Sleep Detection with Wrist-Worn Sensing Units - https://ieeexplore.ieee.org/document/7052479
- Human Activity Recognition from Accelerometer Data - http://rstudio-pubs-static.s3.amazonaws.com/165795_92b97c49b5a74d04940670469a9a40f2.html
- Comparison of Sleep-Wake Classification using Electroencephalogram and Wrist-worn Multi-modal Sensor Data - https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4320808/
- Project repository - https://github.com/Vitalinsh/Sleep-Analysis-with-accelerometer

Thanks for attention!