Optimizing Neural Networks for Activity Recognition in Daily Living: A Case Study Using Signal Processing and Smartwatch Sensors

Prof. Dr. Klemens Waldhör (klemens.waldhoer@fom.de),
Philipp Müller (muellerphilipp17.08@gmail.com)

Authors

Prof. Dr. Klemens Waldhör

- Professor of information science
- Researcher in integrating AI and LLMs in software development
- Working on smartwatch based AAL solutions

Philipp Müller

- Former Student in business information systems
- Currently working as Data Scientist at Deutsche Telekom

Motivation

Test how signal processing can have an influence on the behaviour of deep neural networks (RNN, LSTM, GRU, CNN)

The ability to classify a finite set of daily activities using a deep neural network embedded in a smartwatch.

Possible Use-Case

Healtcare challenge

- Aging population in Germany
- Under current circumstances, additional 280,000-690,000 care professionals needed by 2049

Proposed solution

- Smartwatch-based activity monitoring

Key activities

Drinking

Tumbling

Tooth Brushing

Walking

Initial Data Gathering

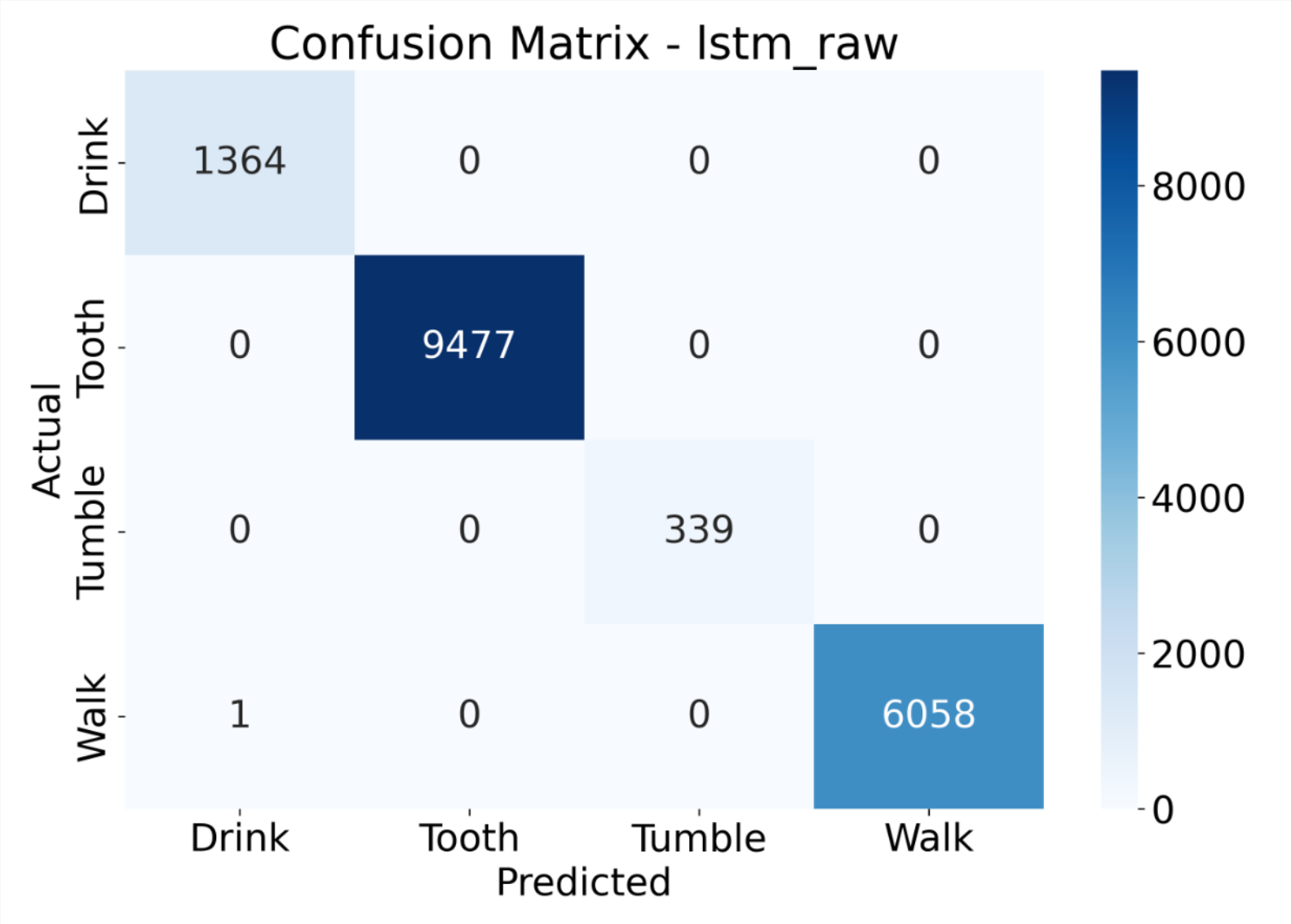
Data Chacracteristics

- Two sensor channels: accelerometer & gyroscope
- Three axes (x, y, z) per sensor
- Inconsistent sampling rates

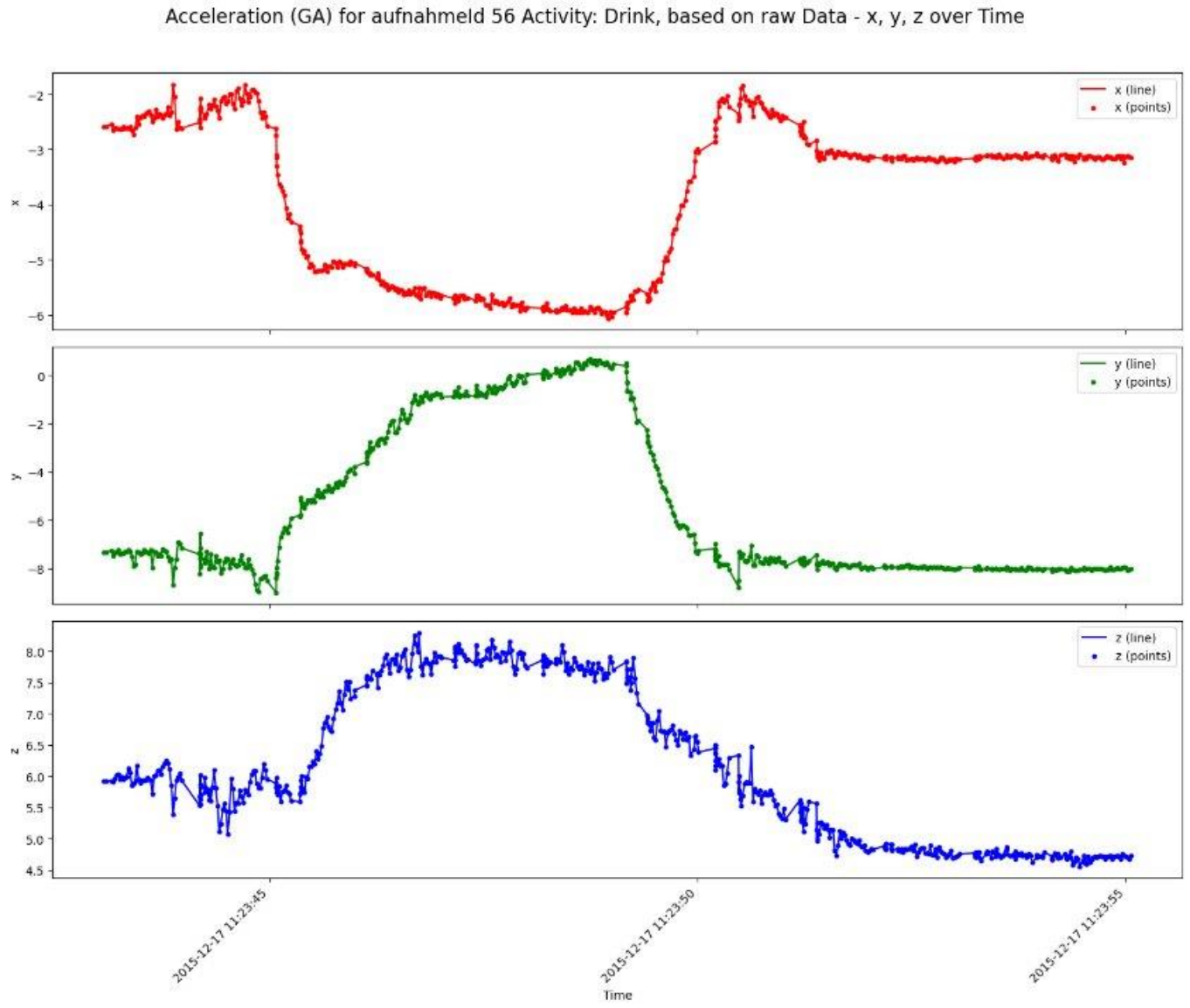
Findings

- Data quality issues
- Structural complexities

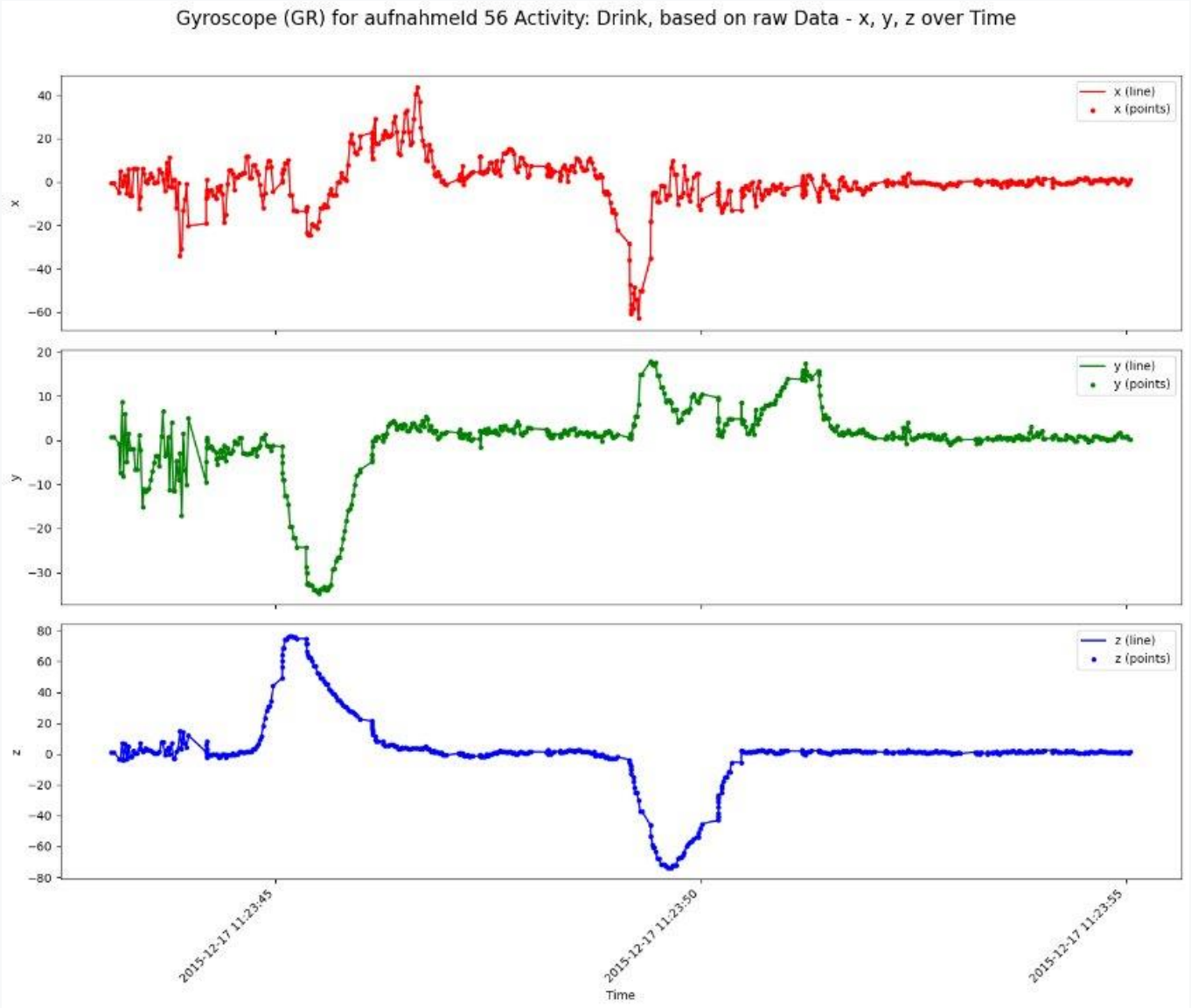
Activity distribution of trainings data



Acceleration over Time



Rotation over Time



Signal Processing Steps

Signal preprocessing steps

- Interpolation (nearest neigbour interpolation)
- DC offset removal (Mean offset removal)
- Gaussian filter
- Normalization (z-standardisation, standard scaler)

Signal transformations

- Fourier transform
- Empirical mode decomposition
- Hilbert Huang transform
- Principal component analysis

Evalution of trained models

Collect new data → Inspect gathered data → Test model

Findings	Activity switches
	Reduce confidence on unknown activities
	Gap between real world testing and controlled testing

CNN LSTM Hybrid Model

File size as h5: 3186 kB

File size as tflite: 1048 kB

Number of parameters: 261,924

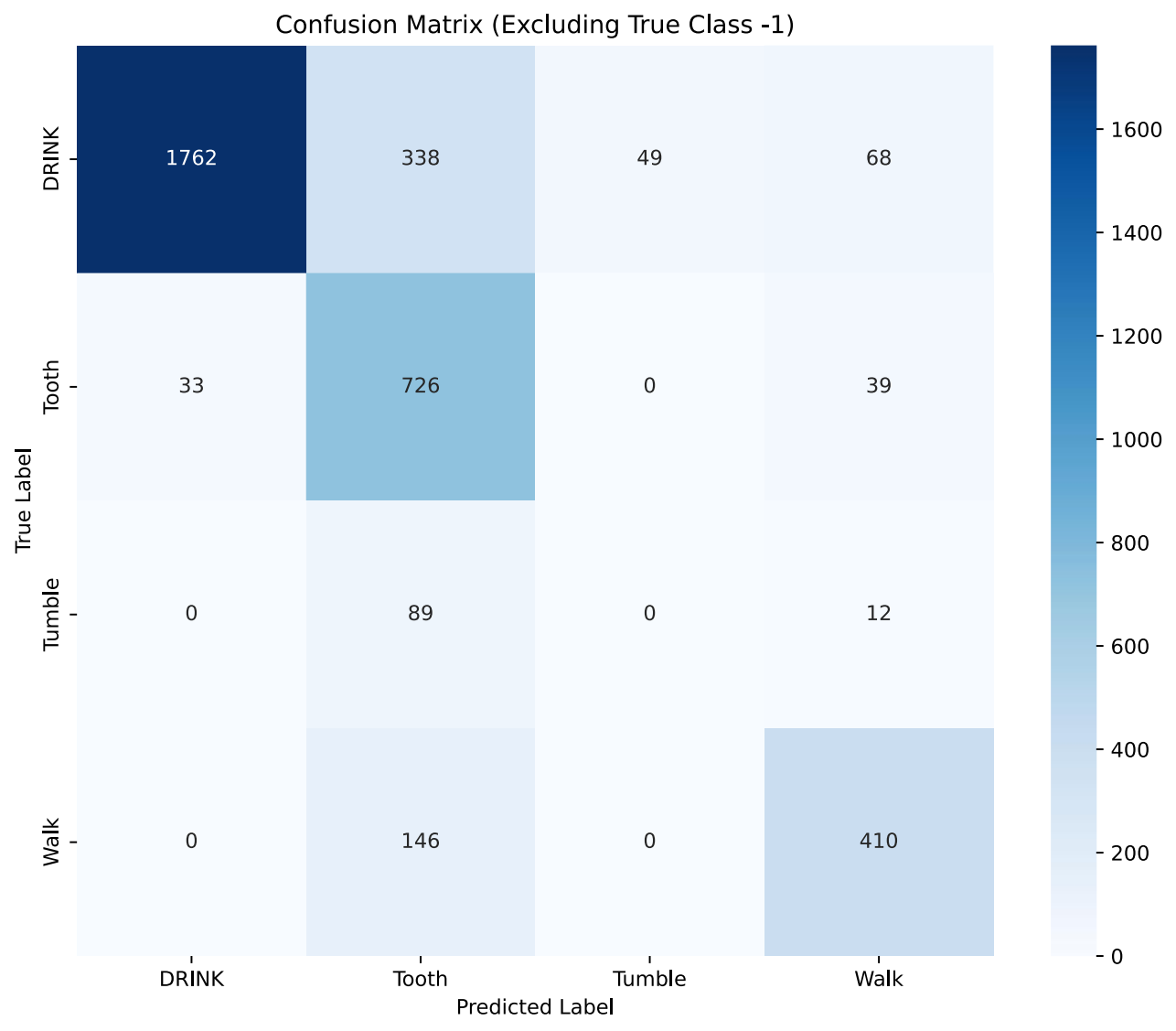
Accuracy: 99.84%

Precision: 99.84%

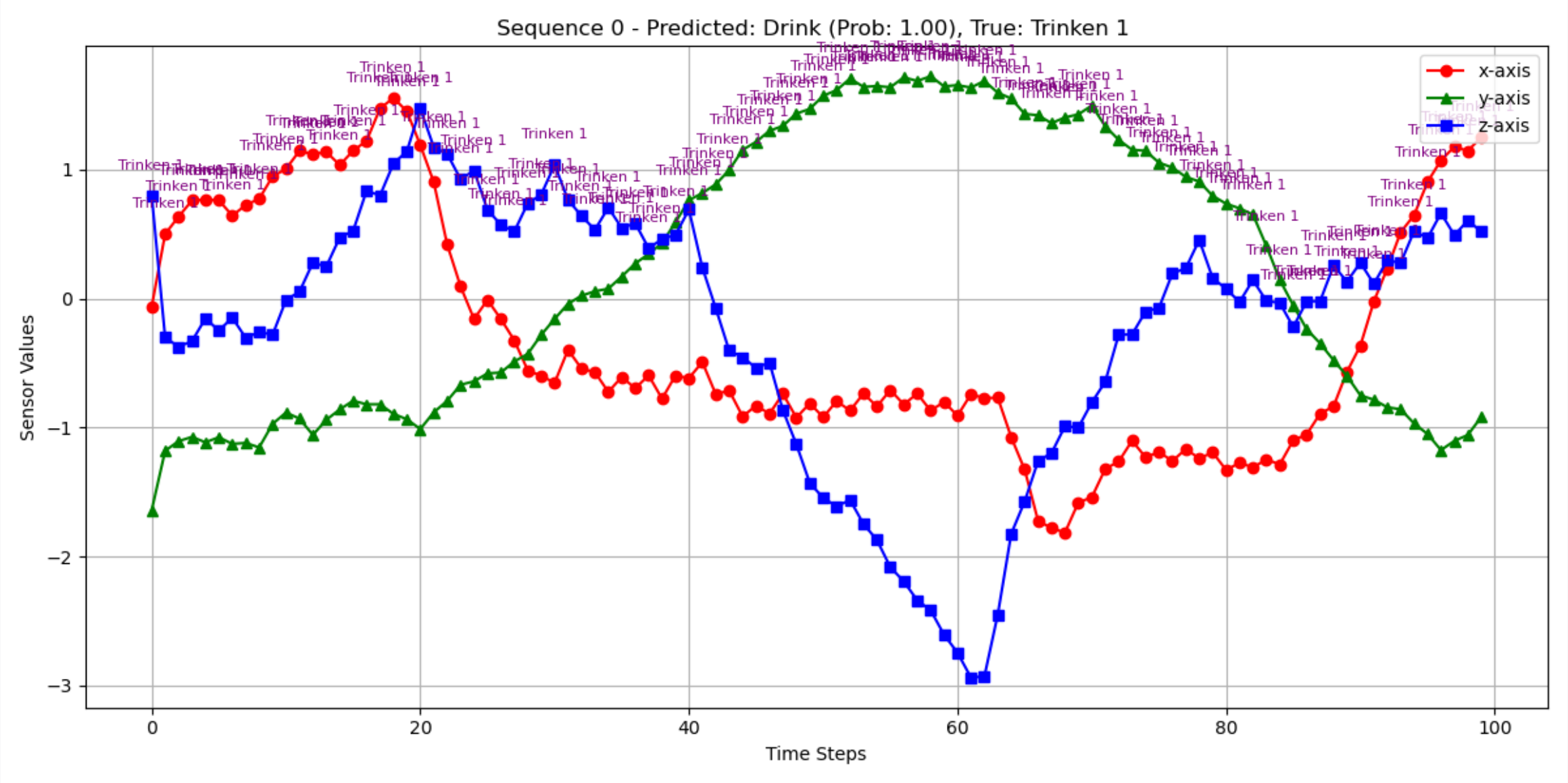
Recall: 99.84%

Trained on 2 epochs

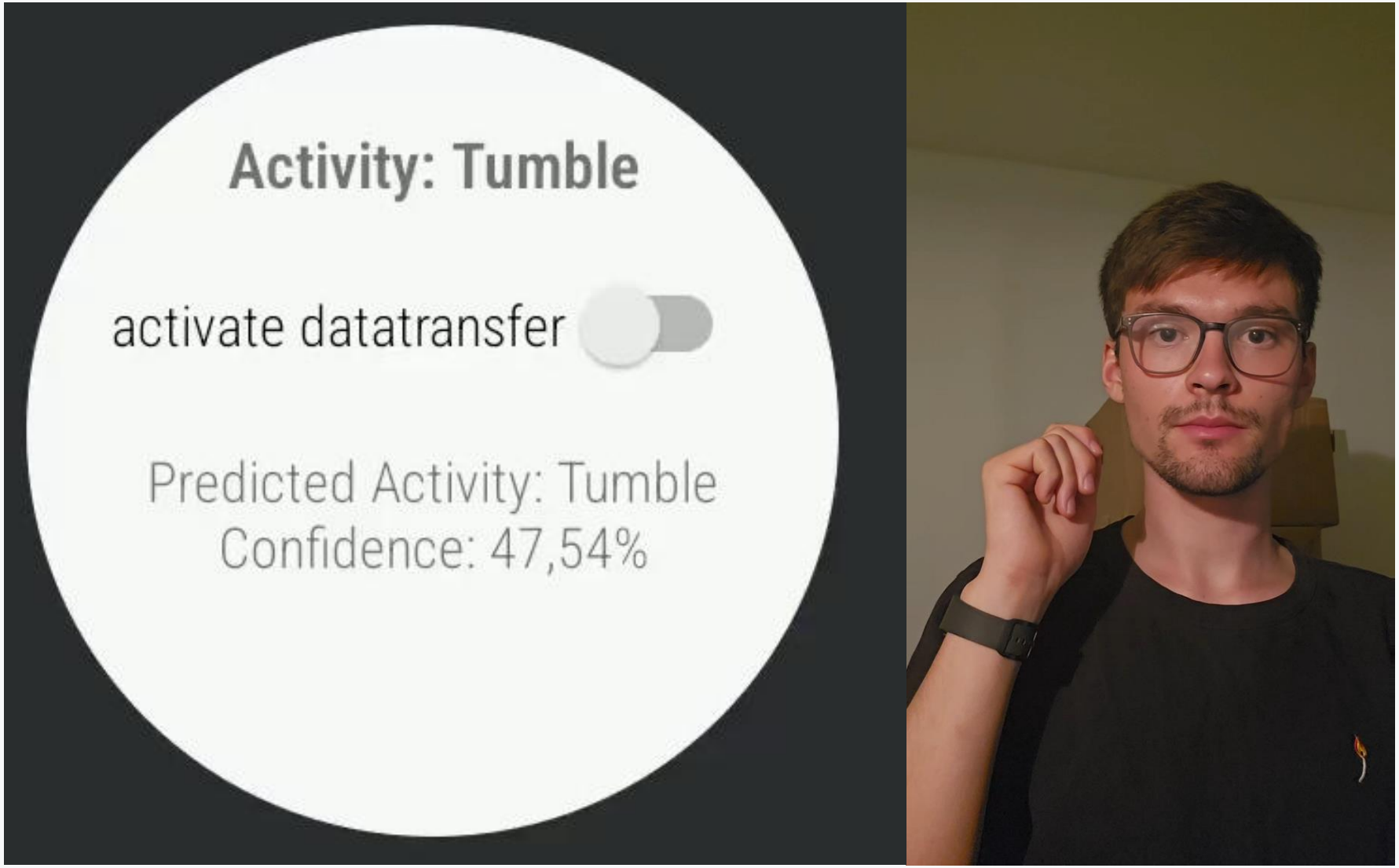
Performance of CNN LSTM Hybrid Model



Example Prediction



Live Demo


Activity: Tumble
activate datatransfer
Predicted Activity: Tumble
Confidence: 47,54%

Key Findings

High classification accuracy (>99%) achieved without complex transformations

Hybrid CNN-LSTM model proved effective for deployment on a smartwatch (Samsung Galaxy Watch 6)

Battery consumption emerged as a significant challenge

Possible Future Work

Causal investigation of the relationship between transformations and neural networks (or Handling of unknown activities)

Power optimization strategies

On-device learning

Thank you for your attention!