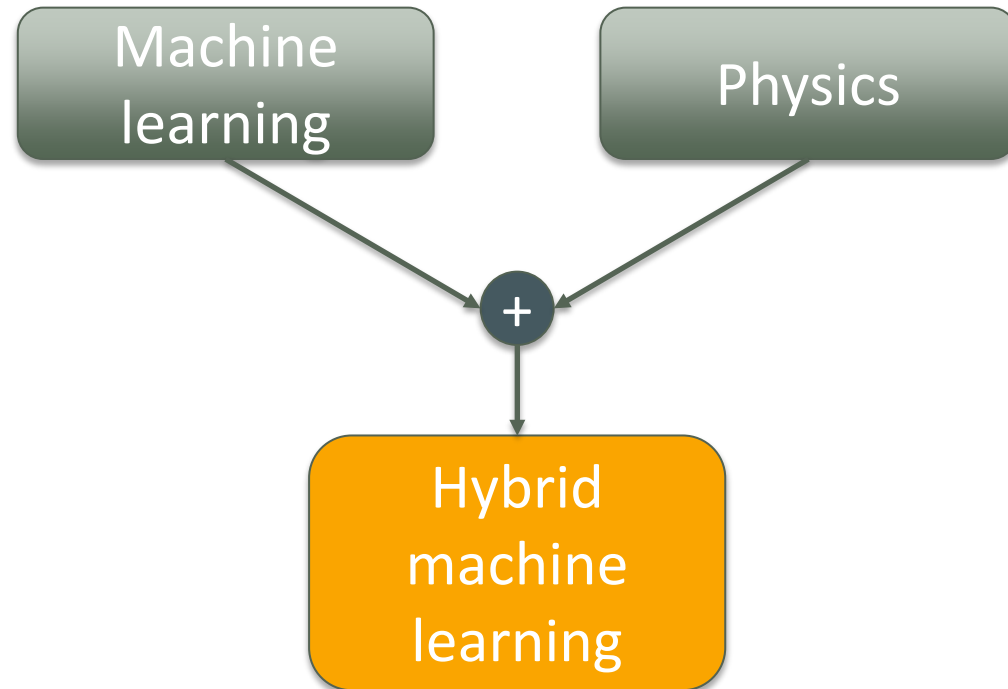


Reduced Data Volumes through Hybrid Machine Learning

25.01.2022 / F&E Konferenz zu Industrie 4.0, Biel / Simon Walther

Hybrid Machine Learning and Little Data



- ▶ **Hybrid machine learning** (figure)
 - ▶ Combination of methods
 - ▶ Machine learning
 - ▶ Physics (formula)
 - ▶ Explainable and simple models
- ▶ **Little data**
 - ▶ Data are costly
 - ▶ Long lifespan of machines in industry
 - ▶ Limited resources

Hybrid machine learning can perform good with little data

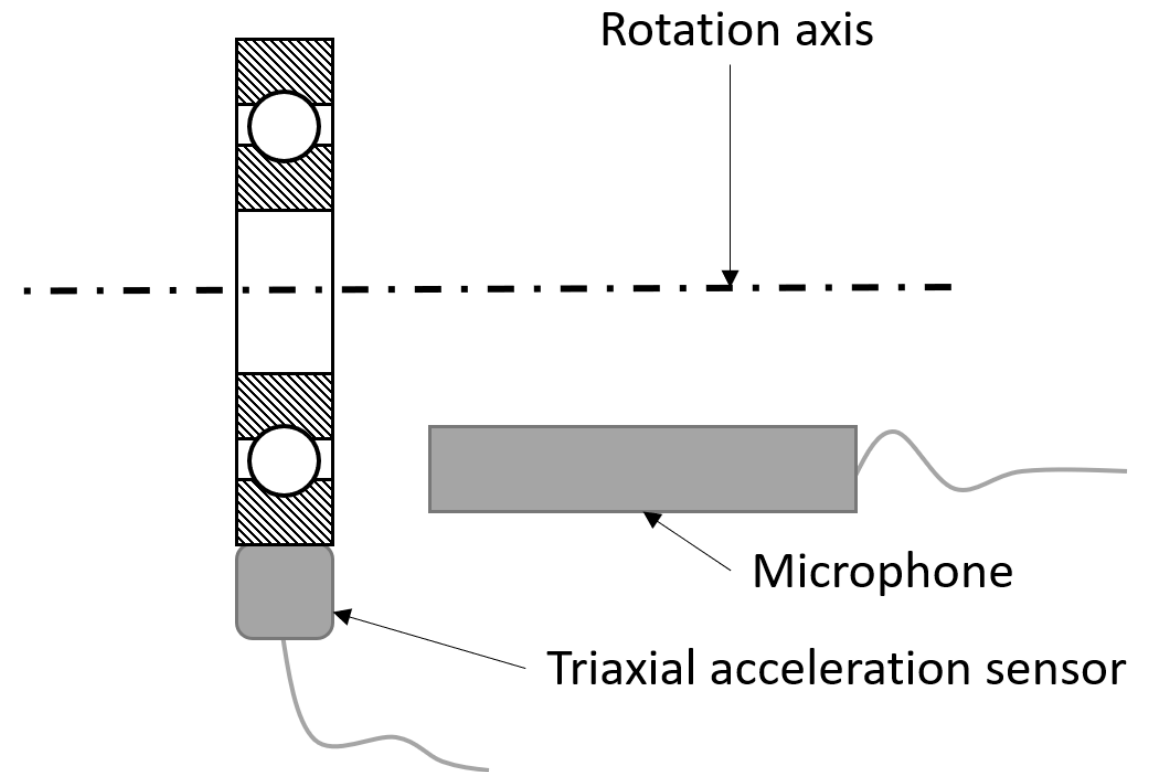
Case Ball Bearings

Goal

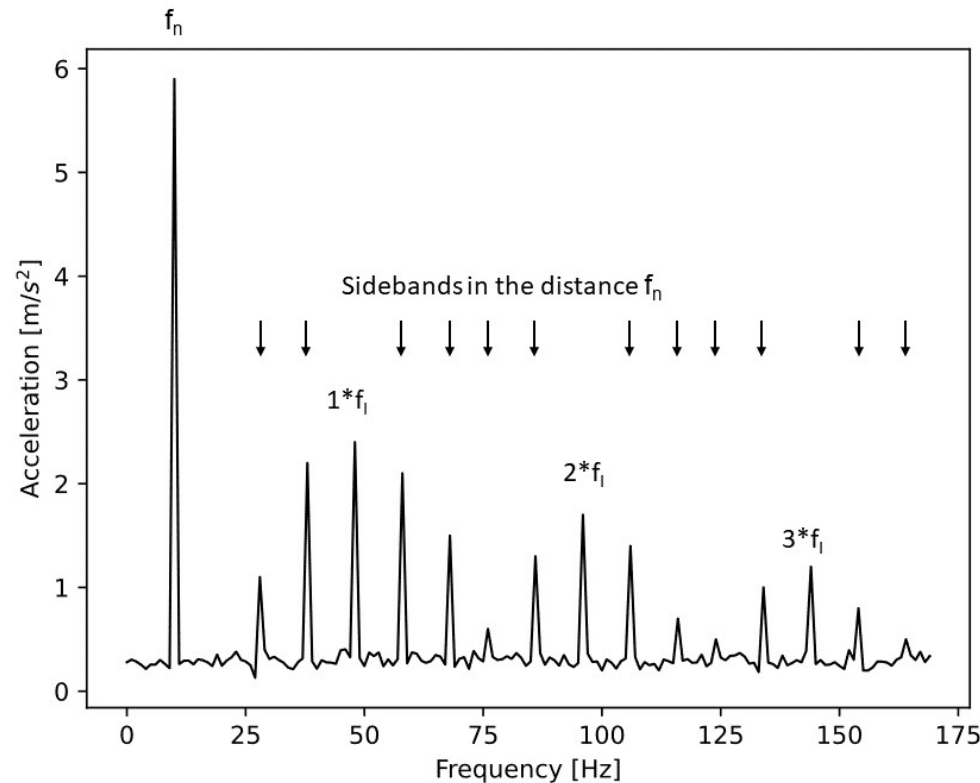
- ▶ Estimate type and state of wear / damage
- ▶ Use different sensors
 - ▶ Acceleration (common approach)
 - ▶ Sound (demand of the industry)

Data is costly

→ Small dataset is collected



Physical Behavior of Ball Bearings with Wear



▶ General

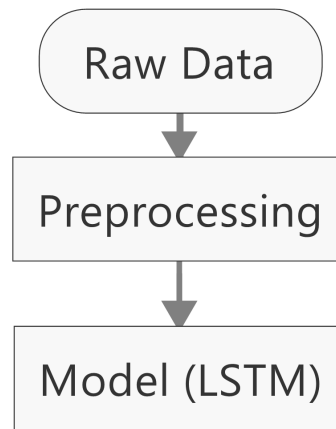
- ▶ Transform signal to frequency space
- ▶ Characteristics are visible

▶ Wear inner ring (figure)

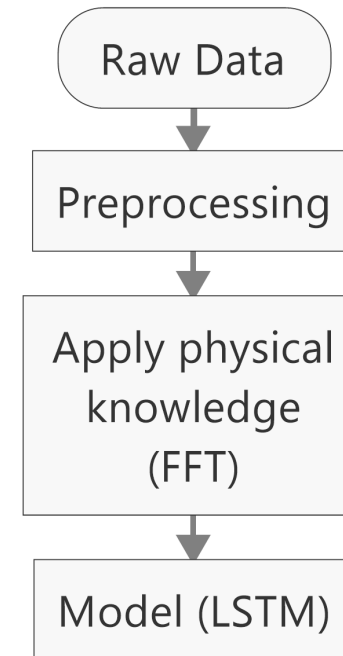
- ▶ Frequency of the rotor f_n
- ▶ Roll over frequency f_i and its multiple
- ▶ Sidebands around f_i with the distance of f_n
- ▶ Calculable
- ▶ State of wear → magnitude of the peaks

The characteristic frequencies and the sidebands allow a reliable classification

Modelling an LSTM-Network for Classification



- ▶ Conventional machine learning pipeline
- ▶ LSTM-model for classification



- ▶ Hybrid machine learning pipeline
- ▶ LSTM-Model for classification
- ▶ Additional step to apply the physical knowledge

Conventional vs. Hybrid Machine Learning

Sensor	All	Acc (radial)	Mic
Train accuracy	98.5%	96.6%	77.9%
Test accuracy	95.9%	92.4%	72.8%

- ▶ Input: Timeseries
- ▶ Samples per category: 10'000
- ▶ 12 categories
- ▶ Good results in general except for the microphone

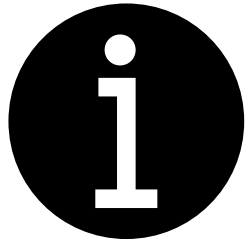
Sensor	All	Acc (radial)	Mic
Train accuracy	100%	100%	98.2%
Test accuracy	100%	91.7%	91.7%

- ▶ Input: Characteristics of 5s measurement
- ▶ Samples per category: 10
- ▶ Very good result even for the microphone

Thank you!



Meet me @Poster or contact by e-mail: simon.walther@bfh.ch
axel.fuerst@bfh.ch



Publication «Reduced Data Volumes through Hybrid machine Learning Compared to Conventional Machine Learning Demonstrated on Bearing Fault Classification» published soon.

Thank you for your attention

Simon Walther, Axel Fuerst
Bernener Fachhochschule Technik und Informatik
Institut für intelligente industrielle Systeme(i3s)
Pestalozzistrasse 20
CH-3400 Burgdorf
i3s.ti.bfh.ch

simon.walther@bfh.ch
axel.fuerst@bfh.ch