#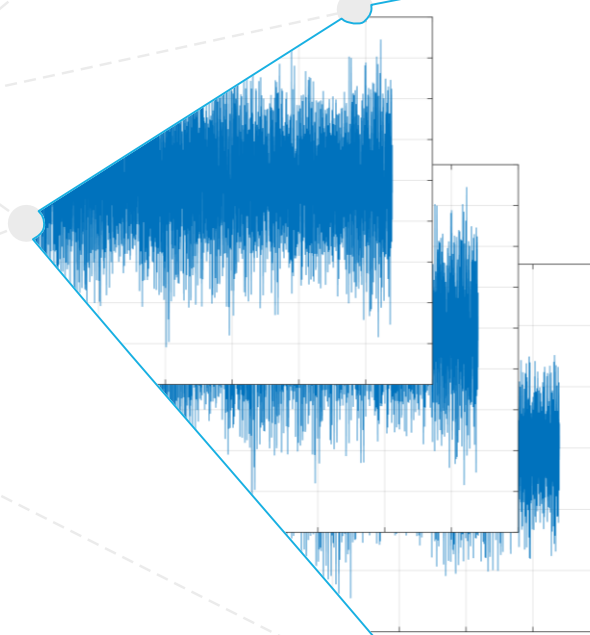 ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS FOR TECHNICAL SYSTEMS OPERATING UNDER VARYING CONDITIONS

CASE STUDY: BEARINGS

CM 2021

Osarenren K. Aimiyekagbon, Amelie Bender, Walter Sextro

ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS FOR TECHNICAL SYSTEMS OPERATING UNDER VARYING CONDITIONS

CASE STUDY: BEARINGS

Outline

Osarenren K. Aimiyekagbon, Amelie Bender, Walter Sextro

ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS
FOR TECHNICAL SYSTEMS OPERATING UNDER VARYING CONDITIONS
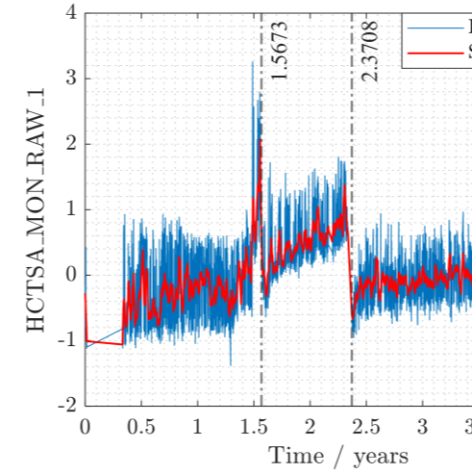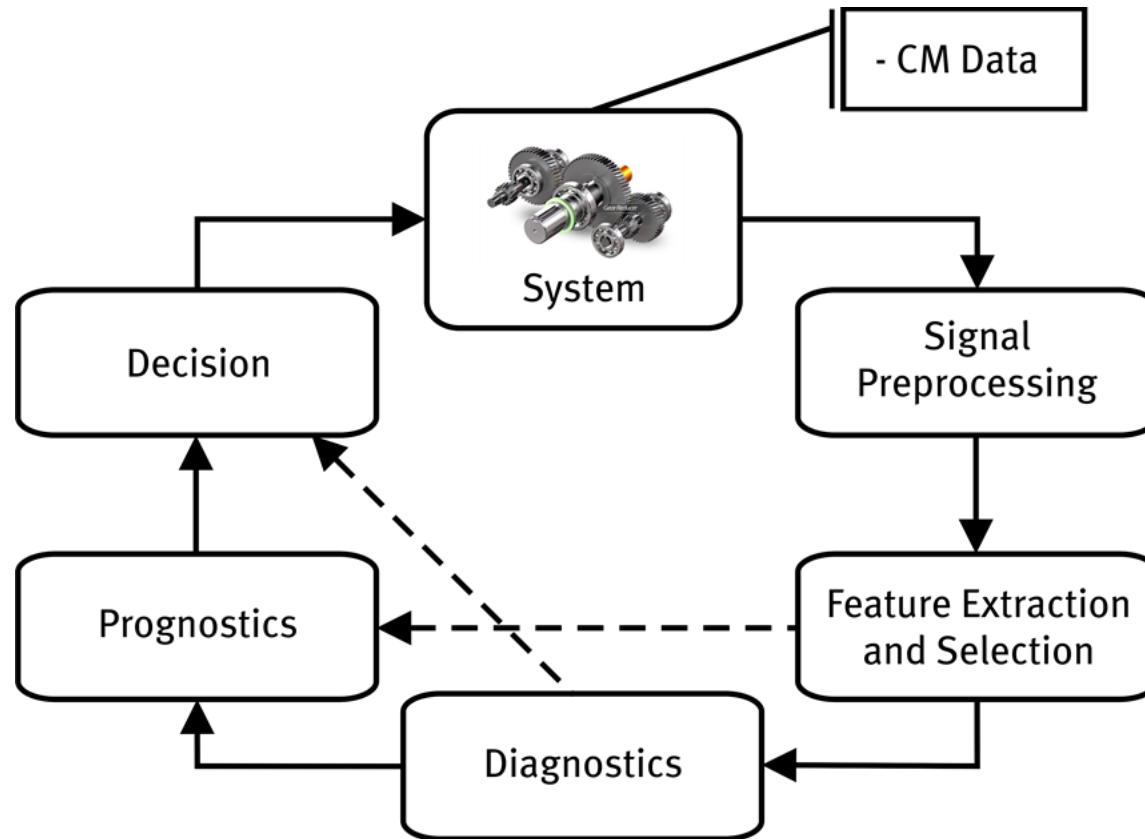
CASE STUDY: BEARINGS

Introduction
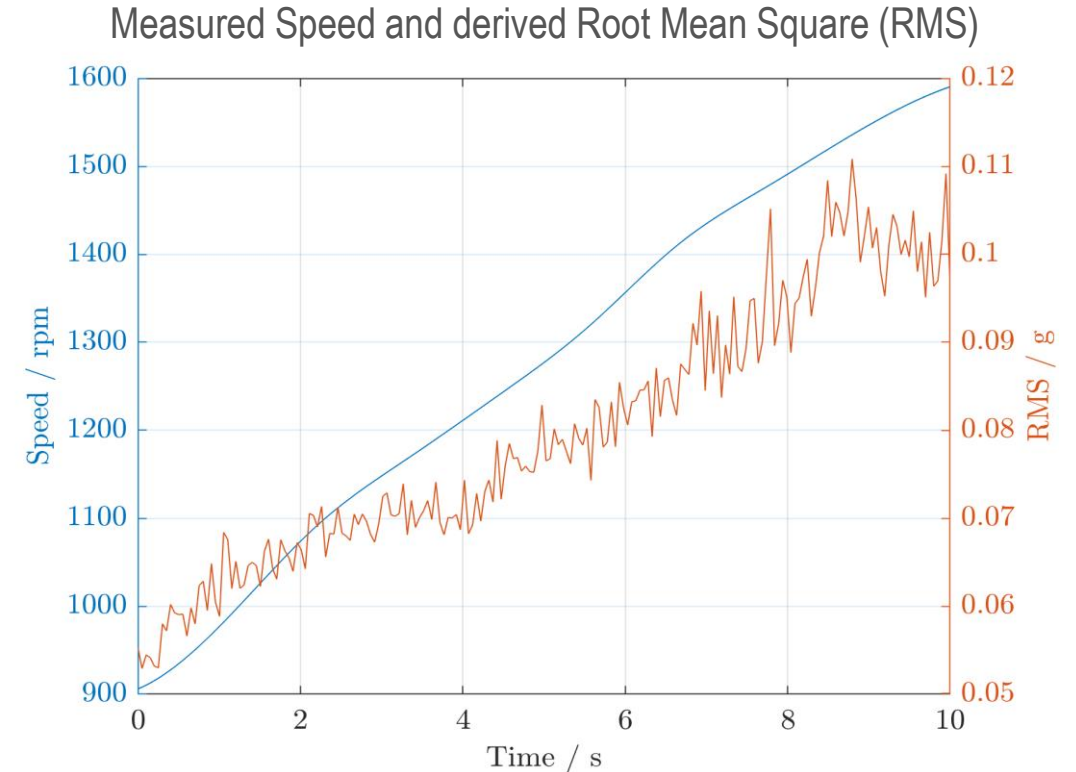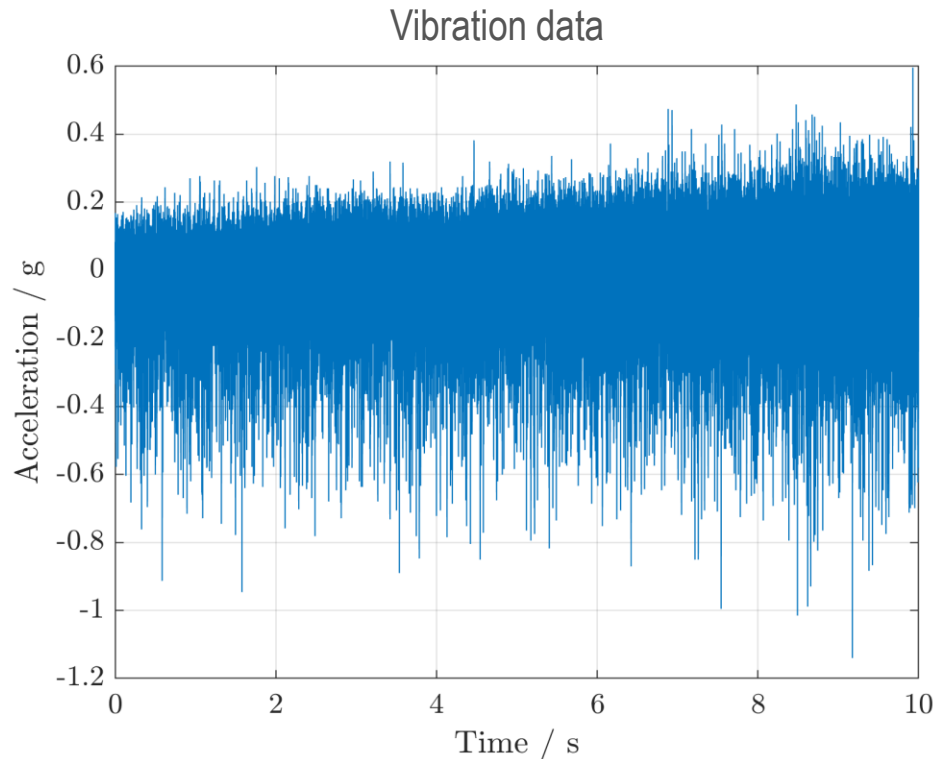

[Goebel et al. 2012]

- Bearing fundamental frequencies can be calculated at constant speed

- Requires knowledge of bearing geometry and rotating speed

- How to account for varying conditions?

- How to quantify faults?

Introduction

○ Time domain analysis

Find features that reflect the degradation despite varying operating conditions

ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS FOR TECHNICAL SYSTEMS OPERATING UNDER VARYING CONDITIONS

CASE STUDY: BEARINGS

Identification of health indicators from time series

o Feature extraction

- Classical time-domain features

- Electromyography (EMG) Feature Extraction Toolbox – MATLAB-Central [Too et al. 2019]

- Highly comparative time-series analysis (HCTSA) MATLAB Database [Fulcher et al. 2021]
  - Courtesy of Researchers from Department of Physics, University of Oxford and Department of Mathematics, Imperial College London

o Feature selection for prognostics [Mathworks 2020]

- Regressional ReliefF [Robnik-Šikonja and Kononenko 2003]
  - … further development of ReliefF: maximal distance between classes and a minimal distance within a class
- Monotonicity [Coble and Hines 2009]
  - …monotonic relationship to describe a trend

ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS FOR TECHNICAL SYSTEMS OPERATING UNDER VARYING CONDITIONS

CASE STUDY: BEARINGS

Case Study

○ Data Description [Martin-del-Campo et. al 2020]

- Real-world data set from a wind farm located in northern Sweden

- Data acquired from six same-model wind turbines

- Approx. 46 months of vibration measurement per wind turbine, each 1.28 s long

- Sampling rate of 12.8 kHz

- Two recorded bearing failures of a wind turbine
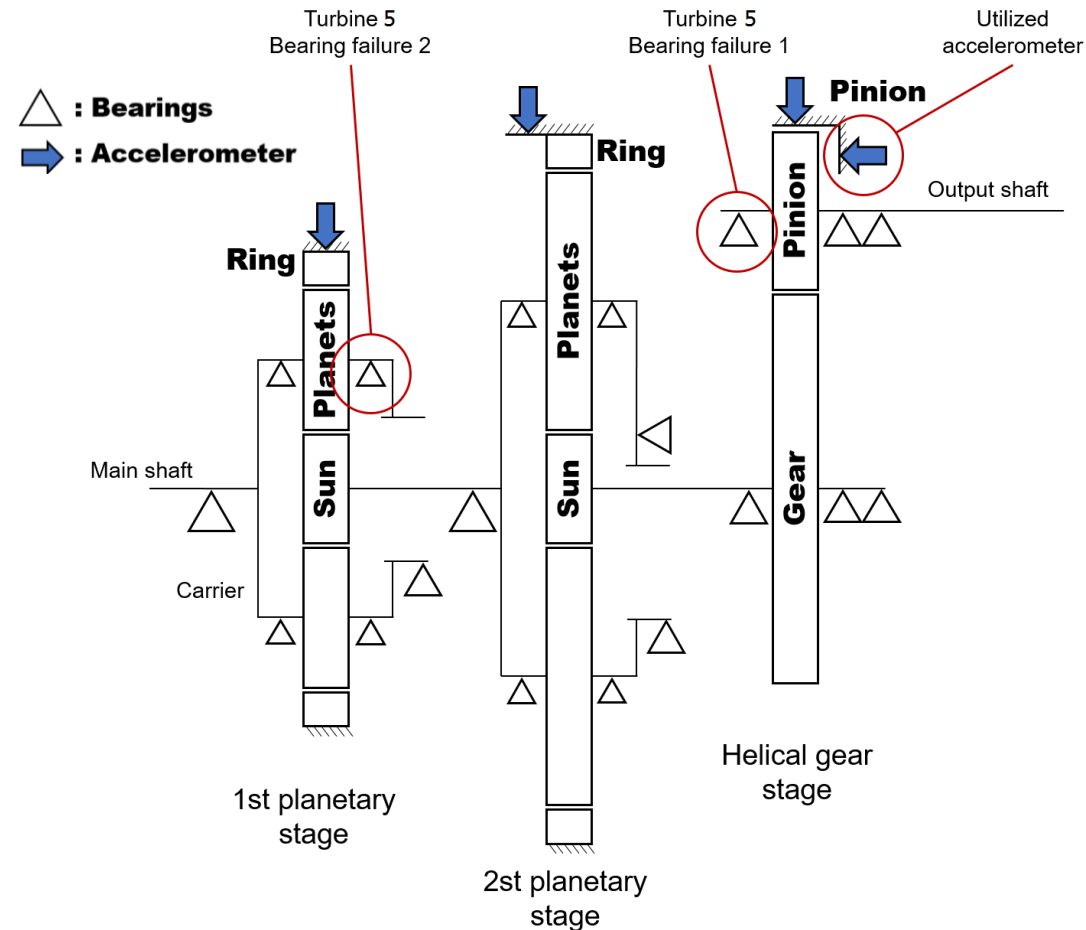
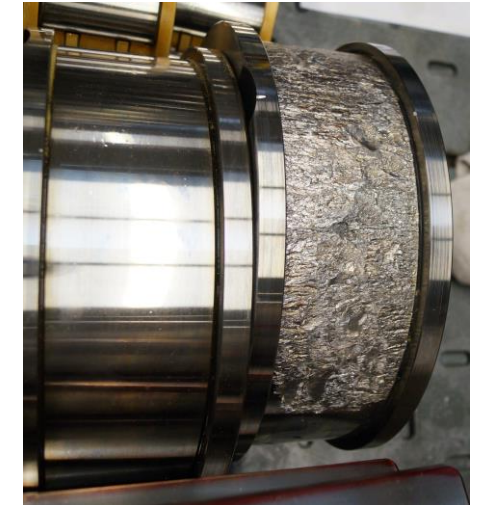- Bearing geometry is unknown!

[Dirk Vorderstraße 2021]

Fault detection irrespective of the non-stationary operating conditions

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Case Study: Fault detection on a real-world wind turbine

○ Data Description [Martin-del-Campo et. al 2020]

- Failure within „Turbine 5"

  • Inner race fault of the output shaft bearing. Bearing replacement at "Time stamp **1.57 years**".

  • Inner race fault on one of the planetary gear bearings. Gearbox replacement at "Time stamp **2.37 years**".

- Possible electrical sensor failure of "Turbine 2"

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ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS
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CASE STUDY: BEARINGS

Case Study: Fault detection on a real-world wind turbine

○ Preliminary analysis

- Non-stationary rotational speed

"Turbine 5"
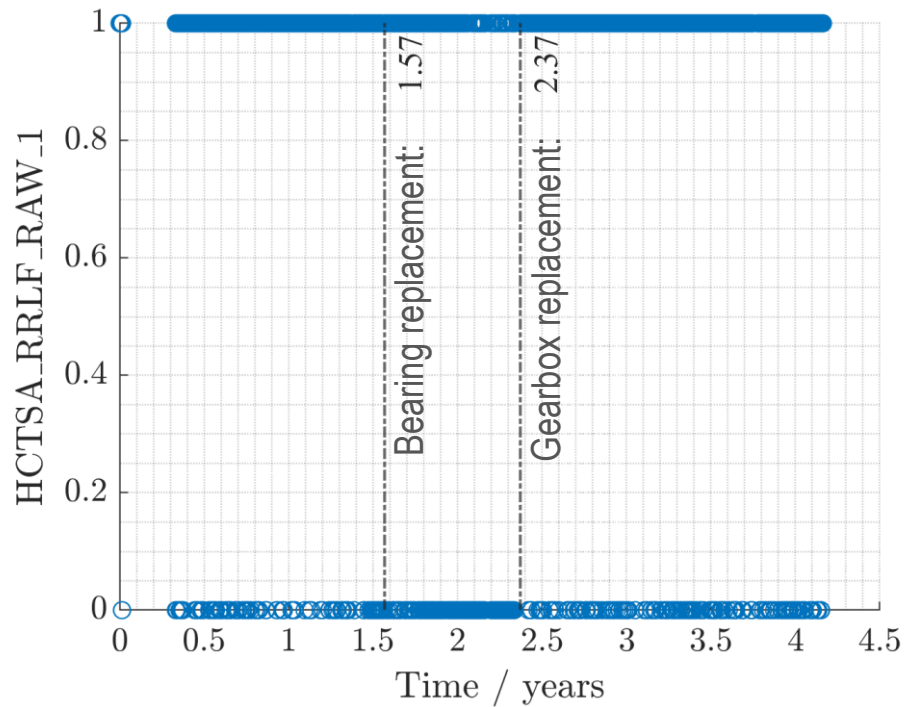
Violin plots of the speed for Turbines 1 - 6
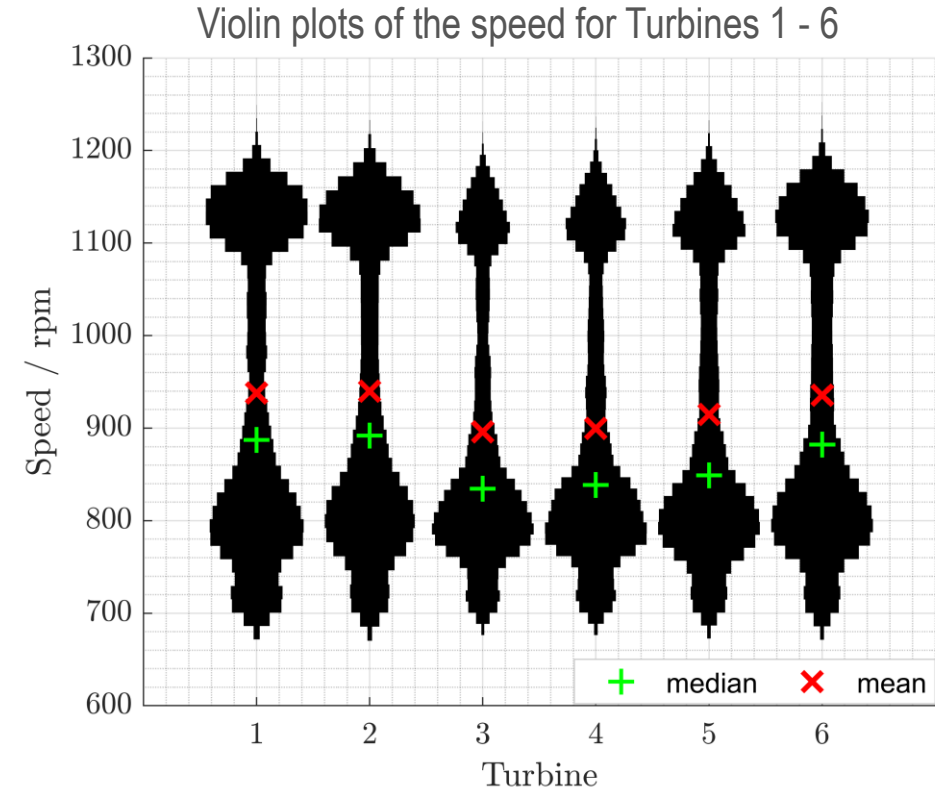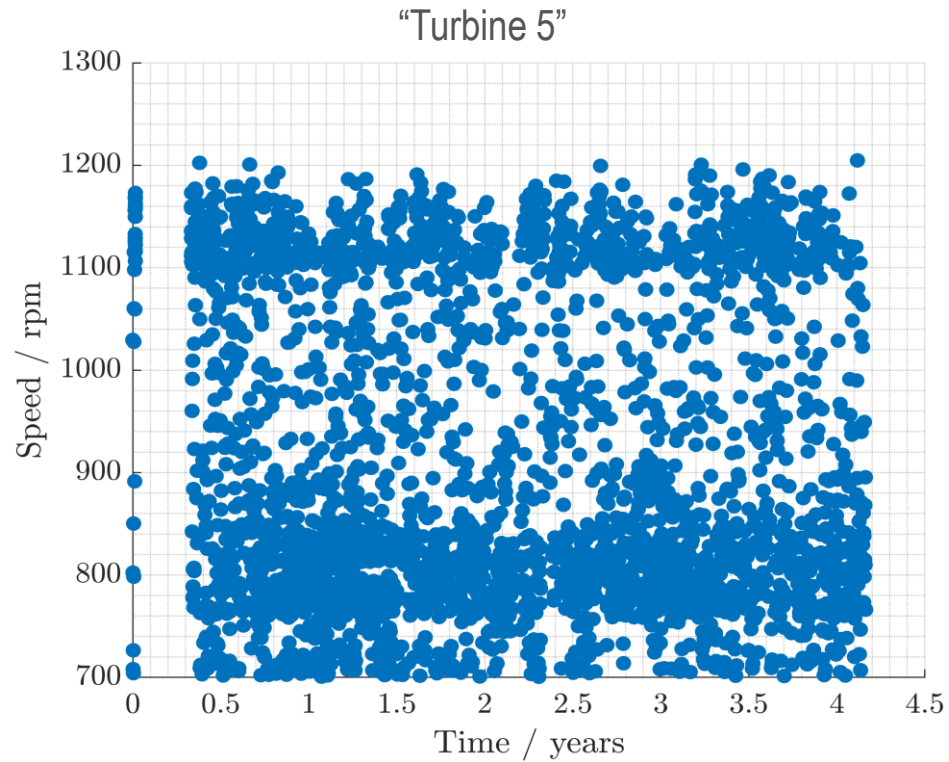
⚏ The wind turbines are not only of the same model but were also subjected to similar operating conditions

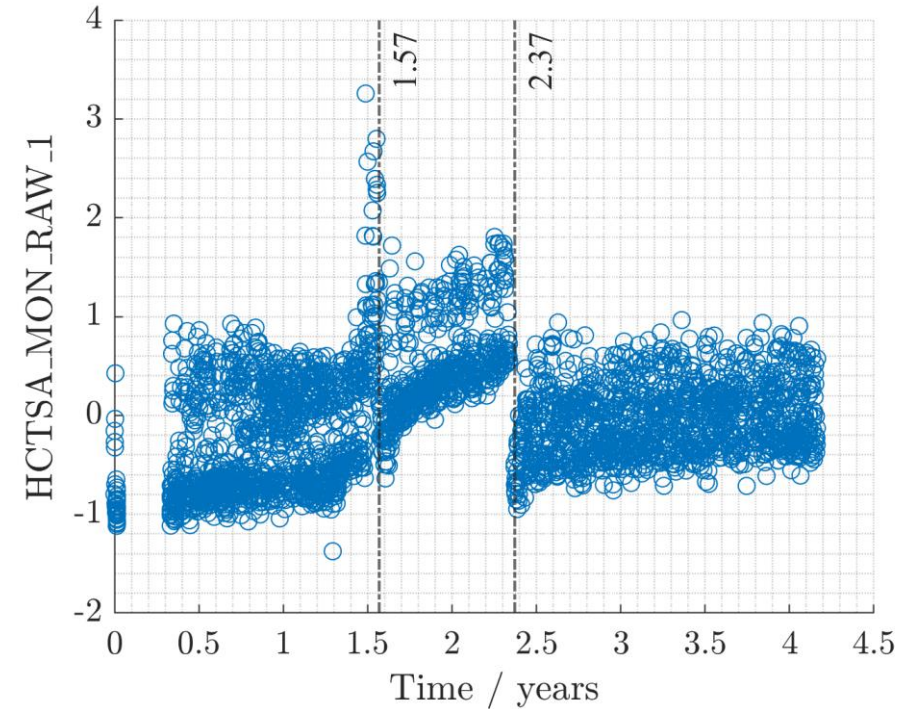## Case Study: Fault detection on a real-world wind turbine

○ Feature extraction and selection

- "Turbine 5"
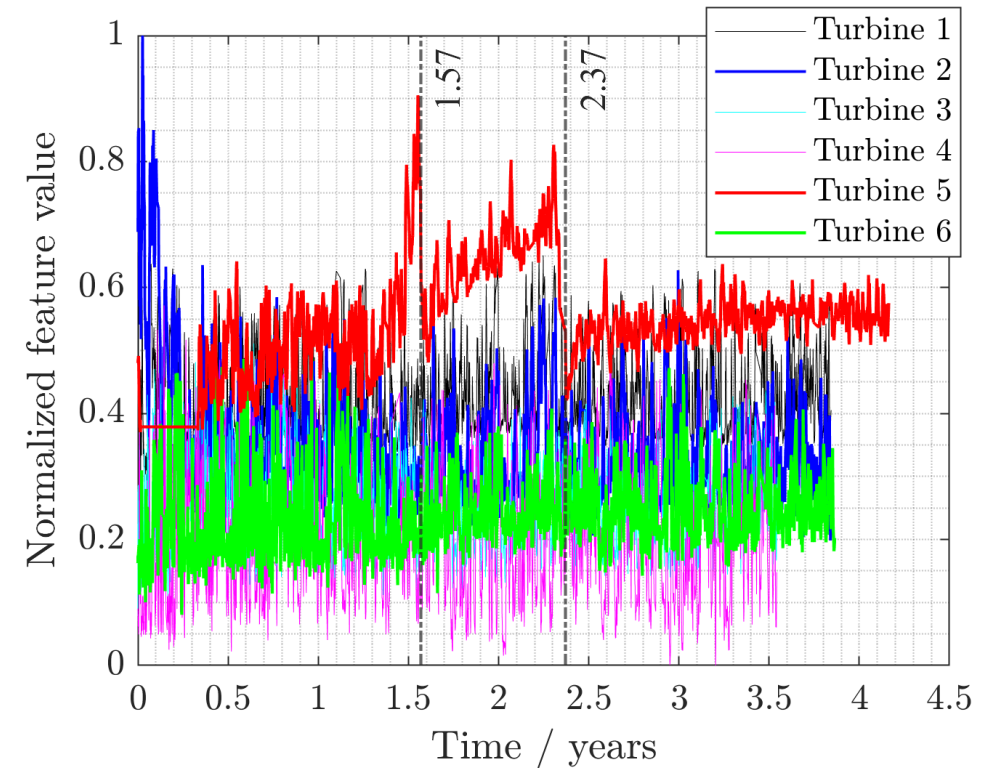
Top-ranked feature by: **RReliefF**

Monotonicity

▨ The top-ranked feature by **Monotonicity** reflects the degradation that occurred within "Turbine 5"

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Case Study: Fault detection on a real-world wind turbine

○ Feature extraction and selection

- Effectiveness across turbines
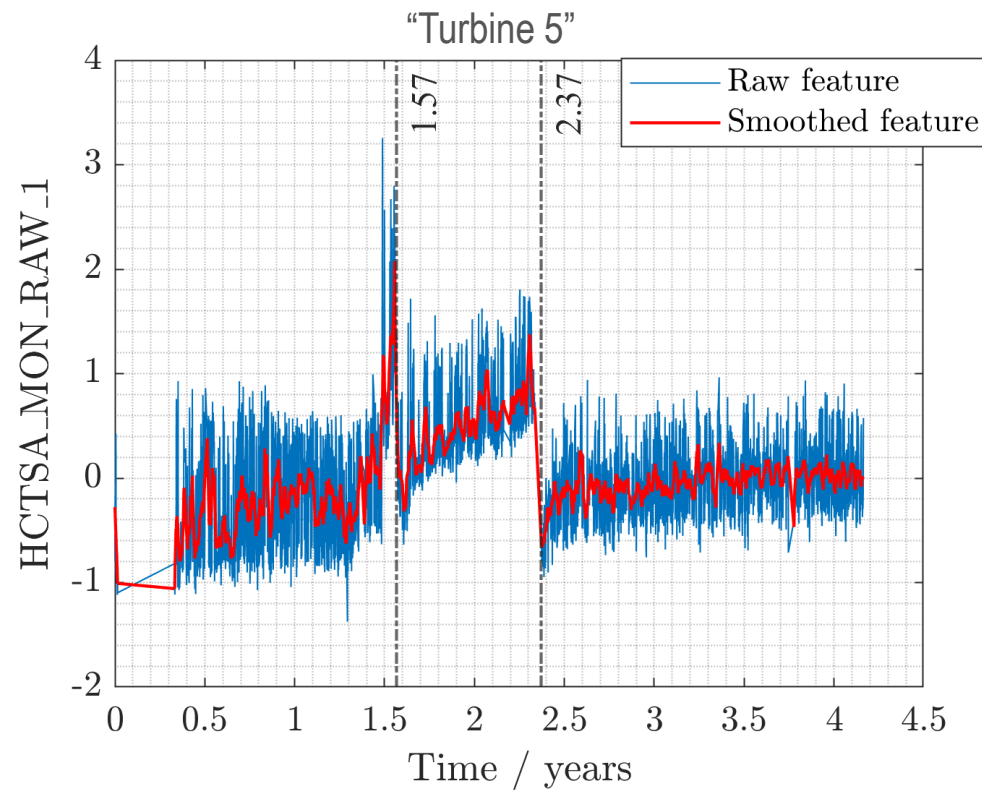

⊞ The top-ranked feature by **Monotonicity** is a viable health indicator for wind turbines operating under real-world conditions

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ON THE APPLICABILITY OF TIME SERIES FEATURES AS HEALTH INDICATORS
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CASE STUDY: BEARINGS

Conclusion

- Health indicators from toolboxes were presented

- A case study for fault detection on a real-world wind turbine

- Possible health indicator(s) for prognostics despite varying operating conditions

- However, for fault localization, either the frequency, the time-frequency analysis or adequate labelled quality data is indispensable

- The presented methods are easily applicable to other technical systems

Outlook

- Further case studies are required to further evaluate the application of the presented methods

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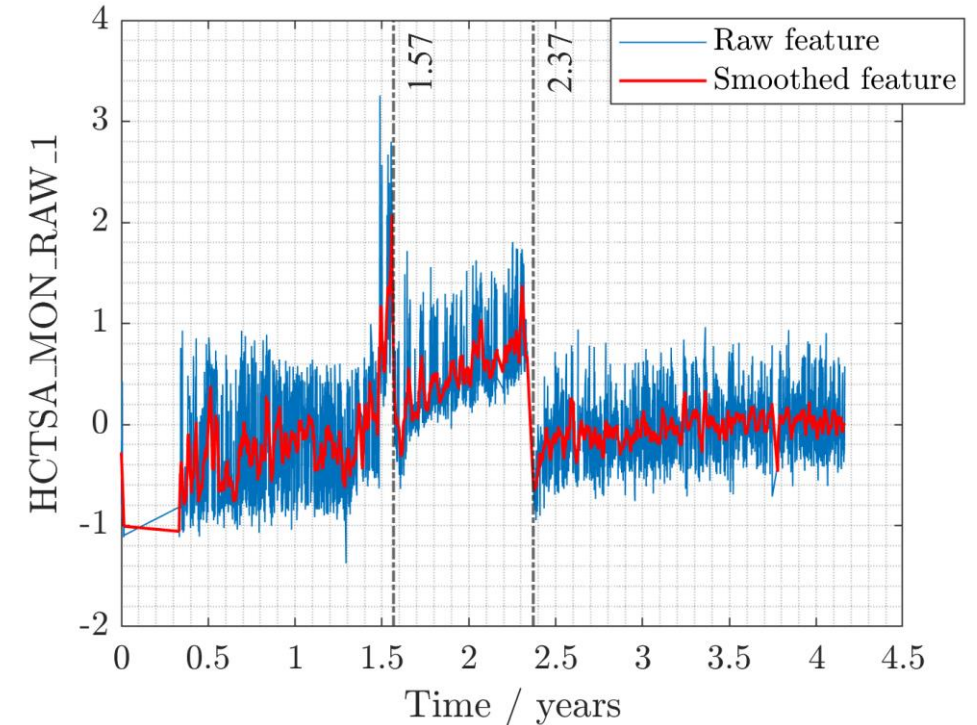
THANK YOU
FOR YOUR ATTENTION!

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- [Dirk Vorderstraße 2021] https://www.vorderstrasse.de/fotos/details/luftbild-windpark-an-der-autobahn-a44/12214/-/. Luftbild Windpark an der Autobahn A44, Urheber: Dirk Vorderstraße, Lizenz: CC BY-NC 3.0. Last viewed on 10.06.2021

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