USING NORMAL BEHAVIOUR MODELS TO IDENTIFY UPCOMING WIND TURBINE FAILURES

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USING NORMAL BEHAVIOUR MODELS TO IDENTIFY UPCOMING WIND TURBINE FAILURES

- Motivation and Aim
- Background: Modelling
- Benefitting of not yet usable maintenance data
- Evaluation of the Failure Detectability
- Discussion

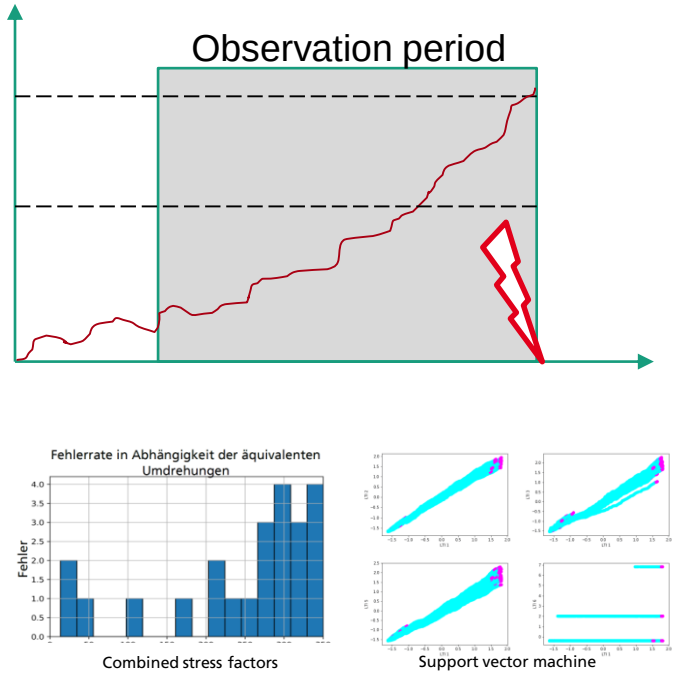
Using normal behaviour models to identify upcoming wind turbine failures - Motivation and Aim -

- Why early failure detection?
  - Reduce downtime of wind turbines → increase energy and earnings
  - From corrective maintenance to preventive
- Our Motivation?
  - Simplify: Reduce complexity, show patterns and relations
    - Ease decision making
  - Efficiency: Energy + Information > Energy

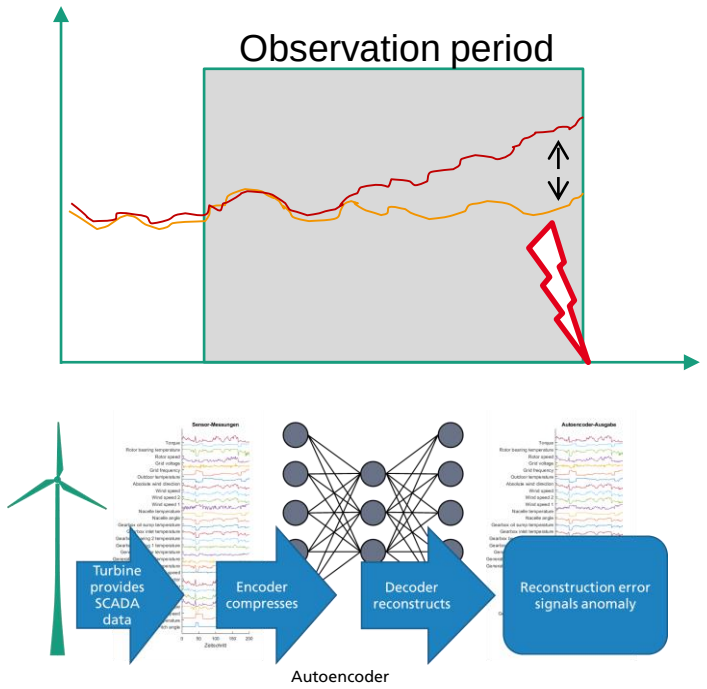
Using normal behaviour models to identify upcoming wind turbine failures - Background: Modelling -

Predictive Maintenance - How to detect wind turbine failures before they appear?

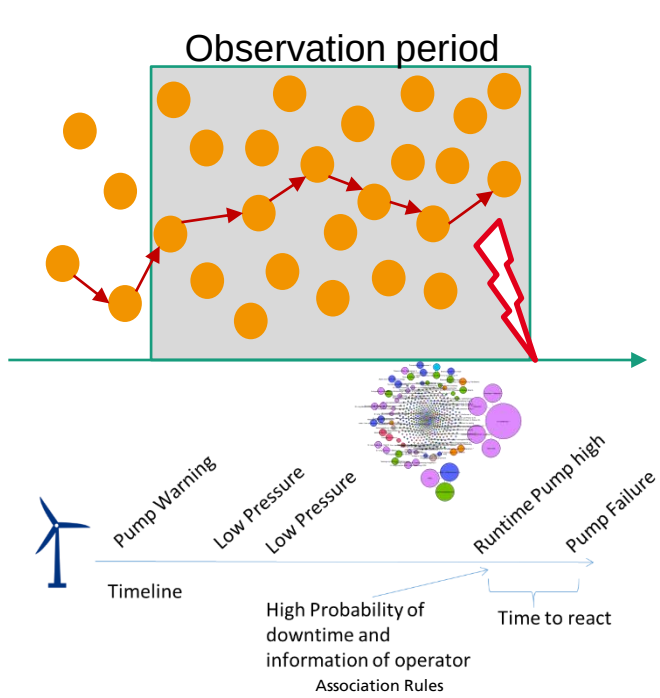
Stress factors



Normal behavior



Transient probability



Using normal behaviour models to identify upcoming wind turbine failures - Background: Modelling -

Stress factors

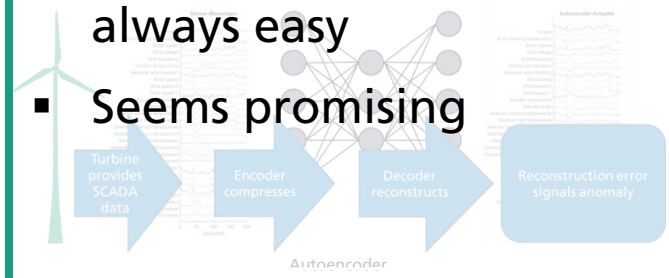
→ Reliability functions, Support Vector Machines, …

- Information about failures needed
- Mostly available
- But tedious to use at this point (to be structured and standardised)

Normal behavior

→ Autoencoder, PCA …

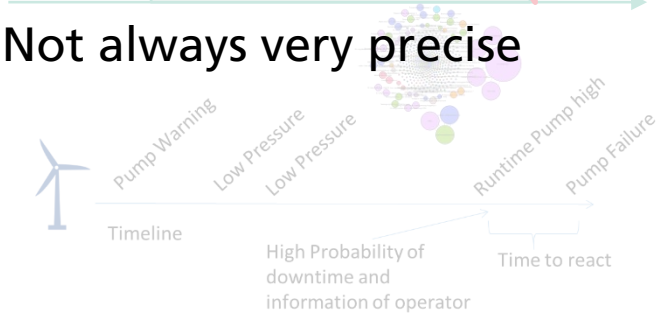
- No failure data needed
- Many normal data points available
- Differentiation between normal and abnormal not always easy
- Seems promising



Transient probability

→ Markov-Chains, association-Rules, …

- Information about states needed
- Mostly available
- Not always very precise



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Using normal behaviour models to identify upcoming wind turbine failures
- Background: Modelling -

Weights are adjusted in training

loss-function will yield a minimum

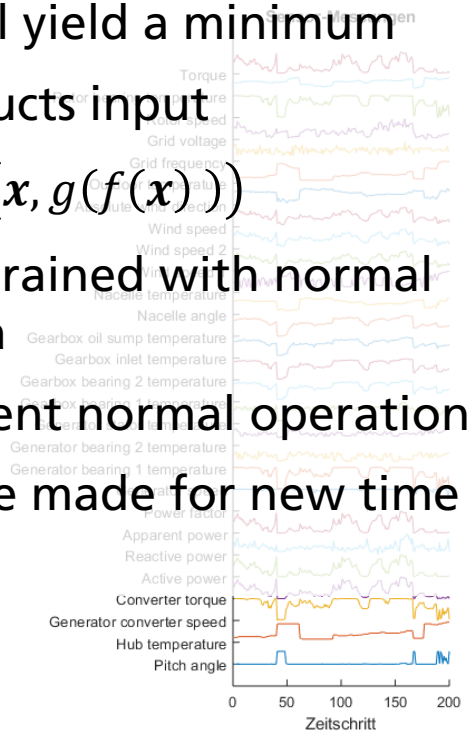
Output reconstructs input

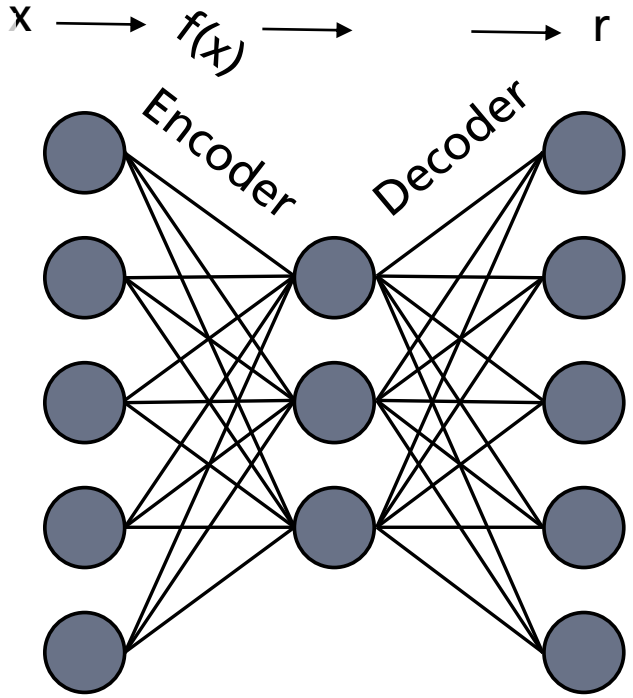
$$L\left(\boldsymbol{x}, g\left(f\left(\boldsymbol{x}\right)\right)\right)$$

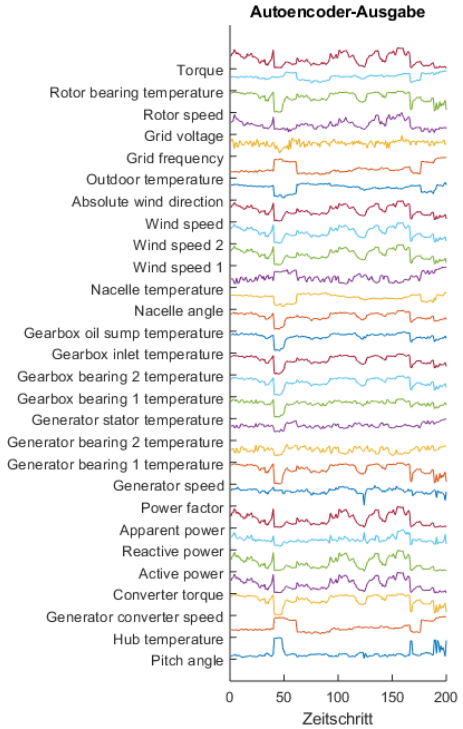
Autoencoder is trained with normal operational data

Learns to represent normal operation

Prediction can be made for new time stamps







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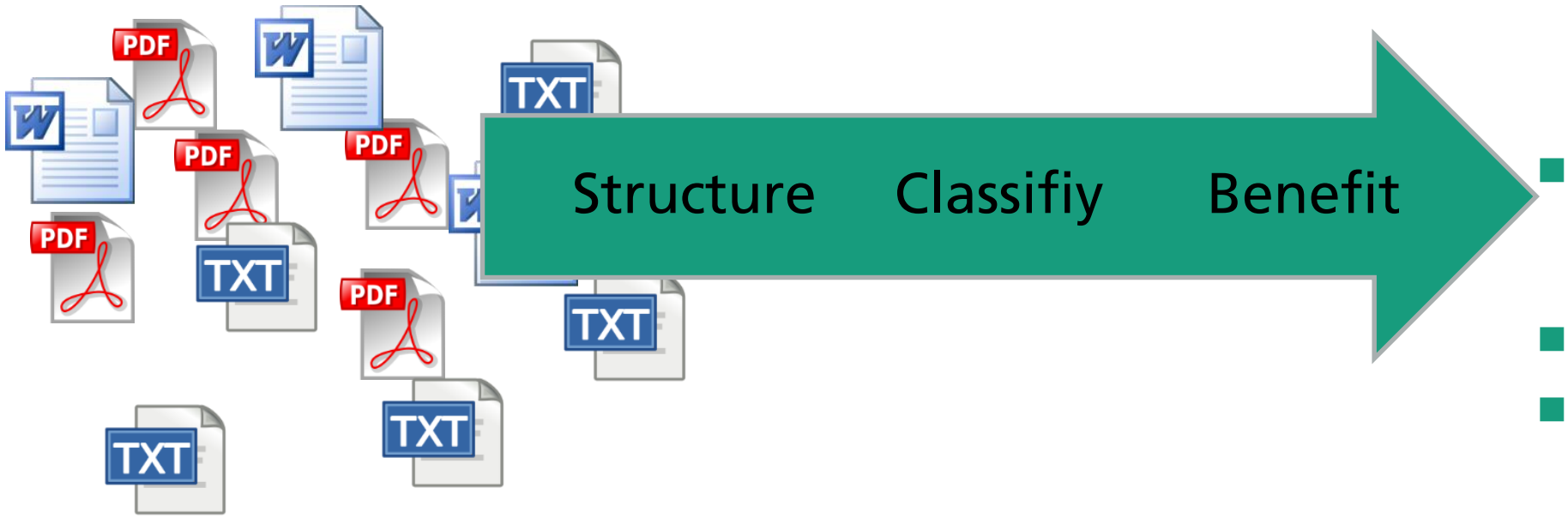
- Motivation and Aim
- Predictive Maintenance with Machine Learning Models
- **Benefitting of not yet usable maintenance data**
- Evaluation of the Failure Detectability
- Discussion

Using normal behaviour models to identify upcoming wind turbine failures - Benefitting of not yet usable maintenance data -

- From Information → Knowledge (Use maintenance information to improve service)
- Classifying service descriptions into domain standards

Many different reports



- Make use of data that is to date not usable
- Classification maintenance description in service reports into given standards (RDS-PP, ZEUS)
- Ease communication between different enterprises
- Better modelling of failures
- Better understanding of asset value by usage of all digital information (buy, sell)

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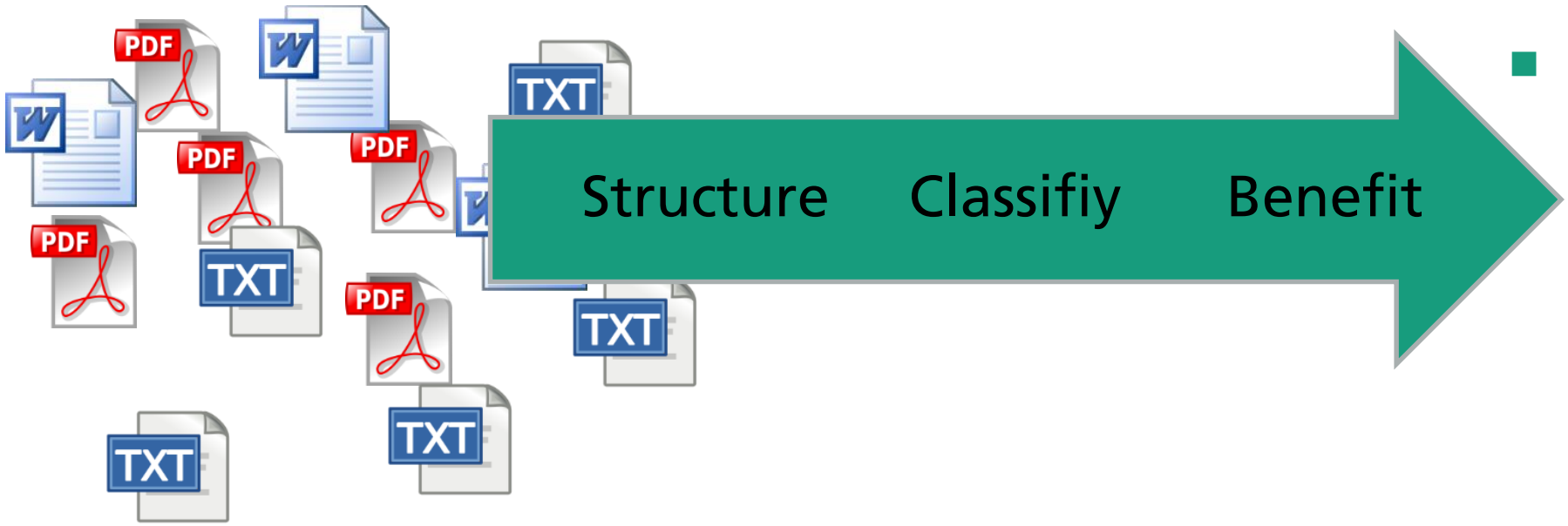
Many different reports



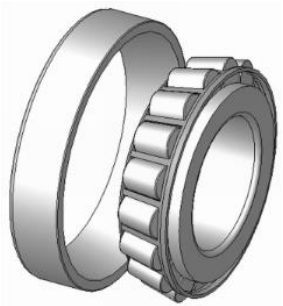
- One classified report each row
- Same information for different reports in the same column
- To database or other data sink

Using normal behaviour models to identify upcoming wind turbine failures - Benefitting of not yet usable maintenance data -

- From Information → Knowledge (Use maintenance information to improve service)

Problem with the generator bearing, needed to add some lubricant

Text Classification →



RDS-PP ID

ZEUS ID

Again the manhole cover was damaged. Most likely due to the last storm. Manhole cover sealad and welded

Some cracks in the tower have been seen. New protection will be added at next sight of turbine

Text Classification →

RDS-PP ID

ZEUS ID

Using normal behaviour models to identify upcoming wind turbine failures
- Benefitting of not yet usable maintenance data -

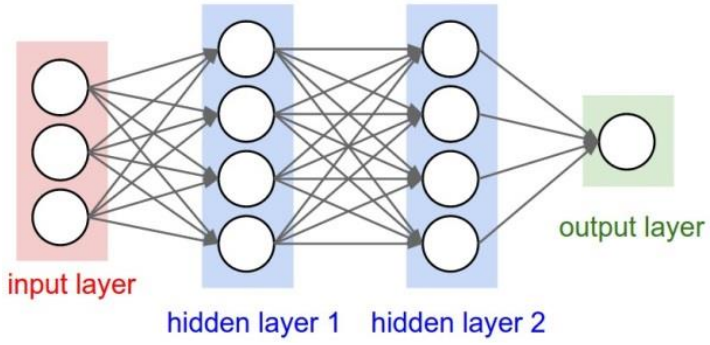
Text classification

How can it be done?

- Manual Labour

- Key word mining

- Machine Learning



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Using normal behaviour models to identify upcoming wind turbine failures - Benefitting of not yet usable maintenance data -

Text classification

How can it be done?

- Manual Labour
- Key word mining
- Machine Learning

- Manual Labour is tedious
  - Necessary as an initial step (> 1000 records)
- Key word mining only partly accurate
- Different methods of text classification implemented
  - Support Vector Machines, Linear Regression, Ada Boost, Artificial Neuronal Networks (ANN), Convolutional Neuronal Networks (CNN)
  - CNNs and ANNs worked best

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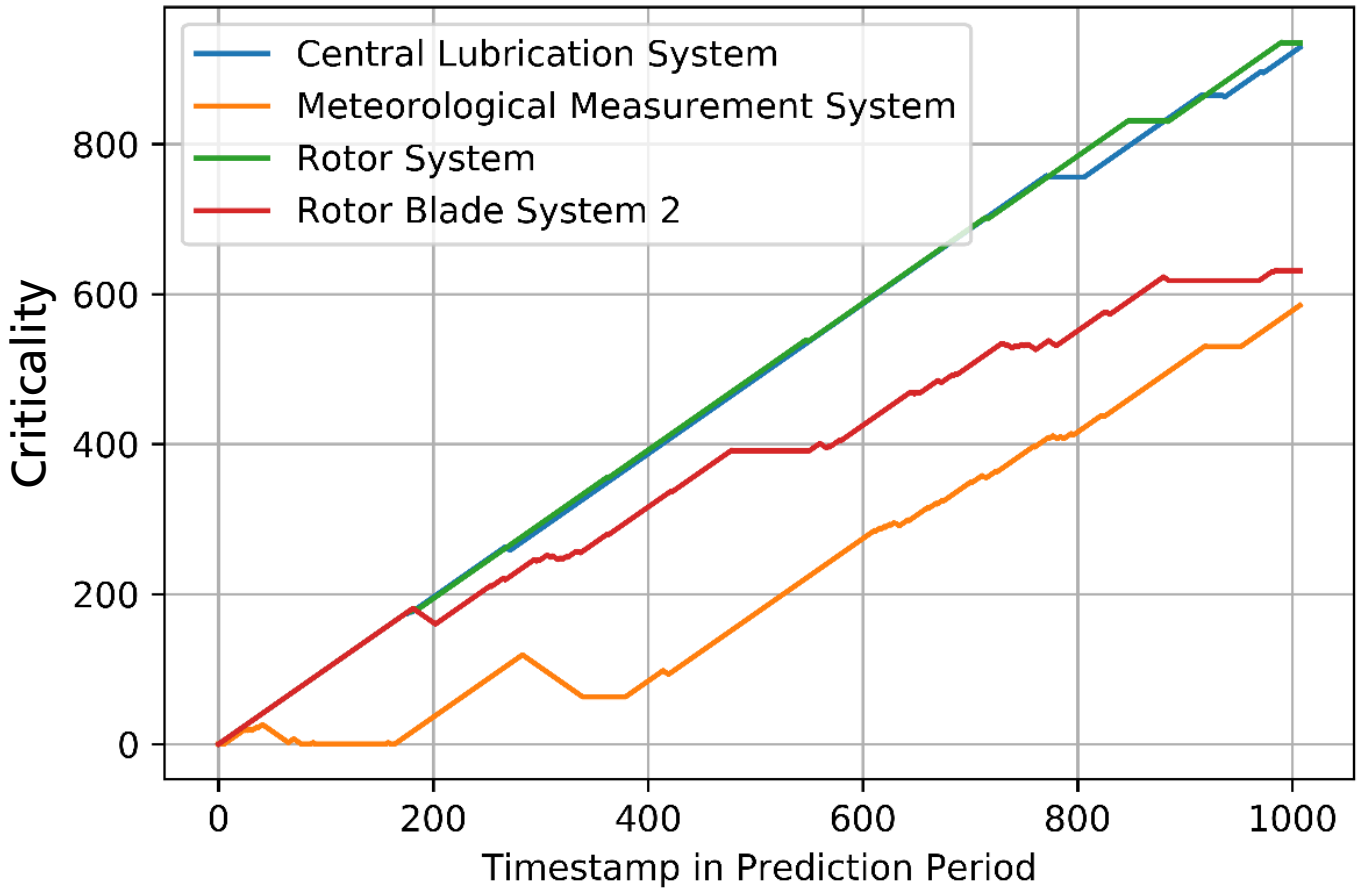

- In around 20 percent of all cases, many anomalies appeared one or more days before an error
- Criticality roughly equivalent to number of anomalous time stamps
  - Increasing for anomalous time stamps
  - Constant for Service or manual stop
  - Decreasing if timestamp is considered normal
- Failures in different systems and subsystems can be detected
  - Wind vane failure
  - Rotor blade
  - Rotor blade system 2, Pitch accumulator

Using normal behaviour models to identify upcoming wind turbine failures - Discussion -

- Autoencoder shows good results
  - Needs further field tests (Daily Prediction one week backwards)
  - Easier decision
  - Focus on “problems”, domain knowledge further needed
- Classifications of service reports done manually
  - In Future:
    - Use standards while acquisition
    - Or text classification a posteriori
  - It is expected that other models detect different anomalies better
    - Ensemble of models mostly better than one

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