Failure and Remaining Useful Life Prediction of Wind Turbine Gearboxes Using Condition Monitoring Data

Sofia Koukoura, James Carroll, Alasdair McDonald

Wind & Marine Energy Systems CDT, Rm 3.36, Royal College Building
University of Strathclyde, 204 George Street, Glasgow, G1 1XW

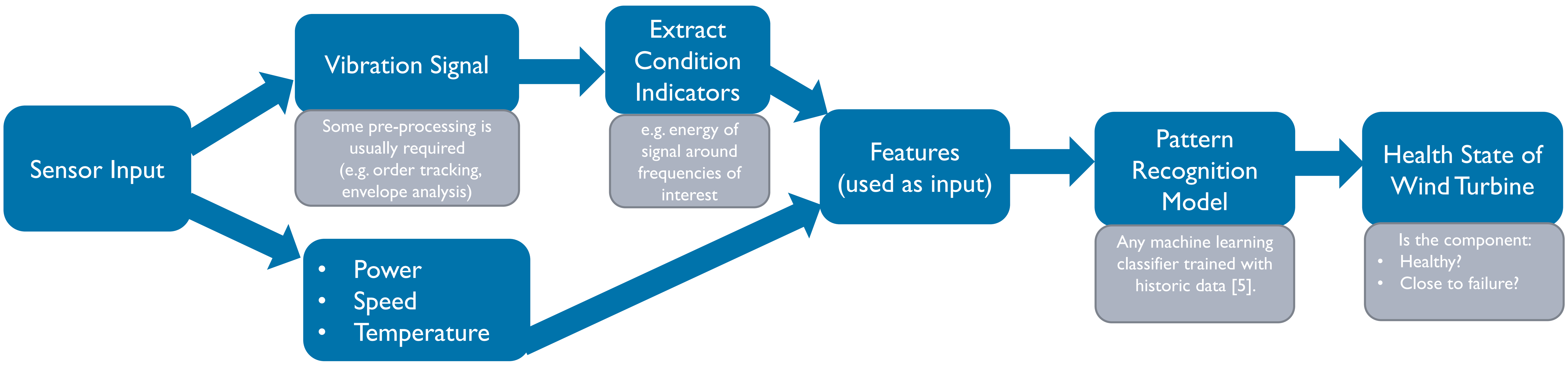
sofia.koukoura@strath.ac.uk

Introduction

Reducing the cost of energy from wind is an important challenge the industry faces today. Increasing the wind turbine availability and therefore reducing O&M costs, can be achieved through the successful detection of incipient faults before they become catastrophic failures. Consequently, condition monitoring systems are increasingly being developed and integrated in wind farms, so that O&M actions are optimised accordingly. Yet, foreseeing incipient faults and identifying the components to be replaced can be a challenging task. One of the components with the highest downtime per failure and the highest replacement cost is the gearbox [1].

Methodology

The purpose of this project is to develop and automatic failure prediction framework of wind turbine gearboxes that utilises condition monitoring data and identifies incipient failures- if any. The framework focuses on component level. Features from vibration and other sensors in the gearbox as used as input in pattern recognition models so that the health state of the turbine can be determined.



Case Study on Real Wind Turbine Data

Wind turbine system and signal acquisition:

- Wind turbine rated between 2.5-3.5MW.
- 95 samples collected at various times prior to failure (2.5 years to 1 week before).
- Acceleration data collected on a sampling rate between 20-30kHz for 10-15s.
- Power, generator speed, wind speed and temperature average for that time frame.
- Failed component: planet bearing on the first planetary stage.
- Failure mode: inner race spalling.

Vibration signal pre-processing:

- Gear components and bearing components are separated using an adaptive filter.
- Spectral kurtosis is used to find the appropriate demodulation band.
- Envelope analysis reveals bearing fault frequencies [4].

Input features to classifier: energy around ball passing frequency and its 3 harmonics, power, generator speed, wind speed, oil temperature, ambient temperature

Classifier used: Support Vector Machines (Linear Kernel)

Data Classes:

- Healthy
- Faulty (up to 6 months before failure)

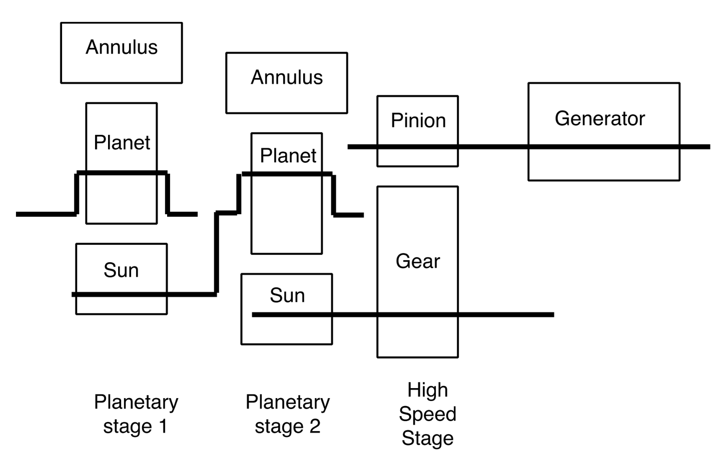


Figure 1: Gearbox internal Structure.

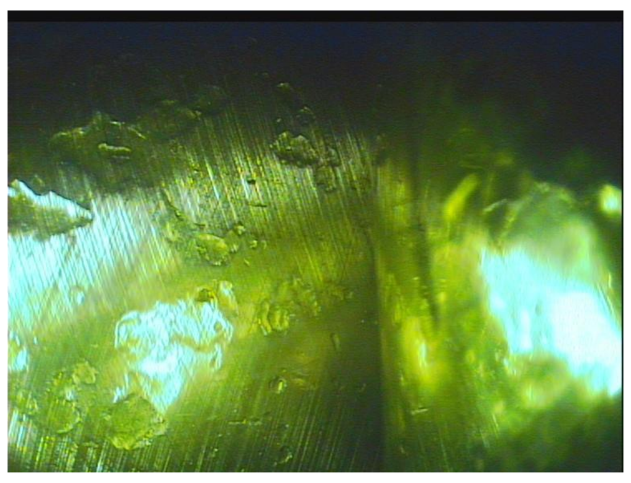


Figure 2: Faulty bearing validation results.

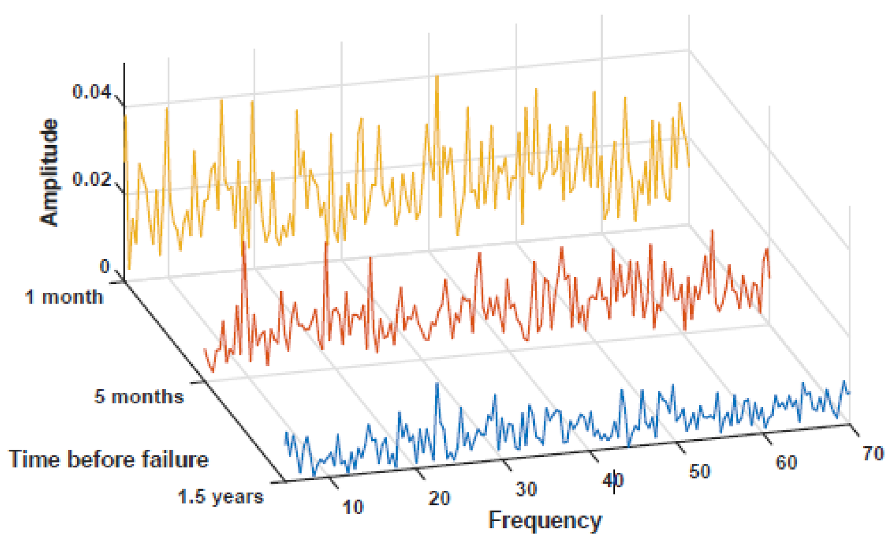


Figure 3: Envelope Spectra at different times prior to failure..

		Predicted class	
		Faulty	Healthy
Actual Class	Faulty	90%	10%
	Healthy	15%	85%

Figure 4: Classification Results

Conclusions

Low speed stage bearing faults may require some signal pre-processing techniques in order to perform fault diagnosis. Given sufficient samples, features can be extracted from condition monitoring sensors and given as inputs to machine learning models that predict the health state of the component.

References

[1] Carroll J, McDonald A, McMillan D. Failure rate, repair time and unscheduled O&M cost analysis of offshore wind turbines. *Wind Energy*. 2016 Jun 1;19(6):1107-19., [2] Sheng, S., 2012. Wind turbine gearbox condition monitoring round robin study–Vibration analysis. Contract, 303, pp.275-3000. [3] Fyfe, K.R. and Munck, E.D.S., 1997. Analysis of computed order tracking. *Mechanical Systems and Signal Processing*, *11*(2), pp.187-205, [4] Randall, R.B. and Antoni, J., 2011. Rolling element bearing diagnostics—a tutorial. *Mechanical systems and signal processing*, *25*(2), pp.485-520., [5] Christopher, M.B., 2016. PATTERN RECOGNITION AND MACHINE LEARNING. Springer-Verlag New York.

EPSRC Pioneering research and skills
CATAPULT Offshore Renewable Energy
DNV·GL
SKF
futureWind & Marine 2018