

Improved yield from wind turbines through online anomaly detection and compensation

Student: Giorgio Zorzi

Supervisor: William Leithead

Industrial partner: Sgurr Control

Research

- Use accelerometers measurements to obtain more info from a wind turbine such as Blade Root Bending Moments (BRBM)
- Estimate anomalies
 - i. Wind Shear
 - ii. Wind veer
 - iii. Blade mass imbalance
 - iv. Aerodynamic imbalance
 - v. Extreme gusts
- Compensation

Advantages

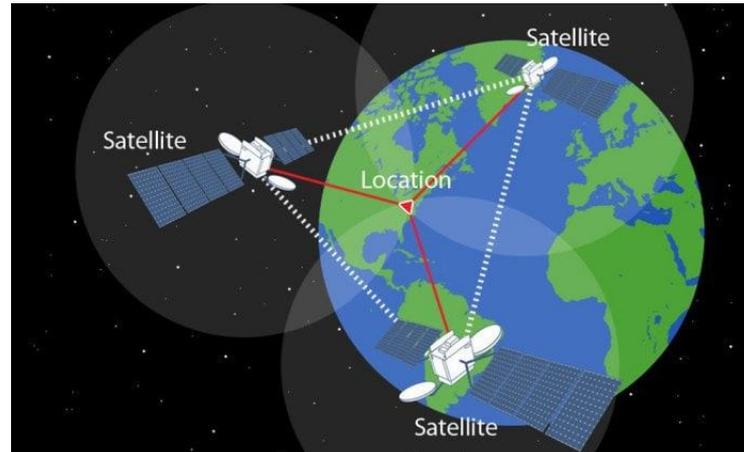
- Accelerometers are cheap
- Accelerometers are robust
- Possibility of retrofitting
- Anomaly estimation
- Improved yield
- Increase fatigue life

Bayesian filtering and smoothing

Used to estimate states of a system.

Some applications include:

- GPS;

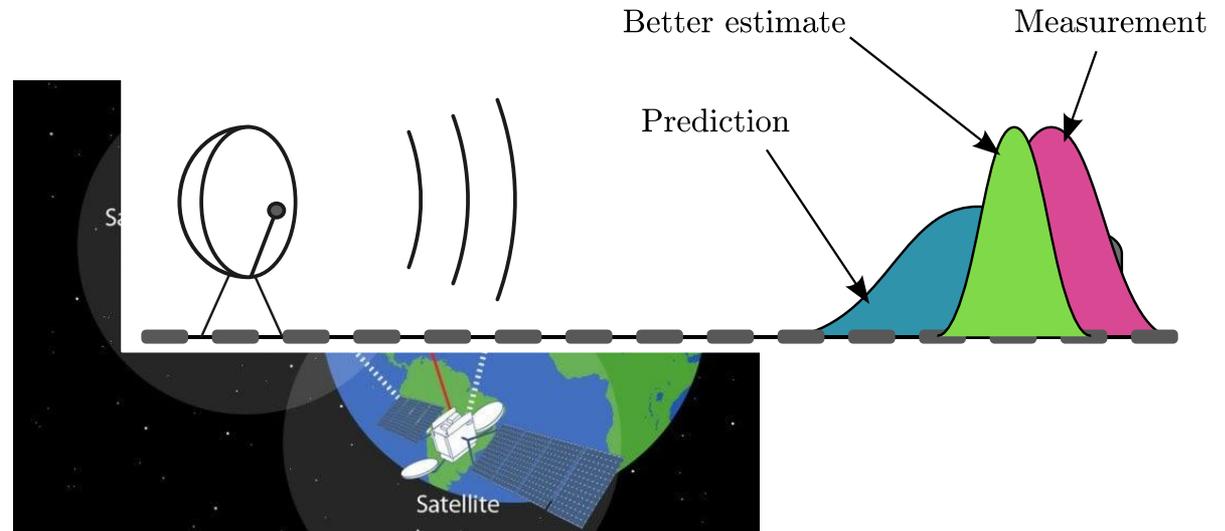


Bayesian filtering and smoothing

Used to estimate states of a system.

Some applications include:

- GPS;
- Target tracking;

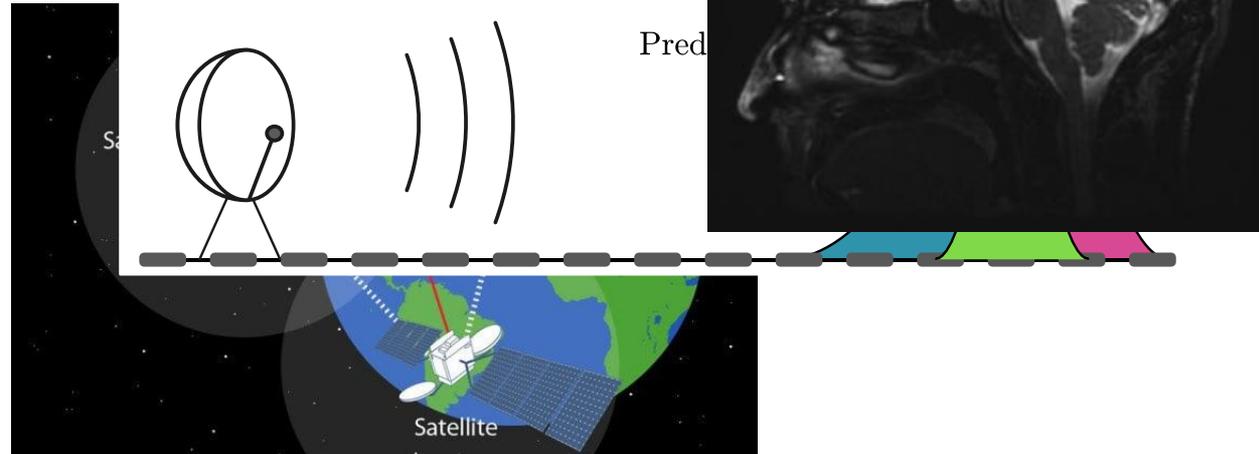


Bayesian filtering and smoothing

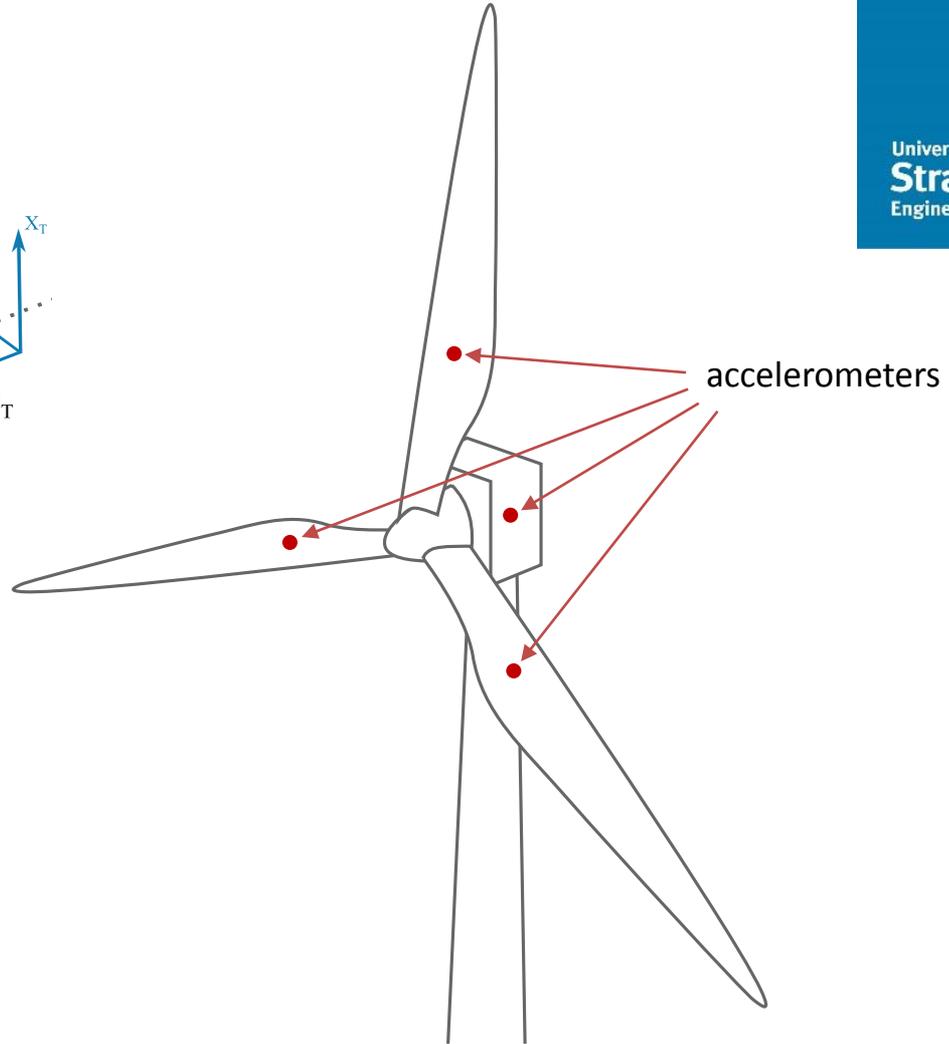
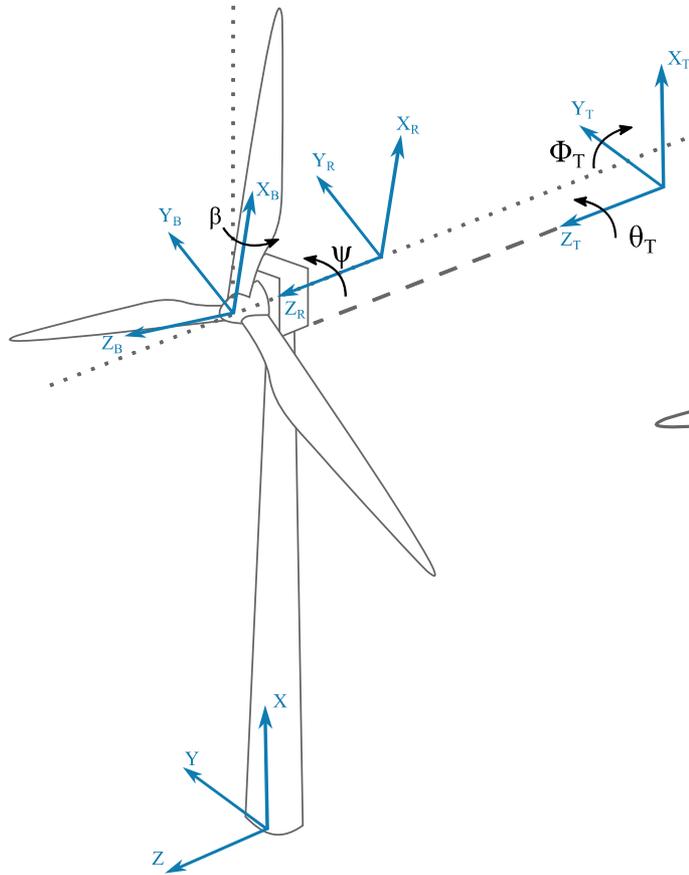
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Some applications include:

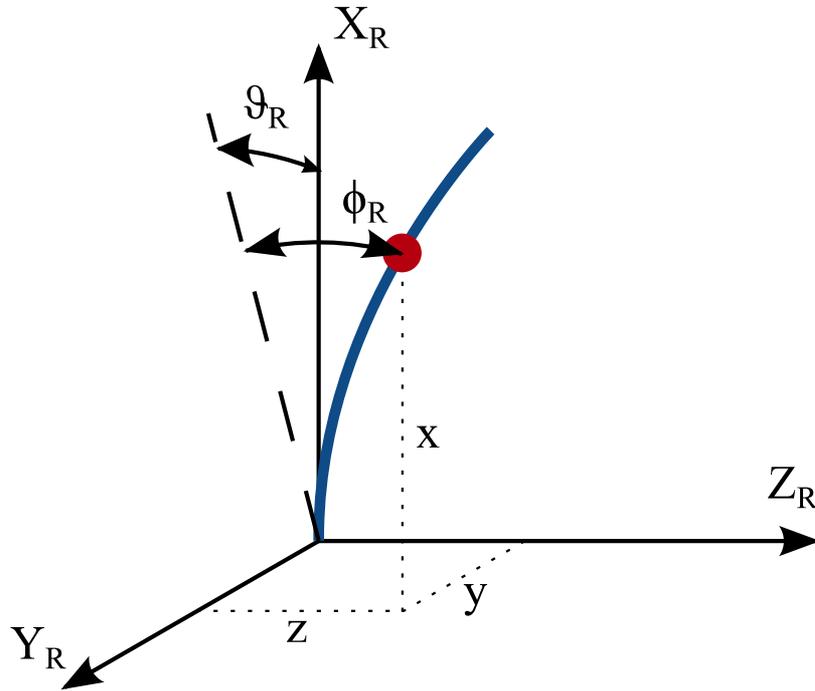
- GPS;
- Target tracking;
- Brain imaging;
- Etc.



The system



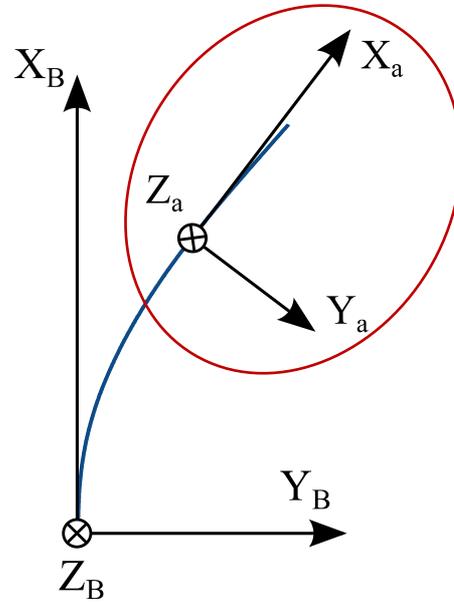
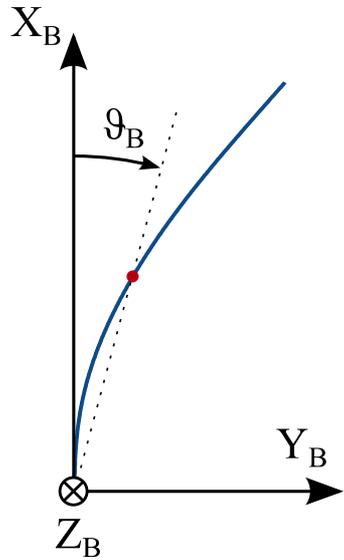
Equations of motion of the blade



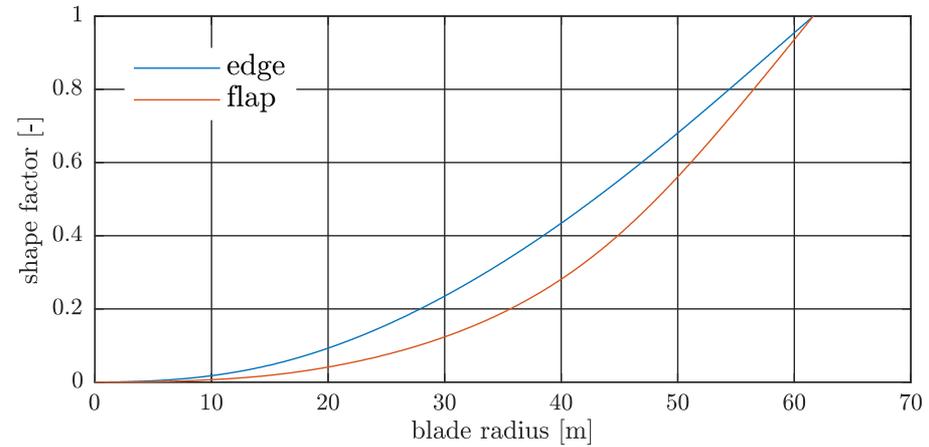
$$\ddot{\vartheta}_R = \dots$$

$$\ddot{\phi}_R = \dots$$

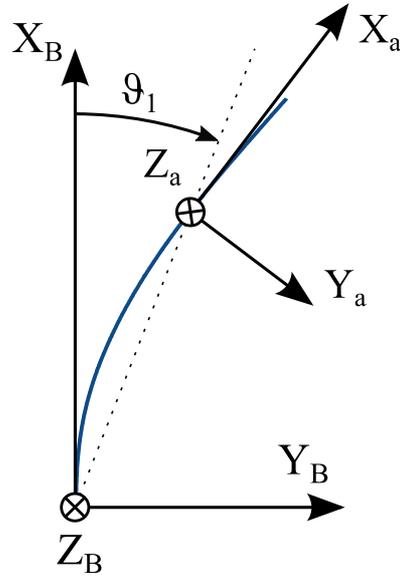
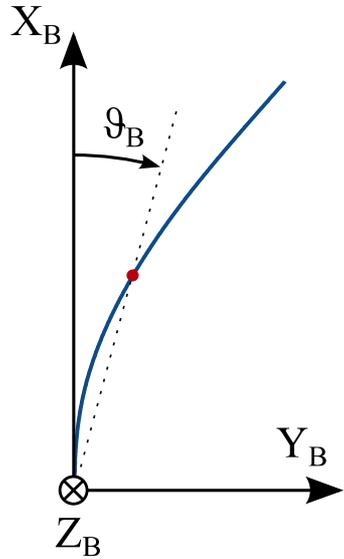
Blades



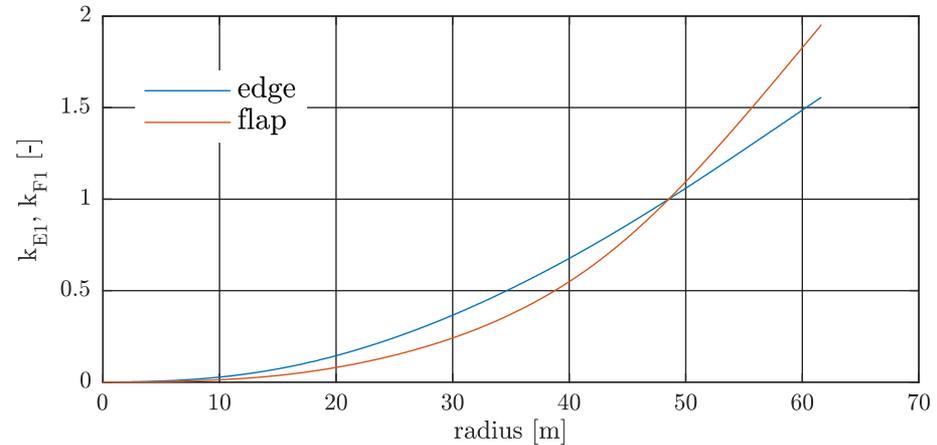
Accelerometer
frame of reference



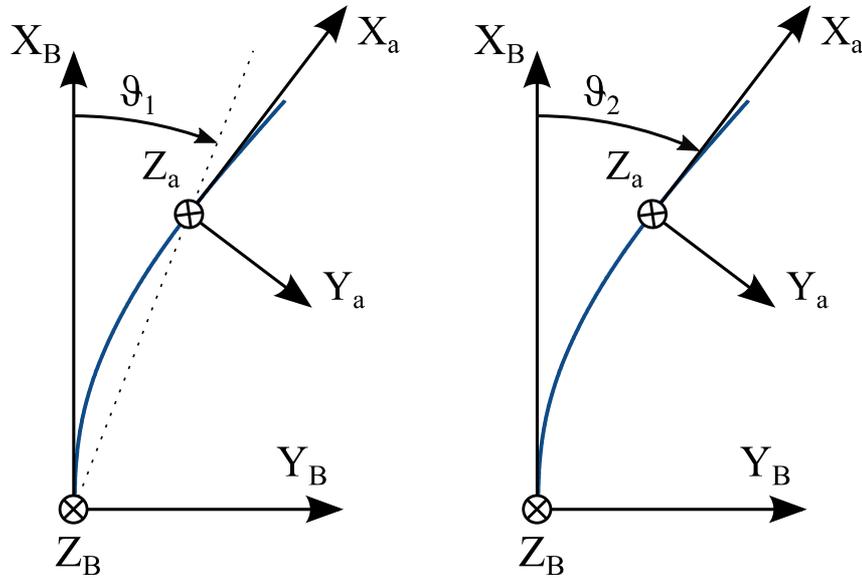
Blades



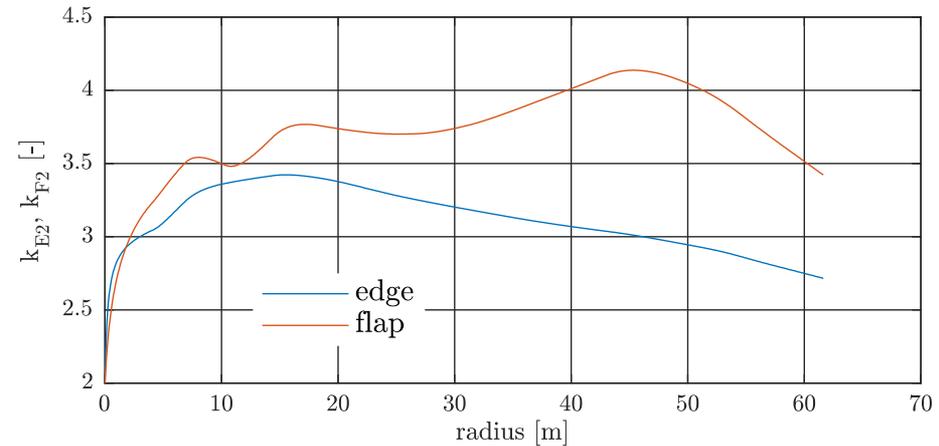
$$k_1 = \frac{\vartheta_1}{\vartheta_B}$$



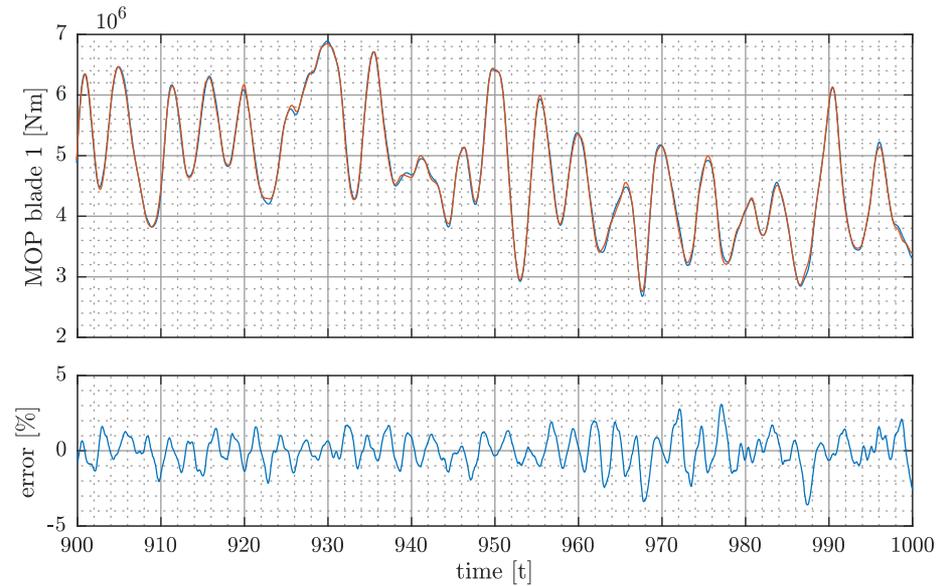
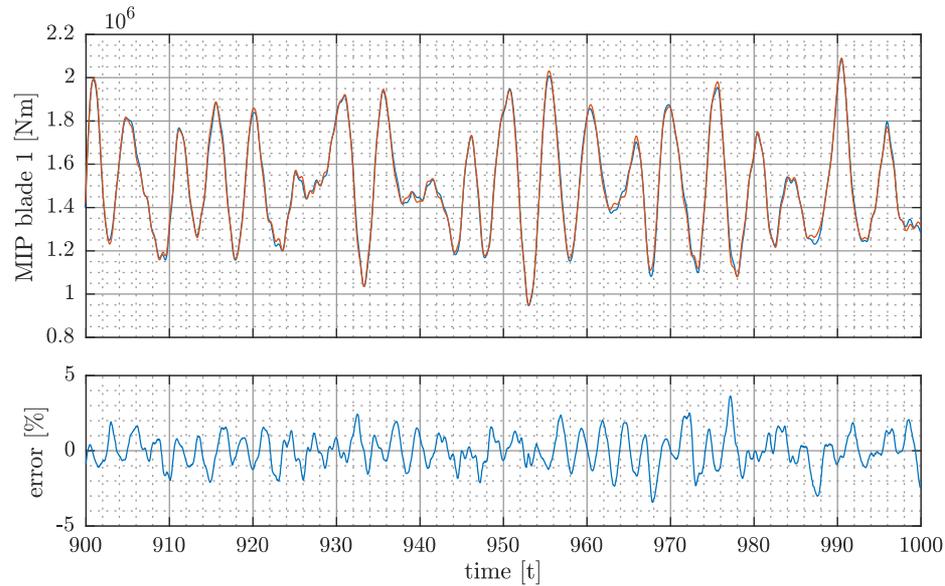
Blades



$$k_2 = \frac{\vartheta_2}{\vartheta_1}$$



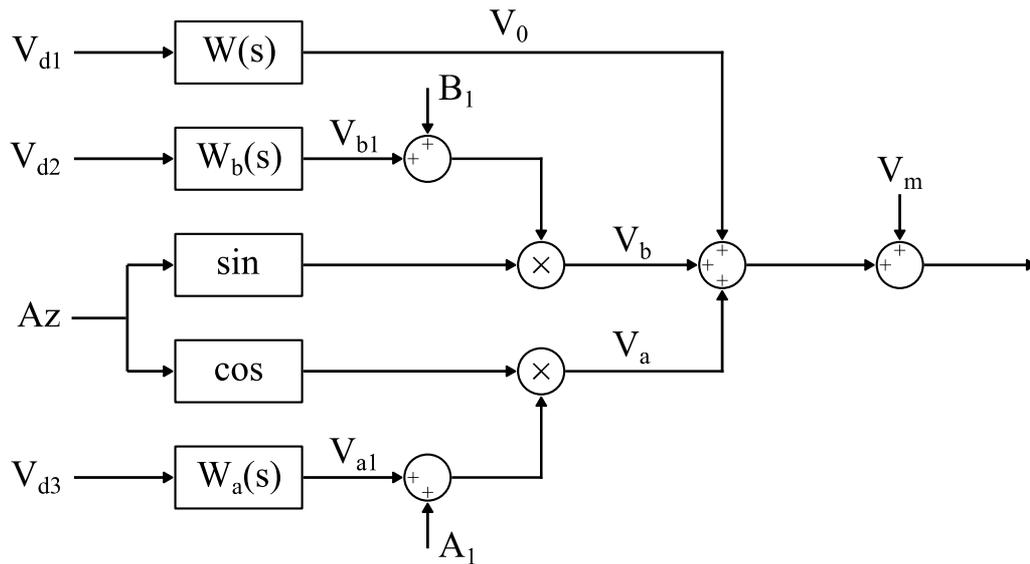
BRBM estimator



BRBM estimation based on accelerometers readings

Wind model

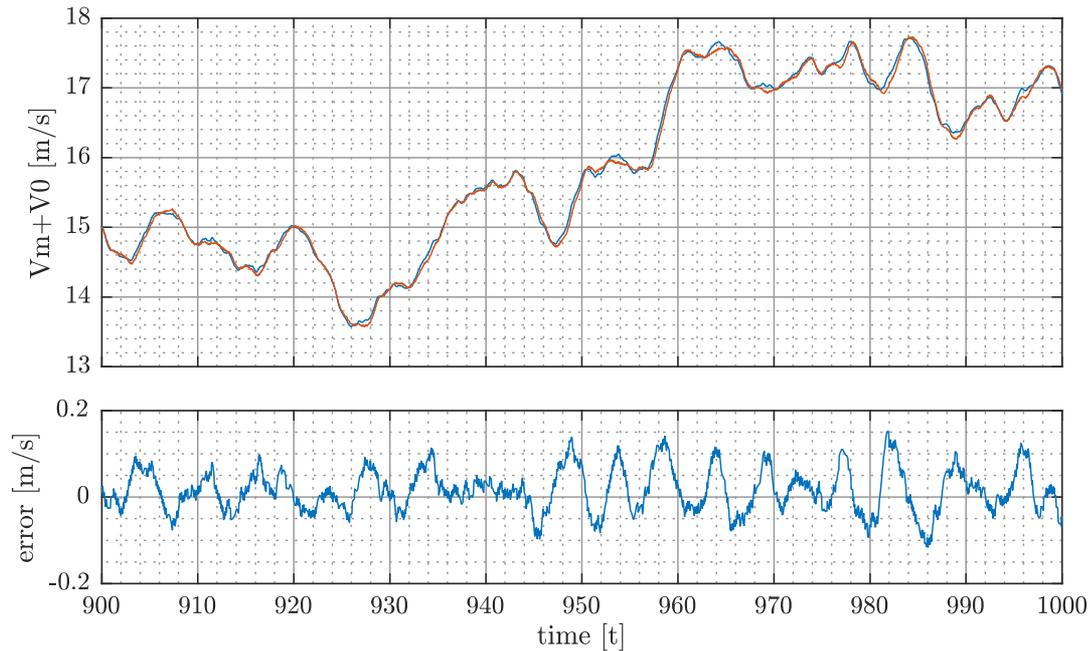
Wind model for
blade 1 up to 1P



Turbulence
Vertical variations
Horizontal variations

Wind model: L. G. Santos, "Aerodynamics and wind field models for wind turbine control" Ph.D. dissertation, University of Strathclyde, 2015.

Wind components estimation

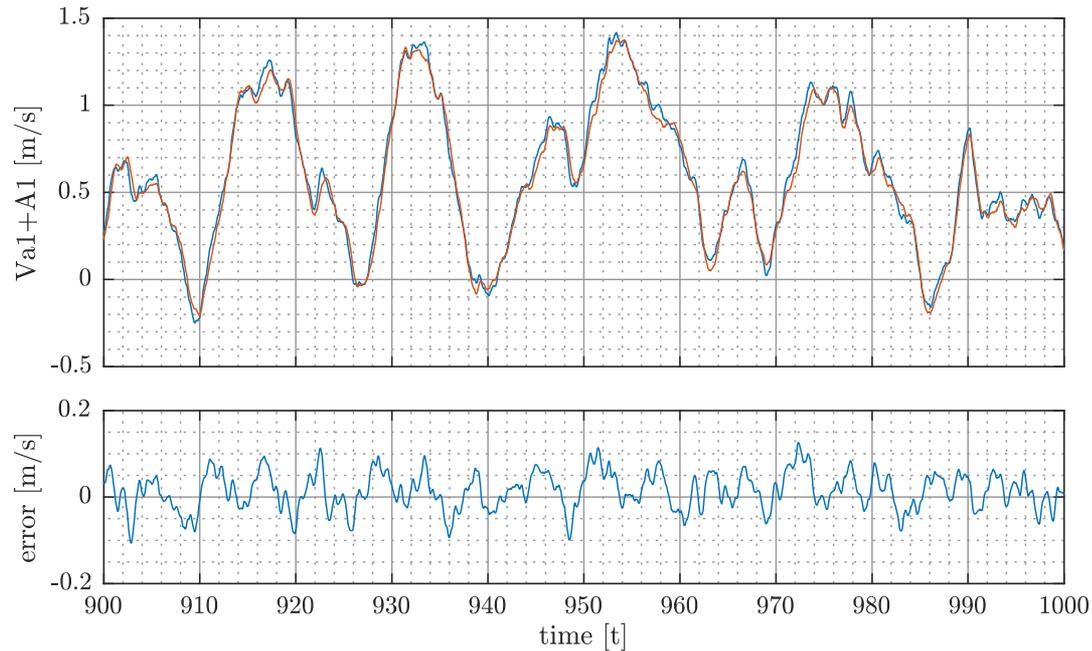


Turbulence

Vertical variations

Horizontal variations

Wind components estimation

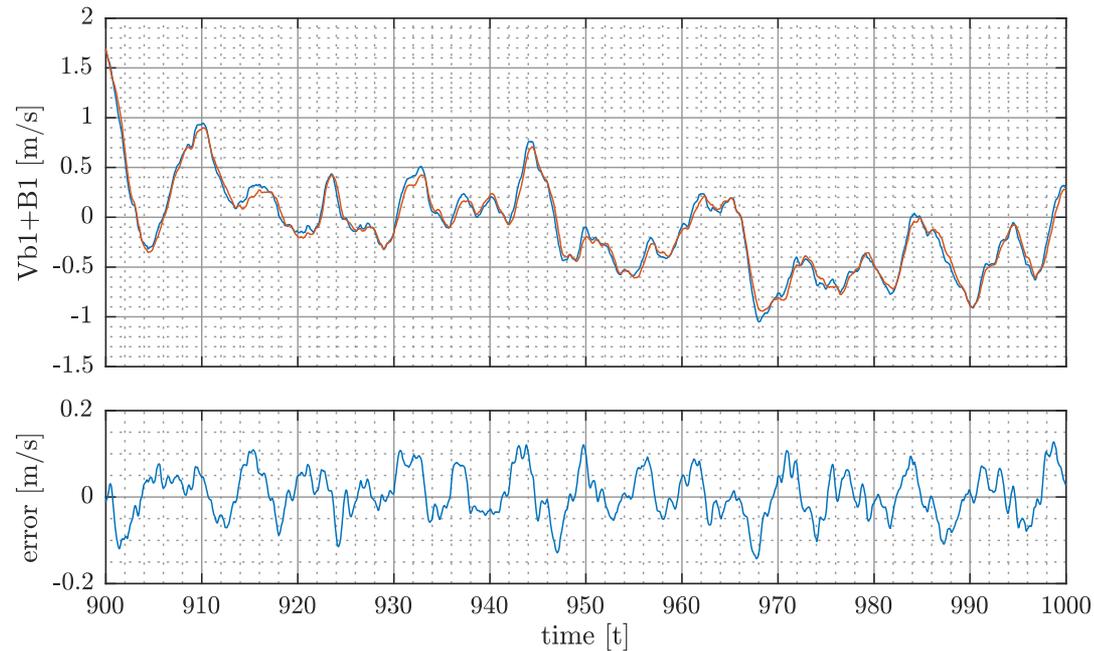


Turbulence

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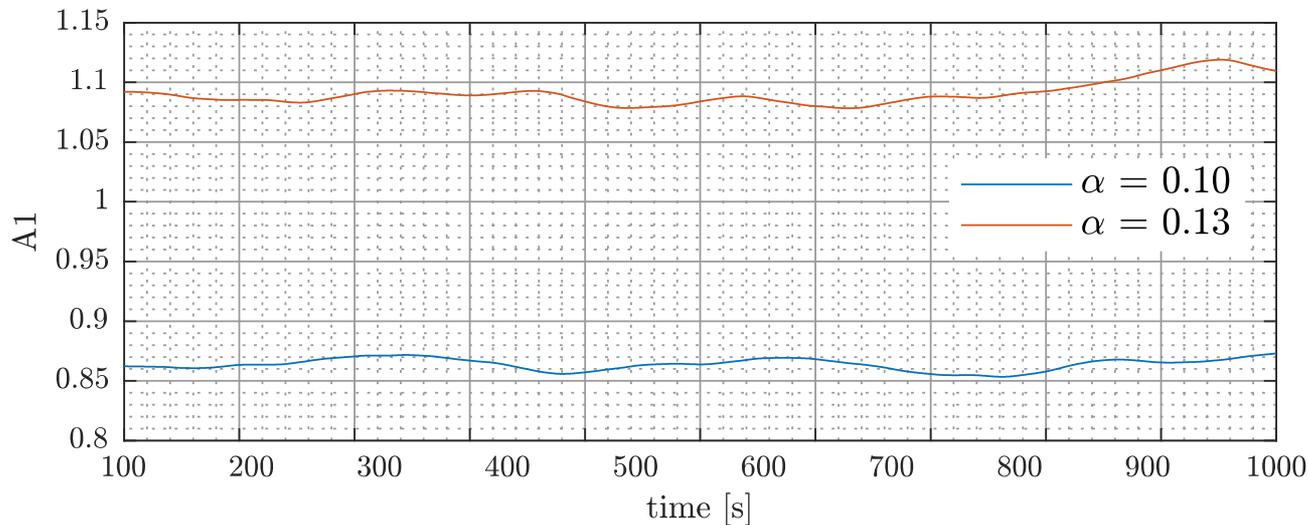
Turbulence

Vertical variations

Horizontal variations

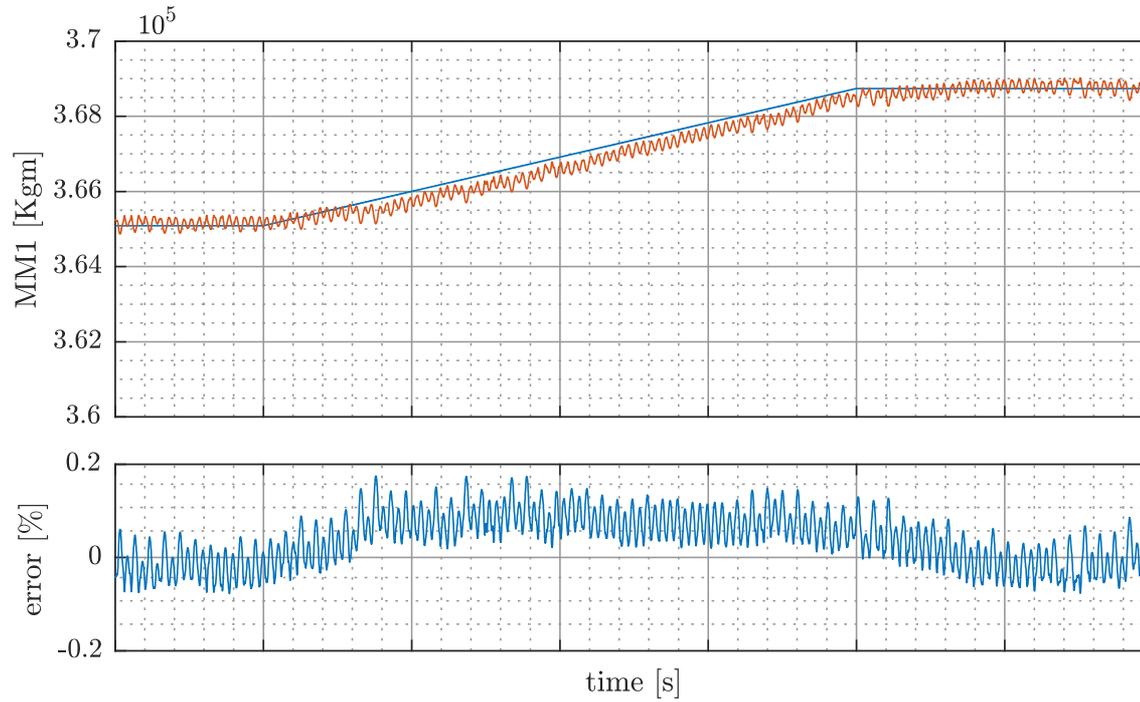
Wind shear estimate

Change in the deterministic component A1 reflects changes in the wind shear exponent



$$v(z) = v(z_0) \left(\frac{h}{h_0} \right)^\alpha$$

Blade first moment of mass estimation



Simulated increase of first moment of mass due to icing (+1%)

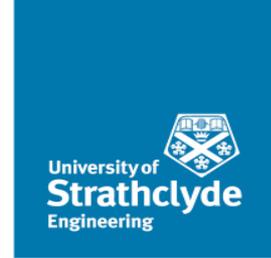
Future work

- Implement aerodynamic imbalance detection;
- Implement gust detection;
- Compensate for anomalies



EPSRC

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futureWind ²⁰¹⁸ & Marine



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