

Improved yield from wind turbines through online anomaly detection and compensation

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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

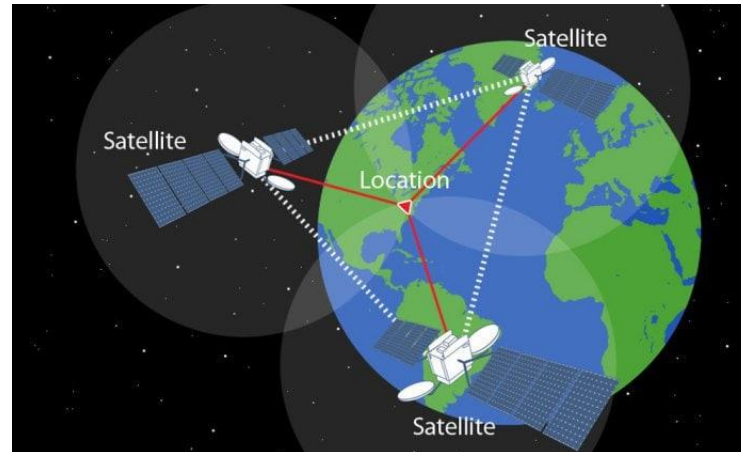
- Accelerometers are cheap
- Accelerometers are robust
- Possibility of retrofitting
- Anomaly estimation
- Improved yield
- Increase fatigue life

Bayesian filtering and smoothing

Used to estimate states of a system.

Some applications include:

- GPS;

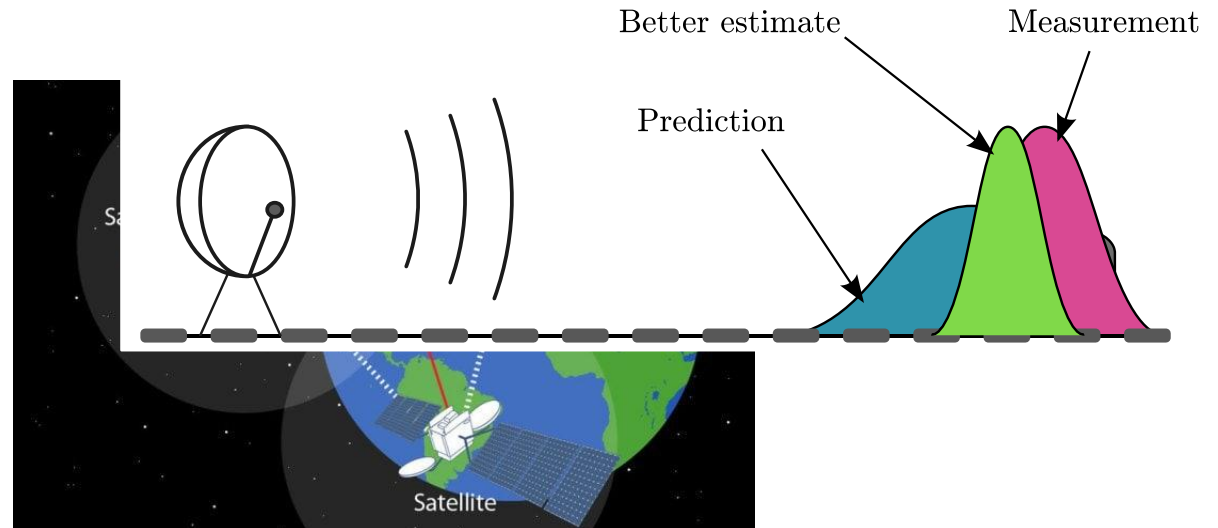


Bayesian filtering and smoothing

Used to estimate states of a system.

Some applications include:

- GPS;
- Target tracking;

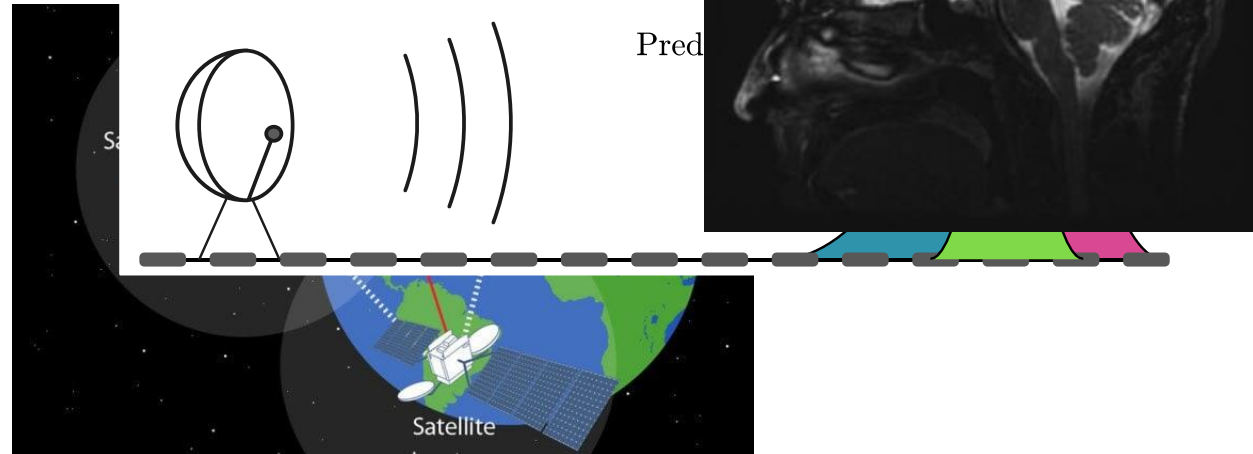


Bayesian filtering and smoothing

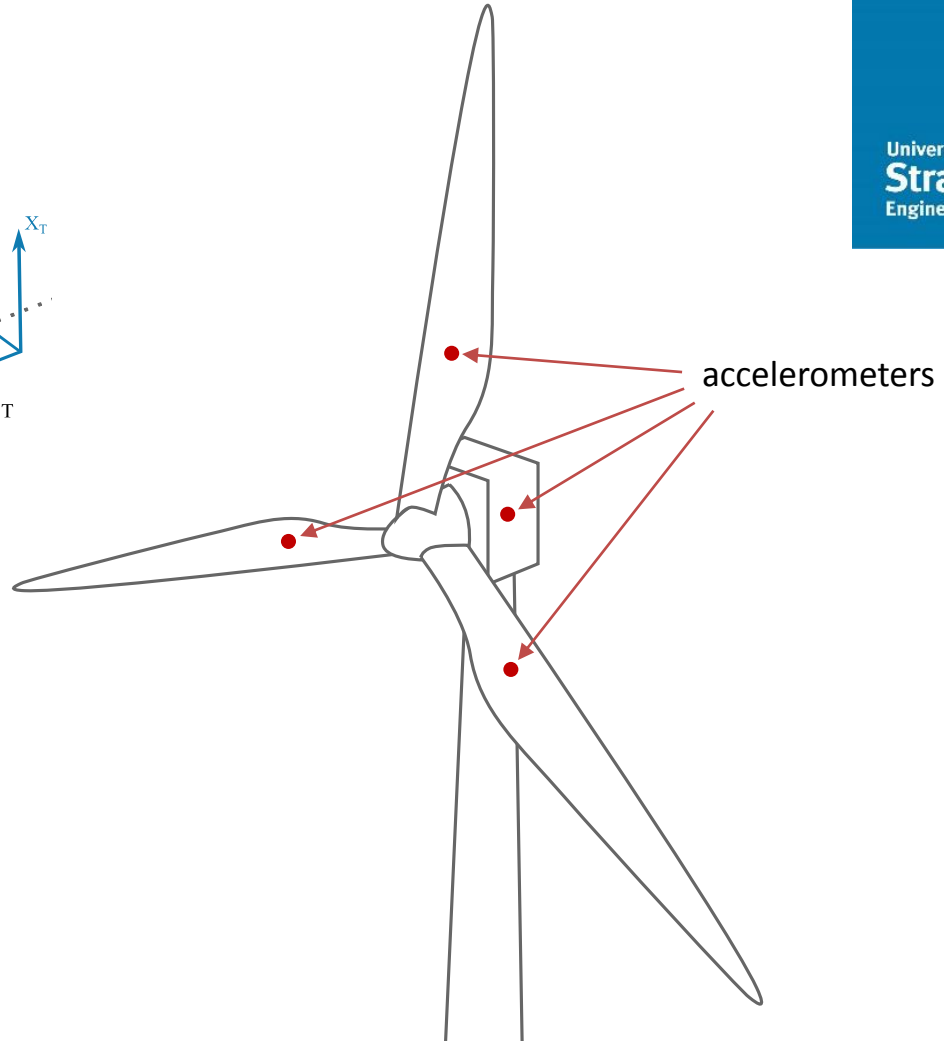
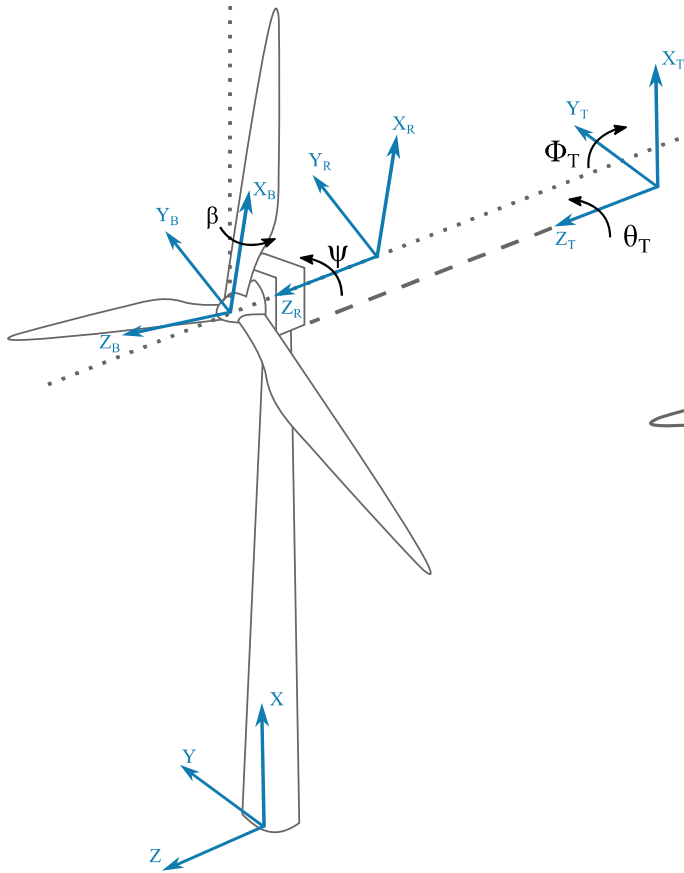
Used to estimate states of a system.

Some applications include:

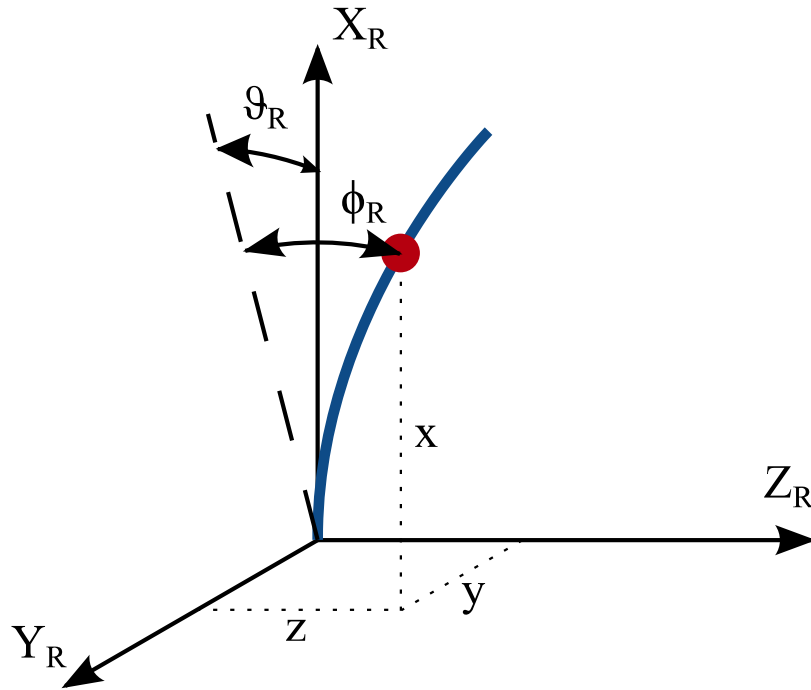
- GPS;
- Target tracking;
- Brain imaging;
- Etc.



The system



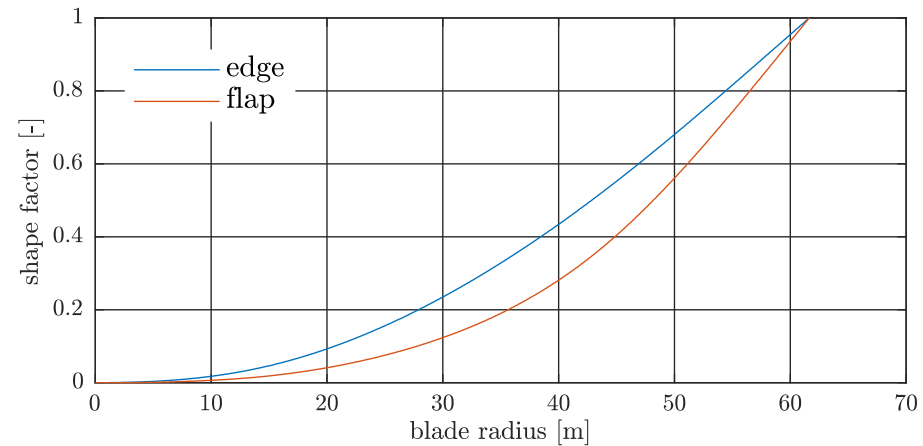
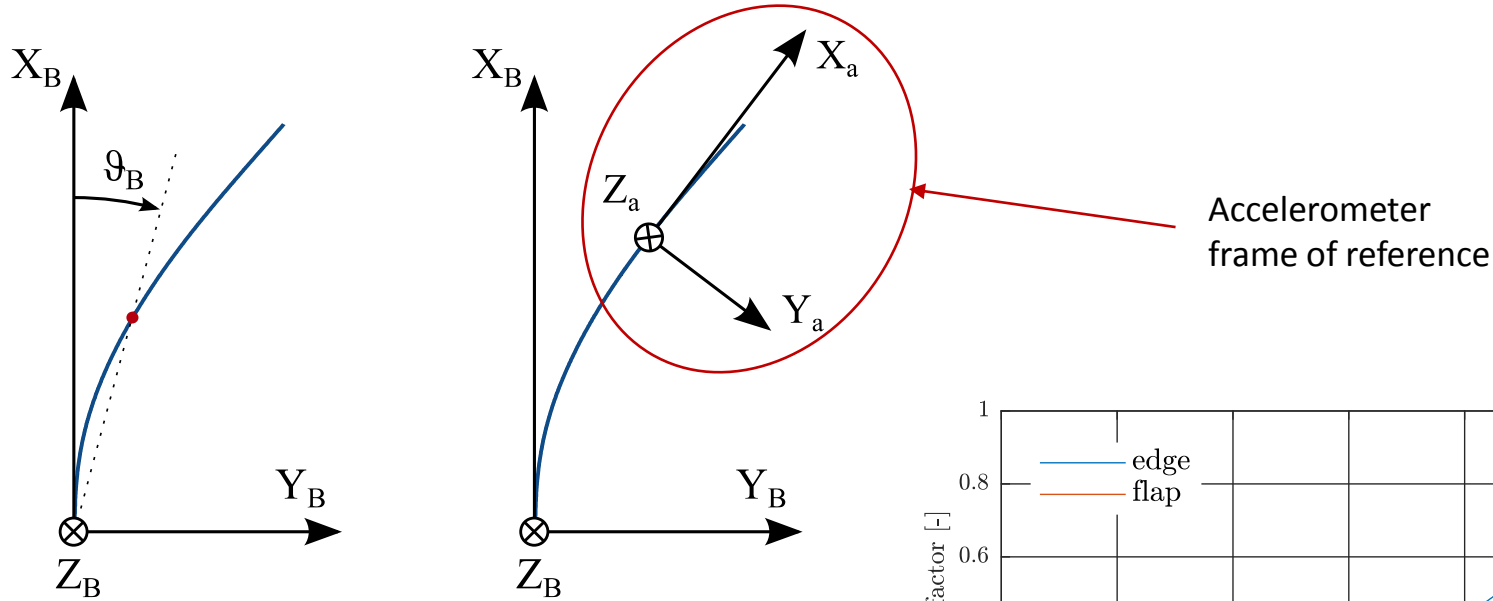
Equations of motion of the blade



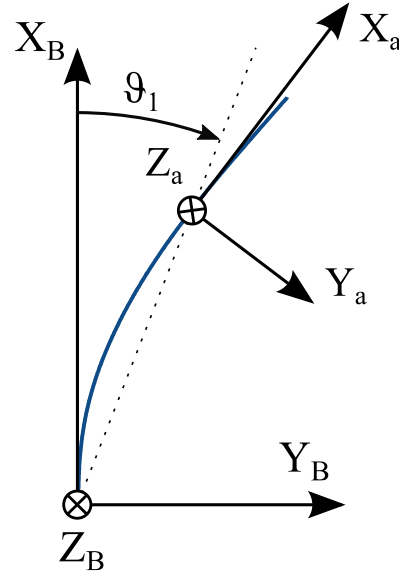
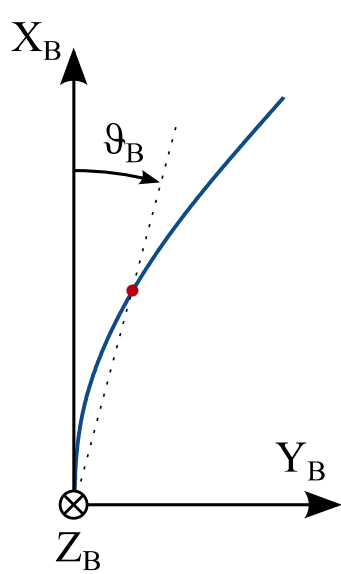
$$\ddot{\vartheta}_R = \dots$$

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

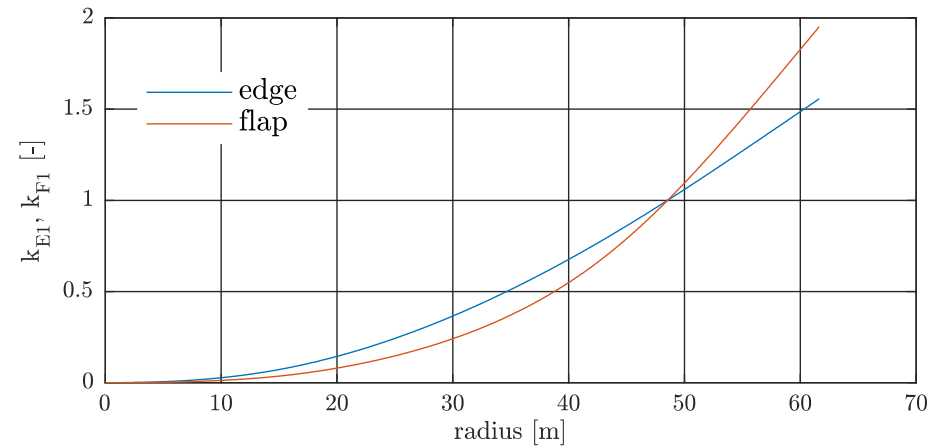
Blades



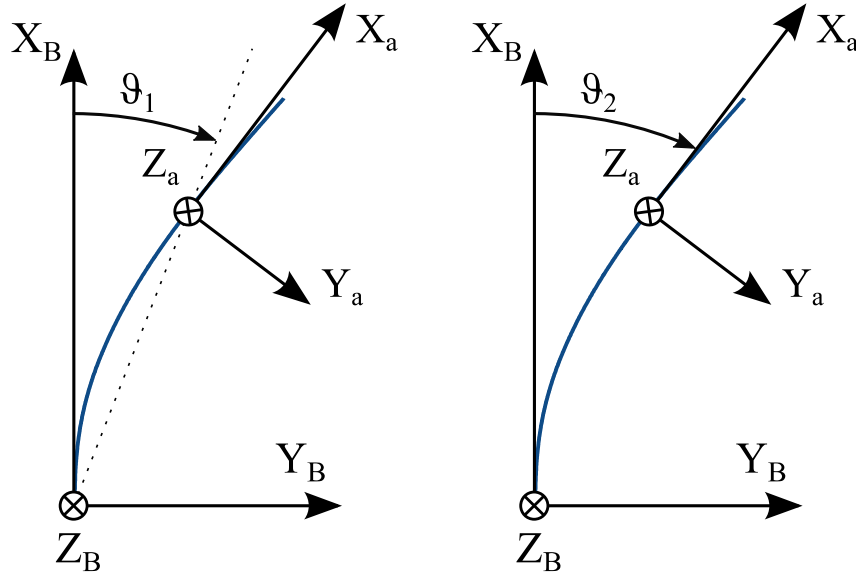
Blades



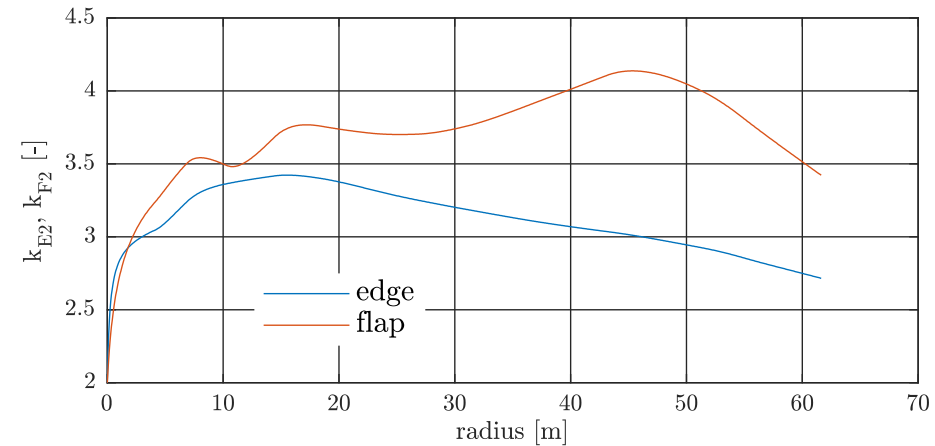
$$k_1 = \frac{\vartheta_1}{\vartheta_B}$$



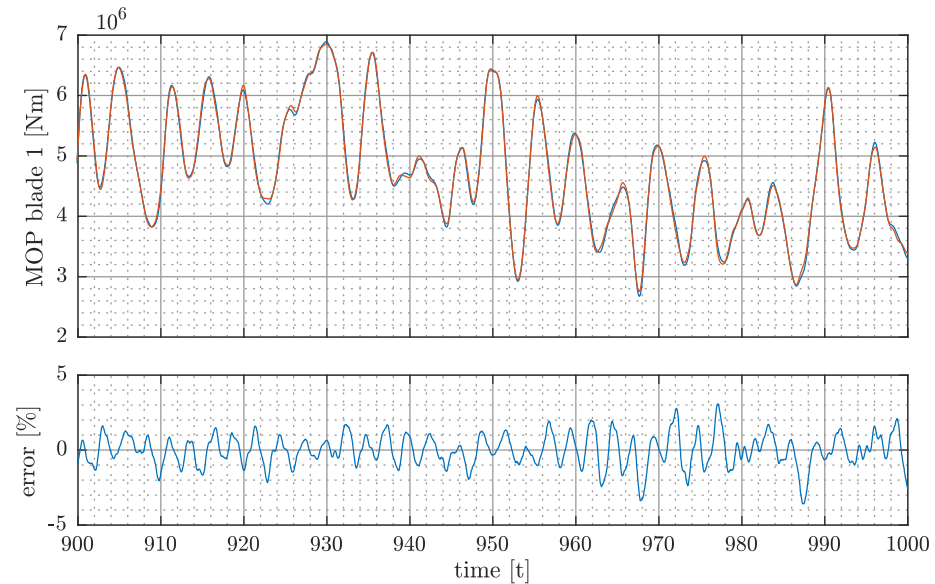
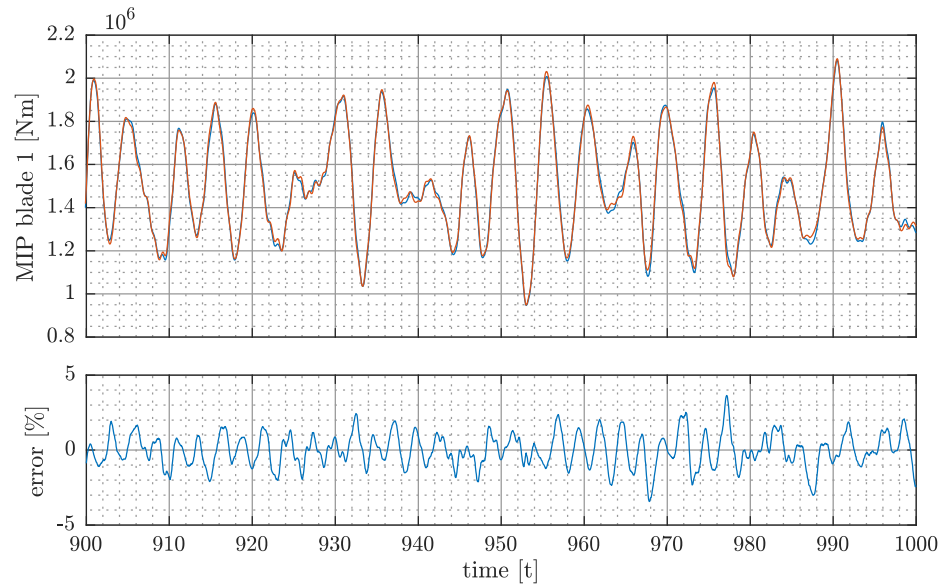
Blades



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



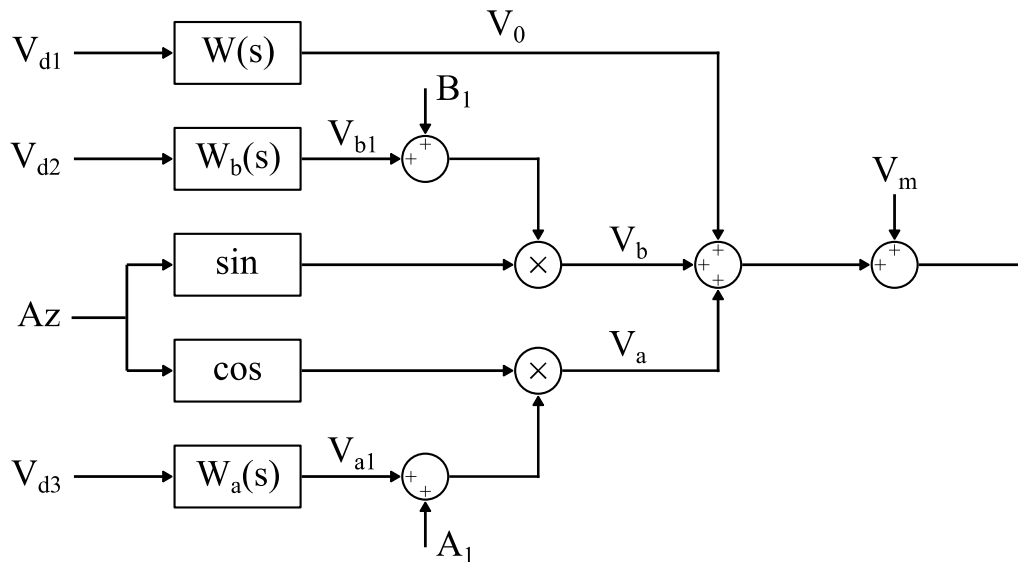
BRBM estimator



BRBM estimation based on accelerometers readings

Wind model

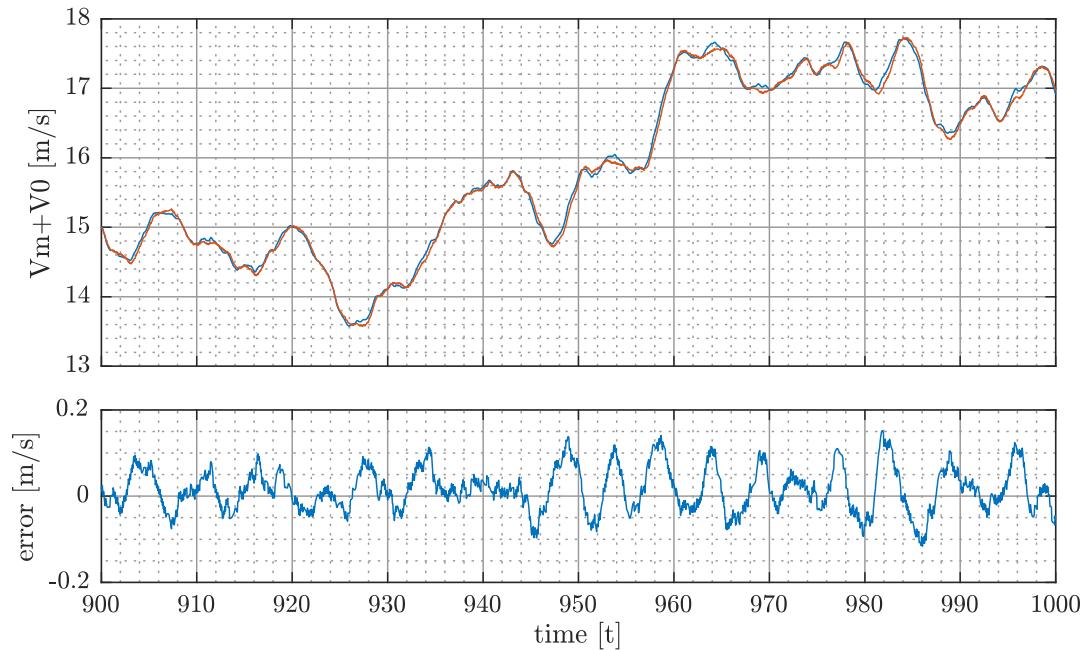
Wind model for
blade 1 up to 1P



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

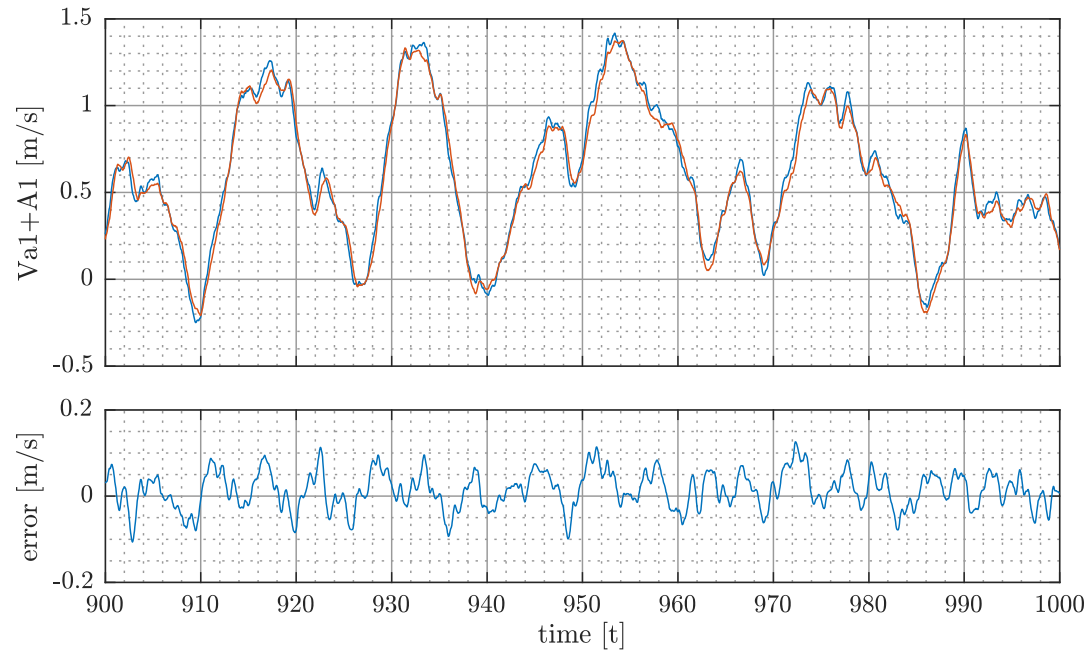


Turbulence

Vertical variations

Horizontal variations

Wind components estimation

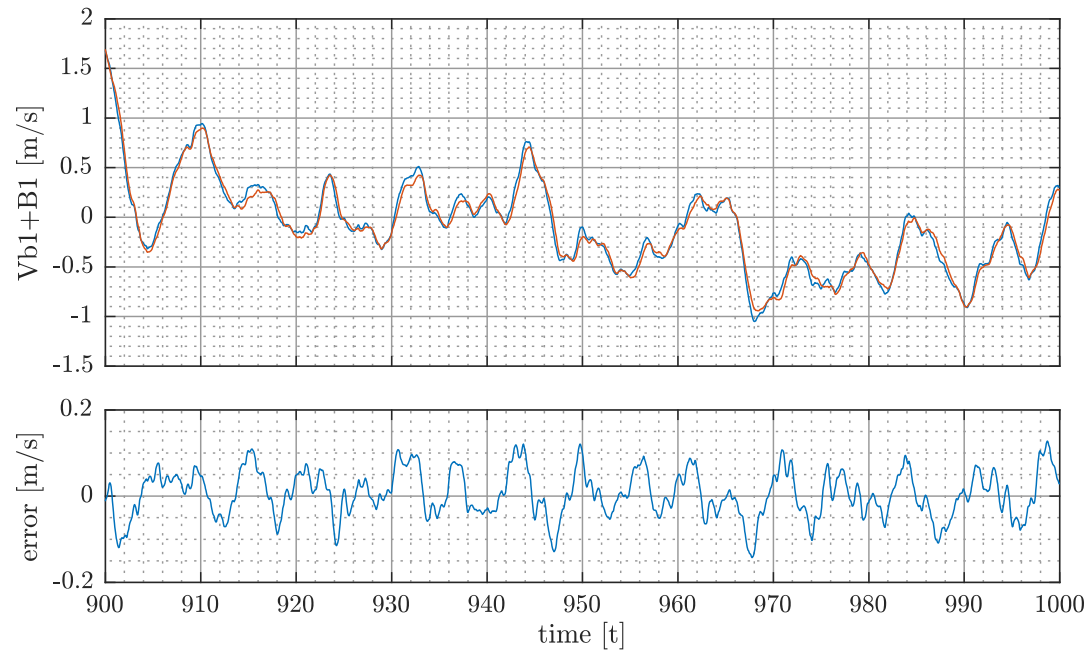


Turbulence

Vertical variations

Horizontal variations

Wind components estimation



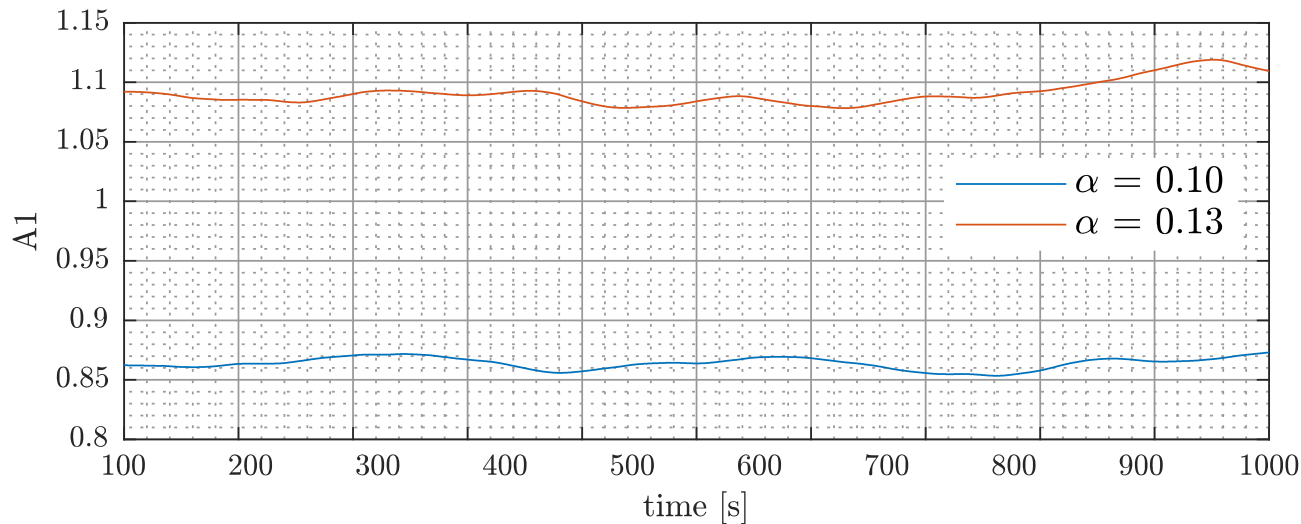
Turbulence

Vertical variations

Horizontal variations

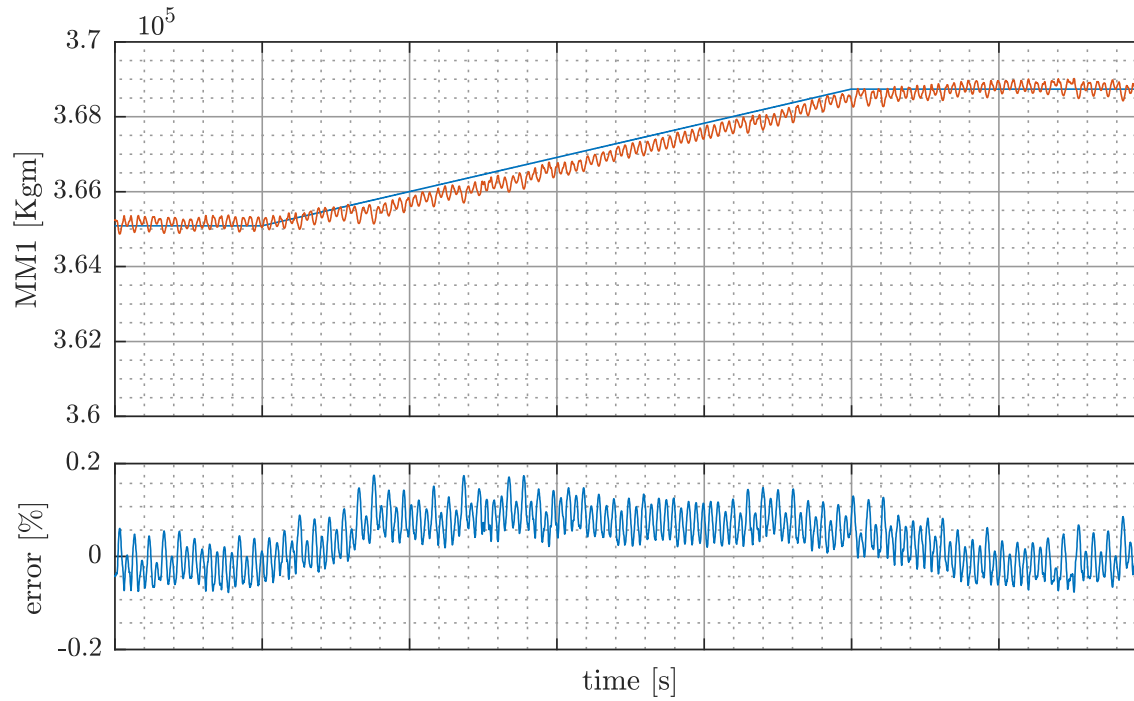
Wind shear estimate

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

futureWind 2018 & Marine



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