Capturing the journey of wind from the wind turbines

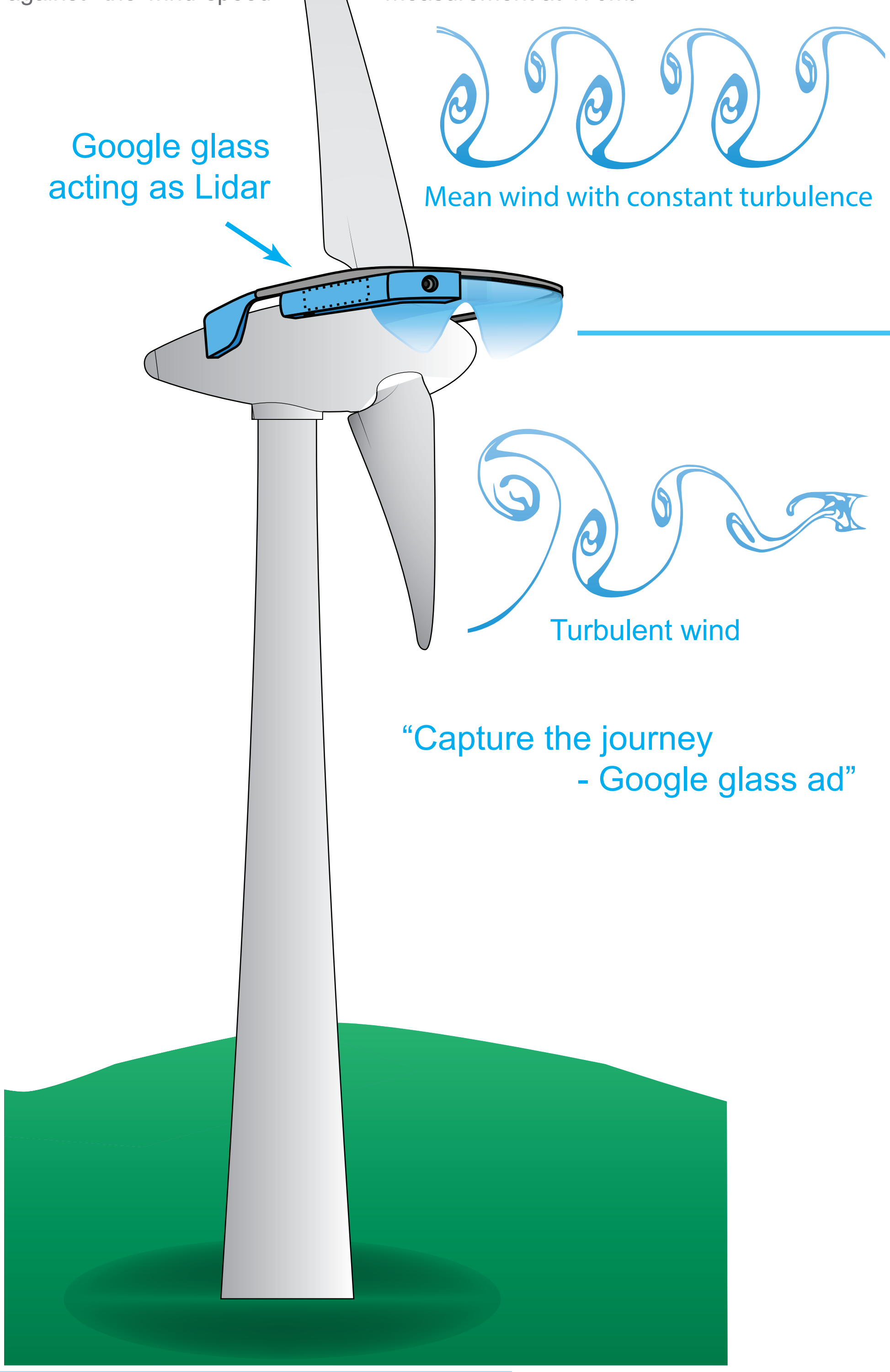
Ashim Giyanani*, Wim Bierbooms, Gerard van Bussel
Delft University of Technology, Wind Energy Research Group,
* a.h.giyanani@tudelft.nl

Abstract

Wind turbine design, control strategies often assume Taylor's frozen turbulence where the fluctuating part of the wind is assumed to be constant. In practise, the wind turbine faces higher turbulence in case of gusts and lower turbulence in some cases. With Lidar technology, the frozen turbulence assumption could be avoided and the evolution of wind towards the wind turbine could be studied. This studey therefore bridges the gap between measurements and controls of the turbine. In this poster, the autoregressive methods for prediction of the wind speeds evolving from farwind to nearwind are analysed and an empirical state space model is developed. The results are therefore useful in developing the transfer function for efficient wind turbine control thereby, reducing fatigue and extreme loads in the wind turbine.

Method

The use of autoregressive models like Autoregressive exogeneus (ARX) models provide insights into the process which are complicated to be explained by the present level of physics. The evolution of wind speed from 185m upwind of the turbine to 170m i.e. 15m is being evaluated here. The evolution of wind for these 15m distance is considered as the state space process. The order of the model, study of the deterministic part, stochastic part and the model parameters are estimated and validated against the wind speed measurement at 170m.



Model equation and Assumptions

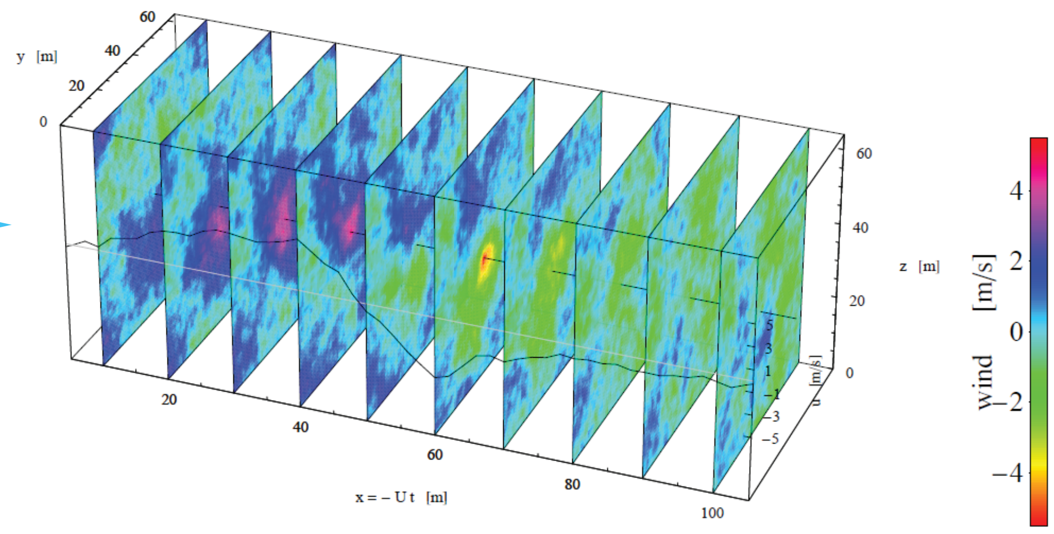
The ARX model assumes the stochastic part of the time series to be predictable while the deterministic part is linearly predictable. The ARX model is given by

$$\hat{y}(k|k-1) = -a_1 y(k-1) + b_1 u(k-1) + \hat{w}(k|k-1)$$

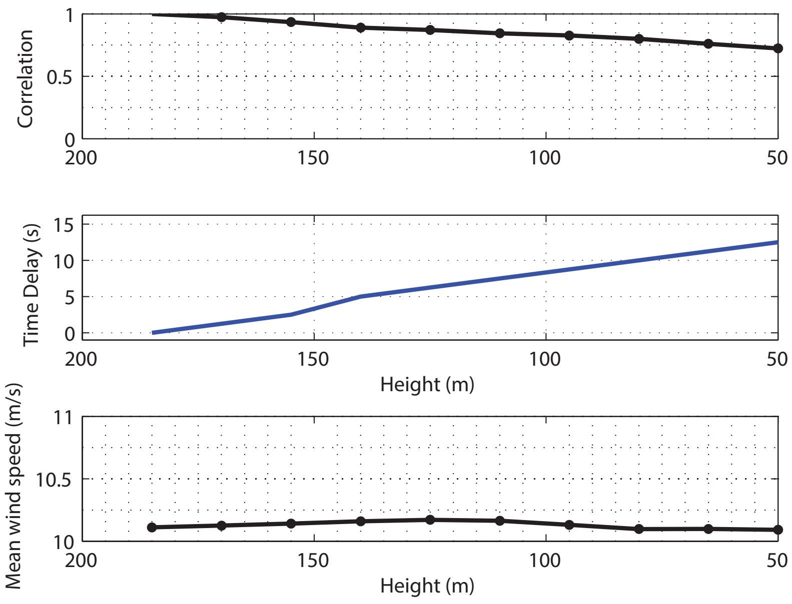
The model predictions are compared for residual correlations based on training data, where information regarding the time lag between the time series, step and impulse response is achieved. This forms the deterministic testing of the model. The stochastic testing of the model compares the residuals using the Autocorrelation and Partial autocorrelation functions, where the confidence limits are defined according to the time series statistics. The final test includes the cross validation of the results using a fresh dataset i.e. the test data set. The test dataset here is taken from the subsequent 10 minute measurements.

Results

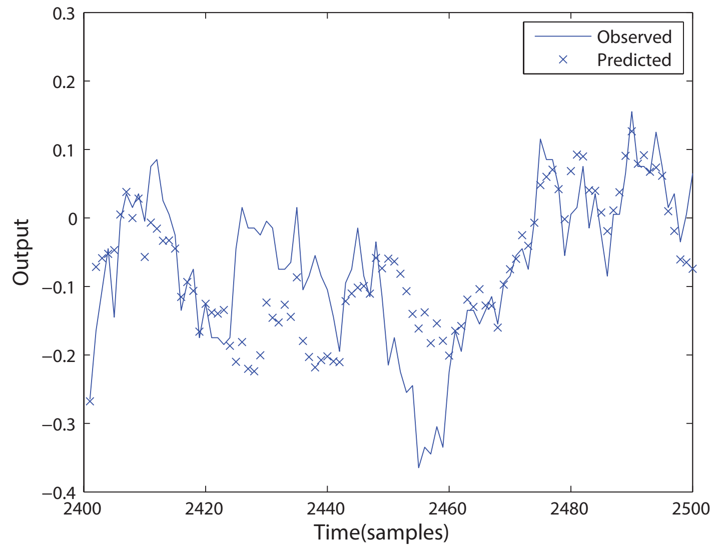
Considering the evolution statistics, The time delay is calculated based on the peak of the correlation and as the correlation decreases steadily, the time delay increases steadily as well. The control systems seem to have only 13 seconds to act on the first wind speed measurement i.e. 185m upwind of the turbine, while the 10 min mean wind speed changes marginally. The predictions obtained from the ARX models with second order polynimials provide a good fit to the measured wind speed at the next measurement distance i.e. 170m upwind of the turbine, however the higher order models for non linear behaviour like the ARMA and ARMAX shall be pursued to incorporate the stochastic part of the input measurement.



Example of the time series extrapolated spatially towards the wind turbine



Evolution statistics as seen by the Lidar, the correlation is performed between the measured distances upwind of the turbine and the time delay derived from the peak of the correlation The mean wind speed is the mean wind speed for the 10 minute period for each range measured at the same time



Predicted wind speed using autoregressive ARX model, The fit obatined from model is 90% and the error in the bias is as low as 0.003. The model determines the deterministic part accurately however, better results could be achieved using ARMA and ARMAX models.

References

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