

A Global Sensitivity Analysis of Wind Turbine Aeroelastic Models

Prashant Kumar

Abstract

Keywords: Wind energy, global sensitivity analysis, UQ, aeroelastic models

1. Introduction

2. Aeroelastic models

2.1. BEM models

2.2. Input parameters of aeroelastic models

3. Global sensitivity analysis

3.1. Sobol' indices

3.1.1. PCE Ordinary Least Square (PCE_OLS)

3.1.2. PCE Least Angle Regression (PCE_LAR)

4. Parametrization of uncertain inputs in the BEM model

4.1. Geometric uncertainty

We use Non-Uniform Rational Basis Splines (NURBS) [?] to perturb the geometrical parameters of the turbine blade, such as the reference chord and twist curves. The main advantage of using NURBS is that it provides great flexibility to approximate a large variety of curves using a very limited number of control points. Further, the set of control points and knots can be directly manipulated to control the smoothness and curvature.

4.1.1. NURBS based perturbation

The value of NURBS curve at each location x is computed using a weighted sum of N basis functions (or B-splines):

$$S(x) = \sum_{i=0}^{N-1} c_i B_{i,p}(x), \quad (4.1)$$

where $S(x)$ is the value of the curve at location x , c_i is the weight of control point i and $B_{i,p}(x)$ is the value of B-spline corresponding to the i -th control point at x . The subscript p denote the polynomial degree of the NURBS curve. The total number of control points $N = m + p + 1$ where m is the number of knots and the degree of NURBS curve. The above definition can be easily extended to higher dimensions.

Email address: pkumar@cwil.nl (Prashant Kumar)

The basis functions are recursive in order, i.e., we can derive quadratic B-spline ($p = 2$) using the linear B-spline ($p = 1$), cubic ($p = 3$) from quadratic B-splines and so on. Given m knot locations t_0, t_1, \dots, t_{m-1} , the B-spline of degree 0 is defined as:

$$B_{i,0}(x) := \begin{cases} 1 & t_i \leq x < t_{i+1}, \\ 0 & \text{elsewhere.} \end{cases} \quad (4.2)$$

Higher order B-splines can be then derived using the recurrence relation[?]:

$$B_{i,p}(x) := \frac{x - t_i}{t_{i+p} - t_i} B_{i,p-1}(x) + \frac{t_{i+p+1} - x}{t_{i+p+1} - t_{i+1}} B_{i+1,p-1}(x). \quad (4.3)$$

In Fig. ??, we show the linear, quadratic and cubic spline for $x \in [0, 1]$ Next, we describe steps to generate perturbed samples of chord from a given reference chord using NURBS based parametrization.

4.2. *Model uncertainty*

4.3. *Wind velocity*

25 5. Description of test case

6. Sensitivity analysis workflow

7. Numerical experiment

8. Interpretation of global sensitivity analysis result

9. Conclusions

30 Acknowledgements