

Treatment of uncertainties in multi-physics model for wind turbine asset management



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Introduction

Part I

Introduction to treatment of uncertainties and wind energy

Chapter 1

Treatment of uncertainties in computer experiments

1.1 Problem specification (step A)

1.1.1 Black-box computer model

1.1.2 Output quantity of interest

1.2 Input uncertainty quantification (step B)

1.2.1 Joint probability distribution [copulogram package]

1.2.2 Parametric multivariate estimation

1.2.3 Non-parametric multivariate estimation

1.2.4 Goodness-of-fit

1.3 Uncertainty propagation for central tendency estimation (step C)

1.3.1 Numerical integration

“Good” properties

[Curse of dim / Sequential / Deterministic]

Gauss-Kronrod

Monte Carlo

Quasi-Monte Carlo and Koksma-Hlawka inequality

1.3.2 Numerical design of experiments

Space-filling metrics

[MinMax / PhiP / MaxMin / Discrepancies]

“Good” properties

[Curse of dim / Projections in sub-spaces / Sequential / Deterministic]

Monte Carlo, quasi-Monte Carlo, randomized quasi-Monte Carlo designs

LHS, optimized LHS designs

1.3.3 Central tendency estimation

Iso-probabilistic transformation

Central tendency estimation is a probabilistic integration

1.4 Uncertainty propagation for rare event estimation (step C)

1.4.1 Problem formalization

Limit-state function, failure event and domain

Risk measures [Failure probability, quantile, super-quantile]

1.4.2 Rare event estimation methods

FORM/SORM

Monte Carlo

Importance sampling

Adaptive sampling (SS/NAIS/IS-CE/Moving particles)

1.5 Sensitivity analysis (step C')

1.5.1 Global sensitivity analysis

1.5.2 Reliability-oriented sensitivity analysis

1.6 Metamodeling

1.6.1 Global metamodel

1.6.2 Reliability-oriented metamodel

Chapter 2

Introduction to wind turbine modeling and design

2.1 Wind turbine modeling

2.1.1 Synthetic wind generation [[TurbSim](#), [Kaimal spectrum](#)]

2.1.2 Synthetic wave generation

2.1.3 Aerodynamic interactions

2.1.4 Servo-Hydro-Aero-Elastic wind turbine simulation [[DIEGO](#)]

2.1.5 Soil modeling

2.1.6 Wake modeling [[FarmShadow](#)]

2.2 Recommended design practices

2.2.1 Design load cases

2.2.2 Dynamic response design

2.2.3 Fatigue response design

2.3 Uncertain inputs

2.3.1 Environmental inputs

2.3.2 System inputs

2.3.3 Probabilistic fatigue assessment

Part II

Contributions to uncertainty quantification and propagation

Chapter 3

Kernel-based uncertainty quantification

- 3.1 Nonparametric fit of the environmental inputs (OMAE cpaper 2023)
- 3.2 Quantifying and clustering the wake-induced perturbations within a wind farm (WAKE cpaper 2023)

Chapter 4

Kernel-based central tendency estimation

- 4.1 Kernel discrepancy
- 4.2 Quantization with kernel herding [[SIAM UQ talk 2022](#), [RENEW cpaper 2022](#)]
- 4.3 Gaussian process regression
- 4.4 Bayesian quadrature [[otkerneldesign package](#)]
- 4.5 Numerical experiments [[ctbenchmark package](#)]
- 4.6 Application to wind turbine mean fatigue estimation ([DCE paper](#))

Part III

Contributions to rare event estimation

Chapter 5

Nonparametric rare event estimation (special issue RESS?)

- 5.1 Bernstein adaptive nonparametric conditional sampling
(MASCOT talk 2023, ICASP cpaper 2023)
- 5.2 Numerical experiments [otbenchmark package]
- 5.3 Application to wind turbine fatigue reliability
- 5.4 Application to a floating offshore wind turbine reliability

Chapter 6

Sequential reliability oriented sensitivity analysis

6.1 HSIC for GSA

6.2 HSIC for TSA & CSA

6.3 Sequential ROSA

6.4 Application to wind turbine fatigue reliability

Conclusion

Appendix A

Multivariate distribution modeling

Appendix B

Nonparametric copula estimation

Appendix C

Rare event estimation algorithms

Appendix D

Résumé étendu de la thèse

