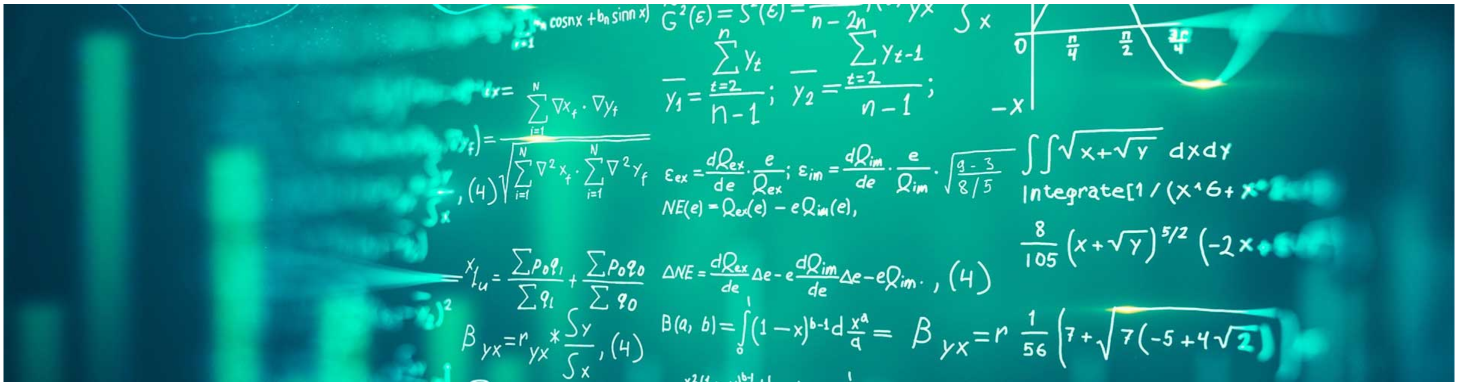

Written on 23 October 2024

3 minutes of reading

News

Fundamental Research

Wind Energy

IC powertrains

Numerical methods and optimization

As part of the drive to develop more environmentally-friendly mobility solutions, PhD research conducted at IFPEN resulted in a methodology to estimate control parameters in a urea injection-based pollution control system for vehicles (figure 1), where pollutant gas emission standards must be strictly respected [1,2,3]. This methodology was then extended to two other applications in the field of wind turbine control and simulation.

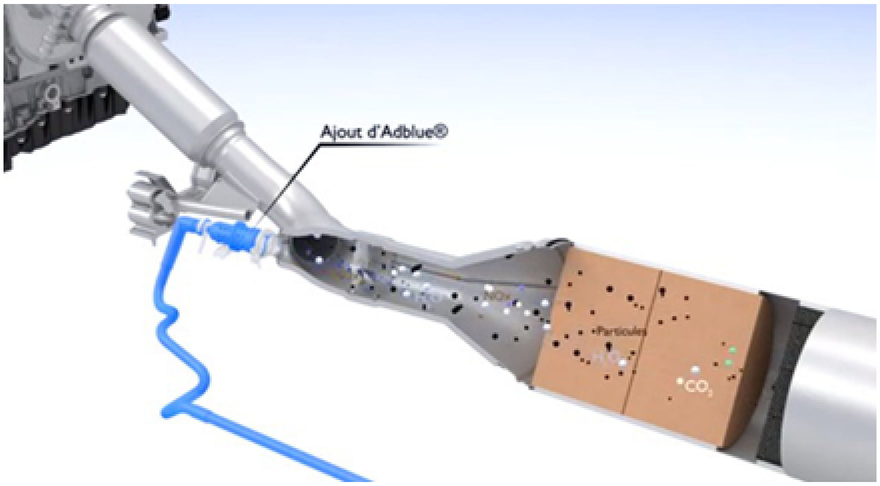

Figure 1: Injection of urea (Adblue) upstream of a Selective Catalytic Reduction (SCR) exhaust gas treatment system

Control parameter determination with uncertainty consideration

The learning methodology developed is aimed at determining the set of admissible control parameters, with a view to reducing the calculation time. It is based on an approximation of the results calculated by the control system simulator, in this case **pollutant emission levels**, taking into account the various sources of uncertainties. The approximation model is based on a Gaussian process defined in the space of the controller variables (two parameters of the “selective catalytic reduction” law [4]) and uncertain variables (vehicle speed cycle). This makes it possible to determine control parameters resulting in an acceptable level of pollution with respect to current standards taking into account uncertainties.

Application to the control of a floating wind turbine

More generally, the estimation of a system’s input parameters via a numerical simulator to achieve the target performances is often costly and time-consuming. This is both a complex numerical problem and a significant technical challenge with multiple applications at IFPEN.
For example, in the renewable energies sector, this problem particularly arises when trying to ensure **the reliable and optimal control of the operation of an offshore wind turbine**. Therefore, the ANR SAMOURAI collaborative research project, coordinated by IFPEN, aimed to determine the control parameters for a floating wind turbine, the objective being to avoid mechanical instability of the system (potentially resulting in malfunctions) while maintaining a minimum level of electricity production. A probabilistic approach [5] was adopted to guarantee robustness vis-à-vis uncertain environmental conditions (wind and swell conditions).

Pre-calibration of a wind turbine simulator

A second example of admissible parameter estimation relates to the pre-calibration of the OpenFAST wind turbine simulator [6,7,8], the focus of another PhD thesis [6]. The method was extended to **multivariate outputs from the wind turbine mechanical behavior simulator**, for the purposes of pre-calibration based on operational modal analysis. [9]. New simulation input selection criteria were developed for a specific purpose: to enable **the learning of the set of blade and mast rigidity**

coefficient values resulting in a calibration error[1] below a pre-defined threshold.
As a result, a methodology for estimating control parameters in an uncertain environment, initially developed at IFPEN for a vehicle pollution control system, was successfully extended to wind turbine control and simulation. The versatility of this methodology will enable the designers of complex systems to adapt it to other applications.

[1] Evaluated from structural deformation modes and vibration frequencies

References:

[1] M. R. El Amri, Analyse d'incertitudes et de robustesse pour les modèles à entrées et sorties fonctionnelles, thèse de doctorat de l'université Grenoble-Alpes, soutenue en 2019.
>> https://dumas.ccsd.cnrs.fr/LJK-MAD-AIRSEA/tel-02433324

[2] M. R. El Amri, C. Helbert, O. Lepreux, M. Munoz Zuniga, C. Prieur, D. Sinoquet, Data-driven stochastic inversion under functional uncertainties, Statistics and Computing journal, Statistics and Computing journal, Vol. 30, pp. 525–541, 2020.
>> https://doi.org/10.1007/s11222-019-09888-8

[3] M. R. El Amri, C. Helbert, M. Munoz Zuniga, C. Prieur, D. Sinoquet, Feasible set estimation under functional uncertainty by Gaussian Process modelling, Physica D: Nonlinear Phenomena, Volume 455, 2023.
>> https://doi.org/10.1016/j.physd.2023.133893

[4] A. Bonfils, Y. Creff, O. Lepreux, N. Petit, Closed-loop control of a SCR system using a NOx sensor cross-sensitive to NH3. IFAC Proc. Vol., 45 (15) (2012), pp. 738-743

[5] A.-L. Ait, R., J. Bect, V. Chabridon, E. Vazquez, Bayesian sequential design of computer experiments for quantile set inversion, 2024, Technometrics, 1–10,
>> https://doi.org/10.1080/00401706.2024.2394475

[6] C. Duhamel, Estimation d'ensembles d'excursion par processus gaussiens pour des fonctions boîtes noires à valeurs scalaires ou vectorielles. Application à la calibration d'un simulateur numérique éolien, thèse de doctorat de l'université Grenoble-Alpes, à soutenir en 2024.

[7] C. Duhamel, C. Helbert, M. Munoz Zuniga, C. Prieur, D. Sinoquet, A SUR version of the Bichon criterion for excursion set estimation, Statistics and Computing, 2023, 33 (2), pp.41.
>> https://doi.org/10.1007/s11222-023-10208-4

[8] OpenFast Release, N. O. D. (2020). v2. 3.0. National Renewable Energy Laboratory: Golden, CO, USA.

[9] D. Tcherniak, G. Larsen. Application of OMA to an operating wind turbine: Now including vibration data from the blades. 5th International Operational Modal Analysis Conference, IOMAC 2013.

[10] Bak, C., Zahle, F., Bitsche, R., Kim, T., Yde, A., Henriksen, L., Andersen, P. B., Natarajan, A., and Hansen, M. H. (2013). Design and performance of a 10 MW wind turbine. Wind Energy, 124.

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