Internship proposal

Active learning for Gaussian processes with functional inputs:

application to wind turbine reliability design

Context

Many applications at IFP Energies Nouvelles rely on computationally-intensive simulators that take scalar variables as inputs, but also functional variables representing, for example, the geometry of mechanical parts, spatio-temporal processes of environmental conditions (such as wind in wind turbine reliability design), or time-dependent control laws of dynamical systems (such as wind turbine blades).

In this context of expensive simulators, it is often necessary to use a surrogate model to evaluate the simulator's output of interest at a lower cost, for a large number of input parameter values. The surrogate model is generally built adaptively (active learning), from simulations associated with an initial design of experiment of limited size. This design is then enriched using criteria adapted to the operational purpose, such as optimizing quantities of interest or estimating a set of admissible parameters.

In the presence of functional variables as simulator input, surrogate modeling and experimental planning approaches need to be adapted. Conventional approaches are based on dimension reduction or feature extraction methods, with the functional variables then represented in the reduced space thus defined. The preliminary step of dimension reduction necessarily induces a loss of information, which needs to be quantified and even controlled during the process.

The general context of this internship is the development of suitable experimental designs for the construction of a substitution model taking functional and scalar variables as inputs, working directly in the functional space of the inputs, and therefore without preliminary dimension reduction.

Main mission(s) and activities

The objectives of this internship are

- the study of meta-models with functional inputs [1-4] ;
- application of the most promising meta-models using space-filling experimental designs built
  - with an intermediate dimension reduction or feature extraction step [5] ;
  - directly in functional space [6] ;

A thesis on the same subject could be envisaged as a continuation of the internship.

References

[1] F. Bachoc, A. Suvorikova, D. Ginsbourger, J.-M. Loubes, V. Spokoiny (2020). Gaussian processes with multidimensional distribution inputs via optimal transport and Hilbertian embedding, Electronic Journal of Statistics, Electron. J. Statist. 14(2), 2742-2772.
[2] C. L. Sung, W. Wang, F. Cakoni, I. Harris, and Y. Hung (2022). Functional-Input Gaussian Processes with Applications to Inverse Scattering Problems, arXiv preprint arXiv:2201.01682.
[3] J. Betancourt, F. Bachoc, T. Klein, D. Idier, R. Pedreros, and J. Rohmer (2020). Gaussian process metamodeling of functional-input code for coastal flood hazard assessment. Reliability Engineering & System Safety, 198, 106870.
[4] B. Thind, K. Multani, and J. Cao (2022). Deep learning with functional inputs. Journal of Computational and Graphical Statistics, 1-10.
[5] M. R. El Amri, C. Helbert, O. Lepreux, M. Munoz Zuniga, C. Prieur and D. Sinoquet (2020). Data-driven stochastic inversion via functional quantization. Statistics and Computing, 30, 525-541.
[6] L. Pronzato, and A. Zhigljavsky (2020). Bayesian quadrature, energy minimization, and space-filling design. SIAM/ASA Journal on Uncertainty Quantification, 8(3), 959-1011.

Diploma, level of education

Master 2 or engineering school in applied mathematics - specializing in statistics and data science

Technical skills and aptitudes

Statistics, data science, optimization, scientific computing

Good knowledge of R / Python programming languages

Location

Ecole Centrale Lyon

https://www.ec-lyon.fr/

Contacts :

Céline Helbert (Centrale Lyon): celine.helbert@ec-lyon.fr (Personal pages)
Clémentine Prieur (INRIA, LJK): clementine.prieur@imag.fr (Personal pages)
Delphine Sinoquet (IFP énergies nouvelles): delphine.sinoquet@ifpen.fr (Personal pages)
Miguel Munoz Zuniga (IFP énergies nouvelles): miguel.munoz-zuniga@ifpen.fr (Personal pages)