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J-M AZAÏS, F. GAMBOA, B. IOOSS

Introduction

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Introduction

J.-M. AZAÏS⁽¹⁾, F. GAMBOA⁽²⁾ AND B. IOOSS⁽³⁾
CNRS GDR MASCOT-NUM⁽⁴⁾

With the advent of computing technology and numerical methods, computer models are now widely used to make predictions on highly complex physical phenomena, to solve optimization problems or to perform sensitivity studies. For example, in aeronautics and automotive industries, expensive experimental tests (as crash tests) can be avoided using virtual numerical experiments. One great advantage of these virtual experiments is that the post-processing analysis gives the full consideration of the system behavior, which can provide many informations unavailable with real experiments. However, these results have to be considered with suspicion because of all the uncertainties arising in the computer model and its input data. Stochastic methods are then essential in order to understand and manage these uncertainties. The development of such methods has been an active research field for more than two decades, mostly in the statistical community. It has opened the ways for very active and challenging research in the fields of design of experiments, non and semi parametric models and Bayesian inference based on Gaussian processes. These statistical methods allow that more intensive explorations become possible, more hazardous configurations can be tested and, hopefully, better understanding and optimized responses can be achieved together with more accurate statements about risk and failures. At the same time, complex simulations require long computations (from several minutes to weeks for a single run), which set a limitation on

⁽¹⁾ Professor of Mathematics Institut de Mathématiques de Toulouse.

<http://www.math.univ-toulouse.fr/~azais/>

⁽²⁾ Professor of Mathematics, Institut de Mathématiques de Toulouse.

http://www.math.univ-toulouse.fr/~gamboa/newwab/Pages_Fabrice_Gamboa/Main_Page.html

⁽³⁾ Senior researcher at EDF R&D, Département de Management des Risques Industriels.

<http://www.gdr-mascotnum.fr/doku.php?id=iooss1>

⁽⁴⁾ <http://www.gdr-mascotnum.fr/>

what can be learnt in reasonable time. The domain of design and analysis of computer experiments aims at defining what should be chosen for the inputs of a numerical model in order to achieve a prescribed objective. In particular, one may want to:

1. Forecast the behavior of a numerical model from the results of a small number of runs;
2. Optimize the response of a numerical model; that is, determine the values of inputs corresponding, for example, to the highest performance or smallest cost;
3. Estimate the variability of a response as a function of that of the inputs (also known as sensitivity analysis);
4. Estimate a probability of failure in presence of uncertainties when some inputs are randomized with a given probability measure.

In France, the CNRS research group MASCOT-NUM brings together scientific communities (statisticians, probabilist, numericians, research engineers, physicists, computer scientists,...), working on computer code experiments. In complement to the special issue of the *Journal de la Société Française de Statistique* [2], that was devoted to the presentation of applied studies in sensitivity analysis, the present special issue of the *Annales de la Faculté des Sciences de Toulouse* contains more fundamental research works from the French community working on computer code experiments. The main mathematical tools are modern statistical learning techniques. They are used to build approximations of expensive computer codes from a few runs as data. Kernel-based (RKHS) methods are well tailored in this context as they lead to fast computable approximations. The issue contains three papers studying properties of covariance kernels:

1. B. Gauthier and X. Bay, Spectral approach for kernel-based interpolation.
2. N. Durrande, D. Ginsbourger and O. Roustant, Additive covariance kernels for high-dimensional Gaussian process modeling.
3. D. Ginsbourger, X. Bay, O. Roustant and L. Carraro, Argumentwise invariant kernels for the approximation of invariant functions.

The first paper studies the performance of additive kernels for the approximation of functions in high dimension. The second one sheds light on spectral representations of interpolation operators involved in kernel methods. The last one uses the a priori invariance properties of the unknown complicated function (as symmetry), to improve interpolation performances. The two following papers are:

4. S. Da Veiga and A. Marrel, Gaussian process modeling with inequality constraints.

5. N. Bousquet, Accelerated Monte Carlo estimation of exceeding probabilities under monotonicity constraints.

In these works, the use of some knowledge on the complicated functions allows either to build specific interpolation methods (4.) or to design special Monte Carlo schema (5.). The last paper is:

6. N. Rachdi, J-C. Fort and T. Klein, Stochastic inverse problems with noisy simulator. Application to aeronautical model.

It deals with semi-supervised models in the frame of computer code experiments. This kind of statistical tools allows controlling very precisely model errors.

This volume is dedicated to Anestis Antoniadis for his 60th birthday. He has been one of the first to aware the French statistical community on the scientific interests of computer code experiment problematic¹. In his pioneering work on functional ANOVA [1], he shed new lights on Hoeffding decomposition and laid the first stone of global sensitivity analysis. Finally, we are grateful to all the referees involved in this special issue, whose comments significantly helped to improve all the papers.

Bibliography

- [1] Analysis of variance on function spaces, Anestis Antoniadis. *Math. Operationsforsch. Statist. Ser. Statist.* Vol 15, 1 (1984).
- [2] Méthodes Stochastiques pour l'Analyse de Sensibilité, Clémentine Prieur, Alberto Pisanisi, François Wahl (Eds). *Journal de la SFdS.* Vol. 152, 1 (2011).

⁽¹⁾ A special conference in honor of Anestis Antoniadis has also been organized in 2011 by GdR MASCOT-NUM, see <http://www.gdr-mascotnum.fr/mascot11.html>