Research Topic for the ParisTech/CSC PhD Program

Subfield: Information and Communication Sciences and Technologies
ParisTech School: Telecom ParisTech

Title: **Uncertainty quantification and surrogate modeling in high dimensional spaces using machine learning**

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Short description of possible research topics for a PhD:

The proposed research is dealing with computational simulation and Uncertainty Quantification (UQ) in high dimensional spaces using machine learning and surrogate modeling (e.g. chaos polynomial approaches).

Thanks to progress in high performance calculation, simulation tools are nowadays increasingly used to design complex systems, such as advanced 5G antennas, or to assess human exposure. In such a context uncertainty quantification is an important task since some parameters are unknown or highly uncertain. Despite the progress in high performance computation, the Monte Carlo method, which is independent of the number of stochastic dimensions, is unsuitable for UQ because of expensive computer codes and the need of a large number of samples.

A large effort has seen spent in the last decade to construct a cheap-to-evaluate surrogate model to replace the forward model solver. Gaussian processes, generalized polynomial chaos expansions, low rank tensor approximation, radial basis functions and support vector machines have been investigated. Despite their success, these methods are facing limits for problems having a large number of input parameters, which is often the case for real physical systems. In such a case, one has to deal with the curse of dimensionality, in which the volume increases exponentially with the number of parameters. Many common dimensionality reduction techniques try to project the high dimensional inputs onto a low-dimensional subspace, which captures most of the information of the original input. The main limit of such a method is its unsupervised character, which is only looking at samples of the input, ignoring information contained in the model outputs. This approach tends to overestimate the effective dimensionality of the system.

To overcome such limitations, efforts have been carried out to build greedy surrogate model using for instance low rank tensor approximations as well a sparse model approaches (such as LARS), in order to identify the terms having most influence. These approaches have been successfully implemented but they are still facing limits in the case of a very large number of input parameters.

To overcome such a limitation, the objective of the PhD research is to investigate the use of polynomial chaos expansions or low rank tensor approximation combined with deep machine learning, neural network and artificial intelligence, so to perform a dimension reduction taking into account information contained in the model outputs.

Required background of the student: The student must have a good background in computational physic and statistics. A background in electromagnetism and wireless communications will be appreciated

List of 5 representative publications of the group:

(1) Kersaudy, B Sudret, N - Varsier, O Picon, J Wiart "A new surrogate modeling technique combining Kriging and polynomial chaos expansions. Application to uncertainty analysis in computational dosimetry" Journal of Computational Physics, 2015

(2) Y. Y. Huang & J. Wiart "Simplified Assessment Method for Population RF Exposure Induced by a 4G Network" IEEE J.R.E.M. Sept 2017

(3) Soumaya Azzi,_, Yuanyuan Huang, Bruno Sudret, Joe Wiart "Surrogate Modeling of Stochastic Functions -Application to computational Electromagnetic Dosimetry" arxiv 2018

(4) Zicheng Liu, Dominique Lesselier, Bruno Sudret, Joe Wiart "Surrogate modeling based on resampled polynomial chaos expansions" Arxiv 2018

(4) RK Arya, P Kersaudy, J Wiart, R Mittra "Statistical Analysis of Periodic Structures and Frequency Selective Surfaces using the Polynomial Chaos Expansions " e-fermat. 2015