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PHD THESIS PROPOSAL

Title : Multi-fidelity optimization under uncertainty, application to aerospace vehicle design

Start of the PhD thesis : 2021	**Deadline for application :** 2021

Keywords : Optimization under uncertainty, multi-fidelity, reliability analysis, aerospace vehicle

Skills and knowledge required:

Diploma from engineering school, Master of Sciences

Applied mathematics, surrogate modeling, uncertainty quantification, optimization

Knowledge in Python and aerospace vehicle could be interesting

PhD subject, context and objectives

Multidisciplinary optimization of aerospace vehicle requires modeling each discipline involved in the design process in order to estimate the performance of the system and its reliability. To model the disciplines, it is possible to choose among different models (for instance for aerodynamics: analytical model, simplified CFD model, full CFD code). The choice of the model to use is often a trade-off between the model computational cost and the model accuracy (i.e., level of modeling uncertainty). Therefore, a low-fidelity model will have a limited accuracy but a low computational cost whereas a high-fidelity model will have a high precision but a high computational cost.

Moreover, the design process of complex aerospace design is usually decomposed into several successive phases. In the early design phase, there exists a large number of possible architectures for the system and these potential candidates are optimized using low-fidelity models. In this framework, it is essential to control the modeling uncertainty introduced in this phase in order to select an optimal candidate solution that will not be rejected in the future phases of the design process when the high-fidelity models will be involved.

One way to solve this issue is to take into account the modeling uncertainty directly in the optimization problem at the early design phase (it is referred to RBDO – Reliability-based Design Optimization problem) [1,2]. Being able to efficiently solve such a type of problems requires to master different challenges among which the mathematical formulation of the problem, uncertainty propagation with reliability analysis, optimization algorithm and the associated computational costs. These approaches may be combined with surrogate modeling to reduce the computational cost [7,10].

Another promising approach which is the subject of this PhD thesis consists in using different fidelity models directly into the RBDO problem in order to reduce the uncertainty associated to the modeling and to improve the representativeness of the found optimal solution. As using only a high-fidelity model is not possible due to the computational cost of repeated evaluations of these models, a research track investigated in this PhD thesis is to involve multi-fidelity approaches to combine the information of different models into RBDO problems and therefore improve the modeling accuracy while controlling the computational cost.

Recently, multi-fidelity techniques have been applied to elementary bricks of RBDO problems (reliability analysis [8,9] or optimization [10]). The objective in the PhD thesis is to develop new methodology to solve a complete RBDO problem using different fidelity models. For that, it will be necessary to work on the mathematical formulation, the possible decomposition of the RBDO problem and the development of optimization strategy for RBDO suited to the context of multi-fidelity. The developed methodologies will be assessed over different analytical test cases and also on a representative design process of aerospace vehicle (for instance reusable launch vehicle).

In that purpose, the PhD thesis will follow these steps:

- State of the art of RBDO techniques with a focus on multi-fidelity,
- Development and implementation of a multi-fidelity strategy to solve RBDO problem,
- Application of the proposed methodology on the design process of a reusable launch vehicle.

References :

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[5] Agarwal, Harish, et al. "An inverse-measure-based unilevel architecture for reliability-based design optimization." *Structural and Multidisciplinary Optimization* 33.3 (2007): 217-227.

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[8] Chaudhuri, Anirban, Alexandre N. Marques, and Karen E. Willcox. "mfEGRA: Multifidelity Efficient Global Reliability Analysis." *arXiv preprint arXiv:1910.02497* (2019).

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[10] Forrester, Alexander IJ, András Sóbester, and Andy J. Keane. "Multi-fidelity optimization via surrogate modelling." *Proceedings of the royal society a: mathematical, physical and engineering sciences* 463.2088 (2007): 3251-3269.

Possible collaborations

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