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POST-DOCTORATE PROPOSAL

Reference : **PDOC-DTIS-2018-04**

Host Laboratory at ONERA :

Branch : Information processing and systems

Location (ONERA center) : Palaiseau or Toulouse

Department : Information processing and systems

Unit : Multidisciplinary Methods and Integrated Concepts

Contacts : Jérôme Morio, Sylvain Dubreuil sylvain.dubreuil@onera.fr- Phone : 0562252364 and Loïc Brevault loic.brevault@onera.fr

Title : Development of sensitivity analysis methods for multidisciplinary design of aerospace vehicles

Keywords : uncertainty propagation, sensitivity analysis, multidisciplinary design, MDO

Context :

In the recent years, aviation is facing with the increasing of fuel price and flights, and the impact is estimated to grow more and more in next years without any action. To reduce its environmental footprint, engineers are trying to design more efficient aircraft, with engines less consuming. Design of complex aerospace systems such as innovative aircraft involves the collaboration of many disciplines such as aerodynamics, structural mechanics, propulsion, control, mission assessment, *etc.* At preliminary design stage, interactions between disciplines are modeled within a MultiDisciplinary Analysis (MDA) framework [1]. MDA basically consists in coupling the various disciplinary solvers in a nonlinear system of equations (*e.g.* aeroelasticity). As a consequence, assessment of complex aerospace system performance is time consuming as it involves the numerical resolution of a nonlinear system.

Moreover, in order to take into account the inherent uncertainty that affects the parameters of such multidisciplinary systems (*e.g.* material, geometric uncertainties) the probabilistic framework is commonly used [2,3]. Among the various results provided by uncertainty propagation, this study focuses on Sensitivity Analyses (SA) [4]. Indeed, SA can be seen as a primordial step in the design of complex systems as it allows to rank the uncertain input variables with respect to their influence on an output of interest and thus to better understand the behavior of the system. The multidisciplinary characteristic of complex system results in a challenge for uncertainty propagation and SA, especially for important number of uncertain input parameters (>10) and for vector valued coupling variables (*e.g.* discretization by finite element of a displacement field, loading vector computed from CFD). The objective of this post-doctorate is hence to study and propose numerically efficient methodologies for SA on coupled multidisciplinary systems.

Detailed description :

Classical SA approaches [4] (*e.g.* DGSM, Sobol, Morris) rely on, potentially numerous, evaluations of the output of interest and/or its partial derivative. In the MDA context previously introduced, these evaluations imply the numerical resolution of a nonlinear system which makes SA numerically costly or even intractable. Moreover, the coupling effect has to be taken into account during the SA. Indeed, even if a variable may have a high influence (or low influence respectively) at a disciplinary level, it does not necessarily result in a high influence (or low influence respectively) at the system level.

One way to tackle this challenging problem could be to uncouple the computation of the sensitivity measures and to appropriately combine these measures to estimate the impact at the system-level. Hence, within this context, Derivative-based Global Sensitivity Measures (DGSM) seems to be an interesting SA approach. Indeed, as these measures are computed thanks to partial derivative it should be possible to efficiently approximate the DGSM by taking advantage of the chain rule to account for the couplings and some recent developments [5,6] in the computation of partial derivatives in MDA context. Consequently, the open source MDA/MDO framework *OpenMDAO* [5] developed by NASA Glenn will be considered for the development of the proposed SA approach. It should be noted that one challenge will thus to adapt this deterministic framework to probabilistic SA.

In order to validate the proposed methodologies, a test case for multidisciplinary design of civil aircraft incorporating partial or total electrification in the propulsive chain will be considered using FAST tool developed at ONERA (Fixed-wing Aircraft Sizing Tool, [7]). This conceptual design test case involves numerous couplings (CFD for aerodynamics and FEM for structural design) and diverse uncertain parameters. This test case will allow comparing the proposed developments with reference techniques to assess their performance.

Expected outputs:

- Development of methodologies and associated python module,
- Validation on aerospace design test case
- Publication of journal article.

References :

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[2] L. Brevault, M. Balesdent, N. Bérend and R. Le Riche (2016) Decoupled MDO formulation for interdisciplinary coupling satisfaction under uncertainty, AIAA Journal, Vol.54(1): 186-205, DOI: 10.2514/1.J054121

[3] S. Dubreuil, N. Bartoli, C. Gogu, T. Lefebvre. Propagation of Modeling Uncertainty by Polynomial Chaos Expansion in Multidisciplinary Analysis. ASME. J. Mech. Des. 2016;138(11)

[4] Sobol,I. M., Kucherenko, S. . (2009), Derivative based global sensitivity measures and their link with global sensitivity indices. Mathematics and Computers in Simulations, 79 (10), 3009-3017

[5] Gray, JS, Hwang, JT, Martins, JRRA, Moore, KT, Naylor, BA, (2019), OpenMDAO: An open-source framework for multidisciplinary design, analysis, and optimization, Structural and Multidisciplinary Optimization

[6] Hwang, JT, Martins, JRRA, (2018) A computational architecture for coupling heterogeneous numerical models and computing coupled derivatives, ACM TOMS

[7] Schmollgruber, P., Bartoli, N., Bedouet, J., Defoort, S., Gourinat, Y., Benard, E., & Sgueglia, A. (2017). Use of a Certification Constraints Module for Aircraft Design Activities. In 17th AIAA Aviation Technology, Integration, and Operations Conference

Duration : 12 months, can be renew once

Candidate Skills

Formation : PhD. doctorate

Skills :

- Applied mathematics,
- Design and engineering,
- Ability to publish.