proposition sujet de stage **2016 - 2017**
MASTER Recherche

Titre du stage : Uncertainty quantification in multidisciplinary derivative-free design optimization

Laboratoire(s) d'accueil : G-SCOP

Responsable(s) du stage :
Jean Bigeon
laboratoire G-SCOP
jean.bigeon@grenoble-inp.fr tél : 06 77 99 49 63 ou 04.76.57.49.04 Bureau : C305
Co encadrement McGill Montreal Canada

Description du sujet

The advances in computer-aided engineering (CAE) tools of the past two decades have revolutionized the engineering design and development process: alternatives of design solutions can now be analyzed, synthesized and evaluated rapidly in virtual, i.e., computational, environments. Computational models are the cornerstones of this simulation-based engineering design paradigm.

Availability of computational models has also enabled conducting elaborate design optimization studies. Optimization requires a large number of analyses to evaluate the functions that govern design objectives and constraints for multiple combinations of variables that represent different design solutions. This is prohibitively expensive to conduct physically in terms of both time and cost. Numerical optimization algorithms utilize computational models for analysis to conduct computational design.

Despite the impressive progress in numerical optimization algorithms and the availability of several software packages, there remain fundamental obstacles that impede full adoption of automated optimization practice particularly for simulation-based engineering design:

- Successful use of gradient-based optimization algorithms depends highly on the quality of the required gradient approximations (since exact gradients are not available in simulations), as well as problem and algorithm parameter values such as scaling and termination tolerance settings. Inadequately trained engineers often underestimate the importance of appropriate optimization problem formulation, algorithm choice and parameter tuning. Therefore, derivative-free optimization (DFO) and evolutionary techniques that are insensitive to problem formulation and do not require gradient information and significant parameter tuning are highly desirable.
- It is widely accepted that the single most important cause of failures or unexpected system behavior is the inability to capture and understand all the interactions and coupling strength that exist among subsystems. This phenomenon is amplified when considering cooperative systems because synergy modes and common objectives are not well understood or defined. The proposed research will investigate the challenges posed by interaction and consistency constraints that exist when connecting different systems to satisfy collective design objectives.
  We use the non-hierarchical analytical target cascading (NHATC) coordination method for multidisciplinary design optimization (MDO) to account for component interactions to ensure system-level integration and optimality.
- Simulation-based engineering design is characterized by the presence of inherent uncertainties, broadly classified as reducible or irreducible, meaning that we can either reduce the amount of uncertainty by collecting more data or not. The

computational models are approximations of the real physical systems and include parameters whose values are not known exactly. Therefore, the simulation-based optimization process must take into account that the predictive capability of computational models may be inadequate, especially in large design spaces. Moreover, there is uncertainty regarding the environmental and operating conditions under which an engineering system will perform. Therefore, the engineering design methodologies must investigate the sensitivity of \optimal" solutions to deviations caused by variability or uncertainty of aforementioned conditions.

Currently, the vast majority of the engineering design community utilizes a probabilistic approach that uses random variables to model uncertain quantities and formulates so-called reliability-based design optimization (RBDO) problems, where reliability is defined as the probability of satisfying a probabilistic design constraint. This approach has two drawbacks:

1. it assumes that the probability density functions associated with the random variables are known or can be inferred;
2. RBDO problems are solved using techniques and algorithms that depend on the availability of gradients. Some research that uses non-probabilistic uncertainty modeling has been reported recently, but it uses gradient-based optimization that requires limiting local approximations.

The objective of this project is to develop uncertainty quantification techniques that are suitable to an MDO framework based on the NHATC coordination that utilizes either DFO or Evolutionary algorithms.

A preliminary phase consists into a survey based on bibliography delivered by supervisors.

Three different known case including the code will be used for testing purpose.