Structural Reliability Analysis based on an automatic selection of Surrogate Models

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Objectives

1. Estimation of the structure’s failure probability using surrogate models.
2. Development of numerical methods for the automatic selection for surrogate that best fits the limit state function by using an evolutionary algorithm.
3. Determination of the surrogate associated weights when ensemble of surrogates are selected to approach the limit state function.

Introduction

Structural reliability analysis is a challenging task as it is a very time-consuming computation. It consists of evaluating the failure probability, which requires a very complex and multi-variable integration based on the limit state function. In engineering problems, the limit state function estimation involves complex and time-consuming finite element analyses. Consequently, surrogate models are usually used instead since they can reduce the computational cost. Various surrogate models exist, such as the polynomial chaos expansion (PC), response surface method, Kriging model etc. exists with different tuning. The choice of the most suitable one for a given problem is not obvious. In this work, we are interested in developing an automatic selection procedure based on an evolutionary algorithm. It should determine the optimal surrogate to any problem. Furthermore, there are situations where none of the meta-models is the best choice and distinguishing between those surrogates in not an evidence. Using ensembles of surrogates, in this case, should be a reasonable solution.

Definitions

Surrogate models

Surrogate models are mathematical models used to approach computationally expensive simulations. They have to be as accurate as possible.

Evolutionary Algorithms

Evolutionary algorithms are population based heuristic optimization algorithms inspired by biological evolution.

State of the art

In the literature, this problem is generally studied using different approaches:


Methods

- Structural Reliability Analysis based on surrogates
  The failure probability of the structure is \( P_f = \int_{g(x) < 0} f(x) \, dx \).

- The estimation of \( P_f \) is done either by approximation (FORM/SORM) or simulation (MCS, IS, etc.).

- Meta-models automatic selection using an Evolutionary Algorithm
  The individuals are the different optimized surrogate models.
  The fitness function is the selection criteria.
  The optimized meta-model settings are the genetic informations of the individuals.
  The aggregation of meta-models occurs if the genetic operators are applied to the settings of two different types.

- Proposing a new relevant surrogate model selection algorithm using an evolutionary algorithm.
- Tuning the evolutionary algorithm parameters.
- Choosing an appropriate criteria of selection.
- Optimizing the surrogate associated weights in case ensembles are created.
- Assessing the level of confidence of the selected surrogate prediction.

References