

The key points approach: combining response surface methodology and reduced order modeling to achieve drastic reduction in surrogates construction cost

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Abstract:

Numerical simulation is currently able to model increasingly complex phenomena. However, it often involves significant computational cost, which hinders its use in some applications requiring frequent calls to the simulation (e.g. optimization, statistical sampling). Response surface methodology is an efficient method for approximating the output of complex, computationally expensive codes. Challenges remain however in decreasing their construction cost as well as in approximating high dimensional output instead of scalar values.

The aim of this article is to present a new methodology that can address both these challenges more efficiently than existing approaches for problems involving partial differential equations (typically problems solved by the finite elements method). Our method is based on the coupling of reduced order modeling by projection, also known as reduced basis modeling, with the construction phase of a response surface in order to achieve more efficient surrogate construction of complex multidimensional output. Reduced basis models are a particular kind of reduced order models obtained by solving the problem projected on an appropriately constructed reduced-dimensional basis, which greatly reduces the resolution cost. Approaches such as principal component analysis, Karhunen Loeve decomposition or proper orthogonal decomposition are a few methods utilizing such reduced bases. The basic idea of the proposed surrogate construction approach is to (1) solve the full problem, but on a small number of points of the design of experiments, (2) to use these solutions to construct a reduced basis, and (3) to use this reduced basis to build approximate solutions for the other points of the design of experiments, while controlling the quality of the approximations.

An application problem is presented involving the construction of a surrogate for the temperature field in a rocket engine combustion chamber wall in terms of eight design variables. Compared to traditional response surface methodology a reduction by about an order of magnitude in the total system resolution time was achieved using the proposed sequential surrogate construction strategy. It is also worth noting that a surrogate of the entire temperature field in the entire chamber wall was obtained, while traditional surrogates usually concern only scalar values (not high dimensional vectors).