Data-driven reduced order modeling for CFD stochastic time-dependent problems

Azzedine Abdedou* and Azzeddine Soulaïmani

* Department of Mechanical Engineering, École de Technologie Supérieure (ÉTS)
1100 Notre-Dame W., Montreal (QC), Canada H3C 1K3
e-mails: azzedine.abdedou.1@ens.etsmtl.ca, azzeddine.soulaimani@etsmtl.ca

ABSTRACT

The substantial improvement in computing power has enabled researchers to tackle increasingly complex CFD problems, thus opening up new opportunities to meet both industrial and societal challenges. However, for time-dependent problems with large-scale configurations, a single simulation can be extremely expensive in terms of computational cost. This situation becomes all the more demanding when the input parameters are subject to uncertainties that propagate through numerical solvers, and which must be considered, further increasing the requirements both in terms of CPU time and memory demands. Therefore, the development of efficient stochastic surrogate models combined with reduced-order concept that significantly alleviate the cumbersome computational effort is of great interest particularly for situations which require real-time and accurate predictions.

In this context, a proper orthogonal decomposition-based B-splines Bézier elements method (POD-BSBEM) has been recently proposed as a non-intrusive reduced-order model for uncertainty propagation analysis for stochastic time-dependent problems [1]. The method uses a two-step proper orthogonal decomposition (POD) technique to extract the reduced basis from a collection of high-fidelity solutions called snapshots. A third POD level is then applied on the data of the projection coefficients associated with the reduced basis to separate the time-dependent modes from the stochastic parametrized coefficients. These are approximated in the stochastic parameter space using B-splines basis functions defined in the corresponding Bézier element [2]. The accuracy and the efficiency of the proposed method are compared to the reduced-order model-based artificial neural network (POD-ANN) and to the full-order model-based polynomial chaos expansion (Full-PCE). The proposed method is applied to analyze the uncertainty propagation through a flood wave flow stemming from a hypothetical dam-break in a river with a complex bathymetry. The results confirm the ability of the POD-BSBEM to accurately predict the statistical moments of the output quantities of interest with a substantial speed-up for both offline and online stages compared to other techniques.

REFERENCES

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