Non-intrusive data-driven model order reduction techniques coupled with parameter space dimensionality reduction for modern naval digital twins

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ABSTRACT

Nowadays the concept of digital twin is well widespread in the industrial community. The simulated systems incorporate real-time data acquisition, complex dynamical behaviour, multi-phase and multi-physics. This results in the need of better integration of all the components of these new digital representations, more sophisticated numerical analysis techniques involving data-driven models. These new challenges are crucial when dealing with industrial design optimization [1, 2]. We present different modular techniques easy to integrate in existing numerical pipelines in a non-intrusive way.

Shape parameterisation and morphing capabilities are the first step in every shape optimization cycle. Techniques such as free form deformation and radial basis functions interpolation are general purpose methods to deform a body. To explore sufficient large design space looking for unconventional solutions, we need to increase the number of geometrical parameters. Moreover other physical and/or structural parameters can play a huge role in the analysis. This leads to intractable problems with too many input parameters. Active subspaces can be used to reduce the dimensionality on the input parameter space taking linear combinations of all the original parameters (see [3] for a naval engineering application).

After reducing the number of parameters, we still need a huge amount of output fields evaluations at untried inputs during the optimization cycle. Reduced order methods (ROM) allow to represent a system using only few basis functions that retain the most energetic components. We will focus on non-intrusive ROMs such as proper orthogonal decomposition with interpolation and dynamic mode decomposition, as data-driven techniques for fast and reliable evaluations of the output fields of interest [4]. The intrusiveness is to be intended in terms of numerical implementation, since non-intrusive methods do not require rewriting of the numerical schemes and are easy to implement even without accessing the source code. This aspect is particularly relevant when commercial codes are employed.

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