Dynamical Data-Driven Model Order Reduction for Fluid-Structure Interaction problems

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The main goal of this study is to develop a reduced order model (ROM) strategy in order to predict at lower cost compared to a full order model (FOM) the time evolution of physical fields of interest in the context of Fluid-Structure Interaction (FSI). The proposed method should act in a non-intrusive manner and be able to interact with preexisting solvers. Initially developed to analyze fluid flows and slightly extended to other fields, the Dynamic Mode Decomposition (DMD) [3] enables for example to identify a reduced dynamical system using data provided by measurements or other simulations in an offline phase. It is a tool for extracting spatial and temporal patterns from multi-dimensional time series. It seems therefore relevant to expand this powerful tool to coupled systems as fluid-structure interactions where the data issued from two solvers with a tricky interface condition could be studied. The main target of this study is to introduce such reduced order modeling to predict the features of fluid-structure interactions.

In this work, the DMD is first applied on a one dimensional toy problem, involving a compressible gas flow contained in a chamber, enclosed on one end by a moving piston attached to a spring [2]. High fidelity (HF) solutions of the FOM are obtained using an Arbitrary Lagrangian Eulerian approach (ALE) with the finite element method. The DMD-based ROM uses HF simulation results as input data and predicts the flow and the piston dynamics. Regularization methods and the effect of including the piston acceleration in the input data are investigated. Monolithic and partitioned ROM methods are also compared in term of time forecasting accuracy compared to the FOM. This approach is finally assessed on a more realistic test case, considering the coupling between an unsteady flow and a deformable wall in a channel. More specifically, a microfluidic device model similar to the one analyzed in [1] is considered, including the fluid-structure interaction between an hyperelastic membrane and an incompressible fluid. The HF solution is obtained using a partitioned FSI coupling between Altair's finite element solvers Acusolve (Fluid solver) in the ALE setting and Optistruct (Structural solver). The DMD approach is then trained on the HF solution and used to predict the ROM solution on a future time domain.

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[2] E. Lefrançois, J.-P. Boufflet. *An introduction to fluid-structure interaction : Application to the piston problem.* SIAM Review, **52(4)**, 747–767, 2010. doi :10.1137/090758313.

[3] P. J. Schmid. *Dynamic mode decomposition of numerical and experimental data.* JFM, **656**, 5–28, 2010. doi :10.1017/S0022112010001217.

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