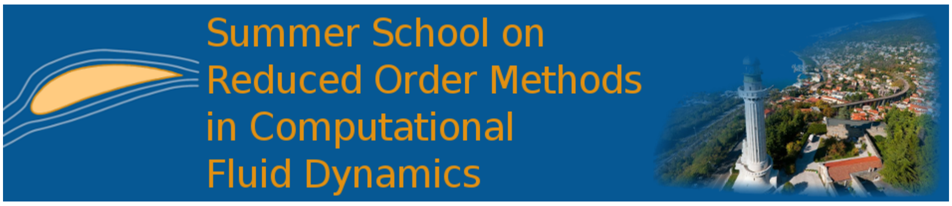

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Adjacency-based DMD on Deforming Grids for Vortex-Induced Vibrations

Vortex-induced vibrations (VIV) of structures pose computationally expensive problems of high practical interest to several engineering fields. In this work, we develop a methodology for non-intrusive, reduced-order modelling of two-dimensional VIV simulations. We consider the problem of an elliptical non-deformable solid mounted on vertical and horizontal springs, subject to a low-Reynolds number incompressible flow.

The fluid model is constructed on the grid nodes rather than on the Euclidean domain, to isolate the solid motion from the fluid data snapshots. Working on this domain, the Dirichlet kinematic boundary conditions at the fluid inlet as well as the fluid/solid interface can be directly enforced to the full-order non-intrusive model.

On this reference domain, the Navier-Stokes equations are transformed to the Arbitrary Lagrangian-Eulerian (ALE) formulation. To approximate the structure of these equations, a discrete-time implicit, quadratic-bilinear model structure is prescribed. Similarly, based on the problem physics, a quadratic model is constructed to predict the force from the flow to the solid body.

Motivated by the computational stencil of the discretized Navier-Stokes equations in ALE formulation, we construct the full-order non-intrusive model with a predefined sparsity pattern. Using the grid adjacency information, only the contribution of 2nd degree adjacent nodes is considered for each grid node model. This approach leads to a significant increase in computational efficiency, especially considering quadratic terms.

By the above sparsity pattern, deriving the model operators requires solving node-wise, low-dimensional least squares (LS) problems. An L2-regularization is applied to each LS problem, optimized through an L-curve criterion.

The projected low-order fluid model is then coupled with the known solid oscillation model along the horizontal and vertical direction. An implicit time integration scheme is employed due to the stiff coupling between the solid and fluid subsystems. Mapping the fluid solution back to the Euclidean domain requires the solution of a Laplace equation once, to account for the grid deformation. Results considering the reduced model error on the flow velocities and the solid oscillatory motion are discussed.

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