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Grid Adjacency-based Dynamic Mode Decomposition for Incompressible Fluid Dynamics

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In recent decades, non-intrusive model reduction has been developed to become a promising solution to system dynamics forecasting, especially in cases where data are collected from experimental campaigns or proprietary software simulations. Hence, the usage of non-intrusive modelling methods in combination with physics-based considerations could comprise a building block towards predictive Digital Twins in critical engineering applications. In this work, we present a method for non-intrusive model reduction, applied to fluid dynamics. The approach is based on the a priori known sparsity of the full-order system operators (e.g. of the discretized Navier-Stokes equations), which is dictated by grid adjacency information. In order to enforce this type of sparsity, we solve a "local", regularized least-squares problem for each degree of freedom on a grid, considering only the training data from adjacent nodes, thus making computation and storage of the inferred full-order operators feasible. After constructing the non-intrusive, sparse full-order model, the Proper Orthogonal Decomposition is used for its projection to a reduced dimension subspace. This approach differs from methods where data are first projected to a low-dimensional manifold, since here the inference problem is solved for the original, full-order system. As an example, we consider the construction of a quadratic, reduced order model for the flowfield prediction over a cylinder at a low Reynolds number. Results considering the accuracy and predictive capabilities of the inferred reduced model are analytically discussed.

Primary authors: GKIMISIS, Leonidas (MPI Magdeburg); Prof. RICHTER, Thomas (Otto von Guericke University); BENNER, Peter

Presenter: GKIMISIS, Leonidas (MPI Magdeburg)