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Explorative In-situ Analysis of Turbulent Flow Data Based on a Data-Driven Approach

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In the last decades, highly-resolved numerical flow simulations, e.g. Large Eddy Simulations (LES) and Direct Numerical Simulations (DNS), have become an invaluable engineering tool to get insights into the physics of turbulent flows. However, the analysis of large simulation bundles, e.g. from variations in the geometry, boundary conditions or material properties, can be a quite challenging task. While a post-processing purely based on analytical scalar or integral quantities can capture only specific aspects of the solution, multi-scale simulations usually contain much more information that can be exploited. On the other hand, data-driven techniques promise a more global prospective on the data and can provide a more automated way to compare multiple simulation runs and identify similarities or patterns in the high-dimensional simulation results [1], [2]. In conjunction with in-situ analysis approaches, these techniques can also be employed to monitor the simulation [3]. That way, trends in the flow solution over time, bifurcating behaviour, or characteristic phenomenons, such flow separation, can be identified and tracked.
We will discuss different linear and non-linear techniques of dimension reduction, e.g. the Principal Component Analysis (PCA) and Diffusion Maps, with the goal to derive suitable low-dimensional representations of the chaotic time-series data from turbulent flow simulations. Thereby, data is taken from industrial relevant use-cases that require the execution and exploration of large simulations bundles to investigate the influence of multiple input parameters. An additional focus will be put on in-situ algorithms to compute the representations during run-time of the simulations. Finally, we perform a visual analysis to identify intrinsic structures in the high-dimensional simulations data.

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