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Spatial Selective Sampling and POD on big data

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The identification of coherent structures is important for understanding and modelling turbulent flows. They reveal key flow features and enable a better understanding of the flow physics. The proper orthogonal decomposition (POD) is an ideal dimensionality reduction tool capable of identifying the most energy-containing coherent structures. The POD is an optimal decomposition in the sense that it guarantees the least residual for a given number of modes. For these reasons, POD has gained wide popularity within the fluid mechanics community. Since its introduction to the field by Lumley [1], POD has been widely used in reduced order modelling [2] and control [3], to name only a few.

Conducting POD analysis on big data is challenging. High fidelity simulations such as large eddy simulations (LES) or direct numerical simulations (DNS) can produce hundreds of gigabytes of data. Such sizable data cannot be handled with standard processes and introduce a range of challenges, such as memory overload and long computational time.

In this study, we review existing enablers of POD on big data and propose a novel mesh sparsification technique, called Spatial Selective Sampling (S^3), that allows computational speed-up and storage reduction. Mesh sparsification uses the fact that most energy-containing coherent structures are spatially limited to a finite region. By choosing the turbulent kinetic energy as a metric, the method is capable of selectively sampling the most important points. A new mesh is then created based on the sampled cloud of points using the Delaunay triangulation and the mesh is improved to correct the skewness that can result from the triangulation. Two cases are investigated: the $2D$ cylinder flow and a more challenging $3D$ DES of an airfoil with Coanda blowing. We show that we can reach a data reduction of 95 % with practically no loss of accuracy in the POD.

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