Cluster-based reduced-order modelling of shear flows

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We propose a novel cluster-based reduced-order modelling (CROM) strategy of unsteady flows [1, 2]. CROM builds on the pioneering works of Gunzburger's group in cluster analysis [3] and Eckhardt's group in transition matrix models [4] and constitutes a potential alternative to POD models. This strategy processes a time-resolved sequence of flow snapshots in two steps. First, the snapshot data is clustered into a small number of representative states, called centroids, in the state space. These centroids partition the state space in complementary non-overlapping regions (centroidal Voronoi cells). Secondly, the transitions between the states are dynamically modelled via a Markov process. Physical mechanisms are then distilled by a refined analysis of the Markov process, e.g. with the finite-time Lyapunov exponent and entropic methods. The resulting CROM is applied to the spatially evolving incompressible mixing layer, to the turbulent jet noise, and to the Ahmed body. For these examples, CROM is shown to distil non-trivial quasi-attractors and transition processes. CROM has numerous potential applications for the systematic identification of physical mechanisms of complex dynamics, for comparison of flow evolution models, for the identification of precursors to desirable and undesirable events, and for flow control design exploiting nonlinearities.

References:

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