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Manifold of clusters for complex flows

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Abstract

Data modeling is critical in flow estimation, prediction, and control. Data-driven manifold learning has successfully extracted low-dimensional representations of flows with coherent structures without [1] and with control [2]. However, complex flows, characterized by multiple instabilities and localized coherent structures with intrinsic dynamics, challenge the application of a single manifold describing the global dynamics. This study aims to overcome this limitation by identifying multiple local manifolds. The key enabler is the clustering of the flow field into regions that are dynamically correlated, each exhibiting relatively simple local dynamics. Low-dimensional representations are then derived for each cluster using manifold learning techniques. The global flow kinematics are then reconstructed by mapping these manifold coordinates onto simple dynamical models. The methodology, illustrated in Figure 1, is demonstrated on the fluidic pinball—a system of three rotating cylinders—under various conditions, including unforced, steady, and periodic forcing, as well as transient states. By separating the flow field based on dynamics, the approach facilitates the automatic identification of actuation mechanisms, paving the way for the development of simple and interpretable models of flows under control.

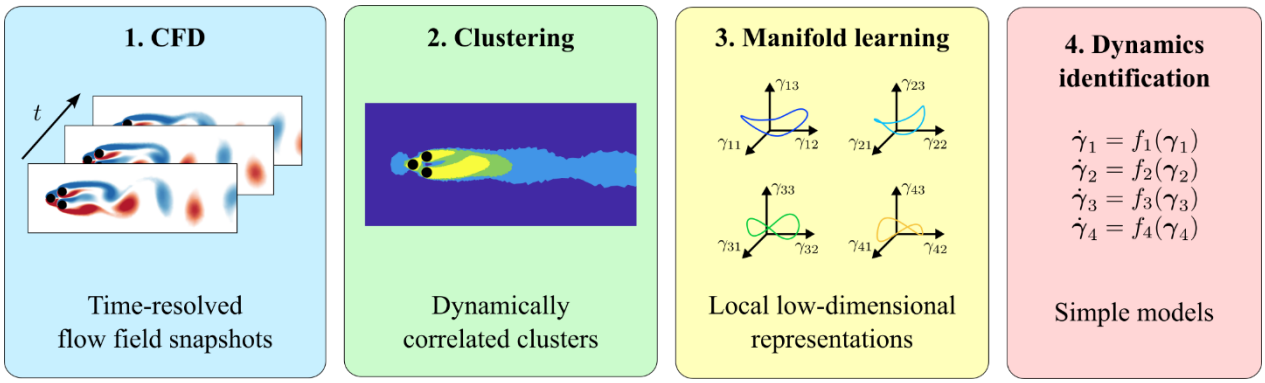

Figure 1 Principle sketch of the manifold of manifolds for simple dynamics identification.

Keywords: Manifold learning; Clustering; Modeling; Flow control.

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