Low-order models for control of fluids: balanced models and Koopman modes

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The ability to effectively control a fluid would enable many exciting technological advances, such as the design of quieter, more efficient aircraft. Model-based feedback control is a particularly attractive approach, but the equations governing the fluid, although known, are typically too complex to be useful for control. This talk addresses model reduction techniques, which are used to simplify existing models, to obtain low-order models tractable enough to be used for analysis and control, while retaining the essential physics. In particular, we will discuss two techniques: balanced truncation and Koopman modes. Balanced truncation is a well-known technique for model reduction of linear systems, that can significantly outperform more conventional methods such as Proper Orthogonal Decomposition (POD). Koopman modes are based on spectral analysis of the Koopman operator, an infinite-dimensional linear operator that describes the full dynamics of a nonlinear system, without resorting to linearization. We show how the associated modes can elucidate coherent structures in examples including a jet in crossflow and the wake of a flat plate.