Journal of Control Science and Engineering

Journal of Control Science and Engineering
Volume 2008 (2008), Article ID 154956, 11 pages
doi:10.1155/2008/154956

Research Article

Empirical Reduced-Order Modeling for Boundary Feedback Flow Control

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Received 27 December 2007; Revised 4 November 2008; Accepted 24 December 2008

Academic Editor: Onur Toker

Abstract

This paper deals with the practical and theoretical implications of model reduction for aerodynamic flow-based control problems. Various aspects of model reduction are discussed that apply to partial differential equation-(PDE-) based models in general. Specifically, the proper orthogonal decomposition (POD) of a high dimension system as well as frequency domain identification methods are discussed for initial model construction. Projections on the POD basis give a nonlinear Galerkin model. Then, a model reduction method based on empirical balanced truncation is developed and applied to the Galerkin model. The rationale for doing so is that linear subspace approximations to exact submanifolds associated with nonlinear controllability and observability require only standard matrix manipulations utilizing simulation/experimental data. The proposed method uses a chirp signal as input to produce the output in the eigensystem realization algorithm (ERA). This method estimates the system's Markov parameters that accurately reproduce the output. Balanced truncation is used to show that model reduction is still effective on ERA produced approximated systems. The method is applied to a prototype convective flow on obstacle geometry. An H∞ feedback flow controller is designed based on the reduced model to achieve tracking and then applied to the full-order model with excellent performance.