Identification and model reduction of nonlinear systems from measured and computed data

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ABSTRACT

The study of technical processes characterized by nonlinear dynamics has been a broad and challenging topic. The need for more accurate spatial discretization schemes of the target domain led to large dimensional models. In most cases, it is not feasible to use the full order models for such tasks as simulation, real-time analysis or control. Instead, in many disciplines, it is of interest to use a reduced order model instead. Model reduction is commonly viewed as a methodology used for reducing the computational complexity of large scale complex models in numerical simulations. The goal is to construct a much smaller system with the same structure and similar response characteristics as the original.

With the ever-increasing supply of available measurements in the study of physical processes, the need for incorporating data in the modeling process has steadily grown. In recent years, data-driven methods have proven to be an appealing tool used in many fields. The main idea is to use measured data to construct models that can accurately identify the underlying dynamics.

The Loewner Framework (LF) is a data-driven identification and reduction technique that uses measured or computed data to construct surrogate models. For a recent tutorial paper on the LF for linear systems, we refer the reader to [1]. The framework has been extended and applied to classes of mildly nonlinear systems, such as bilinear systems in [2], and quadratic-bilinear (QB) systems in [3]. These classes are of interest since nonlinear systems can be reformulated, without any approximation, as QB systems (provided that the nonlinearities are analytical).

In this study, we propose a modeling and complexity reduction technique based on the LF. We apply it to various processes characterized by nonlinear partial differential equations (with polynomial nonlinearities) such as the FitzHugh-Nagumo model or heat transfer equations. Additionally, we compute surrogate models for validating experiments in electrochemical applications. We use measured data related to the nonlinear frequency response of fuel cells (typical models include exponential or fractional nonlinearities).

REFERENCES

