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Original article

Nonlinearity-aware sub-model combination in trajectory based methods for nonlinear Mor

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Abstract

Trajectory based methods approximate nonlinear dynamical systems by superposition of dimensionally reduced linear systems. The linear systems are obtained by linearisations at multiple points along a state-trajectory. They are combined in a weighted sum and the combinations are switched appropriately to approximate the dynamic behaviour of the nonlinear system. Weights assigned at a specimen point on the trajectory generally depend on the euclidean distance to the linearisation points. In this work, limitations of the conventional weight-assignment scheme are pointed out. It is shown that the procedure is similar across all nonlinearities, and hence ignores the nonlinear vector field curvature for superposition. Additionally, it results in an inadequate assessment of the linear systems when they are equidistant from the specimen point. An improved method for weight-assignment, which uses state-velocities in addition to state-positions is proposed. The method naturally takes into account the system nonlinearity and is hence called Nonlinearity-aware Trajectory Piece-wise Linear (Ntpwl) method. Further, a computationally efficient procedure for estimating the state-velocity is introduced. The new strategy is illustrated and assessed with the help of case studies and it is shown that the Ntpwl model substantially improves the approximation of the nonlinear systems considered. Increased robustness to training and negligible stretching of the computational resources is also obtained.

Keywords: Large dynamical systems; Model order reduction; Nonlinear systems; Trajectory piecewise linear; Weight-assignment

1. Introduction

Dynamical systems are used to model many physical and artificial processes. Realistic and accurate description of such systems tend to be of large dimensions, and their simulation is not possible without expenditure of considerable amounts of computational resources and time. Approximation is thus crucial for cost-effective simulation. Model Order Reduction (Mor) techniques help realize this objective in a computationally efficient way. Mor results in a Reduced order model (Rom) with input-output mapping similar to the large-scale system it approximates.

Recently developed Mor techniques for Lti systems can be considered to be *Projection* based. They construct a Rom of order $r \ll n$ that approximates the original system from a subspace spanned by a reduced basis of dimension r in R^n. Broadly, the Projection based methods can be classified into two categories – Krylov subspace projection and methods based on Truncated balanced realizations (Tbr).

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