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# A realization-free approach for constructing surrogate bilinear reduced-order models

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The class of bilinear dynamical systems often arises in the description and approximation of large-scale nonlinear systems with analytic nonlinearities. This bilinear structure allows the extension of various established model order reduction (MOR) approaches, from their linear counterparts. In this work, our aim is to introduce a realization-free, data-based MOR method, inspired by the TF-IRKA method in [Beattie/Gugercin '12] and the BIRKA method in [Benner/Breiten '12, Flagg/Gugercin '15]. The former one is applicable solely to linear systems, but is non-intrusive, while the latter one is applicable to bilinear systems, but is intrusive (requires system matrices).

We propose an approach that we call TF-truncBIRKA, which is a novel non-intrusive reduction method, based on constructing quasi-Loewner matrices (similar to those in the bilinear Loewner frameworks [Antoulas/G./Ionita '16] and [G./Pontes Duff '22]), and therefore relies solely on the evaluation of generalized transfer functions (corresponding to the original system). Starting from a cascaded form of underlying generalized Sylvester equations and based on the standard BIRKA approach, data-based Loewner matrices are computed at each step as system matrices of the surrogate reduced model. To make the presentation as clear as possible, we will stop at the second level in the Volterra series decomposition, hence the prefix "trunc" (truncated) appearing in the name of the method. However, extensions to higher-order truncation levels are indeed feasible and may be explored. The method is indeed iterative (in the fashion of all IRKA-based approaches), and will be stopped based on a termination criterion similar to that of BIRKA (when the poles of the linear subsystem do not change much, i.e., w.r.t. a tolerance value).

The proposed iterative, realization-free approach TF-truncBIRKA reaches the goal of reducing bilinear systems in a data-based manner and successfully replaces the computation of standard projection matrices. Interpolation conditions are also derived, and in order to validate the practical applicability of the method, several numerical test cases are presented.

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