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Review

Propagator-based methods for recursive subspace model identification

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Abstract

The problem of the online identification of multi-input multi-output (MIMO) state-space models in the framework of discrete-time subspace methods is considered in this paper. Several algorithms, based on a recursive formulation of the MIMO Output Error State-Space (MOESP) identification class, are developed. The main goals of the proposed methods are to circumvent the huge complexity of eigenvalues or singular values decomposition techniques used by the offline algorithm and to provide consistent state-space matrices estimates in a noisy framework. The underlying principle consists in using the relationship between array signal processing and subspace identification to adjust the propagator method (originally developed in array signal processing) to track the subspace spanned by the observability matrix. The problem of the (coloured) disturbances acting on the system is solved by introducing an instrumental variable in the minimized cost functions. A particular attention is paid to the algorithmic development and to the computational cost. The benefits of these algorithms in comparison with existing methods are emphasized with a simulation study in time-invariant and time-varying scenarios.

Keywords: System identification; Recursive algorithm; Subspace method; Instrumental variable; Multivariable system

Contents

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1. Introduction

Subspace-based approach for system identification is a particular field of experimental modelling which has reached a definite maturity from now on, as shown by numerous reference articles [1–5] and various application papers [6–10]. Offline subspace identification methods are indeed attractive since a state-space realization can be directly estimated from input/output (I/O) data without nonlinear optimization (generally required by the prediction methods [11]). Furthermore, these techniques are characterized by the use of robust numerical tools such as the RQ factorization and the singular values decomposition (SVD). Interesting from a numerical point of view, the batch subspace model identification (SMI) algorithms are not usable for online implementation because of the SVD computational complexity. Indeed, in many online identification scenarios, it is important to update the model as time goes on with a reduced computational cost. Consequently, it was necessary to find SVD alternative algorithms in order to apply the subspace concept in a recursive framework. First, some works proposed adaptations of SMI methods in order to update the SVD [12,13]. Unfortunately, these techniques had the drawback of requiring that the disturbances acting on the system outputs were spatially and temporally white, which is obviously restrictive in practice. Then, recursive subspace model identification (RSMI) methods based on the Yang's criterion and the projection approximation subspace tracking (PAST) cost function [14] were introduced. These specific techniques were developed to track the subspace spanned by the extended observability matrix in a coloured disturbances framework [15–18]. More precisely, instrumental variable adaptations of the PAST technique to the problem of RSMI were considered, the focus being computational efficiency [15] or estimation accuracy [16,17]. More recently, in order to provide solutions to the approximation induced by the reduction of the fourth order Yang's criterion to a quadratic cost function, new developments in the RSMI class of algorithms have been put forward [19–21]. The proposed methods are based on the adaptation of a particular array signal processing technique to the recursive subspace identification problem: the propagator [22]. The main advantage of this approach over the previous conception lies in the use of a linear operator and quadratic criteria which lead to recursive least squares implementations for the algorithms. This characteristic has newly allowed the analysis of the convergence properties of the developed techniques for the recursive update of the subspace estimates [23]. It has also been used with success to online track the modal parameters of airplanes during test flights [24].