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New gradient based identification methods for multivariate pseudo-linear systems using the multi-innovation and the data filtering ☆

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Abstract

This paper proposes parameter identification methods for multivariate pseudo-linear autoregressive systems. First, a multivariate generalized stochastic gradient (M-GSG) algorithm is presented as a comparison basis. In order to improve the parameter estimation accuracy, a multivariate multi-innovation generalized stochastic gradient (M-MI-GSG) algorithm and a filtering based multivariate generalized stochastic gradient (F-M-GSG) algorithm are presented by means of the multi-innovation identification theory and the data filtering technique. The simulation results confirm that the proposed algorithms are more effective than the M-GSG algorithm.

1. Introduction

For a long time, system modeling and identification have had extensive applications in almost all natural and man made systems [1–4], particularly those industrial control,

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control system designs always need proper models as references [5,6]. Most control laws are designed based on the mathematical models [7–9]. To recognize the internal complex relationship between components and/or less rules to integrate the whole system behaviour, it is alternatively and commonly to determine the mathematical models from input–output data, which is widely known as input–output external models [10,11]. Another observation is that many practical processes/systems are multivariable [12–14]. Anderson et al. discussed the structure of multivariate auto-regressive (AR) and auto-regressive moving average (ARMA) systems, but they just gave the state space representation to derive identifiability results, they did not derive a universal mathematical model and apply it into various identification methods. For multivariate systems with colored noise. Recently, Wang and Ding studied the auxiliary model based recursive and iterative identification methods for multivariable Bx-Jenkins systems using the filtering technique [15–17]. Wang and Zhang discussed an improved least squares identification algorithm for multivariable Hammerstein systems [18]. Wang and Gao presented a recursive maximum likelihood identification method for a multivariable controlled autoregressive moving average system [19].

The multi-innovation identification theory is an important branch of system identification [20], the innovation is the useful information that can improve the accuracy of the parameter estimation or the state estimation [21]. In this aspect, Mao et al. presented a data filtering based multi-innovation stochastic gradient algorithm for Hammerstein nonlinear systems, combining the data filtering technique with the multi-innovation theory [22]. Jin et al. proposed a multi-innovation least squares identification algorithm for multivariable output-error systems with scarce measurements [23]. Wan et al. studied a T-wave alternans assessment method based on the least squares curve fitting technique [24].

The data filtering technique is effective for picking up the useful signals from noisy measurements and has been used in system identification [25–28]. The main idea is to use a special filter to filter the input and output data, and then to identify the filtered system model and the filtered noise model with each other for generating corresponding parameter estimates [29,30]. Wang et al. studied a gradient based iterative identification algorithm for multivariate pseudo-linear moving average systems using the data filtering [31] and a decomposition based recursive least squares parameter estimation algorithm for pseudo-linear systems using the auxiliary model [32]. Ding et al. presented a decomposition based least squares iterative identification algorithm for multivariate pseudo-linear ARMA systems using the data filtering [33]. Guo et al. proposed a recursive least squares algorithm for pseudo-linear ARMA systems using the auxiliary model and the filtering technique [34].

For multivariate pseudo-linear autoregressive system, this paper presents a multivariate multi-innovation generalized stochastic gradient algorithm and a filtering based multivariate generalized stochastic gradient algorithm. The basic idea is to derive the mathematical model of multivariate systems, and then to use the multi-innovation identification theory and the data filtering technique to propose the corresponding gradient based identification algorithms, which can overcome the influence of colored noise to the parameter estimation.

The rest of this paper is organized as follows. Section 2 introduces the identification problems for multivariate pseudo-linear autoregressive systems. Section 3 gives a generalized stochastic gradient algorithm for comparison. Section 4 derives a multi-innovation stochastic gradient algorithm and Section 5 presents a filtering based stochastic gradient algorithm for improving the performances. Section 6 provides two examples for illustrating the results in this paper. Finally, we offer some concluding remarks in Section 7.

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