



Auxiliary model based least squares parameter estimation algorithm for feedback nonlinear systems using the hierarchical identification principle[☆]

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Abstract

This paper presents a decomposition based least squares estimation algorithm for a feedback nonlinear system with an output error model for the open-loop part by using the auxiliary model identification idea and the hierarchical identification principle and by decomposing a system into two subsystems. Compared with the auxiliary model based recursive least squares algorithm, the proposed algorithm has a smaller computational burden. The simulation results indicate that the proposed algorithm can estimate the parameters of feedback nonlinear systems effectively.

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1. Introduction

System modelling is important for studying the motion laws of dynamical systems [1–3]. The parameters of a system can be estimated through an identification algorithm from the

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measurement data [4–6]. Recently, parameter estimation for feedback closed-loop control systems has received much attention on system identification [7,8]. For example, Marion et al. considered the instrumental variable and instrumental variable-related identification methods for closed-loop systems [9].

The auxiliary model can handle the identification problems in the presence of the unmeasurable variables in the information vector. In the area of parameter estimation, Ding and Chen proposed an auxiliary model based recursive least squares algorithm for a dual-rate sampled-data system [10]. They used an auxiliary model to estimate the unknown noise-free outputs of the system and to identify the parameters of the underlying fast single-rate model from available dual-rate input–output data directly. Wang et al. discussed the auxiliary model based recursive generalized least squares algorithm for Hammerstein output error autoregressive systems by using the key-term separation principle [11]. Liu et al. proposed a multi-innovation stochastic gradient algorithm for multiple-input single-output systems using the auxiliary model [12].

The iterative numerical algorithms can be used to solve matrix equations [13–17], and to estimate the parameters of systems from input–output data [18–20]. In the area of system identification, Wang presented a least squares-based recursive and iterative estimation for output error moving average (OEMA) systems using the data filtering, transforming an output error moving average system into two identification models [21]; Wang and Ding derived an extended stochastic gradient identification algorithm for Hammerstein–Wiener ARMAX systems [5], presented the auxiliary model based RELS and MI-ELS algorithms for Hammerstein OEMA systems [22], and developed a least squares based and a gradient based iterative identification algorithms for Wiener nonlinear systems [23].

Recently, Duan et al. proposed a two-stage recursive least squares parameter estimation algorithm for output error models [24]; Yao et al. proposed a two-stage least squares based iterative identification algorithm for controlled autoregressive moving average (CARMA) systems [25]; Hu and Ding proposed a multi-stage least squares based iterative estimation algorithm for feedback nonlinear systems with moving average noises using the hierarchical identification principle [26]. The main contributions of this paper are as follows. On the basis of the decomposition identification technique in [26–29], this paper transforms a complex identification problem into small subproblems which are easier to solve and presents an auxiliary model based least squares parameter estimation algorithm for feedback nonlinear systems.

This paper is organized as follows. Section 2 gives the system description and identification model for feedback nonlinear systems. Section 3 derives an auxiliary model and decomposition based recursive least squares algorithm for feedback nonlinear systems. Section 4 offers a comparison between the proposed algorithm and the least squares based auxiliary model identification algorithm. Section 5 gives an example for the proposed algorithms. Finally, we offer some concluding remarks in Section 6.

2. System description and identification model

Let us introduce some notation [30,31]. The symbol I_n stands for an identity matrix of order n ; the superscript T denotes the matrix transpose; $\mathbf{1}_n$ represents an n -dimensional column vector whose elements are 1; the norm of a matrix X is defined as $\|X\|^2 := \text{tr}[XX^T]$; $\hat{X}(t)$ denotes the estimate of X at time t .

Consider the feedback nonlinear system in Fig. 1, where the $\{r(t)\}$ and $\{y(t)\}$ are the input–output sequences of the system, $\{v(t)\}$ is a stochastic white noise sequence with zero mean and variance σ^2 , $\{x(t)\}$ and $\{\bar{y}(t)\}$ are the internal signals, $A(z)$ and $B(z)$ are polynomials in the unit

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