Available online at www.sciencedirect.com

ScienceDirect

Journal of the Franklin Institute 351 (2014) 1801–1809

Journal of The Franklin Institute

www.elsevier.com/locate/jfranklin

Short communication

A filtering based recursive least squares estimation algorithm for pseudo-linear auto-regressive systems ☆

Sheng Ding[a], Rui Ding[b,*], Erfu Yang[c]

[a]Key Laboratory of Advanced Process Control for Light Industry (Ministry of Education), Jiangnan University, Wuxi 214122, PR China

[b]School of Internet of Things Engineering, Jiangnan University, Wuxi 214122, PR China

[c]Division of Computing Science and Mathematics, School of Natural Sciences, University of Stirling, Scotland, United Kingdom

Received 4 February 2013; received in revised form 8 June 2013; accepted 22 October 2013
Available online 22 November 2013

Abstract

This paper uses the filtering technique, transforms a pseudo-linear auto-regressive system into an identification model and presents a new recursive least squares parameter estimation algorithm pseudo-linear auto-regressive systems. The proposed algorithm has a high computational efficiency because the dimensions of its covariance matrices become small compared with the recursive generalized least squares algorithm.

1. Introduction

Signal processing and prediction, and parameter and state estimation have received much attention in the areas of filtering [1–3], system identification [4–6] and adaptive control [7,8]. Shi and Fang studied Kalman filter based identification for systems with randomly missing measurements in a network environment [9]; Shi and Yu discussed Kalman filter based adaptive control for networked systems with unknown parameters and randomly missing outputs [10]; Wang presented the least squares based iterative estimation algorithm for output error moving

☆This work was supported by the National Natural Science Foundation of China, the Fundamental Research Funds for the Central Universities (No. JUSRP51322B), the 111 Project (B12018) and the PAPD of Jiangsu Higher Education Institutions.

*Corresponding author.

E-mail addresses: sding2011@aliyun.com (S. Ding), rding12@126.com (R. Ding), eya@cs.stir.ac.uk (E. Yang).

0016-0032/$32.00 © 2013 The Franklin Institute. Published by Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.jfranklin.2013.10.018

average systems using data filtering [11]. Other methods include the instrumental variable least squares and bias compensation/correction least squares algorithms [12,13] and the maximum likelihood least squares methods [14], and the recursive least squares algorithm for input nonlinear systems [15–18]. Also, Ding and Chen presented an auxiliary model based least squares algorithm [19] and an auxiliary model based stochastic gradient algorithm [20] for directly identifying the parameters of the underlying single-rate models for dual-rate systems [21].

Xiao et al. presented an interactive least squares algorithm for controlled autoregressive moving average models [22]. Ding, Shi and Chen established the convergence of a least squares algorithm and a stochastic gradient algorithm for nonstationary ARMA processes [23]. Ding et al. studied a hierarchical least squares algorithm for multivariable systems [24,25] and developed a gradient based and a least squares based iterative estimation algorithms for multi-input multi-output systems [26] and for CARARMA systems [27]. A filtering based recursive least squares algorithm was proposed for identifying CARARMA systems [28]. A least squares based iterative algorithm and a gradient based iterative algorithm were developed for Hammerstein nonlinear systems [29].

Many identification algorithms have been developed for pseudo-linear regressive models. For example, Ding et al. presented a two-stage recursive least squares and a two-stage multi-innovation stochastic gradient algorithms for Box-Jenkins systems [30] and a two-stage least squares based iterative algorithms for CARARMA systems [31]. Ding and Chen established the multi-innovation identification theory and presented a multi-innovation stochastic gradient algorithm for linear regressive models [32]. This multi-innovation parameter estimation method has been extended to pseudo-linear regressive models [33] and self-tuning control [34]. Recursive and iterative algorithms have wide applications for designing filters of control systems [35,36].

The objective of this paper is to use an estimated noise transfer function to filter the input–output data and to present a filtering based recursive least squares algorithm for pseudo-linear auto-regressive systems. Through the data filtering, we obtain two identification models, one including the parameters of the system model and the other including the parameters of the noise model. Thus, the proposed algorithm has less computational cost than the recursive generalized least squares algorithm.

This paper is organized as follows. Section 2 gives the recursive generalized least squares identification algorithms of pseudo-linear systems. Section 3 derives a filtering based recursive least squares algorithm for pseudo-linear systems. Section 4 provides an illustrative example for the results in this paper. Finally, concluding remarks are given in Section 5.

2. The recursive generalized least squares algorithm

Consider the following pseudo-linear auto-regressive system in Fig. 1 [1],

$$y(t) = \boldsymbol{\varphi}^{\mathrm{T}}(t)\boldsymbol{\theta} + \frac{v(t)}{C(z)}, \tag{1}$$

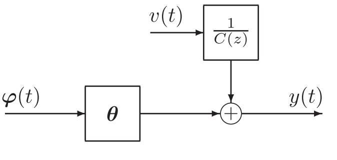

Fig. 1. A pseudo-linear regressive system.