A novel weight function-based robust iterative learning identification method for discrete Box–Jenkins models with Student’s t-distribution noises

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Received 7 May 2016; received in revised form 12 September 2017; accepted 20 October 2017
Available online 7 November 2017

Abstract

In the engineering areas, the impulsive disturbances widely exist due to the presence of outliers. The current identification theories based on Gaussian assumptions cannot meet the needs. In the view of above situations, a weight function-based iterative learning identification method is firstly proposed for discrete Box–Jenkins models, and the robust parameter estimation is achieved under Student’s t noises. Firstly, according to robust estimation theories, the characteristic weight function is designed for residuals and measurement outputs. This results in the reduced impacts of outliers. Secondly, the effective weights, derived from the robust M-estimator, are applied into the iterative least squares procedure. Thus, the each iteration process is similar to the weighted least squares algorithm. From continuous learning of the estimated residuals, the proposed method realizes an effective fusion of robust estimation and optimization techniques. Finally, the simulation examples verify the theoretical findings. © 2017 The Franklin Institute. Published by Elsevier Ltd. All rights reserved.

1. Introduction

The existing identification theories usually take the disturbances as stochastic white or colored Gaussian noises [1–4], and the optimal signal processing techniques based on Gaussian distributions are mature. Nevertheless, in the industrial environments, Gaussian assumptions
cannot give a good description of complex disturbances. The distributions of measurements are heavy-tailed because of the impacts of outliers [5]. At this point, the optimal signal processing based on Gaussian assumptions is biased, or breaks down in the presence of heavy-tailed noises [6]. Nevertheless, in the areas of signal processing, robust estimation theories are the effective methods for dealing with the heavy-tailed noises. These methods have been widely used in the areas of computer vision, image processing and communications [7–10]. Some robust estimators or robust detectors have been exploited successfully. It should be noted that no general robust estimation method is suitable for all of heavy-tailed distributions. Therefore, it is necessary to develop the corresponding robust estimators, according to the different types of heavy-tailed distributions. The typical distributions of heavy-tailed noises include the mixture Gaussian distribution [11], the Student’s t-distribution [12], the Laplace distribution [13], and the Alpha-stable distribution [14].

Specially, in the area of system identification, the model-based robust identification methods have not been studied extensively. The studies under typical heavy-tailed noises are especially seldom. In the existing literature, only for the identification of ARMA models, the bounded innovation propagation-ARMA (BIP-ARMA) robust estimator was proposed in [15]. For the identification of other complex models, there are no specific robust identification methods. Thus, it is promising to apply robust estimation theories into the existing optimization algorithms.

On the other hand, the existing identification methods are divided into three classes: the one-shot methods, the on-line recursive methods [16], and the iterative methods [17,18]. Among these, the iterative algorithms are usually adopted to deal with the unknown terms in the information vectors [19–22]. Recently, the new developed iterative methods are able to handle the identification despite of the less-persistent excitation properties of inputs [23,24].

For the identification of Box–Jenkins models, R. Pintelon et al. proposed the complete theoretical frameworks [25–28]. Further, in order to make the parameter estimators simple, F. Ding et al. proposed the gradient-based and least-squares-based recursive algorithms for the online identification of Box–Jenkins models [29]. It should be noted that the least squares algorithms have fast convergence rates for Gaussian noises [30–35], and the least squares-based iterative methods can deal with the unknown noise variables in the information vectors [36].

Given all of the above, this paper tries to seek a combination of existing optimization techniques and robust estimation theories [37] under the typical heavy-tailed disturbances. Since the Student’s t-distribution gives a useful extension for statistical modeling [38], this paper studies a robust estimation-based iterative learning algorithm for discrete Box–Jenkins models under the Student’s t noises.

The rest of the paper is organized as follows. Section 2 gives the problem formulation. In the presence of Gaussian noises, the traditional iterative identification algorithm is shown in Section 3. Section 4 proposes a novel weight function-based iterative learning identification method in the presence of Student’s t-distribution noises. Section 5 shows the simulation examples. Finally, the conclusions are drawn in Section 6.
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