Rimantas Pupeikis

Reinforced methods for dynamical system identification and adaptive control

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Internet: www.shaker.de • e-mail: info@shaker.de

The author, Rimantas Pupeikis, is working at the Institute of Mathematics and Informatics of Vilnius University.

Preface

In designing adaptive control systems, one ought to determine the type of uncertainties appearing in the plant to be controlled. Some important uncertainties can occur at the output of the control system, inducing negative effects that might sometimes lead to unstable control. One of the main ones is the uncertainty arising in the output disturbance description of a plant model. Nonnormal noise, and, particularly, the presence of outliers due to occasional failures of a signal acquisition device degrade the performance and control of the stochastic dynamical system.

None the less important is the uncertainty that arises due to nonlinearities of measurement devices and/or control actuators. Nonlinearities, such as friction, deadzone, saturation, preload, backlash, and hysteresis, are called *hard-nonlinearities*, and are common in most control systems, especially in electro-mechanical ones. Usually, such nonlinearities can occur at the output of the system, inducing negative effects. They significantly limit the performance of control systems.

The influence of both uncertainties in respect of the proximity of stochastic control system output to the reference or set-up signal is analysed here theoretically and using numerical simulation by PC.

The monograph is a result of more than twenty-year experience of the author in research and teaching of digital signal processing (DSP) and system identification for adaptive control. It is aimed at three major groups of readers: senior undergraduate students, graduate students, and scientific research workers in electrical engineering, computer engineering, computer science, and digital control, too.

The book is an extended version of DSP lecture notes used for junior graduate-level as well as senjor graduate-level courses at the Department of Electronic Systems of Vilnius Gediminas Technical University. It also includes the author's research results obtained at the Process Recognition Department of the Institute of Mathematics and Informatics of Vilnius University and could be suitable for researchers as the background reading and references.

Some results have been obtained by the author during the development and execution of the Deutsche Forshungsgemeinshaft (DFG) project "Echtzeit-Optimierung den Grössen Systemen" (chief of the project Prof. P.J. Huber) and the New Visby project Ref No. 2473/2002 (381/T81) of the Royal Swedish Academy of Sciences and the Swedish Institute (chief of the project Prof. Dalius Navakauskas), during the long-time visit at the Division of Automatic Control of Linköping University (head of the control group Prof. L. Ljung). Collaborative investigations rendered active scientific results that were represented by the author at DFG workshops in Hof (1996) and Bad Fredeburg (1997), and at the seminar of Automatic Control Department in Linchöping University (2002) as well at the European Conference on Circuit Theory and Design in Cracow (2003). Most of further results were published in local journals included in Science Citation Index Expanded (SciSearch, available at http://scientic.thomson.com), such as "Informatica"(the journal of Mathematics and Informatics Institute of Vilnius University) and "Information Technology and Control" (the journal of Kaunas University of Technology), as well as in the worldwide journal "Robust and Nonlinear Control"(2014).

The monograph consists of nine chapters.

The text begins with an introduction to the author's creation, where the reasons for its development are shown and explained briefly. Here the basic approaches to the problems analyzed in the book are outlined and expressed in short. Various but, of course, not all the references to well-known works are presented.

Chapter 2 presents two approaches to determination of the linear time-invariant system (LTI) model order in the absence as well as in the presence of outliers in unknown additive noise.

Chapter 3 considers the ordinary least-squares (LS) algorithm for parametric identification of an open-loop LTI system. As an alternative to the presence of outliers in observations, nonlinear equations are written for generating of M-estimates. A reinforced method, based on the sample medians and on the LS technique, is proposed here, too.

Chapter 4 introduces various recursive parameter estimation techniques, based on the ordinary LS method, that are worked out for different additive correlated noise transfer function structures. In the case of outliers in noise, the recursive M-algorithms are presented and analysed by numerical simulation.

In Chapter 5, we present a direct method for parametric estimation of stationary, slowly time-varying and suddenly jumping parameters of LTI system, acting in the closed loop. For a stationary case, we propose the approach how to check the efficiency of recursive LS (RLS) in the space of parameters. Here various numerical examples are given.

Chapter 6 considers a two-stage approach to estimate slowly time-varying parameters of the LTI system, acting in the closed loop. Here novel structures, assuring optimal identification conditions of the additive noise filter as well as that of the process noise, are worked out. Numerical simulation results are presented here, too.

In Chapter 7, the method based on data rearrangement is proposed for parametric identification, when the LTI system is followed by the hard nonlinearity of the known structure. Various numerical results are presented for different hard nonlinearities.

Chapter 8 includes the self-tuning minimum variance control approach to the LTI system, followed by the saturation nonlinearity. Multifold simulation results are presented here, as well.

In Chapter 9 the problem of joint time-varying parameters and time delay tracking with the estimation, using input-output observations, is analysed. It is known that a mean-square error function is multiextremal for time delay even if system parameters are known in advance. Therefore, the approach based on corrective operators and used to transform the multiextremal criterion into the unimodal function, in respect of a time delay, is developed and analysed.

In Appendix missing data restoration algorithm is presented. It can be used to reconstruct signal samples that are deleted while censoring the outlying data.

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02 2017

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