PERGAMON

Automatica 38 (2002) 1827–1834

automatica

www.elsevier.com/locate/automatica

Book reviews

Control-oriented system identification: An $\mathscr{H}_\infty$ approach☆
Jie Chen and Guoxiang Gu; Wiley, New York, 2000, ISBN 0471-32048-X

System identification is a problem that arises in many disciplines where a mathematical model is sought for a physical system. System identification is a basic problem in control theory because in almost any application of control, the model is not completely specified.

System identification has two basic paradigms. One is stochastic and the other is deterministic. In the stochastic formulation, it is assumed that the measurements of the system are corrupted by noise. The noise is a stochastic process that is often assumed to be white Gaussian noise, that is, the formal derivative of Brownian motion. However, other stochastic processes can be used to model the noise, such as, in the families of martingales, Markov processes or Gaussian processes. The identification criterion is often the expectation of the squared error which gives a least squares estimate of the true system. This approach requires methods from probability and the acceptance of stochastic models.

Another approach to identification is deterministic. This approach assumes that the possible models are a bounded set of systems and the uncertainties (or noise) are deterministic, unknown bounded perturbations. This approach often assumes that the nominal system is an element of H_∞ and the noise or perturbation is an element of ℓ_∞. Recall that $H_\infty(\mathbb{D})$ is a Hardy space that is a subspace of $\mathscr{L}_\infty$ with analytic extension to $\mathbb{D}$, that is,

$$H_\infty(\mathbb{D}) = \{f\colon f \text{ is analytic in } \mathbb{D} \text{ and } \|f\|_\infty = \operatorname*{ess\,sup}_{z\in\mathbb{D}} |f(z)| < \infty\}$$

and ℓ_∞ is the linear space of bounded sequences.

The book, *Control-Oriented System Identification: An H_∞ Approach* considers the basic system identification problem, where the nominal model is an element of H_∞ and the uncertainty is bounded in ℓ_∞. The authors address this problem by developing algorithms for identification. The algorithms use the prior plant information, the prior noise information, and the experimental data. An identification algorithm should select a model from the given class and have the property that as the data values tend to infinity and the noise bound tends to zero, the worst case error tends to zero. These algorithms can occur in the frequency domain or the time domain and can be linear or nonlinear. To determine the quality of an identification algorithm, there is the question of model validation.

Now a more specific description of the contents of the book is given. After some introduction to identification in Chapter 1, the authors provide some of the mathematical background in Chapter 2 that is required for their approach to identification algorithm. These topics include some function spaces, some harmonic analysis and some analytic function approximation. This third topic plays a basic role in the H_∞ approach. In Chapter 3, H_∞ control and identification are introduced in the frequency domain. The discussion of H_∞ control is only a brief introduction that focuses on uncertainty and robustness. The discussion of H_∞ identification provides the basic notions and approach for the subsequent investigation of algorithms. Much of the H_∞ control and identification has been developed in the last two decades.

In Chapter 4, the first algorithms are described. These are linear algorithms. The systems are always considered to be linear and time invariant. An algorithm is said to be linear if the identified model is a linear function of the experimental data. Linear algorithms use polynomial interpolation methods and those algorithms fit frequency response data to the polynomials. The two families of linear algorithms that are developed are based on Fourier analysis and least squares. The algorithms are called untuned or tuned depending on whether they act only on posterior frequency response data or not. The untuned linear algorithms are divergent in the worst case criterion while the tuned linear algorithms are convergent. In both cases bounds are given on the identification errors.

Chapter 5 is devoted to the study of two-stage nonlinear algorithms. The two-stage approach was developed to improve the linear algorithms that either diverge in the worst case or do not converge robustly. A nonlinear algorithm is a nonlinear function from the data to an identified model. A nonlinear algorithm can be tuned or untuned. The authors consider untuned nonlinear algorithms. The objective is to obtain a strong robust convergence property. The first stage in the algorithm is to obtain a noncausal pre-identified system and the second stage obtains a causal model in H_∞ from the pre-identified system. This second stage is obtained by solving a Nehari best approximation problem. There is a detailed analysis of convergence properties and error performance. In Chapter 6, a family of tuned nonlinear algorithm is studied. These algorithms interpolate approximately

☆ A volume in the Wiley Series on Adaptive and Learning Systems for Signal Processing, Communications, and Control, Simon Haykin, series editor.

on the posterior frequency response data. They have good optimality properties for both finite length and asymptotic data and they can accommodate uniformly or nonuniformly spaced data in a unified way. The key technical machinery is the Nevanlinna–Pick interpolation procedures.

In Chapter 7, time domain algorithms are studied. While time domain data can be converted to frequency domain data by a Fourier transform, this operation will introduce additional errors. A time domain interpolatory algorithm is given that uses the solution to an extended Carathéodory–Fejér problem. It can be combined with an algorithm in Chapter 6 if the data consists of both time domain and frequency domain measurements. In Chapter 8, both two stage and interpolation algorithms are extended to continuous time systems.

In Chapter 9, the problem of time domain model validation is studied. This study presumes that time domain input–output measurements are given. The problem is reduced to a Carathéodory–Fejér interpolation problem which is solved by convex optimization. In Chapter 10, an analogous frequency domain model validation problem is studied. In both cases, the computational difficulties are significant.

The authors provide a clear and very careful presentation of all the material. Since many topics are difficult, the authors provide many examples. Furthermore, they provide many exercises which make it very appropriate for teaching. The book is strongly recommended for its presentation of a very important area of system identification.

This book is a very useful publication that gives a broad vision of the problem under discussion. It offers a deep understanding of the robust control-oriented identification theory. Examples and exercises are very carefully chosen to illustrate the presented concepts and they are very well formulated. This book brings together many results and techniques scattered in various research publications and provides important and very useful description of existing publications related to presented subject.

This monograph is strongly recommended as a research monograph and as a graduate textbook.

Bozenna Pasik-Duncan
Department of Mathematics,
University of Kansas, 405 Snow Hall,
Lawrence, KS 66045, USA
E-mail address: bozenna@math.ukans.edu
URL: http://www.math.ukans.edu/ksacg/Bozenna.html

About the reviewer

Bozenna Pasik-Duncan received her Master's degree in Mathematics from Warsaw University in 1970, and her Ph.D. and Habilitation degrees in Mathematics from the School of Economics in 1978 and 1986, respectively. She is a Professor of Mathematics at the University of Kansas. Her research interests are primarily in stochastic adaptive control and Mathematics and Science education. She has held visiting appointments in Poland, Hungary, Czech Republic, France, Italy, Japan and China. Dr. Pasik-Duncan has been actively involved in the IEEE Control Systems Society (CSS) in a number of capacities. She was as Associate Editor of IEEE Transactions on Automatic Control and she is currently an Associate Editor at Large. She has been Chair of the committees on Assistance of Engineers at Risk, Women in Control, International Affairs and Control Education. She served as Control Systems Society Vice-President for Membership Activities. Dr. Pasik-Duncan is an IEEE Fellow and a Distinguished Member of the CSS.

PII: S0005-1098(02)00068-7

Qualitative theory of dynamical systems

A.N. Michel, K. Wang and B. Hu; Marcel Dekker, New York, 2001, ISBN/0-8247-0526-2

The concurrence of a wide variety of factors from geo-economical to technological nature; e.g. the always broader use of chip and reliable electronics, the increasing use of smart materials, versatile switching devices, embedding of *complex systems* in large-scale processes functioning on a *discrete event* basis, etc. has created a brand new range of engineering problems which cannot always be solved using well-established linear control tools nor well-understood (in the academic environment) control theory for nonlinear systems.

The first step at solving such an engineering problem within a modern control theory context is to obtain a *good* model of the plant or process. Nonetheless, a *good* modeling will in general yield a set of equations, inequalities and/or inclusions of different nature: differential, difference, integro-differential, algebraic, etc. After a good model is available one passes to the stage of *controller design* and *stability analysis*. From a theoretically viewpoint, these two stages cannot be dissociated i.e., generally speaking one designs a controller with the aim at making a plant work about some operating point or "regime" and this is validated via a *stability analysis* of the closed-loop system.

Probably the most classical and general control approach is the so-called Lyapunov approach which as its name suggests relies on the well understood and documented *Lyapunov theory* which was conceived and is generally used to analyze the stability of *differential equations*. Certainly, through the years many extensions have been achieved and different results have been obtained to ensure stability of differential inclusions, stability with respect to sets, difference equations, functional differential equations, etc. To mention some classical and specialized texts on stability we cite (Yoshizawa, 1966; Matrosov, Anapolsky, & Vasiliev, 1980; Zubov, 1997; Hahn, 1967; Rouche & Mawhin, 1980; Aubin & Cellina, 1984; Hale, 1969; Lakshmikantham & Leela, 1969; Clarke, Ledyaev, Stern, & Wolenski, 1998). Each of these texts covers a specific topic of stability for a determined type of equations.

From its first edition, "*Qualitative theory of dynamical systems*", sets a theory of stability for systems modeled by