Book reviews

Control-oriented system identification: An $H_\infty$ approach

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 $H_\infty$ and the noise or perturbation is an element of $\ell_\infty$. Recall that $H_\infty(\mathbb{D})$ is a Hardy space that is a subspace of $L_\infty$ with analytic extension to $\mathbb{D}$, that is,

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

and $\ell_\infty$ is the linear space of bounded sequences.

The book, Control-Oriented System Identification: An $H_\infty$ Approach considers the basic system identification problem, where the nominal model is an element of $H_\infty$ and the uncertainty is bounded in $\ell_\infty$. 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 $H_\infty$ approach. In Chapter 3, $H_\infty$ control and identification are introduced in the frequency domain. The discussion of $H_\infty$ control is only a brief introduction that focuses on uncertainty and robustness. The discussion of $H_\infty$ identification provides the basic notions and approach for the subsequent investigation of algorithms. Much of the $H_\infty$ 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 obtained a causal model in $H_\infty$ 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
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.

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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.

Qualitative theory of dynamical systems

The concurrence of a wide variety of factors from geo-economic 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 result 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; Lakshmikanthan & 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...