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Book review:

ADVANCES IN MATHEMATICAL SYSTEMS THEORY

by

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(Editors)

This book contains the lectures presented at the workshop on "Advances in Mathematical Systems Theory", held on the island of Borkum, in Germany, on April 20–23, 1999, and is dedicated to Diederich Hinrichsen on the occasion of his 60th birthday. The book is divided into 14 Chapters written by the former Ph.D. students as well as close colleagues of Diederich Hinrichsen.

The results are presented in a series of chapters that provide an overview of a broad variety of tools that are used to study the different problems in dynamical systems and control theory. The consecutive chapters are based on invited lectures and cover a wide range of topics in linear and nonlinear systems theory, including parametrization problems, different behaviors of control systems, such as the controllability and stabilizability problem for infinite-dimensional systems, discussions on hybrid systems, complementarity systems and convolution codes. The results presented, mainly of theoretical character, are based on functional analytic as well as algebraic approaches. A focal point of this book is stability and robustness of linear and nonlinear dynamical systems using the concepts of stability radii and spectral value sets.

1. Chapter 1. Transitory behavior of uncertain systems – A.J. Pritchard

Chapter 1 contains the notion of transitory excursion for uncertain dynamical systems, which is a measure of the distance a stable semigroup moves away from the origin. Various estimates for the excursion are obtained using properties of spectral value sets of normal matrices and time-varying Lyapunov equations. Moreover, the notion of transitory excursion radius for uncertain dynamical systems is introduced and estimates are obtained.

2. Chapter 2. Robust stability of multivariable polynomials – V.L. Kharitonov

The robustness of the stability property has been under investigation for many years. Chapter 2 presents stability analysis for multivariable polynomials with ity under small perturbations of the coefficients. Moreover, some basic properties and robust stability conditions for stable multivariable polynomials are discussed. Stability radius is also introduced and analyzed. Finally, it should be mentioned that for the case of polynomials with several variables there is a large variety of classes of stable polynomials that may be treated as the extensions of Hurwitz stable polynomials. Therefore, it is quite natural to extend the basic results from robustness analysis from Hurwitz polynomials to the class of multivariable polynomials.

3. Chapter 3. Robustness of nonlinear systems and their domains of attraction – A.D. Paice and F.R. Wirth

The robustness analysis of linear systems via state space approach has been considered in many papers. In Chapter 3 the robustness of stability of nonlinear dynamical systems with respect to time-varying perturbations is considered from both local and semiglobal perspective. The stability radius for the perturbed nonlinear system is defined and then the related stability radii for the linearized system are examined. A method for calculation of the linear stability radius is presented. Moreover, some topological properties of the robust domain of attraction are analyzed and an approximation scheme for its determination is presented.

4. Chapter 4. On stability radii of slowly time-varying systems – A. Ilchman and I.M. Mareels

Chapter 4 is devoted to the study of exponential stability of time-varying linear systems with respect to dynamical nonlinear perturbations. Several stability concepts for nonlineary perturbed linear dynamical systems are introduced and investigated. Sufficient conditions for uniform exponential stability are formulated and proved. Moreover, estimates of the stability radius of time-varying linear systems with respect to finite gain perturbations are presented. The results provided have definite implications for the study of the gain scheduled control systems.

5. Chapter 5. An invariance radius for nonlinear systems – F. Colonius and W. Kliemann

In Chapter 5 the concept of stability radius for nonlinear dynamical systems is analyzed. The relationships between the stability radius and the domain of attraction are discussed and explained. Moreover, it is shown that the stability radius for linear differential equations gives a measure for the robustness of stability with respect to time-varying perturbations.

6. Chapter 6. State and continuity – J.C. Wilems

Chapter 6 deals with the algebraic methods applied to linear, continuous-time, shown that the state of such system consists of the functionals of system variables that evolve continuously in time. Moreover, several remarks and comments on linear system theory are given.

7. Chapter 7. Parametrization of conditioned invariant subspaces – P.A. Fuhrmann and U. Helmke

Conditioned and controlled invariant subspaces play a fundamental role in different areas of linear systems theory, e.g., in disturbance decoupling, observer design, factorization theory, parametrization problems, and realization theory. In Chapter 7 geometric structure of certain invariant subspaces connected with a fixed observable pair of matrices is discussed in detail. Parametrization and topology of conditioned invariant subspaces are also discussed.

8. Chapter 8. Duality between multidimensional convolutional codes and systems – H. Glüsing-Lüersen, J. Rosenthal and P.A. Weiner

Convolutional codes are among the most widely implemented codes. They represent in essence the discrete-time linear systems over a certain fixed finite field. Chapter 8 contains the results on duality between multidimensional convolutional codes and the discrete-time, time-invariant multidimensional systems theory. Using pure algebraic methods the fundamental properties of multidimensional convolutional codes are presented and discussed. It is shown that convolutional codes are dual objects to multidimensional systems.

9. Chapter 9. Control of rate-bounded hybrid systems with liveness constraints – M. Heymann, Feng Lin and G. Meyer

Hybrid systems are dynamical systems in which discrete and continuous behaviors coexist and interact. Hybrid systems frequently arise from computer aided control of industrial continuous-time processes. In Chapter 9 hybrid systems are defined and discussed. The main problem presented is the synthesis of a supervisory controller, where the objective is to guarantee that the system satisfies a set of legal specifications. The legal specifications are partitioned into safety specifications and liveness specifications. In this chapter the synthesis of liveness controllers for hybrid machines is discussed in detail.

10. Chapter 10. A general principle of market extraction – U. Krause

In Chapter 10 a general principle of market extraction in convex sets is discussed. The aim of this chapter is to point out the unifying role of the principle of marked extraction in quite different fields ranging from economics over convexity theory to pure mathematics. Moreover, several remarks, comments and illustrative

11. Chapter 11. Between mathematical programming and systems theory: linear complementarity systems

Complementarity systems arise from the interconnection of an input-output system with a set of complementarity conditions similar to those in mathematical programming. Thus, Chapter 11 presents the relationships between mathematical programming and systems theory. Moreover, several examples which illustrate theoretical considerations are given. In addition, a solution concept for linear complementarity systems is provided, and conditions for existence and uniqueness of solutions are presented.

12. Chapter 12. Exact controllability of C-groups with one-dimensional input operators – B. Jacob and H. Zwart

Controllability plays a crucial role in modern mathematical system theory. In Chapter 12 exact controllability of linear, infinite-dimensional, stationary control systems with unbounded one-dimensional control operator and scalar control is considered. Using spectral theory of linear unbounded operators, the necessary and sufficient conditions for exact controllability in finite time are formulated and proved. Moreover, a simple illustrative example of an exactly controllable system is given.

13. Chapter 13. Normalized coprime factorizations or strongly stabilizable systems – R.F. Curtain and J.C. Oostveen

Chapter 13 is devoted to the study of normalized coprime factorizations for the class of strongly stabilizable and detectable infinite-dimensional stationary control systems. Explicit formulas are given for the normalized left- and right-coprime factors. Explicit formulas for normalized coprime factorizations are required in the solution to the robust stabilization problem. An application to models of hybrid flexible structures is also presented.

14. Chapter 14. Low-gain integral control of infinite-dimensional regular linear systems subject to input hysteresis – H. Logemann and A.D. Mawby

In Chapter 14 certain results pertaining to integral control of infinite-dimensional systems subject to static input nonlinearities are considered. A general class of causal dynamical nonlinearities with certain monotonicity and Lipschitz continuity are introduced. The class of nonlinearities under consideration contains, in particular, various hysteresis operators.

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Summarizing, the monograph contains many recent quite deep theorems and nonlinear dynamical systems. The theorems are often presented with complete and detailed proofs or with references to the literature for details. In addition, many challenging open problems are described and explained, and promising new research directions are indicated.

This volume has something to offer a broad spectrum of readers. The book should be a valuable reference for the graduate students, scientists, and professional researchers in the area of mathematical control theory and control engineering and for mathematicians with an interest in the analysis and design of engineering control systems.

Jerzy Klamka

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