Robust stabilization and H_∞ problems
Vlad Ionescu and Adrian Stoica; Kluwer Academic Publishers, Dordrecht, The Netherlands, 1999,
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The ultimate goal of control system designer is to build a system that will work in a real environment, in which operating conditions may vary from time to time, and the control system must be able to withstand other factors of life such as model uncertainties, disturbances and noises. The mathematical representation of a system often involves simplifying assumptions on system nonlinearities and high-frequency dynamics, which are either unknown and hence unmodeled, or are modeled and later ignored in order to simplify analysis at the design stage. In consequence, control systems designed based on simplified models may not work in real environments. The particular property that a control system must possess for it to operate properly in realistic situations is commonly called robustness. Mathematically, this means that the controller must perform satisfactorily not just for one plant, but for a family of plants. If a controller can be designed such that the whole system to be controlled remains stable when its parameters vary within certain expected limits, the system is said to possess robust stability. In addition, if it can satisfy performance specifications such as steady state tracking, disturbance rejection and speed of response requirements, it is said to possess robust performance. The problem of designing controllers that satisfy both robust stability and performance requirements is called robust control. H_∞ control theory is one of the cornerstones of modern control theory and was developed in an attempt to solve such problems. Over the past decades, we have witnessed a proliferation of literature on H_∞ optimal control since it was first introduced by Zames (1981). Practically, all the research results of the early years involved a mixture of time- and frequency-domain techniques including the following: (1) *Polynomial approach* (see e.g., Kwakernaak, 1986); (2) *Frequency-domain approach* (see e.g., Francis, 1987); (3) *Interpolation approach* (see e.g., Limbeer, & Anderson, 1988); and (4) *J-spectral factorization approach* (see e.g., Kimura, 1989). Recently, considerable attention has been focussed on purely *time-domain methods* based on algebraic Riccati equations (see e.g., DGKF, i.e., Doyle, Glover, Khargonekar, & Francis, 1989, and Zhou, Doyle, & Glover, 1996).

Robust stabilization and H_∞ Problems by Ionescu and Stoica is oriented towards an approach based on the so-called generalized Popov–Yakubovich theory. It is an interesting addition to a very rich literature on the subject. Like most of the titles related to robust and H_∞ control published over the last few years, the monograph under review focuses mainly on the so-called regular problem. The treatment on the regular H_∞ problem for continuous-time systems is fairly complete. Various sets of solvability conditions are obtained in terms of the existence of stabilizing solutions to the corresponding Kalman–Popov–Yakubovich systems. Surely, all these solvability conditions are equivalent to the existence of stabilizing solutions to two indefinite algebraic Riccati equations together with a coupling condition as reported in DGKF. The monograph, however, could be a good introduction to readers, especially to those beginners in the subject, on the root where solutions to the H_∞ problem are derived. Furthermore, the results of Chapter 2 on the Kalman–Popov–Yakubovich systems of indefinite sign could be useful for a variety of problems in linear and nonlinear control. On the other hand, topics related to general singular H_∞ problems covered in the book are relatively brief and weak. Only two robust control problems, i.e., the robust stabilization of systems with multiplicative perturbations and the sensitivity minimization problem, are discussed using the linear matrix inequality approach. Issues on discrete-time H_∞ control are totally non existent.

The book begins with recalling some basic concepts and background materials in linear systems, which are needed throughout the monograph in the development of its core results. Chapter 2 gives a detailed description of the generalized Popov–Yakubovich theory, which is the fundamental framework on which the monograph is developed. Results on the existence conditions of a stabilizing solution to the so-called Kalman–Popov–Yakubovich system of indefinite sign, which covers the well-known Bounded Real Lemma as a special case, are expressed in terms of the so-called signature condition. These results are useful in solving many control problems other than H_∞ control. The main results of Chapter 3, which can be regarded as the core of the book, are the derivation of the solvability conditions to the regular H_∞ problem using the signature condition combined with the Kalman–Popov–Yakubovich technique. Two sets of necessary solvability conditions are first introduced together with some coupled and uncoupled conditions. The authors then show that these conditions are also sufficient by giving an explicit solution to the problem. Chapter 4 deals with one- and two-block Nehari problems, which can be reformulated as special cases of the standard H_∞ problem. Solutions again are derived using the generalized Popov–Yakubovich theory, and are characterized in terms of stabilizing solutions to certain algebraic Riccati equations or Lyapunov equations together with a coupling condition.

Chapter 5 is on finding an optimal solution to the H_∞ control problem by employing the well-known singular perturbation approach. Under certain restrictive conditions, a reduced order control law, which has a dynamical order less than that of the given system, can be obtained to achieve the best level of disturbance attenuation. The results are illustrated by a couple of case studies. Finally, in the last chapter of the book, i.e., Chapter 6, the authors present two well-known robust control problems, namely the robust stabilization of systems with multiplicative perturbations and the sensitivity minimization problem. These problems usually belong to the singular H_∞ problem. As mentioned earlier, the singular problem treated in the book is in a light and brief fashion.

In summary, the book is well organized. Each chapter has a brief introduction at the beginning, and notes and references at the end summarizing related results in the literature, which would be particularly beneficial to the beginners in the field. In general, this reviewer feels that the monograph would be interesting and useful to fresh graduate students and practicing engineers. It could be a good text or reference to courses that cover basic H_∞ control theory.

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Ben M. Chen
Department of Electrical & Computer Engineering,
The National University of Singapore,
Singapore 117576, Singapore
E-mail address: bmchen@nus.edu.sg

About the reviewer

Ben M. Chen received his B.S. degree in mathematics and computer science from Amoy (Xiamen) University, Xiamen, China, in 1983, M.S. degree in electrical engineering from Gonzaga University, Spokane, Washington, in 1988, and Ph.D. degree in electrical and computer engineering from Washington State University, Pullman, Washington, in 1991. He was a software engineer from 1983 to 1986 in the South-China Computer Corporation, China, and was a postdoctoral associate from 1991 to 1992 at Washington State University. He was with the Department of Electrical Engineering, State University of New York at Stony Brook, from 1992 to 1993, as an assistant professor. Since August 1993, he has been with the Department of Electrical and Computer Engineering, National University of Singapore, where he is currently an associate professor. His current research interests are in linear control and system theory, control applications, development of internet-based virtual laboratories and internet security systems.

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