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Robust Control and Filtering of Singular Systems

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To A'jin, Fagen, and Junwei

Shengyuan Xu

To Yeeman, Joanie, and Jamie

James Lam

Preface

Singular systems have been widely studied in the past two decades due to their extensive applications in modelling and control of electrical circuits, power systems, economics and other areas. A great number of fundamental results based on the theory of state-space systems have been successfully extended to singular systems. Interest has grown recently in the stability analysis and control of singular systems with parameter uncertainties due to their frequent presence in dynamic systems, which are often the causes for instability and poor performance of control systems. It is known that the control of uncertain singular systems is much more complicated than that of state-space systems because controllers must be designed so that the closed-loop system is not only robustly stable, but also regular and impulse-free (in the continuous case) or causal (in the discrete case), while the latter two issues do not arise in the state-space case. Many recent advances in this area have made use of the matrix inequality machinery, which has become a somewhat standard approach to deriving appropriate mathematical conditions. This monograph aims to present up-to-date research developments and references on robust control and filtering of uncertain singular systems in a unified matrix inequality setting. It provides a coherent approach to studying control and filtering problems as extensions of state-space systems without the commonly used slow-fast decomposition. It contains valuable reference material for researchers wishing to explore the area of singular systems, and its contents are also suitable for a one-semester graduate course.

The topics covered in this monograph are given in parallel for continuous and discrete singular systems. We first present necessary and sufficient conditions for a singular system to be regular, impulse-free (for continuous singular systems) or causal (for discrete singular systems) in terms of linear matrix inequalities (LMIs). By employing these fundamental results, the concepts of generalized quadratic stability and generalized quadratic stabilization for uncertain singular systems are introduced and both robust stability and sta-

bilization results are obtained via these two notions. Versions of the bounded real lemma are then established and solutions to the problems of robust H_∞ control and filtering are derived. The problem of guaranteed cost control is solved via an LMI approach for both continuous and discrete singular systems. Furthermore, necessary and sufficient conditions for the solvability of the positive real control problem are obtained based on the proposed versions of the positive real lemma. When time delays appear in a singular system, sufficient conditions on the solvability of the robust control and H_∞ filtering of singular delay systems are given. For Markovian jump singular systems, the problems of guaranteed cost control and H_∞ control are addressed and state feedback controllers are synthesized. In the continuous case, the LMI approach is developed in this monograph to design desired controllers and filters, which involves no decomposition of the original systems.

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