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Analysis and Design for Positive Stochastic Jump Systems

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Preface

In the operation process of practical systems, many complex factors, such as environmental interference, component failure, and subsystem connection change, always lead to the jump in system parameters and structures, resulting in deviation of the measurement process and inaccurate research about system model establishment and control. Owing to the performance of control systems largely dependent on the complexity and accuracy of the model, the controller based on the single model has been unable to achieve the desired control requirements, which has prompted people to constantly seek new theories to guide the design of control systems. Stochastic jump systems driven by time and events provide an effective theoretical basis for the study of such problems and promote the research of related control issues. As a typical kind of stochastic jump systems, Markov jump systems are described by state space equations under multiple modes, in which the operating state changes according to the stochastic Markov switching rule among subsystems. In fact, the jump among subsystems meets certain statistical laws. In recent years, Markov jump systems have become one of the research hotspots in the control field, and also have found wide applications in power systems, chemical process, agricultural engineering, aerospace, biomedicine, and network communication. In these circumstances, more and more experts have began to study Markov jump systems from different disciplines, thus promoting the rapid development of the corresponding theory.

As a key factor of Markov jump systems, the transition rate affects the dynamic characteristics of the system, which is mainly subject to the probability distribution function of the sojourn time. For Markov jump systems, the sojourn time follows exponential distribution or geometric distribution. According to the memoryless property of exponential distribution or geometric distribution, the transition rate of Markov jump systems does not depend on past modes and has no relationship with the sojourn time. It is worth noting that, in practice, the sojourn time does not always obey the exponential distribution or geometric distribution. Compared with Markov jump systems, the probability distribution function of the sojourn time in semi-Markov jump systems is relaxed from the special exponential distribution or geometric distribution to the general probability distribution. Then, the transition rate depends on the past modes and meets the sojourn-time-dependent characteristics, thus describing a wider range of stochastic jump systems. Moreover, the study of semi-Markov jump systems provides additional insights into some long-standing and sophisticated problems, such as sliding mode control, adaptive control, event-triggered control, finite-time control, and fault detection.

In the past decades, the analysis and synthesis of stochastic jump systems have been intensively investigated and have attracted increasing attention. Although a large number of the corresponding works have been developed from various disciplines, there still exist many fundamental problems with less well understanding. In particular, there still lacks a unified framework to cope with the issues of analysis and synthesis for positive stochastic jump systems. This motivated us to write the related work.

The monograph aims to present up-to-date research developments and references on the analysis and design for all the subsystems of stochastic jump systems belonging to positive systems. Different from general systems, positive systems are confined to the positive cone instead of the whole state space and depend on the positivity of their state signals, output signals, and input signals. Owing to the particularity of positive systems, many previous approaches for general systems cannot be extended to positive systems, which makes the analysis and synthesis of positive systems full of challenges. By using multiple linear co-positive Lyapunov function method and linear programming technique, a basic theoretical framework is formed towards the issues of analysis and design for positive stochastic jump systems. The book can be used by researchers to carry out studies on positive stochastic jump systems and is suitable for graduate students of control theory and engineering. It may also be a valuable reference for the control design of switched systems by engineers.

The contents of the book are divided into thirteen chapters which contain several independent yet related topics, and they are organized as follows. Chapter 1 introduces some basic background knowledge on positive stochastic jump systems, and also describes the main work of the book. Chapter 2 considers the problems of exponential stability and $\mathscr{L}_1$-gain analysis for positive delayed Markov jump systems. Chapters 3–5 address the problems of stability, stabilization, $\mathscr{L}_1$-gain analysis, and finite-time control for positive semi-Markov jump systems. Chapters 6–9 give theoretical developments in detail for $\mathscr{L}_1$ control, $\mathscr{L}_\infty$ control, robust finite-time stabilization, and fault detection for positive delayed semi-Markov jump systems. Some control problems for positive fuzzy semi-Markov jump systems include stochastic stability, $\mathscr{L}_1$-gain analysis, observer design, and filter design are discussed in Chapters 10–12. Finally, Chap. 13 concludes some future study directions related to the contents of the book.

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Contents

Symbols

$\mathbb{R}$	Set of real numbers
$\mathbb{R}^n$	Set of n-column real vectors
$\mathbb{R}^n_+$	Set of n-dimensional nonnegative real vectors
$\mathbb{R}^{n\times m}$	Set of $n \times m$ real matrices
$\|x(t)\|_1$	$\sum_{i=1}^{n} \|x_i(t)\|$
$\|x(t)\|_\infty$	$\mathrm{Max}_{1\le i\le n} \|x_i(t)\|$
$\|x(t)\|_{\mathscr{L}_1}$	$\int_0^\infty E\{\|x(t)\|_1\}dt$
$\|x(t)\|_{\mathscr{L}_\infty}$	$\int_0^\infty E\|x(t)\|_\infty\}dt$
$\mathscr{L}_1$	Space of all vector-valued functions with finite $\mathscr{L}_1$ norm
$\mathscr{L}_\infty$	Space of all vector-valued functions with finite $\mathscr{L}_\infty$ norm
I	Identity matrix
$\mathbf{1}_n$	All-ones vector in $\mathbb{R}^n$
$\otimes$	Kronecker product
$\in$	Belong to
A^T	Transpose of matrix A
A^{-1}	Inverse of matrix A
$A >> 0$	A is positive
$A \geq\geq 0$	A is nonnegative
$A << 0$	A is negative
$A \leq\leq 0$	A is nonpositive
$\mathscr{E}\{\cdot\}$	Mathematical expectation