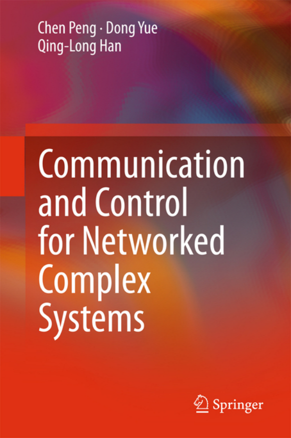

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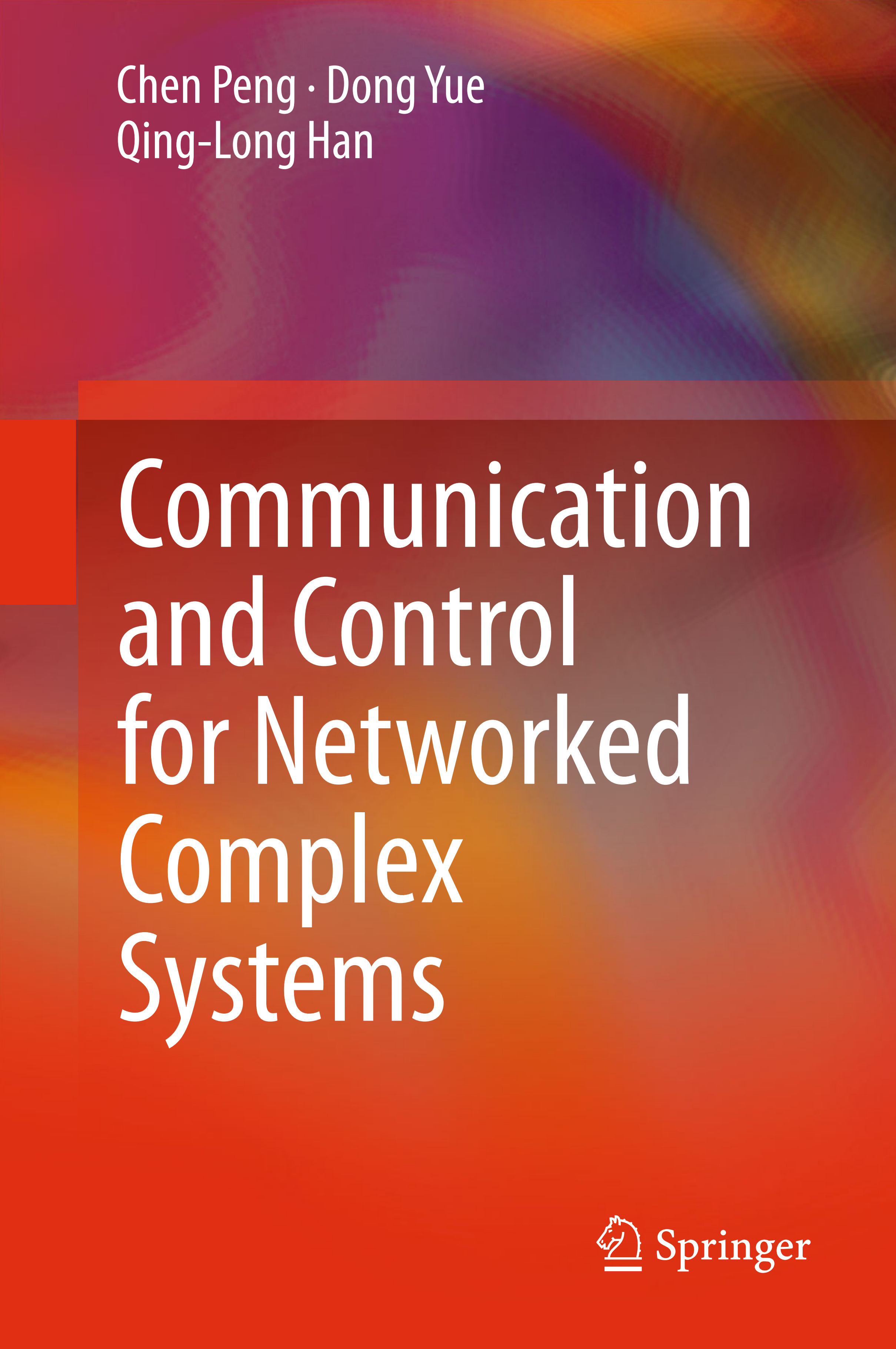

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Preface

Networked control systems (NCSs) are control systems where the control loops are closed via communication channels. With the rapid development of networking communication technologies, NCSs have received increasing attention in the past decade. Compared with traditional point-to-point control systems, NCSs have a number of advantages, such as low cost, easy maintenance, and increased system flexibility. More recently, much attention has also been paid to design the suitable communication scheme to save the limited communication resource for NCSs.

The study of NCSs can be twofold: designing controller over a preselected network and designing appropriate communication scheme for satisfying the requirement of control. In the first designing controller over a preselected network field, Internet Protocol (IP) networks are commonly preselected in NCSs due to their well-developed infrastructure, wide acceptance, simplicity, and affordability. The IP-based network delays display a nonuniform distribution character with small delays being dominant while large delays being exiguous, which implies that the probability of small delays is bigger than the one of large delays. However, this feature has not been well used in the analysis and synthesis of NCSs. Therefore, how to effectively use nonuniform delay distribution character in NCSs has stimulated the first research line of this monograph.

In the second designing appropriate communication scheme field, communication bandwidth is a scarce resource in NCSs. If signal transmission only occurs when the relevant information from the sensor-to-controller needs to be transmitted, then not only all of the transmitted signals from the controller-to-actuator are helpful to ensure the desired performance, but also the redundant information is possibly avoided in the transmission. Therefore, more limited network resources can be released to other communication tasks in need. Notice that time-triggered communication schemes are a common assumption in some existing results, which leads to inefficient utilization of the limited network resources. Therefore, how to design efficient communication schemes to save the limited communication resource while ensuring the desired performance of NCSs has stimulated the second research line of this monograph.

Structure and Readership

This book is structured into three parts; Part I is devoted to introduce an overview of recent developments of NCSs (Chap. 1) and provide a summary of the modeling, communication schemes, and mathematical lemmas used in the derivation of the main results of this book (Chap. 2); they are the premises of the following two parts. Part II is devoted to consider the nonuniform distribution communication character of IP-based communication networks in the analysis and synthesis of linear, nonlinear and large-scale systems under network environments; Part III is devoted to design communication schemes to save the limited network resources while ensuring the desired performance, that is, discrete event-triggered communication schemes, self-triggered communication schemes, co-design of communication and control considering the data loss and communication delay in the communication, and mixed self and event-triggered communication scheme for improving the energy efficiency.

Part II: Internet Protocol (IP) networks are generally used in NCS. Network delays display irregular behavior in Internet Protocol (IP) networks. However, this feature has not been well explored in some existing results in NCSs. Therefore, in Chap. 3, a networked delay distribution-dependent H_∞ control for networked linear control systems is proposed. In Chap. 4, delay nonuniform distribution character of network delay is considered in the PDC fuzzy controller design. Moreover, a premise reconstruct method is also proposed to deal with the asynchronous premise problem of T-S fuzzy systems in network environments. A decentralized control method is proposed for networked large-scale systems considering the above-mentioned delay distribution dependence in Chap. 5.

Part III: Most works on NCSs so far assume that the sampled data by the sensors are periodic transmitted over the communication networks, i.e., time-triggered communications. In general, a time-triggered communication scheme leads to inefficient utilization of limited network resources. Therefore, In Chap. 6, an adaptive event-triggered communication scheme is provided, which can dynamically adjust the event-triggered communication threshold to reduce the conservativeness induced by time-invariant communication threshold. A co-design method to consider the event-triggered communication and robust H_∞ control in a unified framework is presented in Chap. 7, allowing part of event-triggered packets which can be lost in communication. For saving the limited energy in wireless NCSs, in Chap. 8, a novel self-triggered sampling scheme is proposed for the execution of sampling in NCSs by taking into consideration network-induced delays and data packet dropouts. In Chap. 9, a mixed sampling scheme for the execution of sampling in wireless NCSs is proposed by striking a balance between self-triggered sampling and event-triggered sampling to achieve high energy efficiency. In Chap. 10, a discrete event-triggered communication scheme is proposed for a networked T-S fuzzy system, which can reduce unnecessary communication while ensuring the desired control performance.

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We would like to acknowledge the collaborations with Prof. Yuchu Tian and Dr. Engang Tian on the work of communication delay distribution and Prof. Minrui Fei and Dr. Taicheng Yang on the work of event-triggered communication reported in the monograph and Ph.D. candidates: Jin Zhang, Qiang Zheng, and Heng Zhang for their great help in this monograph. The supports from the National Natural Science Foundation of China under Grant (61273114), the Innovation Program of Shanghai Municipal Education Commission under Grant (14ZZ087), the Pujiang Talent Plan of Shanghai City, China under Grant (14PJ1403800), the International Corporation Project of Shanghai Science and Technology Commission under Grant (14510722500), and the Natural Science Foundation of Jiangsu Province of China under Grant (BK20131403) are gratefully acknowledged. Finally, the close cooperation with Springer as publisher and particularly with Dr. Lu Yang as responsible editor is gratefully acknowledged.

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Contents

Part I Introduction and Preliminaries for NCSs

Part II Communication-Delay-Distribution Dependent Method for NCSs

Part III Necessary Communication Based Method for Control Design of NCSs

Acronyms

A	System matrix
A^{-1}	Inverse of matrix A
A^T	Transpose of matrix A
$A \geq 0$	Symmetric positive semi-definite
$A > 0$	Symmetric positive definite
$A \leq 0$	Symmetric negative semidefinite
$A < 0$	Symmetric negative definite
$det(A)$	Determinant of matrix A
$diag(X_1, X_2, \ldots, X_m)$	Diagonal matrix with X_i as its ith diagonal element
I	Identity matrix of appropriate dimensions
lim	Limit
LMI	Linear matrix inequality
$\mathbb{N}$	Positive integers
$Ones(m, n)$	A $m \times n$ matrix of ones
$Prob(\cdot)$	Probability
$\mathbb{R}$	Field of real numbers
$\mathbb{R}^n$	n-dimensional real Euclidean space
$\mathbb{R}^{n \times m}$	Space of $n \times m$ real matrices
$sgn(x)$	The sign of x
$tr(A)$	Trace of matrix A
h	The sampling interval of sensor
$0_{n \times m}$	Zero matrix of dimension $n \times m$
$\lambda(A)$	Eigenvalue of matrix A
$\lambda_{\min}(A)$	Minimum eigenvalue of matrix A
$\lambda_{\max}(A)$	Maximum eigenvalue of matrix A
$x(k)$	The state variable vector at time kT
$\|x\|$	Absolute value (or modulus) of x
$\|\|x\|\|$	Euclidean norm
$\|\|P\|\|$	Induced norm $sup_{\|\|x\|\|=1} \|\|Px\|\|$
$\forall$	For all

$\in$	Belong to
$\rightarrow$	Tend to, or mapping to (case sensitive)
$\otimes$	Matrix Kronecker product
$\sum$	Sum
$\mathbb{E}\{\cdot\}$	Mathematical expectation operator
sup	Supremum
inf	Infimum
$*$	Entries implied by symmetry

Part I

Introduction and Preliminaries for NCSs