Preface

Switched systems, which are used to model many physical or man-made systems displaying switching features, have been extensively studied since the 1990s. Typical applications of switched systems can be seen in engineering practice such as in the vehicle industry, process control, biological systems, and flight control systems. These kinds of systems commonly contain a finite number of subsystems and a switching signal governing the switching among them. The switching signals are therefore crucial in dominating the behaviors of switched systems, which differentiate switched systems from the general time-varying systems, since the solutions of the former are dependent on both system initial conditions and switching signals.

From a perspective of whether a stochastic process is attached to the representation of switching signals, the diverse switching can be categorized as nondeterministic switching versus stochastic switching. Unlike stochastic switching systems where a stochastic process, e.g., a Markov chain can greatly avail the analysis and synthesis of the systems, nondeterministic switched systems are relatively more challenging to cope with. A typical way in this area is to classify the switching signals into different sets with certain time regularities while ignoring the concrete generation mechanism, such as the state-dependent switching or time-dependent switching with the latter being able to represent the former in general. This book refines attention on nondeterministic switched systems that are commonly briefly termed as *switched systems* in the literature, and mainly considers four types of time-dependent switching signals: the arbitrary switching, dwell time (DT) switching, average dwell time (ADT) switching, and persistent dwell time (PDT) switching (the mode-dependent forms of the latter three cases are also considered). The aim is to present the authors' previous findings on the discrete-time switched systems with various types of time-dependent switching signals, as well as to provide some new results by relaxing some assumptions required in existing works which usually introduce conservatism and/or restrict the applications of developed approaches in practice.

Focused on the basic control and filtering synthesis problems for discrete-time switched linear systems under the four typical above-said switching signals, the book is organized into the following seven chapters.

Chapter 1 introduces the backgrounds and motivations of this book. Some preliminaries, the classification of switching signals, and comparisons with other types of hybrid systems are also provided, which aims at giving readers an understanding of the results that will be presented in the book.

In Chap. 2, we focus on the stability and stabilization issues of switched systems. First, the frequently used multiple Lyapunov-like functions (MLFs) approach is discussed, and four typical forms evolved from the general MLFs are introduced by comparing their advantages and disadvantages. Then, considering several classes of time-dependent switching signals, i.e., arbitrary switching, DT switching, ADT switching, PDT switching, and their mode-dependent forms, the corresponding stability and stabilization conditions are obtained based on the general MLFs or the evolved ones.

In Chap. 3, the performance analysis issue is investigated for switched systems with four types of switching signals in the discrete-time context. The results on l_2-gain analysis are first given for the switched systems under arbitrary switching and with l_2 disturbances. The weighted/non-weighted l_2-gain analyses are then studied considering the ADT and PDT switching, respectively. In light of the set-theoretic method, the tube-based robustness analysis is carried out when the modal PDT (MPDT) switching and the l_∞ disturbances are considered simultaneously.

Chapter 4 is concerned with the control synthesis problems for discrete-time switched linear systems. First, for the switched systems under arbitrary switching and with polytopic parameter uncertainties, the design of parameter-independent or parameter-dependent H_∞ controller is addressed. A μ-dependent approach is then introduced to design the H_∞ state-feedback controllers for uncertain switched systems with ADT switching. The parameter μ defines an upper bound for the increasing times of the MLFs at switching instants. Finally, considering the redundant channels existed in the data transmission, the non-weighted H_∞ control problem for discrete-time switched linear systems with MPDT switching is studied via the quasi-time-dependent (QTD) Lyapunov function approach.

In Chap. 5, filtering issues for discrete-time switched linear systems with typical switching signals are investigated in $H_\infty/l_2 - l_\infty$ sense. Considering the switched systems under arbitrary switching signals and with polytopic uncertainties, the robust filter is designed. Then, under ADT switching and considering the systems with time-varying parameters or polytopic uncertainties, the μ-dependent approach is also used to design the weighted (or called exponential) filter. Furthermore, a class of non-weighted QTD H_∞ filter is designed with less conservatism for discrete-time switched linear systems considering the PDT switching property.

Chapter 6 investigates a special problem in switched systems, the so-called asynchronous switching phenomena. Considering that the mode-dependent controllers/filters (less conservative than mode-independent ones) as well as the switching signals that are designed in the case assuming synchronous switching may cause instability or a performance reduction, the asynchronous switched

control/filtering problems for discrete-time switched systems with ADT switching are treated with the aid of the techniques developed in Chaps. 4 and 5. In addition, the H_∞ control problem is dealt with for a class of discrete-time switched linear parameter-varying systems under modal ADT switching in the presence of asynchronous switching phenomenon.

Chapter 7 deals with control and filtering issues for discrete-time switched linear systems with time delays. First, instead of considering state feedback control, the output feedback controller design is addressed for the switched systems under arbitrary switching and with polytopic uncertainties. Under cyclic switching, the stability conditions are derived allowing for the constraints on the DT of each time-delay subsystem by virtue of the MLFs approach, and a numerical searching algorithm is explored to compute the feasible values of DT of the subsystems. Finally, considering the PDT switching regularities and mode-dependent time-varying delays, the filtering problem is treated for a class of discrete-time neural networks with the corresponding switching and time-delay dynamics in H_∞ sense.

To summarize, this book presents the most recent theoretical findings on control and filtering issues for time-dependent discrete-time switched linear systems. By integrating novel ideas, fresh insights, and rigorous results in a systematic way, this book is aimed at providing a base for further theoretical research as well as a design guide for engineering applications. This book can serve as a reference for the main research issues and results on switched systems for researchers devoting to various areas of control theory, as well as a material for graduate and undergraduate students interested in switched systems and their applications. Some prerequisites for reading this book include linear system theory, matrix theory, mathematics, set theory, and so on.

Acknowledgments

We are deeply indebted to our colleagues Profs. Richard D. Braatz (Department of Chemical Engineering, Massachusetts Institute of Technology, USA), El-Kébir Boukas (Department of Mechanical Engineering, Ecole Polytechnique de Montreal, Canada), Huijun Gao (Research Center of Intelligent Control and Systems, Harbin Institute of Technology, China), Changhong Wang (Space Control and Inertial Technology Research Center, Harbin Institute of Technology, China), Michael V. Basin (Department of Physical and Mathematical Sciences, Autonomous University of Nuevo Leon, Mexico), Hamid Reza Karimi (Department of Engineering, Faculty of Technology and Science, University of Agder, Norway), Yang Shi (Department of Mechanical Engineering, University of Victoria, Canada), Ming Liu (Research Center of Satellite Technology, Harbin Institute of Technology, China), and Xudong Zhao (College of Information Science and Technology, Bohai University, China), for inspiring our thinking, reading the manuscript, and offering plenty of valuable advice on the material to improve this book. Lixian Zhang also thanks his

many current and former students Ting Yang, Yanhui Tong, Yong Chen, Ye Zhao and Songlin Zhuang, who are now working or studying all over the world in various occupations, for their great contributions and detailed discussions.

The financial support of the National Natural Science Foundation of China (61322301, 61573112, 61333012), National Natural Science Foundation of Heilongjiang (F201417, JC2015015), Fundamental Research Funds for the Central Universities, China HIT.BRETIII.201211, HIT.BRETIV.201306, Key Laboratory of Integrated Automation for the Process Industry, Northeast University, and Australian Research Council (DP140102180, LP140100471, LE150100079) are gratefully acknowledged.

Harbin — Lixian Zhang
Harbin — Yanzheng Zhu
Adelaide — Peng Shi
Vancouver — Qiugang Lu
October 2015

http://www.springer.com/978-3-319-28849-9

Time-Dependent Switched Discrete-Time Linear Systems: Control and Filtering

Zhang, L.; Zhu, Y.; Shi, P.; Lu, Q.

2016, XIV, 258 p. 72 illus., 23 illus. in color., Hardcover
ISBN: 978-3-319-28849-9