matrices and M matrices instead. Though there are a good monograph (Berman & Plemmons, 1994) and an article (Fiedler & Pták, 1962), these subjects are not covered by a standard linear algebra course.

Notwithstanding the above points, I strongly recommend the book because it covers important properties of positive systems, and it includes wide range of applications. I particularly find the annotated bibliography useful and informative. The book includes many relevant problems, which helps readers to have accurate images of theoretical results. The study on positive nonlinear systems is important, and I agree with the authors' opinion in the Conclusion that it makes sense to acquire a sound background on positive linear systems before studying positive nonlinear systems.

References

Berman, A., & Plemmons, R. J. (1994). *Nonnegative matrices in the mathematical sciences*. Philadelphia, PA: SIAM.

Fiedler, M., & Pták, V. (1962). On matrices with nonpositive off-diagonal elements and positive principal minors. *Czechoslovak Mathematical Journal*, *12*, 382–400.

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About the reviewer

Yoshito Ohta was born in Hyogo, Japan in 1957. He received his B.E., M.E., and D.E. degrees in Electronic Engineering from Osaka University, Osaka, Japan in 1980, 1982, and 1986, respectively. From 1983 to March 1991, he was with the Department of Electronic Engineering, Osaka University, Osaka, Japan. In April 1991, he joined the Department of Mechanical Engineering, Osaka University. Since July 1999, he has been a Professor at the Department of Computer-Controlled Mechanical Systems, Osaka University. From 1986 to 1988, he was a Visiting Scientist at the Laboratory of Information and Decision Systems, Massachusetts Institute of Technology, Cambridge, USA. His research interests include Robust Control and Linear System Theory.

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Qualitative theory of hybrid dynamical systems

A.S. Matveev and A.V. Savkin; Birkhäuser, Boston, 2000, ISBN: 0-8176-4141-6.

Many systems encountered in practice involve a coupling between continuous dynamics and discrete events. Systems in which these two kinds of dynamics coexist are usually called *hybrid*. For example, the following phenomena give rise to hybrid behavior: a valve or a power switch opening and closing; a thermostat turning the heat on and off; biological cells growing and dividing; a server switching between buffers in a queueing network; aircraft entering, crossing, and leaving an air traffic control region; dynamics of a car changing abruptly due to wheels locking and unlocking on ice.

Hybrid systems constitute a relatively new and very active area of current research. They present interesting theoretical challenges and are important in many real-world problems. Due to its inherently interdisciplinary nature, the field has attracted the attention of people with diverse backgrounds, primarily computer scientists, control theorists, and practicing engineers. The literature on the subject is rapidly growing; several books and research monographs on hybrid systems are already available and others will appear shortly. To the best of this reviewer's knowledge, the book under review is the first such monograph; it has therefore made an important contribution to the development of the field.

The book has nine chapters, whose contents we now briefly summarize. Chapter 1 presents two simple motivating examples of switched flow systems taken from the paper (Chase, Serrano, & Ramadge, 1993). The authors explain that the goal of their research monograph is to develop a general qualitative theory of hybrid systems, powerful enough to analyze more complicated higher-dimensional generalizations of these examples. This chapter also contains a detailed outline of the rest of the book.

Chapter 2 introduces a simple class of hybrid systems, called *cyclic linear differential automata*. The dynamics of these systems in each discrete state are described by constant vector fields. A necessary and sufficient condition is obtained for such a system to have a single globally attracting limit cycle. The condition is formulated in terms of eigenvalues of a suitable matrix. This result is then applied to study several classes of switched server systems with cyclic switching policies. The last section of the chapter (which seems a little bit out of place) discusses switched arrival systems whose trajectories do not converge to any limit cycle.

In Chapter 3 the authors develop a general model of a hybrid system, which they call a *multivalued differential automaton*. This model is similar to other hybrid system models which have appeared in the literature. Well-posedness of multivalued differential automata is discussed in detail. It is proved that under certain assumptions, every multivalued differential automaton can be represented as the union of a finite number of differential automata with simple cyclic dynamics. This result is then used to prove existence of periodic trajectories and characterize their behavior.

Chapter 4 studies two-dimensional multivalued differential automata. The main result of this chapter is an analog of the Poincaré–Bendixon Theorem for hybrid systems. It provides conditions for a hybrid system in the plane to have a non-chaotic, eventually periodic behavior. As an application, the authors give a detailed analysis of two specific switched flow systems.

Chapters 5 and 6 deal with hybrid dynamical systems with constant derivatives. This class of systems is related to the one considered in Chapter 2, although the exact relationship unfortunately does not seem to be explained anywhere. Chapter 5 develops general criteria for existence and stability of limit cycles in such systems. Chapter 6 illustrates the theory by studying several specific classes of switched flow systems.

The investigation of switched flow systems is continued in Chapters 7 and 8. Chapter 7 considers single server switched flow networks and provides conditions for existence of a single globally attracting limit cycle. Chapter 8 is concerned with multiple server switched flow networks with time-varying arrival rates. The problem addressed here is design of feedback policies which provide desirable regular behavior in such systems. A simple algebraic necessary and sufficient condition for such a feedback policy to exist is obtained.

Finally, Chapter 9 describes seven open problems. These problems range from the theoretical one of extending the theory of this book to differential automata with nonlinear right-hand side to the problem of proving a specific conjecture for switched server systems with more than three buffers.

The book presents original results due to the authors, with complete proofs provided. The reviewer found the book well organized and methodically written. A particular nice feature of the book is that footnotes are included in the statements of the main results to help the reader quickly find the relevant definitions.

The application domains discussed extensively in the book are queueing networks and manufacturing systems. This book is an essential reading for anyone interested in applying hybrid system methods to these fields. The theory described in the book is likely to be useful for other application areas, such as power systems.

The reviewer also recommends this book to all students and researchers who want to follow a careful development of a general definition of a hybrid system, supplemented with helpful and realistic examples. On the other hand, due to its limited scope, this is not the right book for someone who is looking for an overview of techniques and problems in the general area of hybrid systems and control. For example, one of many important and interesting topics not covered in the book is stability of equilibria for hybrid systems. The book is also probably not suitable as a textbook, except perhaps for an advanced course with a somewhat narrow focus. To get a broader perspective, the reader will need to consult other sources, such as the book by van der Schaft and Schumacher (2000).

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References

Chase, C., Serrano, J., & Ramadge, P. J. (1993). Periodicity and chaos from switched flow systems: Contrasting examples of discretely controlled continuous systems. *IEEE Transactions on Automatic Control*, *38*, 70–83.

van der Schaft, A., & Schumacher, H. (2000). *An introduction to hybrid dynamical systems*. London: Springer.

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Optimal control of singularly perturbed linear systems and applications

Zoran Gajić and Myo-Taeg Lim; Marcel Dekker, New York, 2001, ISBN: 0-8247-8976-8

Singular perturbations arise in systems whose dynamics have sufficiently separate slow and fast parts. They also are seen due to weak coupling of subsystems, and may be induced under feedback when applying high-gain control, or "cheap" optimal control. Since the late 1960s, extensive research on singularly perturbed control systems, and parallel efforts on singularly perturbed ordinary differential equations, has yielded a rich and powerful body of results. The book under review (Gajić & Lim, 2001) is a compact monograph reporting recent developments in the optimal control of linear, time-invariant, singularly perturbed