Hybrid dynamical systems: controller and sensor switching problems, by A. V. Savkin and R. J. Evans. Birkhäuser, Boston, 2002. ISBN 0-8176-4224-2.

Research on hybrid systems has been carried out from essentially two different perspectives. Computer scientists are motivated primarily by the goal of understanding how software components interact with the real world. Control engineers, on the other hand, are investigating how discrete logical components affect the behavior of control systems. This difference in viewpoints is very well explained in the Preface of the book under review, which itself falls into the second category.

This book presents recent results obtained by the authors on the topics of robust control design and estimation using switching. This is a research monograph with a specific focus; in this sense it can be compared with the earlier monograph [1] and contrasted with related books having more general scope, such as [2] and [3]. The book is quite compact: its main body has only 136 pages.

It must be noted that the book is closely patterned after the original journal articles, which makes its technical level quite advanced. For example, global asymptotic stability is not explicitly defined; a definition (even an informal one) of a Filippov solution is deliberately avoided; assumptions and definitions being made are rarely discussed; and many results from robust control are cited in the proofs without hesitation. The authors did not attempt to present the material in a more tutorial style, so as to make the book self-contained for a non-expert reader. For example, a background chapter could have rendered the book more accessible.

The first, introductory chapter provides a very nice overview of the relevant literature and places the contribution of the book in a proper context. The authors make a good decision to bypass a formal definition of a hybrid system, which lets them get to the specific problems of interest more quickly. A weak point of the literature review is that the authors do not cite the work of Wicks, Peleties, and DeCarlo [4, 5] and subsequent work of Feron [6] (unpublished but referenced in several sources), which are directly related to the results presented in Chapter 2. Each subsequent chapter begins with a very helpful and well-written introduction which describes the problem to be studied, provides historical remarks, and outlines the structure of the rest of the chapter. Chapter 2 derives conditions for quadratic stabilizability of linear systems via state feedback controller switching. The conditions are given in terms of completeness of a set of matrices, and are further recast using the S-procedure. Both asynchronous (state-dependent) and synchronous (involving a sampling time) switching sequences are considered. Chapter 3 develops parallel results for the problem of robust stabilization in the face of norm-bounded time-varying uncertainties.

Chapter 4 is devoted to the H^∞ control problem for state and output feedback. The solution involves a discrete-time dynamic programming equation which is used to define the switching sequence. Chapter 5 studies the absolute stabilizability problem for systems with uncertainties satisfying integral quadratic constrains (IQCs). The results obtained here are close in spirit to the ones given in the previous chapter. Uncertainties defined by IQCs are revisited in Chapter 6, which deals with the robust output feedback controllability problem—i.e., the problem of achieving boundedness of the reachable set.

Chapter 7 investigates robust state estimation via sensor switching. For systems with IQC-type uncertainties, conditions for robust observability—i.e., boundedness of the reachable set corresponding to the observed output—are first obtained in terms of solutions to a Riccati differential equation. Then, an optimal sensor schedule is characterized via a dynamic programming procedure. A one-step-ahead model predictive sensor scheduling scheme, which is not optimal but more suitable for real-time implementation, is also discussed.

Chapters 8 and 9 are essentially independent of the rest of the book and probably the easiest to follow (with the exception of the first two chapters). They address strong stabilization—i.e., stabilization by stable controllers—for linear systems. As the authors very clearly explain, conditions for strong stabilizability by linear time-invariant controllers are quite stringent and controller dimension may be large. In this respect, one gains a significant advantage by employing discontinuous controllers. Chapter 8 deals with strong stabilization of linear time-invariant systems, with an LQG optimality criterion, by discontinuous (impulsive) output feedback. Chapter 9 develops a method for simultaneously strongly stabilizing a finite family of linear time-varying systems by impulsive output feedback, under the assumption that a simultaneously stabilizing state feedback gain is available.

A weak point of the book, in this reviewer's opinion, is the practical applicability of the results. Computational aspects of verifying the completeness conditions arising in Chapters 2 and 3 are not discussed (checking these conditions is actually a difficult task, even for the case of two basic controllers; cf. [7]). Solving dynamic programming problems arising in Chapters 4–7 is also very difficult, as the authors admit. A more constructive sufficient condition for absolute stabilizability described in Section 5.6 again relies on checking completeness of a set of matrices. The choice of the output gains for basic controllers is not explained. Chapters 2–5 end with illustrating examples, but the authors do not clarify how they arrived at the specific numbers used in the examples. Also, all these examples—with the exception of the spring-mass example considered in Chapter 3—are of purely academic nature. Thus this book will not be very informative for someone interested in using these results for applications.

In summary, this is a well-written book which presents interesting theoretical results in a concise and rigorous manner. Within the rapidly developing field of hybrid systems, it has a well-chosen focus and is a welcome addition to the literature. The reviewer recommends this book to all researchers who possess expert knowledge of control theory (particularly robust control) and are interested in switching design methods for robust control and estimation.

Daniel Liberzon
Coordinated Science Laboratory
University of Illinois at Urbana-Champaign
U.S.A.

References

[1] A. S. Matveev and A. V. Savkin. *Qualitative Theory of Hybrid Dynamical Systems.* Birkhäuser, Boston, 2000.

[2] A. van der Schaft and H. Schumacher. *An Introduction to Hybrid Dynamical Systems.* Springer, London, 2000.

[3] D. Liberzon. *Switching in Systems and Control.* Birkhäuser, Boston, 2003.

[4] M. A. Wicks, P. Peleties, and R. A. DeCarlo. Construction of piecewise Lyapunov functions for stabilizing switched systems. In *Proc. 33rd IEEE Conf. on Decision and Control*, pages 3492–3497, 1994.

[5] M. A. Wicks, P. Peleties, and R. A. DeCarlo. Switched controller synthesis for the quadratic stabilization of a pair of unstable linear systems. *European J. Control*, 4:140–147, 1998.

[6] E. Feron. Quadratic stabilizability of switched systems via state and output feedback. Technical Report CICS-P-468, MIT Center for Intelligent Control Systems, 1996.

[7] V. Blondel and J. N. Tsitsiklis. NP-hardness of some linear control design problems. *SIAM J. Control Optim.*, 35:2118–2127, 1997.

Daniel Liberzon was born in the former Soviet Union in 1973. He was a student in the Department of Mechanics and Mathematics at Moscow State University from 1989 to 1993 and received the Ph.D. degree in mathematics from Brandeis University, Waltham, MA, in 1998 (under the supervision of Prof. Roger W. Brockett of Harvard University). Following a postdoctoral position in the Department of Electrical Engineering at Yale University, New Haven, CT, he joined the University of Illinois at Urbana-Champaign in 2000 as an assistant professor in the Electrical and Computer Engineering Department and an assistant research professor in the Coordinated Science Laboratory. Dr. Liberzon's research interests include nonlinear control theory, analysis and synthesis of switched systems, control with limited information, and uncertain and stochastic systems. He is the author of the book *Switching in Systems and Control* (Birkhauser, 2003). Dr. Liberzon served as an Associate Editor on the IEEE Control Systems Society Conference Editorial Board in 1999–2000. He received the NSF CAREER Award and the IFAC Young Author Prize, both in 2002.