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★**Switching in systems and control.**

Systems & Control: Foundations & Applications.
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This book is a well-structured and clearly written text addressing pertinent issues on stability and control for switched systems. These are regarded as a collection of individual dynamic systems, which are selected to drive the state according to a switching policy.

The first part of the book consists of a very brief introduction to several classes of hybrid and switched systems as well as a short and limited discussion on some appropriate solution concepts for switched systems.

Stability is addressed in the second part of the book, which comprises chapters two (systems with arbitrary switching signals) and three (determination of classes of stabilizing switching signals).

After introducing key uniform stability concepts in Chapter 2, the author presents a Lyapunov and a converse Lyapunov theorem in terms of a radially unbounded common Lyapunov function shared by all individual subsystems. This is shown to be a less severe requirement than that of global uniform asymptotic stability (GUAS) of the switched system. For switched linear systems specified by a compact set of Hurwitz matrices, local attractiveness of the switched system for every switching signal is equivalent to its global uniform exponential stability (GUES).

Then, several results for linear and nonlinear systems concerning stability and the commutation relations among the individual subsystems are presented and Lie-algebraic stability criteria are discussed. It is shown that a switched system is GUES whenever the finite set of individual linear subsystems with commutative Hurwitz matrices is GUES. The corresponding result for nonlinear systems is also presented with GUAS replacing GUES. Even when the vector fields of the individual subsystems do not commute, sufficient conditions for uniform stability are provided for systems whose associated Lie algebra either is solvable or is the semidirect sum of a solvable ideal and a compact subalgebra.

Finally, results on switched triangular systems and on the stability for feedback systems with a single process being controlled by switching among several controllers are presented, the discussion being cast in terms of passivity, positive realness, and absolute stability.

The third chapter deals with problems for which stability conditions are given in terms of a family of Lyapunov functions associated with the switched system.

The concepts of dwell time and average dwell time are discussed and asymptotic stability conditions for systems with slow switching, i.e., time-dependent switching subject to suitable constraints, are presented and proved. Then, this result is extended in order to verify the stability of systems with state-dependent switching, the "S-procedure" being introduced. The last section of this chapter discusses the synthesis of a switching rule ensuring asymptotic stability.

Switching control, the subject of the third part of the book, is presented in the last three chapters, one for each of the following themes: systems that are not globally asymptotically stabilizable by smooth or continuous feedback, systems with sensor and actuator constraints, and systems with large modelling uncertainty.

In chapter four, the problem of obstruction to continuous stabilization is discussed and Brockett's well-known necessary condition for local asymptotic stabilization by a continuous feedback control law is given. Then, a sufficient condition for the nonexistence of an asymptotically stable continuous feedback for nonholonomic systems is proved, and the benchmark problem of stabilizing a one-dimensional inverted pendulum is presented.

The fifth chapter starts with a conventional discussion of the linear time optimal control problem with control constraints, illustrated with the classic examples of the double integrator and the forced harmonic oscillator.

Then the problem of stabilizing a dynamic system by a hybrid output feedback with a finite discrete set of state values is considered, with a single Lyapunov function synthesis method developed for the linear oscillator, yielding a time- and state-dependent switching strategy. The extension to multiple Lyapunov functions is discussed for switched systems defined by two linear subsystems.

In the last section of this chapter, the Lyapunov stabilization of quantized stabilizable linear or nonlinear dynamic control systems is addressed, global asymptotic conditions being provided in a wide range of contexts which include either the static (fixed parameters) or the dynamic (variable parameters) quantization of either the state, the input, or the output variables (or any combination of these).

Finally, it is shown, for both linear and nonlinear control systems, that, under certain assumptions, there exists an asymptotically stabilizing hybrid feedback control policy exploring the trade-off between the amount of static information and that of probing for information by dynamically changing the quantization parameters.

Chapter six deals with systems with large uncertainty, the model of the uncertain process being regarded as the union of families of systems centered—unmodeled dynamics—around a process model indexed by a parameter ranging in a given set. The supervisory control system is composed of a family of candidate controllers sufficiently rich to stabilize every admissible process model and a mechanism—the supervisor—to generate a switching control policy.

After a discussion of the advantages of supervisory control relative to the conventional adaptive approaches, the supervisory control architecture, composed by a multi-estimator, a monitoring signal generator, and a switching logic system, is presented and illustrated with the problem of driving a stabilizable and detectable linear system to zero by means of output feedback.

After an informal discussion of the requirements to be met by the supervisory control architecture so that robust stability is ensured for a large class of uncertain systems, the foundations for the design of the multi-estimator, candidate controllers and switching logic are presented, first for nonlinear systems and, then, revisited in more detail for linear systems and nonlinear systems with finite index set. Finally, the example of a nonholonomic system with uncertainty is included as an illustration.

The book also includes two appendices succinctly covering some basic facts on stability and Lie algebras. Interesting notes and additional references complementing the main text on a chapter-by-chapter basis are also included.

The book serves well the purpose stated by the author of supporting research and advanced graduate courses on switched systems and control. In what concerns the latter, the role of the proposed exercises in guiding the student seems to be relatively limited.

Reviewed by *Fernando Lobo Pereira*