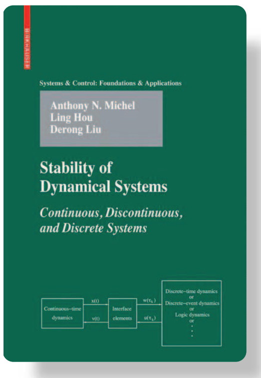
IEEE Control Systems Magazine welcomes suggestions for books to be reviewed in this column. Please contact either Michael Polis or Zongli Lin, associate editors for book reviews.



Birkhäuser, 2008,
ISBN: 978-0-8176-4486-4,
508 pages, US$79.95.

Stability of Dynamical Systems—Continuous, Discontinuous, and Discrete Systems

by ANTHONY N. MICHEL, LING HOU, and DERONG LIU

Reviewed by Alessandro Astolfi

I have always believed that *stability* is the most important concept in systems and control theory. From the early days of my undergraduate studies, when I was first exposed to Lyapunov theory, to these days in which I devote a significant proportion of time to proving stability properties of dynamical systems and teaching stability to second- and third-year undergraduate students, I have never ceased to be fascinated by the elegance of this notion, its far-reaching implications, and its significance in applications.

It is fair to claim that control engineers and mathematicians concur in asserting that stability is a property that, in some form, should be possessed by every system, if the system is to have any practical relevance. For this reason numerous research papers, chapters of books, and entire books are devoted to the study of stability, its characterization, descriptions of its use in analysis and design, and extensions or variations of the standard notions of Lyapunov and Lagrange.

A quick search of the British Library catalog (http://catalogue.bl.uk) reveals that hundreds of books devoted to stability and its applications have been published over the last 60 years. The titles of these books range from the classical *Ustoĭchivost′ Nelineĭnykh Reguliruemykh Sistem* [*Stability in Non-Linear Control Systems* (in Russian)], by A.M. Letov (1955), to the somewhat more intriguing *Inners and Stability of Dynamic Systems*, by E.I. Jury (1974); *The Dynamic Stability of Elastic Systems* (in Russian), by V.V. Bolotin (1956); and *General Longitudinal Stability Equations for Hydrofoil Systems with Specific Application to the Cape Cod Boat*, by C.H. Kahr (1951).

Digital Object Identifier 10.1109/MCS.2008.930838

The reader wanting to learn stability from the classical books from the 1950s and the 1960s has to face a few serious obstacles. First, some of these books are in Russian (although an English translation is often available, see for example [7]); second, the notation, the terminology, the style, and even the *logic* are unfamiliar, and it may be extraordinarily hard, if not impossible, to extract the desired information, essentially since these older books often do not have an index. Finally, the class of systems and the problems that are of interest today are different from those studied in the past, which means that the result or the argument that we are interested in may not be available, or may be given in a form that is of little use.

I do not mean to detract from the classical body of literature on stability—I have learned stability using Hahn's *Stability of Motion* [3], LaSalle and Lefschetz's *Stability by Lyapunov's Direct Method* [5], Carr's *Applications of Center Manifold Theory* [2], and LaSalle's *The Stability of Dynamical Systems* [7]—but rather I believe that textbooks on stability (similarly to everything else) require *modernization*, that is, the subject must be illustrated and taught in modern notation and set in the perspective of current problems.

This goal is partly achieved by existing books, for example, [1], [8], and [4]. Nevertheless, as stated in the preface of the book being reviewed, "there are no books on stability theory that are suitable to serve as a single source for the analysis of system models" that include, simultaneously, continuous-time and discrete-time components, finite-dimensional and distributed-parameter subsystems, and components described by continuous and discontinuous differential equations, that is, systems that are of current interest.

The goal of this book is to provide a reference text forgraduate students and researchers on stability theory for the class of systems encountered in modern applications. In this respect, the goal is indeed achieved since the book offers a self-contained presentation of stability theory.

CONTENTS OF THE BOOK

The book is organized in nine chapters, most of which include sections with notes and references, problems, and bibliography. I like the structure of the book, although I believe that a single bibliography at the end of the book is preferable to having bibliographies at the end of each chapter. In addition, most of the problems and examples are somewhat too theoretical, such as problems and examples that ask the reader to out the proof of an unproved result or condition. This structure renders some parts of

1066-033X/09/$25.00©2009IEEE

Authorized licensed use limited to: University of Illinois. Downloaded on January 27, 2009 at 10:31 from IEEE Xplore. Restrictions apply.

the book very hard to digest for nonexperienced readers and reduces its pedagogical value.

The nine chapters can be clustered into six logical parts. The introduction, Chapter 1, provides a brief description of the notion of dynamical system and gives a concise view of the history of stability theory. In addition, this chapter specifies the goal of the book and its organization.

Chapter 2 is devoted to the formal definition of a dynamical system. Several classes of systems are presented, namely, systems described by ordinary differential or difference equations or inequalities, differential inclusions, integrodifferential equations, partial differential equations, and discontinuous differential equations. Special care is taken to highlight the key concepts and ingredients, and an effort is made to consider all classes of systems that are relevant to applications. In addition, several important issues illustrating properties of solutions are highlighted by means of elementary, yet carefully selected, examples.

Chapters 3 and 4 present the fundamental theoretical results, including direct and converse Lyapunov and Lagrange stability results, invariance theory, and comparison methods for the classes of systems introduced in Chapter 2. These two chapters are the core of the book, since the subsequent chapters primarily discuss applications of the general theory to specific problems or classes of systems. While reading these chapters the reader has the impression that the concepts and statements are somewhat repetitive. This impression is not correct since concepts and statements refer to different types of systems, and therefore there are significant differences. The authors have done an excellent job maintaining the rigor of the presentation, and in providing stand alone statements for diverse types of systems. On the other hand, I think they should have helped the reader more in identifying key differences between the various statements.

Chapter 5 deals with the application of the general theory to a class of discrete-event systems. Although very interesting, this short chapter breaks the logical flow of the book.

Chapters 6, 7, and 8 apply the general theory developed in chapters 3 and 4 to finite-dimensional systems, linear systems, and some classical problems, including the absolute stability problem as well as the stability of Hopfield neural networks, a class of digital control systems, pulse-width-modulated feedback systems, and a class of digital filters. The reader with some background on systems theory will find the content of these chapters familiar. Nevertheless, these chapters contain several nonstandard results and examples, thus making interesting reading even for experts.

Chapter 9 is devoted to the study of stability issues for infinite-dimensional (continuous and discontinuous) systems. This chapter is the most technical. It is notable that the authors include several well-selected and worked-out examples to help the reader grasp the key concepts and tools. The theoretical results are illustrated by means of several applications, including a kinetic model of a nuclear reactor and neural networks with delays.

In conclusion, *Stability of Dynamical Systems—Continuous, Discontinuous, and Discrete Systems* is a very interesting book, which complements the existing literature.

CONCLUSIONS

The use of this book as a reference text in stability theory is facilitated by an extensive index. The table of contents would have been enhanced by the inclusion of third level headings.

In conclusion, *Stability of Dynamical Systems–Continuous, Discontinuous, and Discrete Systems* is a very interesting book, which complements the existing literature. The book is clearly written, and difficult concepts are illustrated by means of good examples. The book is suitable for readers with a solid mathematical background as well as some basic systems and control knowledge. The book should provide a useful reference for researchers working in control theory as well as for Ph.D. students.

REFERENCES

[1] A. Bacciotti and L. Rosier, *Liapunov Functions and Stability in Control Theory*. Berlin: Springer-Verlag, 2005.
[2] J. Carr, *Applications of Center Manifold Theory*. Berlin: Springer-Verlag, 1981.
[3] W. Hahn, *Stability of Motion*. New York: Springer Verlag, 1967.
[4] H.K. Khalil, *Nonlinear Systems*. Prentice-Hall, Upper Saddle River, 3rd edition, 2002.
[5] J. LaSalle and S. Lefschetz, *Stability by Lyapunov's Direct Method*. New York: Academic, 1961.
[6] J.P. LaSalle, *The Stability of Dynamical Systems*. Philadelphia, PA: SIAM, 1976.
[7] A.M. Lyapunov. *The General Problem of the Stability of Motion*. London: Taylor & Francis, 1992.
[8] A.N. Michel, K. Wang, and B. Hu, *Qualitative Theory of Dynamical Systems: The Role of Stability Preserving Mappings,* 2nd ed. New York: Marcel Dekker, 2001.

REVIEWER INFORMATION

Alessandro Astolfi is a professor at Imperial College London and at the University of Rome "Tor Vergata." He received the Ph.D. from ETH Zürich in 1995 and the Ph.D. from the University of Rome "La Sapienza" in 1996. His research interests are focused on mathematical control theory and control applications, with emphasis on discontinuous stabilization, robust stabilization, robust control, adaptive control, observer design, and model reduction.

Authorized licensed use limited to: University of Illinois. Downloaded on January 27, 2009 at 10:31 from IEEE Xplore. Restrictions apply.