71

Book Reviews

In this section, the IEEE Control Systems Society (CSS) publishes reviews of books in the control field and related areas. Readers are invited to send comments on these reviews for possible publication in the Technical Notes and Correspondence section of this TRANSACTIONS. The CSS does not necessarily endorse the opinions of the reviewers.

If you have used an interesting book for a course or as a personal reference, we encourage you to share your insights with our readers by writing a review for possible publication in the TRANSACTIONS. All material published in the TRANSACTIONS is reviewed prior to publication. Submit a completed review or a proposal for a review to:

D. S. Naidu
Associate Editor—Book Reviews
College of Engineering
Idaho State University
833 South Eighth Street
Pocatello, ID 83209 USA

Global Controllability and Stabilization of Nonlinear Systems—S. Nikitin (Singapore: World Scientific, 1994). *Reviewed by Arthur J. Krener.*

I. INTRODUCTION

The theory of controllability for linear time-invariant systems is relatively straightforward and mathematically elegant. Almost all reasonable definitions of linear controllability are equivalent. The most intuitive definition is the ability to use the control to steer the system from one point to another. Another definition is the ability of the control to excite any linear function of the state; this is half of what is needed for a realization to be minimal. There is a simple rank test to decide when a linear system is controllable. Moreover, controllability is intimately connected with stabilizability. A linear system is controllable if and only if it is possible to arbitrarily place its poles by linear feedback. The definition of linear controllability (and observability) was put forth by R. E. Kalman at the first IFAC Congress in 1960 [1].

Unfortunately, the theory of controllability is not as simple nor as elegant for nonlinear systems (and for linear systems subject to state and control constraints). There are many nonequivalent definitions of controllability. The most intuitive definition, the ability to steer the system from one point to another, does not admit any simple characterization or test. The one that has been emphasized most in the literature is the ability of the control to excite any nonlinear function of the state, as this is half of what is needed for a reasonably satisfactory theory of minimal realizations. It also admits a convenient rank test in terms of Lie brackets. For a fuller discussion of this we refer the reader to [2]–[6]. This book emphasizes point-to-point controllability and its relationship with stabilizability by nonlinear feedback.

II. THE BOOK

The book under review is based on courses that the author has given on nonlinear systems at Moscow State University and the University of Kaiserslautern. It is a mixture of a research monograph and a textbook with numerous exercises. The book has two parts, the first dealing with planar systems and the second dealing with higher-dimensional ones.

The reviewer is with the Department of Mathematics, University of California, Davis, CA 95616 USA (ajkrener@ucdavis.edu).
Publisher Item Identifier S 0018-9286(97)00647-8.

Chapter 1 of the first part deals with the control of planar linear systems subject to state and control constraints. A prototypical system called a cart is introduced, and its controllability is analyzed using the concept of a controllable foliation. This is a new technique developed by Nikitin that is well suited to the task at hand.

In Chapter 2, planar nonlinear systems which are equivalent to linear systems are studied. Equivalence is under nonlinear change of state and time coordinates and nonlinear feedback. This group is chosen as it respects the property of point-to-point controllability. Conditions are given for controllability under state and control constraints for those systems that can be covered by a family of controllability foliations. Such covers are called cart garlands.

The semiglobal stabilization of controllable planar systems is discussed in Chapter 3, both for systems that are known exactly and those that are not. The latter problem is one of adaptive stabilization and is solved by high gain and sliding controllers.

The next chapter deals with singular planar systems. These include frequently encountered systems such as the bilinear ones. The author gives a complete classification of two-dimensional bilinear systems, and controllability criteria for each class are derived.

The first chapter of Part II deals with issues of local and global controllability of multidimensional nonlinear systems using tools from Lie theory and topological groups. It begins with basic topological and geometric concepts needed for controllability analysis. Then, it discusses approximate groups, necessary and sufficient conditions for global controlability, and controllability on hypersurface systems.

Chapter 2 investigates the local stabilization of nonlinear systems using Lyapunov functions and center manifold theory. Brockett's necessary conditions are presented along with the approaches of Sontag, Jurdjevic-Quinn, and those based on the center manifold theorem.

The last chapter deals with the semiglobal stabilization of nonlinear systems using piecewise smooth feedback laws.

III. CONCLUSIONS

While the book overlaps to some extent with other monographs [3]–[7] in this area, it has much new material. The first part uses only elementary facts about differential equations and topology and so is readily accessible to advanced undergraduates and beginning graduate students. The second part requires some background in differential geometry. With its numerous exercises it could serve as the basis of a one- or two-semester course in nonlinear control for students in mathematics or applied mathematics. One would probably want to supplement it with more standard material from [2]–[6].

The book also contains many new results on nonlinear controllability and stabilizability that are not readily available elsewhere. Hence, it is of interest to researchers in these fields and is a welcome addition to the literature.

REFERENCES

[1] R. E. Kalman, "On the general theory of control systems," in *Proc. First Int. Congr. Automat. Contr.*, London, 1960, pp. 481–493.

[2] R. Hermann and A. J. Krener, "Nonlinear controllability and observability," *IEEE Trans. Automat. Contr.*, vol. 22, pp. 728–740, 1977.

[3] A. Isidori, *Nonlinear Control Systems,* 2nd ed. Berlin: Springer-Verlag, 1989.

[4] H. Nijmeijer and A. J. Van der Schaft, *Nonlinear Dynamical Control Systems.* New York: Springer-Verlag, 1990.

[5] E. D. Sontag, *Mathematical Control Theory.* New York: Springer-Verlag, 1990.

[6] J. Zabczyk, *Mathematical Control Theory: An Introduction.* Boston, MA: Birkhauser, 1992.

[7] A. Bacciotti, *Local Stabilizability of Nonlinear Control Systems.* Singapore: World Scientific, 1992.