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Book Reviews

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Applied Linear Optimal Control: Examples and Algorithms

Arthur E. Bryson, Cambridge University Press, New York, 2002, 362 pp., $45.00

The author states in the preface, "This book is about the optimization of dynamic systems in the presence of uncertainty." Here, uncertainty includes both random inputs and errors, and parametric uncertainties. The stated intent of this book is to be the successor to the second half of *Applied Optimal Control*,[1] where Ref. 2 is the successor of the first half. The book generally succeeds in its goal.

The book comprises 12 chapters and 2 appendices. The first chapter is dedicated to static estimation, which includes a review of random variables. Chapter 2 provides an overview of random processes, which leads to dynamic estimation using filters and smoothers shown in Chapters 3 and 4, respectively. In Chapter 5 linear-quadratic state-feedback follower-controllers are shown, which leads to the standard linear quadratic Gaussian (LQG) control problem discussed in Chapter 6. In Chapter 7 the results of Chapter 4 are extended to handle controlled plants. The next three chapters are devoted to the application of the results from previous chapters to time-invariant systems. Chapter 11 presents worst-case controllers, and Chapter 12 presents parameter-robust LQG controllers. Appendix A gives various filter and controller designs for systems with colored measurement noise, and Appendix B gives the plant models used for the examples in the book.

The book is aesthetically very well written. The chapters progress in a logical fashion. In particular, the developments shown in the first 10 chapters lead to several advanced topics, such as linear-quadratic worst-case control, disturbance rejection, and minimax control, in the last chapters. Algorithms for both continuous-time and discrete-time systems are provided. Several practical discussions are given that enhance the pedagogical experience as well. For example, the author gives a discussion on estimator divergence, with a common solution to this problem. Problem sets, which are generally given at the end of each section, are scattered throughout the text. This allows the reader a chance to test his or her skills immediately after reading about a certain topic. Clearly, the author used a deliberate and meaningful thought process in the preparation of this book.

Intrinsic with the reading material is the wide use of MATLAB. The book contains a CD-ROM that includes a toolbox as well as codes for nearly all of the examples, figures, and problems within the text. The reader is expected to have at least some experience with MATLAB programming. However, the author successfully backs up the codes with detailed explanations that provide a clear understanding of the overall algorithmic programming. Therefore, anyone with even a terse background in MATLAB should be able to easily comprehend the relationships between the stated applications in the book and the coded scripts.

The intended audience of this book includes first-year graduate students and practicing engineers with some optimal control experience. The author inherently applied the old adage of "the best way of learning is doing" in preparing this book. This is clearly demonstrated by the plethora of examples shown in the book. These examples cover a wide variety of systems, including spacecraft attitude and orbit maneuver control, aircraft and helicopter control, and robotic-type systems and ground vehicle motion systems, as well as standard problems such as planetary gear problems, the overhead crane, and the inverted pendulum. These real-world systems and nontrivial problems provide the reader a good foundation for the application of linear optimal control theory to more complicated systems.

Because the style of this book involves a learn-by-practice approach, it is not as mathematically rich as the author's classic book (Ref. 1). Several of the detailed derivations shown in Ref. 1, for example, the Bayesian approach to optimal filtering and optimal filtering/control for nonlinear systems, have been omitted in the present text. Also, even though the premise of the book is linear systems, a more detailed treatment of nonlinear systems would be useful because nonlinear estimation and control have now reached the mainstream engineering practice. Therefore, some of the concepts may have to be supplemented with more detailed treatments, and the book seems to be most effective when used in conjunction with more mathematically rich texts or detailed theoretical notes.

In summary, *Applied Linear Optimal Control* successfully fills the gap between the theory of optimal control design and practical applications in the face of uncertainties. The student should find this book to be an invaluable supplemental tool combined with a solid theoretical framework in the classroom. The practicing engineer should find this book to be an invaluable reference tool in understanding the issues involved with practical control design. Both the student and the practicing engineer will especially appreciate the several examples backed up with MATLAB codes, which serve to provide more interesting problems than the book's predecessor.

This book should be a valuable addition to an individual's collection or to an institution's library.

References

[1]Bryson, A. E., and Ho, Y.-C., *Applied Optimal Control: Optimization, Estimation and Control*, rev. printing, Taylor and Francis, London, 1975.

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John L. Crassidis
State University of New York at Buffalo

Vibration and Control of Active Structures, An Introduction, 2nd Edition

Andre Pruemont, Kluwer Academic Publishers, Dordrecht, The Netherlands, 2002, 364 pp., $120.00

This is the second edition of a popular book dealing with the vibration and control of structures, a topic also referred to as structural control or active structures. Previous books have not incorporated the use of smart materials as actuation and sensing devices together with the concepts of active control and structural dynamics, with the exception of Clark et al.[1] The previous books that have attempted to bridge the gap between the controls community and the structural dynamics community are Leipholz and Abdel-Rohman,[2] which focused on civil structures; Meirovitch,[3] an undergraduate text combining topics from the two disciplines; Inman,[4] a graduate text integrating topics in vibration and control; and of course the first edition of the Pruemont book, which addressed aerospace applications specifically. None really competes with the current Pruemont book, for it is tied to more practical hardware aspects, as well as ends with several chapters on applications. Later books, such as Clark et al.,[1] tend to focus more on smart structures and, although examples are provided, no problems are given. Pruemont provides a more complete list of references to the aerospace-oriented books and literature in active structures. Furthermore, the Pruemont book is the first of its type to make it to a second edition. Most of the other books do not include ample problems for use as a text, but the Pruemont text provides a full set of problems at the end of each chapter, and solutions are reportedly available from the author.

The format of the book is to present basic material from all of the fundamental subjects. The author relies heavily on root locus methods for explanations. The author also places strong emphasis on collocated controllers and the importance of open-loop zeros. These are points often missed by the pure controls community and hence form an extremely useful selection of topics and emphasis. The author and his laboratory have been key participants in the experimental side of space structures research. As such, the flavor of the book tends to methods that generally work well in the laboratory and hence are useful in practical applications.

For those familiar with the first edition, it is worth noting that the second edition includes three more chapters and more problems. In particular, a chapter on active isolation is included that examines the classic "skyhook damper" approach and focuses on a Stewart Platform as an application. A new chapter on semi-active control examines the use of magnetorheological fluids as an actuator system. The content of this chapter exceeds the information available in any current text (including books on smart structures and materials) and is very useful. The third new chapter focuses on the control of cable-structures. In addition, material has been added to Chapter 3 on modeling piezoelectric-based structures, and there is new material on distributed sensing for vibroacoustics in Chapter 13.

For those approaching this book for the first time, the chapter coverage is as follows: The book starts with a light introduction to smart materials and structures and motivation for active vs passive control in Chapter 1. Basic concepts of structural dynamics are summarized in Chapter 2 with emphasis on modal decompositions and transfer functions. Chapter 3 examines actuators as components of active structures. Actuation devices considered are proof mass type actuators, gyrostabilizers, piezoelectric actuation, and sensing. This chapter also emphasizes the important interaction between transmission zeros in structures and collocated sensing and actuating. This leads very nicely into Chapter 4 on collocated vs noncollocated control designs. Although modern robust control analysis is avoided, the root locus plot is used nicely to point out the robustness offered by alternating poles and zeros as the result of collocation. Chapter 5 introduces the concept of active damping, again with collocation. Active damping is likely the most commonly used method by structural dynamicists approaching the control problem. However, most try to use simple velocity feedback, which generally fails to produce something more impressive than a standard passive damping treatment. The approach in Chapter 5 clearly points out the benefits of not using simple velocity feedback but incorporating some form of compensation.

Chapter 6 focuses on the active vibration isolation problem, taking the reader all of the way through the basics of single-degree-of-freedom isolation to an introduction to the Stewart Platform for six-degree-of-freedom isolation. Discussions of decentralized control, pointing control, and vehicle suspension in the context of isolation are also presented. Chapter 7 moves away from the author's theme of root locus explanations and introduces the state-space approach and corresponding control methods (including optimal control) and then ties the two approaches together using a four-degree-of-freedom example. This leads naturally to Chapter 8 on analysis and synthesis in the frequency domain. Here classical control methods are introduced and summarized. Chapter 9 extends the optimal control approach introduced in Chapter 7 for single-input, single-output systems to multiple-input, multiple-output systems. Emphasis is appropriately given to results rather than derivations, and these results are applied to structural systems.

Chapter 10 focuses on the concepts of controllability and observability with connection to structural aspects. This chapter ends with the use of controllability and observability to perform model reduction. Chapter 11 examines system stability and concludes with energy-absorbing controllers. Chapter 12 is truly unique and examines semi-active control, largely in the context of magnetorheological fluids. This is particularly timely because of the current use of such systems in automobile suspensions. Chapter 13 focuses on applications and implementation issues, and Chapter 14 examines the specific application of tendon control in cable structures, a class of systems common to civil structures. The book ends with an excellent bibliography.

In summary, the second edition remains a viable and current reference book for structural control. It is a valuable addition to the collection of any researcher concerned with active aerospace structures. This latest edition now has enough problems to be used as a text in a senior-level elective or graduate course. This is a very useful book for graduate students, researchers, and professionals interested in structural control. I highly recommend it.

References

[1]Clark, R. L., Saunders, W. R., and Gibbs, G. P., *Adaptive Structures: Dynamics and Control*, Wiley, New York, 1998.

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[3]Meirovitch, L., *Introduction to Dynamics and Control*, Wiley, New York, 1985.

[4]Inman, D. J., *Vibration with Control Measurement and Stability*, Prentice–Hall, Upper Saddle River, NJ, 1989.

Daniel J. Inman
Virginia Polytechnic Institute and State University