Applied Linear Optimal Control: Examples and Algorithms

Arthur E. Bryson, Cambridge University Press, United Kingdom, 2002, 362 pp., $45.00, ISBN 0 521 01231 7 paperback

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 twelve chapters and two 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, while 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 ten 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 are scattered throughout the text, which are generally given at the end of each section. This allows the reader a chance to test their 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 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 in the book 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, 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.

Since the style of this book involves a learn-by-practice approach, it is not as mathematically rich as the author's classic book of 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, since 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 (revised printing)*, Taylor & Francis, London, 1975.

2. Bryson, A.E., *Dynamic Optimization*, Addison-Wesley, Menlo Park, CA, 1999.

John L. Crassidis
University at Buffalo