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Book Review

Publishers are invited to send two copies of new books for review to Dr. I. Michael Ross, Code: AA/Ro, Department of Aeronautics and Astronautics, U.S. Naval Postgraduate School, 699 Dyer Road, Monterey, CA 93943.

Dynamic Optimization

Arthur E. Bryson, Addison-Wesley Longman, Inc., Menlo Park, CA, 1999, 434 pp., $95.00, ISBN 0-201-36187-6

I was very excited to learn that Bryson had a new book on dynamic optimization as I've learned a great deal from his classic text, *Applied Optimal Control*, written in 1969 with Y.-C. Ho. What's so amazing about the 1969 book (revised and reprinted in 1975) is how current it feels even today. Consider this: The Maximum Principle was formulated in the late 1950s and Pontryagin's text (one of my personal favorites) was published (English edition) in 1962. Just seven years later, the Bryson–Ho book was published, and remains one of the most cited texts in the discipline. In the preface of the book currently being reviewed, Bryson writes that it "updates and extends the first half of *Applied Optimal Control*" (1969 text). "An update and extension of the second half is under preparation . . . ." As there have been some remarkable developments in the field since 1969, it seems quite logical to split and update the 1969 text. This new book is called *Dynamic Optimization*, which is defined in the preface as ". . . the process of determining control and state histories for a dynamic system over a finite time period to minimize a performance index."

The book contains 10 chapters and an appendix on the history of dynamic optimization. The titles of the 10 chapters are the following: 1) Static Optimization, 2) Dynamic Optimization, 3) Dynamic Optimization with Terminal Constraints, 4) Dynamic Optimization with Open Final Time, 5) Linear-Quadratic Terminal Controllers, 6) Linear-Quadratic Regulators, 7) Dynamic Programming, 8) Neighboring Optimum Control, 9) Inequality Constraints, and 10) Singular Optimal Control Problems. The last chapter is very short with most of the theory deleted but contains some new examples, plots, and figures. As indicated by the sequence of chapters, inequality constraints are not discussed until Chapter 9. I was impressed by the breadth of the problems that could be discussed with equality constraints alone. Consequently, the Minimum Principle is not discussed until Chapter 7 but only as a consequence of the Hamilton-Jacobi-Bellman equations. Chapter 8 is probably the most updated section of the book. It contains geometric insights (along with Chapter 7) with useful discussions on convexity—the hallmark of modern analysis. Helpful study material is included in the text as a summary section at the end of each chapter.

Perhaps the most obvious updates in this book are the many new examples and problems, and the increased number of supporting plots and figures. Some of the plots are generously large and easy to read. Bryson's enthusiastic endorsement of MATLAB as a great computational tools is evident by the tight integration of the contents of the book with printouts of m-files: function files, script files, and even diary files. This would be very useful for a student interested in understanding the computer-coding of equations by reading m-files. Some of these m-files do not have adequate comments. Fortunately, a CD-ROM (containing a MATLAB Toolbox called DYNOPT) accompanies the book as well, so one could easily run any one of the codes on a personal computer and play with the parameters of the problem. The list of acronyms and abbreviations given at the beginning of the text is quite invaluable in comprehending the subject. It greatly facilitates understanding the shorthand notation used lavishly through-out the book. For example, on page 81, the meaning of "DVDP for Max Range Using DOP0N" can easily be understood by flipping through pages vii–x: DVDP is listed as Discrete Velocity Direction Programming on page ix and DOP0N is listed on page vii as Discrete Optimization with STCs Using NP. Since it is necessary to use MATLAB's Optimization Toolbox, the nonlinear programming code, CONSTR (Ver. 1.5) is explained at several places, and in some detail (including syntex) in Chapter 1. Unfortunately, CONSTR now (i.e. MATLAB 5.3, Optimization Toolbox 2.0) goes by the name FMINCON with a different syntax. The problem with CONSTR and FMINCON is that they easily converge to inaccurate results and typically generate erroneous Lagrange multipliers. A far better solver is NPSOL which can also be run on the MATLAB environment.

Since this is only a first edition of a new book, some of the typographical errors are quite understandable. However, I was puzzled by some of the new definitions of old ideas. In the preface, the direct shooting method employed in POST (Program to Optimize Simulated Trajectories) is referred to as a collocation technique. Some modern numerical methods such as direct collocation techniques are not discussed "in an effort to limit the size of the book." However, direct solution methods are discussed, which apparently mean solving the necessary conditions of optimality (by, for example, a shooting method). Since this approach is commonly referred to as indirect methods, it can easily lead to confusion, particularly among students. On the other hand, Bryson's difinition of inverse dynamic optimization is probably a more appropriate name for the process of solving a dynamic

optimization problem by converting the dynamics to a differential inclusion.

A majority of the references in this book are those published prior to the 1980s. There is still a lack of a good textbook on dynamic optimization that fills in some of the exciting developments that have taken place in this field since 1969. Some recent exellent papers are those by Betts[1] on numerical techniques and Gamkrelidze[2] on a personal history of the Maximum Principle. The latter paper also gives a wonderful account of the geometry of optimal control. All in all, I was delighted to see so many solved examples and problems in this book. This is useful for an instructor in making an introductory class interesting to a wider student audience. In this context, I recommend a marginal thumbs-up.

References

[1]Betts, J. T., "Survey of Numerical Methods for Trajectory Optimization," *Journal of Guidance, Control, and Dynamics*, Vol. 21, No. 2, 1998, pp. 193–207.

[2]Gamkrelidze, R. V., "Discovery of the Maximum Principle," *Journal of Dynamical and Control Systems*, Vol. 5, No. 4, 1999, pp. 437–451.

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