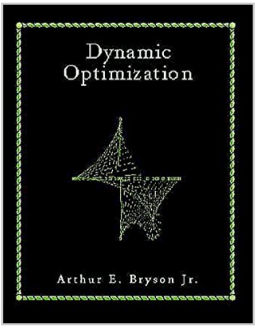

Dynamic Optimization

By Arthur E. Bryson

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Dynamic Optimization takes an applied approach to its subject, offering many examples and solved problems that draw from aerospace, robotics, and mechanics. The abundance of thoroughly tested general algorithms and Matlab codes provide the student with the practice necessary to master this inherently difficult subject, while the realistic engineering problems and examples keep the material interesting and relevant.

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Dynamic Optimization By Arthur E. Bryson Bibliography

- Sales Rank: #2706733 in Books
- Published on: 1998-11-13
- Original language: English
- Number of items: 1
- Dimensions: 9.50" h x 1.00" w x 7.56" l,
- Binding: Hardcover
- 550 pages

Editorial Review

From the Inside Flap

Dynamic optimization is the process of determining control and state histories for a dynamic system over a finite time period to minimize a performance index. There may be constraints on the final states of the system and on the 'in-flight' states and controls. An important special case is when the dynamic system is linear and the performance index is a quadratic functional of the states and controls. The main tools of dynamic optimization are the calculus of variations and dynamic programming. Dynamic optimization is used to determine efficient maneuvers of aircraft, spacecraft, and robots, and in the design of structures where the independent variable is distance along the structure instead of time.

Computational algorithms are developed for solving practical problems and many examples and problems are presented. The algorithms are coded in MATLAB which is a popular software package for engineers interested in dynamics and control. Solutions for the examples and the many problems are provided on a disc that goes with the book. The problems are difficult but doing them is the only way to really learn the subject.

The book starts with a review of parameter optimization (ordinary calculus) and then treats dynamic optimization (the calculus of variations), first with fixed final time and no constraints, then with terminal constraints, and then with terminal constraints and open final time. This is followed by chapters on linear-quadratic problems which are of practical interest in themselves but also develop the theory needed to consider the second variation and neighboring-optimal feedback control. Next is a chapter on dynamic programming, an interesting but not very practical method of nonlinear feedback control, and then a chapter on neighboring-optimal feedback control which is practical. The next to last chapter deals with inequality constraints, first for static systems (nonlinear programming) and then for dynamic systems using inverse dynamic optimization. The last chapter covers singular problems, i. e. problems where the second variation is identically zero for a finite time; these problems occur when the system equations are linear in one or more of the controls. There is an appendix giving a short history of dynamic optimization.

Chapter 5 describes dynamic optimization for linear systems with time-varying feedback gains. With fast computers having large memory storage, this is now an attractive alternative to constant-gain feedback control, since it cuts the time to reach a desired state almost in half. In Chapters 9 and 10 we describe an inverse dynamic optimization method due to Seywald (1994) that uses nonlinear programming software to solve dynamic optimization problems with inequality constraints or singular arcs.

Before the advent of the digital computer (about 1950) only rather simple dynamic optimization problems could be solved (in terms of tabulated functions). Now, with powerful digital computers, numerical solutions can be found for realistic problems. Some current aircraft contain flight management computers that find optimal flight paths in real time and send them to the autopilot for implementation. Digital control is now commonplace, where a digital computer is the logic element in a feedback control system involving sensors and actuators. Spaceflight would not have been possible without digital control. Microprocessors have made it possible to use digital control in cars, home appliances, robots, and even toys.

This book updates and extends the first half of Applied Optimal Control 1. An update and extension of the second half is under preparation with the tentative title "Optimal Control with Uncertainty"; it will deal with optimal linear feedback control in the presence of uncertain inputs and an uncertain dynamic model. In the intervening 29 years the development and spread of personal computers has made it possible to do more interesting problems while learning the subject. Hence this book contains more examples and problems than its predecessor.

The codes presented here were prepared for use on personal computers. Several aerospace companies have developed codes for very large problems which require supercomputers. For example Boeing (Ref. HP) has developed OTIS (Optimal Trajectories by Implicit Simulation) and Lockheed-Martin (Ref. BCS) has developed POST (Program to Optimize Simulated Trajectories) which use collocation techniques with NLP software. Collocation techniques are very effective but are not discussed in this text in an effort to limit the size of the book.

The discrete algorithms presented in Chapters 2 to 4 are largely there for pedagogical reasons since they are simpler and lead into the continuous algorithms. However they also lead into the discrete algorithms for the linear-quadratic problems of Chapters 5 and 6 which are used more than the continuous algorithms in current practice.

I should like to thank Carolyn Edwards for her patient work in putting the text on the computer. Using LATEX I made changes and additions on my personal computer. Special thanks go to Sun Hur Diaz and Paul M. Montgomery for showing me how to use MATLAB to integrate differential equations with ease, and to the Mathworks for creating MATLAB which has made easy work out of things that were very tedious only a few years ago.

Stanford, California
June 1998

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Written with my esteemed colleague Yu-Chi Ho, published in 1969 by the Blaisdell Publishing Co., and reprinted by the Hemisphere Publishing Co. in 1975. Hemisphere later became a member of the Taylor and Francis Group of Bristol, Pa.

From the Back Cover

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FEATURES/BENEFITS

- Covers dynamic programming, relating it to the calculus of variations and optimal control, and neighboring

optimum control (differential dynamic programming), a practical method for nonlinear feedback control.
- Includes a disk that contains 40 gradient and shooting codes, as well as codes that solve the time-varying Riccati equation (the DYNOPT Toolbox). These codes have been thoroughly tested on hundreds of problems.
- Contains many realistic examples and problems. Solutions to the examples and problems, as well as the codes that produce the figures, are included on the accompanying disk.
- Covers dynamic optimization with inequality constraints and singular arcs using inverse dynamic optimization (differential inclusion).

About the Author

Arthur E. Bryson is Pigott Professor of Engineering Emeritus at Stanford University, where he served on the faculty from 1968 to 1994. He has also taught at Harvard and MIT and worked as a research engineer and consultant at Hughes Aircraft and Raytheon. Professor Bryson is a member of the National Academy of Engineering and the National Academy of Sciences. His awards include the IEEE Control Systems Award, the ASME Oldenberger Award, and the AACC Bellman Award. He is an Honorary Fellow of AIAA and an Honorary Member of IEEE. He is the author of 100 papers and three books.

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