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Book Reviews

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Optimal Control Theory for Applications

David G. Hull, Springer-Verlag, 2003, 381 pp., $89.95, ISBN 0387400702

The first chapter of this volume is an overview of the types of problems considered in the rest of the book. Included is a brief discussion of necessary conditions and sufficient conditions. The remaining 20 chapters are divided into three parts: Parameter Optimization (4 chapters), Optimal Control Theory (12 chapters), and Approximate Solutions (4 chapters).

Part I (Parameter Optimization) includes unconstrained, equality-constrained, and inequality-constrained minimization with the use of matrix notation for multivariable problems. In the notation of the book a variable in lowercase roman font can be a scalar, vector, or matrix, and the reader must interpret this in context. Differentials are introduced and used throughout the book. For a function $y(x)$ expressions for higher order differentials such as d^2y are developed with the stipulation that $d(dx)=0$; i.e., differentials of independent differentials are equal to zero.

In Part II (Optimal Control Theory) differentials are used to derive necessary conditions and sufficient conditions for optimal fixed and free final time problems. Also included are free initial time and states, control discontinuities, and path constraints. The last category includes integral constraints, control equality and inequality constraints, and state equality and inequality constraints. In terms of differentials the control $u(t)$ is considered to be the independent variable and the state $x(t)$ the dependent variable. Weak and strong variations are discussed and second-order sufficient conditions are derived, including the Jacobi no-conjugate-point condition. The Jacobi condition is not explicitly termed a second-order necessary condition, but the discussion implies it. The term "optimal path" is used if all first-order necessary conditions are satisfied. Then the statement is made that if the optimal path contains a conjugate point, it is not a minimum.

Part III (Approximate Solutions) covers approximate solutions of algebraic equations, differential equations, optimal control problems, and conversion of optimal control problems into parameter optimization problems. The last category includes a unified discussion of direct shooting, collocation, direct transcription, and differential inclusion methods.

Comparison of this book with the gold standard in aerospace optimal control, *Applied Optimal Control* by Bryson and Ho,[1] is inevitable. By contrast, the examples and problems in the Hull book are primarily mathematical exercises, with a missile guidance example and a few navigation examples. But, of course, the Bryson and Ho engineering examples and problems are still available for use. Unlike in many optimal control books, the Pontryagin minimum principle is not featured but mentioned only briefly with the statement that for bounded controls the first-order optimality conditions plus the Weierstrass condition are equivalent to it. And in Sec. 17.7 the classical minimum time, double-integrator, bounded-control problem is solved using the Weierstrass condition with no mention of the book by Pontryagin et al.[2] in this context.

The author has succeeded in his declared motive for writing this text: treating analytical methods in parameter optimization and optimal control theory using uniform terminology, notation, and methodology by means of differentials. The use of differentials may appeal to some readers and not to others, and some of the terminology is somewhat nonstandard. The text is suitable as an aerospace engineering graduate textbook and a reference book.

References

[1]Bryson, A. E., Jr., and Ho, Y.-C., *Applied Optimal Control*, Hemisphere, Washington, DC, 1975.

[2]Pontryagin, L. S., Boltyanskii, V. G., Gamkrelidze, R. V., and Mishchenko, E. F., *The Mathematical Theory of Optimal Processes*, Interscience, New York, 1962.

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