ChE book reviews

Optimal Control of Engineering Processes

Leon Lapidus and Rein Luus
Blaisdell Publishing Company
Waltham, Mass. (1967)

The field of optimal control of chemical engineering processes is not yet as firmly ensconced in chemical engineering curricula as the optimization of these processes, but promises to develop rapidly. The two areas are, in fact, intertwined, but optimization generally implies steady-state optimal design by best choice of a finite number of parameters, using the methods of linear or non-linear programming, while optimal control involves the choice of a best control function in a continuous (frequently time-dependent) system, or in a discrete staged process. The techniques derive principally from modern extensions of the classical calculus of variations, such as dynamic programming and the Pontryagin maximum principle. The activity in this field has been quite intense in recent years, and the authors have put together an introductory text, primarily for the graduate level, which advisably summarizes this work, including their own. The preface states that the book is suitable for the advanced undergraduate, and indeed nearly all the pertinent mathematics is briefly set forth within the book. Nevertheless, the treatment is quite compact, at times to the point of being difficult to read, and it is likely that the principal use of the text will be on the first or second-year graduate level. In general, however, the style is lucid and forthright, and is welcome for its lack of pretension. Both the beginning and the advanced student of the field will find much of interest in it.

The book begins with a chapter on fundamental definitions and system structures, including a definition of the optimal control problem, the twin concepts of controllability and observability, and stability. The next chapter deals with general mathematical procedures, giving in quick order treatments of dynamic programming, the continuous and the discrete maximum principle, the solution of linearized systems via the adjoint equations, stability analysis by Liapunov's second method, gradient methods and constrained optima, and a cursory treatment of linear and nonlinear programming. Some fairly realistic numerical examples are worked out, and these are used throughout the text to illustrate various aspects of the optimal control problem. An extensive treatment of the optimal control of linear systems with quadratic performance index is given in the next chapter, which is justified, even in chemical engineering, for the illumination it sheds on the non-linear problems which are usually encountered. The next chapter deals with computational methods, to which the senior author has contributed extensively, and deals with a variety of modern techniques, including direct search, gradient methods, and second-variation methods. The last two chapters reflect the special interest of the authors in stability and control of linear and non-linear systems. The use of Liapunov functions for sub-optimal minimum-time control is illustrated.

The most important weakness of the text is the absence of problems or exercises for the student. Granted that the formulation of meaningful problems which can be solved without extensive computer work is difficult in this field, it would nevertheless have been helpful for the student to have had at least a few simple illustrative exercises at the end of each chapter. There are a few other minor flaws, such as the use of a linear formula on p. 166 for a quadratic objective function, and rather poor notation on p. 263 in the explanation of the second variation method, which does not distinguish between total and partial derivatives with respect to the state variables. Nevertheless, the book is remarkably error-free, and contains a great deal of information. It is without question the best book in its field presently available, and will serve as a useful reference for years to come. It should find wide use in optimal control courses on the graduate level both within and without chemical engineering.

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Invitation to Readers

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