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Reviews

RONALD A. HOWARD, *Dynamic Probabilistic Systems, Volume I: Markov Models, Volume II: Semi-Markov and Decision Processes*, John Wiley & Sons, New York, N.Y., 1971, Volume I: 576 pages, \$17.95; Volume II: 543 pages, \$19.95.

THOSE FORTUNATE enough to have read RONALD HOWARD's *Dynamic Programming and Markov Processes* (1960) will approach his *Dynamic Probabilistic Systems* with high expectations. Others interested in Markov decision processes and linear systems will hope to find useful concepts clearly presented. Both groups will be extremely satisfied by the contents of this substantial effort. In the eleven years since his modest early presentation, Professor Howard has produced over 1100 pages, in two volumes, comprising a first rate introduction to many of the topics comprising Markov decision theory. Though a considerable breadth of concepts and techniques is presented, the treatment avoids advanced topics and highly theoretical issues so it must be considered an introductory text. The general level makes it particularly appropriate as an upper class undergraduate or beginning graduate text for systems engineering, operations research, management science, and applied mathematics students. A wide variety of readers, including senior scholars, will find much of interest and value in these volumes.

Volume I contains nine chapters and two appendixes. Chapter I introduces basic ideas of finite Markov chains and the geometric transform (z-transform) method. Two and three state examples are analyzed in detail. State diagrams are discussed, including shrinkage effects. Chapter 2 presents concepts of (signal) flow graphs. Scalar and matrix forms of transform analysis are developed. Linear system theory is discussed for the general reader. Among various topics one finds feedback and matrix inversion by flow graph techniques. In Chapter 3, Howard utilizes the previous chapter's material to treat Markov processes as linear systems, solving various problems by flow graph techniques.

The remaining six chapters of Volume I treat many standard aspects of Markov processes. Chapter 4 considers transient processes with emphasis on one recurrent (trapping) state. The number of transitions until trapped is determined. Flow graphs and modified flow graph methods are used for analysis of small size systems. Utilization of transformed equations, to formulate difference equations for recursive generation of desired results, is stressed as an alternative to inversion. Chapter 5 goes into various statistics of Markov processes. Mean and variance of occupation and first passage times are considered. Asymptotic values are developed. Concepts are illustrated using small size examples. Howard employs congruent matrix multiplication, indicated by a box notation, to advantage as his material becomes increasingly complex. Appendix A discussed properties of congruent multiplication. One can take some issue with Howard's casual remark on page 275 that the central limit theorem can be used for the example under discussion

there. The point is that one does not expect central limit theorems to apply in dependent situations. The significance of Markov's work is that he established limit behavior in cases of (Markov) dependence. An instance of that work is found in Markov's 1907 paper given in translation as Appendix B of Volume I. In addition to the topics already mentioned Chapter 5 contains considerable detailed material including occupancy under random starting, first passage times, pseudo-trapping states, moments of passage times, and a discussion of alternative solution methods.

Chapter 6 gives a detailed discussion of transitions using tagging as a major technique. Classes of transitions and associated statistical properties are studied. Flow graph methods are used to formulate difference equations. Partial knowledge of trajectories is analyzed. One such type of information is when events are known not to occur. Chapter 7 deals with recurrent events and random walks. Howard allows some confusion here between the terms recurrent and renewal. First they are used for the same kind of process, then their meaning becomes slightly different and finally reference is made to recurrent renewal processes on page 381. Birth and death processes and classical ruin problems are treated. Asymptotic results are given. Markovian population models form the subject of Chapter 8. These lead to vector Markov processes. Branching processes are treated for such things as generation size and the probability of extinction. Chapter 9 allows time variation in the Markov process. It develops both forms of Chapman-Kolmogorov equations. Examples study a periodically varying process for limiting values and cycling. Inverse Markov processes are treated in a Bayes' inference formulation.

A brief list of references is given at the end of Volume I. The same list occurs in Volume II. These references are appropriate with the possible exception of Dynkin's *Theory of Markov Processes* which is considerably beyond the level of Howard's book. A useful Notations section and index conclude Volume I.

Volume II begins with three chapters devoted to extending Markov process concepts. Chapter 10 introduces semi-Markov processes. In such processes transitions do not necessarily occur at each transition instant. Those instants at which transitions occur determine an imbedded Markov process. It may be remarked that queuing theory is absent from both volumes but one hardly misses it in the wealth of material that is present. Transform methods and congruent multiplication are utilized to treat many aspects of semi-Markov processes previously discussed for Markov processes. Chapter 11 introduces continuous time semi-Markov processes. The exponential transform is used and has a superficial resemblance to the Laplace transform. However, the complete transform theory for inversion is not discussed and inversion is accomplished by formal reference to transform pairs. Some discussion of theoretical aspects of this transform technique would improve the technical level of the chapter. Many topics, introduced earlier in the book, are discussed for the continuous time case. Chapter 12 continues the discussion for the special case of Markov processes. It includes Chapman-Kolmogorov equations for continuous time and it concludes Howard's development of Markov processes.

The remainder of Volume II deals with decision theory in Markov processes. Chapter 13 is on rewards that are attached to a process at states or to transitions. It provides basic concepts for decision studies. The technique of dynamic programming is presented in Chapter 14 as a tool for optimizing decision making.

Concepts are discussed and illustrated by simple examples. Some fairly involved examples are carried completely through. These give an understanding of how dynamic programming operates and how it can be used in the present class of problems. Chapter 15 is a long final chapter bringing much of the preceding material together for a study of semi-Markov decision processes. It treats process control and decision making. At each state the probability and reward functions are selected from some set (associated with that state). Such selections, made when transitions occur, constitute control on the process. A detailed example (car rental) is used to illustrate concepts and explain solution techniques. Full details are given so that the reader does not become lost in abstract concepts. This is sound exposition since, though the concepts have considerable beauty, it is the details that make dynamic programming techniques work.

Each of the fifteen chapters contains a substantial set of problems. As Howard stresses in his preface these problems form a valuable part of the total exposition. No references are given in the body of the book. One does not feel any lack because of this, since much of the material is in the form of examples and detailed discussion that benefits by being Howard's own exposition. The index to Volume I is for that volume, the index for Volume II is complete. The appendix on congruent multiplication is given in each volume. Both volumes have the same Preface and dedication.

In the Preface Howard plays a trick on his readers by stating that all mistakes in the manuscript have been found and corrected! Of course such a statement can hardly be challenged but it should motivate many to search for errors in the text. As (subjective) probability dictates there are some (e.g., on pages 104, 200, 201, 204, and 278). However, errors seem to be extremely few in number and relatively unimportant in content. The printing of equations, textual material, and illustrations is of high quality as befits Ronald Howard's outstanding presentation.

CLIFFORD MARSHALL

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HAMDY A. TAHA, *Operations Research: An Introduction*, The Macmillan Company, New York, N.Y., 1971, 703 pages, \$14.95.

THIS IS A very noteworthy introduction to the basic techniques of operations research. The author's style is very lucid, the examples are well chosen, and every idea is presented in a careful and precise modular form.

In the first seven chapters, the fundamental notions of linear programming, game theory, networks, and dynamic programming are presented with clear examples, but with little emphasis on the theory. Although this reviewer generally disapproves of teaching by examples, in the present volume the latter are so well chosen that each example makes a contribution to one's intuition regarding the general problem.

The first seven chapters could very well serve as the text for a sophomore-junior course in operations research of finite mathematics.

The theory of linear programming in Chapter 8 is superbly presented at the level of this book. One aspect in particular is commendable. The minor varia-

tions of the simplex method are presented as such. The inexperienced reader will not be misled into believing that all these are fundamentally different algorithms in spite of the profusion of names from which this particular area of programming suffers.

The remaining three chapters of part I deal with parametric programming, integer programming, and critical path analysis.

The second part of the book treats probabilistic models. Although the treatment is better than that in most comparable texts, the presentation of basic ideas is not on a par with that of part I. The treatment is generally more technical and there is the usual profusion of special distributions, special models with little emphasis on why they can be analyzed, and above all the dozens of acronyms and profuse terminology from which queuing, and to a lesser extent, inventory theory suffer.

As an example, the distinction of a stable versus an unstable queue is practically lacking. The student may well come away with the misconception that somehow only ergodic queues in steady state are worthy of his attention.

This reviewer would have preferred to see such notions as traffic intensity, build-up time, and so on, discussed in greater detail.

The latter part, dealing with nonlinear programming, is obviously not intended to be a thorough treatment of this subject. It is rather a collection of examples and intuitive discussions of special algorithms. The reader who has mastered the book up to this point should find himself encouraged and well-prepared to tackle more advanced material.

There is a large collection of problems. Most of these are fairly elementary and are direct applications of the immediately preceding text material. An occasional exercise is ambiguously stated, but in general the choice and presentation of the problems is adequate for a volume of this type.

In summary, this book is a fine addition to the collection of texts on operations research. Both the author and the publisher are to be commended for a job well done.

MARCEL F. NEUTS
Purdue University

A. GHOSAL, *Elements of Operational Research*, Hindustan Publishing Co., New Delhi, India, 1969, 207 pages, \$8.00.

THE CHIEF virtue of this introductory text is its brevity; with 207 small pages, it weighs in at about 10 percent of Wagner's excellent *Principles of Operations Research* (Prentice-Hall, 1969). In seven chapters, the author—a member of the Council of Scientific and Industrial Research in New Delhi—introduces operational research and discusses aspects of linear programming, inventory, replacement, simulation, queuing, and managerial economics.

Linear programming is the subject of the weakest chapter, which the author credits to an associate: the presentation lacks sufficient precision and clarity. For example, a basic feasible solution is defined as a feasible solution with no more than m positive components; it is called nondegenerate if exactly m components are

positive, where m is the number of constraints. The term "basic variable" is used but not defined, with the context implying that it is a synonym for "slack variable." Duality is discussed, but not complementarity.

The inventory chapter treats deterministic lot size and periodic review models, a stochastic model with fixed ordering cost and no shortage cost, and another with no ordering cost but linear holding and shortage costs. The (s,S) policy is defined but is not identified as optimal for any class of problems. Dam models, with deterministic demand but random supply, are also considered. Replacement models are dealt with from several points of view, using actuarial, dynamic programming, renewal, and discounted cash flow methods. The approaches are not compared, and no synthesis is attempted.

The chapter on simulation emphasizes simple cases in which hand calculations can be carried out with the aid of the random number tables provided. Methods are given for converting uniform random numbers to variates with a given distribution. There is no discussion of the statistical problems associated with validating simulation results. Computerized simulation is covered briefly without mention of simulation languages or random number generation.

Under the heading of "Problems of Congestion" the steady-state waiting time and queue length distribution for the $M/M/1$ queue are derived; the case of limited waiting space is also treated. Results are given generally without proof, for $M/M/s$ and $M/E_k/1$ systems, and simulation is proposed for more complicated situations. The final chapter contains some straightforward observations on discounted cash flow computations and cost benefit analysis, and recapitulates an exposition of the Markowitz portfolio analysis.

A number of examples are worked and additional ones are presented as problems—some fairly challenging, but with ample hints. The level of background expected of students is uncertain: an appendix is included that defines vector and matrix operations (but not inverse matrices or linear independence) but the text assumes a good working knowledge of probability. Some simple facts (e.g., compound interest) are derived at length, while more difficult steps (e.g., inverting a $GI/M/1$ waiting time transform) are taken for granted.

In general, there is a reasonable proportion of text to equations and the book reads well. It might serve as a quick, selective introduction to the field for a mathematically inclined general reader.

MARK EISNER
Cornell University

Books Received

- DAVID A. AAKER, *Multivariate Analysis in Marketing*, Wadsworth Publishing Company, Belmont, Cal., 1971, 358 Pages (paper).
 D. W. BARRON, *Computer Operating Systems*, Chapman and Hall, London, England, 1971, 135 pages, \$6.50.
 K. BAUKNECHT AND W. NEF, editors, *Digital Simulation*, Springer-Verlag, New York, N.Y., 1971, 207 pages, \$5.20 (paper).
 M. BECKMANN, editor, *Unternehmensforschung Heute*, Springer-Verlag, New York, N.Y., 1971, 133 pages, \$4.60 (paper).

- R. BELLMAN AND E. D. DENMAN, editors, *Invariant Imbedding*, Springer-Verlag, New York, N.Y., 1971, 148 pages, \$4.60 (paper).
- G. BRUCKMANN AND W. WEBER, editors, *Contributions to the Von Neumann Growth Model*, Springer-Verlag, New York, N.Y., 1971, 216 pages, \$25.80.
- R. F. BYRNE, A. CHARNES, W. W. COOPER, O. A. DAVIS, AND DOROTHY GILFORD, editors, *Studies in Budgeting*, North Holland/American Elsevier Publishing Co., New York, N.Y., 1971, 392 pages, \$24.95.
- MARVIN J. CETRON AND CHRISTINE A. RALPH, *Industrial Applications of Technological Forecasting*, John Wiley & Sons, New York, N.Y., 1971, 563 pages, \$24.95.
- NED CHAPIN, *Computers—A Systems Approach*, Van Nostrand-Reinhold Co., New York, N.Y., 1971, 686 pages, \$13.95.
- R. DUBUC, M. GRATTON, G. LAMBERT-CAREZ, L. ROY, AND A. SHAPIRO, *Dictionnaire Anglais-Français/Français-Anglais de L'Informatique*, Dunod, Paris, France, 1971, 228 pages, 24 French francs (paper).
- AVNER FRIEDMAN, *Differential Games*, John Wiley & Sons, New York, N.Y., 1971, 350 pages, \$17.50.
- JOHN J. FRUIN, *Pedestrian Planning and Design*, Metropolitan Association of Urban Designers and Environmental Planners, New York, N.Y., 1971, 206 pages (paper).
- BELLA GOLD, *Explorations in Managerial Economics*, Basic Books, New York, N.Y., 1971, 297 pages, \$8.95.
- IRWIN GUTTMAN, S. S. WILKS, AND J. STUART HUNTER, *Introductory Engineering Statistics*, John Wiley & Sons, New York, N.Y., 1971, 548 pages, \$13.95.
- D. W. KING AND E. C. BRYANT, *The Evaluation of Information Services and Products*, Information Resources Press, Washington, D.C., 1971, 306 pages, \$15.00.
- DAVID H. KRANTZ, R. DUNCAN LUCE, PATRICK SUPPES, AND AMOS TVERSKY, *Foundations of Measurement, Volume I: Additive and Polynomial Representations*, Academic Press, New York, N.Y., 1971, 577 pages, \$16.50.
- CHARLES H. KRIEBEL, RICHARD L. VAN HORN, AND J. TIMOTHY HEAMES, editors, *Management Information Systems: Progress and Perspectives*, Graduate School of Industrial Administration, Carnegie-Mellon University, Pittsburgh, Pa., 1971, 497 pages (paper).
- CHARLES LUNA, *The UTU Handbook of Transportation in America*, Popular Library, New York, N.Y., 1971, 282 pages, \$1.25 (paper).
- BERNARD M. OLIVER AND JOHN M. CAGE, *Electronic Measurements and Instrumentation*, McGraw-Hill, New York, N.Y., 1971, 729 pages, \$29.50.
- DONALD R. PLANE AND CLAUDE McMILLAN, JR., *Integer Programming and Network Analysis for Management Decisions*, Prentice-Hall, Englewood Cliffs, N.J., 1971, 251 pages, \$13.50.
- C. RADHAKRISHNA RAO AND SUJIT KUMAR MITRA, *Generalized Inverse of Matrices and its Applications*, John Wiley & Sons, New York, N.Y., 1971, 240 pages, \$13.95.
- ROBERT ROGERS, *Mathematical Logic and Formalized Theories*, North Holland/American Elsevier Publishing Co., New York, N.Y., 1971, 235 pages, \$17.25 (\$8.95 in paper).
- RICHARD S. ROSENBLUM AND JOHN R. RUSSELL, *New Tools for Urban Management*, Harvard Business School, Boston, Mass., 1971, 298 pages, \$8.00.

- J. ROSENMÜLLER, *Kooperative Spiele und Märkte*, Springer-Verlag, New York, N.Y., 1971, 152 pages, \$4.60 (paper).
- CH. SCHNEEWEISS, *Regelungstechnische Stochastische Optimierungsverfahren*, Springer-Verlag, New York, N.Y., 1971, 254 pages, \$6.40 (paper).
- GRACE M. TAHER, editor, *University Urban Research Centers*, 2nd edition, The Urban Institute, Washington, D.C., 1971, 299 pages, \$2.75 (paper).
- T. TAKAYAMA AND G. G. JUDGE, *Spatial and Temporal Price and Allocation Models*, North Holland Publishing Co., Amsterdam, The Netherlands, 1971, 528 pages, \$24.50.
- WILHELM H. WACKER, *Betriebswirtschaftliche Informationstheorie*, Westdeutscher Verlag, Opladen, West Germany, 1971, 302 pages (paper).

Notes

THE NEW journal *Mathematical Programming*, published bi-monthly by the North-Holland Publishing Company in Amsterdam, recently produced its first issue. The Editor-in-Chief is MICHEL BALINSKI, P.O. Box 2070, Princeton, N.J. 08540. The following articles appear in Volume 1, Number 1:

- M. HELD AND R. M. KARP, "The Travelling-salesman Problem and Minimum Spanning Trees: Part II."
- M. J. D. POWELL, "Recent Advances in Unconstrained Optimization."
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P. D. WILMOT, "A Comparison of the Methods for Technological Forecasting."
RUDOLPH LEWANDOWSKI, "INCOM—A General System for Medium and Long
Range Forecasting."

The Society for Industrial and Applied Mathematics (SIAM) has initiated a "Regional Conference Series in Applied Mathematics." It is described as "a series of lectures on topics of current research interest in applied mathematics under the direction of the Conference Board of the Mathematical Sciences, supported by the National Science Foundation and published by SIAM." The first three issues are:

GARRETT BIRKHOFF, *The Numerical Solution of Elliptic Equations*, 82 pages (paper).

D. V. LINDLEY, *Bayesian Statistics, A Review*, 83 pages (paper).

R. S. VARGA, *Functional Analysis and Approximation Theory in Numerical Analysis*, 76 pages (paper).

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