$\Phi(\omega) - \Phi(i)$ will maximize the value to B. One measure of this difference is related to the dimension of these input and output vectors as noted above. Other measures may be related to the cost of collecting certain types of data. The model is valuable if it has the property that a relatively small quantity of data produces much useful output.

The many questions concerning a meaningful definition and examples of $\Phi(\cdot)$ are fertile areas for future work. This work is necessary to provide guidelines for model evaluation.

There is one other small point which might be mentioned here. It relates to B's plan for his newly purchased model. B is aware, of course, that the model validity and value will be more questionable as $t - t_0$ increases. Therefore, it is likely that he will not use the model for the full N-year period. After N/K years pass (for $K > 1$) he will again be in the market for a model.

VII. Summary

In this paper a new approach has been suggested for examining model credibility. It has been noted that both validity and value enter into these considerations, and a buyer/seller scenario has formed the basis for defining and exploring these concepts. Questions of ethics are not considered here. We must assume that validity is a virtue. This excludes the possibility that a buyer would select an invalid model simply because it might be useful in supporting his argument. It is clear that much serious work must still be done in order to more sharply distinguish between models and their appropriate applications. The present paper purports to offer some direction in this matter.

Acknowledgment

Some of the ideas contained in this paper were brought into focus by the author's participation in a National Science Foundation sponsored Workshop on Modeling Large-Scale Systems at National and Regional Levels. The final report of this workshop is [10] of the present paper.

References

[1] D. Meadows *et al.*, *The Limits to Growth*. New York: Universe Books, 1972.
[2] M. Mesarovic and E. Pestel, *Mankind at the Turning Point*. New York: E. P. Dutton, 1974.
[3] J. Forrester, *Industrial Dynamics*. Cambridge, Mass.: MIT Press, 1969.
[4] ——, *Urban Dynamics*. Cambridge, Mass.: MIT Press, 1969.
[5] ——, *World Dynamics*. Cambridge, Mass.: MIT Press, 1972.
[6] *A Guide to Models in Governmental Planning and Operations*, U.S. Environmental Protection Agency, Washington, D.C., Aug. 1974.
[7] H. Kwakernaak and R. Sivan, *Linear Optimal Control Systems*. New York: Wiley-Interscience, 1972.
[8] M. Aoki, "Control of large-scale dynamic systems by aggregation," *IEEE Trans. Automat. Contr.*, vol. AC-13, no. 3, pp. 246–253, June 1968.
[9] S. Kahne, "A contribution to decision making in environmental design," *Proceedings IEEE*, vol. 63, no. 3, pp. 518–528, March 1975.
[10] H. Chestnut and T. B. Sheridan, "Final report of NSF Workshop on modeling large scale systems at national and regional levels," Washington, D.C., February 1975
[11] J. Warfield, "Toward interpretation of complex structural models," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-4, no. 5, pp. 405–417, Sept. 1974.
[12] M. G. Reggiani and F. E. Marchette, "On assessing model accuracy," *IEEE Trans. Syst., Man, Cybern.*, vol. SMC-5, no. 3, pp. 322–330, May 1975.
[13] G. A. Mihram, "Some practical aspects of the verification and validation of simulation models," *Op. Res. Q.*, vol. 23, pp. 17–29, 1972.
[14] G. S. Fishman and P. J. Kiviat, "The statistics of discrete-event simulation," *Simulation*, vol. 10, p. 185.

Book Reviews

Syntactic Methods in Pattern Recognition—King-Sun Fu (New York: Academic, 1974, 397 pp.). *Reviewed by Mark A. Aizerman, Institute of Control Sciences, Moscow, USSR.*

In addition to the methods of pattern recognition based on applications of decision rules which are widely described in the scientific literature, recent years have seen more frequent applications of the methods based on the description of pattern classes and on the linguistic analysis of such descriptions. This linguistic (or, as it is sometimes called, structural) approach is related to the application of another mathematical apparatus which leads to a principally different construction of pattern recognition programs, and sometimes even to a cardinal change in the character of the material presented for recognition. The scientific literature devoted to the development of this method is so broad that there are even special journals such as *Computer Graphics and Image Processing*, which consider different aspects of this method. The engineers interested in the problems of pattern recognition were faced with a drastic change: the new method required new mathematical apparatus which was not appropriate for the old body of ideas in this area. The mathematical basis of the new method is the theory of algorithms and formal grammars which originated in the work of Chomsky and which now has its own wide literature. The need for such reeducation has created a necessity for the publication of a monograph devoted specifically to the structural approach to the problems of pattern recognition. It would contain, on one hand, sufficient elementary exposition of the necessary mathematical apparatus, and on the other hand, a description of the corresponding algorithms and all the new problems that arise with the structural approach. This book by Professor Fu is the first attempt to write such a monograph. Published in the well-known series, *Mathematics in Science and Engineering* and edited by Professor R. Bellman, this book is undoubtedly a success.

In a small volume, using simple material, this book easily introduces the reader to this new body of ideas in pattern recognition and makes him familiar with the elementary foundations of the theory of formal grammars and its application to the problems of pattern recognition. The book has seven chapters, and it contains nine small appendices.

Chapter 1 defines basic concepts, explains principal ideas of the structural approach to pattern recognition, briefly presents a technique for the preprocessing of a pattern (image) in order to obtain its automatic description, and shows partitioning of a pattern (image) into its parts. It also discusses the relationships between the structural approach and the traditional approach which dominated the theory of pattern recognition and was related to the construction of decision rules.

Chapter 2 discusses the questions concerning the general theory of formal grammars in the spirit of Chomsky's work and its relationship to the theory of finite automata, turing machines, and intermediate

This review was originally published in the Russian Language review magazine *New Books Abroad* and is reprinted with the kind permission of Professor Mark A. Aizerman. Review translated by Z. J. Nikolic.

abstract models. In particular, it considers context-free grammars and their relationships to automata.

Chapter 3 describes more specific formal grammars which are appropriate for description of patterns (images). This chapter starts with an analysis of the methods for extracting primitive elements of a pattern (image) which can be further considered as the letters of a language. These letters can be used to describe the patterns (images) using certain grammatical rules. In particular, the questions of using semantic information about a pattern (image) and its parts are discussed. As a result, the patterns (images) from a certain class are compared with an empirically formed description. The problem is to decipher such a description, i.e., to find an answer to the following questions: Is this new description close to any other previous description, and to which pattern class does this new pattern belong?

Chapter 4, "Syntactic Analysis of the Recognition Process," is devoted to this body of ideas. Two processes of syntactic search along the description graphs are discussed in detail. One of them is connected with climbing the tree of the graph toward the top from the lower branches, and the other, conversely, with descending the tree from the top toward its lower branches. A special paragraph is devoted to the syntactic analysis of descriptions in a context-free language.

In Chapter 5, the subjects are the theory of stochastic languages and statistical methods of syntactic analysis. It is correct to assume that syntactic methods of structural description are most adequate for the linguistic approach to pattern recognition, and considering that they are relatively little known, the author gives them special attention. Chapter 5 gives a sufficiently detailed introduction to the basic concepts connected with the construction of stochastic grammars and their relationships with probabilistic automata.

Simple grammars are related to finite automata or their natural generalization, and similarly, stochastic grammars are related to stochastic automata and their generalizations. A special paragraph in Chapter 5 is devoted to these questions. The main result is the development of stochastic analogs of different languages of Chomsky's type which are between finite automatic languages and such general languages as the language of recursive descriptions.

In the same chapter, a special paragraph is devoted to syntactic analysis of stochastic description in the solution of pattern recognition problems and to the relationship of this class of methods to the ordinary stochastic methods of constructing decision rules. As in the preceding chapters, the presented material leads to a construction of block diagrams of the computer programs for such structural analysis.

Chapter 5 is closely connected to Chapter 6 in which the material of the general theory of stochastic languages is used for the construction of a structural description of visual patterns (images). In addition to the general methods, this chapter also provides some interesting examples of the analysis of stochastic descriptions of such images as handwritten numerals or simple geometric figures.

The small Chapter 7, which concludes the basic text, is the most interesting since it poses a question concerning the possibility of constructing grammatical descriptions using examples presented by a "teacher" and not on the basis of *a priori* defined grammatical rules of the language given to the computer program. In other words, the problem of automatic generation of grammars from a certain set of descriptions in the language with this grammar is posed. Linguistic approaches which permit, in certain cases, the solution of this difficult problem are pointed out.

The appendices contain examples of the application of the structural approach to the description of different pattern classes: chromosomes, handwritten Fortran symbols, Chinese characters, and in one of the appendices there is a discussion of the possibility of using the same ideas in speech recognition. One part of the appendices is used to inform the reader about certain details of concrete languages and grammars.

This is a unique monograph. The reviewer does not know of any other book, either in Russian or in any other foreign language, which attempts, in a small volume, on a level accessible to the applied mathematician or engineer, and on the basis of sufficiently rigorous material, to "lead" readers into this new and interesting area. This book is undoubtedly very useful, and its translation into Russian would be very timely.

Einführung in die Grundlagen der mathematischen Statistik (Introduction to the Fundamentals of Mathematical Statistics)—V. Fetzer (Heidelberg: Dr. Alfred Hüthig Verlag, 1973, 155 pp., UTB Band 261). *Reviewed by George M. Siouris, Aerospace Guidance and Metrology Center, Newark Air Force Station, Newark OH 43055.*

Statistics plays an important role in practically every aspect of modern life. It spans a wide spectrum of disciplines, such as communications theory, the space sciences, economics, etc., to name a few. The purpose of the present text is to introduce to the student, in a compact manner, the principal problems of mathematical statistics. Completeness in covering the material presented has not been attempted; an effort has been made, however, on a sufficiently broad basis, to provide the student with the tools for solving some of the many other statistical problems. Moreover, the outline format in which this text is written serves as a useful reference for the busy engineer.

The text contains nine chapters. After an introductory chapter, Chapter 2 begins with a discussion of frequency distribution. Chapter 3 deals with arithmetic and harmonic mean, variance, mean error, mean error of the standard deviation, and skewness. Chapter 4 is devoted to probability. In this chapter the reader will find the usual topics of the laws of probability, addition and multiplication of events, conditional probability, and random variables. Chapter 5 is concerned with probability distributions and covers the general distribution function, mean value, and variance of the distribution. The material presented is illustrated by examples. In Chapter 6 the author treats special distributions, divided into discrete and continuous distributions. The applications-oriented reader will find this chapter especially interesting. Among the distributions treated are the binomial, Poisson, hypergeometric, normal, t, Rayleigh, chi-square, and lognormal distributions. For most distributions, graphical representation and tables of values are given. Several examples illustrate the application of the various distributions.

Chapter 7 presents a short discussion of confidence limits. Chapters 8 and 9 give a succinct yet excellent description of linear regression theory and linear correlation. The book concludes with a summary of the most important formulas. In summary, this text is useful for self-study or for use as a reference for those engaged in the application of statistical theory.

Systems Theory (in Italian)—S. Rinaldi (Milano, Italy: CLUP and Hoppli, 1974, 490 pp.). *Reviewed by Thomas J. Higgins, Department of Electrical and Computer Engineering, University of Wisconsin, Madison, WI 53706.*

This book of nine chapters, written by a well-known Italian systems researcher at the Centro Teoria dei Sistemi, Via Ponzio 3415, Milano, Italy, is an introductory systems text, suitable for Master's-level course work. The essential content, as summarized by chapters, is as follows.

1. Definitions, properties and problems: This is an introductory chapter containing abstract definitions of dynamical systems (internal and external); definition of motion, trajectory, equilibrium, reachability, equivalence classes, control law, and state estimation; definition of important classes of systems such as automata, continuous systems, discrete systems, and linear systems. This chapter is 75 pages long and can be considered as a booklet in the book. It is quite suitable for teaching a very short ($\simeq$ 30 hours) introductory but general course on dynamical systems theory.

2. Stability of the equilibrium; 3. Linearization and stability of linear systems; 4. Stability in the large: These three chapters contain the main results of classical stability theory. The presentation is focused on