observations already taken and stored in a memory. The memory for sequential processes leading to closed stopping boundaries (Fu and Chien[5],[6]) is only required to store the observations y_i, y_{i+1}, $\dots$, y_{i+N} where N is the maximum length of observation sequence allowed by the stopping rule.

A. V. CAMERON
Dept. of Elec. Engrg.
Monash University
Clayton, Victoria
Australia

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Book Reviews

THOMAS M. COVER, BOOK REVIEWS EDITOR
ERL 231, Stanford University, Stanford, Calif. 94305

Computation: Finite and Infinite Machines, Marvin Minsky—*Prentice-Hall, Englewood Cliffs, N. J., 1967; 317 + xvii pages.*

This is a beautifully written and produced introduction to finite automata, Turing machines, Post symbol-manipulation systems, and related topics in computability. It is so written as to be understood by a bright high school mathematics student and it will probably be the chosen text for undergraduate introductory courses on automata theory. Although it is too leisurely for graduate courses, it will surely be required for background reading. The experienced automata theorist will learn nothing new except for some elegant proofs, and may occasionally be frustrated when Minsky stops short when a little extra work would have yielded some important result. Anyone who wishes to have a few pleasant evenings acquiring the basic concepts of deterministic computation theory will find no better book than Minsky's.

Part 1 introduces the notion of state for computing devices, shows that any finite-state device can be built up from simple neurons such as the McCulloch–Pitt neuron, and gives the Kleene theorem that characterizes those sets of tapes which can be recognized by a finite automaton. However, there is one mistake here. On page 79 the set of sequences recognized by a machine M should be those which lead one from an initial state to any one of a *Collection* of final states—not to a single final state. This part is characterized by a lavish and most helpful use of network diagrams.

Part 2 discusses the notion of an effective procedure and introduces Turing machines as devices for implementing such procedures. A very clear construction is given of a universal Turing machine, i.e., one which can simulate any other Turing machine. The fact that no Turing machine can solve the Halting problem (i.e., tell from the description of another Turing Machine whether or not it will halt) is used to establish the limitations of effective computability. Rather than use an enumeration of Turing machines, Minsky operates on the strings of symbols which describe the different machines. The discussion of computable real numbers includes describable numbers and repeats, among others, the enjoyable observation that Fermat's last theorem cannot be proved unsolvable unless, in fact, it is true. Chapter 10 introduces the notion of a recursive function and shows that a function is partial recursive if it can be computed by a Turing machine. Later chapters prove the converse via a number of intermediate machines. A useful table on page 215 lists the relationships among different notions of computability, and the locations in the book where the proofs may be found. My only criticism of this discussion is that the reader is not told that functions may be partial (i.e., not always defined) in Chapter 7 when the possibility first arises. Instead he must wait until Chapter 10; certain constructions would have been improved by explicit discussion of the case where the functions involved are partial. Chapter 11 shows that any Turing machine can be simulated by programmed machines even if they are so restricted that the programming unit can only discern whether or not a register is empty, and not what it contains. Minsky's approach in this chapter is similar to that of Shepherdson and Sturgis,[1] and explicit mention should have been made of this fact. The reviewer also noted that no reference was made to his *Brains, Machines and Mathematics* even though such a reference was appropriate in several places in the text. Similarly, the bibliography which was designed to guide the student in future reading, inexplicably omits many standard texts such as Harrison's *Introduction to Switching and Automata Theory* and Hartmanis & Stearns' *Algebraic Structure Theory of Sequential Machines*, to mention but two. One final criticism of this section of the book—and I stress that all such criticism is meant to be mild, and not to detract from what is a beautiful exposition—is that no mention is made of recursive or recursively enumerable sets.

Part 3 introduces Post's symbol-manipulation systems and gives Minsky's elegant but hitherto unpublished proof of Post's theorem: any Post system may be reduced to normal form in which the only string manipulation allowed consists of reading an initial part of the string, deleting it, and inserting a new string at the end depending only on the string deleted. The final chapter is devoted to what Minsky describes on page 112 as his "avocation—the collection of very small 'universal bases' for the assembly of structures which realize the full range of behavior." Giving the proofs due to himself and to J. Cocke that there are universal program machines with one

[1] Shepherdson and Sturgis, "Computability of Recursive Functions," *J. Assoc. Comp. Machinery*, vol. 10, p. 217–255, 1963.

register, universal machines with two tapes that cannot write, and universal nonerasing Turing machines, he uses these results to prove his famous theorem that any Turing machine can be simulated by a "tag" system (a Post normal system in which the initial strings to be deleted are all of the same length and the new string to be added depends only on the first letter of the deleted string), and to present a 4-symbol 7-state universal machine.

The book is rounded out by a collection of solutions to selected problems, a descriptor-indexed bibliography, and an index which includes a glossary of key terms.

Michael A. Arbib—ERL 233b
Stanford University
Stanford, Calif. 94305

BOOKS RECEIVED

Compiled by Thomas Cover

ESP in Life and Lab: Tracing Hidden Channels, Louisa E. Rhine *(275 pages)—Macmillan, New York, N. Y., $5.95.*

Finite Graphs and Networks: An Introduction with Applications, Robert G. Busacker and Thomas L. Saaty *(294 pages)—McGraw-Hill, New York, N. Y., $11.50.*

Human Information Processing, Harold M. Schroder, Michael J. Driver, and Siegfried Streufert *(224 pages)—Holt, Rinehart and Winston, New York, N. Y., $7.95.*

Information, A Scientific American book *(318 pages)—W. H. Freeman and Company, San Francisco, Calif., $5.00 Clothbound, $2.50 Paperbound.*

Information Theory, Statistical Decision Functions, Random Processes: Transactions of the Fourth Prague Conference *(725 pages)—Academia Publishing House, Prague, Czechoslovakia, 98 Czech Crowns.*

Intonation, Perception, and Language, Philip Lieberman *(210 pages)—The M.I.T. Press, Cambridge, Mass., $10.00.*

Linear Sequential Circuits: Analysis, Synthesis, and Applications, Arthur Gill *(215 pages)—McGraw-Hill, New York, New York, $14.50.*

Methods of Signal and System Analysis, George R. Cooper and Clare D. McGillem *(432 pages)—Holt, Rinehart and Winston, New York, N. Y., $11.95.*

Modern Communication Principles: With Application to Digital Signaling, Seymour Stein and J. Jay Jones *(382 pages)—McGraw-Hill, New York, N. Y., $15.00.*

Probability in Communication Engineering, Petr Beckmann *(511 pages)—Harcourt, Brace & World, New York, N. Y., $13.75.*

Quantum Theory and Reality, Mario Bunge, *(117 pages)—Springer-Verlag, New York, N. Y., $7.40.*

Residue Arithmetic and Its Applications to Computer Technology, Nicholas S. Szabo and Richard I. Tanaka *(236 pages)—McGraw-Hill, New York, N. Y., $12.50.*

A Seminar on Graph Theory, Frank Harary *(116 pages)—Holt, Rinehart, and Winston, New York, $5.95.*

Switching Circuits for Engineers (Second Edition), Mitchell P. Marcus *(338 pages)—Prentice-Hall, Englewood Cliffs, N. J., $12.00.*