of T. O. Ellis & W. I. Sibley ("On the Problem of Directness in Computer Graphics") and of R. Resch ("Experimental Structures"), but these, of course, have not been reproduced in the book. The article corresponding to the first of these presentations suffers particularly from this omission.

Several of the papers contain too much detail peculiar to their respective technical specialties to be easily understood by the layman. Included in this category are the papers by D. L. Bitzer & H. G. Slottow ("The Plasma Display Tube—A New Device for Direct Display of Graphics"), M. Faiman ("ARTRIX—A Hybrid Graphical Processor"), C. Levinthal, C. D. Barry, S. A. Ward & M. Zwick ("Computer Graphics in Macromolecular Chemistry"), and B. Herzog ("Computer Graphics for Designers").

In addition to the previously mentioned paper of Knowlton, this reviewer found particularly interesting and informative the papers of C. Levinthal et al., R. Resch, W. F. Miller & A. C. Shaw ("A Picture Calculus"), S. H. Chasen ("Experience in the Application of Interactive Graphics"), C. W. Beilfuss ("Automated Graphics in an Industrial Environment"), and W. A. Fetter ("Computer Graphics").

Levinthal and his associates describe a project for graphical display with simulated manipulation and rearrangement of molecular models by a computer, with the objective of freeing the investigator of molecular structures from the constraints imposed by physical models.

Resch discusses the use of a computer graphic console in the design of three-dimensional geometric structures.

Miller and Shaw attempt to analyze and synthesize "artificial pictures" (i.e., well-defined or structured pictures) by means of a "picture calculus."

Chasen describes the use of computer graphics in the aircraft design process.

Beilfuss discusses problems involved in an attempt to make computer graphics feasible and economical in the preparation of structural steel shop drawings.

In the concluding paper, Fetter describes the application of computer graphics to the choice of location of radar stations for air traffic control by plotting the radar visibility of aircraft and to the drawing of animated human figures.

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62 [13.35].—Michael A. Arbib, *Theories of Abstract Automata*, Prentice-Hall, Inc., Englewood Cliffs, N. J., 1969, xiii + 412 pp., 24 cm. Price $14.95.

The aim of this book is to provide an advanced textbook for graduate study in automata theory. Its scope and depth attest to this purpose. The book is divided into three sections: I. Background, II. An Introduction to Automata Theory, III. Selected Topics.

The background section contains the motivation and mathematical preliminaries for studying automata theory. The author states that "automata theory is the pure mathematics of computer science" by which he further interprets as meaning "automata theory is a branch of mathematics ... asking questions about biological and electronic computers." The mathematical preliminaries are appropriately terse and provide the reader an adequate refreshing of definitions and results needed to understand the remainder of the book.

Part II contains finite automata theory, Turing Machine computability and Post systems. Finite automata are given the most detailed treatment and include the author's view of a *system* of which an automata is a special case. The Winograd [1], [2] and Spira [3] results on minimum computation time and the Minsky and Papert [4] results on perceptrons are featured topics exhibiting a main theme throughout the book, namely, to illustrate the power and complexity of computational systems. The Turing Machine chapter includes the demonstrations of equivalence of multi-head multi-tape TMs to ordinary TMs. The final chapter of this section covers Post systems and includes the theory of phrase-structure grammars with emphasis on CF languages.

The last section of chapters are the author's candidates for important research areas. A preliminary section introduces some recursive function theory, and then computational complexity, algebraic decomposition theory, stochastic automata, and self-reproducing automata are given a chapter. The treatment of the existence of a universal self-reproducing automata [5], [6] follows the author's own [7] module design which while more complex than von Neumann's leads to sizable reduction in the construction of the universal constructor automata.

No other automata theory text has such a broad scope and while this is the book's main strength, it is also its main weakness. It is very difficult to give a fluid insightful treatment to so many topics. Invariably, one must paraphrase and condense from previous sources losing their original elegance. An example of this is some of the results on threshold functions which can be found in *Perceptrons* [4]. The instructor armed with the book's excellent bibliography can, where necessary, flesh out the text treatment and make good use of its organization.

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1. S. WINOGRAD, "On the time required to perform addition," *J. Assoc. Comput. Mach.*, v. 12, 1965, pp. 277–285.

2. S. WINOGRAD, "On the time required to perform multiplication," *J. Assoc. Comput. Mach.*, v. 14, 1967, pp. 793–802.

3. P. M. SPIRA, "The time required for group multiplication," *J. Assoc. Comput. Mach.*, v. 16, 1969, pp. 235–243.

4. M. MINSKY & S. PAPERT, *Perceptrons*, M.I.T. Press, Cambridge, Mass., 1969.

5. J. VON NEUMANN, *Theory of Self-Reproducing Automata* (editor A. W. Burks), University of Illinois Press, Urbana, Illinois, 1966.

6. J. W. THATCHER, *Universality in the von Neumann Cellular Model*, University of Michigan Report, 1964.

7. M. A. ARBIB, "A simple self-reproducing universal automation," *Information and Control*, v. 9, 1966, pp. 177–189.