References

GILL, S., and SAMET, P. A. (1969). Charging for computer time in universities, *The Computer Bulletin*, Vol. 13, No. 1, pp. 14-16.

ROSENBERG, A. M. (1964). Computer usage accounting for generalised time sharing systems, *CACM*, Vol. 7, No. 5, pp. 304-308.

SMITHSONIAN (1968). 6000 Series installation summary of accounting techniques, Smithsonian Astrophysical Observatory, Proc. of VIM 8 Conference, March 1968 (Users Organisation for CDC 6000 Series Computers).

General references on pricing policies

BAUER, W. F., and HILL, R. H. (1967). Economics of time-shared computing systems, Part II, *Datamation*, December 1967, pp. 41-49.

DIAMOND, D. S., and SELWYN, L. L. (1968). Considerations for computer utility pricing policies, Proc. of 23rd Nat. Conf. ACM, ACM Publication P-68, pp. 189-20.

HOOTMAN, J. T. (1969). The pricing dilemma, *Datamation*, August 1969, pp. 61-66.

NIELSEN, N. (1968). Flexible pricing: an approach to the allocation of computer resources, *Proc. of AFIPS FJCC*, Vol. 33, pp. 521-531.

SINGER, N., CANTOR, H., and MOORE, A. (1968). Prices and the allocation of computer time, *Proc. of AFIPS FJCC*, Vol. 33, pp. 493-498.

Book review

Theories of Abstract Automata, by Michael A. Arbib, 1969; 412 pages. (*Prentice-Hall International*, 150s = £7·50)

Dr. Arbib's book is in three sections. The first commences with an excellent overview of automata theory, its concepts, aims and problems. The other chapter in this section is a very compact introduction to modern algebraic ideas and notation.

The second section, of three chapters, deals with the fundamental topics of automata theory. The chapter on finite automata covers minimisation, realisation by networks of logical elements, recent work on the computation time of the latter, the equivalence of finite state languages with regular sets and various characterisations of automata in terms of equivalence relations and semigroups. The treatment of Turing machines includes effective enumeration, demonstration that Turing machines (including multi-head and multi-tape machines) can be simulated by 'simpler' Turing Machines, leading to the Universal Turing machine and the halting problem; finally recursive and recursively enumerable sets are introduced as characterisations of Turing Machine acceptors and generators. Chapter 5 deals with Post Systems; after a brief survey of restrictions to these which preserve universality, the equivalence of Post's Correspondence and the halting problem is demonstrated. Attention is then turned to context sensitive and context free languages (particularly the ambiguity and decision problems of the latter) and relationships with linear bounded and pushdown automata.

The five chapters of the third section comprise an introduction to partial recursive functions (viewed as functions on symbol strings rather than purely numerical functions) followed by presentations of results in four of the areas of current research interest. The topics, reflecting the author's own interests, are complexity of computation, algebraic decomposition theory, stochastic automata and automata that compute and construct.

Chapter 6 on partial recursive functions includes, in its treatment of hierarchies, the work of Ritchie which classifies functions according to the minimum amount of tape required to compute a function. Chapter 7 explores other measures of complexity, in particular that based on the number of times a Turing machine crosses the division between adjacent squares of its work tape during a computation and that involving counting the number of steps carried out by a Turing machine during a computation. The remainder of the chapter is devoted to the Speed-Up Theorem, its relation to the incompleteness of logics and a 'degree of difficulty' partial ordering which it suggests.

The Krohn and Rhodes decomposition theorem takes up most of chapter 8; subsequently the extent to which components can be further decomposed is discussed and a number of irreducibility results are obtained. The relatively short chapter on stochastic automata, provides a brief treatment of Markov chains prior to considering minimisation, stochastic systems and acceptors. The final chapter is a fascinating account of self-reproducing automata concluding with some thoughts on the extension of such automata towards biological models.

This, albeit selective, review of contents does suggest the breadth of treatment, but conveys little of the considerable depth. To achieve both, definitions and theorems have been stated in full while proofs may simply be outlined or, in part or in whole, left as an exercise. This is consistent with Dr. Arbib's stated intention of producing an advanced text to supplement the several good introductory texts now available, but it does imply a textbook of some difficulty, requiring considerable supplementation. Notwithstanding chapter 2, some facility with modern algebra is a prerequisite for much of the material presented; even with this background previous exposure to a more elementary treatment of automata theory would be desirable. The specialist will want this book to hand, containing as it does a unified presentation of much recent work scattered through the literature.

A minor carp against an important addition to the literature is that a few irritating slips have escaped the proof-reading.

J. EVE (Newcastle upon Tyne)