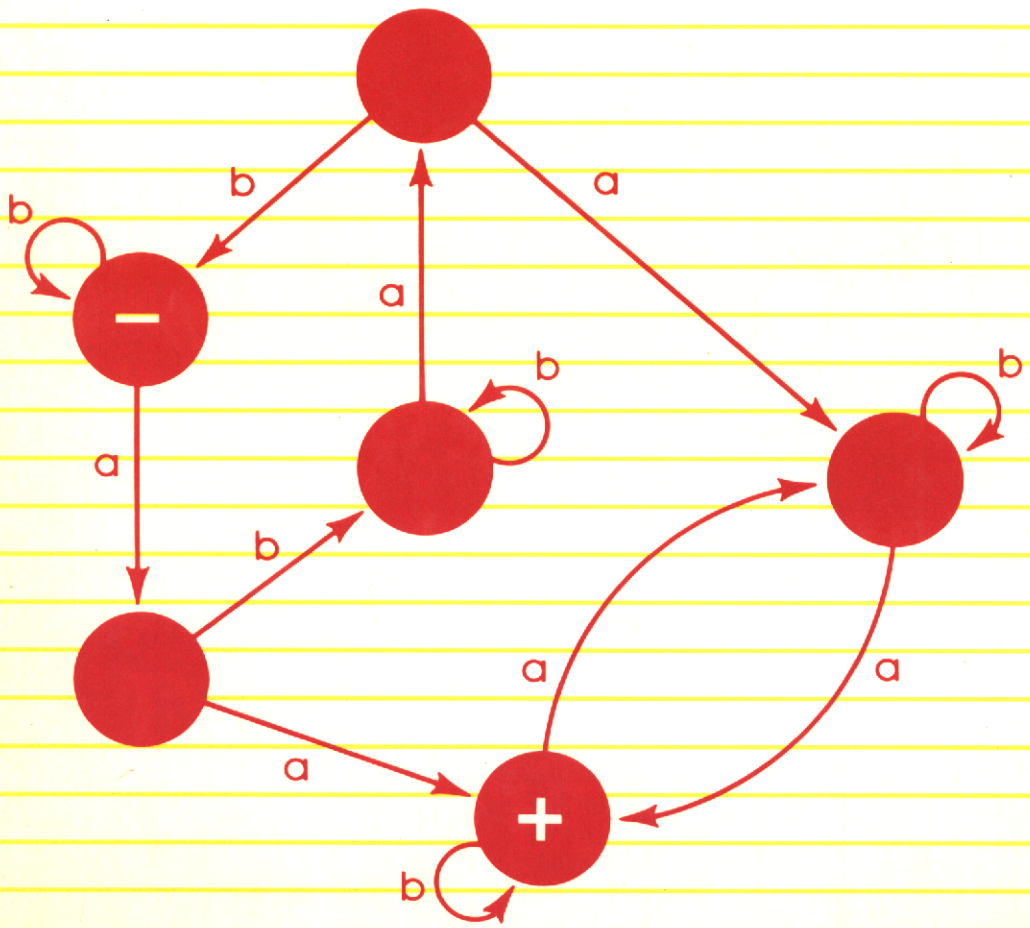
Daniel I. A. Cohen

INTRODUCTION TO COMPUTER THEORY



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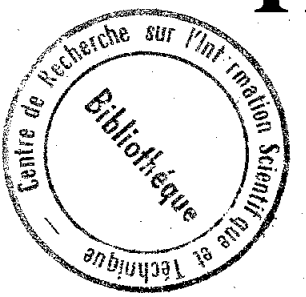

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PREFACE

It has become clear that some abstract Computer Theory should be included in the education of undergraduate Computer Science majors.

Leaving aside the obvious worth of knowledge for its own sake, the terminology, notations, and techniques of Computer Theory are necessary in the teaching of courses on computer design, Artificial Intelligence, the analysis of algorithms, and so forth. Of all the programming skills undergraduate students learn, two of the most important are the abilities to recognize and manipulate context-free grammars and to understand the power of the recursive interaction of parts of a procedure. Very little can be accomplished if each advanced course has to begin at the level of defining rules of production and derivations. Every interesting career a student of Computer Science might pursue will make significant use of some aspects of the subject matter of this book.

Yet we find today, that the subjects of Automata Theory, Formal Languages, and Turing machines are almost exclusively relegated to the very advanced student. Only textbooks demanding intense mathematical sophistication discuss these topics. Undergraduate Computer Science majors are unlikely to develop the familiarity with set theory, logic, and the facility with abstract manipulation early enough in their college careers to digest the material in the existing excellent but difficult texts.

Bringing the level of sophistication to the exact point where it meets the

expected preparation of the intended student population is the responsibility of every carefully prepared textbook. Of all the branches of Mathematics, Computer Science is one of the newest and most independent. Rigorous mathematical proof of the most profound theorems in this subject can be constructed without the aid of Calculus, Number Theory, Algebra, or Topology. Some degree of understanding of the notion of proof is, of course, required, but the techniques employed are so idiosyncratic to this subject that it is preferable to introduce them to the student from first principles. Characteristic methods, such as making accurate conclusions from diagrams, analyzing graphs, or searching trees, are not tools with which a typical mathematics major is familiar. Hardly any students come prepared for the convoluted surprise of the Halting Problem. These then are the goals of this textbook: (1) to introduce a student of Computer Science to the need for and the working of mathematical proof; (2) to develop facility with the concepts, notations, and techniques of the theories of Automata, Formal Languages, and Turing machines; and (3) to provide historical perspective on the creation of the computer with a profound understanding of some of its capabilities and limitations.

Basically, this book is written for students with no presumed background of any kind. Every mathematical concept used is introduced from scratch. Extensive examples and illustrations spell out everything in detail to avoid any possibility of confusion. The bright student is encouraged to read at whatever pace or depth seems appropriate.

For their excellent care with this project I thank the staff at John Wiley & Sons: Richard J. Bonacci, acquisitions editor, and Lorraine F. Mellon, Eugene Patti, Elaine Rauschal, and Ruth Greif of the editorial and production staffs. Of the technical people who reviewed the manuscript I thank Martin Kaliski, Adrian Tang, Martin Davis, and especially H. P. Edmundson, whose comments were invaluable and Martin J. Smith whose splendid special support was dispositive. Rarely has an author had an assistant as enthusiastic, dedicated, knowledgeable and meticulous as I was so fortunate to find in Mara Chibnik. Every aspect of this project from the classnotes to the page proofs benefited immeasurably from her scrutiny. Very little that is within these covers—except for the few mistakes inserted by mischievous Martians—does not bare the mark of her relentless precision and impeccable taste. Every large project is the result of the toil of the craftsmen and the sacrifice and forebearance of those they were forced to neglect. Rubies are beneath their worth.

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CONTENTS