ENCYCLOPEDIA OF COMPUTER SCIENCE

Edited by Anthony Ralston

ENCYCLOPEDIA OF COMPUTER SCIENCE

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PREFACE

When the idea of an Encyclopedia of Computer Science was first proposed to me almost five years ago, I embraced it eagerly. I believed, then, and believe even more strongly now, that computer science has come sufficiently of age as a discipline that it is appropriate and necessary to produce—in breadth and in depth—a snapshot of it (for, after all, a snapshot is what an encyclopedia is). Equally important is a belief that such a snapshot will have value not just for the moment but for some considerable number of years. The discovery and development of new knowledge and techniques and the discarding of the old are still rapid in computer science and technology, at least in relation to other scientific and technical disciplines. But the pace is no longer so breakneck as it was in the 1950s and 1960s when a computer system became obsolete every two or three years; the effective and useful life of an encyclopedia of computer science today, like that of a computer system, should be measured in terms of half-decades or more. Moreover, while parts of any encyclopedia become obsolete after a time, this one contains a major proportion of material which will continue to be of reference value for many years to come.

Five years ago the scope of, as well as the need for, this encyclopedia seemed sufficiently clear that I believed this volume could be efficiently and expeditiously developed. How naive I was! Despite a long and relatively broad association with book publishing, I underestimated the scientific, administrative, and production complexities of a project as large as this one. But, if the result has taken longer to achieve than I anticipated, I do not regret the effort. Editing an encyclopedia like this one is an education itself in one's own discipline. And I value considerably the contacts with the members of the Editorial Board, all eminent computer scientists whose advice has much improved the quality of this volume, and with the over 200 authors of articles, all of whom I love, even the most recalcitrant and prima donnaish of them!

Anthony Ralston

February, 1976

Note

The Editor and Publisher would appreciate an indication from readers of how future editions of this Encyclopedia could be improved. What additional subjects need to be covered? Which articles need improvement? Any such comments or notification of errors found should be sent to Petrocelli/Charter, 641 Lexington Avenue, New York, New York 10022.

EDITOR'S FOREWORD

An encyclopedia has one main purpose—to be a reference work for the layman or the non-specialist who needs elaboration of a subject in which he is not expert. The implication of "basic" is that an encyclopedia, while it should attempt to be comprehensive in *breadth* of coverage, cannot be comprehensive in the *depth* with which it treats most topics. An encyclopedia should, however (and this one does), direct the reader to information at the next level of depth through cross-references to other articles and bibliographic references.

What constitutes breadth of coverage is always a difficult question and especially so for computer science. As a new discipline that has evolved over the past three decades, and which is still changing rather rapidly, its boundaries are blurred. This is complicated further because there is no general agreement among computer scientists or technologists about whether certain areas are or are not part of computer science.

The choice of specific subject matter for this encyclopedia has been necessarily a personal one by the Editor, modulated by the Assistant Editor, the Editorial Board, and by the practical problems of finding authors to write particular articles. My hope is that, while inevitably there will be quibbles about the inclusion of certain topics, little or nothing of major importance has been omitted.

An encyclopedia is *not* a handbook, which is normally intended only for practitioners in the subject area or for professional users of the subject area knowledge. Neither is it a *dictionary* nor a *glossary*.

Articles in this encyclopedia normally contain definitions of the article titles, but even the shortest articles also contain explanatory information to broaden and deepen the reader's understanding. Long articles contain historical and survey information in order in integrate the subject matter and put it into perspective. Overall, it is a basic reference to computer science as well as a broad picture of the discipline, its history, and its directions.

Organization

The organization of this volume is on an alphabetic basis according to the first word of each article title. Titles have been chosen in such a way that the first word is the one most likely to be selected by the reader searching for a given topic. In addition, main cross-references have been provided when more than one word in a title might reasonably be referenced. These cross-references are also used to refer to important subjects that are included in longer, more general articles rather than as separate articles.

Three additional aids to the reader have been provided. The first is the CROSS-REFERENCES at the beginning of each article, which list titles of other articles and names of terms used which may be unfamiliar to the reader.

The APPENDIXES at the back of the book constitute the second aid. These include lists of abbreviations, acronyms, special notation and terminology, as well as some useful numerical tables.

The third aid is the INDEX. In a dictionary or glossary, all terms appear as entries, but in an encyclopedia only the most important terms are used as article titles or even main cross-references. Without an Index the location of much important information would be left to the ingenuity of the reader. In fact, the Index contains *all* terms that should appear in a *dictionary* of computer science. In addition, it contains entries that would not normally appear in a dictionary, such as references to subcategories. The encyclopedia user who searches among the article titles unsuccessfully will find

the Index invaluable in locating specific information. In addition, the Index will often provide pointers to unfamiliar terms.

Using the Encyclopedia

Even a rapidly developing discipline such as computer science exhibits some coherent internal structure. We have been guided in the development of this encyclopedia by our perception of this structure. Five articles cover broad disciplinary subject matter:

Computer Science
Data Processing
Information Science
Information Processing
Symbol Manipulation

The remaining articles may be grouped under ten headings:

I. *Software*
II. *Hardware*
III. *Computer Systems*
IV. *Basic Terminology*
V. *Theory*
VI. *Mathematics for Computer Science*
VII. *Applications*
VIII. *Management, Societal, Economic, and Legal Aspects*
IX. *Professional and Educational Aspects*
X. *History*

To aid the user in grasping the overall taxonomy of computer science, a CLASSIFICATION OF ARTICLES precedes the main body of the Encyclopedia. It includes *all* article titles, except those five designated above as broad disciplinary subject matter, as well as some additional headings. All headings that are not article titles are preceded by an asterisk (*). The CLASSIFICATION OF ARTICLES will enable most readers who wish to concentrate on a particular area of computer science to find a list of relevant articles. In addition, the following lists provide useful groupings of articles not adequately reflected in the CLASSIFICATION.

1. Basic Disciplinary Areas of Computer Science. As an academic discipline, computer science is well established and its basic content is fairly clear. The article "Education in Computing Science" overviews the subject matter of the curricula at the graduate and undergraduate levels. Topics considered to be major subdisciplines of computer science and (or) which form the subject matter of one or more college courses are listed below. As in the CLASSIFICATION OF ARTICLES, italicized titles are for grouping purposes only and do not refer to actual articles.

(a) *Software and Programming-Related:* Programming Languages; Language Processors; Operating Systems; Machine and Assembly Language Programming; Procedure-Oriented Languages; Data Structures; Files; Programming Linguistics; Structured Programming.

(b) *Hardware-Related*: Computer Architecture; Computer Circuitry; Logic Design; Microprogramming.

(c) *Computer Systems*: Computer Networks; Information Systems; Management Information Systems; Time Sharing.

(d) *Theory*: Algorithms, Analysis of; Algorithms, Theory of; Computational Complexity; Formal Languages.

(e) *Mathematics of Computer Science*: Automata Theory; Numerical Analysis; Sequential Machines.

(f) *Applications*: Artificial Intelligence; Computer-Assisted Learning and Teaching; Computer Graphics; Image and Picture Processing; Information Retrieval; Pattern Recognition; Simulation.

2. Scientific Computing and Applications. The following categories contain major articles relating specifically to the use of computers in science and technology, and to articles on applications in science and technology.

(a) *Software and Programming-Related*: Algebraic Manipulation Languages; Mathematical Software; Problem-Oriented Languages; Simulation: Languages.

(b) *Applications*: Computer-Aided Design; Computer Graphics; Control Applications; Engineering Applications; Image and Picture Processing; Medical Applications; Pattern Recognition; Scientific Applications; Simulation: Principles; Speech Recognition; Text-Editing Systems.

This list is not exhaustive, since other articles also contain topics relevant to scientific-technical applications. Conversely, most of the articles listed above contain material applicable to other areas.

3. Administrative and Business Data Processing: The following major articles are related specifically to the use of computers for administration and business and to articles on applications in these areas.

(a) *Software and Programming-Related*: Access Methods; Data Base and Data Base Management; Data Security; Decision Table Languages; Files; Nonprocedural Languages; Software Packages.

(b) *Applications*: Administrative-Business Applications; Credit Applications; Information Systems; Management Information Systems; Planning Applications; Sorting.

Important aspects of these articles are relevant beyond administrative and business data processing.

The foregoing lists and the Classification of Articles that follows have been especially designed to guide curriculum development, to satisfy the requirements of the computer specialist outside his/her areas of expertise, to direct the readings of lay persons who may wish to become familiar with particular aspects of computer science, or to guide readers in following a self-study regime.

It would be pretentious to claim that the Encyclopedia will be "all things to all people," but I am confident that it will fill a much-needed basic reference in the field of computer science.

ANTHONY RALSTON

CLASSIFICATION OF ARTICLES

(Note: This classification list includes all article titles except the five designated as broad disciplinary subjects: All headings that are not article titles are preceded by an asterisk.)

I SOFTWARE

CLASSIFICATION OF ARTICLES

IV *BASIC TERMINOLOGY

*PROGRAMMING-RELATED
- Algorithm
  - Markov Algorithm
  - Parallel Algorithm
- Flowchart
  - Block Diagram
  - Flow Diagram
  - System Chart
- Heuristics
- Identifier
- Iteration
- Job
- Label
- Lists and List Processing
  - String
- Masking
- Program
  - Subroutine
- Recursion
- Stored Program Concept
- Task

*GENERAL
- Automation
- Cybernetics
- Errors
  - Errors, Absolute and Relative
- *Jargon
  - Bug
  - Fix
  - GIGO
  - Glitch
  - Kludge
  - Ping-Pong
- Models

V *THEORY

- Algorithms, Analysis of
- Algorithms, Theory of
- Computability
- Computational Complexity
- Decidability
- Formal Languages
  - Backus-Naur Form
  - Meta Character