INTRODUCTION TO COMPUTER SCIENCE

HARRY KATZAN, Jr.
Chairman, Computer Science Department
Pratt Institute

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PREFACE

Recent advances in computer technology have created the need for a modern up-to-date introduction to computer science that reflects the field as it exists today and is expected to exist in the predictable future. The objective of the book is to present an introduction to the subject matter without being an introduction to programming and problem solving. To be sure, programming and algorithmic processes are covered in the book, but they are placed in perspective. There is much more to computer science than programming, and that point of view has been adopted for this book.

The book covers topics taught in most computer science programs that are omitted in most introductory textbooks that are oriented towards programming and problem solving. Typical examples are introductions to automata theory, computer systems architecture, language processors, and operating systems, and a chapter on computers and society. However, the book does highlight recent advances in programming methodology, including:

Structured programming
Top-down development
Group programming methods
HIPO design and documentation techniques
Virtual storage

It must be emphasized that the newer topics are not included at the expense of the conventional subjects, such as introduction to computing, algorithmic processes, computer hardware, data structures, and numerical analysis. They are all covered in full detail.

The book is composed of the following parts:

I. Fundamental Concepts
II. Computer Systems
III. Computer Software
IV. Topics in Computer Science

Part I is intended to provide a background for the study of computer science and covers: the scope of computer science; an introduction to computing; program and systems development; number systems; and basic data and computation structures. Part II is designed to familiarize the student with computing machines and presents: an introduction to computer hardware; computer systems architecture; and input and output. Part III deals with a popular topic that students want to know about early in their studies. Topics covered are: assembler, macro, and programming languages; language processor methodology; and operating system technology. Part IV is designed to acquaint the student with some of the areas that are part of computer science and surveys the following topics: structured programming, data structures, numeric computing, automata theory, and computers and society.

In effective computer science education, it is important that principles are taught; this point cannot be overemphasized. *Introduction to Computer Science* is relevant to this need because it permits the scope of computer science to be covered in the first course, so that the remaining courses in the computer science curriculum can be placed in proper perspective.

It is a pleasure to acknowledge the valuable comments and suggestions of the reviewers, the help of Mr. Kenneth Antolak of Honeywell Information Systems, and the assistance of my wife Margaret, who typed and helped with the preparation of the manuscript.

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PART I

FUNDAMENTAL CONCEPTS

1

SCOPE OF COMPUTER SCIENCE

1.1 INTRODUCTORY REMARKS

Welcome to the world of computer science. By most standards, it is a new field. In terms of years, however, its short history is misleading, since the field is the product of advanced technological innovation built on a solid foundation of mathematical and engineering principles.

Computer science is one of the most recent disciplines to be developed, but is currently very popular because of the widespread use of computers in everyday affairs. Computers are used in business, government, education, and research. Although most computer utilization involves organizations, there have been remarkable achievements in the areas of personal computers, computers in the home, and in recreational computing. In fact, one of the better stories is about the college professor who programmed a minicomputer to play a variety of board games, such as tick-tack-toe, and to store a large collection of party jokes classified as G, GP, R, and X. In response to a request for an "X joke," for example, the computer would select an X-rated joke at random and display it on the computer's output unit. The portable computer that used ordinary house electrical current was intended to be used for demonstrations and at parties. After one particularly joyful evening, the following report was received: "The computer performed well all evening and was an instant success. The only problem occurred when a happy celebrant poured his cocktail into the computer. Needless to say, the computer reacted violently."

Most applications of computers are complicated, as are the computer systems themselves. In fact, the humorous episode given in the previous paragraph actually represents a nontrivial application of computers. Some applications are complicated because a sophisticated computational process is involved. Other applications are complicated because of the volume of data involved and the manner in which it must be managed. It is the computer scientist's job to design and build computers, systems, and languages to facilitate the use of computers.

Computer science cannot be studied in a vacuum and it is well for the prospective computer scientist to obtain as wide a background as possible in other academic areas. While it is true that most fields now use computers as a tool for increased productivity, the interdependence of computer science and other fields is much stronger. For example, computers are designed and built by electrical engineers; computational processes require a mathematical background; studies of the similarity of computers and the brain require a training in biology; artificial intelligence requires an exposure to psychology and logic; and optimization and simulation techniques require a knowledge of business operations and modeling methods. Computer science differs from other scientific areas such as physics and chemistry; it is not a natural science established to study a class of natural phenomena but rather an "artificial science"—the study of something that man has created.

Computer science is generally regarded as an applied science, which means that it is a discipline encompassing principles for "doing things" and for measuring how well they are done. People with a background in computer science can apply their knowledge to computer programming, systems analysis, computer design, management, and so forth. However, computer science is much more than a way of doing things. There are theories of programs, abstract machines, data structures and languages—to name only a few. In short, computer science is also an academic discipline, and many students continue their formal education in computer science and go into teaching and research.

1.2 THE NATURE OF COMPUTER SCIENCE

The word *computer* in computer science implies that a computer is involved, in one way or another. This is basically true. Computer science is concerned with the process of using the computer, with the applications of computers, with the manner in which information is stored in the computer, with the theory of computers, and so forth. Therefore, a good knowledge of the computer and how to make it work is necessary. *It is important to recognize that computer science is considerably more inclusive than simply a study of computers and how to program them.** There

* A computer program is a series of instructions that tells the computer what to do. The process of developing a program is termed programming. Programs and programming are covered in considerable detail in later chapters.

is a definite orientation in computer science toward the computational process in whatever form it may take. The remainder of this chapter, except for a brief excursion into the history of computers, is concerned with the various areas of computer science and the major applications of computers.

It is important to recognize that no topic introduced in this book is covered completely. (The word *introduction* in the title is to be taken literally.) Most topics covered correspond to other courses in the computer science curriculum. Gaining an appreciation for computer science is desirable and the reader should make full use of the Selected Readings given at the end of each chapter to gain perspective on the field.

1.3 A VERY BRIEF HISTORY

The processing of information is present in almost every activity of our lives and takes place whenever two or more persons or systems interact. Throughout history, many devices have been developed to aid in this information (or data) processing. One of the first aids was the *notched stick* that served as an aid to counting and remembering. The first machine, per se, was the *abacus* developed by the Romans in ancient times. A more popular version, the Chinese abacus, was developed in the 12th century and is still used in China today.

The next major advance in computing machines was the *slide rule* invented in 1621 by William Oughtred, an Englishman. Since that date, many improvements have been made to the slide rule for both general and special-purpose applications. The first adding machine (1642) is credited to Blaise Pascal, the famous French mathematician. This gear-toothed machine was followed in 1673 by a machine that performed multiplication by repeated additions and was developed by the mathematician G. W. Leibnitz. The machines of Pascal and Leibnitz are the forerunners of modern desk calculators.

The modern era in computing began in 1804, when Joseph Marie Jacquard invented a loom in which the weaving operations were controlled by punched cards. The first automatic computer was designed by Charles Babbage in 1822; it could perform numerical calculations. The machine, called the *automatic difference engine*, was originally proposed by J. H. Mueller in 1786 and finally built in Sweden by George Scheutz in 1853. Another of Babbage's machines, the *analytical engine* was designed in 1833 but was never built. It is the forerunner of today's stored-program computers.

The punched card and related processing equipment were developed in the 1880s for use in the U.S. census. As it turned out, the development of the punched card became one of the most significant events in the widespread use and acceptance of computers and data processing equipment.

The first automatic computer was completed by Harvard College and IBM in 1944. This machine, called the Mark I, was constructed from mechanical components and handled 23-decimal-digit words. The inherent slowness of the Mark I resulted in the design and development of the first electronic computer, the ENIAC, at the Moore School of Engineering at the University of Pennsylvania in 1946. Modern computers are an outgrowth of this pioneering research of the middle 1940s.

Every advance in computing machines was associated with an actual need. For example, ancient cavemen and shepherds needed the notched stick to count their flocks (or wives, as the case may be). Similarly, the adding machine resulted from tax computations in France; Babbage's computers resulted from a need for difference tables; and the Mark I and ENIAC efforts were largely influenced by World War II.

The current computer explosion, which we are now witnessing, is not simply the result of a new invention or a new technique—although a multiplicity of technological innovations have been made in the last 25 years in the computer field. Other factors have contributed to this widespread growth.

In the area of science and technology, computers have played a major role in many significant technological advances, and as a result of these advances, computer use has snowballed. Concrete examples in this area are missile guidance, simulation studies, and computer control systems, in addition to the traditional scientific problem solving. In general, scientific computing has received its fair share of publicity.

Computers play an equally important role in business and government, although the glamour seems to be lacking for various reasons. The volume of business and governmental data processing has grown enormously along with the growth in size of businesses and the expanding scope of government. The use of computers for diverse operations, such as check processing, has given rise to a variety of advanced input, output, and mass-storage devices. Many management problems created by geographical locations and distances are presently relieved through the use of telecommunications facilities* that permit information to be transmitted between remote locations at electronic speeds. Here again, reasonable success in using the computer to reduce

* Telecommunications facilities involve the use of ordinary telephone equipment for the transmission of information between locations.