Understanding
and
Programming

COMPUTERS

UNDERSTANDING AND PROGRAMMING COMPUTERS

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Illustrated

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PREFACE

This book was written mainly for liberal arts students. Its main objective is to give an integrated overview of the digital computer and its uses, potentials and limitations. The intention is to educate the students to the basic principles underlying the design of and operation of this machine and not just to train them how to program it.

There are many books that approach the topic from mainly a programming viewpoint since this is what they assume students need to know in order to use the computer in other disciplines, e.g. psychology or business. Although such need is genuine and important, the author believes that it is essential to inform the students about the functioning of the computer if it is hoped to help the students become well rounded, educated people and not just technicians. Training people to program the computer with no attempt to explain its functioning is similar to training them to drive an automobile without explaining how the engine operates. A person who is familiar with the engine, knowing <u>why</u> to shift gears and not just <u>how</u> to shift them, is, no doubt, a better driver than one who just knows the mechanics of driving. He is also more capable of making good decisions in case of malfunctioning emergencies. In addition, he is in a better position to comprehend automobiles in general and the development of automotive technology without having to be an expert. Finally, he will be using the automobile in a non-passive manner, and passivity in the use of technology is one of the main problems in our present society. It is with this philosophy in mind that this book has been written.

The general nature of the computer and its evolution are the topics of the first chapter. The hardware of the machine is covered in chapter two through five. The concepts of mathematics and physics used in these chapters are presented as puzzles and games (binary system and switching circuits) or without complicated algebraical expressions (electromagnetic theory).

Chapter six through nine deal with the programming of the computer. The first of these chapters presents the methodology of computer-oriented problem solving in terms general enough to be applicable to any area of endeavor.

Chapter seven deals with data structure. It is meant as an overview of the topic rather than an in-depth study. After outlining the hierarchy of programming languages, Chapter Eight discusses assembly language, and gives a comparative study of three high-level languages -- BASIC; FORTRAN; and COBOL. In addition, the chapter contains sections on microprogramming, and the psychology of programming. (The reader who needs to learn more about the concepts of assembly language can read Appendix B.) The author chose to illustrate the concepts covered in this chapter by using an actual assembly language, that of the IBM 370 system, instead of a ficticious one, as is usually done in similar textbooks. The rationale for this choice is twofold: first, if the reader eventually decides to learn assembly language, he will have been introduced to it from the beginning; second, it is always better to draw one's

illustrations and examples from actual practice -- particularly when this does not hamper the learning process. Those readers who opt to learn enough FORTRAN to write simple programs are referred to Appendix C. Chapter nine complements chapter six; it demonstrates how the computer is managed internally to follow the instructions submitted by the users. Chapter ten consider computer applications from a new angle. It is customary to focus on the different areas (such as education or business) in which computers are used; in contrast, chapter ten, by focusing on the main roles of the computer -- record keeper, controller, and analyser -- illustrates how the computer has the potential to serve in any of large number of areas. Hence, by way of examples, chapter ten demonstrates the relevance of the computer as a record keeper in business, scientific research and education.

The appendices complement or clarify the chapters. Thus those who are not familiar with electrical and electronic circiuts are advised to read Appendix A. The appendices also include a selected list of periodicals in the computer field, as well as the names of the major professional computer societies. Finally there is a glossary of computer terms, which will be found at the end of the text.

Strong scientific or mathematical background is not a pre-requisite for reading this text. Knowledge of the basic arithmetic operations and an interest in learning about computers are the only requirements. However, those who have had a strong training in

mathematics will not find the text too elementary. This is because its emphasis throughout is on the operational principles of the computer.

The need for the book and its approach have been tested for the last six years of the author's teaching at an undergraduate liberal arts college of Fordham University. The book has been used for a first year course in computational mathematics curriculum as well as for an elective course for non-mathematics majors.

The author wishes to express her deepest appreciation to the students who showed no reluctance in using the first drafts. Their constructive criticism helped improve the presentation and organization of the text. Without Bernard Gilligan's moral support this textbook would never have been written. Finally, and most importantly, the author owes a great deal to Jerry Green, Jr. who patiently typed many drafts, photocopied and collated the students' copies.

Samiha Mourad

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CHAPTER ONE

THE GENERAL NATURE OF COMPUTERS

Today, the word computer is on almost everyone's lips. At school ID numbers and course cards remind one that information regarding registration and tuition has been processed by computer. Telephone and electric bills are punched on IBM cards that remind one not to mutilate them because they will be processed by computer. In the record stores, one can find music produced by the computer.

In each example, the computer appears to be a brain that performs calculations, makes decisions and produces organized reports. Actually, the computer usually referred to is just one member of a family of computers, the most well known of all. The correct name for it is the "general-purpose electronic digital computer."

The qualifiers "general-purpose," "electronic," and "digital" point to the fact that computers fall into different categories based on various factors which will be considered in the next section.

1.1 Classification of Computers

Depending on the mode of representation of information, computers are divided into three main types: analog, digital, and hybrid. In an analog computer, the information is represented in a continuous form by a suitable physical quantity: length in centimeters, current in amperes or voltage in units. The speedometer, for example, is an analog computer that gives an indication of the speed of a car. Other examples are thermometers, gas meters and slide rules.

A digital computer represents information in a discrete form,

beads, knots, or electrical pulses. The abacus and the cash register are examples of digital computers.

Analog computers are less accurate than digital ones since their use entails reading measurements. Even with very fine measuring scales, the accuracy is impaired by the reading itself. They also are suitable only for handling numbers while digital computers accept non-numeric information as well.

The third type of computer represents information concurrently in both a continuous and a discrete form. This is the hybrid type. Hybrid computers form the intersection of the sets of digital and analog computers.

Depending on the components used to construct them, computers can be classified as either mechanical or electronic. Electro-mechanical machines are also widely used. Figure 1.1 shows the different categories in this classification.

The early versions of calculators are examples of purely manual rotation of a system of gears. In later versions, electric motors have been used to operate these gears. Most of the calculators in use nowadays are of the electronic type.

The difference between electrical and electronic concepts is explained in Appendix 1. In general, electronic devices are faster, less noisy and more reliable than electro-mechanical ones. Electronic devices themselves have developed from the vacuum-tube type to the transistorized ones. From Figure 1.2, where real scale diagrams of a vacuum tube and a transistor are shown, it is obvious that devices using transistors can be built smaller in size.

From the standpoint of use, a computer of any of the types

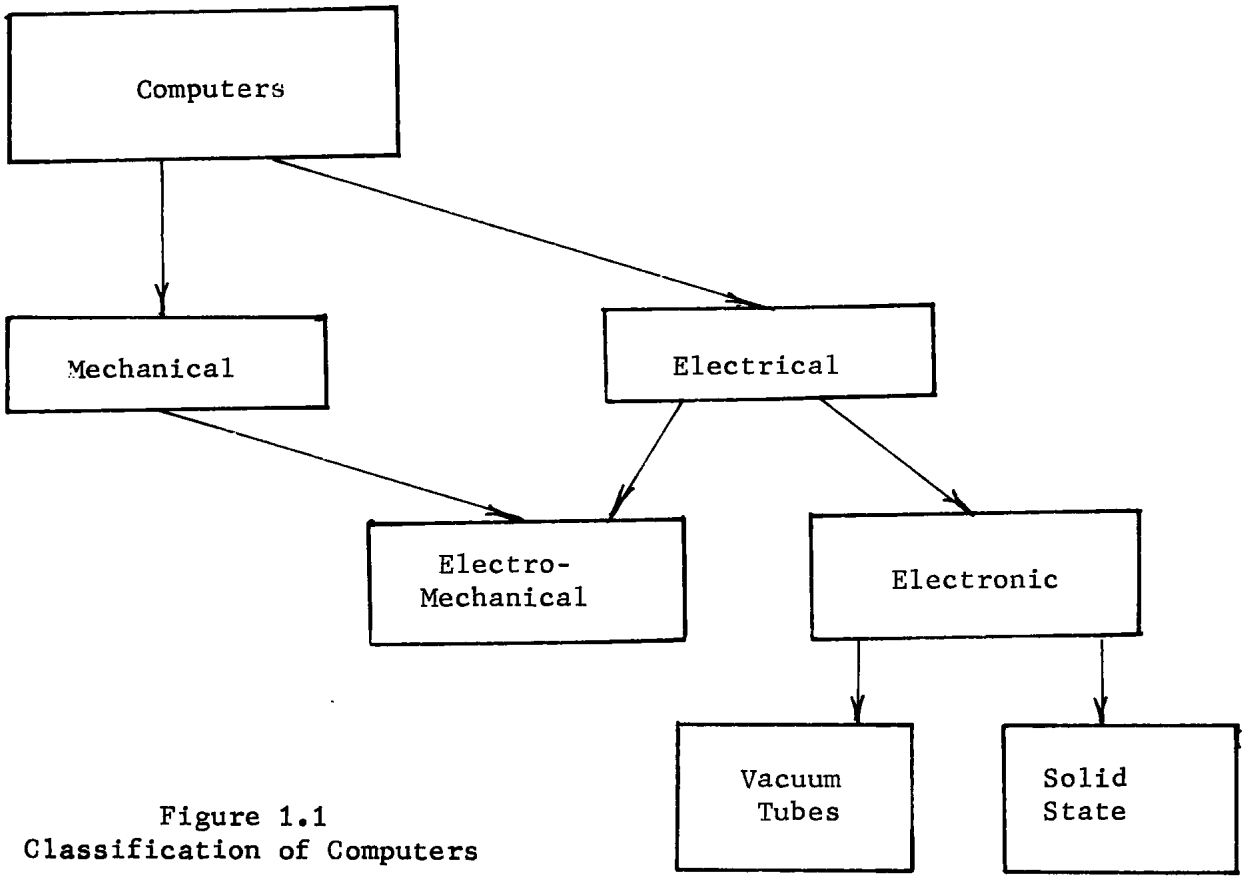

Figure 1.1
Classification of Computers

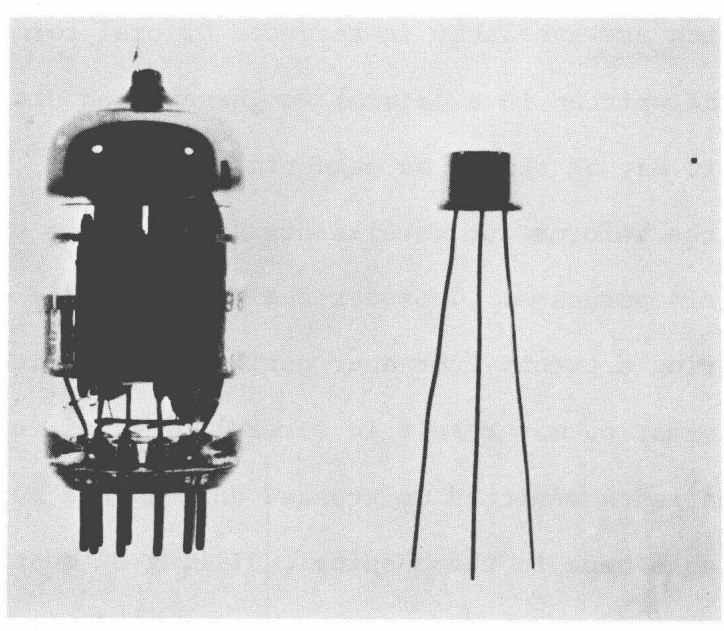

Figure 1.2
Size comparisons of vacuum tubes,
transistors, and solid state technology
(Courtesy IBM Corp.)

mentioned above may be designed for a special purpose or a general purpose. General purpose digital computers may be labeled commercial or scientific according to their use. A digital computer which serves a university community can be utilized for purely scientific research or for processing registration and staff payroll or for both. This subdivision of the general-purpose digital computer is rather artificial since it does not pertain to a special feature of the machine, but rather to the kind of problem solved by the machine.

In this text, the only type of computer dealt with will be the "general-purpose electronic digital computer." Hereafter, therefore, the term "computer" should be understood to refer only to this type.

1.2 The Role of the Computer

The computer has been labeled a universal machine because of the role it plays in processing information. Information is known, intelligible facts which are available in recorded or oral form. Recorded information may be written in a natural language or an artificially coded one; also it may be stored on magnetic tapes.

Processing the information entails organizing it to produce reports for certain purposes. Consider the specific case of information gathered during a twenty-four hour period in a hospital. Processing this information may result in several types of reports: listing of the patients admitted or treated during this period, updates of available beds in the hospital, billing of customers, schedule for nurses and doctors. Such bookkeeping efforts have been carried out manually; however, with the advent of the computer, the task has been enormously accelerated. Computer-oriented information

processing system consists of three main subsystems: people, procedures and the computer.

People collect the data and prepare procedures to organize them. The procedures are usually called programs. A program is a sequence of instructions arranged in a fashion to organize the information to achieve a desired goal.

The computer, which consists of physical equipment called the hardware, processes the information according to the procedures introduced to it by people. Because of the availability of specialized programs, the operating system, the different parts of the hardware are capable of communicating with each other and cooperate to process the information according to the procedures (programs) supplied by the users. Operating system and programs representing the procedures are known as the software of the computer.

In the next two sections, the functional components of the computer will be listed with a brief description of their roles. Then the problem of how people communicate with the computer will be addressed.

1.3 Basic Components of the Computer

Although the general-purpose digital computers may differ in some particulars, they all consist of five basic components which are shown in Figure 1.3. The components are:

1. An input device which receives the data and the procedure, a set of instructions to be followed in solving a problem.

2. An output unit which transmits the results, the outcome of the data processing, outside the computer.

3. An arithmetic and logical unit (ALU) which performs the main