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A General Study of the Computer Process

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The electronic device known as the computer was developed many years ago and is widely used by businessmen, scientists, and engineers to assist in solving many types of problems. In order to understand how computers can help you solve problems, it is best to disregard some of the impressions gained from popular accounts of the computer's use. The computer is not a magic brain which will replace the human brain; the computer simply performs a series of mathematical or logical steps according to instructions which spell out exactly how it is to perform the required operations.

The computer's primary purpose is to provide an efficient and economical method of handling the vast amounts of numerical data and other information involved in the tasks performed in government, business, and industry. A major result of the computer's work is the reduction of time and cost in performing these t tasks. Also computer techniques are sometimes so effective that radical approaches to problem-solving may be attempted.

However, before a problem is ready to be placed on the machine, a considerable amount of time is required for the computer staff to convert the problem statement as originally presented to them into a well-planned, error-free operating program for insertion into the computer. Although much time is required to set up the program, it is the running time which is important, because once a program has been developed and produced, this same program may be run for case after case with only slight programming time or effort. Furthermore, the program will keep indefinitely; it can be brought out and "dusted off" for use with a similar problem at a later date.

Computer applications can be divided into two categories: scientific and engineering applications, and business applications. The first category deals with the development and testing of specific devices or systems. Record-keeping applications also occur in connection with scientific work. "Information retrieval" is of great value in a field such as chemistry, where a great deal of scientific information exists on a given subject, but is scattered throughout the technical literature. An information retrieval system classifies such information and codes it in such a way that references to a particular phase of the subject can be quickly identified and located by machine techniques.

The second category, business applications, can further be divided into two types. One type is involved with planning processes, as in transportation or production scheduling. In the other type, the computer performs the routine operations of data processing. Examples of this type are customer accounting, inventory, and the handling of airline reservations.

Regardless of the type of problem to be solved, the steps in the computer solution follow the same general pattern, although the position of the individual who is concerned with each step of the operation may vary from one organization to another, or even from problem to problem. Two common variations of the subdivision of labor in computer-problem solution are open shop and closed shop. In the open shop, the customer not only prepares the statement of the problem, but carries through the programming steps of numerical analysis, flow-diagramming, and coding the problem for solution on the computer. In this type of operation, the computer staff maintains and operates the computing equipment and provides any incidental assistance the customer may need in the solution of his problem.

In the closed shop, the mathematical statement of the problem is turned over to professional programmers on the computer staff, who convert this mathematical statement into the form required by the computer, operate the computer to obtain the desired solutions, and return those solutions to the customer for interpretation.

A few simple facts about how a computer performs its tasks are essential for a better understanding of computers in general. Basically, there are two types of electronic computers, the analog computer and the digital computer. Both types of computers perform their tasks by means of two general processes which are designated as mathematical operations and logical operations.

Mathematical operations include the familiar operations of arithmetic (addition-subtraction, multiplication-division) and all the techniques of advanced mathematics, such as algebra, trigonometry, and calculus. The computer operates on the numerical data furnished it in order to solve sets of equations for particular cases.

Logical operations are essentially the applications of specific rules of procedure to the handling of numerical or alphabetical data. Such operations are usually performed by the digital computer rather than the analog computer. In each operation of this type, the computer follows an instruction to sense the sign or magnitude of a particular number. Depending on what is sensed, the instruction indicates what action is to be followed by the computer in subsequent steps.

By combining several of these logical operations, the computer can be programmed to sort data into different categories, to arrange numbers in sequence, to store data at designated locations in its memory, to refer to these data as required, to perform a given operation a specific number of times, and to make decisions in the sense of choosing one of many alternative courses of action depending, for example, on the sign or magnitude of a number.

Computers have a language of their own. The language of digital computers consists of numbers. All inputs to and outputs from the machine must be in numerical form. Even the individual instructions which operate the computer are coded in the form of numbers. The language of the electronic analog computer is voltage. All quantities in the system being studied are represented as voltage levels. The problem is communicated to the machine by interconnecting properly the various elements of the computer by means of wires at a patch board and by setting switches and knobs on the front panel of the computer to represent initial conditions and system constants. Outputs are obtained by converting the voltage levels within the computer to a graphic record.

Since the digital computer and the analog computer each has its own characteristic method of operation, one type of computer may have marked advantage over the other for a specific application.

A problem that involves many logical operations, such as an inventory-control problem or a war-game simulation, is necessarily done on a digital computer. The simulation of the dynamics of a physical system, such as a heat transfer system or a mechanical assembly, consists primarily of mathematical operations involving differential equations and is most naturally performed on an analog computer. Often, either type of computer can effectively do the job required. Straightforward numerical computations, such as the solution of a set of algebraic equations or a harmonic analysis, are examples of this type of problem. In some large-scale problems, it has even been found effective to obtain solutions by making a digital computer and an analog computer work together, through interconnecting equipment, to solve separate portions of the same problem.

If either type of computer can be used for a specific problem, the decision between analog and digital will then require careful comparison of estimated time and cost. The form and content of the desired results, the accuracy needed, and the requirement for exploratory runs will also affect the decision.

Before a customer employs the aid of a computer, he must first decide whether his problem can be reduced to a statement which a computer can solve and whether the computer provides the most economical method of solution. The customer must be able to provide a description of the system being studied in both qualitative terms (written descriptions, physical layouts, and schematic diagrams) and in quantitative terms (sets of equations and lists of numbers representing system constants). He must also be able to designate exactly the conditions to which the system is to be subjected and the items of information he wants to obtain concerning the system for these conditions.

Once it is decided that a problem is adaptable to computer solution, the next step is to formulate an initial statement of the problem. The initial statement should contain:

1) a statement giving enough background on the problem to enable the computer staff to understand the significance of its work,
2) a description of those aspects of the system to be considered indicating the components to be used and the interrelationship of these components,
3) the items of information to be computed which are needed to help decide how well the system performs,
4) a list of cases (the particular combinations of conditions) that will be used in studying the performance of the system.

The initial problem statement is mostly qualitative. It contains numbers describing pertinent features of the system being studied (sizes and ratings of the components) and the details of the cases to be considered, but it does not present the system in terms of sets of equations.

The effectiveness of the computer operation can be improved if the computer staff understands the physical problem itself. If the computer staff is aware of the physical significance of the problem, it can detect errors which might otherwise go unnoticed. The number 50,000 by itself has little significance, but if a computer operator knows that this is supposed to represent the speed of a reciprocating gasoline engine in revolutions per minute, he will begin to suspect that something has gone wrong.

A long-winded written statement of the background material is not required, unless the problem is unusually large and complex. Instead, a statement that briefly covers the main points is sufficient. The background information should include any history of previous work on the problem and should refer to reports which relate to the proposed work. A clear-cut statement of the objective of the proposed work should be included.

The next step is the preparation of a descriptive model. This is a general outline of the system listing the major features to be included in its representation. The definition of the mathematical model of the system must be based on the original statement of the descriptive model. The mathematical model describes the system in terms of equations representing its physical operation and other characteristics pertinent to the problem.

In preparing the mathematical model, it is important to recognize that the computer cannot compensate for errors made in the preparation of the problem. A single error can invalidate a complete computer solution. Particular care must be taken to avoid the use of mixed systems of dimensions, such as feet and inches, or degrees and radians.

An important part of the preparation of the system equations is to determine the allowable simplification which may be made in the mathematical model. The following is a list of the types of simplification:

1) study one part of the system at a time
2) omit unimportant system features
3) use approximations of system characteristics.

The simplified systems of equations will be used as a basis for a detailed program of instructions or computer interconnections to enable the computer to carry out the required operations. This process of information handling can become quite complicated for large problems. A method that is helpful in visualizing the correct operation of the computer is to make a "flow diagram" of the equations to be solved.

The form of the equation flow diagram is not rigidly defined. It depends on the particular problem being dealt with and whether a digital or analog computation is being attempted. The first attempt at a diagram for a problem is intended to give only a general picture of the entire operation and will show the process only as a combination of major steps. Later, more detail will be required, and each major step will produce a small diagram of its own. Eventually, a diagram could be prepared in which each operation (adding two numbers, comparing two numbers, or generating a function) is represented by a block on the diagram as an input and one or more outputs.

Once the program has been properly run through the computer, the data obtained in the solution must be interpreted. Digital computers produce results which are generally printed out in tabular form. By properly coding the computer, the tables of data are made easy to interpret. If the meaning of the data might not be clear to everyone concerned, section titles and column headings can be typed out to indicate which conditions relate to which items.

Analog-computer results are usually produced by graphical recording equipment in the form of problem variables plotted with respect to time, or of one problem variable plotted as a function of another variable.

If the results of the solution are entirely unexpected, it is the job of all the personnel concerned with the problem to determine the cause of the discrepency betwe n expected and actual results. It is the obvious reaction of the customer to assume that the discrepancy is due to a mistake on the part of the computer staff in programming or operating procedures. However, when the phases are rechecked, it becomes increasingly evident that the difficulty lies in the customer's concept of the physical action of the system or in the mathematical formulation of the problem. One of the peculiar advantages of the computer approach to a problem is that it clears away misconceptions about the theory of operation of a system and tends to force the customer to arrive at a correct analysis of the problem.

It is expected that the next five years will see the integration of computers into huge reporting and optimizing systems in business and government. By 1970 it is estimated that at least 50% of all information transmission will be done by computers "talking" to one another. It appears that the computer may have a more profound effect on our daily lives than any discovery since speech itself.

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