PRINCIPLES OF DATA PROCESSING WITH COMPUTERS

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THE AUTHOR

Robert G. Van Ness has been actively engaged in the automated data processing field for over 20 years. In his work in the area of administration and management of data processing and related departments, Mr. Van Ness devised methods of operations that gained him recognition in systems development. His experience range is wide, including positions with food processing plants, data processing service bureaus, distributing companies, service organizations and manufacturing plants. Mr. Van Ness studied business administration at Creighton University, Omaha, Nebraska. From 1956 to 1958 he taught "Principles of Machine Accounting" at Chaffey College, Ontario, California. This course was a part of Chaffey's supervisory development-adult education program.

The author has been active in the Data Processing Management Association and its forerunner, the National Machine Accountants Association. He was president of the Orange Empire Chapter of NMAA in 1957-1958 and president of the Pasadena Chapter of DPMA in 1963-1964. As a result of his efforts he has been awarded the Individual Performance Award of DPMA. In 1965 he earned the DPMA certificate in Data Processing.

Mr. Van Ness is technical editor of the Journal of Data Processing, official publication of DPMA. He wrote "Principles of Punched Card Data Processing" as a textbook for colleges and edited the same book for use in secondary schools. His book titled "Principles of Data Processing with Computers," serves as a sequel to these to provide students with a solid foundation of basic information concerning the entire field of data processing.

PREFACE

In the past few years computers have escalated into virtually every facet of human endeavor. The future is unlimited—computers promise to play more and more of a part in the business and scientific world, as well as in our everyday lives. It has been suggested that computers will have more of an impact upon mankind than did the Industrial Revolution or the harnessing of atomic power.

Whatever the future holds, you can be sure that those who understand and know how to use computers properly will have a distinct advantage over their associates. Mastery of this text will provide much of that understanding.

This book is intended to introduce the student and layman to the basic principles and practices associated with the use of computers. The purpose is not to make the reader an expert in any phase of data processing, but to supply a broad, solid background of knowledge to the entire spectrum of Business Data Processing.

Exposure to "Principles of Punched Card Data Processing" by the same author would be helpful but is not required. In fact, no prior experience or courses on computers or the field of Data Processing is necessary for an understanding of the material in this text.

Every attempt has been made not to confuse the reader with unnecessary technical terminology. Unfortunately, computers lean toward the technical and the entire field of Data Processing is cloaked in jargon that is mysterious to the layman and makes communication difficult. Therefore, a certain amount of technical information is essential to an understanding of the subject. However, these technical references have been held to a minimum and every effort has been made to impart principles to the reader without the confusion of vague terminology and superfluous technical details.

ACKNOWLEDGEMENTS

Many organizations have contributed information, illustrations and ideas for which I am most grateful. These include:

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I especially want to thank the many individuals within these organizations who have devoted their time and energy to assist me in the preparation of this text, as well as the other books that I have written. I am particularly grateful to the many representatives of IBM in Glendale, Los Angeles and New York who were extremely helpful. These include E. S. Gudmundson, E. A. Brady, Mrs. J. Bartal and Eric P. Blore. The people from Burroughs Corporation in Los Angeles, especially Hugh Livingston, were also helpful and the final chapter of the book is a reprint of a speech by Charles W. Neuendorf of Burroughs Corporation. explaining how computers can be used in a Management Information System. Representatives of UNIVAC in Los Angeles, especially Floyd Dunn, assisted in gathering material and allowed me to browse through their library.

And finally, a much deserved word of thanks to my wife Madalyn and our eight children who have been so considerate. I certainly could never have brought this book into being without their cooperation, patience and understanding.

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GENERAL CONCEPTS 1

HISTORY

The history of computers is generally conceded to have started with Professor Charles Babbage, English mathematician and scientific mechanician at Cambridge University. In 1822, he conceived the idea of a new type of calculator which he called a "difference engine." Through the recommendation of the Royal Society he received a grant from the British government to work on his machine. After eight years of work, the eccentric genius abandoned the idea of the "difference engine" and turned his attention to a much more complicated "analytical engine" based on the punched-card principle. This switch alarmed the British government and it withdrew its support, thereby dooming the project to failure. Like so many others in history, Charles Babbage had the misfortune to be born 100 years ahead of his time. He was constantly plagued in trying to adapt his twentieth century ideas to nineteenth century machines, materials and techniques. Present-day engineers find Babbage's engineering drawings amazingly similar to those of today, but they were useless in his day because the delicate parts could not be manufactured with the materials and techniques of that era. Babbage's partially completed machines, along with 400-500 plans, were presented to King's College Museum in London and later preserved in the South Kensington Museum.[1] The plans that have been preserved reveal that Babbage's "analytical engine" would have operated very much like today's electronic computers with stored programs and punched-card input and output.

It was almost a century later before any type of computer was developed. In 1915, the Ford Instrument Company (now a division of Sperry Rand) manufactured a mechanical analog machine designed to find and hold the range for naval guns. A series of special purpose analog computers followed over the years. Compared to modern equipment these were mechanical monsters, operating on voltages or the rotation of gears. They acted upon analogies to numbers rather than numbers themselves; they produced approximate answers which are good enough for aiming heavy guns but not good enough for mathematical calculations.

It was not until 1939 that another professor, Dr. Howard Aiken

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[1]The story of his investigations are revealed in his book *Economics of Machines and Manufactures* (1832). *Passages from the Life of a Philosopher* (1864) is an autobiography of the eccentric genius.

of Harvard, completed plans for a digital computer which was the forerunner of today's business data processing computers. This machine made major breakthroughs in two areas; it operated on real numbers rather than analogs and it had the built-in ability to make logical decisions. All digital computers today utilize both of these principles. Dr. Aiken's computer was somewhat limited because it was basically an electromechanical machine and was plagued with errors caused by the wearing of parts.

In 1943, the Army became interested in computers and awarded a development contract to the University of Pennsylvania. Dr. John Mauchly, who had become interested in the possibilities of electronic computers for compiling weather data, and in 1945 J. Presper Eckert, chief project engineer, completed the first all electronic, digital, sequential computer. The substitution of electronics for electromechanics in the principle of computer operation was of major significance. This computer was called the ENIAC (Electrical-Numerical Integrator and Computer) and was delivered to the Army Ordinance Depot at the Aberdeen Proving Ground.

ENIAC was crude and huge compared to modern-day computers. It weighed almost 30 tons and required 15,000 square feet of floor space; it occupied the entire basement of the Moore School of Electrical Engineering at the University of Pennsylvania. Most electronic equipment of that era contained only a couple of hundred vacuum tubes, but ENIAC boasted more than 19,000. Eckert and Mauchly won the Potts Medal of the Franklin Institute for building this first successful electronic computer.

Compared to modern equipment ENIAC was slow, but it was about 60 times faster than the mechanical equipment that it replaced. Operating the machine was difficult because a certain amount of rewiring was necessary for almost every job.

BINAC was a special-purpose computer that was developed right after ENIAC by Eckert and Mauchly. BINAC made four significant breakthroughs: it was the first computer to use serial instead of parallel logic; it was first to be internally programmed; it was the first to use magnetic tape; and it was the first to use solid-state elements.

The use of serial logic reduced the size of the computer because it greatly reduced the number of parts. Parallel logic had required five add circuits to add five-digit numbers—one for each position; serial logic requires only one add circuit because positions are added one at a time.

Internal programming greatly improved man's ability to communicate with the machine. It also eliminated the unsatisfactory task of rewiring the machine when changing from one job to another.

The magnetic tape was only one small reel and had quite limited use. It provided a means of dumping the contents of memory onto a tape when it was necessary to interrupt the program or turn off the equipment.

It achieved faster speeds by the use of solid-state elements—crystal diodes in place of vacuum tubes. It was almost a decade before diodes and transistors came into general use on computers, but the BINAC utilized many of them for switches in 1948. A solid-state component uses the flow of electrons through a solid material the same way that a tube uses the flow of electrons through a vacuum.

In 1946, Eckert and Mauchly had resigned from the University of Pennsylvania and set up their own company, which was purchased in 1950 by Remington-Rand.[1] Remington-Rand had been involved in a guided missile project during World War II that included electronic computer research. Their staff of engineers from this project, coupled with the talents of Eckert and Mauchly, resulted in UNIVAC (Universal Automatic Computer), generally considered to be the first of our present line of computers.

These early computers were used for scientific and engineering work, but in 1951 the first business oriented computer, UNIVAC I, was delivered to the United States Bureau of the Census.

UNIVAC I was operated 24 hours a day, 7 days a week, for 12½ years, by the Bureau of the Census. It was replaced by more modern equipment and presented to the Smithsonian Institute in Washington, D.C., in 1963. This is certainly a testimonial to the fantastic advancements in the computer field—items presented to the Institute are usually centuries old.

IBM (International Business Machines Corporation), a leader in the punched-card data processing field, announced its IBM Type 701 scientific-purpose computer in 1952. Both UNIVAC and IBM seriously underestimated the computer market. After extensive market research, they both concluded that the market saturation point was less than 20 machines. When one considers that these early computers were valued at more than one million dollars each, it is easy to see why the market seemed so limited. Yet, technological advances came rapidly and within 13 short years, approximately 20,000 computers were installed in the United States alone.

Many companies had gained computer capability through government contracts for special-purpose type electronic equipment. In the process of engineering this equipment to serve a special purpose,

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[1]Now known as UNIVAC, a Division of Sperry Rand Corporation.

they obtained valuable experience in computer development and design. It was only natural that this capability should be directed toward the "general-purpose" field when it became apparent that the computer business was going to be very lucrative.

By 1955, Burroughs and RCA were entering the computer race and during the five-year span between 1955 and 1960, they were joined by a multitude of newcomers. Most of these were giant companies such as General Electric, Minneapolis-Honeywell, National Cash Register, Philco, General Mills, Bendix, Underwood, Marchant, Royal-McBee, etc. (See Fig. 1).

One of the major problems encountered by all of these companies has been obsolescence. Technological advances have been made so rapidly that most computers are obsolete by the time they are installed. Huge amounts of capital have been required for continuous

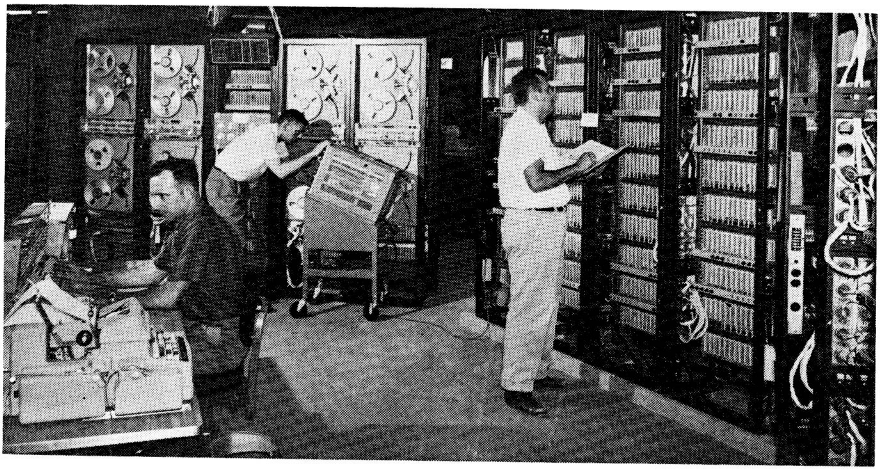

Fig. 1 — Development of Bank of America's famous ERMA. In 1950, Seth Clark Beise, president of the Bank of America, went to the Stanford Research Institute and told them he wanted an automated system developed which would completely process commercial accounts. Five years and $2 million later, Stanford announced development of the prototype. Bids were put out to 30 competitors and General Electric secured the contract. It was — and remains — the largest commercial computer order ever placed. It eventually totaled $50 million. The first ERMA system was installed at San Jose, California in January, 1958, and some 30 systems have been installed throughout California at 13 sites. Pictured above is the central processor of one of the first systems, known as the GE-100, undergoing manufacturing tests at the GE plant in Phoenix, Arizona, prior to delivery to Bank of America. The ERMA systems were the first solid-state general-purpose computer installations in the banking industry. The combined systems are presently processing more than three million items nightly for Bank of America, including checks and deposit slips — a pile of paper higher than the Empire State Building. *Courtesy, of General Electric Company.*

research, in addition to the tremendous expense of production, sales, and systems support. Many companies have either dropped out of the computer race or specialized in military or special-purpose computers.

At this writing, there are eight companies that lead in the general-purpose digital computer business. Listed alphabetically, they are Burroughs Corp., Control Data Corp. (CDC), General Electric Co. (GE), International Business Machines Corp. (IBM), Minneapolis-Honeywell, National Cash Register (NCR), Radio Corporation of America (RCA), and Sperry Rand (UNIVAC). Of these eight, only two had been able to make a profit by 1963—IBM and Control Data.

All of these companies have many types and varieties of computers but it would be confusing to the student to try to cover them at this point.

Before we leave the history of data processing, there is another significant breakthrough that should be mentioned, because it provided the possibility for much of the advancement that has been made. In 1948, Bell Laboratories developed the *transistor* while conducting a series of experiments on crystal ionization. The transistor (solid-state) provides advantages over vacuum tubes as follows:

1. Small, compact, reduces distance impulses have to travel
2. Inexpensive to produce
3. Highly reliable
4. Cool, generates very little heat
5. Requires less power

Sperry Rand utilized transistors for its popular UNIVAC SOLID STATE 80 & 90 Computers.[1] IBM soon turned to transistors also, and by the late 1950's practically all new computers were completely transistorized.

EXPLORING THE PRINCIPLES [2]

Why a Computer?

A relevant preliminary question to a discussion of computers is—why are computers in demand in the first place? Actually, all reasons eventually lead to the same conclusion—they are economical! These economies are seldom apparent to the person who is not thoroughly acquainted with the details of the business or institution for whom

[1]The UNIVAC Solid State 80 accepts 80-column card input; the 90 version is practically the same machine but accepts the 90-column card used by Remington Rand punched-card equipment.

[2]Reprinted from *An Introduction to Basic Computer Concepts* with permission of CONTROL DATA CORPORATION

the computer is installed. Nevertheless, the following factors are generally present and they provide evidence of the economies involved:

- Computers provide new time dimensions for the working day and for the human concept.
- Computers provide efficient and effective controls over human error.
- Computers provide large capacities to store information—and the capability to rapidly access this information.
- Computers provide automatic organizational, administrative and management controls.

There are some operations and some problems where solutions, within practical time limitations, depend upon the speed of calculations. Consider, for example, the problem of multiplying 5,000 numbers of 10 digits each. On a desk calculator, one such multiplication requires 10 seconds. Consequently 50,000 seconds, approximately 14 hours, is required for the 5,000 multiplications. On a fast computer, *all* 5,000 multiplications can be performed in less than $\frac{1}{20}$ of *one second*—approximately one million times as fast. Extending this analogy, it is not difficult to prove that many calculations would never be completed if man had to depend upon a desk calculator and his own speed of calculations.

In the matter of error control, computers make an even more significant impact. The computer performs all operations—all calculations—internally, and without human intervention. Once a computer program has been written and checked out, the desired goals and objectives of the program will be attained unless the hardware components of the system malfunction. In contrast, a system of operations where human capabilities are significantly involved is almost certain to contain many errors. This is particularly true where written records have to be continually monitored, edited, and updated. In using a hand calculator or other common business machine, where manual entries are required, it is estimated that a person makes an error every 500 to 1,000 operations. Computers, on the other hand, will run error-free for hours and days—and in one hour a large computer can perform more than a *billion* operations!

There are no limits to what the human memory can perform! Such statements are common, and there are many examples which indicate new and unexplored marvels of the mind—and the potential aspects of human memory. On the other hand, a practical and realistic analysis of human memory capabilities indicates significant limitations. In the first place, one must admit to *differences*—both in capacity and potential—in individuals. One also realizes that "remembering" is all too often a longer and more difficult process than that which is desired for efficient and effective business practice. Computers have very fast access to tremendous amounts of stored information; this storage area is known as the computer "memory." In addition, computers have auxiliary storage available in the form of magnetic tapes, drums, disks, and other peripheral equipment. Literally *millions* of facts–in coded format–can be stored in these devices. Of equal significance is the fact that information stored in the computer system (in memory or auxiliary storage) can be *randomly* and *quickly* accessed by the computer. The access time is a matter of milliseconds (1 millisecond = 1/1000 of a second), or microseconds (1 microsecond = 1/1,000,000 of a second), or nanoseconds (1 nanosecond = 1 billionth of a second).

Finally, computers provide automatic control features which add strength to the structure of the business organization, which in turn provides more security and returns to the whole enterprise. In recent years, "automation" has sometimes acquired an unenviable reputation as the scapegoat for unemployment. It is interesting to note that critics of automation voice and write their objections through publication and communication media that are made possible by modern automation, ride to work on the wheels of automation, reach their offices via automated elevators, buy foods which are processed and packaged by automation, wear clothes which are automatically tailored, and schedule all activities by time which is set by an automatic clock! Behind this criticism lives a world of progress and a society that is only possible with automation. The truth of the matter is that modern business depends upon automation in order to survive and prosper. Automation becomes the hope and helpmate of all workers! If there is room for wonderment in contemplating the computer, much of it can be reserved for the internal speed of computers. In the past fifty years, man has made fantastic progress in his ability to cover *distance* in decreasing periods of time. The modern jet can cruise at 500 to 600 miles per hour. Satellites, on the other hand, can travel across space at speeds of 20,000 miles per hour. Yet the speed of computers, though a different type of speed, is even more fantastic. Computer speed is associated with executing instructions–that is, accomplishing calculations–rather than covering distances. Many of these tasks are arithmetical in nature, involving addition, subtraction, multiplication, and division. Some modern computers can execute an instruction in *less than ten microseconds.* A microsecond is one-millionth of one second. Thus, the modern computer can execute *one million* instructions in 10 seconds. It is difficult to comprehend the full significance of this tremendous speed. Some realization is gained if one attempts to estimate how long a time is required for the expert mathematician to add one million numbers of seven digits each; for example, numbers such as:

$$\begin{array}{r} 3254267 \\ 2751649 \\ \hline 6005916 \end{array}$$

Assuming each addition can be performed in five seconds, aproximately 5,000,000 seconds are required to add one million numbers. Five million seconds is more than 173 eight-hour days! Working eight hours per day for almost six months, the mathematician might possibly arrive at the same sum that the computer had calculated in 10 seconds!

Problems Conducive to Computers

Some problems are more conducive to computer solution than others. Understanding this concept is helpful. Two questions are helpful in determining whether to use a computer:

(1) Is it economically feasible?

(2) Is it quantitatively feasible?

The time and costs to prepare and program the problem must be considered along with the cost of using the computer and its equipment. Some problems are either too simple, too small, or too unimportant to justify the costs of computer solutions. However, problems which are considered unimportant and economically not feasible for computer solution under today's standards, may look quite different as computer techniques change.

Even a simple problem, if it must be solved for many individuals or for many applications, may be better solved with computers. As an example, consider the income tax return which Joe Smith prepares each year for the Bureau of Internal Revenue. Normally, Joe spends a couple of hours making out his return, and it appears to be uneconomical to prepare his return by computer application. On the other hand, if Joe Smith's return can be programmed to fit the returns of thousands of other taxpayers, a computer application appears in a more attractive light.

The computer, then, is particularly suitable for situations where *one* program solution can be used over and over, processing new problem parameters each time.

The *iterative* type of problem is usually attractive for computer applications. This is a repetitious problem which calculates successive results, with each result coming closer to the true answer of the problem. This successive approximation procedure is commonly used to solve a certain class of mathematical problems. Where calculations of this nature are required, computers are very attractive, since the time to find thousands of approximations by other methods is impractical.

Problem situations which require constant and immediate measures of control are conducive to computer applications, such as a *process,* an *inventory,* a *buy and sell* complex. In such areas, the amount of data that must be handled is considerable. Without computers, the control features of the system which include monitoring, decision-making, editing and updating records, etc., are left completely to manual efforts. In some businesses, the amount of data involved in controlling current stock, providing storage, filling customer orders, costing materials, and adjusting for seasonal variations make it physically and economically impossible to operate without computers

The second question—that of quantitative feasibility—is more insidious and less understood by most persons. *All* computers operate on *numerical* data. This means that alphabetic data must be converted to numerical codes before the computer can handle the data. This conversion is not a problem. More serious is the fact that some data, because of its nature, does not lend itself to numerical manipulation, and is much more difficult to program. For example, using a computer to advance a student's concepts in mathematics is much easier than trying to accomplish the same objective in English. Translating a paragraph of Russian language to English by a computer program is much more difficult than solving a differential equation. A useful rule to remember in this regard is:

> "That which implies capability of sight-vision is more difficult for the computer than that which implies capability to calculate."

It is interesting to note that for humans this rule is generally reversed. Thus, it is easier for a person to choose the two largest numbers from a group of 100 numbers than it is to find their sum. For the computer, the opposite is true. Of course, the computer will do both faster than the human!

Basic Computer Configuration

Consider the ordinary procedures one follows to start his car each day. The ignition key is turned to a position (or a start button is depressed). This in turn provided battery power (INPUT) to turn the fly wheel, which causes a spark to ignite the combustible gas mixture and the motor starts. The proper gear setting (INSTRUCTION) engages the drive shaft and the car moves (OUTPUT). Other INSTRUCTIONS (applied in SEQUENCE) direct the car's speed and direction to its final destination. In summary, once provided an IN-

PUT, the car motor responded to the input (ACTION or CALCULATION) and the car moved forward (OUTPUT).

Consider next a decision to type a letter. One has a copy, either on scratch paper or in his mind. This is the INPUT. He types the desired characters (INSTRUCTIONS) in a predetermined SEQUENCE; the typewriter keys respond (ACTION or CALCULATION) and the printed characters appear on the letter page (OUT-

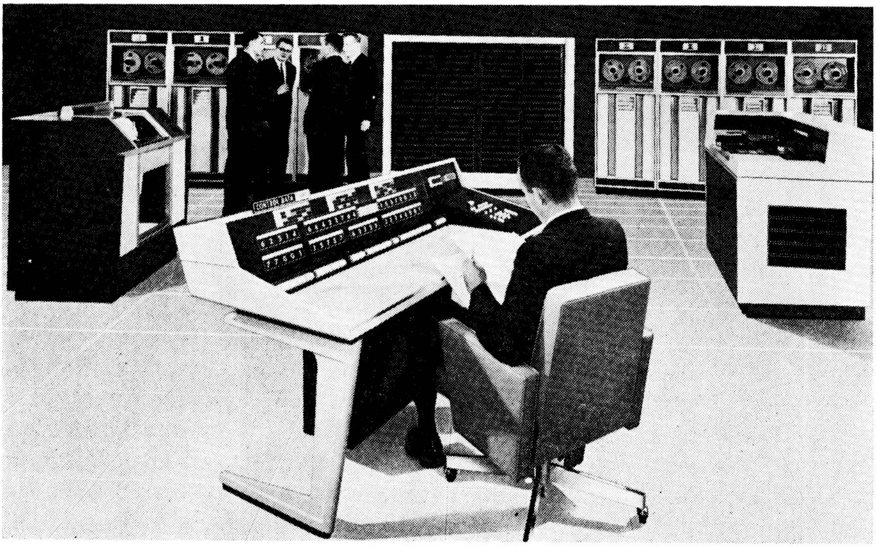

Fig. 2 — A Modern, Computer System. *Courtesy, of General Electric Company.*

The electronic digital computer, (See Fig. 2) like the car or the typewriter, consists of equipment designed and built for man to use. It has distinct and unique characteristics along with its special purposes and functions. Whereas the car is designed to provide point-to-point transportation; the computer is designed to perform calculations on numbers, make simple logic decisions, and control various other data handling equipment. As for the car and the typewriter, one must provide INPUT in the form of data; various calculations or ARITHMETIC are performed on the data; and desired results are then made available (OUTPUT) through some output device. The basic computer configurations can be simplified as shown in Fig. 3.

The various INPUT and OUTPUT devices are chosen to fit the specific application. Many of these devices operate at much faster speeds than others. Consequently, speed of operations may be a criterion for choosing specific INPUT-OUTPUT equipment. Some