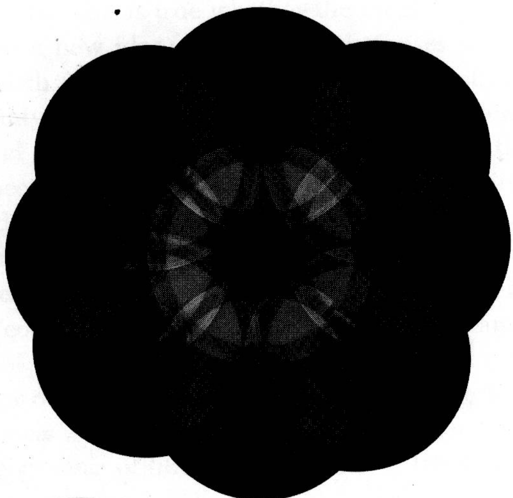
the CHALLENGE of the COMPUTER UTILITY

D. F. PARKHILL



ADDISON-WESLEY PUBLISHING COMPANY
Reading, Massachusetts · Palo Alto · London · Don Mills, Ontario

 Library of Congress Catalog Card Number 66-24245.

Preface

A new birth always has about it an aura of excitement that can be matched by few other spectacles. This is true whether the birth is that of a new being, a new world, or a new idea. The excitement arises not so much from the mere fact of birth (although novelty is always interesting) but rather from the uncertainty, the element of doubt as to the future, that always surrounds a novel event. In this connection, workers in the field of computers are now becoming increasingly excited about the birth of a remarkable new method for the distribution and utilization of computer power. This method has been given a variety of names—"information utility," "information network," "time-sharing," "fireside computer," or as in this book, simply "computer utility." Regardless of the name, however, the development of this method does open up exciting new prospects for the employment of computers in ways and on a scale that would have seemed pure fantasy only five years ago.

Even now the subject of computer utilities is very much in the public eye, as evidenced by the many articles in both the popular and technical press, prognostications by leading industrial and scientific figures, and growing signs of interest on the part of governments everywhere. The author's purpose in this book is to facilitate this growing discussion by providing a broad examination that will reveal something of the history, technology, and economics of the computer utility and explore some of its possible implications for our society.

The scope of the book is of necessity very wide, and, in fact, most of the chapters could well be the beginnings of books themselves. This is particularly true of the sections which deal with legal, political, and social implications, but it is the author's hope that his tentative probes into this tangled jungle of opinion and speculation will whet the reader's appetite for discussion and provide the basis for a more detailed examination of the issues. Likewise, in the technical chapters, the emphasis has been more on the identification of critical parameters and the enunciation of general principles than on the presentation of detailed design data. Chapter 5, for example, introduces such subjects as time and equipment sharing, scheduling algorithms, executive routines, and memory protection, but the detailed treatment of these complex subjects could obviously fill entire volumes.

The book is aimed at a rather wide audience whose members are unlikely to have much in common beyond an appreciation for the role of modern technology in shaping human events. Consequently, the author has attempted to avoid both encyclopedic detail and trivial generality. It is not to be expected, however, that all readers will find all portions of the book equally interesting or intelligible. Some parts, such as the section on memories in Chapter 2, may seem somewhat elementary to most professionals, and conversely, the latter parts of Chapter 2 and some portions of Chapters 4 and 5 may be rather difficult for those readers with no prior knowledge of computers or of computer terminology. Fortunately no great harm will be done if some readers skip and pick their way through such sections, but to provide some assistance to the layman, we have provided an Appendix, containing a glossary of many of the specialized terms used in the book.

ORGANIZATION OF THE BOOK

The concept of the computer utility is not something that has emerged suddenly. Instead it is the latest step in a complex evolutionary process whose roots extend far back in time. Its technology, for example, is not a unique creation, but is rather the logical extension of techniques and ideas that have long been a familiar part of digital-computer and communications-systems engineering. Consequently, before we attempt to discuss the subject of computer utilities, it is almost mandatory that we first consider some of the principal historical and technological developments that form the basic underpinnings.

The first three chapters are therefore devoted largely to providing background data. Chapter 1 is completely historical and tells again, although hopefully in a rather unique vein, the oft-told story of the early development of the computer. Chapter 2, on the other hand, although it does contain some historical material, is more concerned with technological trends as they appear to an observer at the beginning of the third generation of computers. This leads naturally into Chapter 3, which first follows the evolution of the computer public utility concept from its early special-purpose and military beginnings through to the present day, and then presents a general classification scheme for the many different forms that a computer utility might take. This classification scheme is employed in Chapter 4, "Early Computer Utilities," which presents some brief descriptions of a number of computer utilities that were in operation at the time of writing.

In Chapter 5 we first come to grips with the detailed technology of computer utilities. Here many of the various possibilities for software and hardware design are examined and some of the basic organizational forms for a computer utility are discussed. In this chapter, as well as in Chapters 2 and 4, some of the material may be obsolete by the time it is read because of the rapidity of technical change. The publication of a book is a lengthy process, and when it finally reaches the reader, there is a likelihood that new machines and new techniques will have replaced those discussed by the author. It is hoped, however, that the general principles enunciated will still remain true long after the specific equipment details have vanished into history.

At some point in the early history of every new invention, as the glamour and excitement of novelty wears off, the question of cost is raised and one comes face to face with the age-old problems of economics. In this respect the computer utility is no exception, and as practical self-supporting systems come into existence today, the hard facts of efficiency, effectiveness, relative costs, capital investment, optimum rate structures, and the like become crucially important. For this reason, Chapter 6 is devoted to an examination of computer-utility economics. Economic considerations, in addition to many others, are also involved in the discussions of Chapter 7. This chapter, "Legal Factors," provides a first look at some of the complex problems of law—some old but many completely new—that must be faced as we attempt to treat computer power as a public utility.

Even under the best of conditions the art of prophecy is a difficult and even dangerous process. This is particularly true when the subject of that prophecy is a dynamic technology like computer utilities. On the other hand, the present period of transition from the second to the third generation of computers is a particularly opportune time to attempt to create a picture of the world that might be. For it is precisely during critical phases like the present, when all kinds of tangled threads of probability are being sorted out and translated into reality, that the greatest opportunities for shaping the future arise. Accordingly Chapter 8 mixes together discussions of technology, economics, law, and politics in an attempt to examine some of the possibilities of that "society altered almost beyond recognition" that may lie ahead of us.

Finally, in the last chapter, we return to the present to review the over-all conclusions of the book and summarize some of the important unresolved problems that stand in the way of the full realization of the computer utility.

ACKNOWLEDGMENTS

Unfortunately, it is impossible to directly thank all of the many people and organizations who have helped with this book, but some of the principle ones can be mentioned. First, I wish to thank the MITRE Corporation for its encouragement and support, and within MITRE, such colleagues as Claire Farr, George Hawthorn, Jr., Jack Porter, and Ken McVicar for their stimulating comments and advice. In this connection, it must be emphasized, however, that the contents of the book reflect the views of the author, who is solely responsible for the accuracy of the data presented, and do not necessarily reflect the official views or policy of the MITRE Corporation or its employees.

I also gratefully acknowledge my debt to the numerous organizations which provided me with the data used in the equipment and systems descriptions of Chapters 4 and 5. Individuals who were especially helpful in this regard include Mr. Charles W. Adams, President of the KEY-DATA Corporation of Cambridge, Massachusetts; Mr. Ralph E. Hawes of the IBM Data Processing Division, Cambridge, Massachusetts; Mr. Kenneth Hebert of the Computing Center, California Institute of Technology; Dr. Fred Gruenberger of The RAND Corporation; Mr. Al Irvine of the UCLA Western Data Processing Center; Mr. Rolph Kates, Director of the Applications and Systems Division, Honeywell, Inc., Needham, Massachusetts; Professor John McCarthy of Stanford University; Mr. Daniel R. Mason of the Computer Sciences Corporation, Los Angeles, California; and Mr. Jules I. Schwartz of the System Development Corporation, Santa Monica, California. Equal thanks are due to the Electronic Systems Division of the U.S. Air Force for the photographs of Air Force equipment contained in Chapter 3 and to Mr. H. W. Wallace of MITRE for the information concerning communications rates included in Chapters 6.

Finally, I wish to thank Miss Marcia Leighton for the long hours that she devoted to typing the manuscript, J. T. Golden of IBM for reading and criticizing portions of the draft, and Jules I. Schwartz of the System Development Corporation for his thorough review of the manuscript and many helpful suggestions.

Winchester, Massachusetts D.F.P.
January 1966

Contents

Introduction

THE GENERATIONS OF COMPUTERS

An unusually rapid rate of technical advance has always been one of the most obvious characteristics of the digital computer industry. As a consequence, in the 20 years that have passed since the first crude electronic computers came into existence, two generations of machines have appeared and a third is now being introduced.

The first generation, which lasted until about 1957, was the great age of invention. During this period the basic techniques and systems essential to the building of a new technology were worked out. When the first generation began in 1945, the basic computer component was the electromechanical relay, and the first experiments with vacuum tube systems were starting. By 1957 the computer relay, apart from its use in slow-speed business calculators, was a museum piece, and the vacuum tube had been superseded in all new systems by solid-state and ferrite elements.

The second generation, that has just passed, encompassed an explosive expansion in the application of digital computers to almost every area of science, business, and military affairs. Thus at present, tens of thousands of computers are operating day and night in every corner of the globe, in the depths of the sea, and in outer space. In fact, by the end of 1964 over 18,000 machines had been installed in the United States alone, and according to a recent Senate report* [1]† U. S. Government

---

* "Report to the President on the Management of Automatic Data Processing in the Federal Government," Committee on Government Operations, U. S. Senate, March 4, 1965.

† Numbers in brackets are keyed to the references at the end of the text.

expenditures for computers during Fiscal Year 1964 were close to one billion dollars.*

The availability of information-processing power, represented by tens of thousands of computers, has, of course, profoundly affected the growth of both government and industry. Thus it is difficult to see how the complex interrelated governmental and industrial structure of modern America could operate at anything like its present level of efficiency in the absence of the automatic-handling capabilities of the computer. Likewise, without the computer, many of the proudest achievements of contemporary science (space flight is a good example) would have been absolutely impossible. Nevertheless, the actual contact of the average person with the computer has to date been very slight. He may have grumbled at the injunction not to fold or bend his insurance premium bill, may have noticed some peculiar markings on the back of a gasoline credit card, and worried over the fact that the Internal Revenue Service was using computers to crack down on income tax offenders, but all in all, the direct impact of the computer on his daily life seemed to be small in comparison to that of other technological innovations like television or the jet airliner.

Today, as we cross the threshold of the third generation, the anonymity of the computer is about to disappear, for it now appears likely that the coming era will carry to fulfillment a gigantic revolution in the generation and distribution of computer power. Before that revolution has run its course, the computer will have become as much a part of our daily lives as is the telephone of today, and our society will probably have been altered almost beyond recognition. It is the theme of this book that the moving force behind this revolution will be the perfection and rapid growth of the public tele-data-processing system, or computer public utility.

WHAT IS A COMPUTER UTILITY?

Tele-data-processing systems (in which many remotely located users are connected via communication links to a central computing facility) have long been familiar in such specialized areas as airline reservations, air defense, mail-order tallying, inventory control, and department-store point-of-sale recording. More recently, the tele-data-processing concept has been extended to more general-purpose fields with the objective of sharing the use and costs of a digital computer among a number of

* This figure does not include expenditures for military operational and contractor operated machines. If these were included, the expenditure would probably be in excess of three billion dollars.

users, as in any service bureau, but without requiring the physical transport of data and programs between the users and the computing center. In some cases, multiprogramming, so that the central computer can simultaneously operate on many different programs, is also incorporated. In a few systems, programming, debugging, data introduction and retrieval, and computer control can be performed simultaneously, on-line, at each of the remote sites as though each user had the entire computing facility at his full time command. These on-line, general-purpose multi-user systems have generated widespread interest and have led to the concept of the "computer public utility," the major theme of this book. NB

As generally envisaged, a computer public utility would be a general-purpose public system, simultaneously making available to a multitude of diverse geographically distributed users a wide range of different information-processing services and capabilities on an on-line basis. As in any utility, the overhead would be shared among all users, with each user's charges varying with the actual time and facilities used in the solution of his problems. Ideally, such a utility would provide each user, whenever he needed it, with a private computer capability as powerful as the current technology permitted but at a small fraction of the cost of an individually owned system.

The word "utility" in the term "computer utility" has, of course, the same connotation as it does in other more familiar fields such as in electrical power utilities or telephone utilities and merely denotes a service that is shared among many users, with each user bearing only a small fraction of the total cost of providing that service. In the case of the computer utility, however, the services rendered are very much more numerous and much more complex than those of the older utilities. Thus in addition to making raw computer power available in a convenient economical form, a computer utility would be concerned with almost any service or function which could in some way be related to the processing, storage, collection, and distribution of information. In fact, in a provocative article, Professor Martin Greenberger of MIT coined the term "information utility" to describe the sort of system with which this book is concerned.

Likewise, a computer utility differs fundamentally from the normal computer service bureau in that the services are supplied directly to the user in his home, factory, or office. Furthermore, since the user pays only for the service that he actually uses, a man-machine interactive operating mode becomes economically feasible. In such a mode, the human sits at the console and works directly with the computer so that the machine becomes a sort of intellectual partner, responding immediately to the queries of the man, questioning his errors, and amplifying a millionfold his effective mental powers.

In a normal computer installation, such an interactive operating mode would be prohibitively expensive, since during most of the time that the man was sitting thinking or typing at his console, the machine would be idle. In the computer utility, however, this idle time is put to use by the technique of "time-sharing" to permit many other users to simultaneously share the same central computer. Chapter 5 discusses this technique in considerable detail, since it is basic to the efficient functioning of a computer utility.

CHAPTER 1

From Magic To Technology

1.1 THE POWER OF MAGIC

By instinct, man is both lazy and discontented. The first of these characteristics produces in him a natural aversion to work, and the second makes him dissatisfied with the world around him. Consequently, the story of man's progress is largely written in the chronicles of his attempts to find a more satisfactory way of existence that would simultaneously reduce his need to work and increase the degree to which his wants were satisfied. In the physical world, the consequences of this search can be seen in the proliferation of labor-saving machinery—a phenomenon that has created the machine-based civilization of today and introduced as a subject of practical politics the possibility of an economy of plenty for all mankind.

On the other hand, because man is a thinking animal he has needs that transcend his contemporary physical world. In fact, his entire life is played out as an inhabitant of two worlds—one the open universe of physical reality, the other the closed yet at the same time potentially infinite realm of the mind. Just as in the physical world, however, man finds a vast gulf between his aspirations and his capabilities. Consequently, his invention of labor-saving devices has been paralleled since earliest times by a search for ways of augmenting his intellectual powers.

Usually among primitive people the boundaries between the natural and the supernatural are rather imperfectly defined. Thus some of the earliest and most widely employed intellectual aids were those that depended on the practice of magic. In fact, even in the relatively sophisticated intellectual climates of Classical Greece and Rome, the practice of divination and the consulting of oracles were important elements in the decision-making processes of both individuals and governments.

In particular the oracle at Delphi in Greece became with the passage of time a sort of super-information machine whose "attendants," corresponding roughly to the programmers in a modern computing center, stood between the users and the oracle. Thus in a typical session, the Delphic priestess, or Pythia, seated on a special tripod over a sacred chasm, would pass into a hypnotic trance and then reply to the queries of the customer. More often than not, her replies were, as one might expect, hardly more than unintelligible gibberish, but this mattered little because the inquirer was always forbidden to make a direct transcription of the Pythia's replies. Instead, the Delphic officials prepared a written statement which supposedly contained the meaning of what the priestess had said. This decoded (or interpreted) reply constituted the official response of the oracle.

Since the oracle at Delphi was consulted by all the governments of the Greek world for decisions involving the most sensitive areas of national and international policy, it is obvious that the oracle's officials were provided with a magnificent arrangement for influencing the course of world affairs. Thus the power and influence of the oracle at its zenith were very considerable. Used wisely, this power could have been a profound influence for good in the tangled jungle of Greek politics.

Despite its surface gloss of superstition and magic, Delphi did accumulate, from its widespread contacts with all parts of the ancient world, a tremendous store of information embracing a wide range of subjects. Thus, when giving advice, the priests were able to draw on a data base that included the accumulated knowledge and experience of many races and peoples. Consequently, when honestly given, the advice of the oracle was likely to be very valuable indeed.

Unfortunately, however, it appears that in rendering their opinions the Delphians all too often tailored them to further the interests of Delphi rather than the interests of their clients. This was particularly apparent in the international field, where Delphi consistently favored the totalitarian Spartans over the more liberal Athenians, apparently reasoning that she could more easily control a state where all power was concentrated in a few hands than she could a democratic society whose officials were responsible to all of the citizens for their actions.

The ultimate example of such folly occurred in the fifth century B.C. during the struggle with Persia. Greece was faced with an invasion by Xerxes I, but the oracle discouraged resistance and openly worked for a Persian victory. Historians seem to be of mixed opinions concerning the reasons for this stand. A few take the charitable view, crediting the Delphians with merely calling the shots as they saw them. Others hint of Persian gold and talk of bribery. The general feeling, however, seems to be that the oracle's rulers were merely playing power politics, having decided that a Persian victory was inevitable. Thus they hoped that, as Emperor of Greece, Xerxes would feel indebted to the cult of a god that assisted his victory, and consequently would reward its custodians.

1.2 EARLY CALCULATING INSTRUMENTS

Magic was not the only intellectual aid employed in the Ancient World. The *abacus,* for example, a digital hand calculator still employed in some parts of the world, was in common use in China by 600 B.C. and was used in both ancient Greece and Rome. The Egyptians, according to Herodotus (450 B.C.) also used a crude form of calculator in which pebbles served as the counting elements. The Greeks, as well as other ancient peoples, also developed some rather sophisticated clockwork mechanisms that were used for representing various astronomical cycles. In fact, a very remarkable instrument of this type, constructed in about 82 B.C., was recovered in 1900 from a sunken ship near the Greek island of Antikythera.

The Antikythera instrument was the subject of a feature article by Derek J. de Solla Price in the June 1959 *Scientific American* [2]. According to this article, the computer was an extremely complicated device indeed and was equipped with numerous dials, both large and small. These dials apparently represented the motions of the sun, moon, planets, and certain stars in a manner reminescent of the astronomical clocks that centuries later became the show pieces of Medieval Europe.

Blaise Pascal is widely credited with constructing the first machine that was capable of addition and subtraction. His machine was built in 1642 and consisted of a train of number wheels whose positions could be observed through windows in the cover of the box which enclosed the mechanism. Numbers were entered by means of dial wheels. Like the Abacus, Pascal's computer was a digital device and carried out its computations by a process of integer counting. Thus each wheel had 10 teeth to represent numbers, with each tooth standing for a particular digit. It was therefore possible to perform addition by stepping the wheels through a number of intervals equal to the number to be added.

The next step forward occurred in 1671 when Leibniz invented a machine that was capable of multiplication. This it accomplished by a process of repeated addition similar to that used even today in many modern digital computers. A working model of the Leibniz computer was completed in 1794 and was exhibited at the Royal Society in London. Unfortunately, however, the Leibniz machine was rather unreliable, and it was not until 1820 that a machine capable of performing the four