JAMES MARTIN

Programming Real-Time Computer Systems

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PROGRAMMING REAL-TIME COMPUTER SYSTEMS

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Frontispiece. Ninety separate pieces of equipment making up American Airlines' SABRE reservations system are shown in this photograph made at the airline's electronic reservations center at Briarcliff Manor, N. Y., with a Nikon Fisheye lens.

PREFACE

The trend in the use of data processing is towards larger, more integrated systems. The hardware now available is enabling many companies to combine functions that were previously done separately. Scientific, commercial, and real-time processing are being handled on one machine or network of machines. Data transmission links are speeding the flow of business and technical information, and remote enquiry stations are becoming an increasingly common facility.

Scientists and others are finding that time-sharing techniques can vastly increase the availability and usefulness of their computers, while massive random-access storage devices are today part of the solution to many file management problems in business and government. Computers are being used on-line to chemical plants, jet-engine test beds, classrooms, and the shop floor in factories. Man is acquiring a new relationship with the machines through the use of distant displays and console devices.

As these trends spread, programmers and systems analysts are faced with an increasingly difficult task. Many programs may be in the computer at one time. Different operations interrupt each other in a complex fashion. Events no longer fit into predetermined timing patterns, and elaborate Supervisory Programs are needed for coordinating these events and allocating priorities. Data has to be located in and read from large files without holding up other processing. Errors and emergencies have become more difficult to deal with.

This book describes the methods used in programming complex systems of this type. While many of the techniques described apply to non-real-time systems, emphasis is given to real-time with its special problems and dangers.

The state of this art is changing rapidly and by the time a book is edited and published there are already new ideas, new methods, and new machines. It is hoped that, although the details change, the principles set out in this book will remain true long enough for the work to be of value.

J.M.

ACKNOWLEDGEMENTS

There are many acknowledgements that should accompany a book of this nature. The development of the techniques it describes has been the result of the creativity and labor of a very large number of persons. Most of the techniques are now coming into common computer usage, but the work that has led to these methods was originated on certain pioneering installations which include:

SAGE

Project Mercury

American Airlines SABRE System

Pan American Airways PANAMAC System

New York Stock Exchange System

First National Bank of Chicago

IBM's Internal Teleprocessing System

To the many Systems Engineers and Programmers who worked on these and other projects, the author is indebted.

Some material is taken from a report on system testing prepared for the PANAMAC System by Messrs. J. Egglezos, C. Barbel, T. P. Taylor, and the author.

The manuscript was read and valuable criticisms made by Messrs. C. Vince and P. Neall in London, and by Mr. W. B. Elmore in New York.

Generous help was given in the preparation of this book by various members of the International Business Machines Corporation in London, Paris, and the United States.

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BASIC CONCEPTS

There are certain basic concepts, principles, and terms which are defined and explained in this work. The following index lists these, along with the page on which a definition or introductory explanation of them is given. Fig. 1 serves as a guide for the readers of varying interests who will be concerned with the use of the book.

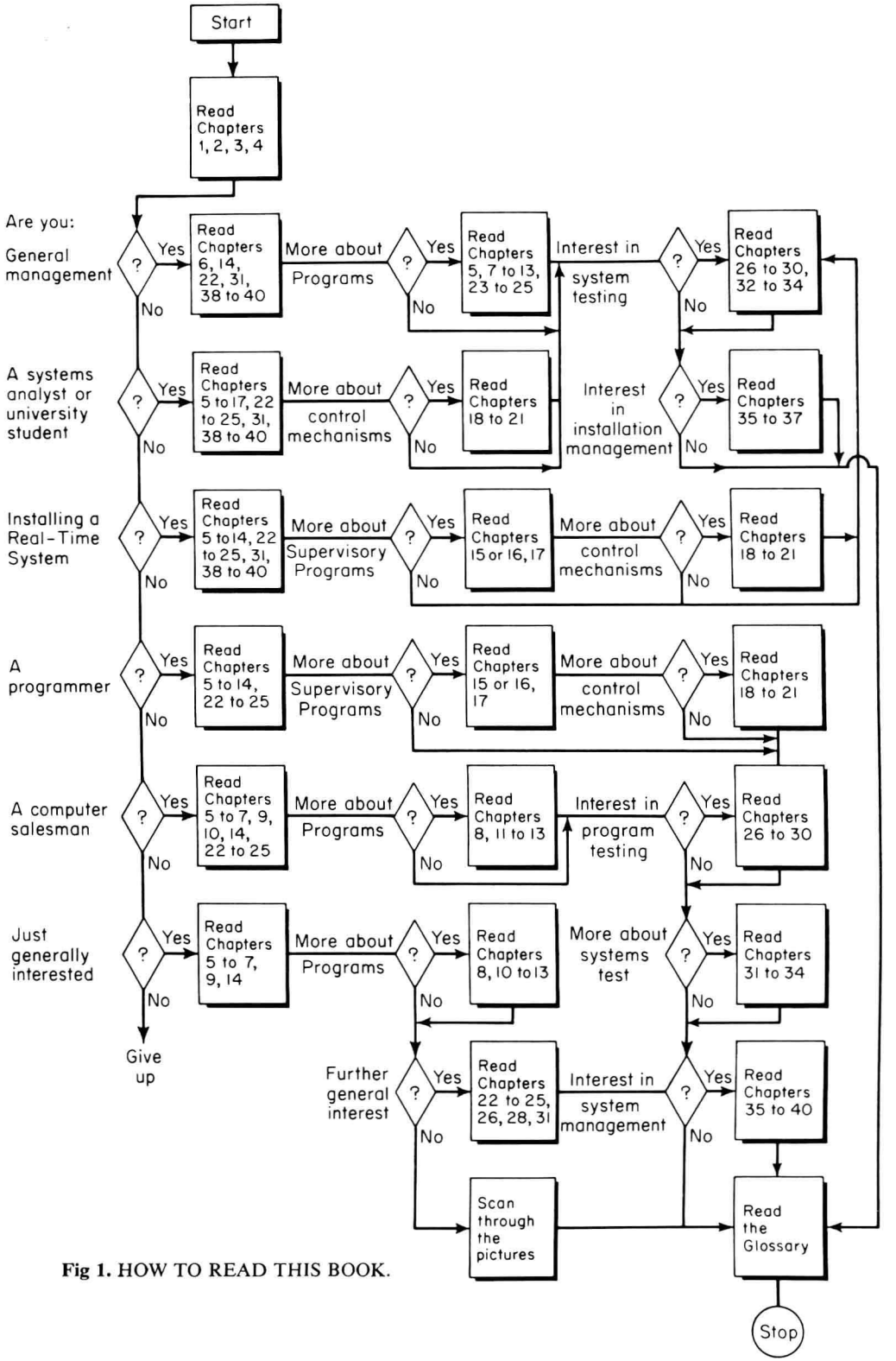

Fig 1. HOW TO READ THIS BOOK.

SECTION I

THE GENERAL PICTURE

1 A REAL-TIME INTRODUCTION

A revolution is taking place in the world of data processing.

The introduction of the electronic computer, a little more than a decade ago, fundamentally changed the techniques of data processing. Punched card installations, accounting machines and calculators were replaced by computers, slowly and cautiously at first, and later more rapidly. The potentialities of data processing expanded enormously. Work previously undreamed of soon became possible on the new machines.

By now computers are a familiar sight in industry and commerce, in laboratories and government departments. They chew through vast files of card or tape, do calculations and make logical decisions. Reams and reams of paper flow from their high speed printers. Whole floors of churning card punches and reproducers, sorters and collators, clanking accounting machines and girls pushing trolley loads of cards, have been replaced by the grey and blue computers flickering their lights and spinning their tape reels.

Today, a second revolution is in progress, and its effect will ultimately be more rewarding than the first.

Systems described as "on-line" and "real-time" are now being installed and planned. In these, data may be entered directly into the computer system from the environment it works with, and information is sent back there. The wide variety of devices which feed data into the computer and which receive the processed information are referred to in this book as *terminals*.

The terminals may be in the computer room or they may be far away, connected to the computer by telephone line or other forms of telecommunication links.

A batch of data travels from the terminal to the computer. It is processed and another batch of data is sent back to the terminal in reply.

These batches of data are referred to throughout the book as *messages* or *transactions*.

Messages arriving at the computer from its terminals are not stored in serial files on tapes or on cards to be sorted and batch-processed; they are processed immediately so that a reply may go back to the requisite terminals within seconds or fractions of seconds. The terminals may be many miles from the computer. For example, in the Pan American Airline Reservation System they are all over the world. A message originating in a travel agent's office in Rome would have a reply from the on-line real-time computer in New York within five seconds.

The terminals in such a system may be designed for entering commercial data or they may be technical equipment such as thermocouples, strain gauges and so on. A very wide variety of devices is possible for collecting data at their source and for delivering the results of the computation at the place where they are needed (Fig. 2). The network of terminals marks the system as "on-line."

An on-line system may be defined as one in which the input data enter the computer directly from their point of origin and/or in which output data are transmitted directly to where they are used.

The intermediate stages of punching data on cards or paper tape, or of writing magnetic tape, or off-line printing, are largely avoided.

The computer system, then, instead of doing a piece of work, the results of which will be used at a later time, can now enter directly into a minute-by-minute *control* of an environment. It can operate a reservation network for hotels or airlines. It can control a steel mill and optimize its efficiency. It can monitor a manned space flight. It can give bank customers up-to-the-minute details of their accounts. It can schedule work through a factory and re-schedule it whenever new requirements occur or when the situation on the shop floor changes. It can speed up the flow of traffic in a city by detecting the positions of vehicles and changing the traffic lights in the optimum manner.

This is "real-time."

A real-time computer system may be defined as one which controls an environment by receiving data, processing them and returning the results sufficiently quickly to affect the functioning of the environment at that time.

"Real-time" is a term that is defined differently by different authorities. The question of "response time" may enter into the definition.

Response time is the time the system takes to react to a given input. If a message is keyed into a terminal by an operator and the reply from the computer is typed at the same terminal, *"response time" may be defined as the time interval between the operator pressing the last key and the terminal typing the first letter of the reply.* For different kinds of terminals response time may be defined similarly as the interval between an event and the system's response to the event.