THE MIND TOOL

COMPUTERS AND THEIR IMPACT ON SOCIETY

THIRD EDITION

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Preface

When the first edition of *The Mind Tool* came out in 1976, the microprocessor revolution was just starting to bring computers out of computer rooms and into the hands of ordinary people. Now, as the third edition appears, the microprocessor revolution continues unabated. With computer-controlled household appliances, television sets, and video games commonplace, few of us can get through a day without using a computer in some way.

The microprocessor revolution has influenced not only the content of *The Mind Tool* but the way in which the content has been revised. The first and second editions were written with a traditional typewriter. For the third edition, the typewriter gave way to a word-processing program run on a personal computer.

The third edition of *The Mind Tool*, like the two before it, is designed to introduce the reader to computers, their applications, and their impact on society. Although the frustrations, dangers, and uncertainties of computer use are not minimized, neither are they allowed to overshadow the many benefits these machines offer to society.

Chapter 1 introduces computers and their applications. It also states the theme for the rest of the book: Computers, like most other technological innovations, have the potential for both benefit and harm. It's important that people know enough about computers to distinguish between their beneficial and harmful applications.

The remainder of the book is divided into three parts: "Computers . . . ," ". . . and society," and "BASIC."

Part 1, "Computers . . . ," concentrates on the computer itself—its history (chap. 2), hardware (chap. 3), operation (chap. 4), software (chap. 5), and programming (chap. 6). In chapter 4, the post-office-box–clerk–calculator computer analogy in the second edition has been replaced by a simple, but realistic, hypothetical computer. Chapter 5 introduces the idea of programming languages, and chapter 6 illustrates the basic ideas of computer programming.

Part 2, ". . . and Society," focuses on computer applications and their impact on society. Chapter 7, "Embedded Computers," and chapter 8, "Home Computing and Telecommunications," discuss the use of computers by individuals. Chapters 9–12 discuss applications by professionals: scientists, teachers, artists, entertainers, and medical workers. Chapters 13 and 14 cover applications in transportation, government, law enforcement, and politics.

Chapter 15 turns to antisocial applications of computers by embezzlers, mischief-makers, saboteurs, and software pirates. Chapter 16 explores the possible consequences of automation and robots, and chapter 17 looks at computers in business and finance—from management information systems and office automation to point-of-sale equipment and electronic funds-transfer. Chapter 18, "Computers and People," addresses questions ranging from invasion of privacy and universal identifiers to ergonomics, the new science of making computers easier to use. Chapter 19, "Artificial Intelligence," has been rewritten to focus on the techniques and applications of artificial intelligence, rather than on fruitless debates about the limits of machine intelligence.

Part 3, "BASIC," is a seven-chapter introduction to BASIC programming. Extra space is devoted to the parts of programming that students find particularly difficult, such as variables, expressions containing more than one operator, and expressions involving parentheses. Separate chapters are devoted to three important techniques for constructing programs: repetition, selection, and the use of functions and subroutines. Programs are written in an indented style to clarify their structure. The final two chapters focus on important data structures in BASIC: arrays and strings. Each chapter in part 3 presents problems ranging in difficulty from easy to intermediate. Most of the problems are nonmathematical.

The standard minimal BASIC is used except for the following string-processing features: comparison of strings for alphabetical order, arrays of strings, and string-manipulating operators and functions. The version of BASIC used is also consistent with Microsoft BASIC, various versions of which are widely used on microcomputers. Variations in implementations of the FOR and NEXT statements and the RND function are discussed in detail. Students are warned that string-processing facilities can vary drastically from one version of BASIC to another.

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Contents

1 Introducing the computer

It used to be that if you wanted to see a computer you had to visit a large corporation, a major university, or a government agency. Once there, you still might not have gotten to see the computer, for in those days most computers were locked away in closely guarded computer rooms, which only the people responsible for operating the computer were allowed to enter. Computer-science students often never got to touch, or even see, the computer they were studying.

How times have changed! Today, computers are almost everywhere—in microwave ovens, automobiles, cameras, typewriters, television sets, and stereos. Many small businesses have their own computers, as do many professionals such as doctors, lawyers, and engineers. Computers are coming into the classrooms of colleges and universities, as well as grammar schools and high schools. Many thousands of people have computers in their homes. Stores that sell home and business computers have sprung up in malls and shopping centers everywhere. Computer-based video games are a popular pastime with young people.

This revolution in the way people use computers came about through advances in *microelectronics,* the art of building complicated electronic circuits on tiny chips of silicon. What once filled a large cabinet in the computer room (and cost hundreds of thousands of dollars) can now be built on a silicon chip that will fit on the end of your finger (and perhaps cost only a few dollars).

One such chip, the *microprocessor,* is the most important component of a computer. A microprocessor carries out calculations according to a set of instructions called a *program*. The instructions, as well as the data used in the calculations, are stored in *memory chips,* another product of microelectronics. It is microprocessors that have made small, inexpensive computers possible. For this reason, the changes brought about by these computers are often referred to as the *microprocessor revolution*.

How does the microprocessor revolution affect you and me? Used intelligently and creatively, computers can open up new realms of human comfort, convenience, pleasure, freedom, and intellectual stimulation. Used thoughtlessly, however, they can threaten our humanity, our privacy, our livelihoods, even our freedom. Only if we are aware of the possibilities for both benefit and harm can we insist that computers be used *for* people and not *against* them.

But before we start talking about how computers should and should not be used, let's look briefly at what computers are and at some of the things they can do.

The Information Machine

The computer

Two outstanding characteristics distinguish computers from all other machines. In this book we will apply the term *computer* to any machine that exhibits these two characteristics, even though some such machines are better known by other names, such as *pocket calculator* or *video game:*

1. A computer is an information-processing machine. Information to be processed goes into a computer and processed information comes out, somewhat as grain goes in one end of a mill and flour comes out the other.
2. The information processing that a computer does is governed by a detailed set of instructions called a *program*. Without a program, a computer can do nothing useful. By changing the program, we can change completely the kind of information processing that the computer is doing. Under the control of different programs, the same computer might do such diverse jobs as printing workers' paychecks, computing the orbit of a spacecraft, or playing a video game with the operator.

Computers were once so expensive that only the largest organizations could afford them. Now they are finding more and more applications in the home, not the least of which is the amusement and instruction of children.

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If a computer is always to execute* the same program, the program can be permanently installed in the computer. A person using such a computer may be unaware that the program even exists. But if we look inside a computer, we will always find a part that stores instructions and a part that follows those instructions. (The part that follows instructions is called the *central processing unit*, or *CPU*. In a small computer, the CPU is always a microprocessor.)

The two fundamental ideas of computing, then, are *information processing* and *programming*. Let's look at each of these ideas in more detail.

Information

The words *information* and *knowledge* refer to the same thing—facts about ourselves and the world around us. When the facts are inside our heads we call them knowledge. But when we pass those facts from one person to another or preserve them, as in books, we call them information. Thus we speak of having knowledge but of receiving, providing, requesting, or looking up information.

Symbols

To convey information from one person to another or to store it for later use, we have to represent it in some concrete, physical form. We use the term *symbol* for any physical object or physical effect that is used to represent information. Familiar symbols include the sounds of human speech and the characters used in writing and printing. The latter includes letters, digits, punctuation marks, and special signs such as the dollar sign, the plus sign, and the minus sign.

Speech sounds and printed characters are symbols that nearly everyone uses (although people who speak different languages use them in different ways). Other symbols are used by particular groups of people for special purposes. Examples of these are symbols used in music, mathematics, chemistry, chess, dance, knitting, architecture, and electronics.

The kind of symbols we choose to represent a particular piece of information depends on what we want to do with the information. For example, if you want to talk to someone in the same room, the sound of your voice will suffice. To talk to someone on the other side of town, however, you need a telephone to convert your voice into an electrical signal that can travel across town through wires. To talk to an astronaut on the moon, you need a radio transmitter to convert your voice into radio waves that can travel through the emptiness of space. Your choice of

*We say that a computer *executes* a program when it carries out the instructions in the program.

representation—sounds in the air, currents in the telephone line, or radio waves in space—depends on where you want to send the information.

The idea of using different kinds of symbols for different kinds of information is important in computing. Information has to be represented in a special form for computer processing, just as it does for telephone or radio transmission. The information that a computer is to process must be translated into a code that is similar in principle, but not in detail, to the telegrapher's Morse code. The codes that computers use are called *binary codes*. (These codes are discussed in more detail later in the book.)

But how do we convert information from symbols that we find convenient, such as the letters of the alphabet, to the binary codes that the computer needs? This conversion is the task of *input* and *output devices*.

A common example of both an input and an output device is a *computer terminal*, which consists of a typewriter-like keyboard (for input) and a television-like display (for output). On some terminals, a typewriter-like printer replaces the display. When one of the keys on the keyboard is struck, the terminal sends an electrical signal over the wires that connect the terminal to the computer. The signal carries the binary code corresponding to the key that was struck. When the terminal receives a signal from the computer, it displays the character corresponding to the binary code that it received.

Modern electronics provides the means for translating almost any kind of information into a form a computer can process. For example, computers can process pictures and sounds as well as written material. Two familiar

A computer terminal—a device for communicating with a computer. Information typed on the keyboard is sent to the distant computer; information received from the computer is displayed on the screen. This terminal is being used to obtain information from an information utility—a company that stores and maintains information in a form accessible to computers and computer terminals.

examples of picture processing are the computer portraits sold in shopping malls and the images that appear on the screen of a video game.

An increasingly important application of computers is monitoring and controlling other machines. *Sensors,* such as thermometers and pressure gauges, provide the computer with information about the operation of the other machine. *Effectors,* such as electric motors, convert signals from the computer into motions of the machine parts. A machine that manipulates other objects (such as a paint sprayer) under the direction of a computer is called a *robot.*

The word *data* is used for symbols that represent information. If *information* refers to the meaning or content of a message, then *data* refers to the symbols that represent that message. In computing, the word *data* does not just refer to numbers, as it does in some other fields. Data can consist of letters, digits, punctuation marks, and mathematical signs, as well as pictures, sounds, and the control signals that direct robots.

Information processing

Three terms are frequently used to describe what a computer does: *information processing, data processing,* and *symbol manipulation.* Information processing emphasizes the meaning of the symbols that go into and come out of the computer. Data processing and symbol manipulation focus more on the physical symbols than on their meaning. Because this book emphasizes the *meaning* of symbols, the term *information processing* will be used most frequently.

What kinds of information processing can computers do? Much of this book is designed to answer just that question. For now, the following two brief examples should give you some feeling for the variety of computer applications.

Video games. A video game is a form of computer. The game is built around a microprocessor, which plays the game according to instructions contained in a program. A video game is an example of a *special-purpose computer.* It is designed for one job—playing games—instead of being able to tackle almost any information processing task, as a *general-purpose computer* can.

Some video games are more specialized than others. Each game machine in an arcade is designed to play only one kind of game. If you get tired of Space Invaders, say, and want to play Pac Man, then you will have to leave one machine and go to another. Many home video-game machines, however, will accept plug-in game cartridges. With a Space Invaders cartridge, the machine will play Space Invaders; with an Asteroids cartridge, it will play Asteroids. Each cartridge contains a program that tells the microprocessor how to play a particular game.

What kind of information processing does a video game do? Let's begin by identifying the input the game processes and the output it produces. The input arises when the player presses a button or manipulates some other control such as a joystick. (A joystick is a lever that can be moved in any direction—up or down, left or right, or at an angle.) The output consists of the images on the screen—the movements of the aliens, spaceships, missiles, asteroids, and what have you—along with accompanying sound effects.

The microprocessor in the game machine monitors the player's controls to determine when a button is pressed or when some other control is moved. Based on the player's manipulations of the controls, the microprocessor determines how to move the objects on the screen. It must also note when missiles hit their targets or spaceships collide with asteroids so that it can produce the appropriate display and sound effects for the collision and update the player's score.

The program that the microprocessor follows—either a program permanently built into an arcade machine or one in a plug-in cartridge for a home game machine—describes in detail such things as how to interpret the motions of the player's controls and how to move various objects about on the screen. The program also covers such fine details as how to draw each object on the screen and how to display objects in different positions so they appear to move smoothly across the screen.

Word processing. In *word processing*, text such as a letter, a report, a magazine article, or a chapter of a book is entered into the computer. Once the text is stored in the computer's memory, we can be revise it by inserting new text, deleting unwanted text, or changing existing text. We can move a block of material—a word, a sentence, a paragraph, or perhaps an entire section—from one part of the text to another. (The latter is what writers call *cutting and pasting*, a term that describes how the job was done before the advent of word processing.)

Since I am using a word processor to write this book, we might talk about my word processor for a moment. Specifically, I am using a desktop computer running under the control of a word-processing program. The program, of course, determines exactly how the computer responds to the commands I give it. A different word-processing program might obey most of the same commands, (such as those for inserting or deleting text), but the key I would press for each command might be different, as might the exact way in which the computer carries out the command.

Actually, I am on my third word-processing program for my computer. The first program (which I purchased) was terrible. The computer's response to commands was very slow, and some common text manipulations required long and clumsy command sequences. Some commands caused the program to hang up, losing all the text stored in the computer's memory. The second program (which I wrote myself) was a little better, and I

A microcomputer, often referred to as a *personal computer* because it is intended for use by individuals. The user types his or her input on the keyboard, and the computer's output appears on the display screen. The two boxes to the right are *disk drives,* which are used to record programs and data on so-called floppy disks.

wrote one book with it before becoming dissatisfied with its limitations. The program I use now (which I purchased) is even better, but it still isn't as convenient as some word-processing programs I have used on other computers. Thus, I still keep an eye open for advertisements for word-processing programs for my computer.

When I type on my computer's keyboard, the words appear in green on the computer's display screen. A flashing block of light, called a *cursor,* shows where the next character I type will appear. The keyboard is divided into three sections. The middle section, which is used for typing text, is very much like a typewriter keyboard. The left and right sections contain control keys that can be used to give commands to the word-processing program* (or whatever other program the computer happens to be executing).

For example, there are four keys with arrows on them. One arrow points up, one down, one left, and one right. Pressing the up-arrow key moves the cursor up one line. Pressing the right-arrow key moves the cursor one character to the right. Holding down any key causes the cursor to move in the indicated direction until the key is released.

When the cursor reaches the top or bottom of the screen, the text *scrolls,* that is, it moves up or down like the credits at the end of a movie or television program. The cursor stays on the screen, but the part of the text shown on the screen changes. The screen acts like a window through which I can see part (24 lines, to be exact) of the text I am working on. With the up- and down-arrow keys I can move this window to any part of the text I want to look at or change.

*We speak of giving commands to the program rather than to the computer, since it is the program that determines how the commands will be carried out.

And how are changes made? To insert a few words at a certain point, I use the arrow keys to move the cursor to the point where the insertion is to be made. I then press a command key marked Ins (for insert) and type the material to be added. Existing text is automatically pushed aside or onto another line to make room for the insertion. To make a deletion, I use the arrow keys to move the cursor to the first character I want to delete. Each time I press a key marked Del (for delete), one character is deleted and the text following the character moves to close up the gap. If I hold down the Del key, characters are deleted until I release the key. If I hold the Del key down too long, and delete something I wanted to keep, I can press another key to restore the just-deleted characters.

When I am through working on a chapter, I instruct the word processing-program to store the text on a *diskette,* a flexible plastic disk on which information can be recorded. When I am ready to work on the same chapter again, I have the word processing-program load the text from the diskette back into the computer's memory. When I am finished with a chapter, I use another program to read the text from the diskette and print the text out (on a printer attached to the computer) in a format acceptable for book manuscripts.

Programs and programming

Since it is the program that is responsible for the useful work that a computer does, the program tends to assume more importance than the computer. Instead of thinking of the program as "merely" a set of instructions for the computer, we are more likely to think of the computer as "merely" a machine for realizing the behavior described by the program.

In this respect we can compare a computer with a phonograph. Within limits set by its construction, a phonograph can reproduce any sound; but the sounds do not originate with the phonograph. Unlike a music box, which always plays the same tune, the phonograph can play any song as long as we put on the right record.

If we think of the computer as being like a phonograph, then the computer program corresponds to the phonograph record. But what corresponds to the music? What do we get when we "play" a computer program?

A computer program determines how a computer behaves, how it responds to its input. If we communicate with a computer through a keyboard and a display screen, the program determines what the computer will display in response to what we type. If we change the program, the computer's responses will change as well.

We can think of the program as giving the computer a particular "personality." By this we certainly don't mean that the computer behaves like a person. But just as we judge a human personality by the way a

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