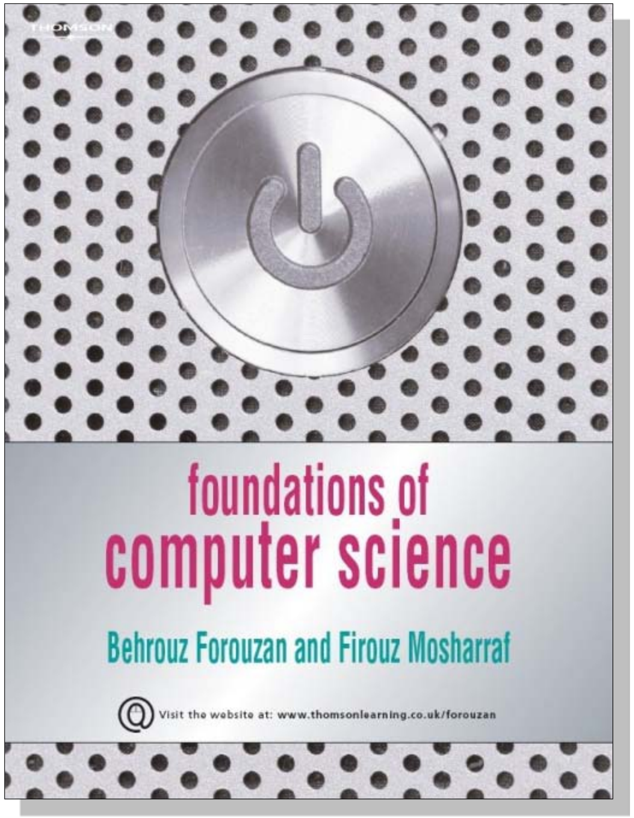
Books

- Foundations of Computer Science, 2nd edition, Behrouz Forouzan and Firouz Mosharraf, Thomson Learning, UK, 2008.
  (歐亞書局，(02)89121188)



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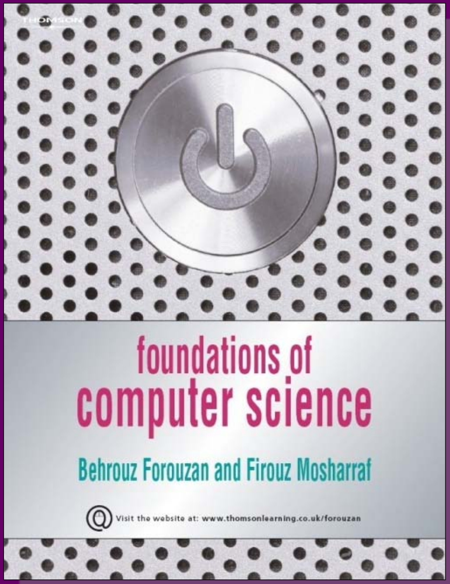

1
Introduction

Objectives

After studying this chapter, the student should be able to:

- ❑ Define the Turing model of a computer.
- ❑ Define the von Neumann model of a computer.
- ❑ Describe the three components of a computer: hardware, data, and software.
- ❑ List topics related to computer hardware.
- ❑ List topics related to data.
- ❑ List topics related to software.
- ❑ Discuss some social and ethical issues related to the use of computers.
- ❑ Give a short history of computers.

1-1 TURING MODEL

The idea of a universal computational device was first described by **Alan Turing** in 1937.

All computation could be performed by a special kind of a machine, now called a **Turing machine**.

He based the model on the actions that people perform when involved in computation. He abstracted these actions into a model for a computational machine that has really changed the world.

Data processors

A computer acts as a black box that accepts input data, processes the data, and creates output data (Figure 1.1).

Although this model can define the functionality of a computer today, it is too general.

In this model, a pocket calculator is also a computer (which it is, in a literal sense).

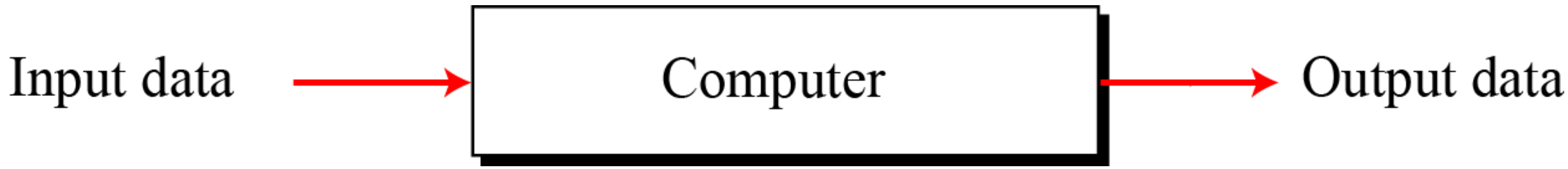

Figure 1.1 **A single purpose computing machine**

Programmable data processors

The **Turing model** is a better model for a general-purpose computer. This model adds an extra element to the specific computing machine: **the program**.

A program is a set of instructions that tells the computer what to do with data. Figure 1.2 shows the Turing model.

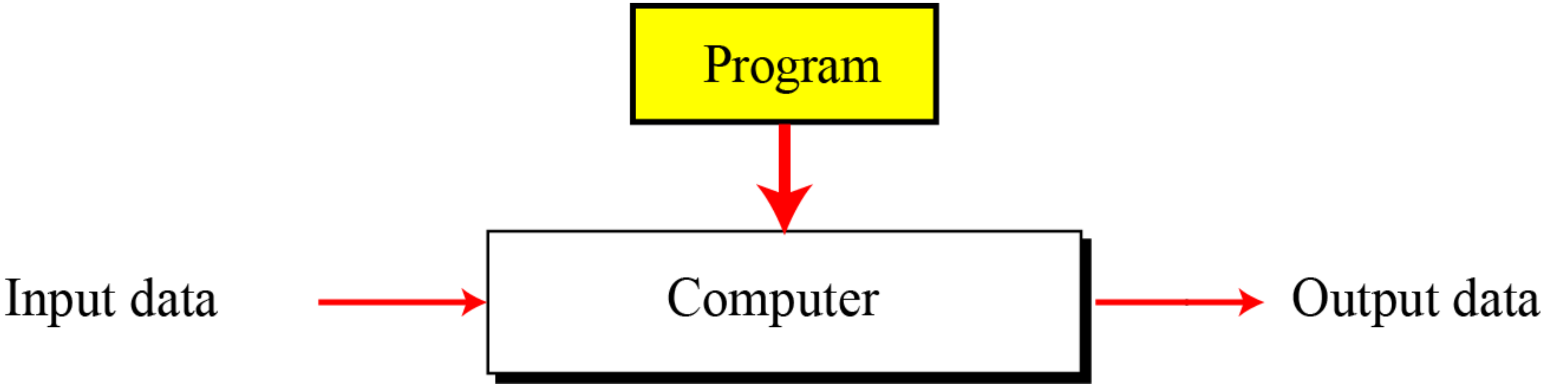

Figure 1.2 **A computer based on the Turing model**

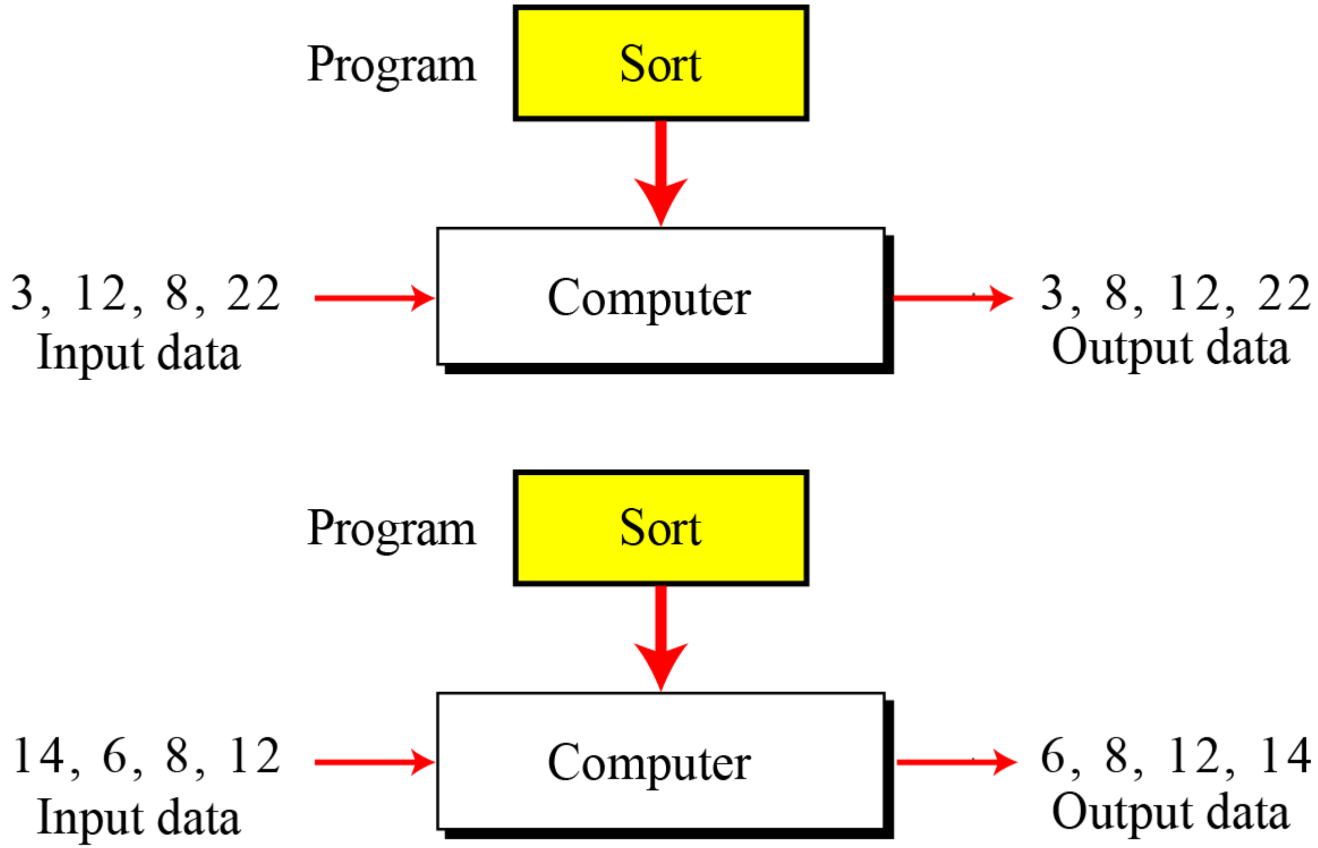

Figure 1.3 **The same program, different data**

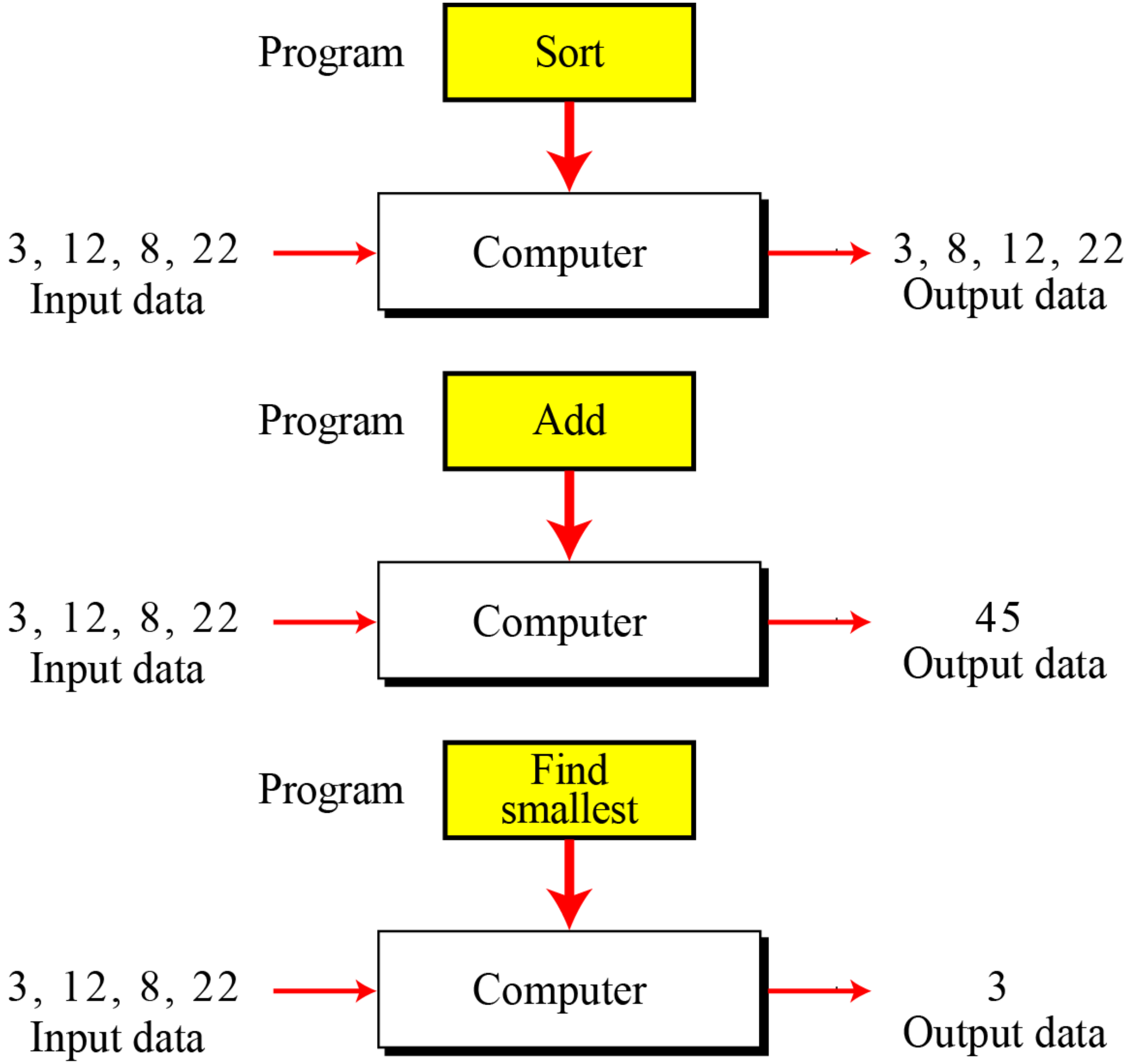

Figure 1.4 **The same data, different programs**

The universal Turing machine

A **universal Turing machine**, can do any computation if the appropriate program is provided, was the first description of a modern computer.

It can be proved that a very powerful computer and a universal Turing machine can compute the same thing. We need only provide the data and the program—the description of how to do the computation—to either machine.

In fact, a universal Turing machine is capable of computing anything that is computable.

1-2 VON NEUMANN MODEL

Computers built on the Turing universal machine store data in their memory. Around 1944–1945, **John von Neumann** proposed that, since program and data are logically the same, programs should also be stored in the memory of a computer.

Four subsystems

Computers built on the **von Neumann model** divide the computer hardware into four subsystems: 1.**memory**, 2.**arithmetic logic unit**, 3.**control unit**, and 4.**input/output** (Figure 1.5).

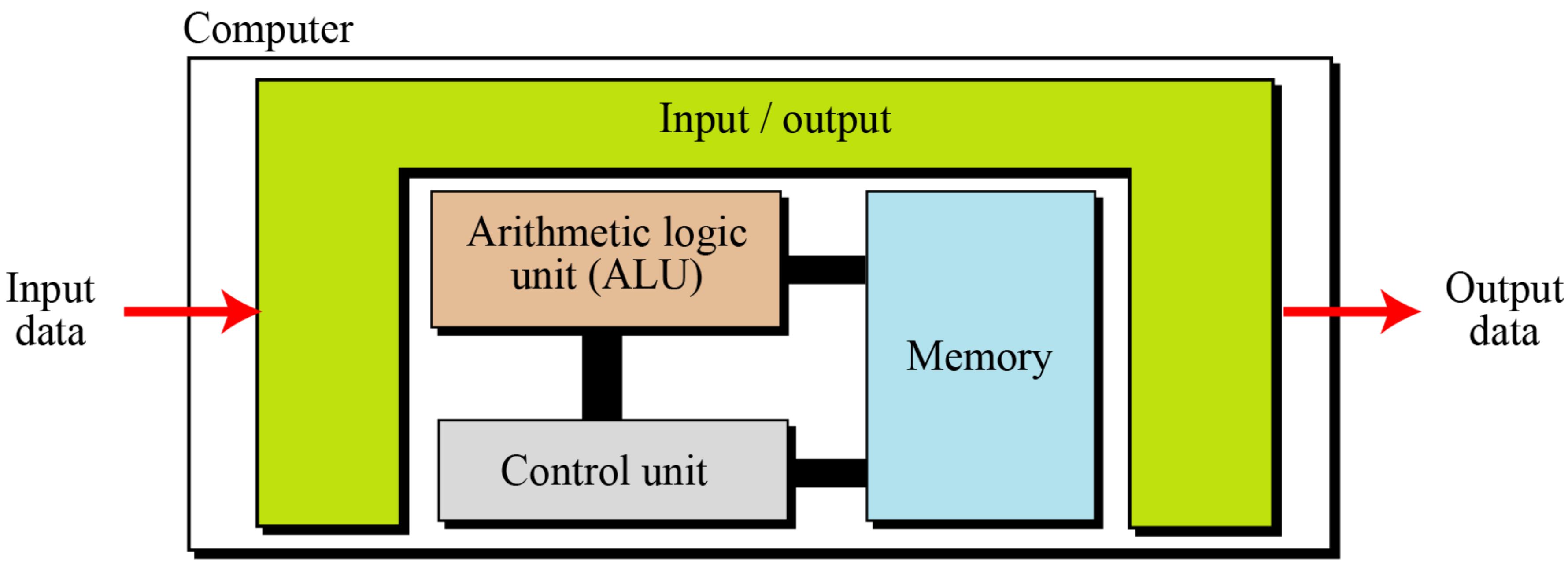

Figure 1.5 **The von Neumann model**

The stored program concept

The von Neumann model states that the program must be stored in memory. This is totally different from the architecture of early computers in which only the data was stored in memory.

They (program and data) are stored as binary patterns in memory—**a sequence of 0s and 1s**.

Sequential execution of instructions

A program in the von Neumann model is made of a finite number of instructions.

The control unit fetches one instruction from memory, decodes it, then executes it. In other words, the instructions are executed one after another. Of course, one instruction may request the control unit to jump to some previous or following instruction, but this does not mean that the instructions are not executed sequentially.

Sequential execution of a program was the initial requirement of a computer based on the von Neumann model.

1-3 COMPUTER COMPONENTS

We can think of a computer as being made up of three components:

1. **computer hardware**
2. **data**
3. **computer software**

Computer hardware

Computer hardware today has four components under the von Neumann model, although we can have different types of memory, different types of input/output subsystems, and so on. We discuss computer hardware in more detail in Chapter 5.

Data

The von Neumann model clearly defines a computer as a data processing machine that accepts the input data, processes it, and outputs the result.

Computer software

The main feature of the Turing or von Neumann models is the concept of the program. Although early computers did not store the program in the computer's memory, they did use the concept of programs.

Programming those early computers meant changing the wiring systems or turning a set of switches on or off.

Programming was a task done by an operator or engineer before the actual data processing began.

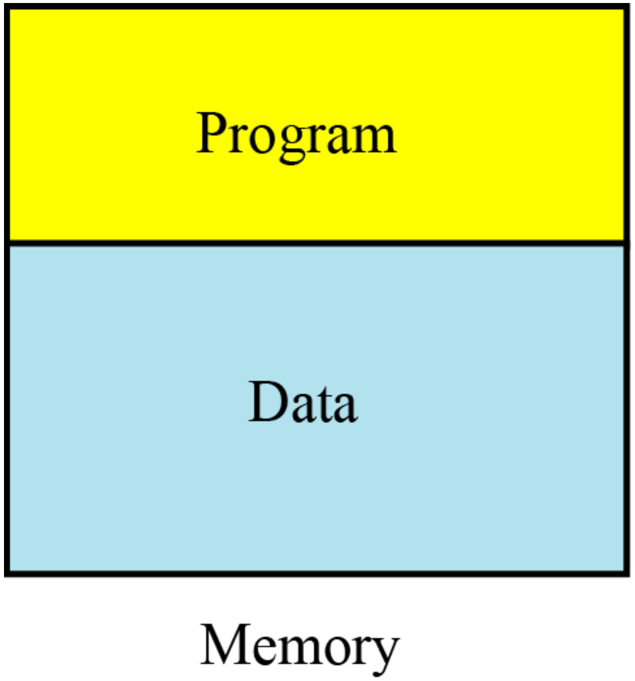

Figure 1.6 **Program and data in memory**

1. Input the first number into memory.
2. Input the second number into memory.
3. Add the two together and store the result in memory.
4. Output the result.

Program

Figure 1.7 **A program made of instructions (add)**

1-4 HISTORY

In this section we briefly review the history of computing and computers.

We divide this history into three periods:

1. **Mechanical machines (before 1930)**
2. **The birth of electronic computers (1930–1950)**
3. **Computer generations (1950–present)**

Mechanical machines (before 1930)

During this period, several computing machines were invented that bear little resemblance to the modern concept of a computer.

- In the 17th century, Blaise Pascal, a French mathematician and philosopher, invented **Pascaline**.

- In the late 17th century, a German mathematician called Gottfried Leibnitz invented what is known as **Leibnitz' Wheel**.

- The first machine that used the idea of storage and programming was the **Jacquard loom**, invented by Joseph-Marie Jacquard at the beginning of the 19th century.

- In 1823, Charles Babbage invented the **Difference Engine**. Later, he invented a machine called the **Analytical Engine** that parallels the idea of modern computers.
- In 1890, **Herman Hollerith**, working at the US Census Bureau, designed and built a programmer machine that could automatically read, tally, and sort data stored on punched cards.

The birth of electronic computers (1930–1950)

Between 1930 and 1950, several computers were invented by scientists who could be considered the pioneers of the electronic computer industry.

Early electronic computers

The early computers of this period did not store the program in memory—all were programmed externally. Five computers were prominent during these years:

- ABC
- Z1
- Mark I.
- Colossus
- ENIAC

Computers based on the von Neumann model

The first computer based on von Neumann's ideas was made in 1950 at the University of Pennsylvania and was called **EDVAC**.

At the same time, a similar computer called **EDSAC** was built by Maurice Wilkes at Cambridge University in England.

Computer generations (1950–present)

Computers built after 1950 more or less follow the von Neumann model. They have become **faster, smaller, and cheaper,** but the principle is almost the same.

Historians divide this period into generations, with each generation witnessing some major change in hardware or software (but not in the model).

First generation

The first generation (roughly 1950–1959) is characterized by the emergence of commercial computers.

Second generation

Second-generation computers (roughly 1959–1965) used **transistors** instead of vacuum tubes. Two high-level programming languages, FORTRAN and COBOL invented and made programming easier.

Third generation

The invention of the **integrated circuit** reduced the cost and size of computers even further. Minicomputers appeared on the market. Canned programs, popularly known as **software packages**, became available. This generation lasted roughly from 1965 to 1975.

Fourth generation

The fourth generation (approximately 1975–1985) saw the appearance of microcomputers. The first desktop calculator, the Altair 8800, became available in 1975. This generation also saw the emergence of **computer networks.**

Fifth generation

This open-ended generation started in 1985. It has witnessed the appearance of **laptop** and **palmtop** computers, improvements in secondary storage media (**CD-ROM**, **DVD** and so on), the use of multimedia, and the phenomenon of virtual reality.

1-5 SOCIAL AND ETHICAL ISSUES

Computer science has created some peripheral issues, the most prevalent of which can be categorized as **social** and **ethical** issues.

Social issues

Computers have created some arguments.

Dependency

Some people think that computers have created a kind of dependency, which makes people's lives more difficult.

Social justice

The advocates of this issue argue that using computers at home is a luxury benefit that not all people can afford. The cost of a computer, peripheral devices, and a monthly charge for Internet access is an extra burden on low-income people.

Digital divide

The concept of digital divide covers both the issues of dependency and social justice discussed above. The concept divides society into two groups: those who are electronically connected to the rest of society and those who are not.

Ethical issues

Computers have created some ethical issues.

Privacy

Computers allow communication between two parties to be done electronically. However, much needs to be done to make this type of communication private. Society is paying a big price for private electronic communication. Network security may create this type of privacy, but it needs effort and costs a lot.

Copyright

Another ethical issue in a computerized society is copyright: who owns data? The Internet has created opportunities to share ideas, but has also brought with it a further ethical issue: electronic copyright.

Computer crime

Computers and information technology have created new types of crime. Hackers have been able to access many computers in the world and have stolen a lot of money. Virus creators design new viruses to be sent through the Internet and damage the information stored in computers. Although there are many anti-virus programs in use today, society is paying a big price for this type of crime, which did not exist before the computer and Internet era.

1-6 COMPUTER SCIENCE AS A DISCIPLINE

With the invention of computers, a new discipline has evolved: **computer science**. Like any other discipline, computer science has now divided into several areas. We can divide these areas into two broad categories: **systems areas** and **applications areas**. This book is a breadth-first approach to all these areas.

1-7 OUTLINE OF THE COURSE

After this introductory chapter, the book is divided into five parts.

Part I: Data representation and operation

This part includes Chapters 2, 3, and 4. Chapter 2 discusses number systems; how a quantity can be represented using symbols. Chapter 3 discusses how different data is stored inside the computer. Chapter 4 discusses some primitive operations on bits.

Part II: Computer hardware

This part includes Chapters 5 and 6. Chapter 5 gives a general idea of computer hardware, discussing different computer organizations. Chapter 6 shows how individual computers are connected to make computer networks and internetworks (internets).

Part III: Computer software

This part includes Chapters 7, 8, 9 and 10. Chapter 7 discusses operating systems. Chapter 8 shows how problem solving is reduced to writing an algorithm for the problem. Chapter 9 takes a journey through the list of contemporary programming languages. Chapter 10 is a review of software engineering.

Part IV: Data organization and abstraction

Part IV includes Chapters 11, 12, 13 and 14. Chapter 11 discuss data structures, collecting data of the same or different type under one category. Chapter 12 discusses abstract data types. Chapter 13 shows how different file structures can be used for different purposes. Chapter 14 discusses databases.

Part V: Advanced topics

This part covers Chapters 15, 16, 17 and 18. Chapter 15 discusses data compression. Chapter 16 explores some issues to do with security. Chapter 17 discusses the theory of computation. Chapter 18 is an introduction to artificial intelligence, a topic with day-to-day challenges in computer science.