Chapter 1
Introduction

1.1 Turing Model

The idea of a universal computational device was first described by Alan Turing in 1937. He proposed that all computation could be performed by a special kind of a machine, now called a Turing machine.

Although Turing presented a mathematical description of such a machine, he was more interested in the philosophical definition of computation than in building the actual machine.

Objectives
After studying this chapter, students 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.
- Give a short history of computers.
- Discuss some social and ethical issues related to the use of computers.

Data Processors
Before discussing the Turing model, let us define a computer as a data processor. Using this definition, 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.

Figure 1.1 A single purpose computing machine
Programmable Data Processors

The **Turing model** (Figure 1.2) 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.

**Program**

Input data → **Computer** → Output data

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

**Example 1: Same Program and Different Data**

**Sort**

3, 12, 8, 22 → **Computer** → 3, 8, 12, 22

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

**Example 2: Same Data and Different Program**

**Sort**

3, 12, 8, 22 → **Computer** → 3, 8, 12, 22

**Addition**

3, 12, 8, 22 → **Computer** → 45

**Find min**

3, 12, 8, 22 → **Computer** → 3

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

**The Universal Turing Machine**

A universal Turing machine, a machine that **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: memory, arithmetic logic unit, control unit, and input/output (Figure 1.5).

![Figure 1.5 The von Neumann model](image)

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: the programs for their task was implemented by manipulating a set of switches or by changing the wiring system.

The memory of modern computers hosts both a program and its corresponding data. This implies that both the data and programs should have the same format, because they are stored in memory. In fact, they 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. In this model, 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. Today’s computers execute programs in the order that is the most efficient.
1-3 Computer Components

We can think of a computer as being made up of three components: computer hardware, data, and 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 therefore a task done by an operator or engineer before the actual data processing began.

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Data

Program and data in memory

![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.

Algorithm

The step-by-step solution for a problem is called an algorithm.

Software Engineering

The software engineering is the design and writing of structured programs.

Operating System

An operating system (OS) originally worked as a manager to facilitate access to the computer’s components by a program, although today OS do much more.
1–4 History

In this section we briefly review the history of computing and computers. We divide this history into three periods.

Mechanical Machines (before 1930) (Continued)

- In 1823, Charles Babbage invented the Difference Engine, which could do more than simple arithmetic operations and solve polynomial equations, too. Later, he invented a machine called the Analytical Engine that parallels the idea of modern computers, four components: a mill (ALU), a store (memory), an operator (control unit), and output (I/O).
- 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 First Mechanical Computer

The baggage difference engine created in 1823 and it used 25000 parts.
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:

- The first special-purpose computer is called ABC (John V. Atanasoff and Clifford Berry Computer) in 1939 that could encode information electrically and was specially designed to solve a system of linear equations.
- At the same time, a German called Konrad Zuse designed a general-purpose machine called Z1.

The First Electronic Computer

The first general-purpose electronic computer called ENIAC (Electronic Numerical Integrator and Calculator) was made by John Mauchly and J. Presper Eckert in 1946. It used 18000 vacuum tubes and was 100x10feet² and 30 tons.

The Birth of Electronic Computers (1930–1950)

- In the 1930s, US Navy & IBM supported a project at Harvard University for Prof. Howard Aiken that he build a huge machine called Mark I (used both electrical and mechanical components).
- In England, Alan Turing invented a computer called Colossus that was designed to break the German Enigma code.

Computers Based on 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 (IC) 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.
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. We introduce some of these arguments here.

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

Social Justice
Social justice is another issue we often hear about. 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. We introduce some of these here.

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.
Part IV: Data Organization and Abstraction

Part IV includes Chapters 11, 12, 13 and 14. Chapter 11 discuss data structure, collecting data of the same or different type under one category. Chapter 12 discusses abstract data types. Chapter 13 shows how different file structure 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.

Key Terms

- Arithmetic Logic Unit (ALU)
- Program
- Algorithm
- Computer Language
- Instruction
- Operating System (OS)
- Digital Divide

Review Questions

- Please show the diagram of Turing model in a computer.
- Please show the diagram of Von Neumann model in a computer.
- What are the differences between Turing model and Von Neumann model?
- What are the differences among desktop, laptop, and palmtop computers?
- What the sequential operations are for executing an instruction?
- Please briefly describe the history of computers.
- What is digital divider?