1 Types and components of computer systems

In this chapter you will learn about:

- ★ hardware
- ★ software
- ★ analogue and digital data
- ★ central processing unit (CPU)
- ★ internal memory (RAM and ROM)
- ★ input and output devices
- ★ backing store
- ★ operating systems
- ★ types of computer – desktop computers and mobile computers (laptop, smartphone, tablet and phablet)
- ★ emerging technologies – artificial intelligence (AI) and extended reality (virtual and augmented).

Computer systems are now commonplace in every part of our daily life. This first chapter introduces the basic components that make up these computer systems; most of which will be described in much greater depth in later chapters. Basic components, including hardware (both external and internal) and software (both applications and system), are all briefly introduced in the following sections.

Comparing books with computers is a good analogy: the actual pages and the ink used on the pages are equivalent to the hardware used to make up computers; the words written on these pages are equivalent to the software. Without the words, the book is useless. Similarly, without software, computers would be of little use to any of us.

1.1 Hardware and software

1.1.1 Hardware

Hardware is the general term for the physical components that make up a typical computer system. For example:

- keyboard
- mouse
- camera

} input device

- monitor
- printer
- plotter

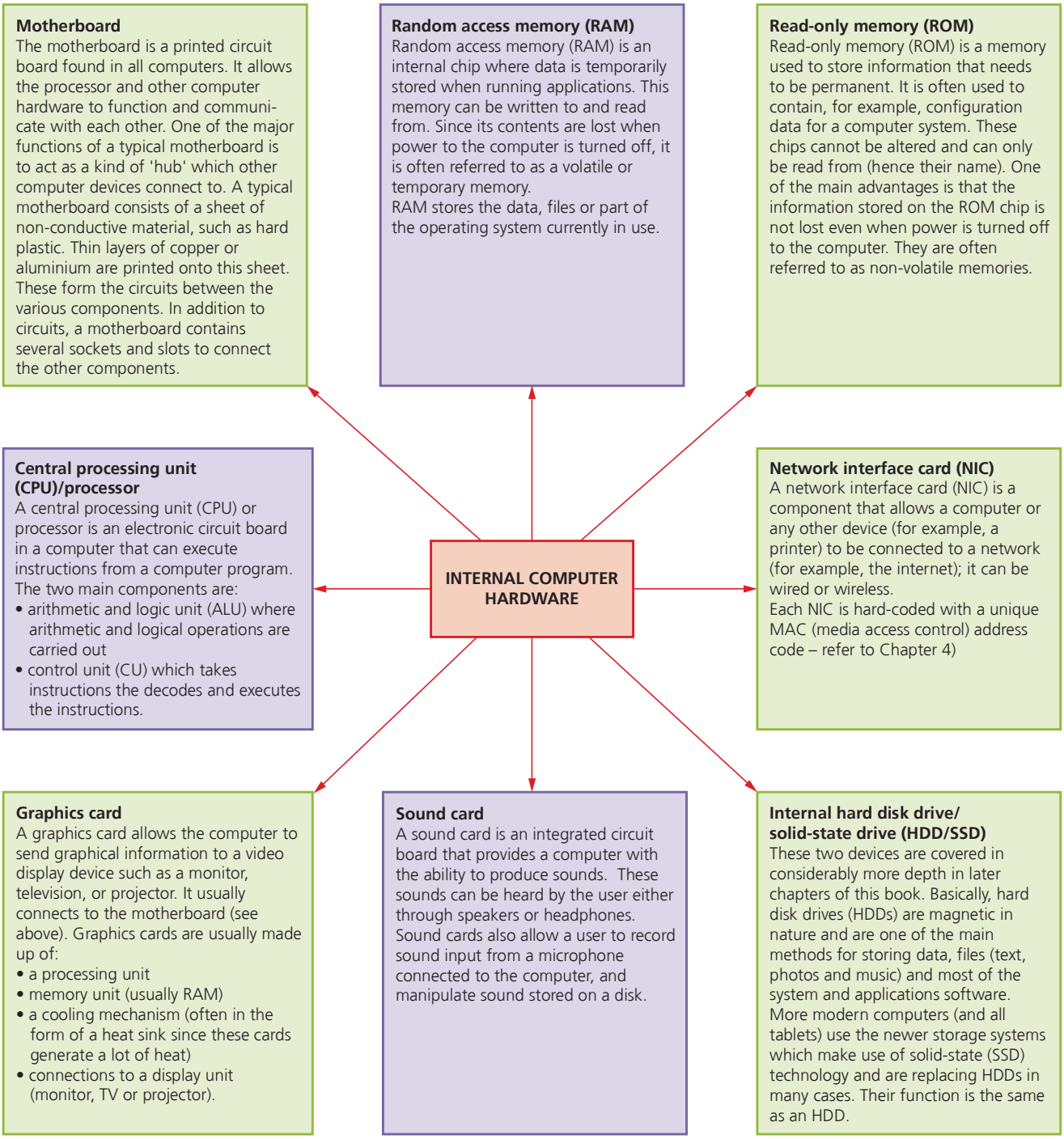
} output device

Hardware falls into two categories: internal and external. The list above are examples of external hardware, which is discussed in detail in Chapter 2. Figure 1.1 considers the following internal hardware devices:

- motherboard
- central processing unit (CPU)/processor
- random access memory (RAM)

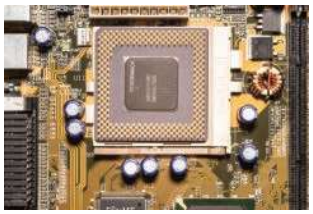
- read-only memory (ROM)
- graphics card
- sound card
- network interface card (NIC)
- internal storage devices (hard disk drive and solid-state drive).

Because it is not always possible to see the internal hardware devices, the photographs in Figure 1.2 will give you some idea of the physical appearance of the components described in Figure 1.1.

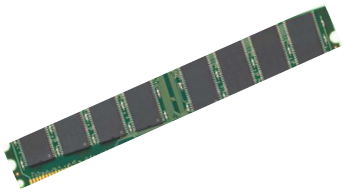


▲ **Figure 1.1** Internal computer hardware

Motherboard:



RAM:



ROM:

Graphics card:

Sound card:

SSD:

HDD:

▲ **Figure 1.2** Examples of internal hardware

1.1.2 Software

Software is the general term used for the programs that control the computer system and process data. The software considered in this book falls into two categories: applications and system.

Applications software provides the services that the user requires to solve a given task. For example:

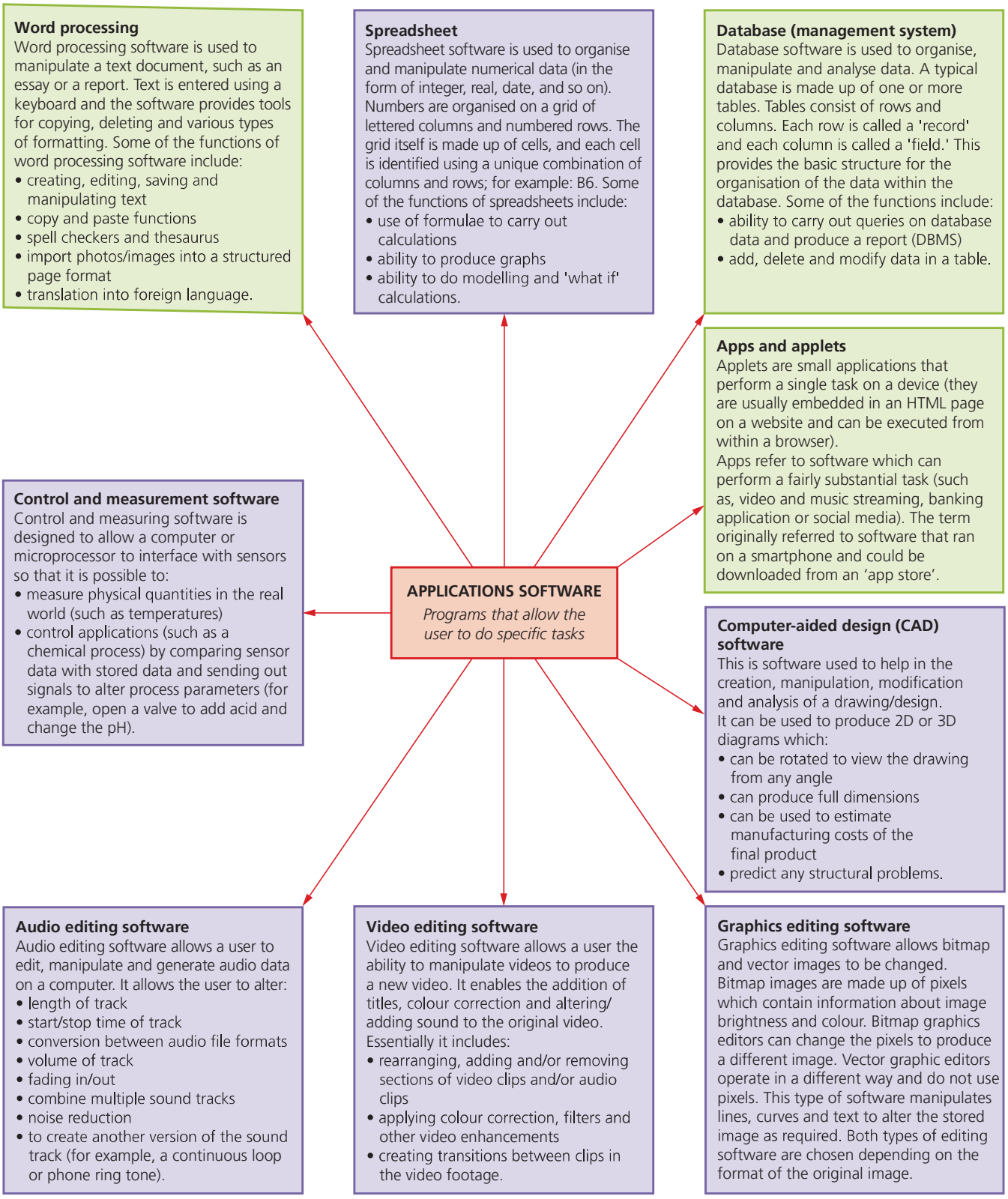
- word processing
- spreadsheet
- database (management system)
- control and measurement software
- apps and applets
- video editing
- graphics editing
- audio editing
- computer-aided design (CAD).

(Refer to Figure 1.3 for more details.)

System software is the software designed to provide a platform on which all other software can run. For example:

- compilers
- linkers
- device drivers
- operating systems
- utilities.

(Refer to Figure 1.4 for more details.)



▲ **Figure 1.3** Applications software

Compiler
A compiler is a computer program that translates a program written in a high-level language (HLL) into machine code (code that is understood by the computer) so that it can be directly used by a computer to perform a required task. The original program is called the **source code** and the code after compilation is called the **object code**. Once a program is compiled, the machine code can be used again and again to perform the same task without recompilation. Examples of high-level languages include Java, Python, Visual Basic, Fortran, C++ and Algol.

Linkers
A linker (or link editor) is a computer program that takes one or more object files produced by a compiler and combines them into a single program that can be run on a computer. For example, many programming languages allow programmers to write different pieces of code, called modules, separately. This simplifies the programming task since it allows the program to be broken up into small, more manageable sub-tasks. However, at some point, it will be necessary to put all the modules together to form the final program. This is the job of the linker.

Device driver
A device driver is the name given to software that enables one or more hardware devices to communicate with the computer's operating system. Without drivers, a hardware device (for example, a printer) would be unable to work with the computer. All hardware devices connected to a computer have associated drivers. As soon as a device is plugged into the USB port of a computer, the operating system looks for the appropriate driver. An error message will be produced if it cannot be found. Examples of hardware devices that require drivers include printers, memory sticks, mouse, CD drivers, and so on.

Operating systems (OS)
The operating system (OS) is essentially software running in the background of a computer system. It manages many of the basic functions. Without the OS, most computers would be very user-unfriendly and the majority of users would find it almost impossible to work with computers on a day-to-day basis. Operating systems allow:
- input/output operations
- users to communicate with the computer (for example, *Windows*)
- error handling to take place
- the loading and running of programs to occur
- managing of security (for example, user accounts, log on passwords).

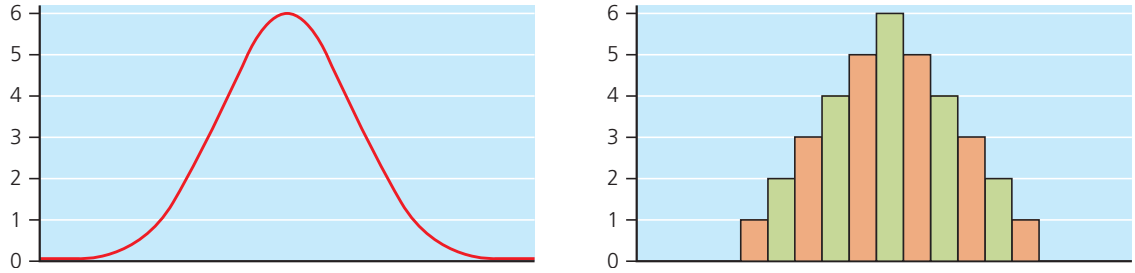
SYSTEM SOFTWARE
Programs that allow the hardware to run properly and allow the user to communicate with the computer

Utilities
Utility programs are software that has been designed to carry out specific tasks on a computer. Essentially, they are programs that help to manage, maintain and control computer resources. Examples include:
- antivirus
- anti-spyware
- backup of files
- disk repair
- file management
- security
- screensavers
- disk defragmenter.

▲ **Figure 1.4** System software

1.1.3 Analogue and digital data

Computers can only understand data which is in a binary format (that is, a base 2 number system where only the values 0 and 1 can be used). This is often referred to as **digital data** (because it can only have discrete, discontinuous values). However, data in the real world is actually **analogue** in nature. Analogue data is physical data that changes smoothly from one value to the next, and not in discrete steps as with digital data.



▲ **Figure 1.5** Analogue and digital data

In Figure 1.5, the graph on the left shows analogue data; an infinite number of values can exist between 0 and 6 (for example, 2.5, 4.652, and so on) because the curve is smooth in shape. The graph on the right shows digital data; notice **only** the **exact** values of 0, 1, 2, 3, 4, 5 or 6 can be taken.

If analogue data is being sent to a computer, it must first be converted into digital data; this is done by hardware known as an **analogue to digital converter** (ADC). If the computer is controlling a device (such as a motor) then the digital output from the computer needs to be converted into analogue form. This is done by a **digital to analogue converter** (DAC).

1.2 Main components of computer systems

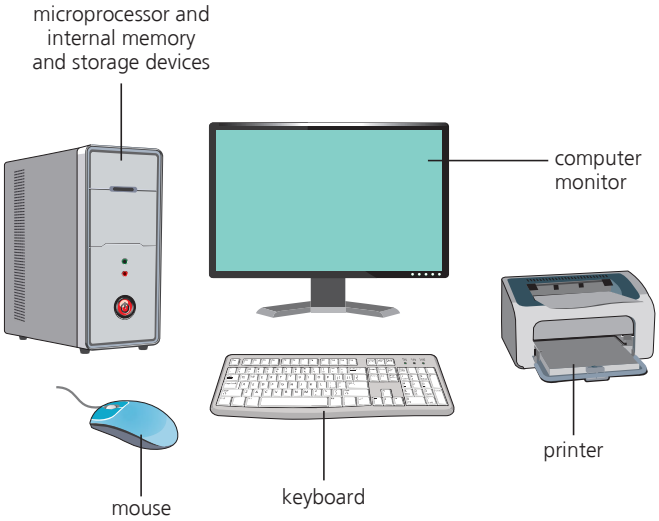
As already mentioned in Section 1.1, a typical computer system is made up of hardware and software. The diagram in Figure 1.6 shows an example of a computer system consisting of input devices, output devices and secondary storage. These will be discussed in more detail in Chapter 2, but some examples are listed in Table 1.1.

▼ **Table 1.1** Examples of input, output and secondary storage devices

Device	Examples
Input devices	keyboard, mouse, camera, microphone, sensor, scanner
Output devices	monitor, printer, speakers, projector, (graph) plotter
Secondary storage devices	hard disk drive, solid-state drive, pen drive

The internal hardware devices were shown in Figure 1.2 – these consist of four key components:

- the central processing unit (CPU) (contained on the motherboard)
- internal hard disk drive or solid-state drive
- random access memory (RAM)
- read-only memory (ROM).



▲ **Figure 1.6** A typical computer system

1.2.1 CPU

The **central processing unit** (CPU) is the part of the computer that interprets and executes the commands from the computer hardware and software. It is normally part of the computer motherboard.

CPUs used to be made up of discrete components and numerous small integrated circuits; these were combined together on one or more circuit board(s). However, due to modern manufacturing techniques, the CPU is now referred to as a **microprocessor**. This is a single integrated circuit which is at the heart of most PCs and is also found in many household devices and equipment where some control or monitoring is needed (for example, the engine management system in a car).

The CPU/microprocessor is made up of a control unit, which controls the input and output devices; an arithmetic and logic unit (ALU), which carries out calculations and makes logical decisions, and small memory locations called registers.

1.2.2 Internal memory

Random access memory (RAM) is an internal chip where data is temporarily stored when running applications. This memory can be written to and read from. Because its contents are lost when power to the computer is turned off, it is often referred to as a volatile or temporary memory. This was fully described in Figure 1.1.

Read-only memory (ROM) is a memory used to store information that needs to be permanent. It is often used to contain, for example, configuration data for a computer system. Chips used for ROM cannot be altered and can only be read from (hence their name). One of the main advantages is that the information stored on the ROM chip is not lost, even when power is turned off to the computer. They are often referred to as non-volatile memories. This was fully described in Figure 1.1.

It is worth noting that that ROM also contains some coding known as the **boot file**. This code tells the computer what to do when it first starts up; it is often referred to as the **BIOS (basic input/output system)**.

When the computer is turned on, the BIOS carries out a hardware check to find out if all the devices are present and whether they are functional. Then it loads the **operating system** into the RAM.

The BIOS stores the date, time and system configuration in a non-volatile chip called a **CMOS (complementary metal oxide semiconductor)** – this is usually battery powered.

Table 1.2 provides a summary of the main differences between RAM and ROM.

▼ **Table 1.2** RAM and ROM differences

RAM	ROM
Temporary memory device	Permanent memory device
Volatile memory	Non-volatile memory device
Can be written to and read from	Read-only, data stored cannot be altered
Used to store data, files, programs, part of operating systems (OS) currently in use	Used to store BIOS and other data needed at start up
Can be increased in size to improve operational speed of a computer	

1.2.3 Input and output devices

Input devices are hardware that allows data to be entered into a computer (these are covered in detail in Chapter 2). They use either manual entry (such as a keyboard or a mouse) or direct data entry (such as sensors or optical character readers). Essentially, these devices turn input into a form the computer can understand – for example, a mouse turns hand movements into cursor movements on the screen. As mentioned earlier, sometimes the data has to go through an ADC before the computer can make any sense of it.

When a computer processes data, and the human operator wants to see the results of the processing, then the computer sends the data to an output device. An output device shows the computer's output in a form that is understood by a human – for example, as text on a printer or moving images on a monitor.

Some devices can act as both input and output. For example, a touch screen can do both, as can a DVD writer/player; but most devices are only capable of **either** inputting data into a computer **or** displaying the results of computer processing (output device).

Table 1.3 summarises the differences between input and output devices.

▼ **Table 1.3** Comparison of input and output devices

Input devices	Output devices
An input device is any hardware device that allows a user to enter data or instructions into a computer directly.	An output device is any hardware device that takes the output data from a computer and puts it into a human-readable format or uses it to control another device.
An input device can send data to another device, but it cannot receive data from another device.	An output device is capable of receiving data from another device in order to generate an output, but it cannot send data to another device.
Input devices are necessary for a computer to receive commands from its users and data to process; the devices are under the control of the user or can be direct data entry.	Output devices are needed by a computer so it can share the results of its processing with a human; output devices are under the control of the computer.
Input devices can be fairly complicated because they have to ensure that the user can interact with the computer correctly.	Output devices are less complex than input devices because they only have to turn computer signals into an output.

1.2.4 Backing storage

The main memories in a computer are RAM and ROM. However, to permanently store large amounts of data it is necessary to use backing storage. This normally takes the form of the internal **hard disk drive (HDD)** or **solid-state drive (SSD)**. This is the computer's main internal storage where the applications software, disk operating system and files (for example, text, photo or music) are stored. A key feature of a backing store is that it must store data permanently – that is, it must be non-volatile.

Unlike RAM and ROM, backing storage is not directly addressable (that is, it cannot be read directly by the CPU). The data access time for RAM and ROM is much shorter than it is for backing storage. Backing storage is considerably larger than RAM because it is considerably less expensive per byte.

Backing storage can either be fixed (very often internal to the computer) or removable. The advantage of removable backing storage is that it can be used as a backup in case of data loss or corruption. Data from the main HDD or SSD can be copied onto another device (such as a pen drive or portable HDD) and then stored in a separate location. If the original data on the HDD/SSD has been lost or corrupted, it can be restored from the backup device.

Examples of removable storage include external hard disk drives (HDD), external solid-state drive (SSD) and Blu-ray discs.

Table 1.4 summarises the differences between backing storage and internal memory.

▼ **Table 1.4** Comparison of internal memory and backing storage

Internal memory	Backing storage
RAM contents are lost when computer is powered down; ROM contents are readable only.	Backing storage devices hold their contents permanently, even when powered down.
RAM and ROM are much smaller memories than backing storage.	Have considerably larger capacity to store data than RAM or ROM.
Data access time on RAM and ROM is extremely fast.	Has much slower data access time than RAM and ROM.
Much more expensive per byte than backing storage devices.	Is much cheaper per byte than RAM or ROM.
RAM and ROM are fixed inside the computer (internal memories).	Backing storage can either be fixed (external or internal) or it can be removable.
RAM and ROM can be read directly by the CPU.	Before data on a backing storage device can be read by the CPU, it must first be moved into RAM; this means backing storage is not directly addressable by the CPU.

1.3 Operating systems

Reference to operating systems has already been made earlier on in this chapter (see Figure 1.4).

To enable computer systems to function and to allow users to communicate with computer systems, special software, known as **operating systems (OS)**, have been developed. The general tasks for a typical operating system include:

- control of the operation of the input, output and backing storage devices
- supervising the loading, running and storage of applications programs
- dealing with errors that occur in application programs
- maintaining security of the whole computer system
- maintaining a computer log (which details computer usage)
- allowing communication between user and the computer system (user interface).

1.3.1 User interfaces

Operating systems offer various types of user interface. We will consider four different types:

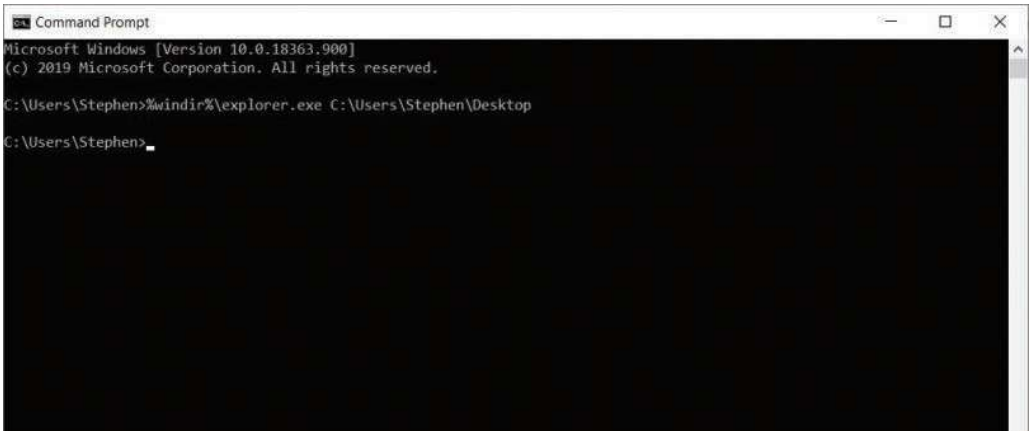
- command line interface (CLI)
- graphical user interface (GUI)
- dialogue-based user interface
- gesture-based user interface.

Command line interface (CLI)

A **command line interface (CLI)** requires a user to type in instructions to choose options from menus, open software, etc. There are often a number of commands that need to be typed in, for example, to save or load a file. The user has to learn a number of commands just to carry out basic operations. It is also slow, having to key in these commands every time an operation has to be carried out. However, the advantage of a CLI is that the user is in direct communication with the computer and is not restricted to a number of pre-determined options.

For example, *Windows* has a CLI called the 'command prompt'. The following command opens the desktop folder in *Windows Explorer*:

%windir%\explorer.exe C:\Users\YourName\Desktop



▲ **Figure 1.7** Sample of CLI code

The statements in Figure 1.7 show how complex it is just to carry out a fairly straightforward operation using CLI.

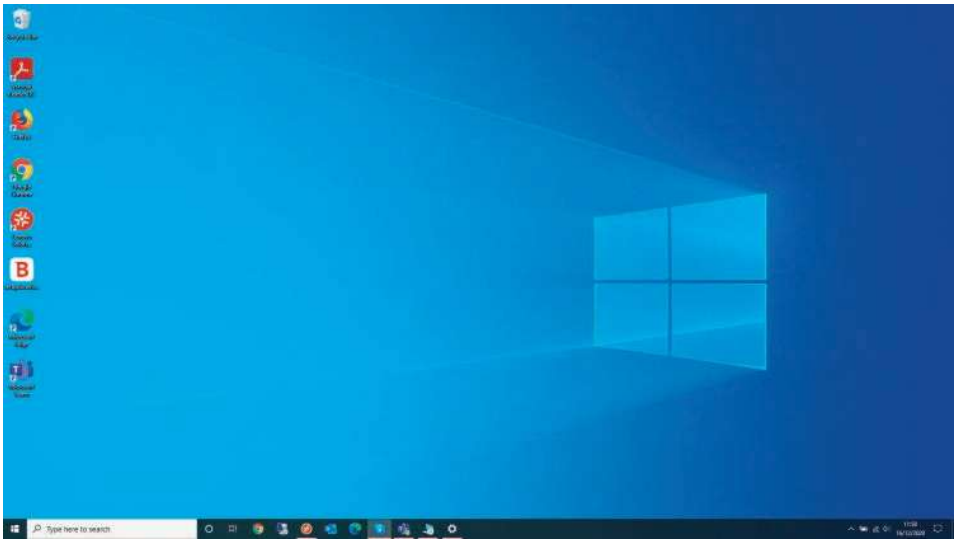
Graphical user interface (GUI)

A **graphical user interface (GUI)** allows the user to interact with a computer (or MP3 player, gaming device, mobile phone, etc.) using pictures or symbols (**icons**) rather than having to type in a number of commands. For example, the whole of the CLI code in Figure 1.7 could have been replaced by clicking on the Desktop icon within Windows Explorer.

Simply selecting this icon would automatically execute all the commands shown in Figure 1.7 without the need to type it in.

GUIs use various technologies and devices to provide the user interface. One of the most common is **WIMP (windows icons menu and pointing device)** which was developed for use on personal computers (PC). Here, a mouse is used to control a cursor and icons are selected to open/run windows. Each window

contains an application and modern computer systems allow several windows to be open at the same time. An example is shown in Figure 1.8 (here, a number of icons can be seen on the on the bottom of the screen 'window'):



▲ **Figure 1.8** Screen image showing icons

A window manager looks after the interaction between windows, the applications and window system (which handles the pointing devices and the cursor's position).

In recent years, devices such as **touch screen** smartphones and tablets use **post-WIMP** interaction, where fingers are in contact with the screen allowing actions such as **pinching** and **rotating**, which would be difficult to do using a single pointer and device such as a mouse.

Table 1.5 summarises the main advantages and disadvantages of CLI and GUI.

▼ **Table 1.5** Advantages and disadvantages of CLI and GUI interfaces

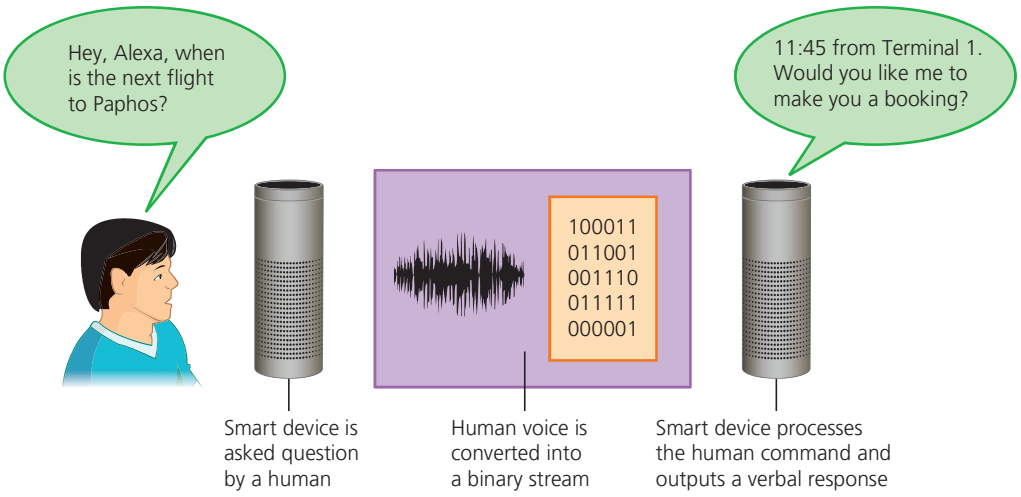
Interface	Advantages	Disadvantages
Command line interface (CLI)	The user is in direct communication with the computer. The user is not restricted to a number of pre-determined options. It is possible to alter computer configuration settings.	The user needs to learn a number of commands to carry out basic operations. All commands need to be typed in, which takes time and can be error-prone. Each command must be typed in using the correct format, spelling, and so on.
Graphical user interface (GUI)	The user does not need to learn any commands. It is more user-friendly; icons are used to represent applications. A pointing device (such as a mouse) is used to click on an icon to launch the application – this is simpler than typing in commands.	This type of interface uses up considerably more computer memory than a CLI interface. The user is limited to the icons provided on the screen. Needs a more complex operating system, such as *Windows*, to operate, which can be slower to execute commands.

Who would use each type of interface?
CLI: a programmer, analyst or technician; basically, somebody who needs to have direct communication with a computer to develop new software, locate errors and remove them, initiate memory dumps (contents of the computer memory at some moment in time), and so on.

GUI: the end-user who does not have to (or does not need to) have any great knowledge of how the computer works; a person who uses the computer to run software, play games or store/manipulate photographs, for example.

Dialogue-based user interfaces

Dialogue-based user interfaces use the human voice to give commands to a computer system. An example of its use is in some luxury modern cars, where voice activation is used to control devices such as the in-car entertainment system or satellite navigation system. By speaking certain commends, such as 'Hey BMW, drive me to the nearest airport', the system allows natural speech to enable the driver to intuitively interact with the car. The satellite navigation system will automatically direct the driver to their chosen destination (in this case, the nearest airport). This type of interface could also be used in the home; by using voice commands, it is possible to switch on/off lights, operate electronic equipment and so on. In recent years, devices such as Amazon Alexa, Google Now, Apple Siri and Microsoft Cortana have all been developed to interact with a human by recognising verbal commands. These devices act as a personal assistant.



▲ **Figure 1.9** Smart voice activated devices

Gesture-based interfaces

Gesture-based interfaces rely on human interaction by the moving of hands, head or even the feet. Gesture recognition allows humans to interface with a computer in a more natural fashion without the need for any mechanical devices. This type of interface uses techniques known as **computer vision** and **image processing**. For example, using our car example again, the following gestures can be used to carry out certain functions:

- rotating a finger clockwise near the radio will increase the sound volume (rotating the finger anti-clockwise will reduce the sound volume)

- opening the thumb and next finger will change the track being listened to (for example, in a playlist)
- moving the foot under the rear bumper of the car automatically opens the boot lid
- moving a hand near a window switch automatically opens a window.

There are many other examples. Either a sensor or a camera is used to pick up the gesture and a signal is sent to an on-board computer to carry out the required action. It eliminates the need for an array of buttons and dials on the dashboard.

Table 1.6 summarises the main advantages and disadvantages of dialogue-based and gesture-based interfaces.

▼ **Table 1.6** Advantages and disadvantages of dialogue-based and gesture-based interfaces

Interface	Advantages	Disadvantages
Dialogue-based interface	• no need for a driver to take their hands off the steering wheel • in a home, very useful for people with disabilities, because many tasks can be carried out by the spoken word only • possible to use as a security feature, because voice recognition could be used to identify a person	• still unreliable, with many commands not being recognised or needing to be repeated several times (especially if there is background noise) • can be quite complex to set up • user needs to know which commands can be used
Gesture-based interface	• replaces mechanical input devices • no physical contact required • very natural interface for a human operator • no training needed to interface with the computer	• possible for unintentional movement to be picked up • only works fairly near to the camera or sensor (maximum of 1.5 metres) • may only accept a limited number of movements (for example, it may take several attempts to find out exactly what finger movements are recognised)

1.4 Types of computer

There are many types of computer systems in existence. The following summarises some of the more common types currently available:

1.4.1 Desktop computers

Desktop usually refers to a general-purpose computer that is made up of separate monitor, keyboard, mouse and processor unit. It is distinguished from, for example, a laptop computer by the fact that it is made up of a number of separate components, which makes them not very portable.

Because laptop and desktop computers tend to be used for very similar purposes, it is worth making a comparison between the two types of computer.

▲ **Figure 1.10** Desktop computer

The advantages of desktop computers over laptop computers are:

- Spare parts and connections tend to be standardised, which usually results in lower costs.
- Desktop computers are easier, and less expensive, to upgrade or expand.
- The desktop tends to have a better specification (for example, faster processor) for a given price (often due to size and construction constraints in laptops).
- Power consumption is not critical because they usually plug straight into a wall socket, and the larger casings allow a better dissipation of any heat build-up.
- Because they are usually fixed in one location, there is less likelihood of them being damaged or stolen.
- Internet access can be more stable because a desktop computer is more likely to have a wired internet connection (the user will always have the same data transfer rate); however, due to their portability, laptop computers usually use wireless internet connectivity where the signal can be very variable (giving variable data transfer rate).

They do have disadvantages when compared to laptop computers:

- The most obvious is that they are not particularly portable because they are made up of separate components.
- They tend to be more complicated because all the components need to be hooked up by wiring, which also clutters up the desk space.
- Because they are not particularly portable, it is necessary to copy files on, for example, a memory stick, when you want to do some work elsewhere (for example, doing office work at home); although cloud storage has diminished this disadvantage recently, it still may not be possible to save sensitive data files on the cloud.

Link

For more on cloud storage see Section 4.1.

The main uses of desktop computers include:

- office and business work (word processing, spreadsheets, finance software and databases being the main use)
- educational use (using interactive software to teach or learn from)
- use as a gaming device (for example, games such as chess, crossword puzzles, fantasy games, and so on)
- general entertainment (for example, live or 'catch-up' streaming of television programmes).

1.4.2 Mobile computers

Mobile computers, by their very name, suggest a group of computers which are considerably more portable than desktop computers. Such computers fall into four categories:

- laptop computers
- smartphones
- tablets
- phablets.

Laptop (or notebook)

Laptop (or notebook) refers to a type of computer where the monitor, keyboard, pointing device and processor are all together in one single unit. This makes them extremely portable.

▲ **Figure 1.11** Laptop computer

Key features you would expect to find in a laptop:

- lightweight (to aid portability)
- low power consumption (and also long battery life)
- low heat output (cooling is very important).

Laptop computers do have advantages when compared to desktop computers:

- The most obvious advantage is their portability; they can be taken anywhere because the monitor, pointing device, keyboard, processor and backing store units are all together in one single unit.
- Because everything is in one single unit, there are no trailing wires (only one single cord is used).
- They take up much less room on a desk, so they can be used anywhere (for example, in a café).
- Their portability allows them to take full advantage of Wi-Fi features.
- Because they are portable, they can link into any multimedia system.

Laptop computers also have disadvantages when compared to desktop computers:

- Because they are easily portable, they are also easier to steal!
- They have limited battery life so the user may need to carry a heavy power adaptor.
- The keyboards and pointing devices can sometimes be more awkward to use.
- It is not always possible to upgrade them, for instance by adding more RAM.

The main uses of laptop computers include:

- office and business work (word processing, spreadsheets, finance software and databases being the main use)
- educational use (using interactive software to teach or learn from)
- used as a gaming device (for example, games such as chess, crossword puzzles, fantasy games, and so on)
- general entertainment (for example, live or 'catch-up' streaming of television programmes)
- used in control and monitoring (because they can be operated anywhere using their internal battery, it is possible to use laptops to gather data directly from the environment – for example, they can be plugged into a gas boiler during maintenance to monitor its performance).

Smartphones

Smartphones allow normal phone calls to be made, but also have an operating system (such as iOS, Android or Windows) allowing them to run a number of computer applications (known as apps or applets). They allow users to send/receive emails, use a number of apps, use a camera feature (to take photos or videos), MP3/4 players (for music and videos), and so on. Smartphones communicate with the internet either by using Wi-Fi hot spots or by using 3G/4G/5G mobile phone networks.

▲ **Figure 1.12** Smartphone

Some of the typical features of smartphones include:

- high-definition, anti-glare displays
- front- and back-facing cameras (which are used to take photos, videos or act as a webcam when doing video calls over the internet)
- lower weight and longer battery life than laptops
- use Bluetooth for connection to printers and other devices
- make use of flash (solid state) memory and cloud storage facilities to back up and synchronise (often just referred to as 'sync') data sources
- they use a number of sensors to carry out the following functions:
  - proximity sensors to detect if the device is close to, for example the ear, which allows it to block unintended 'touches'
  - accelerometers, which detect movement and orientation of the device (for example, move the display from portrait to landscape to view videos, or allow it to be used as a 'steering wheel' in-car racing games)
  - can use sophisticated speech recognitions systems (such as Siri) to enable the user to ask the device to look for things (such as search the address book).

The new generation of smartphones are becoming even thinner and lighter, because they make use of OLED (organic light emitting diode) touch screens.

Future smartphones will also use OLED touch screens that are coated with a crystalline layer that allows the phones to be partially solar powered; this allows them to use Li-Fi (similar to Wi-Fi, except communication uses visible light rather than radio waves). Communication using Li-Fi is considerably faster than with Wi-Fi (much higher data transfer rate); it is also more secure (by stopping internet 'piggybacking'). The Li-Fi system can also be used during aeroplane flights because it does not use radio waves and therefore does not interfere with flight control systems.

Advantages of smartphones:

- They are very small in size and lightweight – therefore they are very easy to carry and have on your person at all times (this is more difficult with laptops because they are much bulkier and much heavier).
- You can use them to make phone calls, but also connect to the internet while on the move.

- Because they use Wi-Fi and mobile phone networks they can be used almost anywhere (this is not the case with laptops or desktops; although tablets also use the same technology).
- They have apps which make use of sensor data provided by the smartphone, for instance location data for maps – this can provide services that are not available on desktops or laptops.
- They have a reasonable battery life compared to laptops.

Disadvantages of smartphones:

- The small screens and keyboards make pages difficult to read.
- It is more difficult and slower when typing things in (laptops and desktops have much bigger screens and much larger keyboards).
- Web browsing and photography can quickly drain the battery.
- Memory size in most phones is not very large when compared to laptops and desktops – although it is comparable with tablets (however, the latest generation smartphones come with 1 TiB memories).
- Not all website features are compatible with smartphone operating systems.
- Because of their small size, it is much easier to lose a smartphone or for it to be stolen compared to laptops or desktops.
- The data transfer rate using mobile phone networks can be slower than with Wi-Fi – this makes streaming of video or music, for example, less than satisfactory at times.

Tablets

Tablets are becoming an increasingly used type of mobile computer. They work in a similar way to a smartphone. Tablets use touch screen technology and do not have a conventional keyboard. The keyboard is **virtual**; that is, it is part of the touch screen and keys are activated by simply touching them with a finger or a stylus. However, it is possible to buy tablet cases which contain a normal-sized keyboard. Internet access is usually through Wi-Fi or 3G/4G/5G (mobile phone) connectivity. Like smartphones, tablets are equipped with a series of sensors which include camera, microphone, accelerometer and touch screen.

▲ **Figure 1.13** Tablet

The typical features of tablets are identical to those of a smartphone (described earlier).

Advantages of tablets compared to laptops:

- very fast to switch on (no time delay waiting for the operating system to load up)
- fully portable – they are so lightweight that they can be carried anywhere
- touch screen technology means they are simple to use and do not need any other input devices
- can use several apps as standard (such as built-in camera, MP3/4 players and so on)

- not much heat – they use solid-state technology
- battery life of a tablet is a lot longer
- when the power button is pressed, it goes into standby, but remains connected to the internet so the user still hears alerts when emails or other 'events' are received.

Disadvantages of tablets compared to laptops:

- tend to be rather expensive when compared to laptops (but this will probably change with time as they become more common)
- they often have limited memory or storage when compared to a laptop (although some of the latest devices have 1 TiB memory capacity)
- if 3G/4G/5G mobile phone networks are used, they can be expensive to run if the internet is being accessed frequently
- typing on a touch screen can be slow and error-prone compared to a standard keyboard
- transferring of files often has to be done through an 'application atore'; this lack of 'drag and drop' facility can prove to be irritating to users
- laptops tend to support more types of file format than tablets and are also better equipped to run different types of software.

Some of the latest smartphones have been designed as a hybrid between a tablet and a smartphone; these are referred to as a **phablet**. They have much larger screens than a smartphone but are smaller than a tablet. All the features of a smartphone (described earlier) also apply to phablets together with the typical features of a tablet.

Smartphones

up to 5.1 inches in size (that is, 13 cm)

Phablets

between 5.1 inches and 7 inches (that is, 13 cm to 18 cm)

Tablets

over 7 inches in size (that is, over 18 cm)

▲ **Figure 1.14** Comparison of smartphone, phablet and tablet

The main uses of smartphones, tablets and phablets include:

- entertainment (streaming of music, videos and television programmes)
- gaming (including group games)
- as a camera or video camera (the quality of videos and photos now matches a good digital cameras)
- internet use (online sales, social networks, using QR codes, and so on)
- sending/receiving emails
- global positioning system (use of maps to navigate to a location)
- calendar functions
- telephone banking (sending and receiving money using the banking apps)
- Voice over Internet Protocol (VoIP) – telephone network using the internet which also allows video calling
- instant access to social networks (social contact with friends no matter where you are in the world)
- instant messaging
- office and business management (particularly the features that allow rapid voice and video communication)
- education use (using interactive software to teach or learn from)
- remotely control devices (it is possible to remotely operate devices in the home, such as microwave ovens, which contain embedded microprocessors; by using internet-enabled smartphones or tablets, it is possible to start/stop the oven even while several kilometres away from home by using an App and the internet).

Exercise 1a

Name a number of devices in the home that contain embedded microprocessors, which can be controlled by smartphones, tablets or phablets using an app and the internet.

What are the advantages and disadvantages of using smartphones, tablets or phablets to control these devices?

1.5 Emerging technologies

1.5.1 Impact of emerging technologies

Artificial intelligence

There are many definitions of **artificial intelligence (AI)**. Essentially, AI is a machine or application which carries out a task that requires some degree of intelligence. For example:

- the use of language
- recognising a person's face
- the ability to operate machinery, such as a car, aeroplane, train, and so on
- analysing data to predict the outcome of a future event, for example weather forecasting.

AI duplicates human tasks which require decision-making and problem-solving skills. Eventually, many tasks presently done by humans will be replaced by robots or computers, which could lead to unemployment. However, the positive side includes improvements in safety and quality of services and products. Some examples are detailed below.

The impact of AI on everyday life

Whenever AI is mentioned, people usually think of science fiction fantasies and think of **robots**. The science fiction writer Isaac Asimov even went as far as producing his three laws of robotics:

- robots may not injure a human through action or inaction
- robots must obey order given by humans without question
- a robot must protect itself unless it conflicts with the two laws above.

Many science fiction movies continue to fuel people's imagination with slightly sinister interactions between humans and machines. However, AI goes way beyond robotics and covers many areas, such as those shown in Figures 1.15–1.11

▲ **Figure 1.15** An autonomous (driverless) vehicle – we already have driverless trains and autopilots on aeroplanes, but future developments include driverless cars.

▲ **Figure 1.16** Robotic research is leading to improvements in technology to help amputees and people with disabilities.

▲ **Figure 1.17** Robots are used to help people carry out dangerous or unpleasant tasks – for example, bomb disposal, welding of car bodies, entering nuclear disaster areas (such as Chernobyl or Fukushima) where the radiation would kill a human in under two minutes.

There are many more examples and the list becomes longer and longer with time.

Negative impacts of AI

All of the above examples give a very favourable view of the effect of AI on our everyday lives. However, in any balanced argument, we should also consider the drawbacks of the new technology:

- could lead to many job losses in a number of areas (although it is true to say that new technical jobs would also be created); many jobs could be lost in manufacturing, but other roles are likely to be affected (such as bus, taxi, lorry and train drivers)

- dependency on technology and the inability to carry out tasks done by robots, for example, could be an issue in the future
- loss of skills – even now, skills from previous generations have been lost as humans have been replaced by machines and software applications.

Extended reality

Extended reality (XR) refers to real and virtual combined environments, and is a 'catch all' term for all immersive technologies. The three most common examples at the moment are:

- augmented reality (AR)
- virtual reality (VR)
- mixed reality (MR).

All these immersive technologies extend the reality we experience by either blending the virtual and real worlds or by creating a fully immersive experience.

In this chapter, we will only consider the first two examples.

Augmented reality (AR)
The features of augmented reality include:

- allow the user to experience the relationship between digital (virtual) and physical (real) worlds
- virtual information and objects are overlaid onto real-world situations
- the real world is enhanced with digital details, such as images, text and animation
- the user can experience the AR world through special goggles or via smartphone/phablet screens
- the user is not isolated from the real world and is still able to interact and see what is going on in front of them
- examples include the Pokémon GO game which overlays digital creatures onto real-world situations.

In the future, augmented reality will have an impact on all the following areas:

- safety and rescue operations (for example, it is possible to provide 3D images of an area where a rescue mission is to take place, giving the team the opportunity to interact with the environment and try out rescue procedures before doing the real thing)
- entertainment (for example, AR takes users into a virtual environment where it is possible to interact with the characters; imagine the characters of your favourite film interacting with you at home)
- shopping and retail (this is one of the big areas – for example, using your smartphone camera you can try out make-up and see how it looks on you before buying it, or you can experience a virtual tour of a new car where you can 'sit' in the interior and try out the driving experience before buying the car)

- healthcare (doctors can make use of AR to have a better understanding of a patient's body; software, such as *Echopixel* enables doctors to use CT scans from patients to build up a 3D image of their body to help with surgery and diagnosis).

Virtual reality (VR)
The features of virtual reality include:

- the ability to take the user out of the real-world environment into a virtual (unreal) digital environment
- in contrast to AR, the user is fully immersed in a simulated digital world
- users must wear a VR headset or a head-mounted display which allows a 360° view of the virtual world (this 'fools' the brain into believing they are walking on an ocean bed, walking in an alien world or inside a volcano)
- this technology can be used to good effect in: medicine (teaching operation procedures), construction, engineering and the military.

In the future, virtual reality will have an impact on all the following areas:

- military applications (for example, training to operate a new tank)
- education (for example, looking inside an ancient building as part of a history lesson)
- healthcare (for example, as a diagnostic tool to recommend treatment)
- entertainment (for example, games where gloves, goggles or helmets are worn to fully immerse players and make it seem very real)
- fashion (for example, to do fashion shows before doing the real thing – see the clothes on people, check out the venue and so on)
- heritage (for example, allowing users to walk around and close up to monuments like Stonehenge)
- business (for example, training courses and role-playing scenarios for staff)
- engineering (for example, seeing how new designs like bridges will look in an existing environment)
- sport (for example, a golfer trying to improve his swing can use this technology and get feedback to improve his game)
- media (for example, interactive special effects in movies)
- scientific visualisation (for example, part of a molecular structure in chemistry, or a cell in biology).

Exam-style questions

1 There are a number of different types of computer. Write down the type of computer that best fits the following descriptions.

a A computer that is difficult to move and has a separate monitor and keyboard. [1]

b A portable computer that includes a physical keyboard. [1]

c A thin portable computer that has a touch screen and a battery in a single unit, not normally used to make phone calls. [1]

d A mobile phone that can be used as a computer. [1]

Cambridge IGCSE Information and Communication Technology (0417) Paper 12 Q1, February/March 2016

2 Tick (✓) whether the following are features of operating systems containing a command line interface (**CLI**) or a graphical user interface (**GUI**). [2]

	CLI (✓)	GUI (✓)
Instructions have to be typed.		
Applications are represented by icons.		
Options are chosen from a menu.		
Many instructions have to be memorised.		

Cambridge IGCSE Information and Communication Technology (0417) Paper 12 Q2, February/March 2016

3 Most smart phones can carry out many functions which, until recently, only a computer could perform. Explain why computers of all types are still needed. [7]

Cambridge IGCSE Information and Communication Technology (0417) Paper 12 Q10, February/March 2015

4 Computer operating systems have developed since early computers used Command Line Interfaces (CLI). Many computers now use Graphical User Interfaces (GUI), some of which are capable of using touch screen technology.
Compare and contrast CLI and GUI. [8]

Cambridge IGCSE Information and Communication Technology (0417) Paper 11 Q14, May/June 2017

5 Nine statements about random access memory (RAM) and read-only memory (ROM) are given below. By putting a tick (✓) in the appropriate box, indicate whether each statement refers to RAM or ROM. [9]

	RAM (✓)	ROM (✓)
Data on a chip is stored permanently and cannot be deleted		
It is not possible to alter or delete the data stored on the chip		
Data on the chip is stored temporarily and can be deleted by the user		
Data is retained even when the computer is powered down		
Stores data, files or part of the operating system which is currently in use		
Data is lost when power to the computer is turned off		
It contains the basic input/output system used to boot up the computer when it is first powered up		
It is a form of volatile memory		
It is a form of non-volatile memory		

6 a Describe what is meant by augmented reality and virtual reality. [4]

b Describe how augmented reality and virtual reality could affect society in the near future. [4]

7 Six descriptions are shown on the left and six computer terms are shown on the right.
Draw lines to link each statement to its correct computer term. [6]

Method whereby a person uses their voice to carry out a function	output device
Physical component that allows data to be entered into a computer system	analogue
Physical component, such as a monitor, printer or projector under the control of the computer	computer-aided design
Small application that carries out a single task; usually embedded in the html page on a website	dialogue-based interface
Software used to help in the creation, manipulation, modification and analysis of a drawing	input device
Physical data that changes smoothly and is not step wise; has an infinite number of possible values	applet