Cambridge

OL- IGCSE

Computer science

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Chapter 06

Automated and emerging technologies

6.1 Automated systems

6.1.1 Sensors, microprocessors and actuators

An **automated system** is a combination of software and hardware (for example, sensors, microprocessors and actuators) that is designed and programmed to work automatically without the need of any human intervention. However, such systems often involve human monitoring.

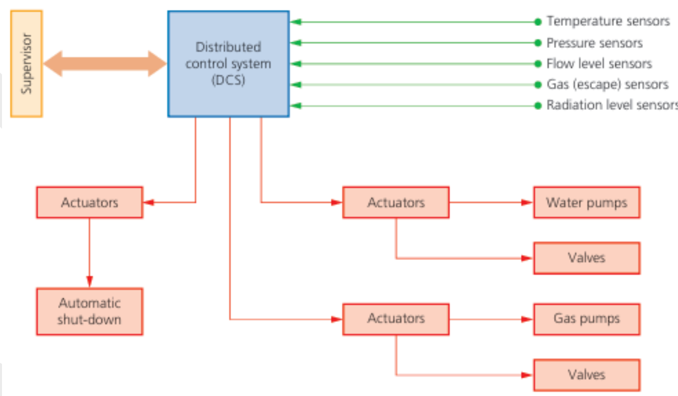
6.1.2 Advantages and disadvantages of automated systems

In this section, a number of examples will be used to show the advantages and disadvantages of using automated systems. This list is by no means exhaustive, and simply intends to show the role of sensors, microprocessors (or computers) and actuators in the following application areas:
» Industrial » Transport » Agriculture » Weather » Gaming » Lighting » Science.

Industrial applications

Automated systems are used in a number of industrial applications. Many of the automated systems involve robotics.

A key use of automated systems is in the control and monitoring of a nuclear power station. This is a good example, since automation gives increased safety both in the process itself and to the workforce. At the centre of the system is a **distributed control system (DCS)**



▲ **Figure 6.1** Nuclear power station (automated system)

The main advantages of this automated system are:

» Much faster than a human operator to take any necessary action
» Much safer (an automated system is more likely to make timely interventions than a human; it also keeps humans away from a dangerous environment)
» The process is more likely to run under optimum conditions since any small changes needed can be identified very quickly and action taken
» In the long run, it is less expensive (an automatic system replaces most of the workforce who would need to monitor the process 24 hours a day).

The main disadvantages of this automated system are:
» Expensive to set up in the first place and needs considerable testing
» Always possible for a set of conditions to occur that were never considered during testing which could have safety implications (hence the need for a supervisor)
» Any computerised system is subject to cyberattacks no matter how good the system (one way round this is to have no external links to the DCS; although the weak link could potentially be the connection to the supervisor)
» Automated systems always need enhanced maintenance which can be expensive.

Transport

As with industrial processes, many of the automated systems in transport refer to robotic systems (for example, autonomous buses/cars, autonomous trains and unpiloted aircraft). These will be considered in Section 6.2. But automated systems are still used in manually controlled transport, which includes cars, buses/lorries, trains and aircraft. (Examples 3 and 4 which follow, will use cars as the application.)

Agriculture

There are many examples of the use of automated systems in agriculture. Again, many of the systems involve robotics, which is fully described in Section 6.2. We will now consider one important example that is being used in Brazil to irrigate crops automatically.

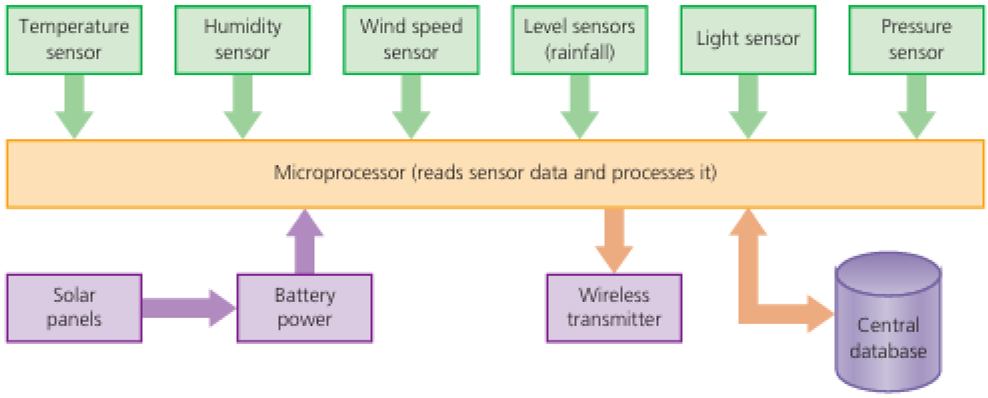
Data from an automatic weather station (see next example) is received by the **controller** (a computer system) every ten minutes. This is particularly important if very wet or very dry conditions are being predicted or detected by the weather station. Ultrasonic water level sensors are used in the crop fields that measure the amount of water in the irrigation channels.

Weather (stations)

Automated weather stations are designed to save labour and to gather information from remote regions or where constant weather data is a requirement. Automated weather stations require a microprocessor, storage (database), battery (usually with solar-powered charging) and a range of sensors:

» Thermometer (to measure temperature)
» Anemometer (to measure wind speed)
» Hygrometer (to measure humidity)
» Barometer (to measure air pressure)
» Level sensor (to measure rain fall)
» Light sensor (to measure hours of daylight).

The only part of the weather station that needs to use actuators is the 'tipping bucket rain gauge'. At a pre-determined time interval, a signal is sent from the microprocessor to an actuator to operate a piston, which tips a bucket that was collecting rain water. The water is tipped into a vessel where level sensors are then used to measure the amount of rainfall that fell during the required time interval.



▲ **Figure 6.9** Automated weather station

Gaming

Gaming devices involve sensors to give a degree of realism to games:

» Accelerometers (these measure acceleration and deceleration and therefore measure and respond to tilting the gaming device forward/backward and side to side)

» Proximity sensors (used in smart touch pads; here electrodes are embedded in touch pads that can detect hand/finger position thus increasing user awareness)

Science

Automated systems in scientific research are widely used. There are literally thousands of possible applications. The example we will use here is the automatic control of a laboratory experiment which requires accuracy and repeatability.

Finally, there are many automated systems being used in both industry and scientific research that incorporate artificial intelligence (AI). It is therefore worth considering the generic advantages of using AI in these automated systems (also refer to Section 6.3):

» Ability to access and store vast amounts of facts (very important in research)

» They are able to learn from huge amounts of available data that would overwhelm humans (or at the very least take them many months/years to do the same analysis)

» They are able to see patterns in results that could be missed by humans. While all of this is positive, there are a few disadvantages in this approach:

» A change in skills set (is it the human or the AI that controls the research?)
» AI is dependent on the data which trains it.

6.2 Robotics

6.2.1 What is robotics?

The word robot comes from the Czech word robota (which means 'forced labour') and the term was first used in the 1920s play 'Rossum's Universal Robots'. The concept of the robot has fired the imagination of science fiction writers for countless years; indeed Isaac Asimov even composed his three laws of robotics:

» a robot may not injure a human through action or inaction
» a robot must obey orders given by humans, unless it comes into conflict with law 1
» a robot must protect itself, unless this conflicts with law 1.

So what is a robot in the real world? Robotics is a branch of (computer) science that brings together the design, construction and operation of robots. Robots can be found in:

▲ **Figure 6.12** Robot welder

- factories
  - welding parts together
  - spray-painting panels on a car
  - fitting windscreens to cars
  - cutting out metal parts to a high precision
  - bottling and labelling plants
  - warehouses (automatic location of items)
- in the home
  - **autonomous** floor sweepers (see Figure 6.13)
  - autonomous lawn mower
  - ironing robots (for example, 'dressman')
  - pool cleaning
  - automatic window cleaners
  - entertainment ('friend' robots)

▲ **Figure 6.13** Robot carpet sweeper

▲ **Figure 6.14** Reconnaissance drone

- drones
  - unmanned aerial vehicles (UAVs) are drones that are either remotely controlled or totally autonomous using embedded systems
  - can be used in reconnaissance (for example, taking aerial photographs)
  - can be used to make parcel deliveries (for example, Amazon).

6.2.2 Characteristics of a robot

To be correctly called a robot, they need to have the following characteristics:

1. Ability to sense their surroundings:– this is done via sensors (such as light, pressure, temperature, acoustic, and so on)– sensors allow a robot to recognise its immediate environment and gives it the ability to determine things like size, shape or weight of an object, detect if something is hot or cold, and so on; all sensor data is sent to a microprocessor or computer.

2. Have a degree of movement: – they can make use of wheels, cogs, pistons, gears (etc.) to carry out functions such as turning, twisting, moving backwards/forwards, gripping or lifting
– they are **mechanical structures** made up of many parts (for example, motors, hydraulic pipes, actuators and circuit boards)
– they contain many **electrical components** to allow them to function
– can make use of end **effectors** (different attachments to allow them to carry out specific tasks such as welding, spraying, cutting or lifting).

3. Programmable: – they have a 'brain' known as a **controller** that determines the action to be taken to perform a certain task (the controller relies on data sent from sensors or cameras, for example)
– controllers are **programmable** to allow the robots to do certain tasks.
TWO IMPORTANT NOTES:
1. Many robots don't possess artificial intelligence (AI) since they tend to do repetitive tasks rather than requiring adaptive human characteristics.

2. It is important not to confuse physical robots with software robots such as:
– search engine bots or WebCrawlers (these 'robots' roam the internet scanning websites, categorising them for search purposes)
– chat bots (these are programs that pop up on websites that seem to enter some form of conversation with the web user – see Section 6.3)

According to our definition above, software robots are not true robots. Physical robots can be classified as **independent or dependent:**
» Independent robots:– have no direct human control (they are said to be autonomous, for example, an **autonomous** vehicle)– can replace the human activity totally (no human interaction is required for the robot to function fully).
» Dependent robots:– have a human who is interfacing directly with the robot (the human interface may be a computer or a control panel)
– can supplement, rather than totally replace, the human activity (for example, in a car assembly plant where both humans and robots work together to produce a car).

6.2.3 The role of robots and their advantages and disadvantages

We will now consider the use of robots in a number of areas, together with the advantages and disadvantages of using robots in each of these areas:
» industry » transport » agriculture » medicine » domestic (home) use » entertainment.

Industry

Control of robots is either through embedded (built-in) microprocessors or directly linked to a computer system. Programming of the robot to do a series of tasks is generally done in two ways:

1. The robot is programmed with a sequence of instructions which allow it to carry out the series of tasks (for example, spraying a car body with paint).

2. Alternatively, a human operator manually carries out the series of tasks; this can be done in two ways. In our example, we will assume an object is being painted using a robot arm. Figure 6.18 shows a robot arm equipped with a spray gun end-effector. Different end-effectors allow the robot arm to carry out many different tasks:

i. the robot arm is guided manually by a worker when spraying the object; each movement of the arm is stored as an instruction on the computer; or

ii. the worker straps sensors to his own arm and sprays the object; each movement is stored as a set of instructions on a computer; the sensors send back information such as position relative to the object, arm rotation and so on – this information forms part of the instructions stored on the computer.

▼ **Table 6.1** Advantages and disadvantages of using robots

Advantages	Disadvantages
robots are capable of working in conditions that may be hazardous to humans robots work 24/7 without the need to stop	robots can find it difficult to do 'non-standard' tasks (for example, windscreen being fitted to a car is cracked)
robots are less expensive in the long run (since there will be fewer salaries to pay)	robots can lead to higher unemployment amongst manual labour tasks
robots are more productive than humans (higher productivity) although not necessarily more accurate, robots are more consistent	there is a risk of deskilling when robots take over certain tasks (for example, welding and paint spraying)
robots are better suited to boring, repetitive tasks than humans (therefore less likely to make mistakes)	factories can now be moved to anywhere in the world where operation costs are lower (leading again to unemployment in some countries)
there will be less cost in heating and lighting (robots don't need good light or warmth)	robots are expensive to buy and set up in the first place

Transport

Driverless vehicles are increasing in number every year. These are very complex robots, but the big problem is not really the technology (since problems will be ironed out through time), it is human perception.

Autonomous cars and buses

In this section, we will consider autonomous cars as our example. Autonomous cars use sensors, cameras, actuators and microprocessors (together with very complex algorithms) to carry out their actions safely.

Microprocessors process the data received from cameras and sensors and send signals to actuators to perform physical actions, such as: » change gear » apply the brakes » turn the steering wheel.

▼ **Table 6.2** Advantages and disadvantages of autonomous vehicles

Advantages of autonomous vehicles	Disadvantages of autonomous vehicles
safer since human error is removed leading to fewer accidents	very expensive system to set up in the first place (high technology requirements)
better for the environment since vehicles will operate more efficiently	the ever-present fear of hacking into the vehicle's control system
reduced traffic congestion (humans cause 'stop-and-go' traffic known as ***'the phantom traffic jam'***, autonomous vehicles will be better at smoothing out traffic flow reducing congestion in cities)	security and safety issues (software glitches could be catastrophic; software updates would need to be carefully controlled to avoid potential disasters)
increased lane capacity (research shows autonomous vehicles will increase lane capacity by 100% and increase average speeds by 20%, due to better braking and acceleration responses together with optimized distance between vehicles)	the need to make sure the system is well-maintained at all times; cameras need to be kept clean so that they don't give false results; sensors could fail to function in heavy snowfall or blizzard conditions (radar or ultrasonic signals could be deflected by heavy snow particles)
reduced travel times (for the reasons above) therefore less commuting time	driver and passenger reluctance to use the new technology
stress-free parking for motorists (the car will find car parking on its own and then self-park)	reduction in the need for taxis could lead to unemployment (imagine New York without its famous yellow cabs!)

Autonomous trains

As mentioned earlier, autonomous (driverless) trains have been around for a number of years in a number of large cities. As with other autonomous vehicles, driverless trains make considerable use of sensors, cameras, actuators and on-board computers/microprocessors. Autonomous trains make use of a system called **LiDaR.**

▼ **Table 6.3** Advantages and disadvantages of autonomous trains

Advantages of autonomous trains	Disadvantages of autonomous trains
this improves the punctuality of the trains	the ever-present fear of hacking into the vehicle's control system
reduced running costs (fewer staff are required)	system doesn't work well with very busy services (at the moment)
improves safety since human error is removed	high capital costs and operational costs initially (that is, buying the trains, expensive signalling and control equipment and the need to train staff)
minimises energy consumption since there is better control of speed and an optimum service requires less energy (trains stuck in stations still use energy)	ensuring passenger behaviour is acceptable particularly during busy times (for example, jamming doors open on trains, standing too near the edge of platforms and so on)
it is possible to increase the frequency of trains (automated systems allow for shorter times between trains)	passenger reluctance to use the new technology
it is easier to change train scheduling (for example, more trains during busier times)	no drivers mean there will be a need for CCTV to monitor railway stations

Autonomous (unpiloted) airplanes Airplanes have used auto-pilots for many years to control flights. Human pilots only take over during take-off and landing. Autonomous (pilotless) airplanes would make even more extensive use of sensors, actuators and microprocessors to control all stages of the flight. Some of the main features of a control system on a pilotless airplane would include:

» Sensors to detect turbulence to ensure smooth flights
» An increase in self-testing of all circuits and systems
» Sensors that would automatically detect depressurisation in the cabin; thus allowing for quick stabilisation of the airplane
» Use of GPS for navigation and speed calculations » use of actuators to control, for example, throttle, flaps (on the wings) and the rudder.

▼ **Table 6.4** Advantages and disadvantages of pilotless airplanes

Advantages of pilotless airplanes	Disadvantages of pilotless airplanes
improvement in passenger comfort (reasons given earlier)	security aspects if no pilots on-board (for example, handling terrorist attacks)
reduced running costs (fewer staff are required)	emergency situations during the flight may be difficult to deal with
improved safety (most crashes of airplanes have been attributed to pilot-induced errors)	hacking into the system (it might be possible to access flight controls)
improved aerodynamics at the front of the airplane since there would no longer be the need to include a cockpit for the pilots	passenger reluctance to use the new technology
	software glitches (recent software issues with modern airplanes have highlighted that software glitches can have devastating results)

Agriculture

With the world's population predicted to reach nine billion by the year 2050, more efficient agriculture via increased use of robotics is inevitable. We will consider the following five areas where robotics could play a big role:
» harvesting/picking of vegetables and fruit
» Weed control

» Phenotyping (plant growth and health)
» Seed-planting and fertiliser distribution
» Autonomous labour-saving devices.

Harvesting and picking

» Robots have been designed to do this labour-intensive work; they are more accurate (only pick ripe fruit, for example) and much faster at harvesting

» For the reasons above, this leads to higher yields and reduces waste (for example, vegebot (Cambridge University) uses cameras to scan, for example, a lettuce and decide whether or not it is ready to be harvested

» A second camera in vegebot (near the cutting blades) guides an arm to remove the lettuce from its stalk with no damage.

Weed control

» Weed management robots can distinguish between a weed and crop using AI (see Section 6.3)

» Examples of weed control robots are being used in France (by Mouton Rothschild) to remove weeds between grape vines in their vineyards; this saves considerably on labour costs and improves vine growth

» Weed control robots use GPS tracking to stay on course to move along the rows of vines and remove the weeds; a weed removal blade is operated by an actuator under the control of the controller (microprocessor) in the robot

» Very often a **drone** (flying robot) is used first to do an aerial view of the vineyard, so that a programmed course of action can be produced, which is then sent to the weed control robot’s memory.

Phenotyping

» Phenotyping is the process of observing physical characteristics of a plant in order to assess its health and growth

» Robots designed to do phenotyping are equipped with sensors (including spectral sensors and thermal cameras) that can create a 3D image/model of the plant, thus allowing it to be monitored for health and growth

» Machine learning (see Section 6.3) is used to recognise any issues with leaves (for example, if they have a blight or have the wrong colour) so that the robot can convey this back to the farmer

» These robots are much more accurate and faster at predicting problems than when done manuall.

Seed-planting drones and fertiliser distribution

» Drones (flying robots) can produce an aerial image of a farm sending back a ‘bird’s eye view’ of the crops and land

» They allow seed-planting to be done far more accurately

» They also allow for more efficient fertiliser-spreading to reduce waste and improve coverage (this is much more efficient than conventional crop spraying)

» Drones can also be used in cloud seeding where the drone can add silver iodide crystals to a cloud forcing it to give up its rainwater

» The drones use a very complex camera system to target seeding and allow fertiliser spraying.

Autonomous agriculture devices

Several of the devices described above could be referred to as autonomous.

The following list summarises some of the devices that can work independently of humans:

» Grass mowers/cutters
» Weeding, pruning and harvesting robots
» Seeding robots
» fertiliser spraying
» All of these devices use sensors and cameras to go around obstacles, or they can even be programmed to 'go to sleep' if the weather turns bad.

Medicine

» Robots are used in surgical procedures, which makes the operation safer and also makes the procedures quicker and less costly

» Robots can be used from monitoring patients to doing actual minor surgery

» The disinfecting of rooms and operating theatres can all be done by autonomous robots (similar to the types described in agriculture)

» robots can take blood samples from patients:– less painful to patients since the robot is better at determining a 'good vein'– safer to doctors and nurses if the patient has an infectious disease– doctors and nurses can be freed up to do more skilled work

» Microbots can be used in target therapy:– these use microscopic mechanical components (including microprocessor) to localise a drug or other therapy to target a specific site causing less damage to surrounding tissue

» Prosthetic limbs are now mini robots in their own right (since they meet the three characterisations of what defines a robot)– bionic skins and neural implants that interface with the human nervous system (of the damaged limb) giving feedback to allow for better control of the prosthetic limb

Domestic robots

Robots used around the house vary from devices to carry out household chores through to devices used to entertain people. For example:

» Autonomous vacuum cleaners: – these use proximity sensors and cameras to avoid bumping into obstacles and allows them to cover a whole room automatically.

– these robots have a microprocessor to control the overall operation of the device; this also allows the user to program the device
– actuators are used to control motors which allow movement forward/ backward and from side to side

» Autonomous grass cutters (mowers)
:– these use the same type of sensor, camera, microprocessor and actuator set up as vacuum cleaners

» Personal assistants (such as 'Vector')
– this is a robot controlled by a micro-processor that also uses cloud connectivity to connect to the internet
– it understands voice commands (using a microphone) and will answer any questions it is asked
– it also makes use of an HD camera, utilising computer vision, allowing it to recognise somebody's face as well as navigate a room (using proximity sensors and actuators) to steer around objects in its way.

Robots used in entertainment

The use of robots in the entertainment industry is increasing.

They are now found in areas such as:

» Entertainment parks and arenas/venues

» The film and TV industry. The following examples indicate where robots are being used in the world of entertainment. The reader is advised to research the ever-increasing number of examples.

» Theme parks are now using autonomous robots to entertain visitors to the park; these robots (often dressed as cartoon characters) can interact with visitors to allow them to engage safely with the theme park attractions and make the whole experience 'more realistic'

» Music festivals are much more immersive for the audience; robotic methods are used to control lighting (including laser displays), visual effects and animation, the visual performances can be fully synchronised with the music

» Use of robots to control cameras; for example, keeping them steady and auto focusing when moving around a scene; the movie Gravity used many robots to operate cameras, props and the actors

» Humanoid robots (either remote-controlled or pre-programmed) can perform 'stunt' action in movies/ television by performing tasks impossible for a human to do; they use CGI (computer-generated imagery) and image capture techniques to generate special effects

» Robots are capable of producing special effects with a precision, speed and coordination which is beyond human capabilities; actions and special effects can be synchronised to within a millisecond and produce fully coordinated/ synchronised sound effects

6.3 Artificial intelligence (AI)

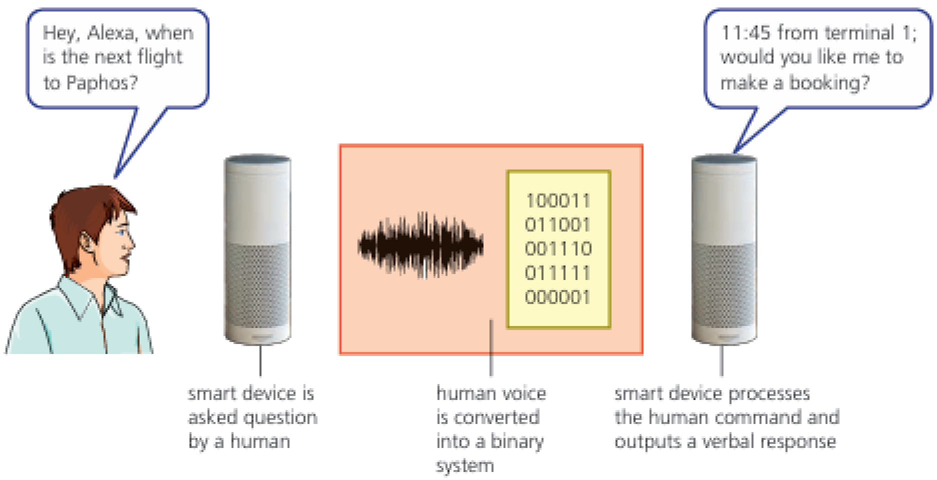
6.3.1 Introduction

Artificial intelligence (AI) is a branch of computer science dealing with the simulation of intelligent human behaviour by a computer. This is often referred to as the **cognitive** functions of the human brain (that is, the mental process of acquiring knowledge and understanding through thought, experience and the five senses).

6.3.2 Characteristics of AI

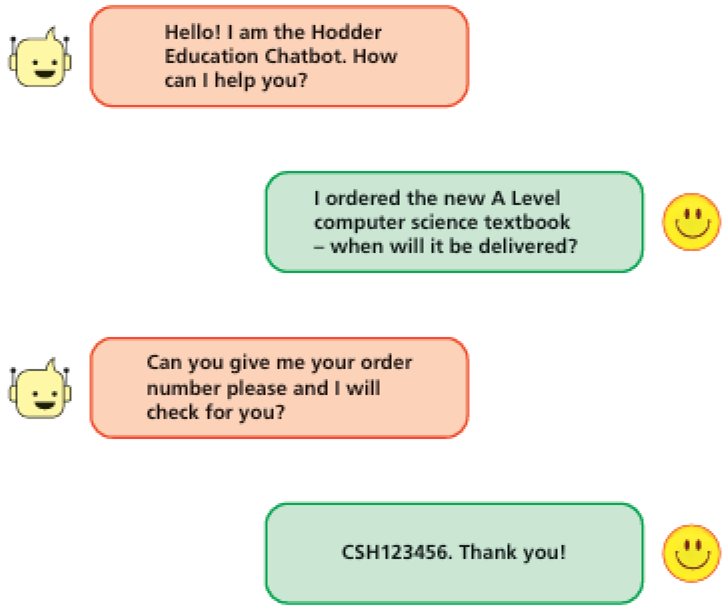
Essentially, AI is really just a collection of rules and data, and the ability to reason, learn and adapt to external stimuli. AI can be split into three categories:

» Narrow AI – this occurs when a machine has superior performance to a human when doing one specific task
» General AI – this occurs when a machine is similar (not superior) in its performance to a human doing a specific task
» Strong AI – this occurs when a machine has superior performance to a human in many tasks.



▲ **Figure 6.21** Smart home devices

» Use of **chatbots** that interact through instant messaging, artificially replicating patterns of human interactions using AI to respond to typed or voice messages; when a question is asked, the chatbot responds using the information known at the time:



▲ **Figure 6.22** Chatbots

6.3.3 AI systems

This section considers two types of AI system:

» Expert system – a computer system that mimics the decision-making ability of a human; expert systems use AI to simulate the judgement and behaviour of a human or organisation that has expert knowledge and experience

» Machine learning – this is the science of training computers with sample data so that they can go on to make predictions about new unseen data, without the need to specifically program them for the new data.

Expert systems

Expert systems are a form of AI that has been developed to mimic human knowledge and experiences. They use knowledge and inference to solve problems or answer questions that would normally require a human expert.

Expert systems have many advantages:

» They offer a high level of expertise

» They offer high accuracy

» The results are consistent » they have the ability to store vast amounts of ideas and facts

» They can make traceable logical solutions and diagnostics

» It is possible for an expert system to have multiple expertise

» They have very fast response times (much quicker than a human expert)

» They provide unbiased reporting and analysis of the facts

» They indicate the probability of any suggested solution being correct.

Expert systems also have disadvantages:

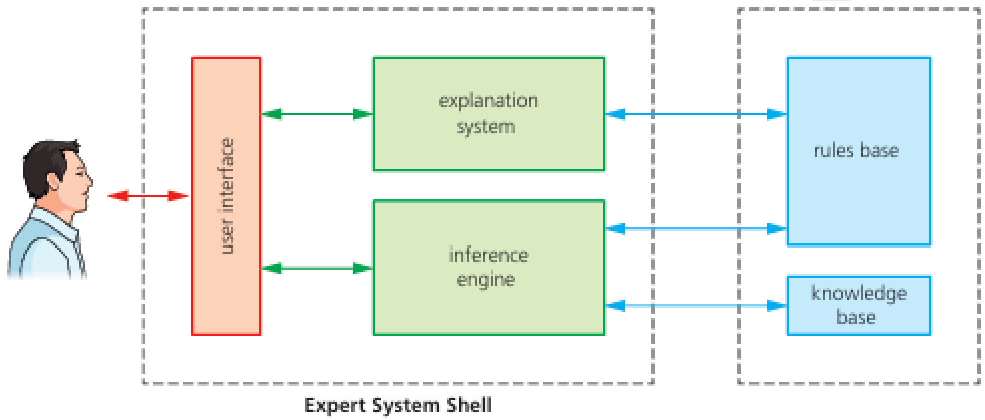
» Users of the expert system need considerable training in its use to ensure the system is being used correctly

» The set up and maintenance costs are very high

» They tend to give very 'cold' responses that may not be appropriate in certain medical situations

» They are only as good as the information/facts entered into the system

» Users sometimes make the very dangerous assumption that they are infallible.



▲ **Figure 6.23** Expert system structure

User interface

» Method by which the expert system interacts with a user
» Interaction can be through dialogue boxes, command prompts or other input methods
» The questions being asked usually only have Yes/No answers and are based on the responses to previous questions.

Inference engine

» This is the main processing element of the expert system
» The **inference engine** acts like a search engine examining the **knowledge base** for information/data that matches the queries
» It is responsible for gathering information from the user by asking a series of questions and applying responses where necessary; each question being asked is based on the previous responses
» The inference engine is the problem-solving part of the expert system that makes use of **inference rules** in the **rules base**
» Since the knowledge base is a collection of **objects** and **attributes**, the inference engine attempts to use information gathered from the user to find an object that matches (making use of the rules base to find a match)

Knowledge base

» The knowledge base is a repository of facts
» It stores all the knowledge about an area of expertise obtained from a number of expert resources
» it is basically a collection of objects and their attributes;

Object	Attribute 1	Attribute 2	Attribute 3	Attribute 4	Attribute 5	Attribute 6
dog	mammal	can be a pet	lives on land	makes bark sounds	body is covered in fur	walks on 4 legs
whale	mammal	not a pet	lives in water	makes sonic sound	body covered in skin	swims; no legs
duck	bird	not a pet	lives in water	makes quack sounds	body covered in feathers	swims; has two legs

- so if we had a series of questions:
  - is it a mammal? YES
  - can it be a pet? NO
  - does it live in water? YES
  - does it make sonic sounds? YES
  - is its body covered in skin? YES
  - does it have any legs? NO

  conclusion: it is a WHALE.

Rules base

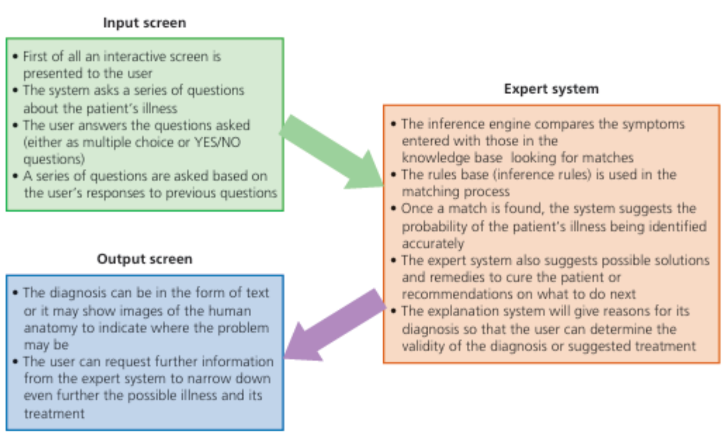
- the rules base is a set of inference rules
- inference rules are used by the inference engine to draw conclusions (the methods used closely follow human reasoning)
- they follow logical thinking like the example above; usually involving a series of 'IF' statements, for example:

IF continent = "South America" AND language = "Portuguese" THEN country = "Brazil"

Setting up an expert system

- information needs to be gathered from human experts or from written sources such as textbooks, research papers or the internet
- information gathered is used to populate the knowledge base that needs to be first created
- a rules base needs to be created; this is made up of a series of inference rules so that the inference engine can draw conclusions
- the inference engine itself needs to be set up; it is a complex system since it is the main processing element making reasoned conclusions from data in the knowledge base
- the user interface needs to be developed to allow the user and the expert system to communicate
- once the system is set up, it needs to be fully tested; this is done by running the system with known outcomes so that results can be compared and any changes to the expert system made.

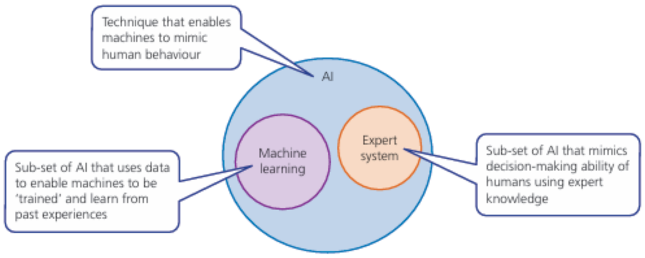
Example use of an expert system (medical diagnosis)



▲ **Figure 6.24** Use of an expert system

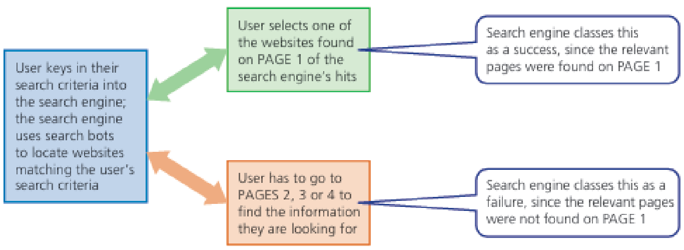
Machine learning

Recall the AI 'family' as shown in Figure 6.25.



▲ **Figure 6.25** AI family

Machine learning is a sub-set of artificial intelligence (AI), in which algorithms are 'trained' and learn from their past experiences and examples. It is possible for the system to make predictions or even take decisions based on previous scenarios. They can offer fast and accurate outcomes due to very powerful processing capability.



▲ **Figure 6.26** Search engine success or failure

Differences between AI and machine learning

▼ **Table 6.5** Difference between AI and machine learning

AI	Machine learning
represents simulated intelligence in machines	this is the practice of getting machines to make decisions without being programmed to do so
the aim is to build machines that are capable of thinking like humans	the aim is to make machines that learn through data acquisition, so that they can solve new problems

Key terms used throughout this chapter

automated system – a combination of software and hardware designed and programmed to work automatically without the need for any human intervention

distributed control system (DCS) – a powerful computer system programmed to monitor and control a complex process without the need for human interaction

adaptive cruise control – the use of sensors, actuators and microprocessors to ensure that a vehicle keeps a safe distance behind another vehicle

accelerometer – a sensor that measures acceleration and deceleration and that can detect, for example, the orientation of a device

robotics – the branch of (computer) science that encompasses the design, construction and operation of robots

robot – a mechanical device that can carry out tasks normally done by humans

autonomous – able to operate independently without any human input

controller – a microprocessor that is in control of a process

WebCrawler/search bot – a software robot that roams the internet scanning websites and categorising them; often used by search engines

chatbots – a pop-up robot on a website that appears to enter into a meaningful conversation with a web user

end-effector – an attachment to a robot arm that allows it to carry out a specific task, such as spray painting

LiDaR – a contraction of light detection and ranging; the use of lasers to build up a 3D image of the surroundings

drone – a flying robot that can be autonomous or operated using remote control; a drone can be used for reconnaissance or deliveries

phenotyping – the process of observing the physical characteristics of a plant to assess its health and growth

cognitive – relating to the mental processes of the human brain involved in acquiring knowledge and understanding through thought, experiences and input from the five senses

artificial intelligence (AI) – a collection of rules and data which gives a computer system the ability to reason, learn and adapt to external stimuli

expert system – a form of AI that has been developed to mimic a human's knowledge and expertise

explanation system – part of an expert system which informs the user of the reasoning behind its conclusions and recommendations

inference engine – a kind of search engine used in an expert system which examines the knowledge base for information that matches the queries

inference rules – rules used by the inference engine and in expert systems to draw conclusions using IF statements

knowledge base – a repository of facts which is a collection of objects and attributes

object – an item stored in the knowledge base

attribute – something that defines the objects stored in a knowledge base

rules base – a collection of inference rules used to draw conclusions

machine learning – a sub-set of AI in which algorithms are trained and learn from past experiences and examples

web scraping – a method of obtaining data from websites

Revision questions

1. Nov/2021/Paper_11/No.6
A washing machine uses sensors and a microprocessor to control the washing cycle of clothes.
(a) A sensor is used in each of the given tasks.
Identify one suitable sensor that would be used for each task.
Each sensor given must be different.

Task	Sensor
checking the water is 30 °C	
checking the water acidity level after detergent is added	
checking the weight of the clothes to make sure that the machine is **not** overloaded	

[3]

(b) Describe how the sensor and the microprocessor are used to make sure the water remains at 30°C.

2. Nov/2021/Paper_12/No.8
An electronic game has three square mats that are coloured red, green and blue.
The player will see a colour displayed on a screen and has 1 second to hit the mat that matches the colour. If the player hits the correct mat, within 1 second, a counter is incremented. When a player hits an incorrect mat, the game ends.

The game uses sensors and a microprocessor to determine if the player hits the correct mat within 1 second.
Explain how the game uses sensors and a microprocessor to count the number of times a player hits a correct mat within 1 second.

3. Nov/2021/Paper_13/No.2d
A sports stadium has an electronic counter that counts each person that enters the stadium.
The count is stored as binary in a 16-bit register.
A denary value of the count is displayed on a screen at the entrance.
(a) The screen currently displays:

0	0	7	1

Give the binary value that is stored in the register to display the count shown.

(b) More people enter the sports stadium and the screen now displays:

0	2	5	7

Give the binary value that is stored in the register to display the count shown.

(c) After everyone has entered the stadium, the register stores the binary value:

0000001000000100

Show what the screen will display when this binary value is stored.

(d) Sensors are used at the entrance to count the number of people entering the stadium.
(i) Identify two sensors that could be used to count the number of people entering the stadium.
(ii) Tick (✓) one box to show if a sensor is an example of an input device, storage device or output device.

Device	Tick (✓)
input	
storage	
output	

4. June/2021/Paper_11/No.5
Jamelia has a greenhouse that she uses to grow fruit and vegetables. She needs to make sure the temperature in the greenhouse stays between 25°C and 30°C (inclusive).
A system that has a temperature sensor and a microprocessor is used to maintain the temperature in the greenhouse. The system will:

- open a window and turn a heater off if it gets too hot
- close a window and turn a heater on if it gets too cold.

Describe how the system uses the temperature sensor and the microprocessor to maintain the temperature in the

5. June/2021/Paper_12/No.5
A security light system is used by a factory. The light only comes on when it is dark and when movement is detected. The light will stay on for 1 minute before switching off.
Sensors and a microprocessor are used to control the security light system.

(a) Identify two sensors that would be used in the security light system.
(b) Describe how the sensors and the microprocessor control the security light system.

6. June/2021/Paper_13/No.9
An underground car park has a system that checks the height of vehicles. A vehicle can be no higher than 1.8 metres to enter the car park.
The system also counts the number of vehicles that have entered the car park, so that it can display how many parking spaces are still available.
Each parking space has a red and a green light above it. If a car is parked in the parking space only the red light is on, otherwise only the green light is on.
Sensors and a microprocessor are used to control the system.

(a) Complete the table to identify a suitable sensor for each part of the system.

Task	Sensor
check if a vehicle is too high	
count the vehicles entering the car park	
check if a vehicle is parked in a parking space	

(b) Describe how the sensor and the microprocessor are used to display the red or green light above the parking space.

7. Nov/2020/Paper_13/No.11
A theme park has a game where a player tries to run from the start to the finish without getting wet.
The system for the game uses sensors and a microprocessor to spray water at a player as they run past each sensor.
Describe how the sensors and the microprocessor are used in this system.

8. Mar/2020/Paper_12/No.7
A room has an automatic lighting system. Electric lights are automatically turned on when a person enters the room and the natural light level in the room is 10 or less.
Explain how sensors and a microprocessor are used to control the electric lights in the room.

9. June/2020/Paper_11/No.6 Four scenarios are given.
Identify the most suitable sensor for each scenario.
A different sensor must be used for each scenario.

Sensor	Scenario
	Detecting when a person is approaching an automatic door system
	Monitoring the pollution level in a river
	Checking if a tropical aquarium is 25 degrees Celsius
	Counting the number of cars that cross a bridge