

Automated and emerging technologies

IGCSE Computer Science

Automated systems

An **automated system** 自动化系统 is a mix of software and hardware that senses and responds to data in its **environment** 环境, with no need for **human intervention** 人工干预. In other words, it works on its own.

Examples of automated systems:

- a central heating 中央供暖 system;
- a chemical process 化学过程 in a factory;
- a **greenhouse** 温室 (for growing plants);
- a **car park barrier** 停车场道闸.

Sensors, microprocessors and actuators

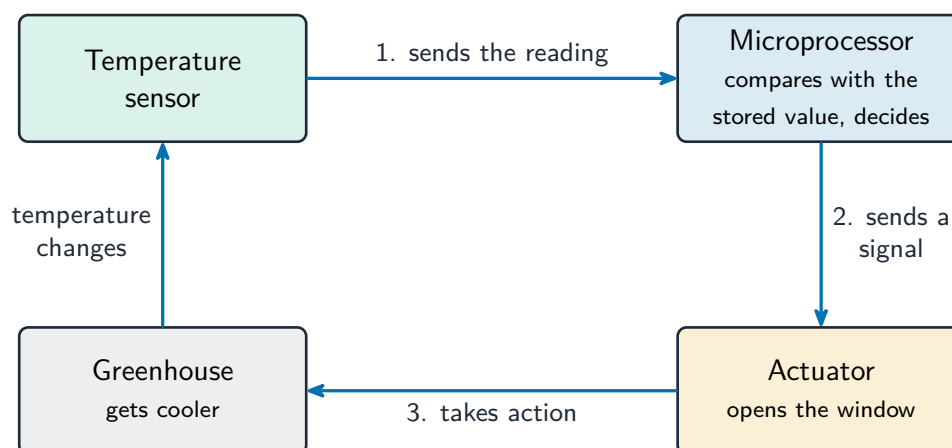
Three parts work together in an automated system.

Part	Job
sensor 传感器	measures a physical quantity (such as temperature or light) and sends the data
microprocessor 微处理器	compares the data with stored values and makes decisions
actuator 执行器	receives a signal and causes movement or action (such as opening a valve)

The cycle works like this:

1. The sensor sends data to the microprocessor.
2. The microprocessor compares this data with **stored values** 存储值 and makes a decision.
3. The microprocessor sends signals to the actuators to take action.

For example, in a greenhouse: a temperature sensor reads the heat; the microprocessor compares it with the wanted value; if it is too hot, the microprocessor signals an actuator to open a window.



A sensor feeds the microprocessor, which compares the reading with a stored value and signals an actuator; the loop then repeats

The syllabus names many **sensor types** 传感器类型, each reading one physical quantity –for example an **accelerometer** 加速度计 (movement or tilt), a **humidity** 湿度 sensor (water in the air), and a **proximity** 接近 sensor (a nearby object):

Sensor	Measures	Typical use
temperature	heat	ovens, greenhouses, heating
light	brightness	automatic lights, cameras
pressure	force on a surface	alarm floor mats, touchscreens
infra-red / proximity	a nearby object	automatic doors, parking sensors
acoustic (sound)	sound level	noise monitors
humidity / moisture	water in air or soil	greenhouses, irrigation
gas	a gas being present	smoke and CO alarms
pH	acidity	pools, fish tanks
accelerometer	movement or tilt	phones, airbag triggers
magnetic field	magnetism	door contacts, compasses
flow / level	fluid flow or depth	pipes, tanks

To pick a sensor for a scenario, choose the one that reads the **right physical quantity**: a fish tank needs pH and temperature sensors; an automatic door needs an infra-red / proximity sensor.

Advantages and disadvantages

Automated systems are used in many situations, such as industry, transport, agriculture 农业 (farming), weather (gathering data), gaming and lighting.

advantages	disadvantages
✓ work 24/7, no breaks	✗ high setup cost
✓ consistent, fewer mistakes	✗ jobs may be lost
✓ safe in dangerous places	✗ cannot handle the unexpected
✓ lower running costs over time	✗ needs maintenance and power

The advantages and disadvantages of automated systems



A camera drone: it can fly itself along a set route to collect data

Image: Josh Sorenson, CC0 (commons.wikimedia.org)

Advantages	Disadvantages
work all day and night, without rest	cost a lot to buy and set up
faster and more consistent 一致的 than people	can break down and need expert repair
can work in places unsafe for people	may replace people's jobs
fewer human mistakes	cannot easily react to a situation they were not built for

Worked example. Describe how an automatic greenhouse holds the temperature at 25 °C. A **temperature sensor** continuously measures the temperature and sends its reading, converted to digital by an ADC, to the **microprocessor**. The microprocessor **compares** the reading with the stored value of 25 °C. If the temperature is above it, the microprocessor signals an **actuator** to open a window or switch on a fan; if it is below, it switches on a heater. The whole loop then **repeats continuously**. Two marks nearly always sit on the words "compares with a stored (pre-set) value" and "the process repeats" - a description that stops at "the sensor tells the computer" leaves them behind.

Robotics

Robotics 机器人技术 is the branch of technology that deals with the design, building and operation of **robots** 机器人.

A robot has these characteristics:

- a **physical structure** 物理结构 (a mechanical 机械的 body, such as arms);
- **electrical components** 电子元件 (motors, sensors and wiring);
- **programmable instructions** 可编程指令—it follows a program that can be changed.

What robots do

Robots can perform many roles, for example:

- **factory equipment** 工厂设备—building cars, welding, moving heavy parts;
- **domestic appliances** 家用电器—such as a robotic **vacuum cleaner** 吸尘器.



An industrial robot arm. It follows a program and can be reprogrammed to do a new job.

Image: , CC BY-SA 4.0 (commons.wikimedia.org)



A robot vacuum cleaner: a home robot that drives itself around to clean the floor

Image: Popey900, Copyrighted free use (commons.wikimedia.org)

Advantages	Disadvantages
do dull or dangerous jobs	expensive to buy and maintain
work quickly and accurately	can replace human workers
do not get tired or bored	a robot has a lack of independent decision-making 缺乏独立决策—it only does what it is programmed to do

A key limit of a robot is that it cannot think for itself. It cannot make its own choices when something unexpected happens.

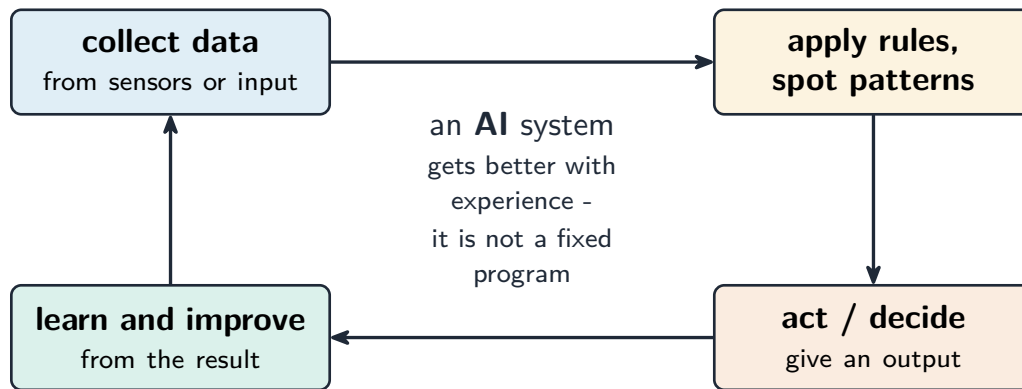
Artificial intelligence

Artificial intelligence 人工智能 (AI) is the **simulation** 模拟 of human intelligence by computer systems. This means a computer doing tasks that normally need human thinking.

Characteristics of AI

AI systems usually have these features:

- they **collect data** and the **rules** 规则 for using that data;
- they have the ability to **reason** 推理 (work things out using the rules);
- they have the ability to **draw conclusions** 得出结论, which may be **approximate** 近似的 (a best guess) or **definite** 确定的 (certain);
- they have the ability to **learn** 学习 from data;
- they have the ability to **adapt** 适应—to change their behaviour as they get new data.



An AI system collects data, applies rules, acts, then learns and improves

Examples of AI

- **expert systems** 专家系统—software that gives advice like a human expert (for example, helping a doctor with a diagnosis);
- **natural language processing** 自然语言处理—understanding human speech or text;
- **self-driving cars** 自动驾驶汽车.



A self-driving car: sensors on the car let a computer steer it with no driver

Image: 9yz, CC BY 4.0 (commons.wikimedia.org)

Inside an expert system

An **expert system** stores human expertise and reasons from it. It has four parts:

- a **knowledge base** 知识库—the stored facts about the subject;
- a **rule base** 规则库—the "if...then..." rules a human expert would apply;

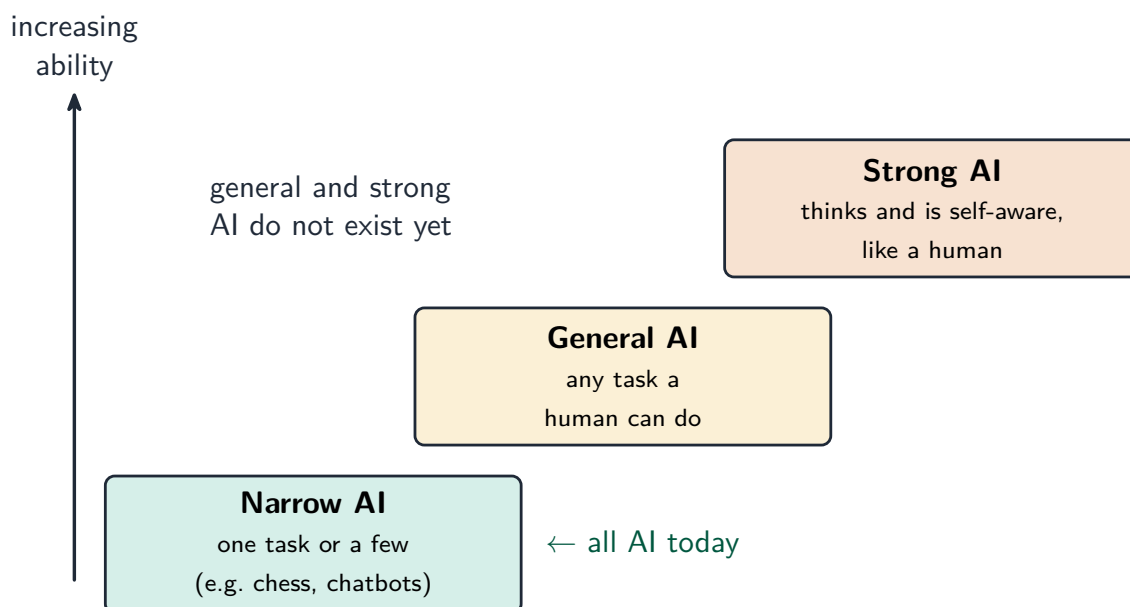
- an **inference engine** 推理引擎—applies the rules to the facts to reach a conclusion;
- a **user interface** 用户界面—asks the user questions and shows the result.

The interface collects facts from the user; the inference engine runs the rule base against the knowledge base; and the system outputs a diagnosis or a probability—as used to help a doctor diagnose an illness or to find a car fault.

Machine learning

Machine learning 机器学习 is a program that improves its own performance from **experience**, without being explicitly reprogrammed. It finds patterns in data and adapts: a search engine gets better at ranking results, a voice assistant recognises spoken commands more accurately, and a robot vacuum gradually learns the layout of a room.

Narrow, general and strong AI



Narrow AI does one task (all AI today); general AI could do any human task; strong AI would be self-aware —neither exists yet

Type	What it means
narrow AI 弱人工智能	can do only one task or a small set of tasks (for example, a chess program). All AI today is narrow AI.
general AI 通用人工智能	could do any task a human can do, switching between many different tasks.
strong AI 强人工智能	would think and be aware like a real human mind. This does not exist yet.

Exam tips

- Learn the control loop: a **sensor** measures a quantity → the **microprocessor** compares it with a stored value → an **actuator** takes action; then the loop repeats.
- Do not confuse the parts: a **sensor** sends data *in*; an **actuator** causes movement *out*.

- A robot follows **programmable instructions** and cannot make its own decisions when something unexpected happens.
- **AI** simulates human thinking: it collects data and rules, reasons, draws conclusions, and can learn and adapt.
- Know the AI levels: **narrow** (one task; all AI today), **general** (any human task), **strong** (self-aware; does not exist yet).