CAIE Computer Science IGCSE

6 - Automated and emerging technologies

Advanced Notes

6.1 Automated systems

An automated system is a technology-driven mechanism designed to perform tasks with minimal or no human intervention.

Automated systems usually comprise three distinct components: sensors, microprocessors and actuators.

Sensors

Sensors are devices that detect physical inputs from the environment (e.g. temperature, light, motion and pressure) and convert them into electrical signals. Different types of sensors are described in the notes for Topic 3.2: Input and output devices.

Microprocessors

Microprocessors are small computers or processors embedded within a system that receive data from sensors, process that data, and make decisions based on programmed instructions.

Actuators

Actuators are devices that take action based on commands from the microprocessor to physically change something in the system. Different types of actuators are described in the notes for Topic 3.2: Input and output devices.

Automated systems in context

There are several areas where automated systems can be used, each of which has several advantages and disadvantages.

Industry (e.g. robotic assembly lines)

Advantages	Disadvantages
Increased efficiency and speed of production	High initial setup and maintenance costs
Improved accuracy and consistency	Potential job losses due to reduced need for manual human labour
Ability to work continuously without fatigue	System failures can halt production entirely
Can operate in hazardous environments, improving worker safety	Require the hiring of highly skilled workers to maintain and service them

Transport (e.g. automated trains, driverless cars)

Advantages	Disadvantages
Increased safety by reducing human error	High development and infrastructure costs
Optimised traffic flow and reduced congestion	Complex technology can fail or be hacked
Better fuel efficiency and environmental benefits if people choose to use cheaper, automated public transport	Ethical and legal challenges around decision-making in emergencies - who is held responsible: the developer, manufacturer or owner?

Agriculture (e.g. automated irrigation, crop monitoring)

Advantages	Disadvantages
Precise watering and fertilising reduce waste and costs	Expensive to install and maintain equipment
Ability to monitor crops constantly for disease or growth	Dependency on technology may reduce traditional farming skills
Reduced labour requirements in harsh environments	Sensors and systems can fail due to weather or damage

Weather (e.g. automated weather stations)

Advantages	Disadvantages
Continuous data collection improves weather forecasting accuracy	Equipment can be damaged by extreme weather
Can operate in remote or dangerous locations	Initial costs and regular calibration required
Quick data processing and reporting	Reliance on technology means system outages can disrupt data flow

Gaming (e.g. AI opponents, automated testing)

Advantages	Disadvantages
Provides challenging and adaptive gameplay experiences	AI may not always behave realistically or fairly
Can automate game testing to find bugs quickly	Can reduce social interaction if overused
Allows for real-time interaction without human opponents, benefiting players with bad/no internet connection	Complex AI development is costly and time-consuming

Lighting (e.g. automated street lighting)

Advantages	Disadvantages
Energy savings by switching lights on/off based on presence or daylight	Sensors may fail or be triggered falsely
Improved safety with better lighting control	Initial installation costs can be high
Reduced maintenance with automated monitoring	System faults may lead to lights being off at wrong times

Science (e.g. automated lab equipment, telescopes)

Advantages	Disadvantages
High precision and repeatability in experiments	Equipment can be expensive and complex to maintain
Reduces human error in data collection	Over-reliance on automation can reduce hands-on skills
	Technical failures can disrupt experiments or data accuracy

6.2 Robotics

Robotics is a branch of computer science that incorporates the design, construction and operation of robots. Examples include factory equipment, domestic robots, and drones.

Characteristics of robots

A robot has a **mechanical structure or framework** which forms its physical body. This structure is usually made from materials like metal or plastic and provides the shape and support needed for the robot to function. Depending on its purpose, a robot's framework might include arms, legs, wheels, or a chassis, allowing it to move and interact with its environment.

Inside the robot are **electrical components** that enable it to sense, process, and act. Sensors detect changes in the environment such as light, temperature, or distance and send this information to the robot's microprocessor. The microprocessor acts like the robot's brain, processing the sensor data and making decisions. Actuators, such as motors or servos, then carry out these decisions by moving parts of the robot or performing specific actions.

Robots are also **programmable**, meaning their behavior is controlled by software instructions. Programming allows a robot to carry out tasks automatically, respond to sensor inputs, or follow a set sequence of actions. This programmability makes robots flexible because their tasks and behavior can be changed or improved simply by updating the software without needing to alter the physical hardware.

Advantages and disadvantages of using robots

Advantages	Disadvantages
Can work continuously without fatigue	High initial cost to buy and install
Perform tasks with high precision and accuracy	Can cause job losses for human workers
Can operate in dangerous or hazardous environments	Require regular maintenance and repairs
Increase productivity and efficiency	Complex systems can fail and halt operations
Can perform repetitive or boring tasks	Lack human judgment and creativity
Improve safety by reducing human exposure to risks	Programming errors can cause accidents

Areas of usage

Robots can be used in many different areas including:

- **Industry** - for example, robots are used in assembly lines for welding, painting, and packaging products.
- **Transport** - for example, driverless cars, automated guided vehicles (AGVs) in warehouses, and drones for delivery.
- **Agriculture** - for example, to undertake tasks like planting, harvesting, weeding, and crop monitoring.
- **Medicine** - for example, surgical robots assisting with precise operations and robots delivering medication in hospitals.
- **Domestic settings** - for example, robotic vacuum cleaners, lawn mowers, and window cleaning robots. Robots are helpful in these scenarios as they alleviate the responsibility of repetitive jobs and their impacts on peoples' time.
- **Entertainment** - for example, robotic toys, animatronics in theme parks, and robots used in movies for special effects.

6.3 Artificial intelligence

Artificial Intelligence (AI) is a branch of computer science dealing with the simulation of intelligent behaviours by computers.

Characteristics of AI

Here are three of the main characteristics of AI:

Collection of data and rules for using that data
AI systems rely on gathering large amounts of data, which serves as the foundation for making decisions or predictions. Along with data, AI uses predefined rules or algorithms to process this data in meaningful ways, allowing the system to interpret inputs and produce outputs.

Ability to reason
AI can simulate human-like reasoning by analyzing data, identifying patterns, and drawing logical conclusions. This reasoning capability enables AI to solve problems, make decisions, and carry out complex tasks without explicit instructions for every possible situation.

Ability to learn and adapt
Some AI systems can improve their performance over time by learning from new data and experiences. This means they can adapt to changing environments or requirements, becoming more accurate or efficient without human intervention, often through techniques like machine learning.

Basic operation and components of AI systems to simulate intelligent behaviour

Expert Systems

- Expert systems are AI programs designed to mimic human expert decision-making in specific domains.
- They consist of a **knowledge base**, which stores facts and information about the problem area.
- A **rule base** contains a set of “if-then” rules derived from expert knowledge, which guides the decision-making process.
- The **inference engine** applies the rules to the knowledge base to draw conclusions or make decisions. It simulates reasoning by logically combining rules and facts.
- An **interface** allows users to interact with the system by inputting data and receiving advice or decisions.

Machine Learning

- Machine learning is a type of AI where programs automatically improve their performance by learning from data.
- Instead of following fixed rules, machine learning algorithms adapt their internal processes based on patterns in data they receive.
- This ability to **automatically adapt** enables the system to handle new or changing data without needing to be explicitly reprogrammed.
- Examples include image recognition, recommendation systems, and language translation.