Automated and Emerging Technologies

How automated systems work, what makes something a robot, and how artificial intelligence, expert systems and machine learning simulate intelligent behaviour.

6.1 Automated systems

Automated Systems

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. This is how they work:

1. **Sensors** are input devices that take readings from their surroundings and send this data to a microprocessor or computer.
2. If the data is analogue, it is first converted into a digital format by an **analogue-digital converter (ADC)**.
3. The **microprocessor** will process the data and take the necessary action based on programming. This will involve some form of output, usually involving signals sent to **actuators** to control motors, wheels, solenoids, and so on.

Advantages and Disadvantages Common in all Scenarios

Advantages

- Automated systems perform tasks faster and more consistently than humans, leading to higher productivity and efficiency.
- Automation reduces the chances of human error, ensuring more accurate and precise results.
- While the initial setup can be expensive, automation reduces long-term operational costs by minimizing the need for human labour and reducing errors.
- Automated systems can operate continuously without breaks, increasing output and availability.
- Automation can handle hazardous tasks, reducing the risk of injury to human workers.
- Automated systems can be easily scaled up or down to meet demand without significant changes to infrastructure or workforce.

Disadvantages

- The setup and installation of automated systems can be very expensive, requiring significant investment in technology and infrastructure.

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- Automation can lead to job losses as machines replace human workers in various tasks.
- Automated systems require regular maintenance and can be prone to technical issues, leading to downtime and repair costs.
- Automated systems are designed for specific tasks and can struggle with tasks that require human creativity and adaptability.
- Over-reliance on automated systems can lead to vulnerabilities if the technology fails or is compromised.
- Employees need to be trained to work with automated systems, and there can be a skills gap if the workforce is not adequately prepared.

6.2 Robotics

Robotics

Robotics is a field that involves the design, construction, operation, and use of robots, which are programmable machines that can carry out a series of actions autonomously or semi-autonomously. Robots are used in various sectors such as military, industrial, healthcare, etc. For instance, in the military sector, bomb disposal robots are used so that human lives are not put at risk.

There are **three main characteristics** of a robot:

- **Mechanical structure:** The physical structure or body of the robot, which gives it form and enables it to interact with the environment. It can consist of the main body, which supports all other components, joints, which allow movement and flexibility, and end effectors, which are tools or devices at the end of a robotic arm, such as grippers, drills, or welding torches. For example, in a robotic arm, the mechanical structure includes the arm segments, joints, and gripper.
- **Electrical components:** The electrical systems that power the robot and enable it to sense its environment and perform actions. This includes sensors, actuators and microprocessors.
  - **Sensors** are devices that detect changes in the environment and send this information to the control system, for example, cameras and ultrasonic sensors (distance measurement).
  - **Microprocessors** are the 'brain' of the robot, which processes information from sensors and makes decisions.
  - **Actuators** are devices that convert electrical signals into physical movement. Examples include motors and servos.
  - *Example:* In a robotic vacuum cleaner, sensors detect obstacles, the microprocessor processes this data, and actuators adjust the movement accordingly.
- **Programmable:** The ability of a robot to be programmed to perform a variety of tasks based on instructions or software. For example, a programmable robot can be coded to follow a specific path, respond to voice commands, or sort objects based on colour.

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Advantages and Disadvantages Common in all Roles

Advantages of robots

- Robots can work faster and more consistently than humans, increasing output and reducing production time.
- Robots can perform tasks with high accuracy, leading to fewer errors and higher quality products.
- Robots can take over dangerous tasks, reducing the risk of injury to human workers.
- Robots do not get bored or tired and can work 24/7, making them ideal for repetitive tasks that may be monotonous for human workers.
- Robots can operate in extreme conditions, such as high temperatures, toxic atmospheres, or areas with high radiation levels, where it would be unsafe for humans.

Disadvantages

- The cost of purchasing and installing robots can be very high, which may be a barrier for small businesses.
- Robots require regular maintenance and can be expensive to repair if they break down.
- The use of robots can lead to job losses for workers who perform tasks that robots can take over.
- Robots can follow programmed instructions but lack the ability to think creatively or make intuitive decisions.
- The operation of robots requires workers with specialized skills in programming and maintenance, which may necessitate additional training.

6.3 Artificial intelligence

Artificial Intelligence

Artificial intelligence (AI) is a branch of computer science dealing with the simulation of intelligent human behaviour by a computer.

AI has 4 main **characteristics**, which are:

1. **Collection of data**
    - AI systems gather data from various sources, such as sensors, databases, and online sources.
    - AI often relies on large datasets, commonly referred to as "big data," to identify patterns, trends, and insights that are not immediately apparent in smaller datasets.
    - Once collected, data needs to be processed and organized so that the AI can use it effectively.
2. **Rules for using data**
    - AI uses algorithms, which are sets of rules or instructions, to process and analyze data.

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- AI systems apply logical rules to the data to draw conclusions and make decisions. This involves using if-then statements, probabilistic reasoning, and other logical frameworks to evaluate information.

3. **Ability to reason**

   - AI systems can infer new information from the data they have, using logical reasoning and pattern recognition.
   - AI can solve complex problems by breaking them down into smaller, manageable parts and systematically working through them using algorithms and logical rules.
   - AI can weigh various factors and make decisions based on the data and rules it has.

4. **Ability to learn and adapt**

   - AI systems can learn from data through machine learning techniques.
   - AI can adapt to new information and changing environments.
   - AI systems can continuously improve by learning from their experiences and refining their algorithms.

Expert Systems

Expert systems are AI programs that simulate the decision-making abilities of a human expert. They are used in various fields such as medical diagnosis, financial planning, and technical support. These are its characteristics:

- It has an **interface** used to input data and view output.
- It has a **knowledge base**, which is a collection of facts and rules about a specific domain.
- It has a **rule base**, which is a set of conditional statements (if-then rules) that define the logic of decision-making.
- It has an **inference engine**, which is the component that applies logical rules to the knowledge base to deduce new information or make decisions.

Machine Learning

Machine learning employs learning algorithms and training data to develop models that adapt and improve over time, allowing AI systems to learn from experience and make predictions. These are the characteristics of ML:

- It is a form of artificial intelligence, which means it can adapt its own processes.
- It can edit its own data.
- It can be trained. This can be supervised or unsupervised, meaning it can learn with or without human interaction.

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- **Supervised** means a user tells the system the input and output.
- **Unsupervised** means the system is given the input and needs to work out the output.
- Analyses patterns and stores successful/unsuccessful results to use to make decisions in the future.

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