Session 12 - Robots and Robotics

What are robots?

Robots are **programmable and smart machines** that are designed to carry out a range of tasks, often complex in nature.

They mostly contain multiple systems (mechanical, electrical, electronic, software) working in harmony, and mostly equipped with sensors to perceive its environment and actuators to perform actions.

Robots have a wide range of applications across different fields, from manufacturing to space exploration.

- Manufacturing: Robots are commonly used in manufacturing processes to assemble, package, and transport products.

- Healthcare: Robots can be used to assist with surgery, monitor vital signs, and provide physical therapy.

- Agriculture: Robots can be used for tasks such as planting, harvesting, and monitoring crops.

- Space Exploration: Robots are used in space exploration to gather data, perform experiments, and conduct repairs.

- Military: Robots are used by the military for tasks such as bomb disposal, reconnaissance, and surveillance.

- Construction: Robots can be used in construction for tasks such as demolition and excavation.

- Transportation: Robots are used in transportation for tasks such as driving and delivery.

- Environmental: Robots can be used to monitor environmental conditions and collect data for research purposes.

- Entertainment: Robots are used in entertainment for tasks such as animatronics and special effects. √Animatronics refers to the use of robotic technology to create lifelike movements in objects or characters, often for use in entertainment or media. Animatronics are commonly used in movies, theme parks.)

Robotics

Robotics is the branch of technology that deals with the design, construction, and operation of robots.

It combines multiple fields such as mechanical engineering, electronics, and computer science to create machines that can work autonomously or semi-autonomously, with the ability to perceive their environment and adapt to changing circumstances.

Difference between robots and ordinary machines

Machines and robots both serve to automate tasks or actions, but they differ fundamentally in their complexity, adaptability, and autonomy. Following are the main differences between a machine and a robot:

- **Functionality**:
  - **Machine** Typically designed for a specific task or a set of closely related tasks. It doesn't have the capability to perform outside its designated function without being retooled or modified.
    - *Example* A washing machine is designed to wash clothes. You can't ask it to brew coffee or mow the lawn.
  - **Robot** Can often perform a range of tasks and might be reprogrammed to undertake different activities without physical modifications.
    - *Example* A robotic arm in a car manufacturing plant can be reprogrammed to weld different parts of a vehicle or even to paint them.

- **Adaptability**:
  - **Machine** Generally static in its operation. If a problem arises during its operation, a human usually needs to intervene to correct it.

- *Example:* If a paper jam occurs in a printer, it stops working and waits for human intervention.
  - **Robot:** Can be designed to adapt to new situations or problems using sensors and feedback mechanisms.
    - *Example:* Some robotic vacuum cleaners can detect obstacles and navigate around them while cleaning a room.

- **Autonomy**:
  - **Machine:** Operates based on human initiation and oversight. It doesn't make decisions on its own.
    - *Example:* A microwave oven will cook food for a set time, but it won't decide on its own when the food is ready.
  - **Robot:** Has a degree of autonomy and can make decisions based on pre-programmed logic and sensory input.
    - *Example:* A self-driving car can make decisions about speed, direction, and when to stop based on its surroundings.

- **Complexity**:
  - **Machine:** Usually has a straightforward mechanism or set of mechanisms.
    - *Example:* A manual hand drill is turned by hand to create a hole.
  - **Robot:** Contains multiple systems (mechanical, electrical, software) working in harmony, often equipped with sensors to perceive its environment and actuators to perform actions.
    - *Example:* A drone that can autonomously navigate through a forest, avoiding trees using onboard cameras and sensors.

- **Programming & Control**:
  - **Machine:** Typically controlled manually or has a very fixed set of operations.
    - *Example:* A fan can be turned on or off, and maybe its speed can be adjusted.
  - **Robot:** Operates based on a set of instructions or a program that can be updated, changed, or modified to fit different scenarios.
    - *Example:* A robot used in a warehouse can be reprogrammed to pick different items or navigate a newly arranged layout.

In essence, while all robots can be considered machines, not all machines qualify as robots. Robots generally possess a higher level of autonomy, adaptability, and multifunctionality compared to other machines.

Developmental milestones in the field of robotics

- **Early 20th Century**:
  - The term "robot" was coined in the 1920 play "R.U.R." √Rossum's Universal Robots) by Czech writer Karel Čapek.
  - Westinghouse Electric Corporation introduced "Televox" in 1927 ⏚ one of the first machines controlled by voice commands.
  - The first patent for an industrial robot was granted in 1939 to Griffith P. Taylor.

- **1950s and 1960s**:
  - George Devol patented the first programmable robot in 1954 and, together with Joseph Engelberger, founded the world's first robot company.
  - The Unimate robot √1961√ ⏚ the first industrial robot to work on an assembly line in a General Motors plant.

- **1970s**:
  - The development of the Stanford Arm in 1969, an early precursor to today's more advanced robotic arms.
  - The ASEA IRB 6/60, developed in 1975, was the first robot to be controlled by a microprocessor.
  - MIT's Silver Arm in 1974, which had touch and pressure sensing capabilities.

- **1980s**:
  - The introduction of direct drive motors, which enhanced the speed and precision of robotic movements.
  - The PUMA √Programmable Universal Machine for Assembly) robotic arm became an industry standard.

- **1990s**:
  - Honda introduced the humanoid robot "P3" in 1996. It was designed to

walk and climb stairs, and had the ability to recognize and respond to human voice commands. "P3" was an improvement over Honda's previous humanoid robot, "P2", which was much less advanced. "P3" was also notable for its use of artificial muscles, which allowed for smoother and more natural movement. However, "P3" was not intended for commercial production, and was primarily used for research purposes.

- Development of smaller, collaborative robots designed to work alongside humans without protective barriers ⊿ Co-bots.

- **2000s**:
    - Boston Dynamics introduced BigDog in 2005, a quadruped robot designed for the U.S. military.
    - The DARPA √Defence Advanced Research Projects Agency of USA⸹ Grand Challenge √2004 & 2005⸹ boosted developments in autonomous vehicles.

- **2010s**:
    - Robots became more interconnected with the Internet of Things √IoT⸹.
    - Open-source robot operating systems, such as ROS √Robot Operating System), gained popularity, enabling more collaboration and faster innovation.
    - Soft robotics emerged, inspired by the flexibility and adaptability of biological organisms.
    - Boston Dynamics unveiled "Spot" and "Atlas", showcasing advanced mobility and balance. Boston Dynamics unveiled "Spot" and "Atlas" as their most advanced robots in 2016 and 2013, respectively. "Spot" is a four-legged robot designed for mobility and rough terrain, while "Atlas" is a humanoid robot with impressive mobility and balance. Both robots are equipped with advanced sensors and software that enable them to navigate complex environments and perform a range of tasks. "Spot" has been used for applications such as remote inspection of oil rigs and construction sites, while "Atlas" has been used for disaster response and search and rescue missions.
    - Advancements in deep learning and artificial intelligence resulted in robots with better perception, decision-making, and task performance.

- **2020s and Beyond**:
    - Continued integration of AI and machine learning in robotics for more

intelligent decision-making.

- Greater emphasis on human-robot collaboration and co-bots.

- Expansion of robotics in healthcare, especially in surgeries and patient care.

- Autonomous vehicles and drones became more commercialized and integrated into societal infrastructures.

Components of a robot

Robots are multifaceted systems made up of several components. These components are typically designed to grant the robot its sensing, actuation, and processing capabilities. Here's an overview of the primary components found in many robots:

- **Mechanical Components**:

  - **Frame/Body** Provides structure and shape to the robot.

  - **Actuators** Convert energy into movement. Common actuators include motors (DC, servo, and stepper motors), linear actuators, and pneumatics.

- **End Effectors** The device at the end of a robotic arm, designed to interact with the environment. Examples are grippers, tools, or sensors.

- **Transmission** Systems like gears, belts, or chains that transfer the movement generated by the actuator to the end effector.

- **Joints** Allow relative movement between different parts of the robot. They can be rotary (rotational) or prismatic (linear).

- **Sensors**:

  - **Position and Velocity Sensors** Detect changes in position or speed of robot parts.

  - **Proximity and Range Sensors** Measure the distance between the robot and an object, like ultrasonic or infrared sensors.

  - **Vision Systems √Cameras)** Allow the robot to receive visual information from its surroundings.

  - **Inertial Measurement Units √IMUs)** Measure linear and angular motion.

  - **Environmental Sensors** Such as temperature, humidity, or gas sensors.

  - **Tactile Sensors** Detect touch or pressure.

- **Control System**:

  - **Microcontroller or Microprocessor** Acts as the brain of the robot, processing information and sending commands.

  - **Motor Drivers** Control and drive the motors based on commands from the microcontroller.

  - **Feedback Systems** Integrate sensors to provide real-time data back to the controller, enabling responsive actions.

  - **Control Algorithms** Software methods used to achieve desired motions or actions.

- **Power Supply**:

  - **Batteries** Commonly used in mobile robots.

  - **Mains Power** Used for stationary robots or those with high energy demands.

  - **Solar Panels** Provide power in some outdoor robots.

- **Fuel Cells** An emerging energy source for some robotic applications.

- **Communication System**:

  - **Wired Systems** Ethernet, USB, etc.

  - **Wireless Systems** Wi-Fi, Bluetooth, Zigbee, cellular networks, etc.

- **User Interface**:

  - **Software Interface** Allows users to program or give commands to the robot.

  - **Physical Interface** Buttons, joysticks, or touchscreens used to control the robot.

- **Software and Programming**:

  - **Operating System** Systems like the Robot Operating System (ROS) provide a platform for robot software development.

  - **Middleware** Facilitates communication and data sharing between different software components.

  - **Algorithms** Dictate the robot's decision-making, planning, and behavior.

- **Safety Systems**:

  - **Emergency Stop** Ensures the robot can be immediately deactivated.

  - **Collision Detection** Prevents the robot from causing harm due to unexpected collisions.

It's worth noting that the specific components of a robot can vary widely based on its intended function and design.

Types of robots

Robots can be classified in various ways, depending on their application, design, locomotion, or function.

- **Industrial Robots**:

  - **Articulated Robots** These are like mechanical arms with joints that allow them to move and reach in different directions.

  - **Cartesian Robots** These robots move in straight lines along tracks that go up and down, left and right, forward and backward.

  - **SCARA Robots** Used for putting things together with precision, like in a

factory assembling small parts.

- **Service Robots**:

  - **Professional Service Robots** These do specific jobs such as helping in surgeries, farming, or even fighting fires.

- **Personal Service Robots** These are for use around the house or for fun, like robots that clean floors or mow the lawn.

- **Medical Robots**:

  - **Surgical Robots** These assist doctors during operations, offering precision.

  - **Rehabilitation Robots** Help people recover their movement after injuries.

- **Mobile Robots**:

  - **Wheeled Robots** They roll on wheels and are quite stable and easy to control.

  - **Tracked Robots** Have tracks like tanks and can move over rough or slippery surfaces.

  - **Legged Robots** Can have two or more legs, and some can even jump or climb.

  - **Swarm Robots** Tiny robots that work together in big groups to do tasks.

- **Autonomous Vehicles**:

  - **Ground Vehicles** These robots move goods around places like factories without needing a human driver.

  - **Drones** Fly in the air for watching over places, taking photos, or carrying things.

  - **Underwater Robots** Explore or work in the ocean.

- **Collaborative Robots √Cobots)** These robots are safe to be around and can work right next to people.

- **Exoskeletons** Special suits that people can wear to make them stronger or help them heal.

- **Social Robots** These are made to hang out with humans, like robots that can talk or pet robots.

- **Nano Robots** Super tiny robots that can do tasks, especially in medicine, at a very small scale.

- **Soft Robots** These are made of bendy materials and are designed to be gentle and safe around people.

- **Space Robots** These are used for exploring space and can be rovers on other planets or robotic arms in space stations.

- **Educational Robots**: These are used to learn about robots and technology, like building and programming a LEGO robot.

Benefits

Robots offer a wide range of benefits across various sectors. Here are some of the major benefits of robots:

- **Increased Productivity**:
  - Robots can operate continuously without breaks, vacations, or shifts, leading to higher output.
  - They can achieve faster cycle times compared to human workers in many tasks.

- **Cost Savings**:
  - Over the long term, robots can reduce labor costs, especially in repetitive and high-volume production scenarios.
  - Decrease in waste due to higher precision.

- **Improved Quality**:
  - Robots offer consistent and precise operations, leading to fewer errors and higher product quality.
  - They can maintain exact specifications and tolerances, ensuring product uniformity.

- **Enhanced Safety**:
  - Robots can handle hazardous tasks, reducing human exposure to dangerous situations.
  - They can operate in environments unsuitable for humans, such as extreme temperatures or toxic atmospheres.

- **Flexibility**:
  - Robots can be reprogrammed to perform different tasks, offering adaptability to changing production needs.

- **Labor Shortage Alleviation**:
  - Robots can fill jobs where there's a shortage of skilled workers.
  - They can perform mundane and repetitive tasks, allowing human workers to focus on more value-added activities.

- **Accessibility and Exploration**:
  - Robots can access environments that are inaccessible to humans, such as deep underwater, space, or disaster-stricken areas.
  - They have been instrumental in space exploration, deep-sea investigations, and studying inaccessible terrains.

- **Scalability**:
  - Robots can be replicated and scaled more easily than human labor, especially for growing production demands.

- **Operational Reliability**:
  - Robots are less prone to fatigue, leading to consistent performance and fewer mistakes over extended periods.

- **Reduction in Lead Time**:
  - Automated processes can streamline operations, reducing production and delivery times.

- **Customization**:
  - With advances in AI and machine learning, robots can cater to individual customer specifications, facilitating mass customization.

- **Global Competitiveness**:
  - For businesses, automation and robotics can enhance global competitiveness by reducing production costs and improving product quality.

- **Medical and Healthcare Improvements**:

  - Surgical robots can assist surgeons in performing delicate and complex operations with precision.

  - Robots can facilitate rehabilitation and provide care, especially for the elderly.

- **Environmental Benefits**:

  - Robots can be employed in recycling and waste management, promoting environmental sustainability.

  - Precision agriculture robots can optimize the use of resources, reducing waste and environmental impact.

Major areas where the robots are already applied

Robots have been applied in a variety of sectors due to their versatility, efficiency, and capability to operate in challenging environments. The following are major areas where robots are currently applied, along with specific examples:

- **Manufacturing**:

  - **Automobile Production** Robots assist in tasks like welding, painting, and assembly. For example, robotic arms in Tesla factories.

  - **Electronics Manufacturing** Robots place and solder components on circuit boards.

- **Healthcare**:

  - **Surgery** The da Vinci Surgical System allows surgeons to perform minimally invasive procedures with robotic assistance.

  - **Rehabilitation** Robots like the Lokomat aid patients in physical therapy by helping them relearn walking motions.

  - **Telepresence** Robots like the InTouch Health's RP-VITA enable physicians to interact with patients remotely.

- **Agriculture**:

  - **Harvesting** Robots like Ripe Robotics' fruit-picking robot can identify ripe fruits and pick them.

  - **Weed Control** Robots like Blue River Technology's "See & Spray" can identify and precisely spray weeds, reducing herbicide use.

- **Retail**:
  - **Inventory Management** Robots like Tally from Simbe Robotics autonomously scan shelves and take inventory.
  - **Delivery** Starship Technologies has robots that deliver food and parcels in urban settings.

- **Logistics & Warehousing**:
  - **Material Handling** Amazon uses Kiva robots to transport shelves and items within their fulfillment centers.
  - **Sorting** Robots sort parcels in facilities like FedEx or DHL.

- **Domestic Use**:
  - **Cleaning**: iRobot's Roomba vacuums floors autonomously.
  - **Lawn Care** Robots like the Husqvarna Automower can mow lawns without human intervention.

- **Military and Defense**:
  - **Surveillance** Drones like the MQ‑9 Reaper provide aerial reconnaissance.
  - **Bomb Disposal** Robots like the iRobot PackBot can safely disarm explosives.

- **Space Exploration**:
  - **Planetary Exploration** NASA's Perseverance rover explores Mars, conducting scientific experiments and taking samples.
  - **Maintenance & Repair** Robotic arms on the International Space Station, like Canadarm2, assist in various tasks.

- **Entertainment**:
  - **Theme Park Attractions** Disney has developed animatronics and robots for use in their parks.
  - **Filmmaking** Robots can create complex and precise camera movements for specific shots.

- **Education**:
  - **Teaching Tools** Robots like LEGO Mindstorms and Sphero provide hands-on learning experiences in coding and robotics.

- - **Research**: Universities use robots like the NAO humanoid for research in robotics and AI.
- **Construction**:
  - **Bricklaying**: SAM √Semi-Automated Mason) can lay bricks alongside human masons.
  - **3D Printing**: Robots are used in large-scale 3D printing projects to construct architectural structures.
- **Mining & Drilling**:
  - **Exploration**: Robots can explore and map underground mines, improving safety and efficiency.
  - **Deep-sea Drilling**: Autonomous robots can drill in deep-sea environments for oil and gas extraction.
- **Transportation**:
  - **Autonomous Vehicles**: Companies like Waymo and Tesla are pioneering self-driving vehicle technology.
  - **Delivery Drones**: Companies like Wing (an offshoot of Google's parent company, Alphabet) are exploring drone deliveries.
- **Emergency Response**:
  - **Disaster Response**: Robots like the Boston Dynamics' Spot can be deployed in disaster-stricken areas for search and rescue.
  - **Firefighting**: Robots can assist in situations too dangerous for human firefighters.
- **Research & Development**:
  - **Testing & Experimentation**: Robots can perform repetitive tasks in labs, such as pipetting or sample processing.

Issue associated with robots

The rise of robotics has brought numerous benefits to various sectors; however, the integration of robots into human society and industries also presents several significant challenges and concerns.

- **Job Displacement and Economic Impact**:
  - As robots take over repetitive, manual, and even some complex tasks, there's concern about human job displacement. While some industries benefit from the increased efficiency robots bring, many workers face

job losses. This displacement can lead to increased unemployment rates, especially if retraining opportunities are not provided.

- The economic impact is two-fold: businesses may see increased profits due to reduced labor costs, but there might also be a decrease in consumer purchasing power if large portions of the population are unemployed.

- **Safety Concerns**:

  - **Physical Safety**: Robots in workplaces or public spaces might cause accidents if they malfunction or if there's an unpredicted interaction with humans. This is especially a concern with heavy industrial robots or fast-moving autonomous vehicles.

  - **Data Safety**: As robots often rely on vast amounts of data to operate, there's potential for data breaches or misuse, particularly if personal or sensitive information is involved.

- **Ethical and Moral Dilemmas**:

  - **Decision-making**: For instance, autonomous vehicles might have to make split-second decisions in emergencies that could have moral implications (e.g., the trolley problem where the vehicle must decide between harming its passengers or pedestrians).

- **Social Interaction**: Robots designed to mimic human behaviors, especially in caregiving or companionship roles, raise concerns about authentic human interaction and relationships.

- **Privacy**: Robots equipped with cameras or sensors in public or private spaces could infringe on people's privacy.

- **Dependency and Security Vulnerabilities**:

  - As societies become more reliant on robots, there's a risk of over-dependency, where essential skills could be lost over time (e.g., if automated systems fail and there's a lack of skilled human operators).

  - Robots, especially those connected to the internet or other networks, are susceptible to hacking. A compromised robot could pose physical dangers or lead to data theft.

- **Regulation and Legal Challenges**:

  - **Liability**: If a robot causes harm or damage, determining liability can be complex. Is it the manufacturer's fault, the software developer's, the operator's, or a combination?

  - **Standards**: Establishing safety and operation standards across different regions or countries can be challenging.

  - **Rights and Recognition**: As AI and robotics advance, questions arise about whether highly sophisticated robots should have rights or legal recognition, especially if they display traits of consciousness or self-awareness.

Addressing these issues requires collaboration between technologists, policymakers, ethicists, and other stakeholders to ensure that the development and deployment of robots are both beneficial and responsible.