

CHAPTER 3 COMPONENTS OF ROBOTS

Learning Outcomes

- Introduction to Visualization Tools
- Parts of Robot
- Designing and Modeling
- Control Units

Robots are machines designed to perform tasks with accuracy and efficiency. Just like the human body has different parts that work together, a robot also has various components that help it function. These components can be grouped into three main types: mechanical, electronic, and computational. Mechanical parts, like the frame, joints, and motors, give the robot its shape and allow it to move. Electronic parts, such as sensors, circuits, and batteries, help the robot sense and respond to its surroundings. The computational part, which includes microcontrollers and software, acts as the robot's "brain," making decisions based on instructions. Each of these parts is important for the robot to work properly, whether in factories, hospitals, or homes. By learning about these components, we can create better robots that help make our lives easier. Robots are complex machines made up of different components that work together to perform tasks. To design and create a robot, engineers use advanced tools like **Computer-Aided Design (CAD) modelling** and **precision manufacturing** to build its parts, including **sensors, actuators, and control units**.

System Visualization and Design

System visualization and design are important steps in building robots. This process helps plan, design, and understand how a robot will work before it is actually made. It ensures that the robot functions properly, meets user needs, and works within given limits.

What is System Visualization?

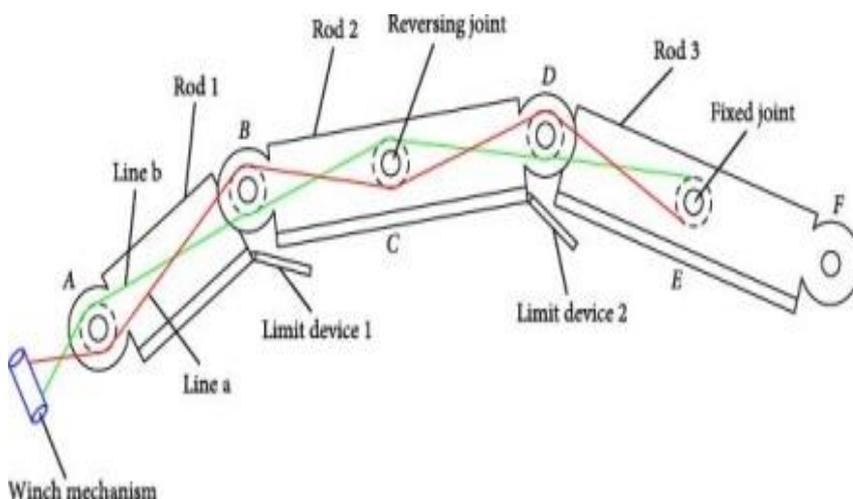
System visualization means creating a picture or model of a robot before making it. This helps designers see how different parts will fit and work together. It can be done using:

- **Simple Sketches** – Rough drawings to show the robot's structure.
- **Block Diagrams** – Diagrams that show how different parts connect and communicate.

- **3D Models** – Computer-generated designs using software like CAD (Computer-Aided Design).
- **Simulations** – Virtual tests to check if the design will work correctly.

1. Simple Sketches

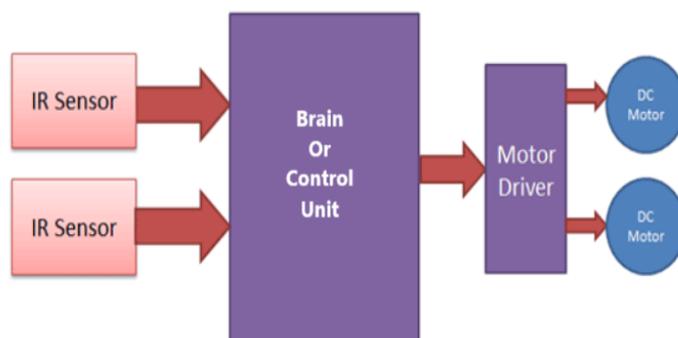
A **simple sketch** is a rough, hand-drawn representation of a robot's structure. It helps designers quickly put their ideas on paper before creating detailed models. These sketches are not precise but provide a basic layout of the robot's shape, movement parts, and placement of key components. **Ex:** A rough drawing of a robotic arm showing its joints and movement range before making a detailed design.



Before building a robot, engineers first create a digital model to plan its structure, movement, and functionality.

2. Block Diagrams

A **block diagram** is a simple diagram that shows how different parts of a robot connect and communicate with each other. Instead of focusing on detailed mechanical parts, it represents systems using labelled blocks and arrows. **Ex:** A block diagram of a line-following robot may include blocks for **sensors, motor drivers, microcontrollers, and power supply**, with arrows showing connections between them.



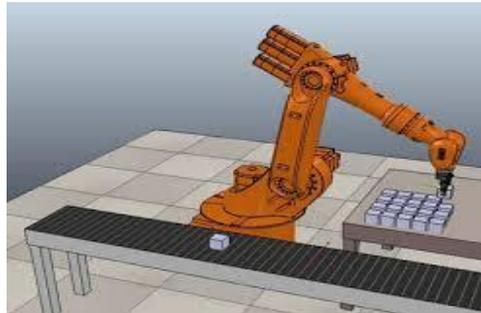
3. 3D Models

A **3D model** is a computer-generated design of a robot using software like **CAD (Computer-Aided Design)**. It provides a detailed, realistic view of the robot's structure, including exact measurements and material properties. **Ex:** A **3D model of a humanoid robot** can show how its joints will move, how sensors are placed, and how the outer body will look.



4. Simulations

A **simulation** is a virtual test environment where a robot's design and programming are tested before real-world implementation. Engineers use software to check how a robot will behave under different conditions. **Ex:** A **robotic arm simulation** can test how it picks up and moves objects before assembling the real hardware.



Computer-Aided Design (CAD) in Robotics

Computer-Aided Design (CAD) is a technology that helps engineers and designers create digital models of robots before making them in real life. It uses special software to draw, design, and test different robot parts on a computer. This makes it easier to check if the design works before spending time and money building it.

What is CAD Modelling?

CAD modelling means making a 3D (three-dimensional) digital version of a robot using software. It shows how different parts fit together and how the robot will look and move. This helps engineers plan and improve the design before creating the actual robot.

Why is CAD Important in Robotics?

- **Accurate Designs:** CAD helps make precise models, ensuring all robot parts fit together correctly. Even small mistakes in design can cause big problems when building a robot.
- **Easy to Modify:** If a design needs changes, CAD software allows quick updates without starting over. This saves time and effort.
- **Better Visualization:** Engineers can see how the robot will look and function before making a real one. This helps in planning and improving the design.
- **Team Collaboration:** CAD models can be shared with other designers and engineers, making teamwork easier, even if they are in different locations.
- **Testing Before Building:** Many CAD programs allow engineers to **simulate** (test) the robot's movement and function before making a physical model. This helps find and fix issues early.

Steps in CAD Modelling for Robotics

- **Concept Planning:** First, designers decide what the robot will do and what parts it will need.
- **Creating the Structure:** Basic shapes and parts, like the robot's frame, wheels, and arms, are designed using CAD software.

- **Assembling the Parts:** All parts are put together in the software to make a complete model of the robot.
- **Adding Features:** Details like joints, sensors, motors, and other important parts are added to make the robot functional.
- **Simulation & Testing:** The robot is tested in a virtual environment to check if it moves and works as expected.
- **Final Changes & Optimization:** If any issues are found during testing, modifications are made to improve the design.

Popular CAD Software Used in Robotics

There are many CAD software programs available, and the choice depends on the complexity of the robot and the designer's preferences. Some popular CAD tools used in robotics include:



SolidWorks

One of the most widely used CAD tools in robotics. It is known for its strong 3D modelling capabilities and extensive simulation options.



AutoCAD

A popular tool for designing both 2D and 3D models. AutoCAD is used in many industries, including robotics, for its versatility and precision.



Fusion 360

A cloud-based CAD tool by Autodesk. It is used for designing, simulating, and sharing designs. Fusion 360 is particularly useful for collaborative projects and rapid prototyping.



Blender

While Blender is typically used for animation and 3D rendering, it can also be used for designing robot parts, especially when aesthetics and detailed rendering are important.



CATIA

A powerful tool used for designing complex mechanical systems, CATIA is commonly used in industries like aerospace and automotive engineering, as well as robotics.

Advantages of CAD Modelling in Robotics

- **More Accurate Designs:** CAD software helps create robot designs with exact measurements, reducing mistakes and ensuring everything fits and works properly.
- **Saves Time and Money:** Since robots can be designed and tested on a computer first, there's less need to build multiple physical models. This speeds up development and reduces costs.
- **Easy to Make Changes:** If any part of the design needs improvement, CAD allows quick modifications. Engineers can test different ideas without having to start over.
- **Clear Documentation:** CAD software creates detailed drawings and reports that show how each part of the robot should be made and assembled. This helps during manufacturing.

- **Faster Prototyping:** Once a design is complete, CAD files can be used for 3D printing or sent to manufacturers to quickly create a physical version of the robot.

Key Components of a Robot

A robot is made up of different parts that help it work and complete tasks. These parts include the body, sensors, motors, a control system, a power source, and communication systems. Each part has a special role in making the robot function properly.

1. Body (Mechanical Structure)

The body is the physical shape of the robot. It can be made of metal, plastic, or other materials. The design of the body decides how the robot moves and performs tasks. Some important parts include:

- **Frame and Chassis** – Holds all the robot's parts together.
- **Joints and Links** – Allow movement in robotic arms or legs.
- **Wheels and Tracks** – Help robots move from one place to another.

2. Sensors

Sensors help robots sense their surroundings, just like our eyes and ears. They collect information and send it to the control system. Some common types of sensors are:

- **Distance Sensors (Infrared, Ultrasonic)** – Detect objects and measure distance.
- **Cameras and LIDAR** – Capture images and help in navigation.
- **Touch and Pressure Sensors** – Detect when the robot touches something.
- **Temperature and Humidity Sensors** – Measure weather conditions.

3. Motors and Actuators (Movement System)

Motors and actuators make the robot move. They convert electrical power into motion. Some types of actuators include:

- **DC, Servo, and Stepper Motors** – Move wheels, arms, or other parts.
- **Hydraulic and Pneumatic Systems** – Use liquids or air to create strong movements.

4. Control System (Robot's Brain)

The control system acts like the robot's brain. It processes information from the sensors and decides what the robot should do. Some control systems are:

- **Microcontrollers (like Arduino, Raspberry Pi)** – Used in small robots.
- **Computers** – Used in advanced robots for complex tasks.
- **AI and Machine Learning** – Help robots make smart decisions on their own.

5. Power Source

The power source gives energy to the robot to function. Some common power sources are:

- **Batteries (Lithium-ion, Lead Acid)** – Used in mobile robots.
- **Solar Power** – Used in outdoor robots.
- **Electric Power (Wired Connection)** – Used in factory robots.

6. Communication System

Some robots need to communicate with people or other robots. They use:

- **Wi-Fi and Bluetooth** – Wireless connections for remote control.
- **Wired Connections** – Used in factory robots for fast communication.
- **Cloud Storage** – Allows robots to share and process information online.

Precision Manufacturing of Sensors, Actuators and Control Unit

Precision manufacturing plays a crucial role in creating the key components of a robot, such as sensors, actuators, and control units. Sensors help robots detect and respond to their surroundings, and they must be made with high accuracy to provide precise data. Advanced techniques like photolithography are used to create tiny circuits, while materials such as silicon, piezoelectric substances, and optical glass ensure high performance. After manufacturing, sensors undergo testing and calibration to ensure they deliver accurate readings.

Actuators, which enable robot movement, also require precision manufacturing to function smoothly and last longer. They are produced using techniques like CNC (Computer Numerical Control) machining for shaping metal and plastic, injection moulding for creating durable plastic parts, and 3D printing for custom designs. Different types of actuators, such as electric motors, hydraulic cylinders, and smart materials like shape memory alloys, are carefully manufactured to ensure efficiency and reliability.

Control units, often called the brain of the robot, process data from sensors and send commands to actuators. These units are built using semiconductor technology to produce microchips and processors, while printed circuit boards (PCBs) hold and connect all the electrical components. High-precision assembly ensures that control units function correctly, with rigorous testing to verify performance under different conditions.

Overall, precision manufacturing ensures that all robotic components work efficiently and reliably. By using advanced techniques and strict quality control, manufacturers create robots that can sense, move, and make decisions accurately, making them more effective in various real-world applications.

Chapter Highlights

- Creating a model before building the actual robot using sketches, block diagrams, 3D models, and simulations.
- CAD software helps design, modify, and simulate robots before real-world implementation.
- Benefits of CAD include accuracy, easy modifications, teamwork, virtual testing, and integration with 3D printing.
- Popular CAD tools include SolidWorks, AutoCAD, Fusion 360, Blender, and CATIA.
- A robot consists of a mechanical structure, sensors, motors, control systems, power sources, and communication modules.
- Sensors detect environmental changes using distance, touch, and vision-based technologies.
- Motors and actuators such as DC motors, servo motors, and stepper motors enable movement.
- Microcontrollers like Arduino and Raspberry Pi process data and control robotic functions.
- Power sources include batteries, solar panels, and wired connections.
- Communication methods involve Wi-Fi, Bluetooth, and cloud-based networks.
- Precision manufacturing ensures high-accuracy components for sensors, actuators, and control units.
- Advanced fabrication techniques like CNC machining, injection molding, and micro fabrication enhance efficiency and reliability.

Exercise

Multiple Choice Questions (MCQs)

1. What is the primary purpose of CAD software in robotics?
 - a) Playing video games
 - b) Designing, modifying, and simulating robots
 - c) Writing robotic control codes
 - d) Measuring robotic speed
2. Which of the following is **not** a CAD tool?
 - a) SolidWorks
 - b) AutoCAD
 - c) Python
 - d) Fusion 360
3. Sensors in robots are used to:
 - a) Detect environmental changes
 - b) Provide power to motors
 - c) Store data permanently
 - d) None of the above

4. Which component processes data and controls robotic functions?
 - a) Actuator
 - b) Sensor
 - c) Microcontroller
 - d) Power source
5. What is the main function of actuators in robots?
 - a) Detecting objects
 - b) Enabling movement
 - c) Storing data
 - d) Transmitting wireless signals
6. Which of the following is not a communication method used in robotics?
 - a) Bluetooth
 - b) Wi-Fi
 - c) Infrared
 - d) Diesel engine
7. The role of a power source in a robot is to:
 - a) Process information
 - b) Provide energy for operation
 - c) Store movement data
 - d) Transmit signals
8. CNC machining is used for:
 - a) Wireless communication
 - b) Precision manufacturing
 - c) Cloud storage
 - d) Power supply
9. Which of the following is an example of a microcontroller?
 - a) Arduino
 - b) Bluetooth module
 - c) CNC machine
 - d) Stepper motor
10. Which power source is commonly used in robots?
 - a) Gasoline
 - b) Batteries
 - c) Hydraulic oil
 - d) None of the above

Fill in the Blanks _____

1. _____ software is used to design and simulate robots before building them.
2. Microcontrollers such as _____ and _____ process data and control robotic functions.
3. _____, _____, and _____ are common types of actuators used in robotics.
4. CNC machining is an advanced _____ technique used for precision manufacturing.
5. Robots can communicate using _____, Bluetooth, and cloud-based networks.

True & False []

1. Sensors in robots are used to provide power to motors.
2. Arduino and Raspberry Pi are examples of microcontrollers.

3. Communication in robots can be done using Wi-Fi and Bluetooth.
4. 3D printing is unrelated to CAD software.
5. Actuators are responsible for enabling movement in robots.

Assertion and Reasoning Questions

1. **Assertion (A):** CAD software helps in designing and simulating robots.
Reason (R): CAD software allows real-world implementation before testing a model.
 - a) Both A and R are true, and R is the correct explanation of A.
 - b) Both A and R are true, but R is not the correct explanation of A.
 - c) A is true, but R is false.
 - d) A is false, but R is true.
2. **Assertion (A):** Batteries are the only power source for robots.
Reason (R): Robots can also use solar panels and wired power connections.
 - a) Both A and R are true, and R is the correct explanation of A.
 - b) Both A and R are true, but R is not the correct explanation of A.
 - c) A is true, but R is false.
 - d) A is false, but R is true.
3. **Assertion (A):** Actuators are responsible for movement in a robot.
Reason (R): Actuators can be DC motors, servo motors, or stepper motors.
 - a) Both A and R are true, and R is the correct explanation of A.
 - b) Both A and R are true, but R is not the correct explanation of A.
 - c) A is true, but R is false.
 - d) A is false, but R is true.
4. **Assertion (A):** CNC machining is used for precision manufacturing in robotics.
Reason (R): CNC machining reduces errors and enhances efficiency in fabrication.
 - a) Both A and R are true, and R is the correct explanation of A.
 - b) Both A and R are true, but R is not the correct explanation of A.
 - c) A is true, but R is false.
 - d) A is false, but R is true.
5. **Assertion (A):** Microcontrollers help in sensing environmental changes.
Reason (R): Sensors in robots detect environmental changes, not microcontrollers.
 - a) Both A and R are true, and R is the correct explanation of A.
 - b) Both A and R are true, but R is not the correct explanation of A.
 - c) A is true, but R is false.
 - d) A is false, but R is true.

Short Answer Questions

1. What are the key benefits of using CAD software in robotics?
2. Name three types of actuators used in robots and their functions.
3. Explain the role of microcontrollers in a robotic system.
4. What are the different power sources used in robots?
5. How do robots communicate with external devices?

Long Answer Questions

1. Describe the different components of a robot with examples.
2. Explain how CAD software is used in the design and development of robots.
3. Discuss the various types of sensors used in robotics and their applications.

4. What are the different fabrication techniques used in precision manufacturing for robotics?
5. Explain the importance of microcontrollers in robotics and compare Arduino with Raspberry Pi.