MODULE - V

AUTOMATION AND ROBOTICS AUTOMATION

Introduction to Automation

Automation is gaining widespread adoption due to its numerous advantages for businesses, such as lowering labor costs, enhancing speed and precision, boosting product quality, and improving safety. By automating tasks, companies can streamline their processes and concentrate on other critical areas of their operations. Its growing presence in industries like manufacturing, transportation, and healthcare highlights its transformative potential in how tasks are executed. Automation aims to minimize human labor while maximizing efficiency, accuracy, and productivity across various sectors. The technology involved ranges from simple machines for repetitive tasks to sophisticated systems utilizing artificial intelligence and machine learning to make decisions traditionally handled by humans

Types of Automated Systems

1. **Manufacturing:** Automation is widely utilized in manufacturing for tasks such as assembly, welding, painting, and quality control. In the automotive sector, robots handle tasks like welding car frames, applying paint, and installing components like windows and doors, which enhances production speed and consistency while reducing dependency on human labor. Automated quality control systems inspect finished products to ensure they meet specified standards, minimizing the risk of defects.

2. **Transportation:** The transportation industry is increasingly adopting automation, notably through self-driving cars and trucks. These vehicles leverage sensors and artificial intelligence to navigate and transport goods or passengers, potentially reducing the reliance on human drivers, enhancing safety, and improving transportation efficiency by cutting down travel time.

3. **Healthcare:** Automation in healthcare covers tasks such as medication dispensing, patient monitoring, and medical image analysis. Automated dispensing machines help ensure accurate medication administration, while monitoring systems alert medical staff to changes in patient conditions. Automated image analysis supports doctors in identifying health issues more precisely, aiding in accurate diagnoses.

4. **Banking:** The banking sector employs automation for transaction processing, credit risk assessment, and fraud detection. Automated teller machines (ATMs) enable customers to conduct transactions independently. Automated credit risk systems assist in more accurate lending decisions, and fraud detection systems can identify suspicious activities early, mitigating potential threats.

5. **Agriculture:** Automation is revolutionizing agriculture with technologies like automated irrigation, robotic harvesters, and drones. Automated irrigation systems optimize water usage and minimize waste, while robotic harvesters enhance the efficiency and speed of crop collection, reducing labor needs. Drones monitor crop health and identify potential issues before they escalate.

Elements of Automation

Automation systems consist of four key elements: sensors, actuators, controllers, and communication networks. These components work in harmony to allow machines and systems to function autonomously, minimizing the need for human intervention.

1. **Sensors**
   Sensors detect changes in physical or environmental conditions and convert these into electrical signals for processing by a computer or electronic system. They are critical in providing the data needed for automated systems to make informed decisions and take action. Common types of sensors include:

   - **Temperature Sensors:** Measure the temperature in HVAC systems and industrial processes requiring precise temperature control.
   - **Pressure Sensors:** Gauge the pressure of gases or liquids, commonly used in hydraulic and pneumatic systems.
   - **Proximity Sensors:** Detect objects without contact, often used in manufacturing for part detection and position verification.
   - **Vision Sensors:** Capture images and identify objects, colors, and patterns for quality control and inspection processes.

2. **Actuators**
   Actuators control the movement of machines and systems. Types of actuators include:

   - **Electric Motors:** Convert electrical energy into rotational motion.
   - **Pneumatic Actuators:** Use air pressure to generate linear or rotational motion, often used in valve control and robotic grippers.
   - **Hydraulic Actuators:** Utilize hydraulic fluid pressure for motion, common in heavy machinery and construction equipment.

3. **Controllers**
   Controllers receive input from sensors and manage the movement of actuators, acting as the decision-making hub of automated systems. Types of controllers include:

   - **Programmable Logic Controllers (PLCs):** Digital computers used to automate manufacturing processes and other industrial applications.
   - **Distributed Control Systems (DCSs):** Manage large-scale industrial processes like refineries and power plants through multiple coordinated controllers.
   - **Supervisory Control and Data Acquisition (SCADA) Systems:** Monitor and control large-scale systems, such as power grids and water treatment facilities.

4. **Communication Networks**

Communication networks connect system elements, enabling information exchange and coordinated action. Common types include:

- **Ethernet:** Facilitates wired communication between devices.
- **Wireless Networks:** Use radio waves for data transmission without physical cabling, ideal for remote monitoring.
- **Fieldbus Networks:** Specialized for real-time communication between sensors, actuators, and controllers in industrial automation.

In summary, sensors, actuators, controllers, and communication networks are fundamental to automation systems, enabling autonomous operation across various industries. By automating repetitive tasks, these systems enhance efficiency, reduce costs, and improve safety

Types of Automation

1. **Fixed Automation**

Fixed automation, or hard automation, involves using specialized machines designed for specific tasks, ideal for high-volume production of standardized products. These systems are inflexible, as the equipment is dedicated to a particular process and cannot easily adapt to different tasks. Examples include automobile assembly lines and food packaging systems. Fixed automation offers advantages such as high productivity, consistent quality, and low per-unit cost, but it is less suited for processes requiring frequent changes or low-volume production.

2. **Programmable Automation**

Programmable automation uses computer-controlled machines capable of performing a variety of tasks through reprogramming. It is more flexible than fixed automation and is used in manufacturing for tasks like cutting, welding, or painting. Other applications include robotic arms in warehouses and medical diagnostic equipment. The benefits of programmable automation include adaptability and the ability to perform diverse tasks, but it requires significant investment, maintenance, and skilled personnel for programming and operation.

3. **Flexible Automation**

Flexible automation, or soft automation, utilizes advanced robotics and computer systems for complex and variable tasks. It is highly adaptable and can handle changes in the production process efficiently. Common in aerospace, pharmaceuticals, and logistics, flexible automation enables high precision in tasks like assembling components or sorting products. While offering high productivity and adaptability, flexible automation involves high costs and demands ongoing technological updates and training.

Part Transfer Methods and Mechanisms

In manufacturing, transferring parts or products between stations is essential. There are three main methods of part transfer:

1. **Manual Transfer**

   This involves human labor to move parts between stations. It is suitable for low-volume production but is inefficient and labor-intensive.

2. **Mechanical Transfer**

   This method uses equipment like conveyors and cranes to move parts, offering more efficiency than manual transfer but still requiring human operation.

3. **Automated Transfer**

   Automated transfer employs robotic arms, automated guided vehicles (AGVs), and other systems to move parts with minimal human intervention. It is ideal for high-volume and complex processes due to its speed and efficiency.

Flow Lines and Their Types: Introduction

Flow lines are production systems designed to move parts through a sequence of operations, each performing a specific task. They are used in high-volume production of standardized products, characterized by efficiency, high productivity, and low cost.

Types of Flow Lines

1. **Straight Flow Lines**

   Straight flow lines are the simplest and most common, consisting of a series of stations arranged in a straight line. Parts or products move continuously from one station to the next, with each station performing a specific operation. These lines are widely used in industries such as automotive, electronics, and food processing for high-volume production of standardized products. They are efficient, straightforward to design and implement, and easily automated.

2. **U-Shaped Flow Lines**

   U-shaped flow lines are similar to straight flow lines but arranged in a U-shape, with stations located along the inner curve. Parts or products travel from one end of the U to the other, passing through various operations. These lines are prevalent in industries like automotive, aerospace, and pharmaceuticals, where processing complex or large parts is necessary. U-shaped flow lines offer enhanced efficiency by reducing the travel distance for parts, and they facilitate easier inspection and maintenance.

3. Serpentine Flow Lines

Serpentine flow lines, arranged in a zigzag pattern, are the most complex type. Parts or products move along this pattern, with each station performing specific tasks. These lines are commonly used in industries such as electronics, where small or delicate parts need processing. Serpentine flow lines maximize space efficiency by accommodating more stations in a smaller area and minimize the time and energy needed to transport parts through the line.

Introduction to Robotics

Robotics is a multidisciplinary branch of engineering and technology that focuses on the design, construction, operation, and use of robots. It integrates fields such as mechanical engineering, electrical engineering, computer science, and artificial intelligence to develop machines that can perform tasks autonomously or semi-autonomously

ROBOTICS

Introduction to Robotics

Robotics is a multidisciplinary field of science and engineering dedicated to the design, construction, and operation of robots—machines that can perform tasks autonomously or semi-autonomously, often emulating human actions or assisting in tasks that require precision, repetition, or safety. This field integrates mechanical engineering, electronics, and computer programming to create systems capable of sensing, thinking, and acting.

Applications of Robotics

Robots are utilized across various industries to enhance efficiency, precision, and safety. Some of the most common applications include:

- **Manufacturing:** Industrial robots handle tasks such as assembly, welding, painting, and packaging. Designed to operate in harsh environments and perform repetitive tasks with high precision, these robots significantly boost productivity and reduce operational costs.
- **Healthcare:** Robots in healthcare perform tasks like surgery, patient monitoring, and drug administration. These medical robots enhance the accuracy and precision of procedures, lower the risk of human error, and reduce patient trauma and recovery time.
- **Agriculture:** Agricultural robots take on tasks such as planting, harvesting, and crop spraying. These robots increase the efficiency and accuracy of farming operations, reduce labor costs, and optimize resource usage like water and fertilizers.
- **Logistics:** In logistics, robots manage order fulfillment, inventory, and transportation. These robots improve the speed and accuracy of order processing, reduce errors and damages, and optimize warehouse space utilization.
- **Entertainment:** Robots enhance entertainment experiences through stage performances, film production, and theme park attractions. They provide immersive, interactive experiences and perform tasks that may be too challenging or hazardous for humans.

As robotics technology advances, robots are becoming more sophisticated, versatile, and capable of handling increasingly complex tasks.

Laws of Robotics

The concept of the "Laws of Robotics" was introduced by science fiction writer Isaac Asimov in his 1942 short story "Runaround." These three laws are:

1. A robot may not injure a human being or, through inaction, allow a human being to come to harm.
2. A robot must obey the orders given it by human beings, except where such orders would conflict with the First Law.
3. A robot must protect its own existence as long as such protection does not conflict with the First or Second Law.

The Three Laws of Robotics

- A robot cannot harm a human being or, by inaction, allow a human being to come to harm.
- A robot must obey the orders given by human beings, except where such orders would conflict with the First Law.
- A robot must protect its own existence as long as such protection does not conflict with the First or Second Laws.

The purpose of these laws is to ensure that robots are programmed to act ethically and responsibly. By adhering to these principles, robots are designed to prioritize human safety and well-being above all else. These laws are intended to prevent robots from harming humans and ensure that their actions align with human values and ethics.

Ethics in Robotics

As robots become more integrated into various aspects of society, ethical guidelines and standards are crucial to ensure that their use aligns with human values and interests. Key ethical considerations in robotics include:

- **Safety**: Robots must be designed to prevent accidents and injuries, ensuring safe interaction with humans.
- **Privacy**: Robots should respect individual privacy and avoid unauthorized data collection or use.
- **Autonomy**: Robots should act in ways that align with human values and ethics, avoiding harm and respecting individual rights.
- **Accountability**: Robots need mechanisms to be accountable for their actions, allowing humans to hold them responsible for any harm caused.
- **Transparency**: Robots should provide clear information about their capabilities, limitations, and actions to promote trust and understanding.

Anatomy of Robots

Robots are complex machines comprising several critical components that enable their operation:

- **Actuators**: These components enable movement and task performance, using systems like electric motors, hydraulics, or pneumatics.
- **Sensors**: Sensors allow robots to perceive their environment, detecting objects, measuring distance, or sensing temperature.

- **Controllers**: Controllers manage and coordinate robot actions, processing sensor input to determine appropriate actions.
- **Power Supply**: Robots require power sources, such as batteries or fuel cells, selected based on the robot's power needs and usage duration.

Design Considerations for Robot Bodies

The design of a robot's body affects its performance and efficiency:

- **Size and Shape**: Optimized for the robot's application, whether in narrow spaces or outdoor environments.
- **Weight**: Balanced to ensure efficient movement and task performance, avoiding excessive power use.
- **Material**: Durable, lightweight materials like aluminum, steel, or composites ensure strength and longevity.
- **Joints and Linkages**: Designed to provide the necessary range of motion for the robot's tasks.
- **Grippers and End Effectors**: Customized for specific tasks, such as grasping, cutting, or welding.

Configuration of Robots

Robots are classified based on their configuration, which includes:

- **Number of Joints**: Determines the robot's flexibility and range of motion.
- **Orientation of Joints**: Affects the robot's ability to navigate and manipulate objects.
- **Range of Motion**: Defines the operational scope and versatility of the robot.

Understanding these aspects is essential for designing, building, and operating robots effectively, ensuring they meet the demands of their applications while adhering to ethical standards.

Types of Configurations

1. **Cartesian Configuration**:

   A robot with a Cartesian configuration consists of three orthogonal slides aligned with the Cartesian x, y, and z axes. These slides allow the robot to move its arm within a rectangular, three-dimensional workspace. This configuration is suitable for tasks requiring linear and precise movements, such as CNC machines or 3D printing.

2. **Cylindrical Configuration**:

   In a cylindrical configuration, the robot body is a vertical column that rotates around a vertical axis. The arm can move up or down and in or out relative to the body, enabling a cylindrical workspace. This setup is often used in assembly operations, material handling, or spot welding.

3. **Polar Configuration**:

   Also known as spherical configuration, the polar configuration allows the robot to move within a partially spherical workspace. It features a rotating base and a telescoping arm that can pivot and extend, making it ideal for tasks requiring a wide range of motion, such as robotic welding or material handling in large areas.

4. **Jointed-Arm Configuration**:

   This configuration is a combination of articulated and cylindrical designs, resembling a human arm with joints at the shoulder, elbow, and wrist. The arm is composed of multiple segments connected by joints, allowing it to operate in a nearly spherical workspace. It is commonly used in applications

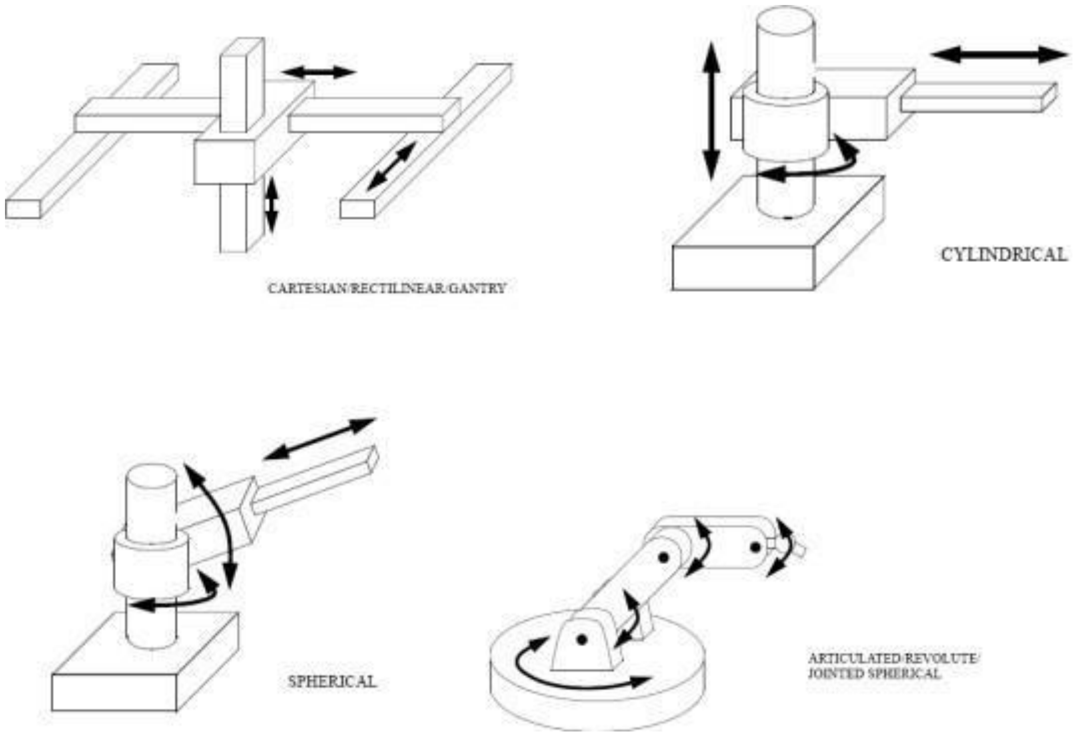

Figure 12 Types of Robot configurations

Robot End Effectors - Classification

Robot end effectors, also known as grippers, are the devices attached to the end of a robot's arm that allow it to perform specific tasks such as gripping, manipulating, or interacting with objects. End effectors come in various types and designs depending on the task at hand. Below is a breakdown of the most common types of robot end effectors:

1. Grippers

- Mechanical Grippers: These grippers use two or more fingers to grasp objects. They can be used in various environments and are designed to handle a wide range of objects.
- Pneumatic Grippers: These use air pressure to operate. They are often faster and provide a strong gripping force.
- Electric Grippers: These use electric actuators to open and close. They are highly precise and efficient.
- Grippers are ideal for tasks requiring grasping, lifting, or moving objects.

2. Suction Cups

- Suction cups use vacuum pressure to hold onto objects, making them effective for handling flat or smooth surfaces like metal sheets, glass, or plastic.
- Flat Suction Cups: These have a flat surface and are ideal for gripping thin, flat objects.
- Bellows Suction Cups: These cups are flexible and can conform to irregular shapes, making them ideal for handling slightly curved surfaces.

3. Electromagnets

- Electromagnetic end effectors use magnetic fields to attach to ferromagnetic objects (e.g., iron or steel). They are commonly used for material handling and picking up heavy metallic parts in assembly lines or warehouses.
- Electromagnets are often used in industries like automotive, metalworking, and recycling.

4. Tool Changers

- A tool changer allows a robot to easily swap between different tools (grippers, welding torches, spray guns, etc.) depending on the task. This is crucial for applications that require different tools throughout the production process, such as machining, assembly, and welding.

- They improve flexibility and efficiency in automated systems by enabling quick task reconfiguration.

5. Cameras

- Cameras can be used as end effectors for vision systems, providing robots with the ability to "see" their environment. Cameras are typically integrated with machine vision software to enable tasks such as inspection, part recognition, or navigation in an environment.
- This capability is especially useful in quality control, packaging, and sorting applications.

6. Force/Torque Sensors

- These sensors enable the robot to measure the forces and torques applied during tasks like assembly, gripping, or welding. They are essential in applications where delicate handling is required, such as in electronics or medical device manufacturing.
- Force/torque sensors provide feedback to the robot, ensuring precise and safe interaction with objects, avoiding damage or errors.

Robotic Joints and Grippers

Robots are designed with various joints and grippers that help them perform diverse tasks. The types of joints determine the movement capabilities of the robot, while the grippers allow it to handle or manipulate objects. Below are the main types of robotic joints:

Types of Robotic Joints:

1. **Rotational Joint (R-Joint):**
    - This joint allows rotational movement around an axis that is perpendicular to the arm's axis. It enables the robot to rotate a part of its body or end effector.
    - Commonly used in robot arms for rotation around an axis, similar to how a human shoulder works.
2. **Linear Joint (L-Joint):**
    - A linear joint allows for sliding or translational motion. It can extend or retract along a linear axis, similar to a piston mechanism.
    - These joints are used for moving the robot in straight lines, often for lifting or extending tasks.
3. **Twisting Joint (V-Joint):**
    - This joint provides twisting motion between the input and output links. The output link's axis will be vertical to the rotational axis of the input link.
    - Twisting joints are used to achieve precise turning or rotation in robots, especially in tasks like tightening bolts.
4. **Orthogonal Joint (O-Joint):**
    - The orthogonal joint is similar to the linear joint, but the input and output links move at right angles to each other.
    - These joints enable the robot to move along perpendicular axes, typically used in Cartesian robots.
5. **Revolving Joint (V-Joint):**
    - A revolving joint allows for rotational movement where the input link is parallel to the rotating axis, and the output link rotates around this axis.
    - This type of joint is often used in robots that need a full range of rotation for precise operations, such as robotic arms used in welding or painting.

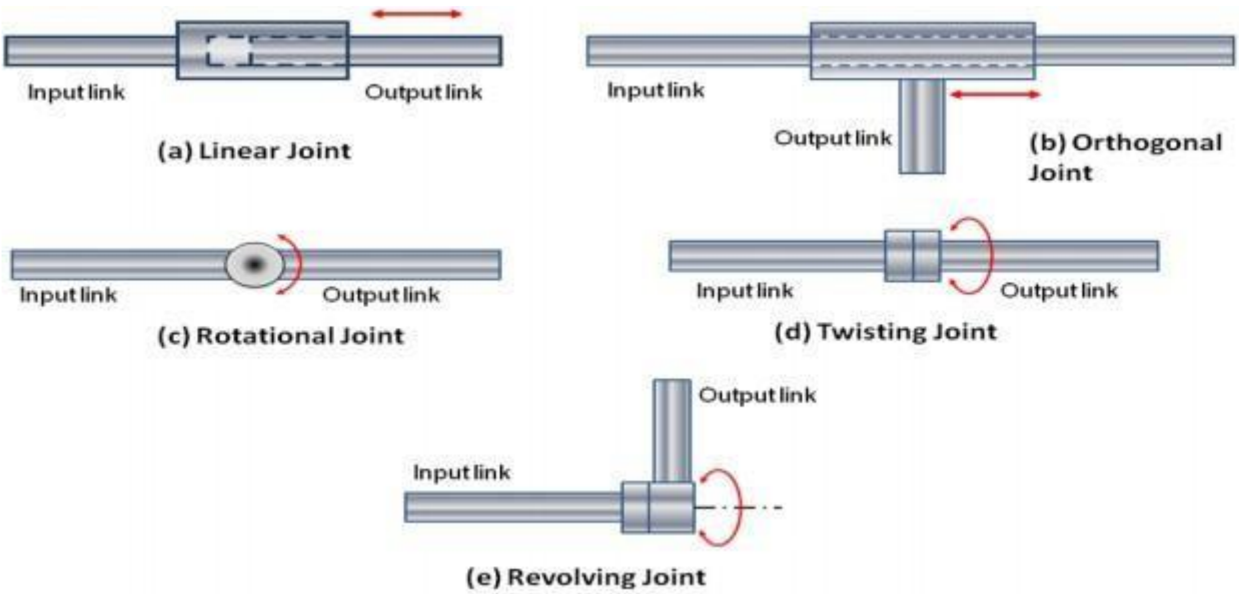

Figure 13 Robot Joints

Types of Robotic Grippers:

- **Mechanical Grippers:**

Mechanical grippers are one of the most widely used types of end effectors in robotics. These grippers are designed to mimic the function of a human hand by using mechanical fingers that can open and close to grasp objects securely. They are known for their simplicity, versatility, and reliability, making them suitable for a variety of industrial applications.

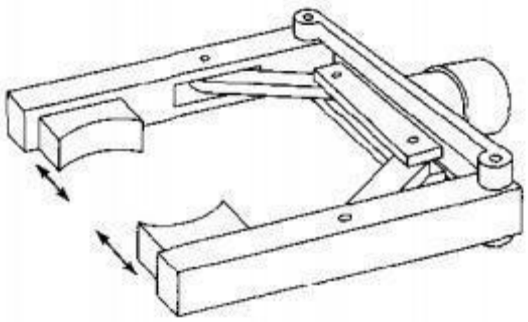

Figure 14 Mechanical gripper

- **Vacuum Grippers:**

Vacuum grippers, also known as suction grippers, use the principle of suction to pick up and hold objects. These grippers are ideal for handling objects that have flat, smooth, or non-porous surfaces. The suction is typically created by generating a vacuum inside the gripper's cup, which adheres to the surface of the object. When the vacuum is maintained, the object is securely held, allowing it to be moved and manipulated by the robot.

Figure 15 Suction gripper

• **Magnetic Grippers:**

Magnetic grippers are robotic end effectors that use magnetic fields to grasp and hold ferromagnetic objects, such as iron, steel, or other materials that are magnetically responsive. These grippers are particularly useful in material handling and assembly operations where the objects to be handled are ferromagnetic, making them an ideal solution for industries such as automotive, metalworking, and manufacturing.

Figure 16 Magnetic gripper

• **Pneumatic Grippers:**

Pneumatic grippers are robotic end effectors that use compressed air to open and close their gripper fingers. These grippers are highly effective in applications where quick movements, high gripping force, and reliability are required. Pneumatic grippers are widely used in industrial automation, particularly in applications involving repetitive tasks, precise handling, and quick cycle times.

Figure 17 Pneumatic gripper

- **Servo Grippers:**

Servo grippers are a type of robotic end effector that uses **servo motors** to precisely control the movement of the gripper fingers. These grippers are highly versatile and are often chosen for applications that require fine control over the gripping process, such as delicate handling, assembly tasks, and precision-based operations.

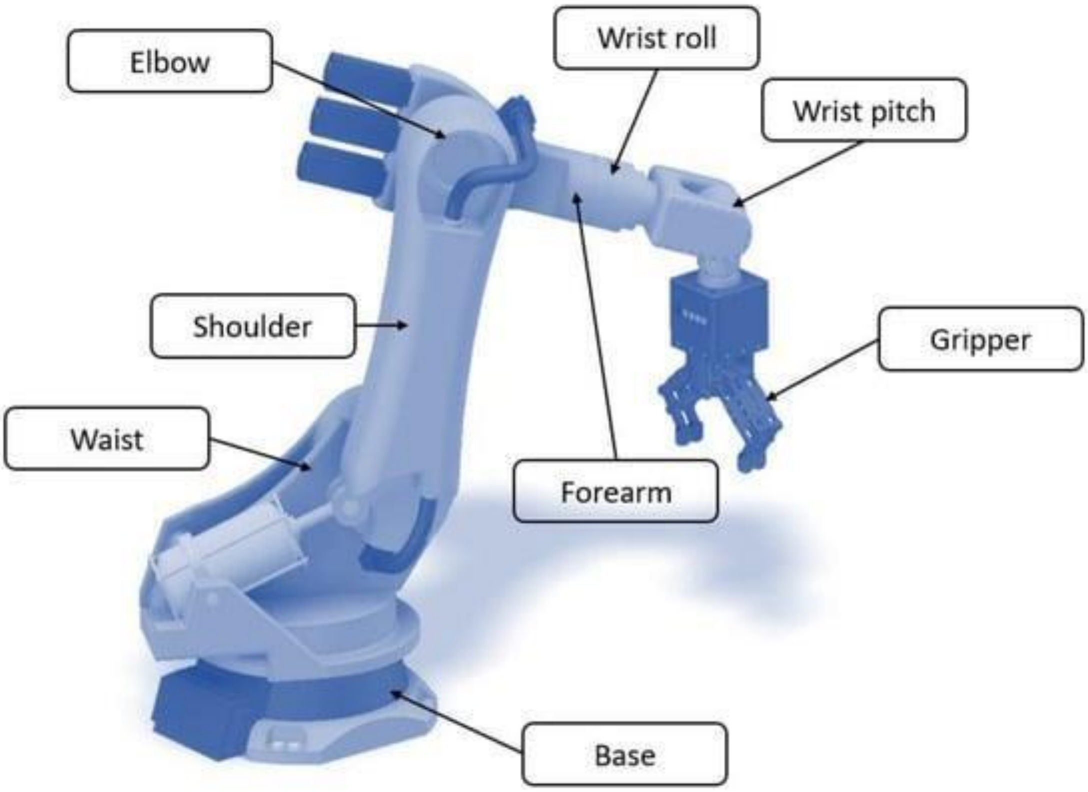

Figure 18 Servo gripper

- **Electrostatic Grippers:**

Electrostatic grippers are robotic end effectors that use **electrostatic forces** to attract and hold onto objects, typically those made of **insulating materials** such as plastics, ceramics, and thin films. These grippers leverage the principles of electrostatic attraction, which involves the interaction between electric charges to generate a holding force.

Figure 19 Electrostatic gripper

Applications of Robotic Grippers:

Robotic grippers are versatile end effectors that play a key role in various industries. They are used to manipulate, handle, and position objects in a wide range of applications, offering improved precision, speed, and efficiency. Below are some of the most common applications of robotic grippers:

1.Material Handling:

Loading and Unloading: Robotic grippers are widely used in material handling applications to load and unload parts from conveyor belts, assembly lines, or storage areas. They are designed to handle a variety of materials, from small components to heavy objects, ensuring smooth and efficient movement in manufacturing and warehousing environments.

Palletizing and Depalletizing: In industries like food, beverage, and logistics, robotic grippers are employed to pick up and stack products onto pallets or remove items from pallets. They ensure high-speed, accurate, and safe handling of items, reducing manual labor and increasing throughput.

2. Assembly:

Pick and Place: Robotic grippers are used to pick up components from one location and place them in another during the assembly process. This is common in industries like automotive and electronics, where robots precisely place parts such as screws, bolts, and electronic components into predefined positions.

Component Insertion: In the assembly of complex products, robotic grippers are used to insert components into parts or fixtures, such as inserting microchips into circuit boards or placing components in molds during injection molding processes.

3. Inspection:

Holding for Inspection: Grippers are used to hold parts in place for visual or mechanical inspection. This includes tasks such as checking the dimensions, surface quality, and integrity of parts. For example, in the automotive industry, robotic grippers hold car parts while vision systems or sensors inspect them for defects or dimensional accuracy.

Quality Control: Grippers also assist in automating quality control tasks, including non-destructive testing, 3D scanning, or pressure testing, by securely holding the part in the correct position during the inspection process.

4. Packaging:

Picking and Placing Products: In packaging, robotic grippers are used to pick products from conveyors and place them in packaging containers, such as boxes, cartons, or pallets. This application is prevalent in industries such as food and beverage, consumer electronics, and pharmaceuticals.

Case Packing: Robotic grippers are used to pack products into specific patterns in packaging boxes or crates. They are designed to handle different product shapes and sizes, allowing for more efficient packing and reducing waste in packaging lines.

5. Welding:

Holding Parts During Welding: In robotic welding applications, grippers are used to hold and position parts while they are welded together. The grippers ensure that the parts are correctly aligned during the welding process, leading to higher quality and precision in the finished product.

Tack Welding and Spot Welding: Grippers in welding applications can also be used to perform tack welding or spot welding, where small portions of parts are temporarily fixed before the main welding process.

6. Material Sorting:

Sorting and Distribution: Robotic grippers are used to sort materials, products, or components based on size, shape, color, or weight. In industries like recycling, grippers can pick up and sort recyclable materials, while in manufacturing, they help in sorting parts based on specifications.

Automated Distribution Systems: Grippers are utilized in automated distribution systems where they pick and place items into the correct bins or containers according to predetermined sorting rules.

7. Medical and Healthcare:

Surgical Assistance: In the medical field, robotic grippers are used in surgery to handle delicate instruments or tissue with precision. These grippers, combined with robotic arms, are used for minimally invasive surgeries, where human hands might lack the fine motor skills required for certain tasks.

Drug Handling and Dispensing: Robotic grippers can be used in pharmaceutical applications to handle drugs and medications safely, including sorting pills, filling prescriptions, and dispensing doses to patients.

8. Agriculture:

Picking and Harvesting: In agricultural applications, robotic grippers are used for harvesting fruits, vegetables, or flowers, picking them with care to avoid damage. Grippers designed for delicate crops can use soft-touch mechanisms or vacuum-based systems to handle produce gently.

Weeding and Sorting: In agricultural robots designed for weeding, grippers can be used to remove weeds from crops or sort them based on size and type for proper handling.

9. Construction:

Brick and Block Handling: Robotic grippers are employed in construction and building materials handling, such as placing bricks, blocks, or other construction materials in the correct position on the site.

Concrete Forming and Molding: Grippers are used in placing concrete forms, molds, and other materials, reducing human labor in physically demanding and repetitive tasks.

10. 3D Printing:

Material Handling for 3D Printers: Robotic grippers can assist in handling materials such as filaments, resins, or powders used in 3D printing applications. They ensure accurate and consistent material placement and can automate the process of switching materials during printing.