



CHAPTER 13 SPECIFICATION OF “ROBOTS”

Learning Outcomes

- Resolution of Robot
- Integrated Vision System
- Accuracy
- Importance of Accuracy

Robots are widely used in industries like manufacturing, healthcare, and space exploration. Their efficiency depends on key features such as precision, accuracy, and consistency. Understanding these features helps in selecting the right robot for a task and improving its performance.

Resolution refers to the smallest movement a robot can detect or make. Advances like high-resolution sensors, ultra-precise movements for tiny components, and smart vision systems are improving a robot’s ability to adjust in real time.

Accuracy is how precisely a robot can reach a target position. New techniques like advanced calibration, automatic error correction, and laser tracking help robots achieve better accuracy.

Repeatability is the ability of a robot to return to the same position again and again. This is important for tasks like welding in car production. Improved mechanical design and smart control systems are making robots more reliable for repeated tasks.

Resolution of a Robot

Resolution is the smallest movement a robot can detect or make. It plays an important role in tasks that need precise control, like assembling tiny electronic parts or performing delicate medical surgeries.

What Affects Resolution?

1. **Control System:** The system that guides the robot helps it make small, accurate movements. A better control system allows smoother and finer adjustments.
2. **Sensors:** Special sensors, like encoders and cameras, help the robot detect tiny changes in position, making it more precise.
3. **Mechanical Parts:** The quality of motors, gears, and other moving parts affects how small and smooth the robot’s movements can be.

Why is High Resolution Important?

- **Factories:** Robots with high resolution help in making tiny electronic parts with great accuracy.
- **Medical Use:** In surgeries, precise movements ensure safety and better results.
- **Quality Check:** Robots can spot small defects in products, improving quality control.

With new technology, robots are becoming even more precise using **better sensors and advanced vision systems**, helping them perform complex tasks with greater accuracy.

Current Trends in Robot Resolution

Robots are becoming more accurate with the use of **high-resolution encoders**, especially in fields like electronics and medical manufacturing, where even tiny mistakes can cause problems.

What are High-Resolution Encoders?

Encoders are special devices that help robots measure their position and movement. **High-resolution encoders** can detect very small movements, making robots more precise and reducing errors.

Where Are They Used?

1. **Electronics Manufacturing:** When making smartphones, microchips, or circuit boards, robots must place tiny parts very accurately. High-resolution encoders help them do this perfectly.
2. **Medical Device Production:** Robots help make medical devices like pacemakers and surgical tools. These devices need to be made with extreme accuracy, and high-resolution encoders ensure that each part is placed correctly.
3. **Surgical Robots:** Some robots assist in surgeries, where precision is critical. High-resolution encoders allow robotic arms to make smooth and accurate movements, making surgeries safer.

As **encoder technology improves**, robots are becoming more precise and reliable, helping industries that require **high accuracy and careful handling**.

Sub-Micron Resolution in Robots

Sub-micron resolution means a robot can detect and move by distances smaller than a micrometre, which is one-millionth of a meter. This level of precision is very important in industries where even the tiniest mistake can cause problems. In **semiconductor manufacturing**, robots with sub-micron resolution are used to place and inspect tiny components on microchips and circuits. **Medical and biotechnology fields** also use such robots for tasks like making medical devices and handling small samples with great accuracy. To achieve this precision, modern robots use **high-resolution sensors, laser tracking systems, and advanced control systems** that help them adjust and move with extreme

accuracy. With these advancements, robots are now able to perform highly delicate tasks, making them essential in industries that require **high precision and reliability**.

Integrated Vision Systems in Robots (Simplified)

What Are Integrated Vision Systems?

Integrated vision systems help robots "see" and understand their surroundings. These systems use cameras, sensors, and smart computer programs to process images and make decisions. This makes robots more accurate and useful in industries like manufacturing, healthcare, cars, and warehouses.

Parts of an Integrated Vision System

A vision system has different parts that work together to process images:

1. **Camera(s)**
 - Takes pictures or videos of objects.
 - Can be 2D (for simple images) or 3D (to understand depth).
2. **Lighting System**
 - Provides good lighting for clear images.
 - Uses LED lights, lasers, or infrared sensors.
3. **Image Processing Unit**
 - A computer program that improves images and finds useful details.
 - Uses AI to recognize objects and patterns.
4. **Sensors**
 - Help detect distance, movement, or object surface texture.
 - Includes LiDAR, depth sensors, and thermal cameras.
5. **Communication System**
 - Sends the image data to the robot's control system.
 - Helps robots make real-time decisions.
6. **Control System**
 - Uses image data to guide robot movements.
 - Helps robots do tasks like picking objects or checking product quality.

How It Works

1. **Capturing Images** – The camera takes pictures or records video.
2. **Improving Image Quality** – The system removes noise and adjusts brightness.
3. **Recognizing Objects** – The program detects objects, barcodes, or patterns.
4. **Making Decisions** – The robot decides what to do next.
5. **Adjusting in Real-Time** – If something moves, the robot changes its actions instantly.

Where Are Vision Systems Used?

1. **Factories & Manufacturing**
 - **Quality Check** – Detects defects in products.
 - **Assembly Work** – Helps robots fit parts correctly.
 - **Sorting Items** – Picks and places objects in the right spot.

2. Car Industry

- **Painting & Welding** – Ensures neat and precise work.
- **Checking Parts** – Inspects car components for errors.

3. Healthcare & Medical

- **Surgery Robots** – Helps doctors perform delicate operations.
- **Medicine Checking** – Ensures correct packaging and labelling.

4. Warehouses & Delivery

- **Sorting Packages** – Identifies and organizes items using barcodes.
- **Self-Driving Robots** – Helps robots move around safely.

5. Farming & Food Industry

- **Checking Crops** – Analysis plant health.
- **Food Sorting** – Removes damaged items from production lines.

Advantages of Vision Systems in Robots

- **More Accuracy** – Robots can correct mistakes in real time.
- **Faster Work** – Reduces human effort and speeds up processes.
- **Flexible Use** – Can be programmed for different tasks.
- **Less Waste** – Fewer mistakes mean less material waste.
- **Improved Safety** – Helps robots avoid accidents.

Challenges of Vision Systems

- **Expensive** – High-tech cameras and software cost a lot.
- **Complex Setup** – Needs experts to program and adjust.
- **Lighting Problems** – Bad lighting can affect image quality.
- **Slow Processing** – High-resolution images take time to process.

Future of Vision Systems in Robots

- **Smarter AI** – Robots will recognize objects better using deep learning.
- **3D Vision** – Robots will understand depth more accurately.
- **Faster Processing** – Computations will be done on the robot itself.
- **Multiple Sensors** – Robots will use vision along with other sensors like LiDAR.
- **Better Human Interaction** – Robots will adapt better to changes in real-time.

Vision systems have made robots smarter by giving them the ability to see and react. They are widely used in different industries like manufacturing, healthcare, logistics, and more. With improvements in AI and 3D vision, robots will become even better at their jobs, making automation easier and more efficient.

Accuracy in Robots

Accuracy in robots means how precisely a robot can place its tool or arm in the correct position. It ensures that the robot follows instructions correctly without making mistakes. Accuracy is very important in industries like **automobile manufacturing, medical surgeries, and electronics assembly**, where even a small error can cause problems.

Factors That Affect Accuracy

1. **Robot's Design:**
 - The way a robot is built, including its joints and motors, affects how accurate it is.
 - If parts wear out over time, the robot may become less precise.
2. **Calibration (Adjustments to Improve Accuracy):**
 - Robots need to be properly adjusted so that they move exactly as programmed.
 - New technology allows robots to **self-calibrate** and improve accuracy automatically.
3. **Control Systems:**
 - Robots use sensors to **check and adjust their position** while working.
 - **Feedback loops** help correct any errors in movement.
4. **Environment Factors:**
 - Temperature changes, vibrations, and external forces can reduce accuracy.
 - Some robots work in **controlled environments** to prevent mistakes.

Latest Developments in Accuracy Improvement

1. **Better Calibration Methods:**
 - New calibration techniques help robots adjust every part of their structure to **reduce movement errors**.
 - Some robots can **automatically calibrate** themselves, removing the need for human adjustments.
2. **Error Correction Systems:**
 - Robots can now **detect and fix mistakes in real time** by adjusting for temperature, wear, or other changes.
 - **AI-powered correction systems** help robots stay accurate over time.
3. **Laser-Based Feedback:**
 - Some robots use **laser tracking systems** to check if they are in the correct position and make corrections if needed.
 - **High-precision sensors** help robots move more accurately.

Where Accuracy is Most Important

1. **Medical Surgeries:**
 - **Surgical robots** help doctors perform delicate operations with extreme precision.
 - In medicine, robots are also used for tasks like **making and packaging medicines**.
2. **Electronics Manufacturing:**
 - Robots assemble **tiny circuit board components** with high accuracy.
 - In **semiconductor factories**, robots work at the **micron or sub-micron level** to place tiny parts perfectly.
3. **Car Manufacturing:**
 - Robots help with **welding, painting, and assembling** car parts.
 - High accuracy ensures that all car parts fit together perfectly.
4. **Aerospace Industry:**
 - Robots **assemble airplane parts** and **drill precise holes** in aircraft structures.

- Precision is important to ensure aircraft safety.
5. **3D Printing:**
- Robots must be **highly accurate** to ensure that layers are placed correctly in **3D printing**.
 - This is especially important in making **medical implants, car parts, and aerospace components**.

Why High Accuracy is Important

- **Reduces Mistakes:** Robots make fewer errors, leading to **better quality products**.
- **Saves Time:** Accurate robots **work faster** with fewer corrections.
- **Improves Product Quality:** Ensures **consistent** and **high-standard** manufacturing.
- **Handles Tiny Components:** High accuracy allows robots to **assemble very small parts**, like in electronics.
- **Reduces Human Work:** Robots with high accuracy require **less manual supervision**.

Challenges in Achieving High Accuracy

- **Expensive Technology:** High-accuracy robots need **advanced sensors and software**, which increases cost.
- **Sensitive to Environment:** Changes in **temperature, dust, and vibrations** can affect accuracy.
- **Difficult to Maintain:** Robots need **regular adjustments** to keep their accuracy high.
- **Wear and Tear:** Over time, **robotic parts may wear out**, reducing accuracy.

Future of Accuracy in Robots

- **AI-Based Learning:** Future robots will use **artificial intelligence** to **learn from mistakes and improve accuracy** over time.
- **More Advanced Sensors:** New sensors will allow robots to detect **even smaller movements**, improving precision.
- **Self-Adjusting Robots:** Robots will **automatically correct their errors** in real time.
- **Faster Communication (5G & Cloud):** Robots will be connected to **cloud systems** for better accuracy adjustments.

Accuracy is a key feature of robots, helping them perform tasks **correctly and efficiently**. **New technologies, AI, and real-time feedback systems** are improving how accurately robots work. In the future, robots will become even **smarter and more precise**, making them even more useful in industries like **medicine, aerospace, and manufacturing**.

Chapter Highlights

- **Key Features** – Robots need high **resolution**, **accuracy**, and **repeatability** for precise tasks.
- **Resolution** – Smallest movement a robot can detect. Important in electronics, surgery, and quality checks.
- **High-Resolution Encoders** – Help robots make tiny, precise moves in electronics and medical fields.
- **Sub-Micron Resolution** – Used in chip-making and biotechnology for ultra-precise movements
- **Vision Systems** – Cameras + AI help robots "see" and make real-time decisions. Used in factories, cars, healthcare, etc.
- **Accuracy** – Ensures robots reach exact positions. Important in surgeries, electronics, cars, aerospace.
- **Improvement Tools** – Self-calibration, AI error correction, and laser feedback boost accuracy.
- **Benefits** – Better quality, fewer mistakes, faster work, less human effort.
- **Challenges** – High cost, sensitivity to environment, maintenance issues.
- **Future Trends** – Smarter AI, 3D vision, self-adjusting robots, cloud & 5G integration.

Exercise

Multiple-Choice Questions (MCQs)

1. What does resolution in a robot refer to?
 - a) The speed of the robot
 - b) The smallest movement a robot can detect or make
 - c) The weight of the robot
 - d) The size of the robot
2. Which part helps a robot detect tiny position changes?
 - a) Gears
 - b) Encoders
 - c) Wheels
 - d) Batteries
3. Where is **sub-micron resolution** mostly used?
 - a) Agriculture
 - b) Clothing industry
 - c) Semiconductor manufacturing
 - d) Food delivery

4. What is the role of the control system in resolution?
 - a) Heating the robot
 - b) Controlling speed only
 - c) Guiding accurate small movements
 - d) Playing sounds
5. What does an integrated vision system allow a robot to do?
 - a) Fly
 - b) Swim
 - c) See and make decisions
 - d) Lift heavy objects
6. Which industry commonly uses surgical robots?
 - a) Construction
 - b) Healthcare
 - c) Retail
 - d) Education
7. High-resolution encoders are mainly used in:
 - a) Textile industry
 - b) Medical and electronics manufacturing
 - c) Mining
 - d) Tourism
8. What improves accuracy in robots?
 - a) Painting systems
 - b) Laser-based feedback and calibration
 - c) Large motors
 - d) Bright colours
9. A challenge in using vision systems is:
 - a) Too much light
 - b) Low cost
 - c) Complex setup and high cost
 - d) Simple programming
10. What is a benefit of robots with high accuracy?
 - a) More errors
 - b) Slower production
 - c) Better quality and fewer mistakes
 - d) More waste

True or False

1. Vision systems in robots reduce the need for manual supervision.
2. Accuracy and resolution are unrelated in robot design.
3. Sub-micron resolution is suitable for agricultural robots.
4. Lighting plays an important role in robot vision systems.
5. Robots with poor accuracy are suitable for surgical tasks.

Fill in the Blanks

1. _____ is the smallest movement a robot can detect or make.
2. High-resolution _____ help robots move with great precision.
3. Integrated vision systems use _____ to help robots "see".
4. Accuracy in robots ensures tasks are done with minimum _____.
5. _____ resolution is important in making microchips and medical tools.

Assertion and Reason

1. **Assertion (A):** Robots with high resolution can perform surgeries better.
Reason (R): High-resolution helps robots move with accuracy.
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):** Vision systems in robots can identify objects in real-time.
Reason (R): Vision systems include cameras and AI processing units.
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):** Sub-micron resolution is useful for farming tasks.
Reason (R): Farming requires placement of micro-components.
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):** Accuracy helps robots assemble electronic components.
Reason (R): Electronic parts are large and don't require precision.
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):** Laser-based feedback improves robot accuracy.
Reason (R): It helps the robot correct its position during tasks.
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 is the role of encoders in a robot's resolution?
2. Why is accuracy important in 3D printing robots?
3. List any two components of an integrated vision system.
4. Give one example each where resolution and accuracy are crucial.

5. Mention two challenges of using vision systems in robots.

Long Answer Questions

1. Explain the importance of resolution, accuracy, and repeatability in robot performance.
2. Describe the working and components of an integrated vision system.
3. How do high-resolution encoders improve robot function in medical or electronics industries?
4. What factors affect a robot's accuracy and how can they be improved?
5. What are the benefits and future trends in using vision systems in robotics?