Sensors and Robotics Technology

Robot End-Effectors and Robot Programming

Unit - 5

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Robot End-Effectors & Robot Programming

- A robot end-effector is the device attached to the robot's arm that interacts with the environment. It's the tool that the robot uses to perform specific tasks. The choice of end-effector depends on the task the robot is designed to accomplish.
- Robot programming is the process of instructing a robot to perform specific tasks. This involves writing a program that outlines the sequence of movements and actions the robot should take.

Different Types of Robot Grippers

- Robot grippers are essential tools that enable robots to interact with the physical world.

Mechanical Grippers

- **Parallel Grippers:** These are the most common type, consisting of two jaws that move towards or away from each other to grasp objects. They're simple, reliable, and suitable for a wide range of applications.
- **Angular Grippers:** Similar to parallel grippers, but the jaws move in an angular motion, making them ideal for gripping objects in tight spaces or at odd angles.
- **Three-Finger Grippers:** These grippers offer more flexibility than two-finger grippers, allowing them to handle a wider variety of objects, including delicate or irregularly shaped items.

Magnetic Grippers

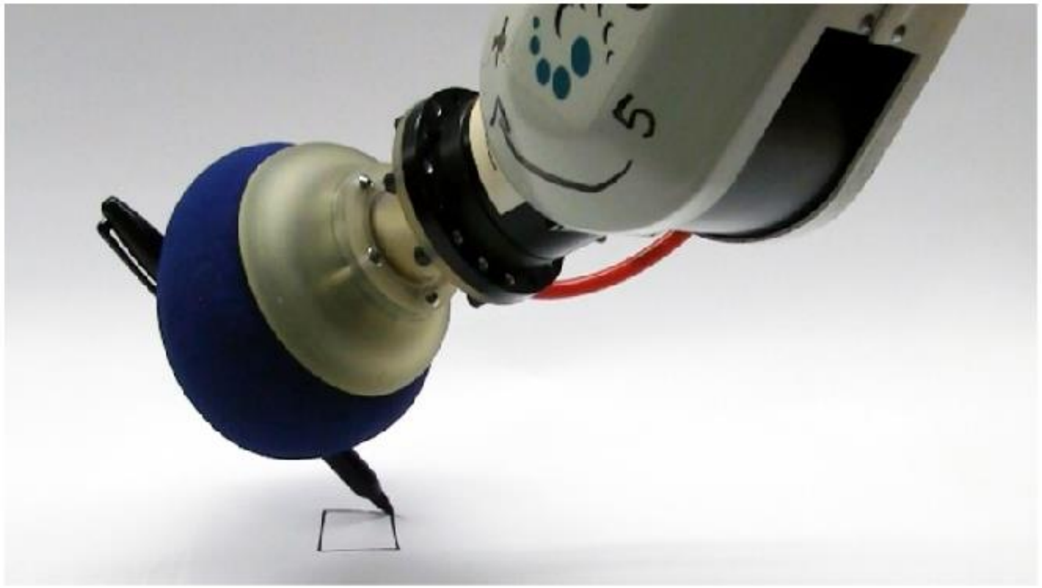
- These grippers use powerful magnets to attract and hold ferromagnetic objects. They're particularly useful for handling metal parts in manufacturing and assembly processes.

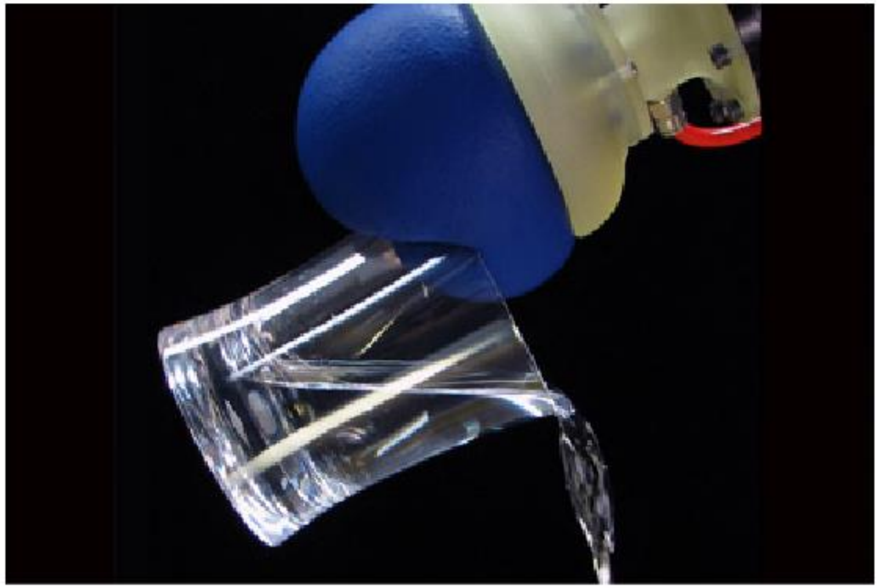
Vacuum Grippers

- Vacuum grippers create a vacuum seal to hold objects, often used for handling flat, smooth surfaces like glass, cardboard, or plastic sheets.

Adhesive Grippers

These grippers use adhesive materials to grip objects. They're suitable for handling delicate or fragile items that might be damaged by other types of grippers.





Choosing the Right Gripper

The choice of gripper depends on several factors:

- Object shape and size: The gripper must be able to securely grasp the object without damaging it.
- Object weight: The gripper must be strong enough to lift the object.
- Surface properties: The gripper must be compatible with the object's surface.
- Environment: The gripper must be able to operate in the specific environment, such as a cleanroom or a harsh industrial setting.

Gripper Force Analysis

Gripper force analysis is a crucial step in robot design, ensuring the gripper can securely grasp objects without damaging them or slipping.

Object Weight and Shape:

- Weight: The gripper must exert enough force to overcome the object's weight and any additional forces, such as acceleration or friction.
- Shape: The shape of the object determines the contact area between the gripper and the object, affecting the required force distribution.

Friction Coefficient:

- The friction coefficient between the gripper and the object influences the required gripping force. A higher friction coefficient reduces the necessary force.

Safety Factor:

- A safety factor is often applied to account for uncertainties in the object's weight, friction, and the gripper's mechanical properties.

Gripper Force Calculation

A common approach is to calculate the minimum gripping force required to prevent slipping. This can be done using the following formula:

F_grip = (W * μ) / (2 * μ * cos(θ) - sin(θ))

Where:

- F_grip: Minimum gripping force
- W: Weight of the object
- μ: Coefficient of friction between the gripper and the object
- θ: Angle between the gripping force and the vertical direction

Gripper Design

Gripper design involves considering various factors to ensure optimal performance and reliability:

- **Material Selection:**
  - The material should be strong, lightweight, and resistant to wear and tear.
  - Common materials include aluminum, steel, and plastics.
- **Actuator Selection:**
  - The actuator (e.g., pneumatic, hydraulic, or electric motor) must provide sufficient force and speed to operate the gripper.

Gripper Design

Sensor Integration:

- Sensors like force sensors, tactile sensors, or vision systems can be integrated to provide feedback on the gripping force and object properties.

Ergonomic Design:

- The gripper should be designed to minimize operator fatigue and maximize productivity.

Gripper Perception

Gripper perception involves using sensors to gather information about the object being grasped. This information can be used to adjust the gripping force, orientation, or other parameters to ensure a secure and reliable grasp.

Common Sensors:

- **Force Sensors:** Measure the force exerted by the gripper on the object.
- **Tactile Sensors:** Provide information about the object's surface properties, such as texture and temperature.
- **Vision Systems:** Use cameras to capture images of the object and provide information about its shape, size, and orientation.

Localization and Mapping & Probabilistic Robotics Perspective

- (SLAM) is a fundamental problem in robotics and computer vision, where a robot or autonomous vehicle simultaneously builds a map of an unknown environment while keeping track of its location within that map.
- Probabilistic Robotics is a framework that uses probabilistic methods to model and reason about uncertainty in robotic systems. This framework is particularly well-suited for SLAM, as it allows us to represent and update our beliefs about the robot's pose and the map as we gather more sensor data.

Bayesian Filtering

- Particle Filter: A sampling-based approach that represents the robot's pose and map as a set of particles, each with an associated weight. As new sensor data arrives, the particles are resampled and reweighted to reflect the updated belief.
- Kalman Filter: A recursive filter that estimates the state of a dynamic system (e.g., the robot's pose) from a series of noisy measurements. It is particularly useful for linear systems with Gaussian noise.
- Extended Kalman Filter (EKF): An extension of the Kalman filter that can handle nonlinear systems by linearizing them around the current state estimate.
- Unscented Kalman Filter (UKF): A nonlinear filtering technique that uses a deterministic sampling approach to propagate the mean and covariance of the state distribution through the nonlinear system.

Graph-Based SLAM:

GraphSLAM: Represents the SLAM problem as a graph, where nodes represent robot poses and edges represent constraints between them. The robot's pose and map are estimated by solving a least-squares optimization problem on the graph.

Sensor Fusion:

Combines information from multiple sensors (e.g., LiDAR, cameras, wheel odometry) to improve the accuracy and robustness of SLAM.

Tutorial 3

- Path planning
- BFS
- DFS
- Dijkstra
- A-star
- D-star
- Introduction to Reinforcement Learning.

Voronoi Diagrams

- Concept: A Voronoi diagram is a partitioning of a plane into regions based on distance to specific points called sites. In robotics, these sites can represent obstacles or target points.

Application in Robotics:

- Path Planning: The Voronoi diagram's edges represent the paths with maximum clearance from obstacles. By following these edges, a robot can navigate safely.
- Coverage Path Planning: Voronoi diagrams can be used to divide a space into regions, allowing multiple robots to efficiently cover an area.

Potential Fields

Concept:

- A potential field is a scalar field where each point in the environment is assigned a potential value. Attractive potentials pull the robot towards the goal, while repulsive potentials push the robot away from obstacles.

Application in Robotics:

- Obstacle Avoidance: Repulsive potentials generated by obstacles create a force field that guides the robot away from them.
- Goal Seeking: Attractive potentials towards the goal create a force that pulls the robot towards its destination.

Hybrid Approaches

Combining the Best of Both Worlds: Hybrid approaches combine the strengths of Voronoi diagrams and potential fields to overcome their limitations.

Benefits:

- Efficient Path Planning: Voronoi diagrams can provide a global view of the environment, while potential fields can handle local obstacles and dynamic environments.
- Smooth and Obstacle-Free Paths: Hybrid approaches can generate smoother and more efficient paths compared to either technique alone.

Simultaneous Localization and Mapping (SLAM)

- Simultaneous Localization and Mapping (SLAM) is a computational problem that involves
- constructing or updating a map of an unknown environment while simultaneously keeping track of an agent's location within 1 it. It's a fundamental challenge in robotics, autonomous vehicles, and augmented reality.