Sensors and Robotics Technology

Robot Kinematics and Dynamics Unit - 4

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Trajectory Planning

Trajectory planning is a critical aspect of robotics, involving the generation of smooth and efficient paths for a robot to follow between two or more points in space. This process ensures that the robot moves safely, accurately, and without causing damage to itself or its surroundings.

Path Planning

- Configuration Space: Defines all possible positions and orientations of the robot's joints or end-effector.
- Obstacle Avoidance: Identifies obstacles in the environment and finds a collision-free path.
- Path Generation: Creates a sequence of points or waypoints that the robot must follow.

Trajectory Generation

- Time Parameterization: Assigns a specific time to each point on the path.
- Smoothness Constraints: Ensures that the trajectory is smooth, with continuous velocity and acceleration profiles to avoid jerky movements.
- Dynamic Constraints: Considers the robot's physical limitations, such as joint limits, motor torques, and payload capacity.

Trajectory Tracking

- Feedback Control: Uses sensors to measure the actual position and velocity of the robot and compares them to the desired trajectory.
- Control Law: Calculates the necessary control inputs (e.g., joint torques) to correct any deviations from the desired trajectory.

Common Trajectory Planning Techniques

- **Polynomial Trajectory Planning:**
  - Uses polynomial functions to generate smooth trajectories.
  - Offers flexibility in controlling the shape of the trajectory.
- **Cubic Spline Interpolation:**
  - Creates smooth curves that pass through a set of waypoints.
  - Ensures continuity of position, velocity, and acceleration.
- **Bézier Curves:**
  - Defines a curve using control points, allowing for flexible shape control.
  - Widely used in computer graphics and animation.

Common Trajectory Planning Techniques

- **Time-Optimal Trajectory Planning:**
  - Generates trajectories that minimize the time taken to reach the goal while satisfying constraints.
  - Often involves solving complex optimization problems.

Applications of Trajectory Planning

- **Industrial Robotics:**
  - Assembly line automation
  - Material handling
  - Welding and painting
- **Mobile Robotics:**
  - Autonomous vehicles
  - Drones
  - Service robots
- **Medical Robotics:**
  - Surgical robots
  - Rehabilitation robots

Robot Control

Robot control is a multifaceted field that involves a variety of techniques to ensure precise and efficient movement.

PWM (Pulse-Width Modulation):

- A fundamental technique for controlling the speed and direction of DC motors.
- Involves rapidly switching a DC voltage on and off.
- The duty cycle, or the proportion of time the voltage is on, determines the average voltage applied to the motor.
- Higher duty cycles result in higher speeds, while lower duty cycles result in lower speeds.

Joint Motion Control

- Focuses on controlling the individual joints of a robot arm or manipulator.
- Involves specifying desired joint positions, velocities, or torques.

Common techniques include:

- PID Control: A classic control method that uses proportional, integral, and derivative terms to adjust the control signal.
- Model-Based Control: Utilizes a dynamic model of the robot to predict its behavior and compute appropriate control inputs.
- Learning-Based Control: Employs machine learning algorithms to learn optimal control strategies from data.

Feedback Control

- A control system that uses feedback from sensors to adjust the control input.
- Involves measuring the actual output of a system and comparing it to the desired output.
- The error between the actual and desired output is used to adjust the control input.
- PID control is a common example of feedback control.

Computed Torque Control

- A model-based control technique that aims to cancel out the nonlinear and coupled dynamics of a robot manipulator.
- Involves computing the torques required to achieve the desired motion, taking into account the robot's dynamic model.
- The computed torques are then applied to the joints using actuators.
- This technique can achieve high-precision and high-performance control.

Combining These Techniques

In practice, these techniques are often combined to achieve complex robot behaviors. For example, PWM may be used to control the speed of DC motors that drive the robot's joints, while feedback control and computed torque control may be used to ensure accurate joint positioning and trajectory tracking.