EN3563 - Robotics

Mini Project: Implementation of a Robot Arm

Overview

Industrial robot arms are widely used across industries, from simple pick-and-place operations on assembly lines to advanced applications such as telesurgery. In this assignment, students will work in groups to perform a pick-and-place task using a robot arm with at least four degrees of freedom (DoF). Each group may have a **maximum of three members**, and students can form their own groups. The task can be implemented either on a physical robot arm or in the Gazebo simulation environment using the provided SolidWorks design files. Students are expected to model the robot, compute its kinematics, and execute the pick-and-place task with appropriate trajectory planning and velocity control.

Physical Implementation

Those who choose to implement the task physically must build a suitable serial link manipulator robot arm with at least 4 degrees of freedom (DoF). Open-source designs are permitted to use, provided that proper acknowledgment is given. Perform the tasks outlined below and submit both a report and a video demonstration of your work.

1. Motion Task

- Pick up a regular object from a predefined coordinate and place it specified destination point.
- Object must remain **upright** (orientation unchanged) during the entire motion.

Simulation

Alternatively, students can demonstrate the implementation through a simulation in the Gazebo environment with a given industrial robot arm. The SolidWorks CAD files and specifications of the YASKAWA GP7 robot arm are available on Moodle. Please note that the provided CAD model does not include an end effector; students may use a suitable simplified gripper model as the end effector in the simulation. The details on the maximum joint ranges and speeds are available in the specification document. Perform the following in the simulation and submit a screen-recorded video along with the report.

1. Simulation Setup in Gazebo

- Import the robot arm into Gazebo.
- Setup the simulation environment as follows:
  - Place the robot arm at the origin $(0, 0, 0)$.
  - Place **Box A** ($30\,\text{cm} \times 30\,\text{cm} \times 20\,\text{cm}$) at position $(1\,\text{m}, 1\,\text{m}, 0)$.
  - Place **Box B** ($5\,\text{cm} \times 5\,\text{cm} \times 5\,\text{cm}$) at a random reachable location on the ground.

2. Motion Task

- Pick up **Box B** and place it at the **center of the top surface of Box A**.
- Box B must remain **upright** (orientation unchanged) during the entire motion.

Tasks

1. Modeling and Kinematics

- Visualize and label the coordinate frames for each link.
- Create the **Denavit–Hartenberg (D-H) parameter table**. Dimensions can be measured using SolidWorks.
- Compute the **forward kinematic matrices** using the D-H parameters.
- Derive the equations required to calculate joint angles for a given end-effector position and orientation (**inverse kinematics**).

2. Motion Planning and Control

- Implement **trajectory planning** to maintain the upright orientation of Box B.
- Apply a **smooth velocity profile** (e.g., trapezoidal or S-curve).

Implementation Notes

- You are encouraged to begin the simulation with a **simplified model** of the robot using accurate D-H parameters before incorporating the full CAD model.
- ROS2 (Robot Operating System) can be used for joint control and motion planning.

Submission Requirements

A group should make one submission with,

- A concise report that includes:
  - index numbers of all members
  - Coordinate frame assignment
  - D-H parameter table
  - Forward and inverse kinematics calculations
  - Code snippets for:
    - Inverse kinematics
    - Trajectory planning
    - Velocity control
  - Brief explanation of the implementation process and results.
- A video footage of physical implementation or a screen-recorded video of simulation.
- (Optional but recommended) A **GitHub repository** for your code and documentation. Include the link in your report.

Resources

- ROS2 Documentation - https://docs.ros.org/en/jazzy/Releases.html
- Gazebo Tutorials - https://gazebosim.org/docs/latest/tutorials/