Project Title: Pick-and-Place Robotic Manipulator using UR5 and ROS 2

Course: Robotics  
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### **1. Introduction**

Industrial robotics has become a cornerstone of modern manufacturing, logistics, and material-handling systems. Among the most common and essential applications of industrial robots is the pick-and-place task — the process of automatically picking up an object from one location and accurately placing it in another. These operations require precise motion planning, repeatability, and coordination between perception, control, and mechanical actuation.

With the rise of open-source robotics software such as the Robot Operating System 2 (ROS 2) and modern physics simulators such as MuJoCo, researchers and students can now design, simulate, and test robotic systems with realistic physics before deploying them on physical hardware. In this project, the Universal Robots UR5 manipulator is selected to perform a simulated pick-and-place operation using ROS 2 and MuJoCo.

### **2. Robotic Application Overview**

The pick-and-place task involves three key stages:

1. Pick: The manipulator identifies and reaches toward an object at a defined location.
2. Transfer: The robot moves the object to a desired position along a planned trajectory.
3. Place: The manipulator accurately positions and releases the object in its target pose.

This application is fundamental in packaging, sorting, and automated assembly lines. The system must achieve high positional accuracy and smooth motion to avoid collisions or part damage. The use of simulation enables safe testing of motion strategies before applying them to real industrial robots.

### **3. Selected Robotic Arm: UR5 Manipulator**

The UR5 from Universal Robots is a 6-degree-of-freedom (DoF) collaborative robotic arm widely used for academic and industrial applications. It features:

* 6 Revolute joints allowing full spatial manipulation of end-effector pose.
* Payload capacity: 5 kg.
* Reach: Approximately 850 mm.
* Repeatability: ± 0.1 mm.
* Collaborative design: Allows safe human-robot interaction.

Its moderate payload, light weight, and open software ecosystem make it ideal for educational robotics projects. The UR5’s kinematics and dynamic models are publicly available, enabling students to study forward and inverse kinematics, trajectory planning, and control strategies.

The UR5 model is provided in ROS through the ur\_description package, which defines its geometry in Xacro/URDF format. This file describes all links, joints, and meshes necessary for simulation in tools such as Gazebo or MuJoCo.

### **4. Simulation Environment**

This project uses ROS 2 Humble Hawksbill as the middleware for robot control and communication. ROS 2 provides standardized interfaces for topics, services, and actions, which enable modular design of robotic systems. Motion planning will later be integrated through MoveIt 2, while perception and gripper control can be added in future milestones.

For physics-based simulation, MuJoCo 3.2.0 is selected due to its high-fidelity dynamics and real-time performance. MuJoCo allows visualization of articulated bodies with contact dynamics, enabling realistic testing of the UR5’s motion before hardware implementation.

### **5. Proposed Project Flow**

1. Setup: Install and verify ROS 2 and MuJoCo functionality.
2. Model Integration: Load the UR5 Xacro file into the simulator and generate its URDF model.
3. Motion Testing: Visualize the arm’s joint motion in simulation.
4. Pick-and-Place Logic: Implement a sequence to grasp and relocate an object.
5. Evaluation: Analyze trajectory smoothness, accuracy, and computation time.

This flow ensures a structured progression from environment setup to task automation, emphasizing simulation and modular control design.

### **6. Conclusion**

The pick-and-place application using the UR5 robot offers an accessible yet powerful platform to study robotic manipulation. Through ROS 2 and MuJoCo, the project provides hands-on experience with robot modeling, simulation, and control. Future milestones will extend this foundation by implementing motion planning, perception, and feedback control to achieve fully automated object handling in a simulated industrial environment.