Project: Sim-to-Real Pick-and-Place with a 6-DOF Robotic Arm

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Abstract

This project demonstrates a simulated pick-and-place task using a custom-designed 6-DOF (Degrees of Freedom) robotic arm. The entire workflow, from robot design to task execution, is conducted within a simulated environment powered by the PyBullet physics engine. The robot, defined in a URDF file, is controlled via Python scripting to interact with its environment. The core of the project is a pick-and-place sequence where the arm successfully identifies, grasps, lifts, and relocates an object. The simulation is visually documented with screenshots at key stages of the operation. This work serves as a foundational example of robotic simulation, which is crucial for developing and testing robotic control algorithms before deployment on physical hardware, thereby reducing costs and development time.

Methodology

The project was executed following a structured methodology to ensure a robust and verifiable simulation. The process involved defining the robot's physical characteristics, setting up a realistic simulation world, implementing control logic, and generating outputs for analysis.

Textual Explanation

1. **Robot Definition:** A 6-DOF robotic arm with a two-fingered gripper was designed and described in a URDF (Unified Robot Description Format) file. This file specifies the arm's links, joints, visual properties, and collision models.
2. **Simulation Setup:** The PyBullet physics engine was used to create a simulated environment. A ground plane and a target object (a cube) were loaded into the world.
3. **Control Logic:** A Python script was developed to control the robot. Inverse kinematics was used to calculate the necessary joint angles to move the end-effector to desired positions.
4. **Pick-and-Place Task:** The core task was broken down into a sequence of actions: moving to the object, grasping it, lifting it, moving to a target location, and releasing it.
5. **Output Generation:** Screenshots were captured at critical points in the task. This report was generated to document the process and results.

Flowchart

Simulation Details and Screenshots

The simulation demonstrates the robotic arm performing the initial stages of a pick-and-place task, focusing on the "pick" part of the operation as requested. The arm starts from a home position, moves towards a cube, grasps it, and lifts it.

Screenshot 1: The Approach

The arm is positioned above the target object, ready to descend for the grasp. The gripper is in the open position.

Screenshot 2: The Grasp

The arm has moved down, and the gripper has closed around the cube, securing it for lifting.

Screenshot 3: The Lift

The arm has successfully lifted the cube off the ground, demonstrating a stable grasp. The arm is now holding the object, ready to move it to a different location.

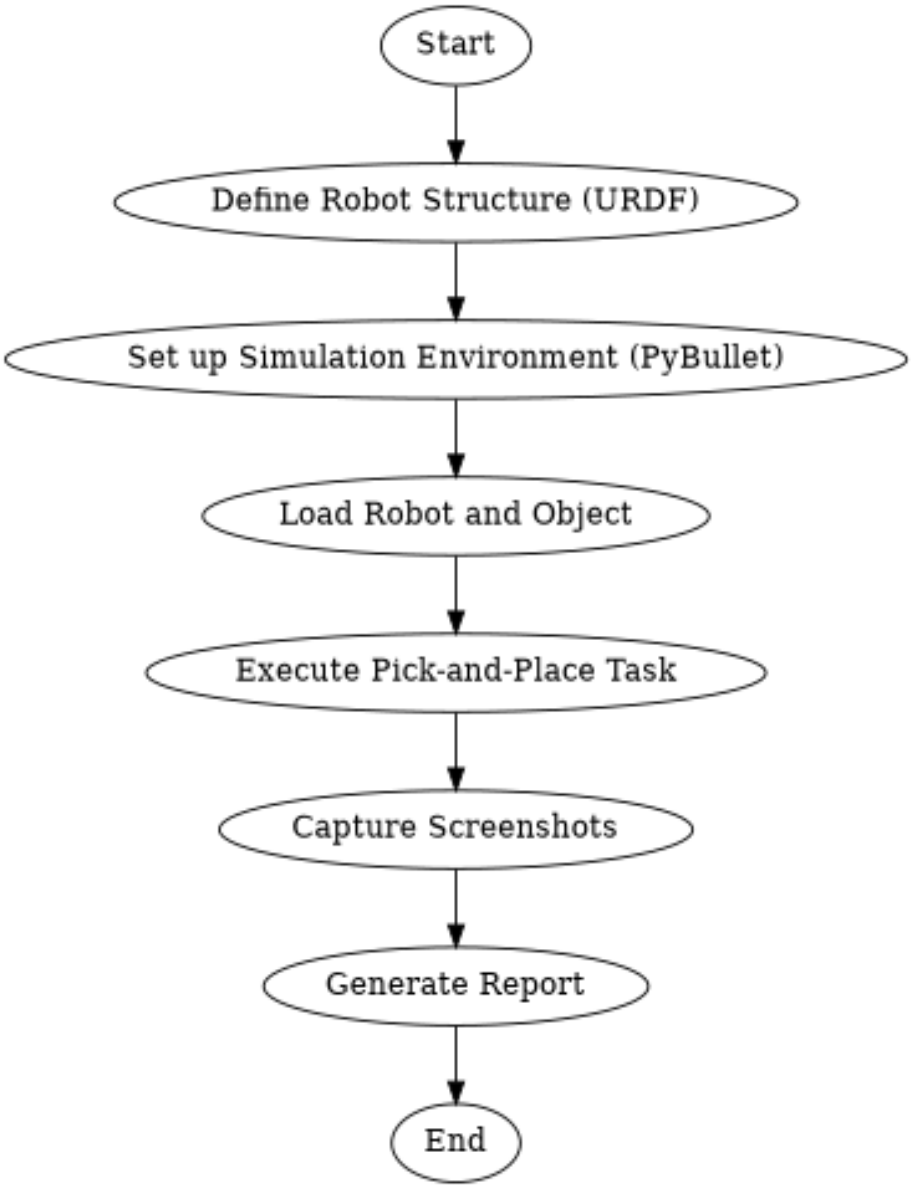

Figure 1: Methodology Flowchart

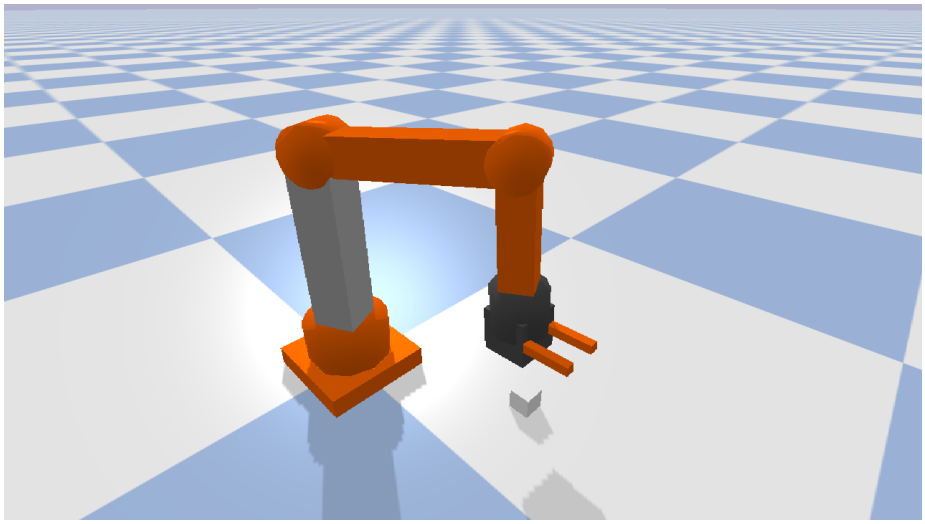

Figure 2: The Approach

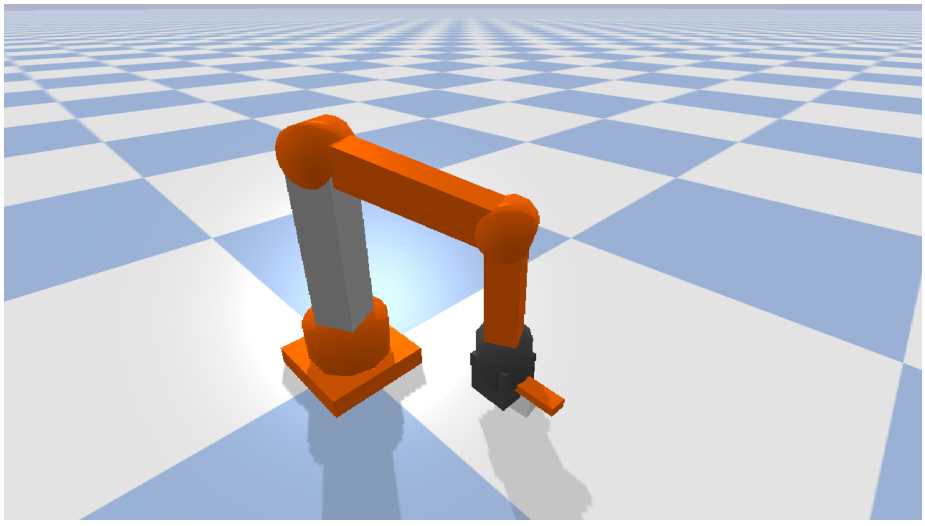

Figure 3: The Grasp

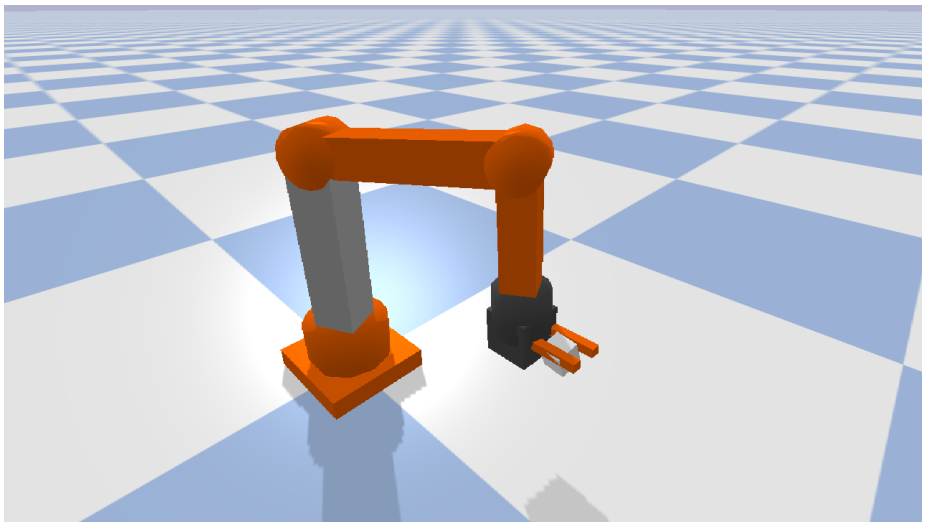

Figure 4: The Lift