Lab 3

D-H Representation, Forward and Inverse Kinematics

Objective

In this experiment, students will continue using the PUMA 260 robot to achieve the following objectives:

1. Utilize D-H representation to solve the PUMA 260 robot forward kinematics.
2. Verify the forward kinematics of the PUMA 260 robot by comparing the results from Matlab simulation and the robot manipulator.
3. For a given XYZ_OAT, write a Matlab program to solve the inverse kinematics.
4. Verify the inverse kinematics of the PUMA 260 robot by comparing the results from Matlab Simulation and the robot manipulator.

Reference Materials

1. Lecture notes, i.e. D-H representation, forward/inverse kinematics and OAT definition of Puma 260.
2. Supplemental material about geometrical approach solving inverse kinematics of Puma 260.

Hints: Refer to lecture notes of D-H table for PUMA 260 Robot.

Pre-lab

Please read the following materials:
Lecture notes about "Denavit-Hartenberg", "DH for Puma 260", "OAT (Puma)", "Supplemental materials in Lecture 21".
Note: There may be a small quiz at the first of the first lab session related to these materials.

Background

Suppose that we have a robot whose configuration is known, which means all the link lengths and joint angles of the robot are known. Calculating the position and

orientation of the end-effector of the robot is called forward kinematics analysis. In other words, if all robot joint variables are known, using forward kinematics equations, we can find where the robot's end effector is. However, if we want to place the end-effector at a desired position and orientation, we have to know how to adjust the robot joints. This is called the inverse kinematics. Instead of inputting the known robot joint angles as in the forward equations, we need to derive the inverse of these equations in order to find the necessary joint angles to place the end-effector in the desired position and orientation.
The Denavit-Hartenberg (D-H) representation is a simple way of modeling robot links and joints. It can be used for any robot configuration, regardless of the type of joints and links. We can also use D-H representation to describe the transformation in any coordinates, such as Cartesian, cylindrical, spherical, Euler, and RPY. Although the direct modeling of simple robots such as cylindrical robot, spherical robot and articulated robot are faster and more straightforward, the D-H representation is very useful in modeling configurations of general robots. Additionally, the D-H representation helps to solve some other problems such as the calculation of Jacobians, force analysis, etc.

Lab Procedure

This lab consists of the following two parts:

Part 1: Forward Kinematics

1. Write a soft-coded Matlab program that calculates the total transformation between the base and the end-effector of the robot. (Use "sym" and "syms" commands in Matlab if it is needed)
2. Given a set of joint configurations: (θ_1=30 ˚,θ_2=30 ˚,θ_3=30 ˚,θ_4=30 ˚,θ_5=30 ˚,θ_6=30 ˚) Use the Matlab program created in step 1 to calculate the XYZ_OAT position of the end effector.
3. Using the same joint configuration specified in step 2, use minicom or the binaries provided in lab 2 to display the position of the end effector. Compare these results with the ones obtained in step 2.
4. Repeat the same procedures for another 3 arbitrary joint configurations.

Part 2: Inverse Kinematics

1. Derive the inverse Kinematics of the PUMA 260. (Hints: use your notes from lecture 21 and make sure you use the position of joint 4 when deriving θ1, θ2 and θ3).
2. Write a Matlab program to implement the inverse kinematics.

3. Select four arbitrary XYZ_OAT (i.e. XYZ_OAT in Part 1 could be an alternative), and use the Matlab program you created for inverse kinematics, to find all joint angles.
4. Use those joint angles to define a location in the PUMA 260, and move the robot to that position. What is the XYZ_OAT? Compare it with the one you picked in step 3.
5. Write down those joint angles in step 4 and use the forward kinematics program you wrote in Part 1 to verify the result again.

Post-Lab Questions:

- Explain how you found OAT angles from rotation matrix in part 1. Derive all required equations.
- Derive all steps to solve the inverse kinematics for puma260