Assignments 3 & 4

ME 639 - Introduction to Robotics

IIT Gandhinagar

Due: 11:59pm on Monday, **9th October, 2023** on GitHub
Collaboration Policy: Discussion within groups is permitted, but all submitted material must be your own material.

Tasks:

1. Review the discussion on singularities, decoupling of singularities, and various examples of singularities and singular configurations in the textbook. Describe in 3-4 sentences in your own words what is a singular configuration and how do you find singular configurations. Also, can you detect if a particular configuration is close to a singular configuration using the Manipulator Jacobian?
2. Read the definition of DH parameters in the textbook including the summary of steps. Pay particular attention to the end-effector frame and wrist as that was not discussed in class.
3. Write a python subroutine that takes in as inputs the number of links and the DH parameters in table/matrix form, and returns the (a) complete manipulator Jacobian, (b) the end-effector position, and (c) end-effector velocity. If you need any other inputs (such as information about the nature of joints (R/P), incorporate this as an additional input to the python code. However, the code is to be setup in a way that if this information is not provided, default assumption of all joints being revolute joints is to be assumed.
4. Apply the above code to the two common RRP configurations of Stanford manipulator and SCARA manipulator. Verify that the results obtained using the code match with the expressions derived earlier (by yourself and in the textbook). You may choose a few configurations (numerical values) to verify your results.
5. Solve problem 3-7 in the textbook and also verify your hand-derived answers using the code in Task 3.
6. Solve problem 3-8 in the textbook and also verify your hand-derived answers using the code in Task 3.
7. Compare the three different configurations for 2R manipulator (direct drive, remotely-driven, and 5-bar parallelogram arrangement) and explain the key differences and advantages of each arrangement.
8. Complete the derivation of the dynamic equations of 2R manipulator discussed in class and compare your results with those in the miniproject. Remark on any discrepancies or observations.

9. Review derivations of dynamics equations of motion for other two configurations of 2R manipulator discussed in the textbook.
10. Summarize neatly in your own handwriting, the key steps to derive equations of motion when you are already provided $\mathbf{D}(\mathbf{q})$ and $\mathbf{V}(\mathbf{q})$.
11. Write a code that uses symbolic computation and differentiation to derive the equations of motion for any robot given $\mathbf{D}(\mathbf{q})$ and $\mathbf{V}(\mathbf{q})$.
12. Write a python subroutine to solve for the inverse position kinematics for the Stanford manipulator using the discussion in Section 4.3.2 in the textbook. Plug in a few representative numerical values to compute the joint variables. Then confirm if you plug in these resulting joint variable answers with your earlier forward position kinematics code that you are indeed obtaining correct answers.
13. Write a python subroutine to solve for the inverse position kinematics for the SCARA manipulator using the discussion in Example 4.4.2 in the textbook. Plug in a few representative numerical values to compute the joint variables. Then confirm if you plug in these resulting joint variable answers with your earlier forward position kinematics code that you are indeed obtaining correct answers.
14. Write a python subroutine to calculate the joint velocities using end-effector cartesian velocities (using the discussion in Section 5.4 in the textbook). Heads up: You don't need to write the part about calculating joint accelerations, however, you may need to create that in the future for your projects and future tasks.
15. Read about Euler angles from Section 2.3.2.
16. Read about spherical wrist and tool frame from Section 1.4.7, the last few paragraphs before the Summary 3.2.1, step 6 of Summary 3.2.1, and about its inverse kinematics from Section 4.4.
17. Write a python subroutine for the inverse kinematics of the spherical wrist using the discussion in Section 4.4.
18. Determine the DH parameters for a 3D printer (PPP configuration), and use earlier written forward kinematics and Jacobian subroutines to compute the end-effector position and velocities for a few representative numerical values (of your choice).
19. Work out the inverse kinematics for the 3D printer. Hint: This is an easy question! Heads up: You don't need to write or submit the part about calculating the joint variable for any given 3d print trajectory at the moment, but you will see this on a future assignment/task.