Robotic Systems Engineering
Coursework 2: Jacobian, Inverse Kinematics and Path Planning

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To get full credit for an answer, you are *required* to provide a full working solution. For some questions, you will be asked to write code; for these you are expected to include a *full print out* of any requested results or graphs in the report. Furthermore, you will be required to *upload* your code to Moodle along with your submitted coursework manuscript in .zip extension. The necessary packages are available on https://github.com/surgical-vision/comp0127_lab

Jacobian and Inverse Kinematics

1. How many inverse kinematic solutions exist for a 2D 4R-planar manipulator, if an achievable pose of the end-effector x_e is given? Give a full explanation to support your answer. [5 marks]

2. Suppose that the robot is moving in a free space (i.e. there is no obstacle) and that more than one inverse kinematic solution exist for a desired pose of the end-effector x_e, what criteria should you consider when choosing an optimal solution? [5 marks]

3. When is the output of the function atan2(x, y) different from atan$(\frac{x}{y})$? [3 marks]

4. The complete standard DH parameters of the YouBot are given in Table 1. Complete the questions by filling in the code in the package "cw2/cw2q4". The explanation in the report is only needed for subquestion b.

Table 1: DH parameters for YouBot manipulator

i	a_i	α_i	d_i	θ_i
1	-0.033	$\frac{\pi}{2}$	0.145	$\theta_1 + \pi$
2	0.155	0	0	$\theta_2 + \frac{\pi}{2}$
3	0.135	0	0	θ_3
4	-0.002	$\frac{\pi}{2}$	0	$\theta_4 - \frac{\pi}{2}$
5	0	π	-0.185	$\theta_5 + \pi$

a. Write a script to compute a Jacobian matrix for the YouBot manipulator. [10 marks]

b. Derive the closed-form inverse kinematics solutions for the YouBot manipulator. You can represent any non-zero length parameters as variables. [10 marks]

c. Write a script to compute the closed-form inverse kinematic solution. [2 marks]

d. Write a script to compute the iterative inverse kinematic solution. [10 marks]

e. Write a script to detect singularity in any input pose. [5 marks]

Path and Trajectory Planning

5. Create a ROS node to perform trajectory planning from the checkpoint data. For subquestion c, you will have to work with obstacles in the scene whose positions and physical dimensions can be obtained from the gazebo simulator. These properties can be hard-coded into your scripts. The marking criteria for each subquestion is provided below each subquestion. There is no time constraint on subquestions b and c. You can input any value in "time_from_start" as appropriate.

   a. Use the data "data1.bag" in the package "cw2/cw2q5" to perform trajectory planning. Choose any kind of trajectory model and justify your choice in the report. Each checkpoint must be 10 seconds apart, i.e. the arm must reach the first checkpoint at $t = 10$ s and so on. Your JointTrajectory message must contain the trajectory point for every $dt = 1$ s. [15 marks]
      - Each checkpoint is worth 2 marks. (10 marks in total)
      - The explanation in the report is worth 5 marks.

   b. Use the data "data2.bag" in the package "cw2/cw2q5" to perform trajectory planning and achieve the shortest path (measured by the distance travelling by the end-effector). Only this subquestion, you are allowed to shuffle the checkpoint to get the shortest path. [18 marks]
      - Each checkpoint is worth 2 marks. (10 marks in total) If your code does not attempt to achieve the shortest path, you will get 0 mark for each checkpoint.
      - The explanation about the shortest path in the report is worth 5 marks.
      - The five shortest paths among the submissions will get 5 extra marks. These marks will be added to your coursework mark if the full score has not been already achieved. The maximum score cannot be exceeded in such manner.

   c. Use the data "data3.bag" in the package "cw2/cw2q5" to perform trajectory planning. The report should explain how you avoid obstacles in your path planning. [20 marks]
      - Each checkpoint is worth 3 marks. (15 marks in total)
      - The explanation in the report is worth 5 marks.

END OF COURSEWORK