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University of Tehran
College of Engineering
School of Electrical and Computer Engineering (ECE)
School of Mechanical Engineering (ME)

Mechatronics & Robotics

Homework 5 (Bonus)

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Deadline: 28 June 2024 (15 Tir), 23:59

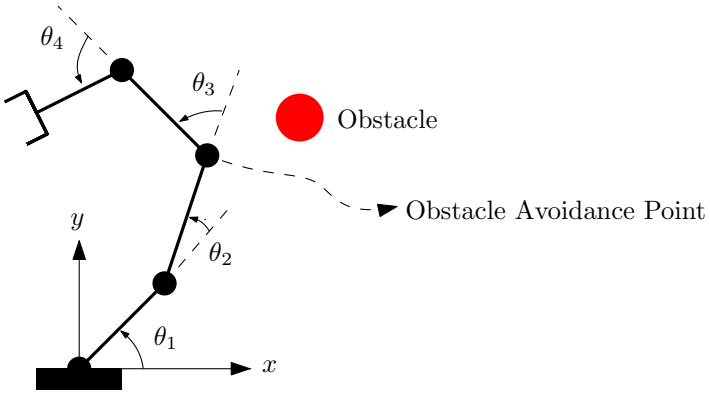
List of Problems

Problem : Take Care of the Obstacle!

This homework is an introduction to the kinematic analysis of the redundant planar serial manipulators. In robotic mechanisms, redundancy occurs when the robot has more actuators than its degrees of freedom. In such manipulators, the solution to the forward kinematics problem (FKP) remains the same as other robots. However, the inverse kinematics problem (IKP) faces more challenging issues. The aforementioned redundancy in the actuation of such mechanisms results in many solutions to the IKP, given a certain point in the task space. In order to address this problem, other constraints and objectives are added, and the problem would be defined as an optimization problem. Hence, the solution to the IKP using this approach is optimal, with respect to the defined objectives.

In the course material, the most used method of redundancy resolution has been taught and mentioned. Defining the minimum velocity norm for the problem, and using the lagrange multipliers method of optimization, the IKP could be reached using the pseudo-inverse of jacobian matrix. However, other objectives, such as obstacle avoidance or kinematic measures could also be used for redundancy resolution.

The case study in this homework, is a RRRR planar serial arm. As can be seen, the task space of the robot includes x, y, and ϕ. On the other hand, the joint space includes the values of θ_1, θ_2, θ_3, and θ_4. Therefore, this manipulator has one degree of redundancy (Consider lengths of the links to be $l_1 = 0.4$, $l_2 = 0.3$, $l_3 = 0.2$, and $l_4 = 0.1$). Moreover, there is an obstacle located on $X_O = 0.3$ and $Y_O = 0.45$.



- Form the FKP for this manipulator.
- Form the jacobian matrix for this manipulator
- For the given trajectory in the task space, solve the IKP for the manipulator and simulate its performance. Use the methods available for obstacle avoidance (See the attached paper). Program the robot in a way that the obstacle avoidance point of the robot, avoid any collision with the obstacle.

Note: Define the initial state of the robot as $\theta_1 = \frac{\pi}{3}$ and $\theta_2 = \theta_3 = \theta_4 = 0$. Afterwards, program the robot to follow the trajectory below:

$$x = 0.4\cos(5t) + 0.1$$
$$y = 0.3\sin(5t) + \frac{\sqrt{3}}{2}$$
$$\phi = \frac{\pi}{3}\cos(5t)$$

- Program a code, that shows the movement of the robot in an animation. This could be done using MATLAB plotting methods. Note that in the animation, the collision avoidance should be shown.

Homework Guidelines and Instructions

- The deadline for sending this exercise will be until the end of Friday, June 28th.
- This time cannot be extended and you can use time grace if needed.
- The implementation must be in Python programming language and your codes must be executable and uploaded along with the report.
- This exercise is done by one person.
- If any similarity is observed in the work report or implementation codes, this will be considered as fraud for the parties.
- Using ready-made codes without mentioning the source and without changing them will constitute cheating and your practice score will be considered zero.
- If you do not follow the format of the work report, you will not be awarded the grade of the report.
- Handwritten exercise delivery is not acceptable.
- All pictures and tables used in the work report must have captions and numbers.
- A large part of your grade is related to the work report and problem solving process.
- Please upload the report, code file and other required attachments in the following format in the system: `HW1_[Lastname]_[StudentNumber].zip`
  For example, the: `HW1_Ezati_12345678.zip`
- If you have questions or doubts, you can contact the assistants through the following e-mail with the subject 5HW_MechatronicsRobotics. Stay in touch educationally:
  - The first question: `pnamazian@ut.ac.ir` (Parsa Namazian)
- Be happy and healthy