University of Tehran

College of Engineering

School of Electrical and Computer Engineering (ECE)

Robotics

Homework 2

Teaching Assistant:

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Deadline: 24 November 2025 (3 Azar), 23:59

List of Problems

Problem 1: Relative Rotation and Representations(15 Points)

A robot's end-effector moves from an initial orientation R_{si} to a final orientation R_{sf} relative to the space frame $\{s\}$.

$$R_{si} = \begin{pmatrix} 1 & 0 & 0 \\ 0 & 0 & -1 \\ 0 & 1 & 0 \end{pmatrix} \qquad R_{sf} = \begin{pmatrix} 0 & -1 & 0 \\ 1 & 0 & 0 \\ 0 & 0 & 1 \end{pmatrix}$$

1. Calculate the relative rotation matrix R_{if} that describes the orientation of the final frame $\{f\}$ as seen from the initial frame $\{i\}$.

2. Find the exponential coordinates $\hat{\omega}\theta$ (the axis-angle representation) that describe this relative rotation R_{if}.

3. Represent this relative rotation R_{if} using **ZYX Euler angles** (α, β, γ) (i.e., a rotation of α about the body's $\hat{z}$-axis, then β about the new $\hat{y}$-axis, then γ about the new $\hat{x}$-axis).

Problem 2: Nova's D-H Parameters(15 points-Extra)

Introduction: The DOBOT Nova 2 is a six-degree-of-freedom (6DoF) collaborative robot. These robots are designed for commercial applications, such as processing or delivering food or other products, and are intended for human-robot collaborative operation. Full specifications for this robot are provided in the user guide (`Dobot-Nova-Series-User-Guide-V1.5.pdf`).

Problem: Using the technical information, diagrams, and dimensional specifications found in this "datasheet," derive the Denavit-Hartenberg (D-H) parameter table for the **Nova 2** robot.

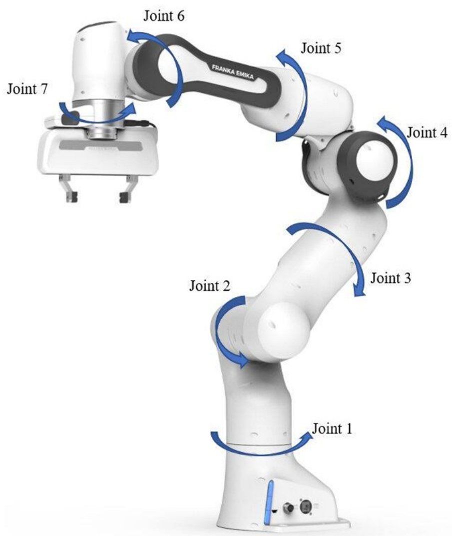
1. **Frame Assignment:** Assume the robot's "home posture" (zero position, $\theta_i = 0$ for all joints) corresponds to the dimensional drawing in **Figure 5.1 (Nova 2 dimensions and working space)**. Propose a suitable frame assignment (from base frame $\{0\}$ to tool frame $\{6\}$) based on the **Classic D-H convention**. Clearly define the origin and axes (especially z_i and x_i) for each frame relative to the robot's structure (you may sketch this on the diagram in your answer sheet).

2. **D-H Parameter Table:** Using your frame assignment, complete the D-H parameter table below. Extract all constant values (α_{i-1}, a_{i-1}, d_i) directly from the numerical dimensions (in mm) provided in the datasheet (see Figure 5.1). Clearly indicate the joint variables (θ_i) in the table.

Link i	α_{i-1} **(rad)**	a_{i-1} **(mm)**	d_i **(mm)**	θ_i **(rad)**
1				
2				
3				
4				
5				
6				

Problem 3: 7-DOF Robot D-H Parameters and Jacobian (30 point)

1. Specify the D-H table for the given robot and draw the axes on the question sheet. (Note that all D-H parameters must be positive).
2. Provide the Jacobian matrix numerically for the given robot configuration (Figure 1-a).



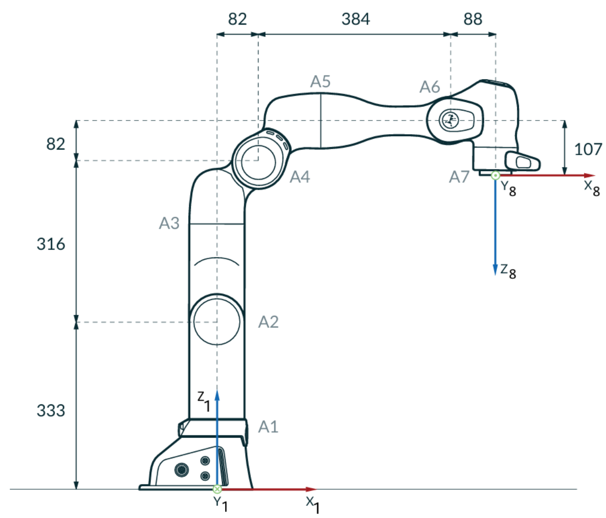


Figure 1: Different views of the robot. (a) Robot view in a specific orientation. (b) Robot view in a general configuration.

Problem 4: 3-DOF Robot Kinematics (45 point)

Consider the 3-DOF robot below, which is used for pick-and-place operations in (x, y, z) space. (45 points)

1. Derive its D-H parameter table.
2. Provide the parameters q_i and a_i.
3. Derive the forward kinematics.
4. Derive the inverse kinematics analytically. Discuss the number of solutions.
5. Provide the Jacobian matrix in general form.

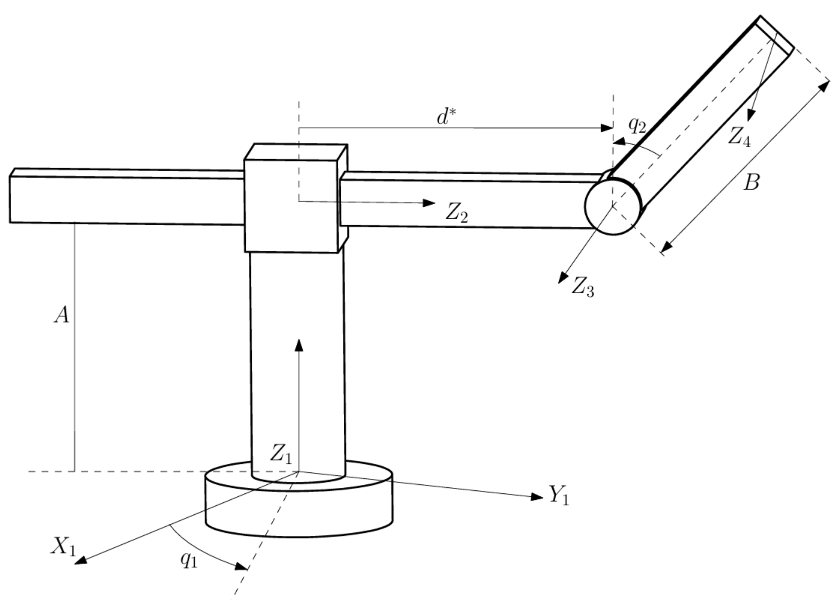


Figure 2: Image related to question five.

Problem 5: Calculation of the Jacobian Matrix (10 point)

Derive the Jacobian matrix for the robot below in the configuration shown. Draw the **e** and **r** axes on the robot diagram on the question sheet.

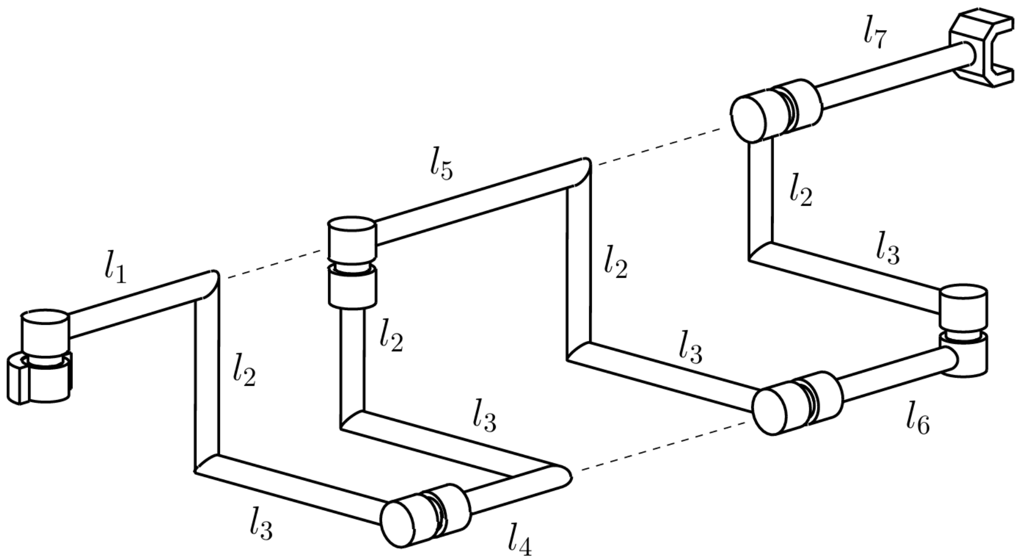


Figure 3: Image related to question seven.

Homework Guidelines and Instructions

- The deadlines are fixed and cannot be changed. If you need extra time, you can use your grace period (14 days) and upload your answers up to 5 days after the deadline.
- If you write your report of this homework in LaTeX, you will be rewarded 5% extra points.
- Programming problems can either be completed in Python or MATLAB 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. Only mathematical procedures and formulas are allowed to be handwritten.
- 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: `HW1_Ahmadi_123456789.zip`
- You can ask your questions or doubts either via Telegram group or sending an email directly to the teaching assistants of this homework.
- The questions that are asked in Telegram PV of teaching assistants will not be answered as they are not traceable for the chief TA.
- If you wanted to ask your questions or doubts via email, use the following subject: "Robotics_HW1_[Lastname]_[StudentNumber]" and make sure to cc the chief TA at shayanahmadi9999@gmail.com:
  - 1379hmk2@gmail.com (Hossein Mollayousefi)
- Be happy and healthy