# ME 5402/EE 5106 Advanced Robotics

# Part 1 CA – AY24/25 Semester 2

## *Robot Simulation*

You will be assigned to a random group of 2-3 students to work on the project. The software must be developed using MATLAB. You are encouraged to utilize the Symbolic Math Toolbox. There is no need to use any robotic toolbox to complete this CA. However, you are permitted to use MATLAB's Robotics System Toolbox and/or any other toolboxes.

This is a group project. Please submit only one set of report and software. All members of the group will receive the same score. Name your submission as "Group XX.zip". Please indicate the names and IDs of all group members on the cover page of your report. The project contributes 25% of the final grade of the module.

**Tasks**

Figure 1 illustrates the three wrist joints of a PUMA 600. The kinematic configuration of the wrist joints is defined in Table 1, with reference to the coordinate frames shown in the figure. The robot is grinding a work surface, using a grinding tool grasped in its hand. The grinding tool is in contact with the work surface at point A, whose coordinates with reference to $O_3$-$x_3y_3z_3$ are $x_3$ = 100 mm, $y_3$ = 0 mm and $z_3$ = 50 mm.

1. Model the manipulator using the classical D-H representation.

2. Derivate the forward kinematics.

can also provide numerical solution

3. Solve the analytical inverse kinematics problem, which involves finding the set of joint configurations that satisfy the desired position and orientation of the final link.

4. Derive the 6 x 3 Jacobian matrix associated with the relationship between joint displacements and the position and orientation of the tool at point A.

5. During the grinding operation, reaction forces and moments act on the tool tip A. Represent the force and moments by a 6 x 1 vector **F**, derive the equivalent joint torques.

6. For Task 7, define a suitable 3D work plane and specify the time required for the grinding tool to engrave or mark the designated pattern on the surface.

7. Write a program to move the tool and engrave the text “E2-01-06” on the surface using the grindind tool. The program should ensure smooth and controlled motion to create clear, legible markings rather than deep material remova. State any assumptions made.

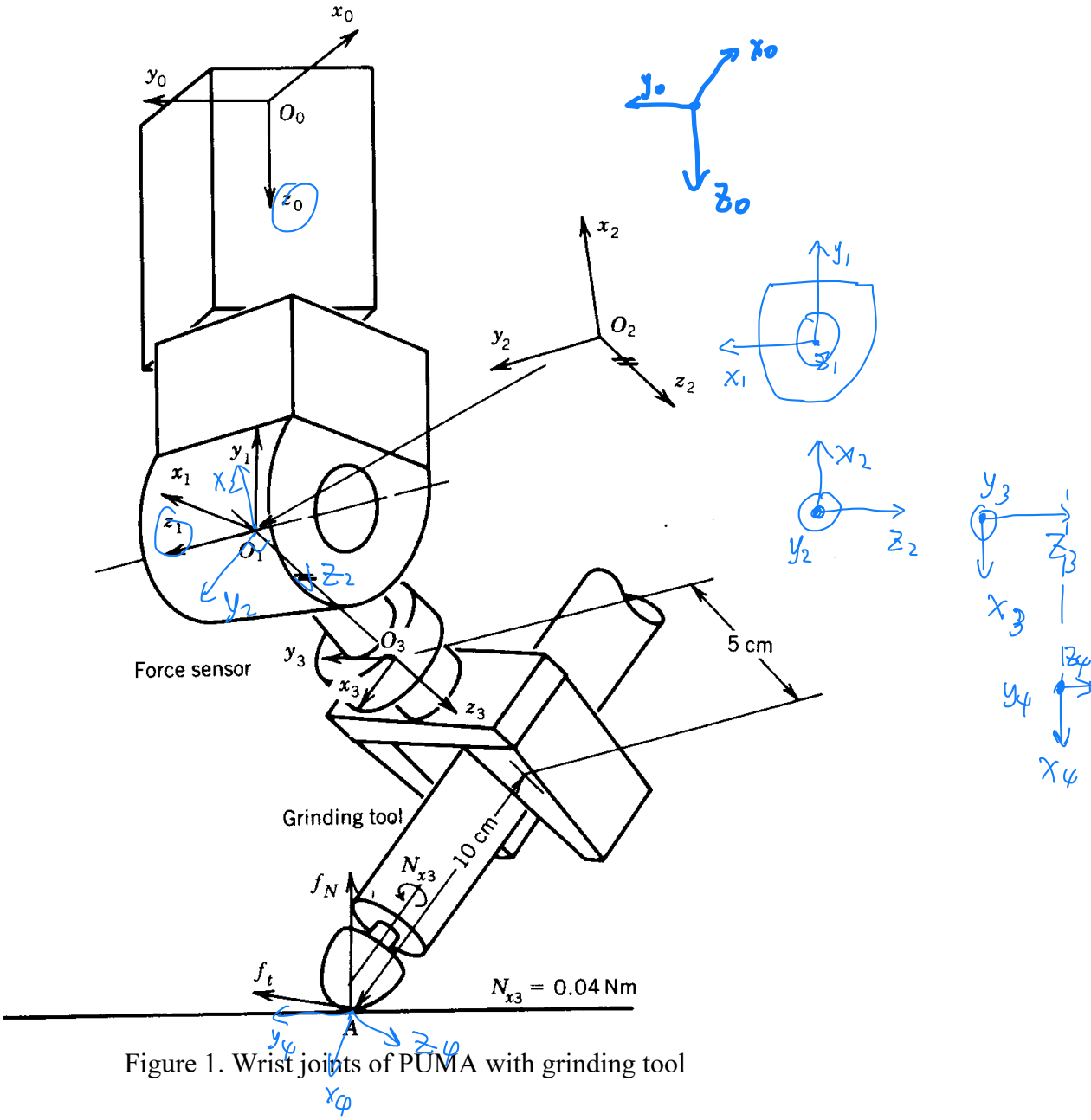


Figure 1. Wrist joints of PUMA with grinding tool

Table 1

| Link number | $\alpha_i$ | $a_i$ | $d_i$ |
|---|---|---|---|
| 1 | -90° | 0 | 400 mm |
| 2 | +90° | 0 | 0 |
| 3 | 0 | 0 | 100 mm |
| 4 | 0 | 100 | 50 |

## Submission Instructions

Upload a single zip document to Assignments on NUS Canvas by 14 April 2025 (Monday) 23:59 hours.

The zip document should contain the following:

1. Report (about 30 - 50 pages)

1.1 Cover Page with your names, student numbers and email addressed clearly indicated

1.2 Introduction

1.3 Solution Descriptions
Provide detailed explanations of your solutions for each task, including forward and inverse kinematics with detailed workings, and Jacobian matrices with derivations.

1.4 Screenshots and Plots
Include screen captures of your simulations, plots, and results.

1.5 Discussions and Conclusion

2. Programs
Include all source codes and provide a README.txt file explaining how to execute the codes.

3. Short movie/animation
Submit a short video or animation demonstration your simulation.