University of Belgrade
School of Electrical Engineering

Robotics and automatization (13E053RA)

Second homework assignment

Students: Dositej Cvetković 20/0224
Matea Koković 19/0004

Belgrade, September 2024

Task

The robot consists of two rotational joints and two segments of equal lengths and mass mmm. The task is to implement the robot's movement between three points in space (A-B-C). From point A to point B, it is necessary to ensure smooth movement along a trajectory where the internal coordinates of the robot change according to a cubic polynomial profile during the first 0.5T0.5T0.5T of movement. Between points B and C, the movement should follow the point-to-point principle for the remaining time of 0.5T0.5T0.5T. It is assumed that the robot was initially in a resting phase and that the positive reference direction of movement is in the clockwise direction (see Figure 1).

Control should be implemented according to Table 1. Analyze the movement of the robotic system if an external force F=−2NF = -2NF=−2N acts on the end effector along the X-axis during the interval 0.35T−0.4T0.35T - 0.4T0.35T−0.4T. Implement functions that calculate the kinematics and dynamics of the robot, plan the trajectory, and perform numerical integration of the described robotic system over time TTT, using moments as control variables.

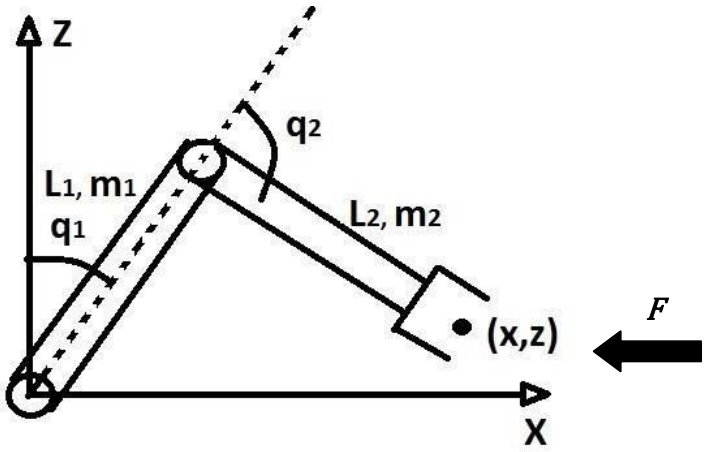


Figure 1. Robot in a plane with two degrees of freedom and corresponding reference directions.

Parameters for Simulation:

- Segment lengths – $l=0.3$m
- Segment masses – m=2kg
- Assume the robot segments are homogeneous.
- Initial position of the gripper is A:$(q_{A,1},q_{A,2}) = (45,45)$ [deg]; desired position of point B is $(X_B, Z_B)= (0.3,0)$m; desired position of point C is $(X_C,Z_C) = (0.3\sqrt{3}, 0)$m.
- Duration of the simulation – T = (3 + BBBB mod 4) s, where GGGG/BBBB is the index number.

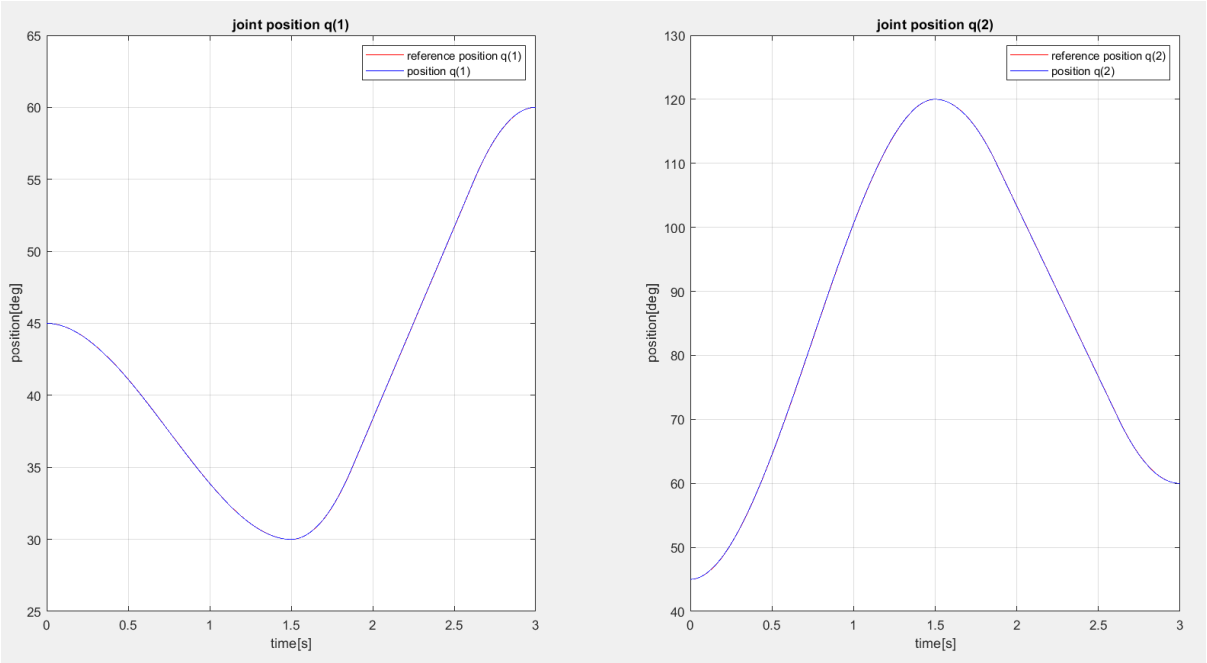
$$T = (3 + 0224 \bmod 4) = 3s$$

$$(0224+0004)\bmod 3 = 0$$

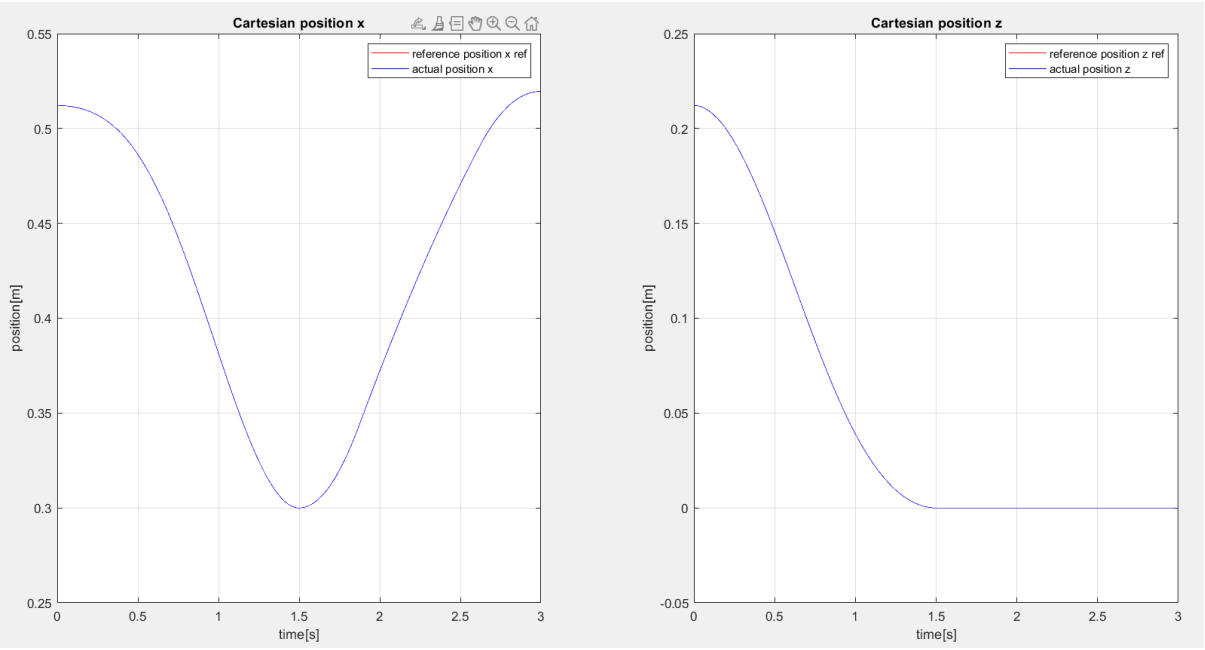
Table1. Control Type Arrangement According to Student Index Numbers

(BBBB1+BBBB2) mod 3	Type of Control
0	Feedforward computed torque + PD controller in the feedback branch
1	Inverse dynamics controller + PD controller in the feedback branch
2	Decentralized control
Instructions:	BBBB1 – index number of the first student, BBBB2 – index number of the first student

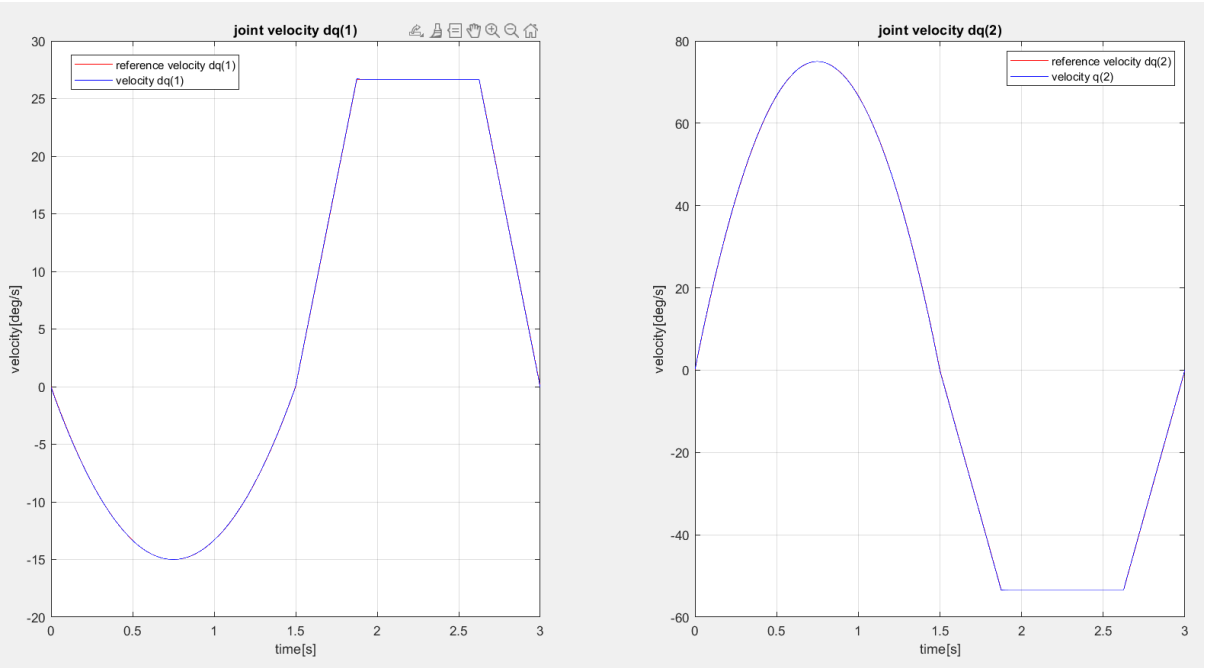
Graphs



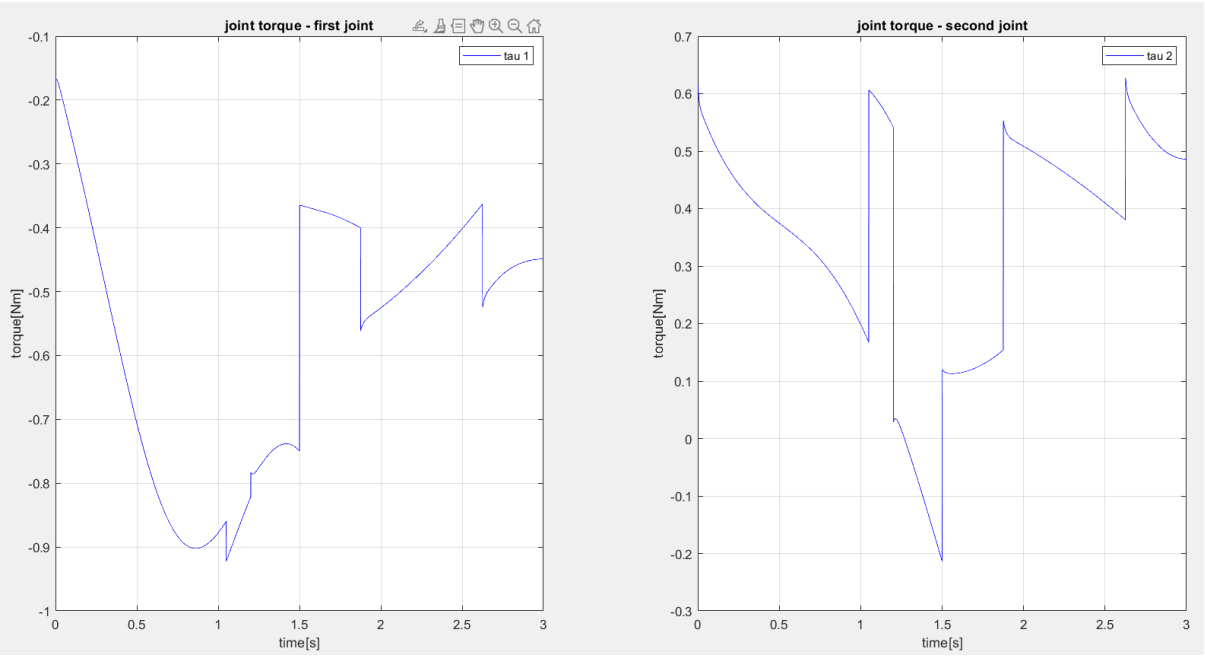
Picture 1. – reference and achieved values of internal coordinates



Picture 2. – reference and achieved values of external coordinates



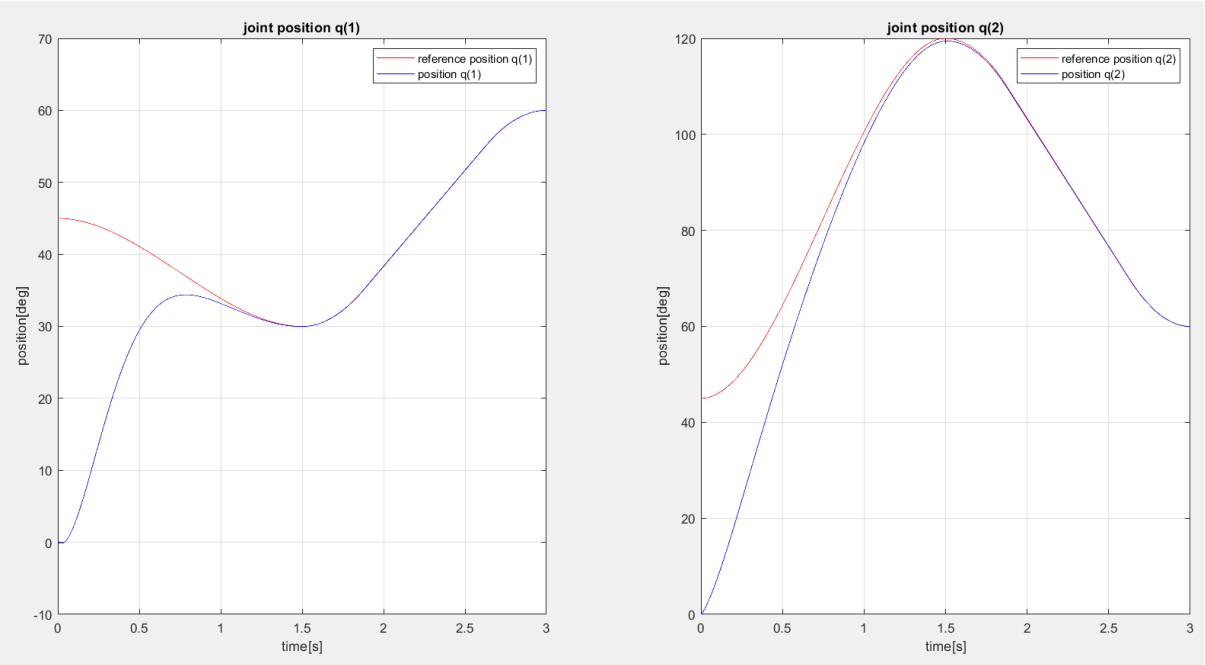
Picture 3. – reference and achieved values of joint speeds



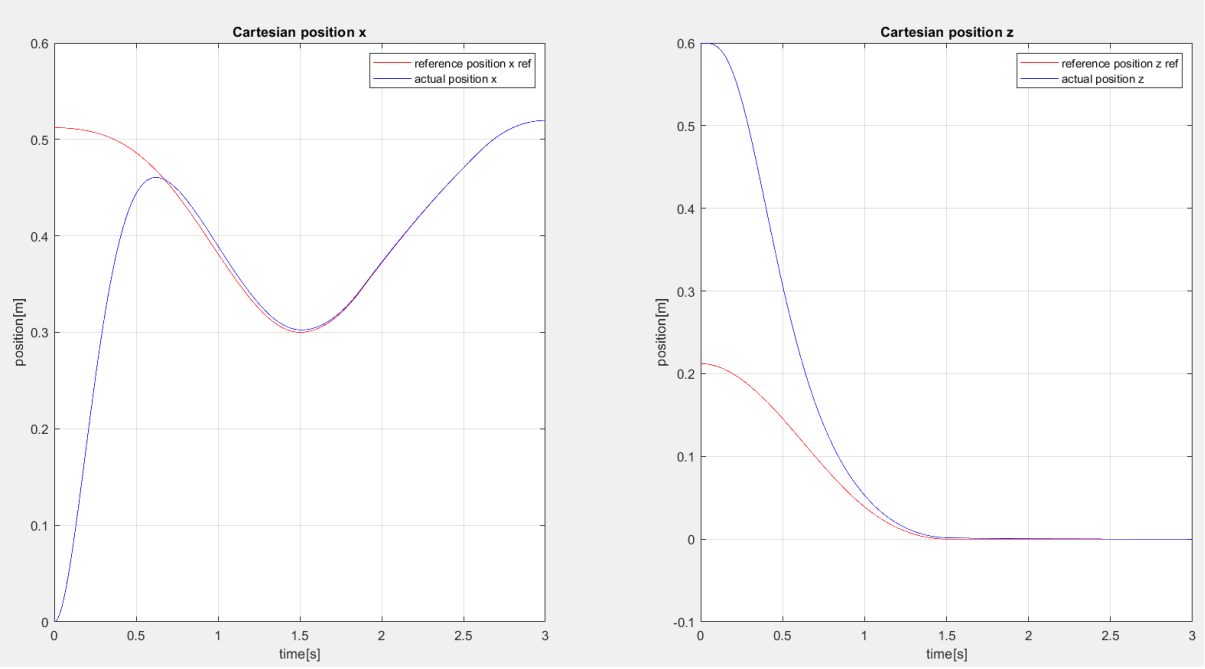
Slika 4. – achieved torque of the joint motors

From Picture 4, we can observe sudden jumps in the moments during the external force interaction at 1.05-1.2s. Additionally, jumps are noticeable during changes in the movement profile used.

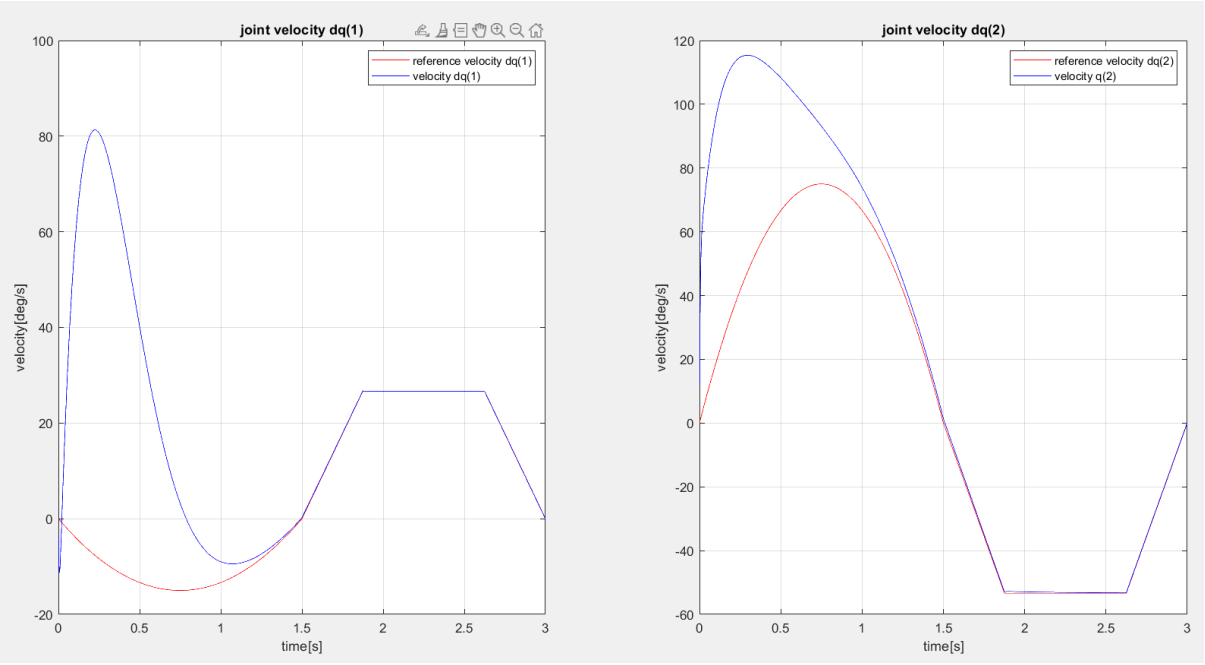
Since we have set the same initial conditions for the reference motion and the actual position of the robot, we can note that it almost perfectly follows the reference position/velocity. For a more detailed analysis, we will set the initial position of the robot to q=[0;0]q = [0; 0]q=[0;0].



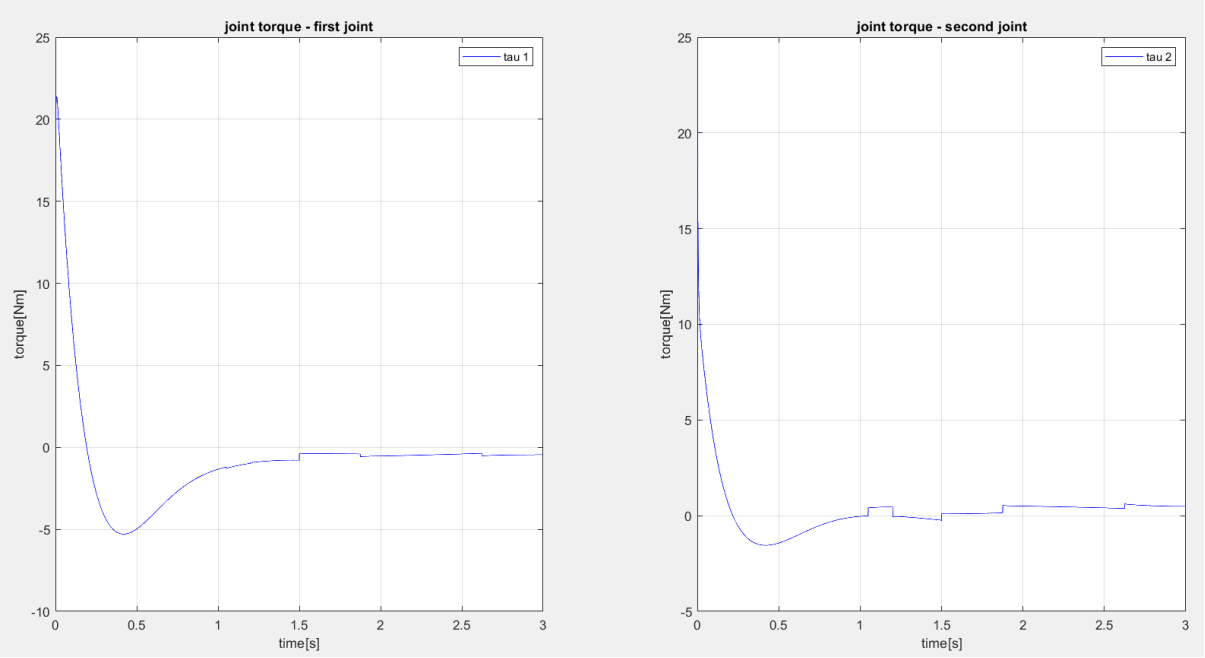
Picture 5. – reference and achieved values of internal coordinates



Slika 6. – reference and achieved values of external coordinates



Slika 7. – reference and achieved values of joint speeds



Slika 8. – achieved torque of the joint motors

If we were to reduce the gains of the PD controller, we would achieve a faster system response, but with a larger error.