Recommended Assessment
Inverse Kinematics

Teach Pendant

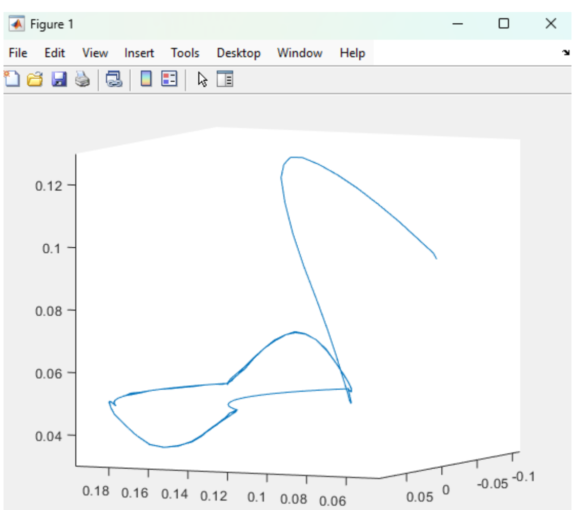
Initially, the experiment was run using four end-effector positions to map the workspace. Now consider increasing the number of points to eight by adding additional waypoints along the edges of the rectangular path. How do you think this would affect the trajectory? Would using more points result in smoother motion between waypoints, or would there still be noticeable abrupt changes?

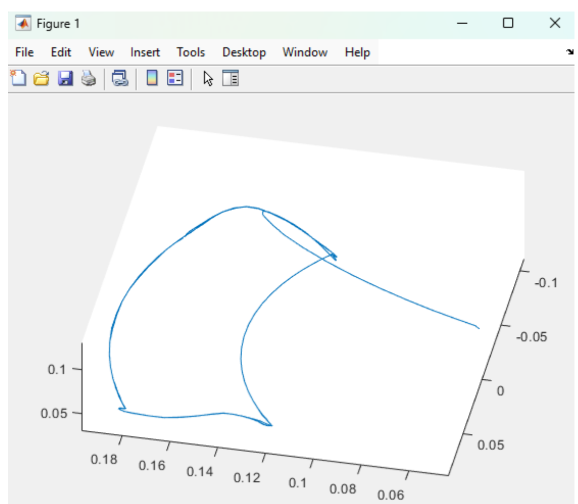
Adding more waypoints improves the smoothness of the trajectory by providing finer control over the manipulator's path, ensuring more gradual transitions between movements. However, increasing the number of waypoints also introduces complexity. If the controller is not well tuned, excessive waypoints could lead to small jerks as the manipulator attempts to follow the trajectory precisely.

1. How accurately did the end-effector reach each recorded waypoint? Did you notice any deviations from the expected path? If so, what could be the possible causes?

The end-effector reached each recorded waypoint with reasonable accuracy, but the discrepancies were noticeable, especially in transitions between waypoints. This was expected since no predefined path was given, and the system only aimed to reach each waypoint individually.

The deviations in motion were caused by the manipulator's kinematics and dynamics. The shoulder, elbow, and wrist joints are coupled, meaning their movements influence each other. However, the controller in each of the joints operates in a decoupled manner, meaning each joint independently attempts to move the end-effector to the target position without accounting for how the other joints contribute to the motion. As a result, the movement between waypoints appeared unnatural, even though it was consistent and repeatable.





2. What are some potential applications of using a teach pendant in an industrial environment, and what advantages does it offer?

   Teach pendant learning provides an intuitive and flexible way to program the manipulator without requiring advanced coding or mathematical skills. Operators can manually guide the robot to desired positions, making it easier to adapt to new tasks or make adjustments on the fly. This is particularly useful in applications where production requirements frequently change, such as small-batch manufacturing or prototyping. Additionally, teach pendant learning allows for faster setup since users can define waypoints interactively, rather than spending time calculating precise trajectories.

3. What are the limitations of using teach pendant learning compared to pre-programmed motion paths in an industrial setting?

   Since waypoints are recorded manually, the resulting motion may not be as smooth or optimized as a pre-programmed path, leading to inefficiencies in speed or energy usage. Additionally, the lack of trajectory planning can result in abrupt movements, which may cause mechanical wear over time. In contrast, pre-programmed motion paths offer higher precision, repeatability, and efficiency, as they are carefully designed using kinematics and optimization techniques. However, they require more time to develop and often need programming expertise.

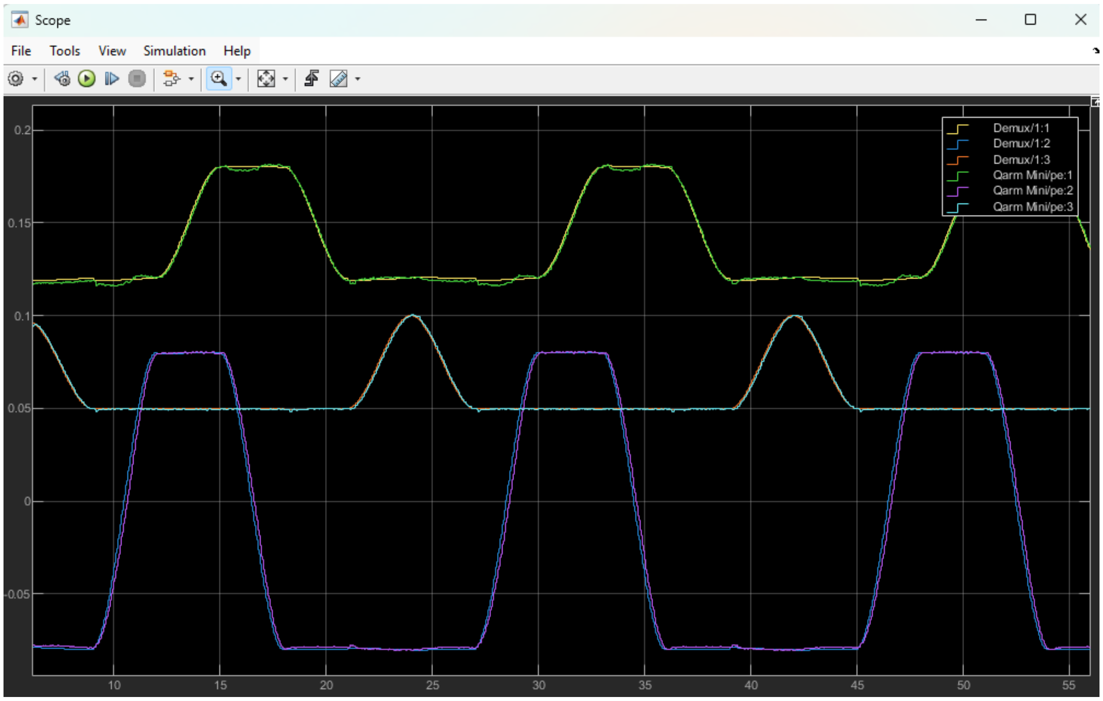
   While teach pendant learning is ideal for rapid setup and flexibility, pre-programmed paths are better suited for applications that demand high precision, smooth motion, and long-term efficiency.

Trajectory Generation

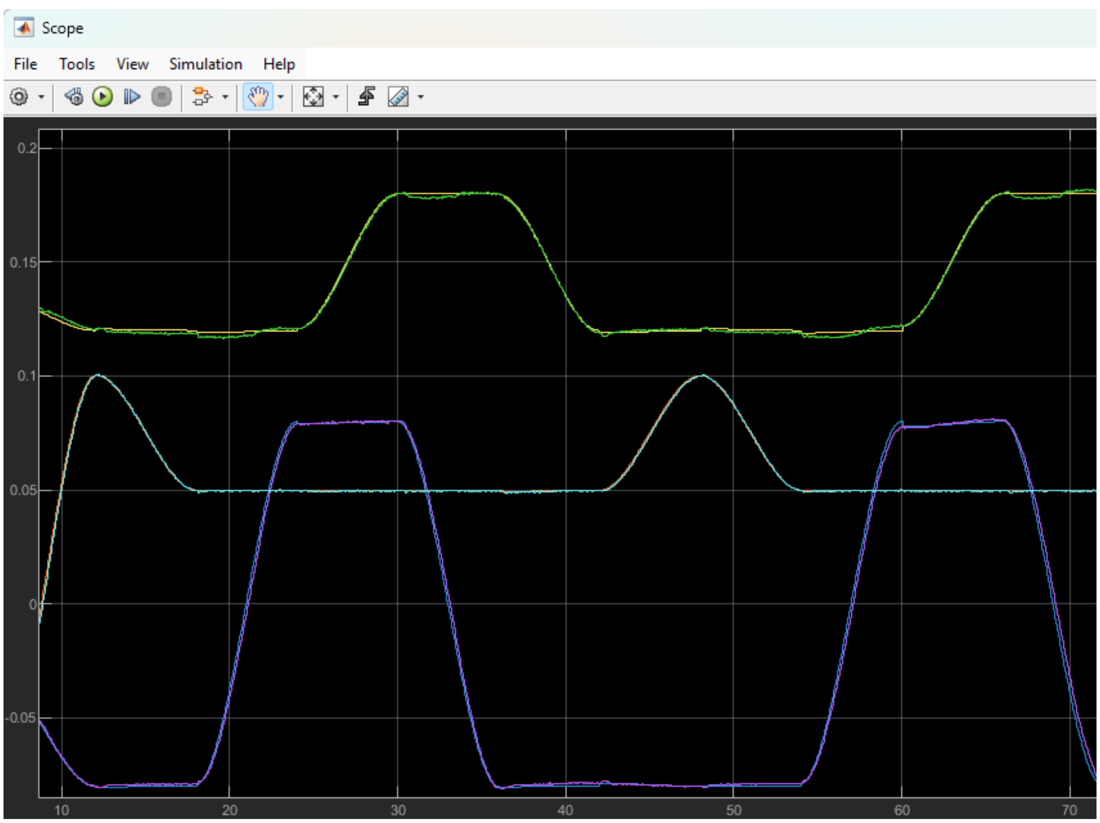
1. How does the motion between waypoints get affected when you increase the duration from 3s to 6s? What trade-offs exist when increasing this value? Attach screenshots of your scope.

   Increasing the duration will slow down the motion, allowing the manipulator to move more smoothly and with less risk of overshooting the desired positions. This can lead to more accurate positioning but may reduce overall efficiency, as the manipulator takes longer to complete the task.

   The comparison between a 3-second and a 6-second duration between waypoints shows that while the 6-second duration provides slightly better accuracy, it takes twice as long to complete the same task.



Duration between waypoints: 3s (commanded vs measured positions scoped)

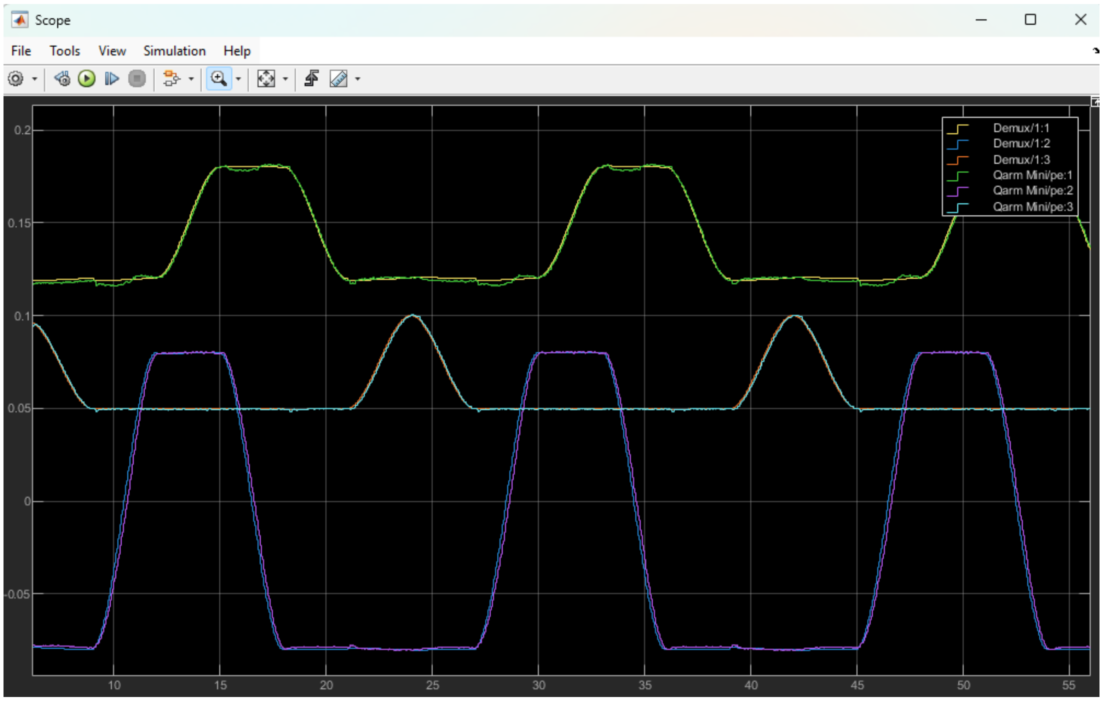


Duration between waypoints: 6s (commanded vs measured positions scoped)

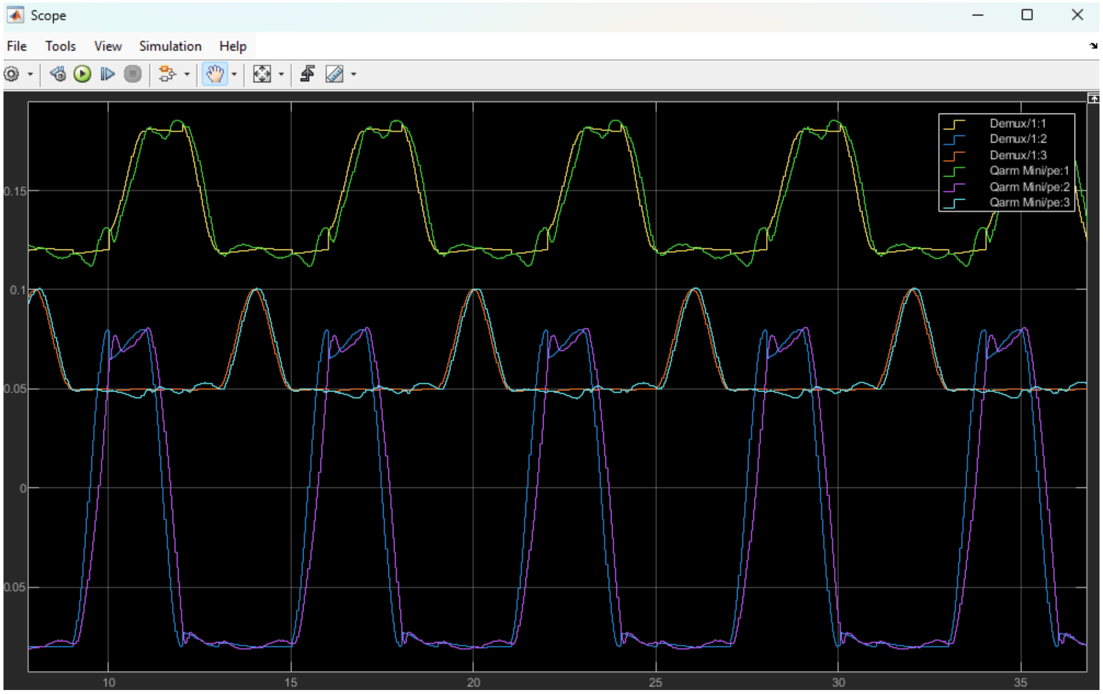
2. How does the motion between waypoints get affected when you decrease the duration from 3s to 6s? What trade-offs exist when decreasing this value?

   Decreasing the duration speeds up the motion, which might be desirable for tasks requiring quick movements, but can lead to jerky motion or decreased accuracy if the manipulator does not have enough time to smoothly transition between waypoints.

   A comparison between a 3-second and a 1-second duration shows that while the 1-second duration completes the task much faster, it sacrifices accuracy in the process.



Duration between waypoints: 3s (commanded vs measured positions scoped)



Duration between waypoints: 1s (commanded vs measured positions scoped)

3. Compare the trajectory generated in this procedure and the trajectory when doing Teach Pendant Follow. What differences do you observe, and why might they occur?

   Both follow a rectangular trajectory, but key differences arise from the method of trajectory planning. In the Teach Pendant Follow lab, the manipulator moves directly between the four specified waypoints, resulting in deviations as there was no predefined path given and the controller operating in a decoupled manner. In contrast, the trajectory generation procedure utilizes cubic spline interpolation, which produces smoother and more continuous motion. This method more accurately follows the intended rectangular path, as demonstrated by the 3D plot generated at the end when the model is stopped.