

# Final Project Report

Ignacio Duarte

MECH 4332 - Mechanical Computational Applications in Vision and Robotics

December 12, 2025

## 1 Introduction

The objective of this project is to design and implement controls that enable different end-effector motions for a Kinova Gen3 robotic manipulator. Three different tasks are to be completed end-effector position trajectory tracking, end-effector orientation trajectory tracking, and null-space motion while maintaining a fixed end-effector position. The controllers are implemented in MATLAB using the Robotics System Toolbox and are designed to be executable in MATLAB Online.

The Kinova Gen3 robot is modeled using MATLAB's 'rigidBodyTree' representation. Inverse kinematics is employed to compute the joint configurations that achieve the desired end-effector poses. For trajectory tracking tasks, warm-starting is used by initializing each inverse kinematics solve with the previous solution to ensure a smooth motion and computational efficiency. End-effector poses are obtained through forward kinematics for visualization and plotting.

## 2 Task 1: Position Trajectory Tracking on End-Effector

In Task 1 the controller tracks a prescribed Cartesian position trajectory for the end effector while no explicit orientation for the trajectory is enforced. The end effector follows a linear path in Cartesian space, returning to its initial position. Inverse kinematics is solved at each way point using a weighting scheme that prioritizes position accuracy. The resulting joint trajectory produces smooth motion along the desired path. Plots of end-effector position and orientation versus way point index are provided to illustrate the evolution of the motion.



Figure 1: Task 1 Position vs Time

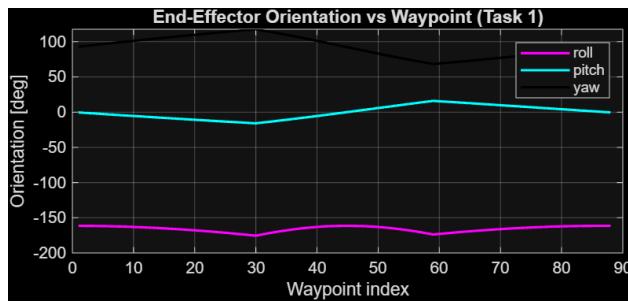


Figure 2: Task 1 Orientation vs. Time

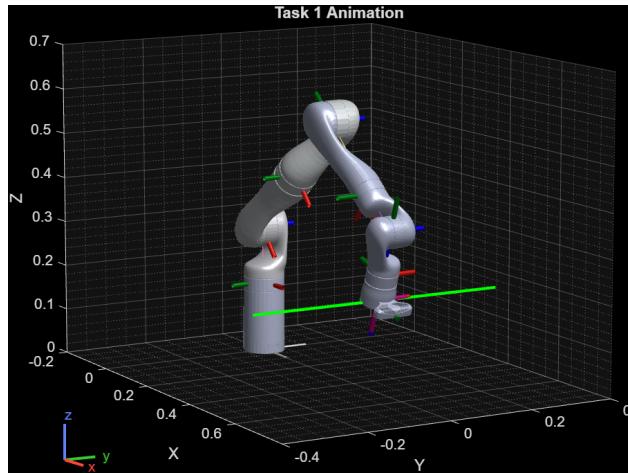


Figure 3: Task 1 Home Position

### 3 Task 2: Orientation Trajectory Tracking on End-Effector

Task 2 focuses on tracking a desired orientation trajectory while keeping the end-effector position approximately fixed. The orientation trajectory is defined as a smooth rotational motion about a fixed axis, and inverse kinematics is used to compute joint configurations

that satisfy both position and orientation constraints. Equal weighting is applied to position and orientation tracking. The resulting motion demonstrates controlled rotation of the end effector with minimal position deviation. Plots show the evolution of both position and orientation along the trajectory.

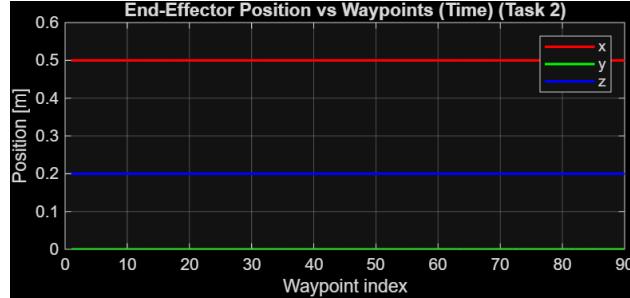


Figure 4: Task 2 Position vs Time

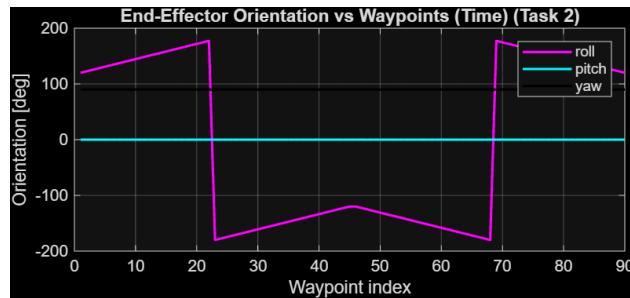


Figure 5: Task 2 Orientation vs. Time

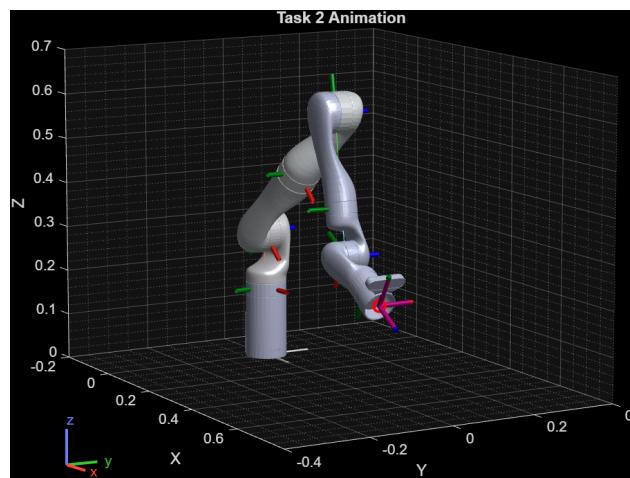


Figure 6: Task 2 Home Position

## 4 Task 3: Trajectory Projecting on Null-space

In Task 3, a null-space controller is implemented to generate internal joint motion while regulating the end-effector position near a fixed Cartesian location. The controller combines a null-space velocity component with a small corrective term to prevent end-effector drift. This task demonstrates redundancy resolution, where secondary joint motions are achieved without violating the primary task constraint. Plots of end-effector position and orientation confirm that the position remains approximately constant during the motion.

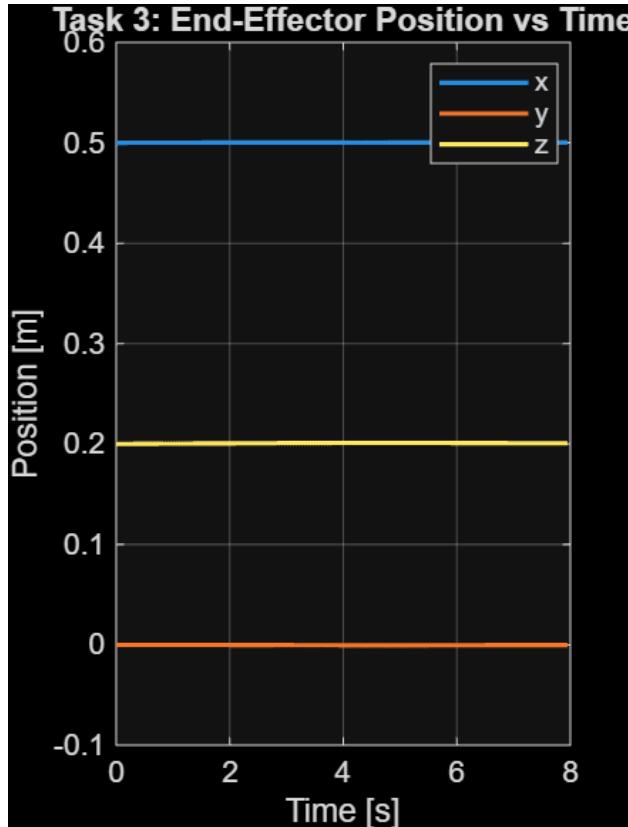


Figure 7: Task 3 Position vs Time

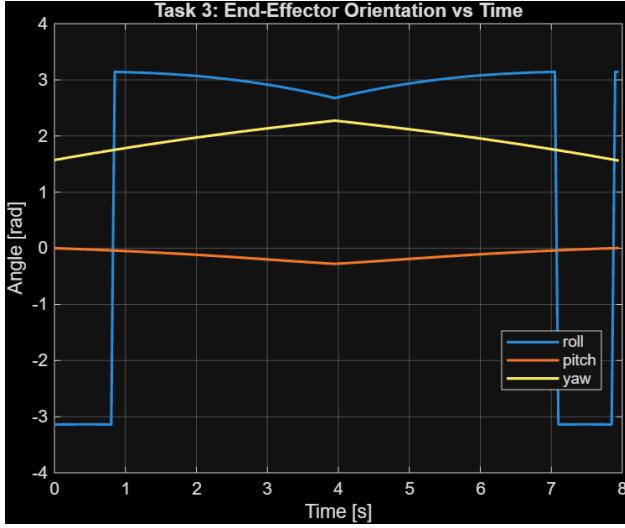


Figure 8: Task 3 Orientation vs. Time

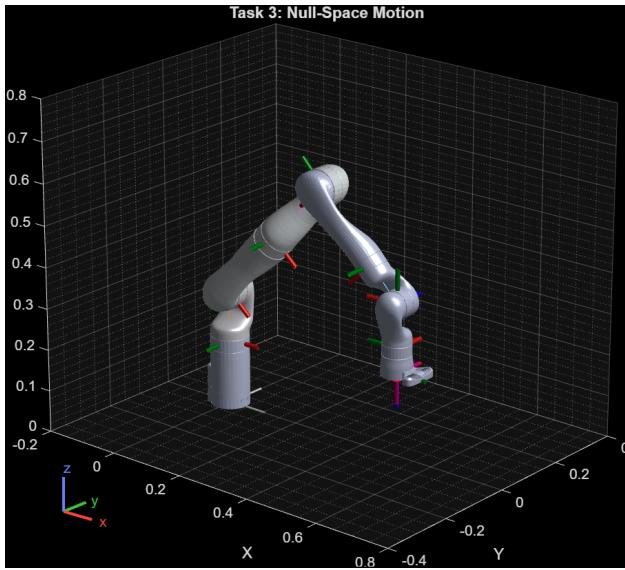


Figure 9: Task 3 Home Position

## 5 Conclusion

All three tasks successfully demonstrate the intended behaviors. The position tracking task shows accurate following of a Cartesian path, the orientation tracking task produces smooth rotational motion with a fixed position, and the null-space task illustrates redundancy exploitation while maintaining end-effector constraints. The accompanying plots and animations validate the effectiveness of the controllers. This project demonstrates the application of inverse kinematics and null-space control techniques for end-effector motion generation in robotic manipulators. By separating position, orientation, and redundancy

objectives into distinct tasks, the flexibility of the Kinova Gen3 robot is effectively showcased. The implemented controllers meet the project requirements and provide clear visual and quantitative confirmation of correct behavior.