INTERNATIONAL ISLAMIC UNIVERSITY MALAYSIA

Garden of Knowledge and Virtue

INTRODUCTION TO ROBOTICS

MCTA 3332

SECTION 1

ASSIGNMENT

DESIGNING, SIMULATING AND ANALYZING CYLINDRICAL ROBOT

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Objectives

1. To design a cylindrical robotic manipulator using SolidWorks.

2. To model and simulate the robot’s dynamics in MATLAB using the Robotics System Toolbox and Simscape Multibody.

3. To analyze the robot’s kinematics and workspace.

Introduction

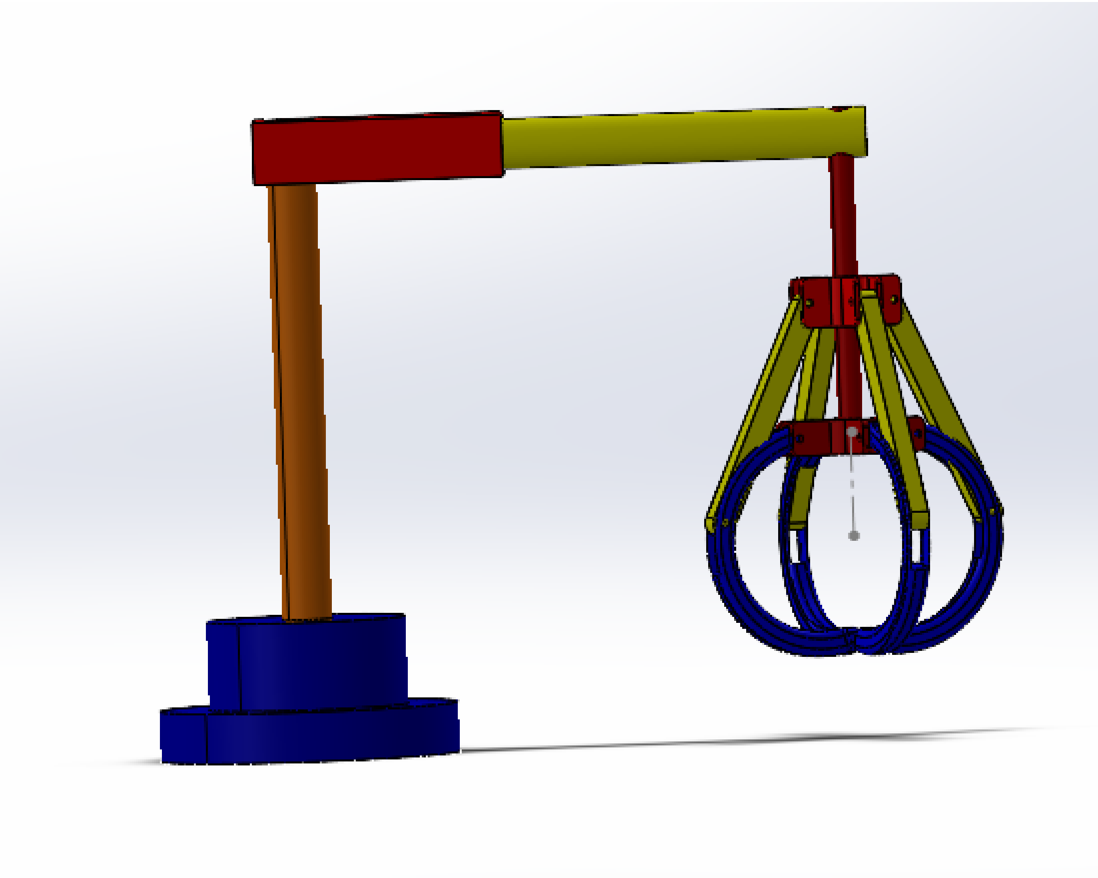
The design and analysis of robotic systems play a critical role in modern automation, addressing various industrial and research challenges. This assignment focuses on the conceptualization, design, simulation, and analysis of a cylindrical robot which is a type of robotic manipulator widely used in material handling, assembly, and precision tasks. The cylindrical robot's structure, comprising a prismatic joint for vertical motion, a revolute joint for rotation, and another prismatic joint for radial extension, offers a versatile platform to study robotic kinematics and dynamics.

This report outlines a systematic approach to developing a cylindrical robot using SolidWorks for mechanical design, MATLAB for kinematic modeling and simulation, and Simscape Multibody for dynamic analysis. The objective is to design a functional robotic manipulator, simulate its performance under various operational conditions, and evaluate its workspace, kinematics, and control dynamics. The integration of state-of-the-art tools ensures a comprehensive understanding of the robot's capabilities and limitations, laying the foundation for real-world applications and future enhancements.

The subsequent sections provide detailed insights into the design process, mathematical derivations, simulation results, and potential applications of the cylindrical robot.

Assignment Task

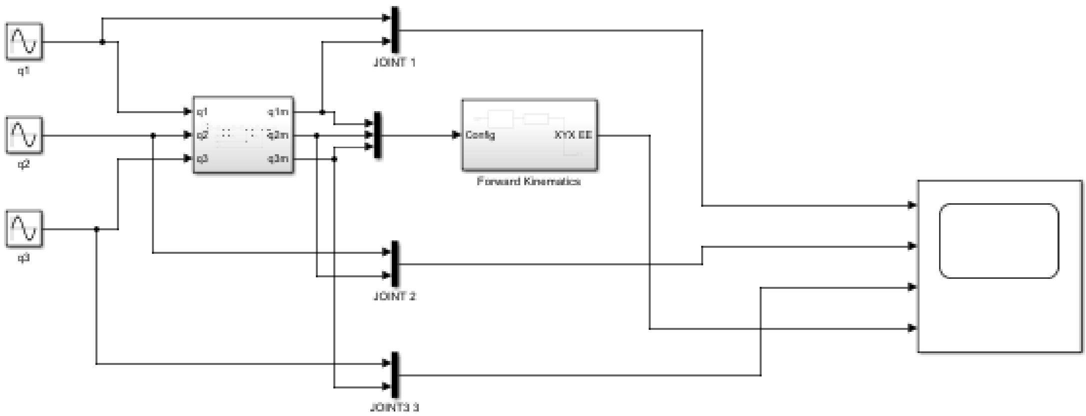
Part 1: Robot Design in SolidWorks

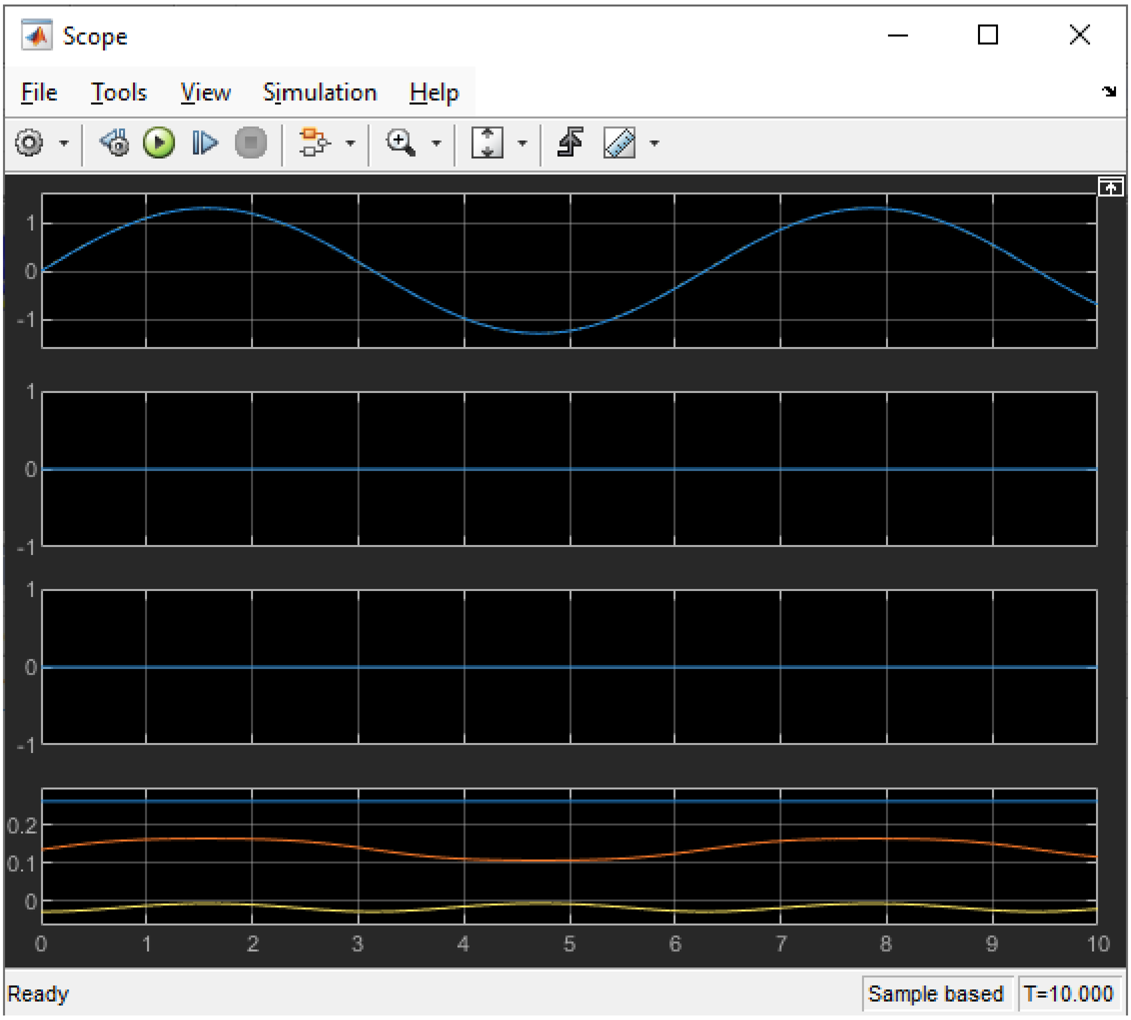


Base support:	Circumference: 120 mm Height: 20 mm
Base (revolute joint):	Circumference: 80 mm Height: 50 mm
Prismatic joint (Vertical arm);	Length: 17 mm Width: 20 mm Height: 200 mm
Horizontal arm:	Length: 100 mm Width: 30 mm Height: 25 mm
Prismatic joint (horizontal arm):	Length: 200 mm Width: 25 mm Height: 20 mm Extension: 0 to 55 mm
End effector:	Height: 125 mm Extension: 37.21323898 to 67.21323898mm

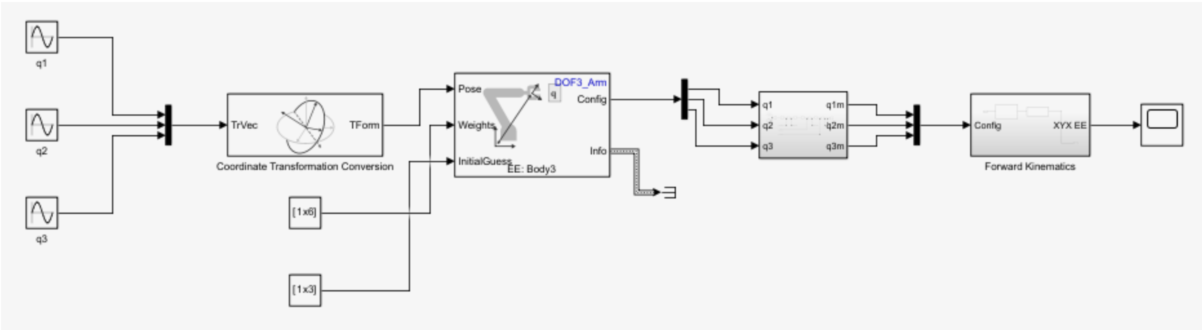
Part 2: Kinematics Analysis

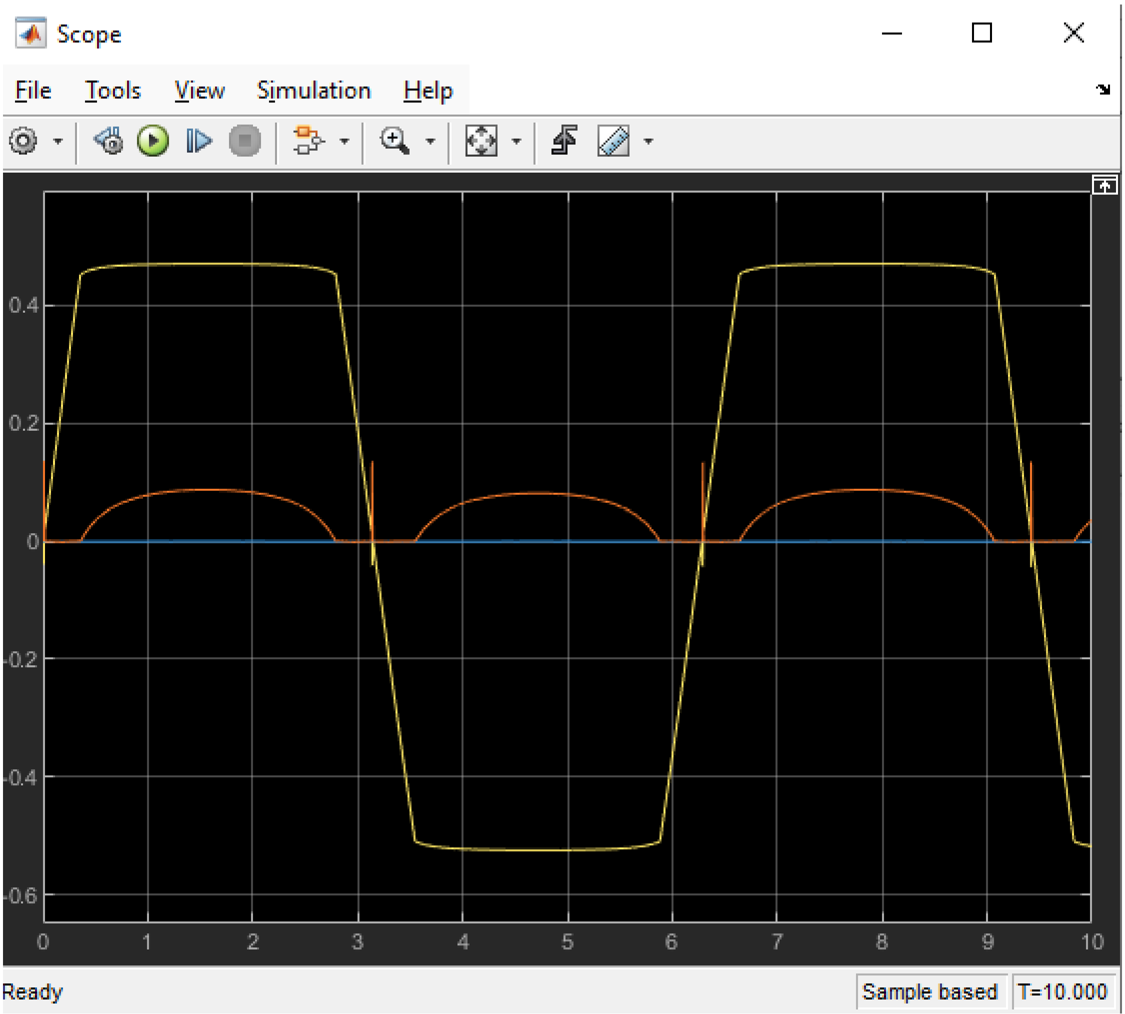
Forward kinematics: transform joint angle to end-effector position





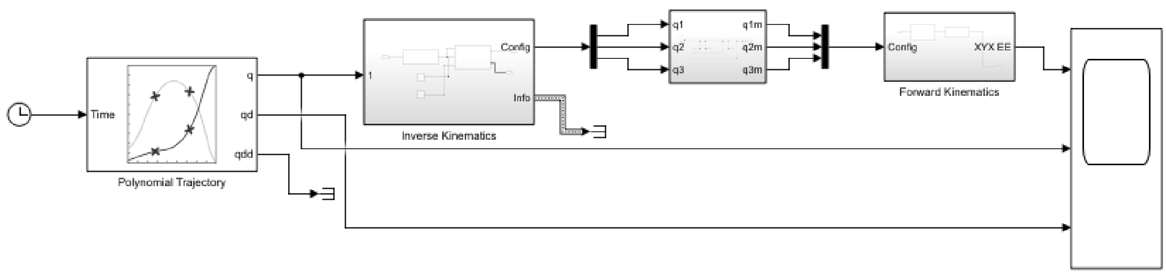
Inverse kinematic: transform end-effector to joint angle

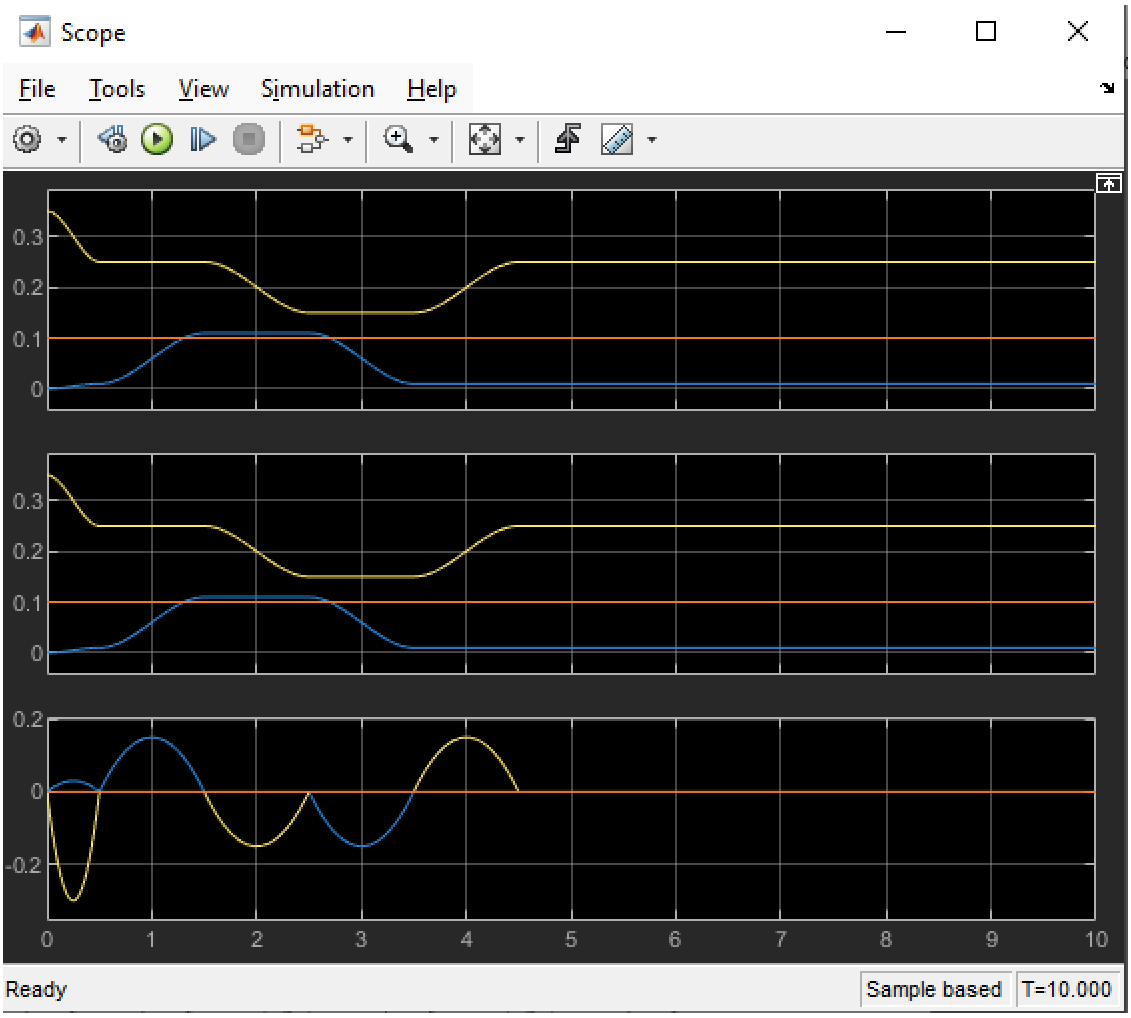




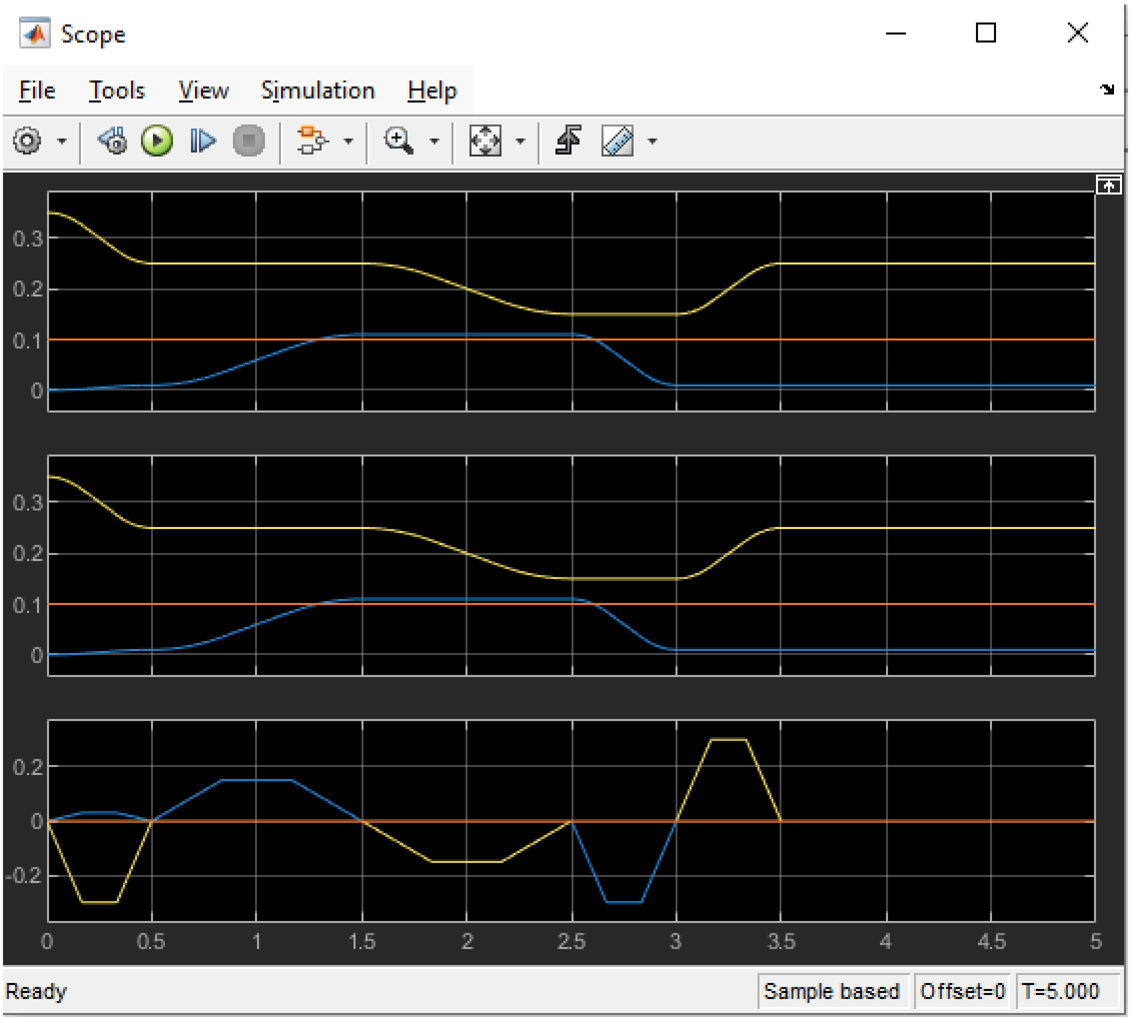
Trajectory:

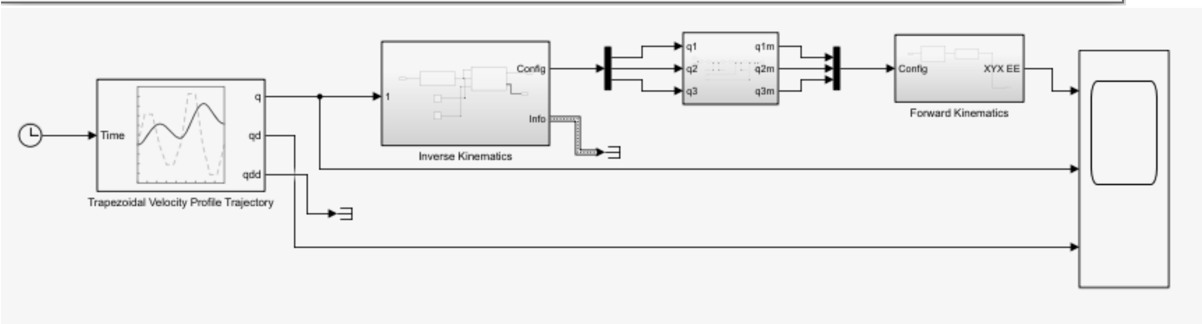
Using polynomial:





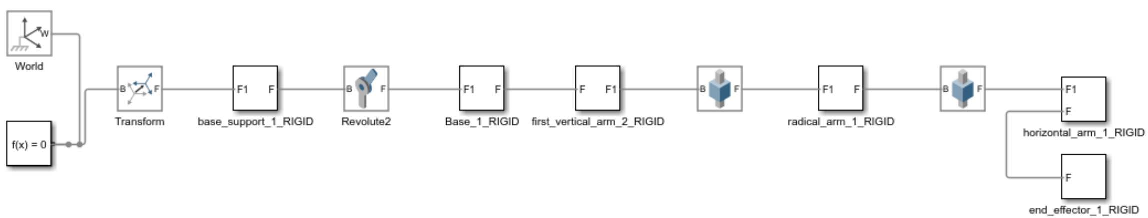
Using trapezoidal:



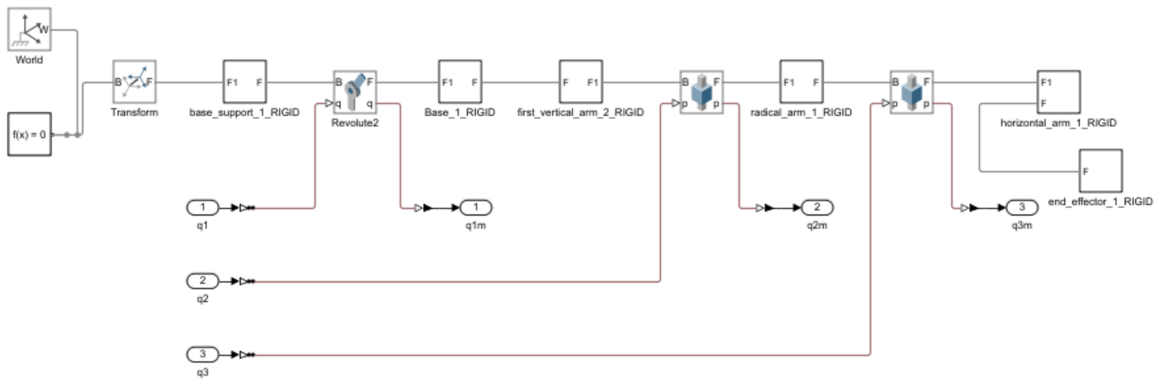


Part 3: Modeling and Simulation in MATLAB

After exporting:



Inside subroutine ‘robot’:

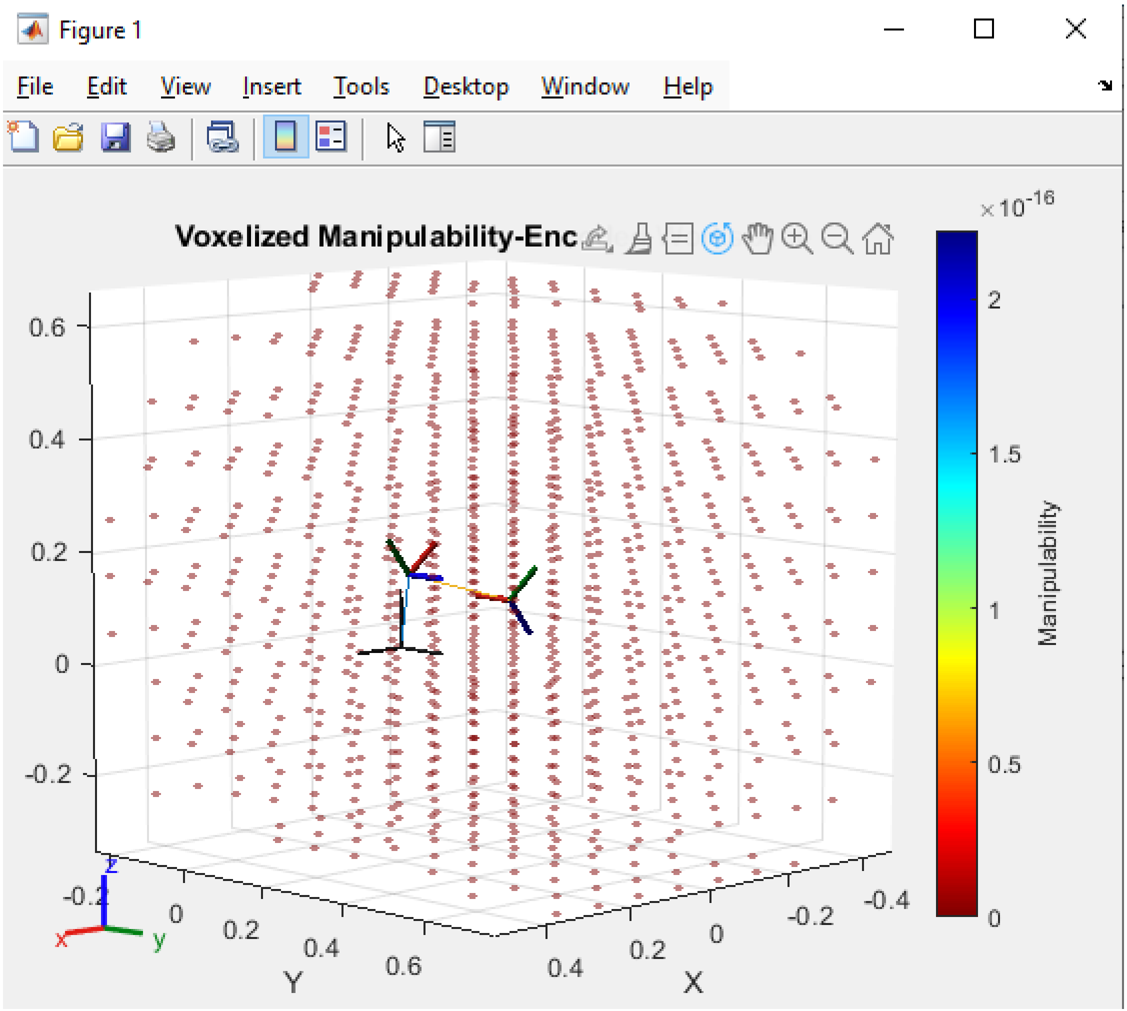


Part 4: Workspace and Performance Analysis

Rigid Body Tree:

```
Ts = 0.001;
[DOF3_Arm,ArmInfo] = importrobot('Assem21');
```

```
% Step 1: Use your existing rigidBodyTree object
robot = DOF3_Arm;
robot.DataFormat = 'row'; % Ensure the data format is set to 'row'

% Step 2: Visualize the robot
show(robot);

% Step 3: Define the end-effector
ee = "Body3";

% Step 4: Generate the robot workspace
rng default
[workspace, configs] = generateRobotWorkspace(robot, {}, ee, IgnoreSelfCollision="on");

% Step 5: Compute manipulability index
mIdx = manipulabilityIndex(robot, configs, ee);

% Step 6: Visualize the workspace analysis
hold on
showWorkspaceAnalysis(workspace, mIdx, Voxelize=true);
axis auto
title("Voxelized Manipulability-Encoded Workspace");
hold off
```



Waypoint:

```
wp = [0.35,0,0.1; 0.25, 0.01, 0.1; 0.25, 0.11, 0.1; 0.15, 0.11, 0.1; 0.15, 0.01, 0.1; 0.25, 0.01, 0.1]';
```

Conclusion

This assignment effectively demonstrated the design, simulation, and analysis of a cylindrical robotic manipulator by integrating advanced mechanical design and computational tools. Using SolidWorks, a detailed 3D model was developed to conceptualize the robot's structural components, including prismatic and revolute joints. The kinematic analysis, leveraging Denavit-Hartenberg parameters, provided valuable insights into the robot's motion and workspace capabilities.

Simulations conducted in MATLAB and Simscape Multibody verified the robot's functionality under dynamic scenarios, such as trajectory tracking and pick-and-place tasks. The workspace analysis highlighted the robot's operational flexibility and adaptability, while the use of trajectory planning algorithms underscored the precision achievable in path control. The implementation of PID control further validated the system's robustness, ensuring stable and accurate end-effector movements.

This project underscores the practicality and industrial relevance of cylindrical robots, particularly in material handling and assembly applications. Future enhancements could focus on integrating advanced control methods, optimizing energy efficiency, and incorporating real-time sensory feedback to extend the robot's adaptability to more complex tasks and environments

Challenges and Proposed Enhancements

During the simulation and analysis of the cylindrical robot, it was observed that the robot's movements did not align perfectly with the intended trajectory. This discrepancy highlighted certain limitations in the model, particularly in the accuracy of kinematic parameters and control strategies. One potential cause is the simplification of the model, which may not fully account for real-world dynamics, such as joint friction or load variations. Additionally, the tuning of the PID controller might not have been optimal, leading to inaccuracies in the robot's response to dynamic changes.

To address these challenges, several improvements can be implemented. Re-calibrating the Denavit-Hartenberg parameters could enhance the model's precision by better reflecting the actual geometry of the robot. Advanced control strategies, such as feedforward control or adaptive control, could be explored to minimize trajectory errors. Incorporating sensory feedback, such as encoders or accelerometers, would also allow for real-time corrections and improved accuracy during operation.

Future work could focus on integrating optimization algorithms to fine-tune the robot's performance and reduce systematic errors. Additionally, machine learning techniques could be utilized to predict and compensate for deviations in the robot's movements, improving adaptability to complex tasks. These enhancements will not only resolve current issues but also pave the way for the cylindrical robot to perform more efficiently in diverse industrial applications.

References

https://www.mathworks.com/help/smlink/ref/mates-and-joints.html

https://www.youtube.com/watch?v=20ENJ7jOJzE

https://www.youtube.com/watch?v=xB5epLnoURM&t=697s

https://www.youtube.com/watch?v=_8YCc3pJDPI&list=PLWF9TXck7O_ymYWT8Q33omPb5K-A5v4Ae