CONTROL OF 5-DOF ROBOTIC MANIPULATOR SYSTEM

*Adarsh R   *Abhijith Krishnan   *Sajima Santhosh   *Sneha S   ** Dr. Sneha Gajbhiye   ***Vinod G

*UG Scholar - ECE, NSSCE Palakkad   **Assistant Professor - Dept. of EE, IIT Palakkad

***Associate Professor – Dept. of ECE, NSSCE Palakkad

NSS COLLEGE OF ENGINEERING
Palakkad, Kerala, India

Abstract

Robotic manipulators play a significant role in the manufacturing sector. Several industries, including welding, pick-and-place, assembly, packaging, and labelling, heavily utilise arm robot manipulators. They are utilised for a variety of purposes, which require repeatability, accuracy, and speed. One of the most challenging tasks in robotics is to move a robotic arm quickly and precisely. The major purpose of learning control in robotic manipulators is to deal with the problem of friction at joints of robotic mechanisms and other uncertainties that may occur in the dynamic models, which are extremely complicated and may even be mathematically impossible to model. So, in this context, OpenMANIPULATOR-X is used to model the dynamics, track the desired trajectory, and design a controller. OpenMANIPULATOR-X is a 5DOF robotic arm under an open-source platform designed for various applications, such as research, education, and industrial automation. To analyse the robotic arm, forward and inverse kinematics are implemented, and it is verified that the robot is tracing the desired paths by using trajectory tracking. Proportional-Integral-Derivative (PID) controller is also designed for this robotic arm. In this study, to achieve the above said objectives, simulation in MATLAB, Gazebo, and hardware implementation is adopted. In the end, modelling and hardware implementation was done successfully and the corresponding results are provided which serve as the theoretical and practical framework for the examination and subsequent analysis of the robot arm.

Introduction

- A robot arm is made up of a series of joints that connect moveable links, with one end usually having an end-effector or hand attached, and the other end being fastened to the ground. Robotic arms are used in industries and hazardous environments where great precision is required. They are capable of carrying out repetitive tasks faster and more accurately than human operators. It has proven difficult to manage robot arms with more degrees of freedom (DoF). The robot arm's design and control hence require undertaking position analysis and trajectory planning.

- Significant progress has been made in robotics research as a result of improvements in robot technology and the expanding use of robotics in a variety of fields. Researchers in robotics have been focusing on current configurations, intelligent actions, autonomous robotics, and high-level intelligence, all of which are connected to robot kinematics, both forward and inverse. However, it is still difficult to come up with excellent universal algorithms for the forward and inverse kinematics of a robot arm, particularly when trying to establish a correlation between the two kinematic models. The problem is the inaccurate correlations between a robot arm's forward and inverse kinematics.

- Understanding the relationship between the forward and inverse kinematics of the actuators is crucial for properly controlling the robot's final position and for planning accurate movements of a robot arm. Therefore, there is still room for more research and effort in search of better solutions.

- The goal of this work is to develop a practical approach for quickly and easily solving the forward and inverse kinematic problem of a 4-DoF articulated robotic manipulator. An accurate correlation between the forward and inverse kinematics of a 4-DoF articulated robotic manipulator is achieved using the MATLAB software. The study evaluates Robotis' OpenMANIPULATOR-X robot arm, an open-source robotic platform.

Design Methodology

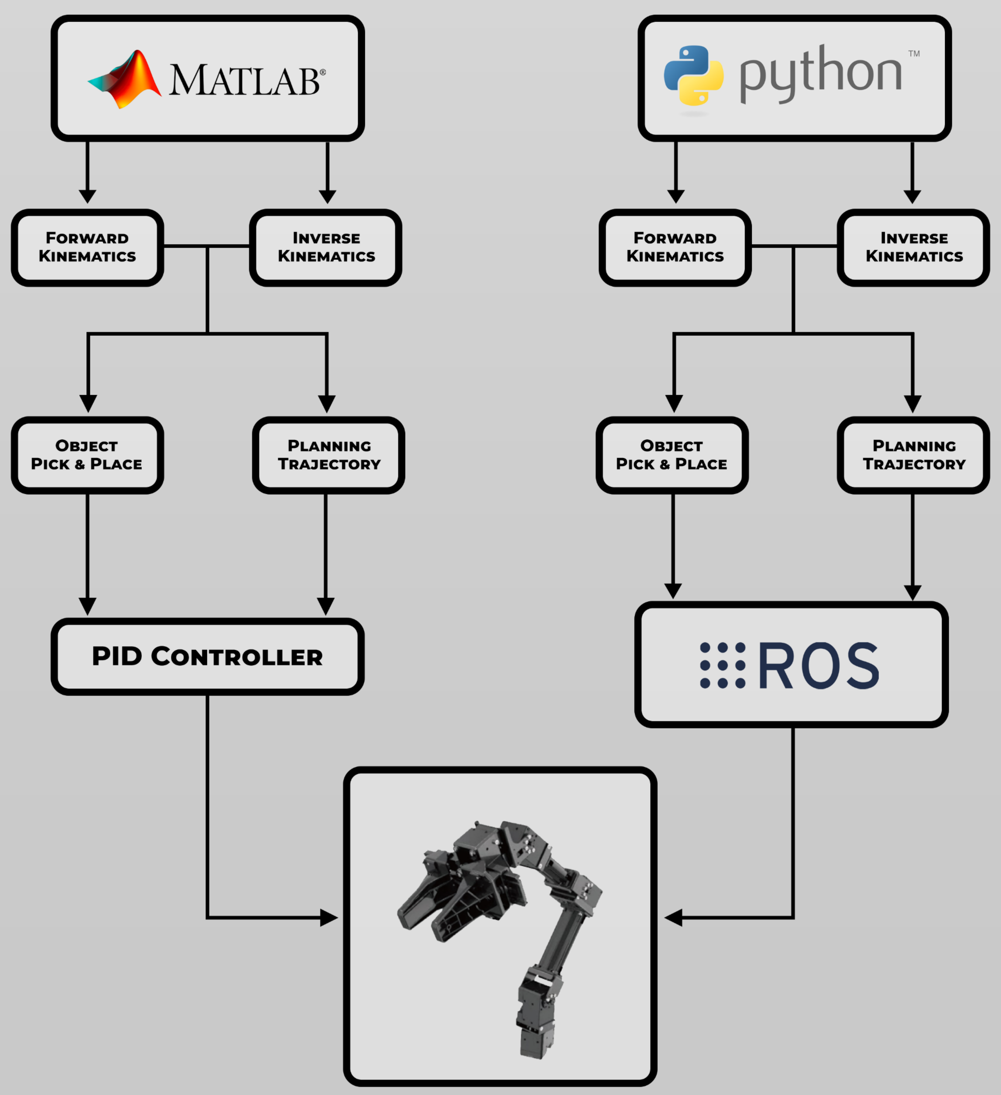
Analysing the dynamics of the robotic manipulator, trajectory tracking, and design of the controller are the design objectives. Forward and inverse kinematics are the two broad ways to implement the dynamics. Forward kinematics determines the configuration of the end-effector (the gripper) given the relative configurations of each pair of adjacent links of the robot whereas, inverse kinematics is the process of obtaining the joint angles from the position and orientation of the end-effector. For a specific end-effector position and orientation, they offer an infinite variety of joint motions, which makes inverse kinematics more complex than forward kinematics. In trajectory planning, given a set of endpoints, the robot is required to traverse a path through the points. PID controller is also designed, to control the robotic arm movements and the below equation gives the output of PID controller:

$$u(t) = K_p e(t) + Ki \int e(t)\,dt + K_p \frac{de}{dt}$$

$u(t)$ = PID control variable
K_p = Proportional gain
K_d = Derivative gain
K_i = Integral gain
$e(t)$ = Error value

Using a rigid body tree of OpenMANIPULATOR-X and necessary blocks as per the task at hand, SIMULINK in MATLAB is used to simulate dynamics and trajectory tracking. PID Controller design is also implemented in SIMULINK and the error tolerances are rectified. With the help of dynamics and trajectory tracking, picking and placing an object in the desired position is simulated in Gazebo. This is achieved by creating Python scripts in Visual Studio code and interfacing that with Gazebo. For the verification of this theoretical modelling hardware implementation is also adopted.

Block Diagram



Hardware Setup

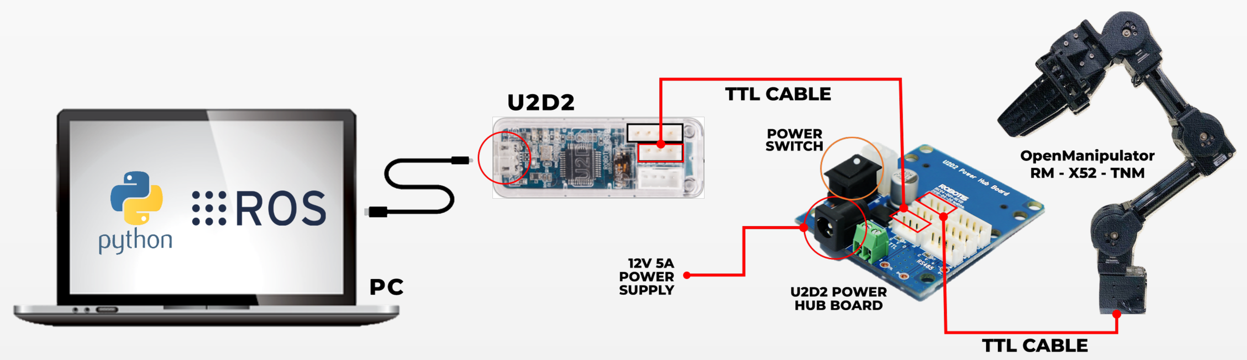
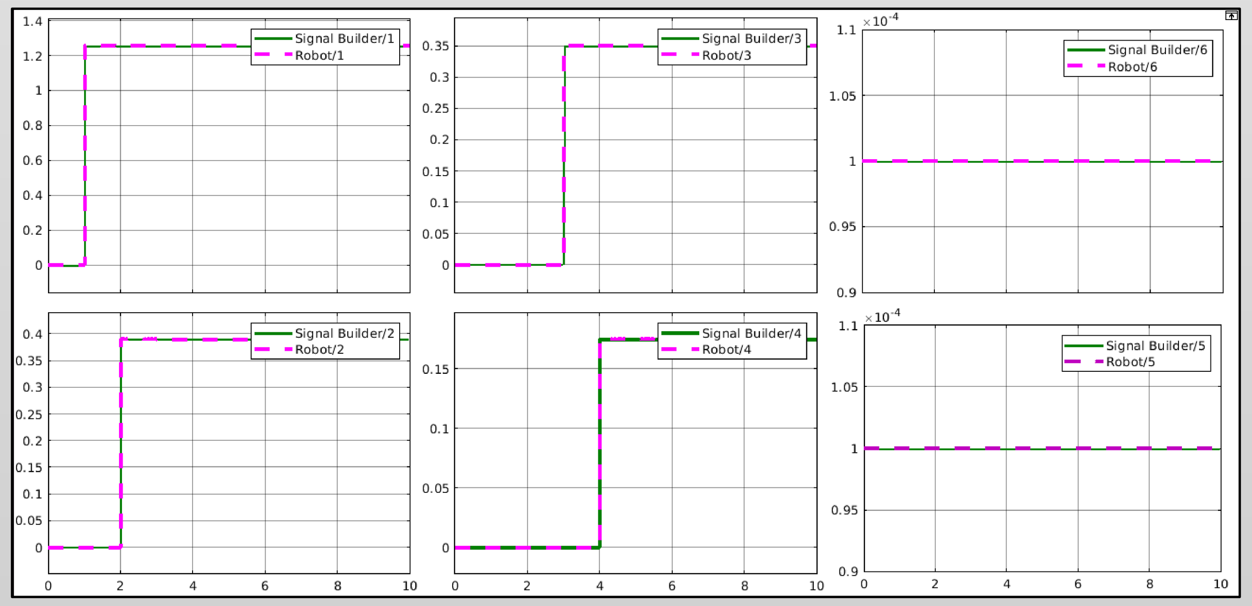


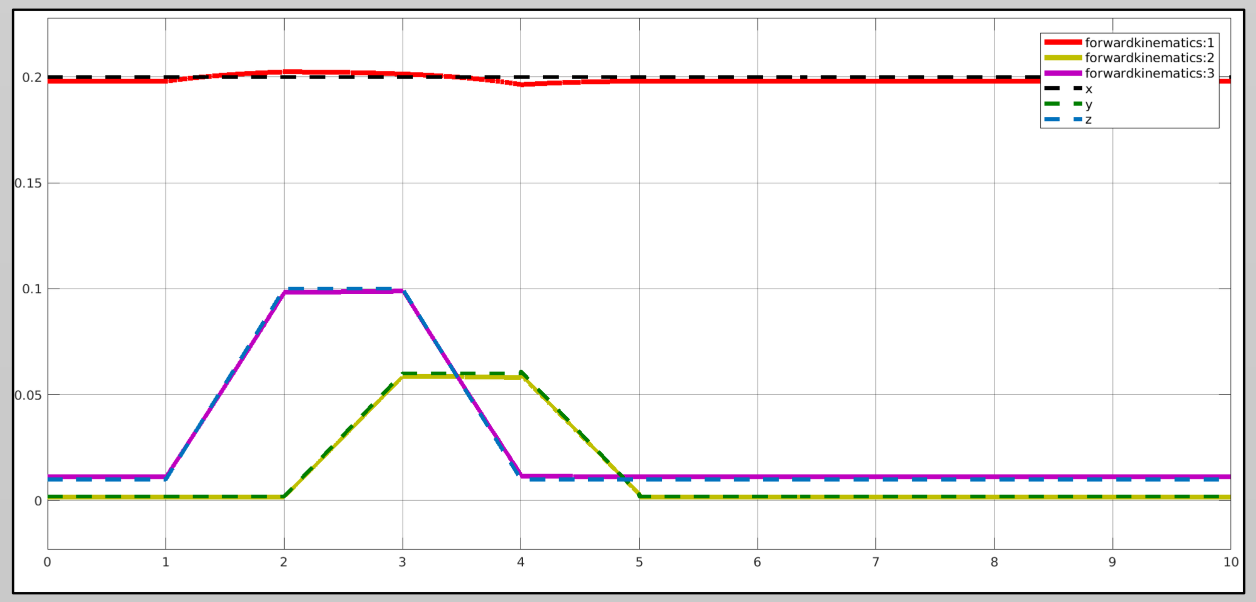
Fig. above shows the connection of OpenManipulatorX to the Laptop/PC by using U2D2 as the communication interface.

Figures above shows the assembled hardware kit of OpenManipulatorX interfaced to the Laptop using U2D2.

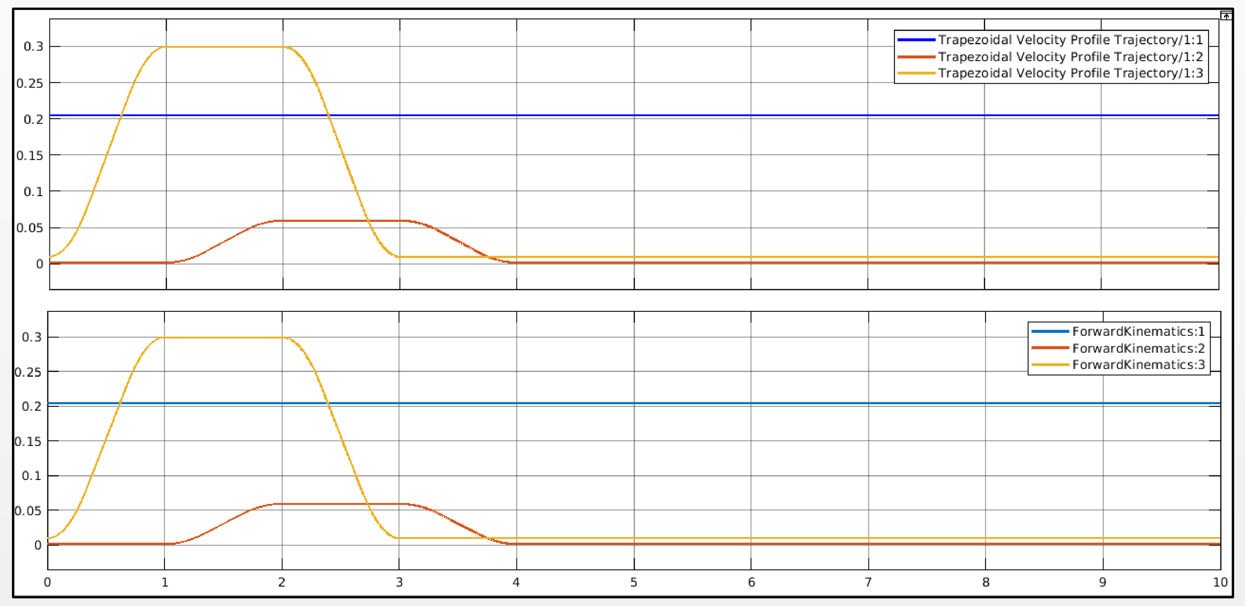
Results



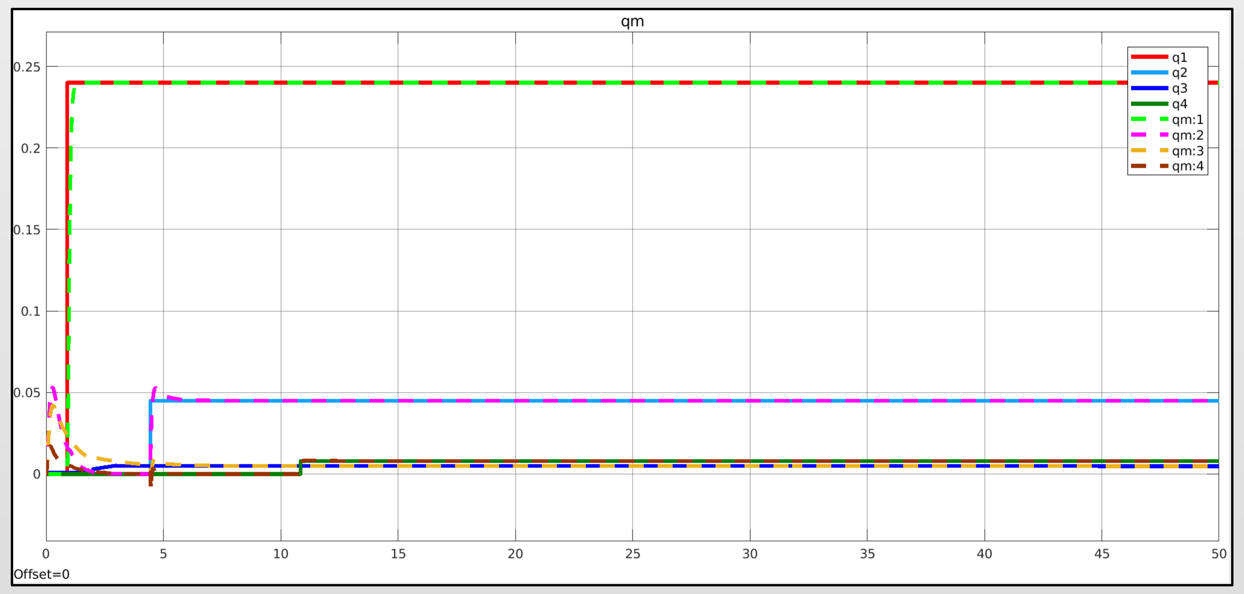
In the above graph, Signal Builder/1 refers to the signal output of the signal builder and Robot/1 refers to the rotational movement(in radians) of the joint 1. The same convention holds for all other joints as well.



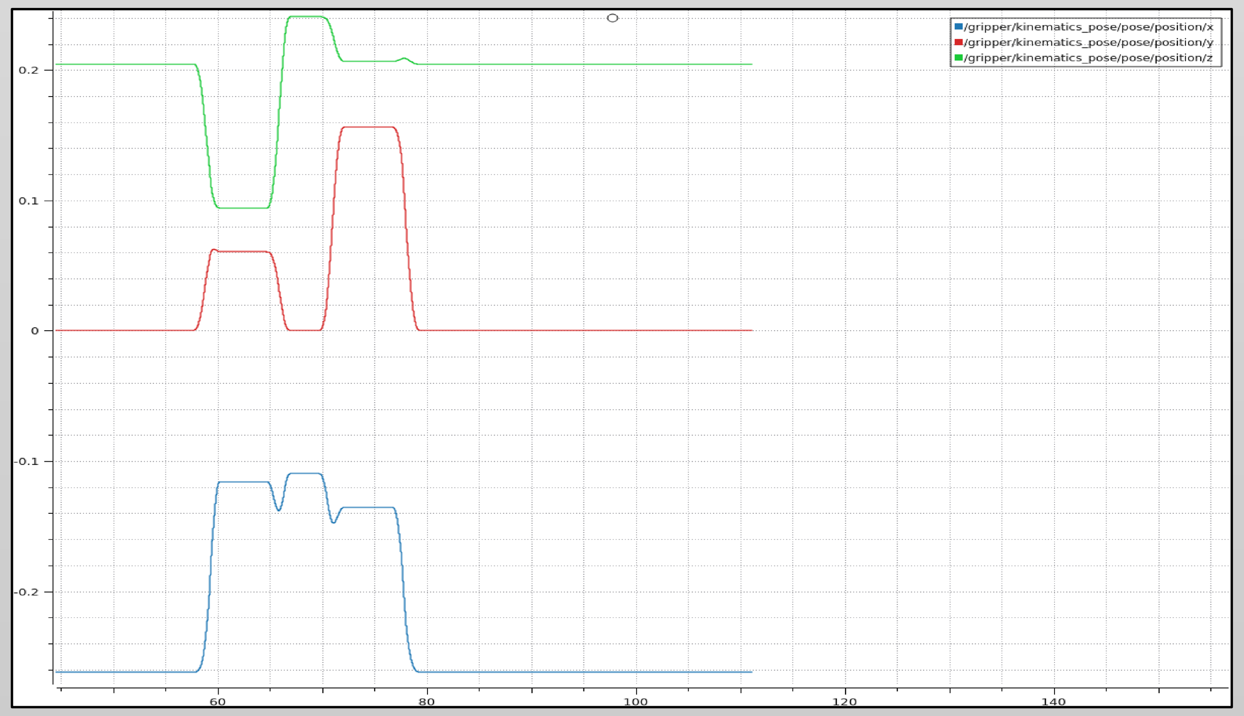
In the above graph, x, y, z corresponds to the desired positions of gripper respectively and forward kinematics:1/2/3 corresponds to the x,y,z coordinates that the gripper traversed respectively.



In the above graph, Trapezoidal Velocity Profile Trajectory:1/2/3 corresponds to the given waypoints and ForwardKinematics:1/2/3 are the points tracked by the robot .



In the above graph, PID Controlled joint movements of robotic arm are represented. Here q1/q2/q3/q4 represents the desired input path, and the qm:1/2/3/4 represents the robotic arm movement controlled by the PID controller.



In the above graph, x, y, z corresponds to the positions of gripper traversed for the picking and placing of the object.

Conclusions

- The dynamics and trajectory planning of OpenManipulator-X has been simulated, verified and implemented in hardware.
- The introduction of PID controllers has improved the system's response and reduced errors in motion.