

Laboratory Report 2

Section 1

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1. Introduction

The development of robotic systems is mainly done within the framework of the Robot Operating System (ROS). In this report we studied the 5 Degree of Freedom (DoF) Planar Manipulator, a versatile robotic arm designed for various applications in research and industry. By leveraging the extensive resources available within the ROS community, we compiled and utilized several packages from Git repositories to enhance our understanding and control of the manipulator.

Our primary objectives included initiating the robot's movements, implementing single joint control, and analyzing the performance of a PID controller in response to a step input. Visualization of these responses was facilitated through the "rqt" tool, providing valuable insights into the system's dynamics. Additionally, we explored the complexities of coordinating multiple joints to achieve more intricate motions, such as those resembling the fluid movement of a snake.

Through this report, we aim to present our methodologies, findings, and the implications of our work, contributing to the broader understanding of robotic manipulation and control within the ROS ecosystem.

The code and files can be found at <https://github.com/asemqr/RoboticsLabs/tree/LabReport2>

2. Task 1

Before proceeding with the main task, several preparatory steps were necessary to ensure proper functioning of both the simulated and real robot environments.

2.1. Simulation Setup The robot simulation was initiated with the command:

```
$ roslaunch gazebo_robot gazebo.launch
```

A new terminal was used to publish a new angle to the last joint: `/robot/joint5/command`

2.2. Real Robot Setup The USB adapter was connected, and access was granted with: `sudo chmod -R 777 /dev/ttyUSB0`

Configuration files were modified to switch from simulation to the real robot by updating the file path in the `hand_tutorial_moveit_controller_manager.launch.xml` file.

2.3. A ROS node named **joint_controller** was developed within the **controller** package to manage the planar robot's joints. This node listens for `std_msgs/Float64` data and only publishes a command to move a joint if the incoming value is higher than the previous one, ensuring efficient operation by preventing unnecessary movements.

The core functionality is implemented in the `jointCommandCallback` function, which compares each incoming message to the previous value. If the new value is higher, it publishes the command to move the joint. Otherwise, no command is sent, conserving the robot's movement and enhancing operational efficiency.

The node is initialized with `ros::init(argc, argv, "rotate")`, and it subscribes to a topic (`/joint5/input`) to receive the data. The node then spins, processing incoming messages and invoking the callback function as necessary. The node's implementation includes a comparison of incoming values with a previously stored value. If the new value exceeds the previous one, it publishes the command to the joint's position controller. The node subscribes to the `/joint5/input` topic and publishes commands to `/robot/joint5_position_controller/command`.

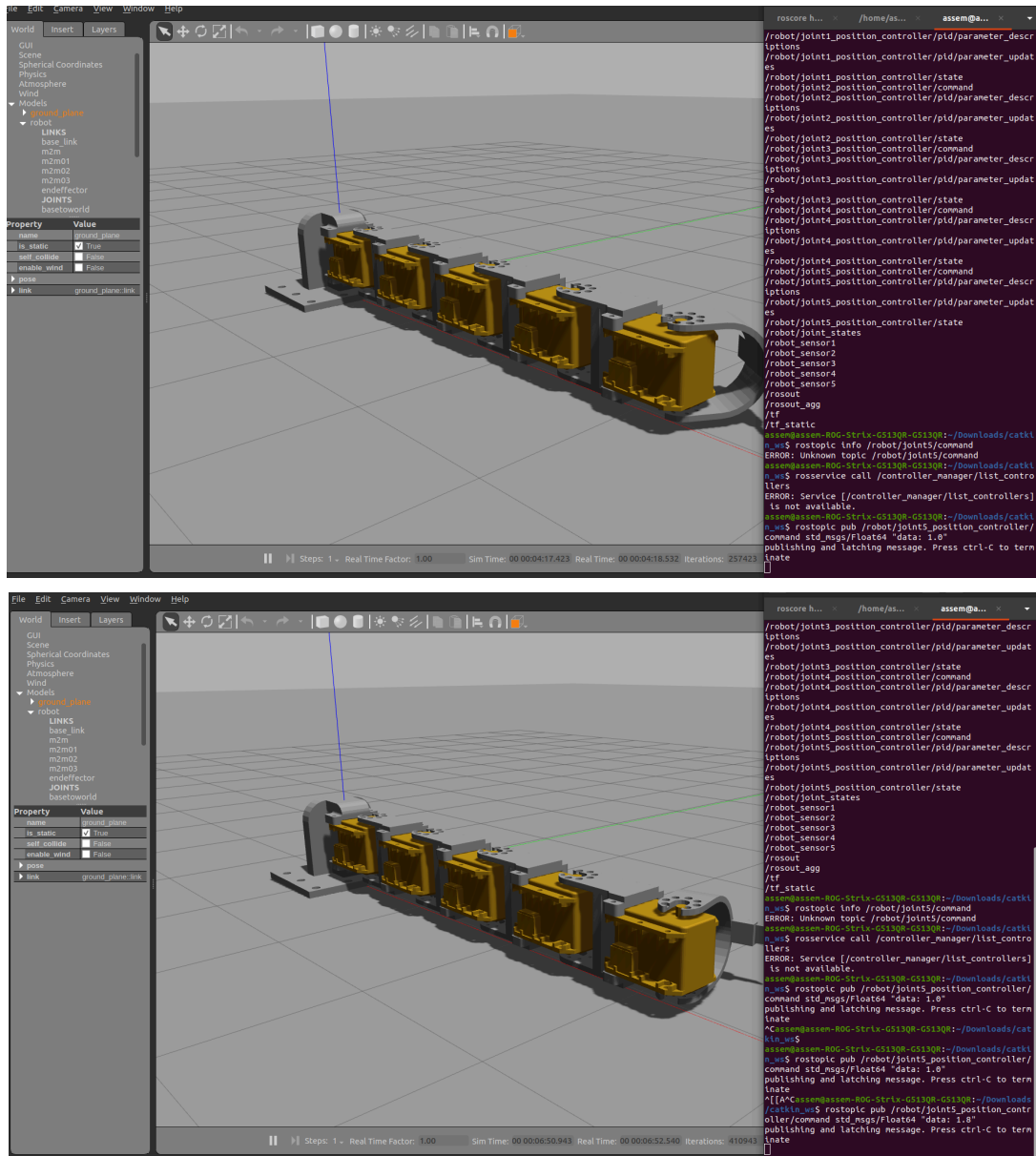


Figure 1. Publisher and listener node in beginner tutorials package

3. Task 2

In Task 2, we generated the step response for both the base and end-effector joints of the robot by sending a square-wave function through a ROS node, named square-node controller. We compiled catkin_ws space using `catkinmake`, ran the node and observed the plot in `rqt`, choosing the topics like joint's `current pos` and `goal pos`.

For joint 1, we observed a quick rise time and some overshoot before the joint stabilized with little oscillation. The response was relatively fast. In contrast, the fifth joint exhibited a slower rise time, with a noticeable delay before the joint started moving. There was less overshoot, and the joint settled more gradually. Overall, the base joint responded faster and with more overshoot, while the end-effector joint was more stable but slower.

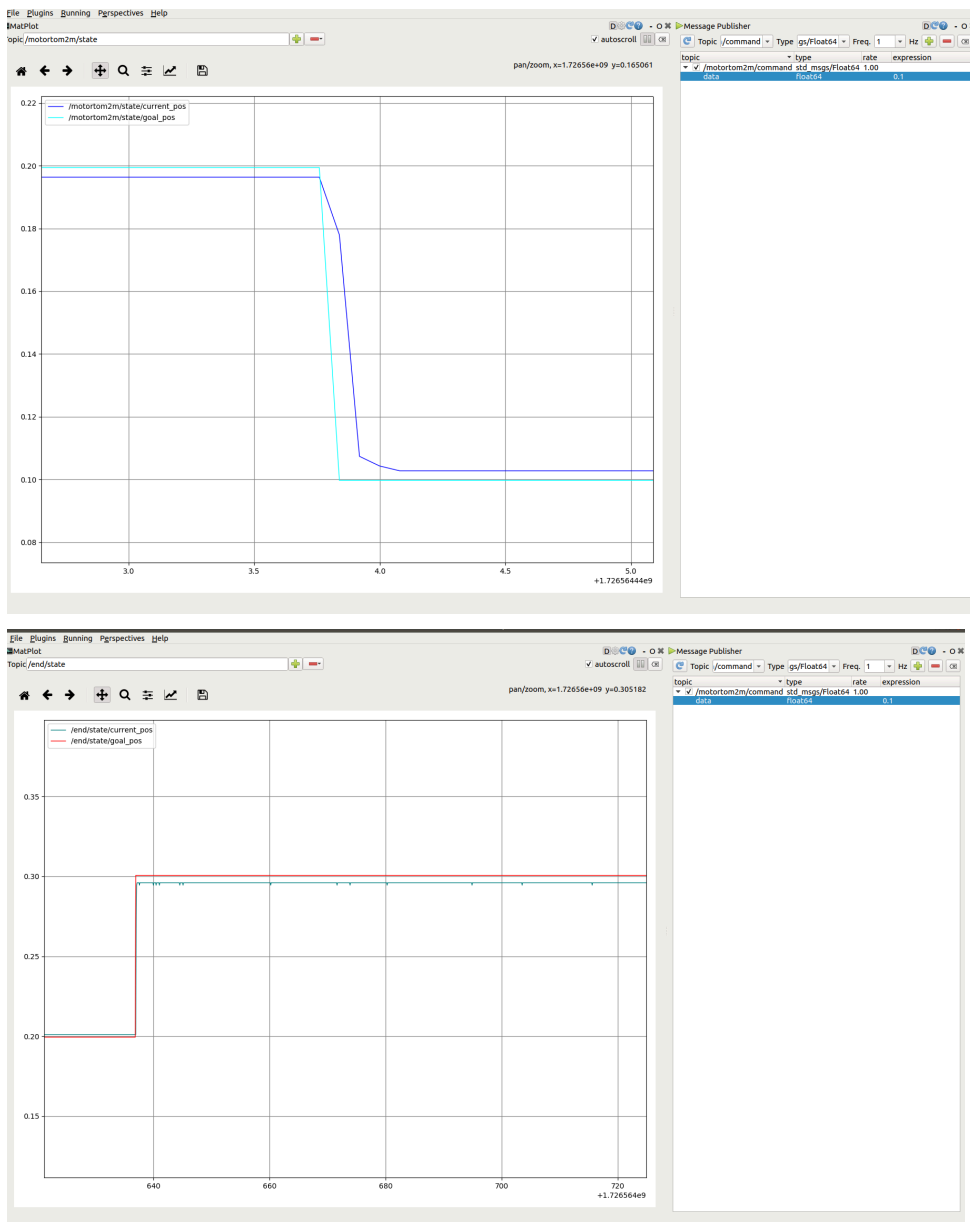


Figure 2. The step wave outputs of joint 1 and 5

4. Task 3

We modified the existing ROS node to generate and publish a sine-wave function as the velocity command to the joints. This involved creating a publisher node that sends a `std_msgs/Float64` type message, where the sine function's output was assigned to the angular velocities of both joints.

The sine-wave signal was continuously updated and published to the `/robot/joint_command` topic at regular intervals. This commanded the robot to oscillate the joints smoothly, following the sine-wave pattern.

After making the necessary modifications to the node, we recompiled the package using `catkin_make`. Once the node was successfully built, it was executed, and we observed the robot's response in real-time.

Using `rqt`, we visualized the response of the joints to the sine-wave command. The `rqt` plot displayed the desired sine-wave signal in blue (command value) and the actual movement of the joints in red (real value). Any deviation between the two curves indicated the lag or errors in the joint response. This process helped us evaluate the robot's dynamic performance under varying conditions.

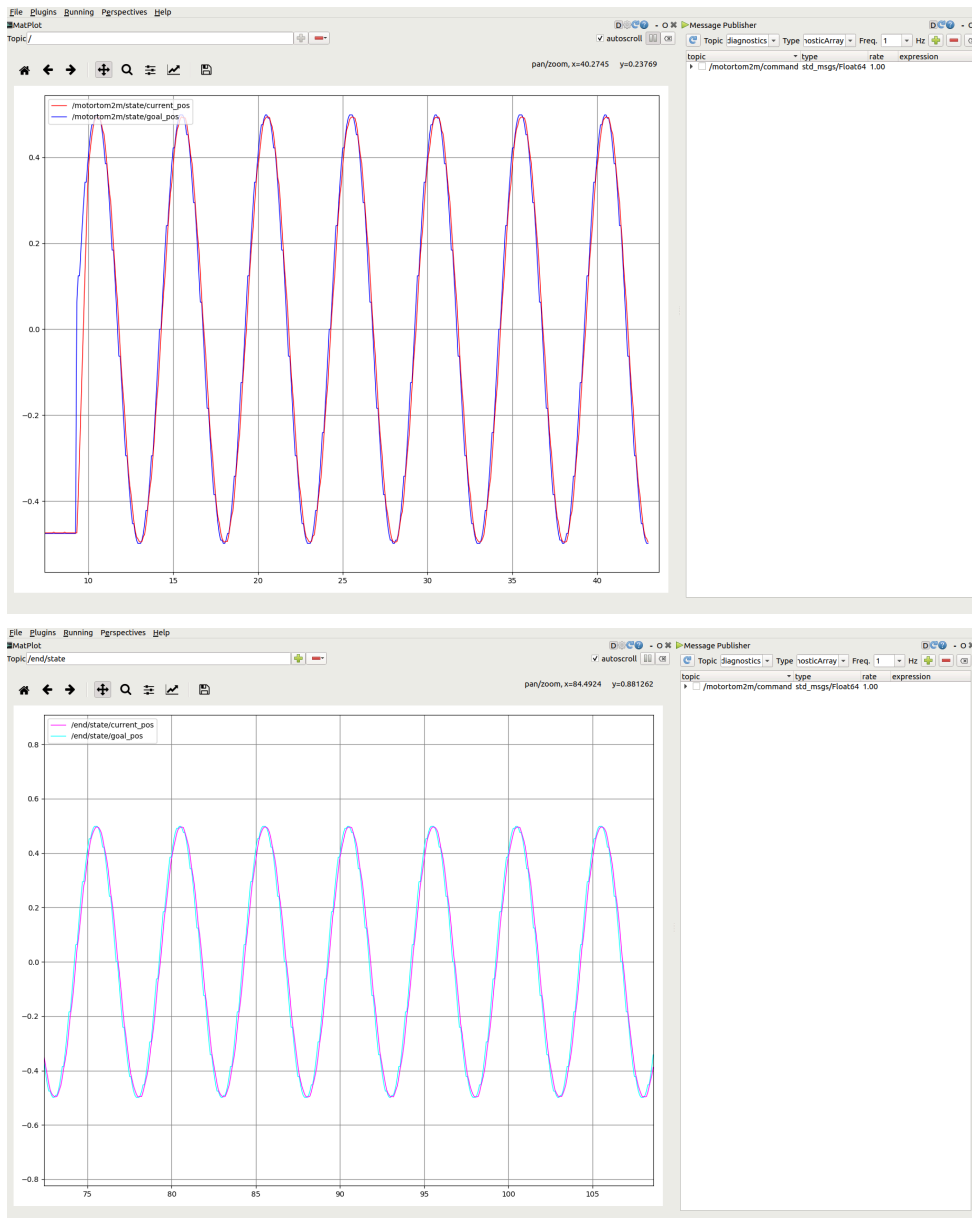


Figure 3. The sine wave outputs of joint 1 and 5

5. Task 4

During Task 4, we experimented with adjusting the Proportional gain (P) of the PID controller for the robot's joints and observed the effects on both the step and sine responses.

When we increased the Proportional gain P , we observed that the joints, both at first and the fifth joint, reached the desired position more quickly. However, this also led to some overshoot and for joint 1. When we decreased P , the response became slower and more controlled, with reduced overshoot. Still, we had a slight steady-state error, where the joint did not settle exactly at the desired position.

For the sine-wave response, increasing P improved led to bigger oscillations. On the other hand, decreasing P caused fewer oscillations. Overall, our adjustments show that if we increase P , we improve precision but lose stability, while decreasing P improves stability but slows down the system, making it less reactive and accurate.

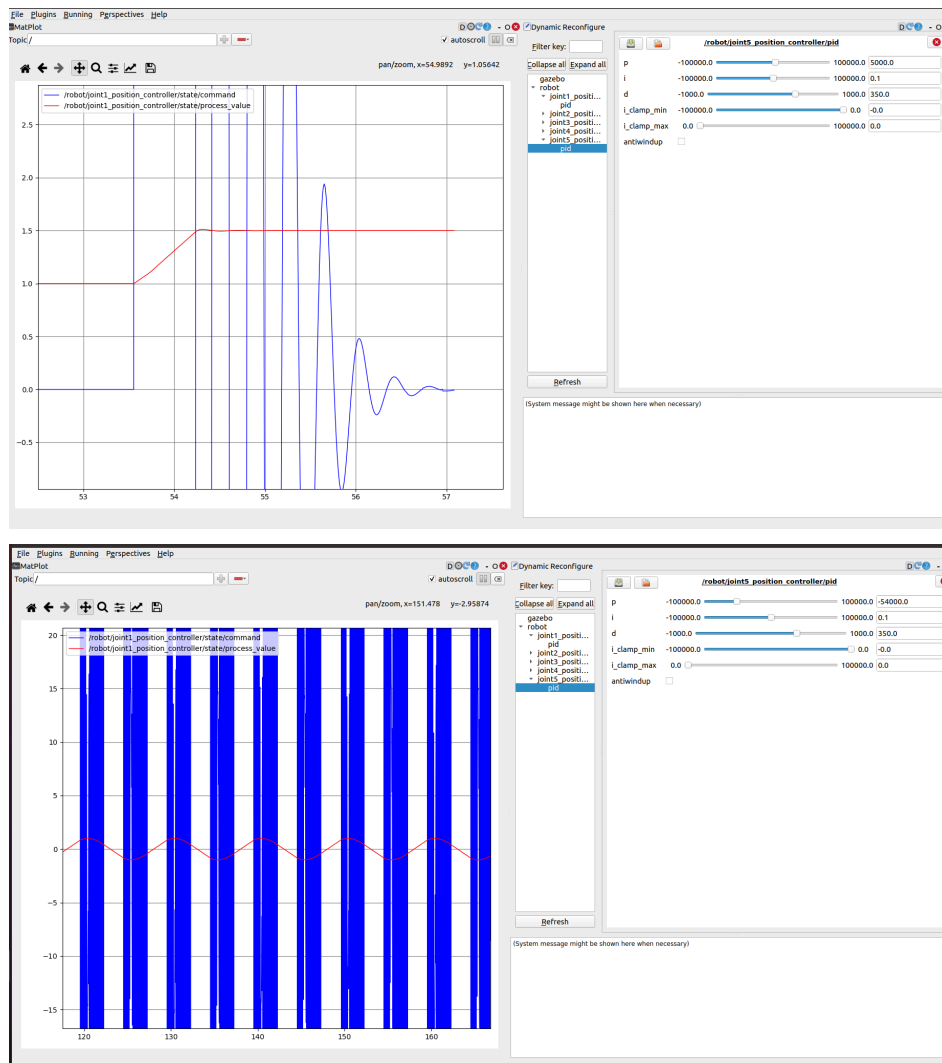


Figure 4. PID Tuning outputs of base and end-effector joints (included only main two graphs)

6. Task 5

For this task, our code calculates the position of each joint using a sine wave, with phase shifts applied between joints to ensure coordinated wave motion. Five ROS publishers are set up to send these positions to the robot's joints in real-time, updating at a rate of 10 Hz. The program continuously runs in a loop, calculating new positions for each joint based on elapsed time and publishing these values to the corresponding topics. This creates the desired snake-like movement, with the robot's joints moving in a smooth, wave-like pattern, mimicking a slithering motion.

```
[H] home/ubuntu/catin ws/src/snake-noetic/my dynamikl tutorial/src/controller_manager.launchhttp://localhost:11311 tx10x30 | ubuntu@ubuntu:~$ catkin_ws
auto-starting new master
process[master]: started with pid [123222]
ROS_MASTER_URI=http://localhost:11311

setting /run_id to b6d92900-74df-11ef-bfbd-4c5262100f9e
process[rosout-1]: started with pid [123355]
started core service [/rostopic]
process[dynamixel_controller-2]: started with pid [123388]
the rosdsp view is empty; call 'sudo rosdsp int' and 'rosdsp update'
[INFO] [1726568978.657151]: pan_tilt_port: Pinging motor IDs 1 through 20...
[WARN] [1726568980.129915]: Exception thrown while getting attributes for motor 1 - Invalid response received from motor 1. List index out of range
[ERROR] [1726568980.252894]: exception thrown while getting attributes for motor 1 - Invalid response received from motor 1. List index out of range
[WARN] [1726568980.302889]: Exception thrown while getting attributes for motor 1 - Checksum received from motor 1 does not match the expected one (3 != 254)
[INFO] [1726568980.637821]: exception thrown while getting attributes for motor 2 - Invalid response received from motor 2. Wrong ack prefix [11fff]
[WARN] [1726568980.918801]: Exception thrown while getting attributes for motor 3 - Invalid response received from motor 3. wrong ack prefix [11fff]
[INFO] [1726568981.249878]: pan_tilt_port: Found 5 motors ~ 5 MX-28 [1, 2, 3, 4, 5], Initialization complete.
[WARN] [1726568994.498801]: [main_arm] not all dependencies started, still waiting for ["motortomzn", "jointn2", "end", "jointn1"]...
[INFO] [1726568994.498637]: [main_arm] not all dependencies started, still waiting for ["motortomzn", "end", "jointn2"]...
[WARN] [1726568994.512366]: [main_arm] not all dependencies started, still waiting for ["motortomzn", "end"]...
[WARN] [1726568994.544973]: [main_arm] not all dependencies started, still waiting for ["end"]...
[H] home/ubuntu/catin ws/src/snake-noetic/my dynamikl tutorial/src/start moveit arm controllers.launchhttp://localhost:11311 tx10x30 | ubuntu@ubuntu:~$ cd catkin_ws
source devel/setup.bash
robot_state_publisher (robot_state_publisher/robot_state_publisher)
tilt_controller_spawner (dynamixel_controllers/controller_spawner.py)
tilt_controller_spawner_meta (dynamixel_controllers/controller_spawner.py)
ROS_MASTER_URI=http://localhost:11311

process[tilt_controller_spawner-1]: started with pid [130393]
process[tilt_controller_spawner_meta-2]: started with pid [130366]
process[robot_state_publisher-3]: started with pid [130377]
process[moveit_mqtt_state-4]: started with pid [130388]
[INFO] [1726568994.216985]: pan_tilt_port controller_spawner: waiting for controller_manager dxl_manager to start up in global namespace...
[INFO] [1726568994.216745]: meta controller_spawner: waiting for controller_manager dxl_manager to start up in global namespace...
[INFO] [1726568994.226609]: pan_tilt_port controller_spawner: All services are up, spawning controllers...
[INFO] [1726568994.229835]: meta controller_spawner: All services are up, spawning controllers...
[INFO] [1726568994.333701]: Controller joint0 successfully started.
[INFO] [1726568994.452273]: Controller joint1 successfully started.
[INFO] [1726568994.481579]: Controller joint4 successfully started.
[INFO] [1726568994.513138]: Controller joint2 successfully started.
[INFO] [1726568994.546094]: Controller motortomzn successfully started.
[INFO] [1726568994.593616]: Controller end successfully started.
[tilt_controller_spawner_meta-2] process has finished cleanly
log file: /home/ubuntu/.ros/log/b6d92900-74df-11ef-bfbd-4c5262100f9e/tilt_controller_spawner_meta-2*.log
[tilt_controller_spawner-1] process has finished cleanly
log file: /home/ubuntu/.ros/log/b6d92900-74df-11ef-bfbd-4c5262100f9e/tilt_controller_spawner-1*.log
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[INFO] [1726568994.593616]: Controller end successfully started.
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[tilt_controller_spawner-1] process has finished cleanly
log file: /home/ubuntu/.ros/log/b6d92900-74df-11ef-bfbd-4c5262100f9e/tilt_controller
```

Figure 5. The commands to run snake robot in Ros Melodic