

# MCT 344 Industrial Robotics



## *Assignment 1*

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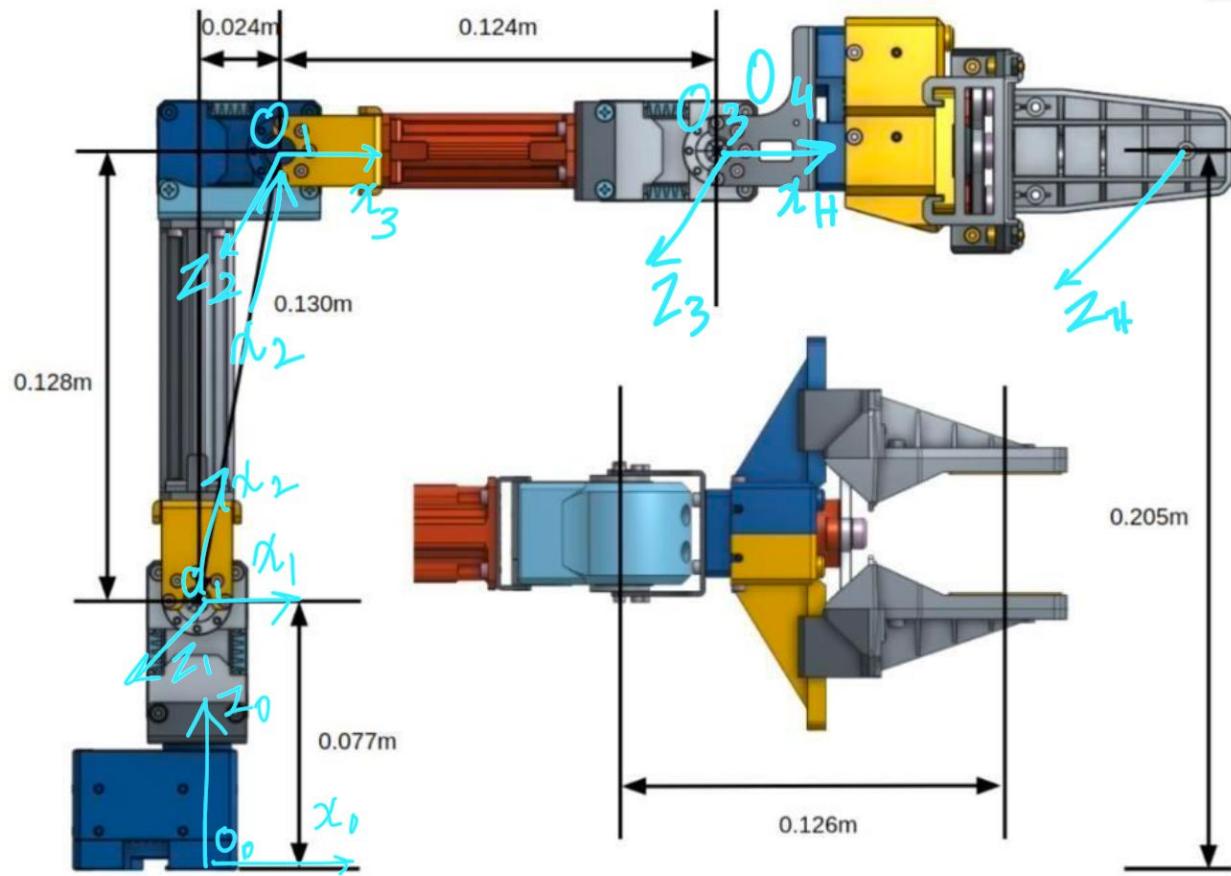
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## 1.0 DH PARAMETERS TABLE



$i$	$T$	$\theta$	$d$	$a$	$\alpha$
1	${}^0{}_1T$	$\theta_1$	0.077	0	90
2	${}^1{}_2T$	$\theta_2$	0	0.130	0
3	${}^2{}_3T$	$\theta_3$	0	0.124	0
$H$	${}^3{}_H T$	$\theta_H$	0	0.126	0



## 2.0 CODE

```
import rospy
import numpy as np
from std_msgs.msg import Float64, Float32MultiArray

# DH parameter function which returns the DH matrix
def std_DH (theta, d, a, alpha):
    DH = np.array([ [np.cos(theta), -np.sin(theta) * np.cos(alpha),
    np.sin(theta) * np.sin(alpha), a * np.cos(theta)],
                    [np.sin(theta), np.cos(theta) * np.cos(alpha), -
    np.cos(theta) * np.sin(alpha), a * np.sin(theta)],
                    [0, np.sin(alpha), np.cos(alpha), d],
                    [0, 0, 0, 0],
    1] )

    return DH

# angle and Matrix as global variable
global theta1, theta2, theta3, theta4, FinalMat

if __name__ == '__main__':
    # initialization the variable with 0
    theta0, theta1, theta2, theta3, theta4, FinalMat = 0, 0, 0, 0, 0, 0

    # create and initializing node
    rospy.init_node("Forward_Kinematics")

    # the translation matrix for the offset of the first joint with the
    origin
    translation = np.array([ [1, 0, 0, 0.012],
                            [0, 1, 0, 0],
                            [0, 0, 1, 0],
                            [0, 0, 0, 1] ])

    # position publisher
    position_pub = rospy.Publisher("/position_robot", Float32MultiArray,
queue_size = 10)

    # joint actuators
```



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```
joint1_pub = rospy.Publisher("/joint1_position/command", Float64,
queue_size = 10)
joint2_pub = rospy.Publisher("/joint2_position/command", Float64,
queue_size = 10)
joint3_pub = rospy.Publisher("/joint3_position/command", Float64,
queue_size = 10)
joint4_pub = rospy.Publisher("/joint4_position/command", Float64,
queue_size = 10)

# initialization joints with 0
joint1_pub.publish( Float64(0) )
joint2_pub.publish( Float64(0) )
joint3_pub.publish( Float64(0) )
joint4_pub.publish( Float64(0) )

# the angle between 2nd and 3rd joint
theta0 = np.arctan2(0.024, 0.128)

# joint angles
theta1 = np.pi / 2 # 1.571 rad
theta2 = -np.pi / 3 # -1.043 rad
theta3 = np.pi / 4 # 0.783 rad
theta4 = np.pi / 6 # 0.523 rad

rate = rospy.Rate(10)

while not rospy.is_shutdown():
    # moving the robot
    joint1_pub.publish( Float64(theta1) )
    joint2_pub.publish( Float64(theta2) )
    joint3_pub.publish( Float64(theta3) )
    joint4_pub.publish( Float64(theta4) )

    # calcualting the DH matrices (theta considering initial position)
    T01 = std_DH (theta1, 0.077, 0, np.pi / 2)
    T12 = std_DH (-theta2 - theta0 + (np.pi / 2), 0, 0.130, 0)
    T23 = std_DH (-theta3 + theta0 - (np.pi / 2), 0, 0.124, 0)
    T3H = std_DH (-theta4, 0, 0.126, 0)
```



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```
# the transformation matrix from the end effector to the origin
FinalMat = translation @ T01 @ T12 @ T23 @ T3H

# getting the cordination
pos_msg = Float32MultiArray()
x = FinalMat[0, 3]
y = FinalMat[1, 3]
z = FinalMat[2, 3]

# getting the orientation
roll = np.arctan2( FinalMat[2, 1],
FinalMat[2, 2])
pitch = np.arctan2(-FinalMat[2, 0], np.sqrt(FinalMat[2, 1] ** 2 +
FinalMat[2, 2]))
yaw = np.arctan2( FinalMat[1, 0],
FinalMat[0, 0])
pose = [x, y, z, roll, pitch, yaw]

# publishing the message
pos_msg.data = pose
position_pub.publish(pos_msg)
rospy.loginfo("Robot Position [x y z roll pitch yaw]")
rospy.loginfo(np.array(pose).astype(np.float16))
rate.sleep()
```

## 3.0 TERMINAL WORK AND GAZEBO

```
amalamr@ubuntu: ~$ mkdir catkin_ws
amalamr@ubuntu: ~$ cd catkin_ws
amalamr@ubuntu:~/catkin_ws$ mkdir src
amalamr@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/amalamr/catkin_ws
Source space: /home/amalamr/catkin_ws/src
Build space: /home/amalamr/catkin_ws/build
Devel space: /home/amalamr/catkin_ws/devel
Install space: /home/amalamr/catkin_ws/install
Creating symlink "/home/amalamr/catkin_ws/src/CMakeLists.txt" pointing to "/opt/ros/noetic/share/catkin/cmake/toplevel.cmake"
#####
#### Running command: "cmake /home/amalamr/catkin_ws/src -DCATKIN_DEVEL_PREFIX=/home/amalamr/catkin_ws/devel -DCMAKE_INSTALL_PREFIX=/home/amalamr/catkin_ws/install -G Unix Makefiles" in "/home/amalamr/catkin_ws/build"
#####
```

*Figure 1: Creating Folders*

```
amalamr@ubuntu: ~/catkin... x roscore http://ubuntu:113... x amalamr@ubuntu: ~/catkin... x
-- Configuring done
-- Generating done
-- Build files have been written to: /home/amalamr/catkin_ws/build
#####
##### Running command: "make -j4 -l4" in "/home/amalamr/catkin_ws/build"
#####
amalamr@ubuntu:~/catkin_ws$ cd src
amalamr@ubuntu:~/catkin_ws/src$ catkin_create_pkg milestone1 roscpp rospy std_msgs
Created file milestone1/package.xml
Created file milestone1/CMakeLists.txt
Created folder milestone1/include/milestone1
Created folder milestone1/src
Successfully created files in /home/amalamr/catkin_ws/src/milestone1. Please adjust the values in package.xml.
amalamr@ubuntu:~/catkin_ws/src$ cd ..
amalamr@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/amalamr/catkin_ws
Source space: /home/amalamr/catkin_ws/src
Build space: /home/amalamr/catkin_ws/build
Devel space: /home/amalamr/catkin_ws/devel
Install space: /home/amalamr/catkin_ws/install
#####
##### Running command: "cmake /home/amalamr/catkin_ws/src -DCATKIN_DEVEL_PREFIX=/home/amalamr/catkin_ws/devel -DCMAKE_INSTALL_PREFIX=/home/amalamr/catkin_ws/install -G Unix Makefiles" in "/home/amalamr/catkin_ws/build"
```

*Figure 2: Creating a Package*



```
-- Generating done
-- Build files have been written to: /home/amalamr/catkin_ws/build
#####
##### Running command: "make -j4 -l4" in "/home/amalamr/catkin_ws/build"
#####
amalamr@ubuntu:~/catkin_ws$ rosrun milestone1 publisher.py
[rospack] Error: package 'milestone1' not found
amalamr@ubuntu:~/catkin_ws$ source devel/setup.bash
amalamr@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/amalamr/catkin_ws
Source space: /home/amalamr/catkin_ws/src
Build space: /home/amalamr/catkin_ws/build
Devel space: /home/amalamr/catkin_ws/devel
Install space: /home/amalamr/catkin_ws/install
#####
##### Running command: "make cmake_check_build_system" in "/home/amalamr/catkin_ws/build"
#####
#####
##### Running command: "make -j4 -l4" in "/home/amalamr/catkin_ws/build"
#####
amalamr@ubuntu:~/catkin_ws$ rosrun milestone1 publisher.py
[INFO] [1681506775.453919]: 1
[INFO] [1681506776.456027]: 0
[INFO] [1681506777.455133]: 0
[INFO] [1681506778.455542]: 2
[INFO] [1681506779.460317]: 1
[INFO] [1681506780.455351]: 2
```

Figure 4: Running ROS

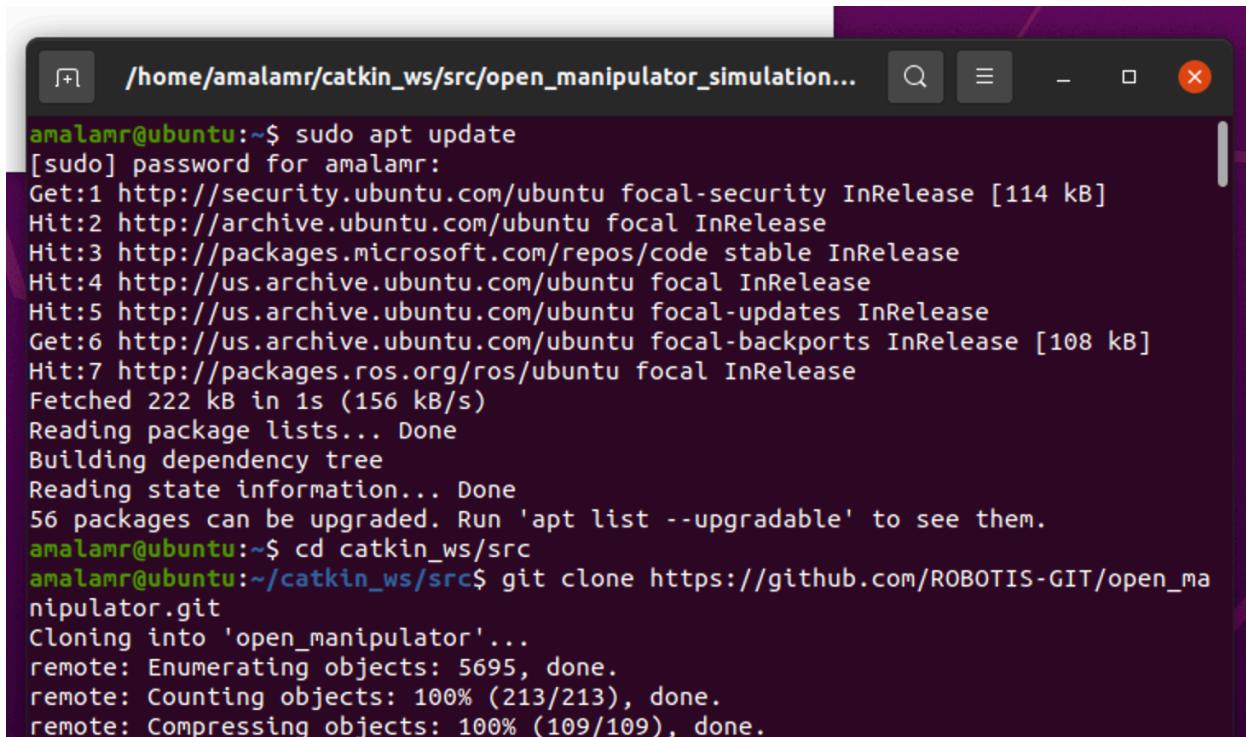
```
roscore http://ubuntu:11311/
amalamr@ubuntu:~/catkin_ws$ roscore
... logging to /home/amalamr/.ros/log/5ce86b86-db08-11ed-ada7-7b59d5a6cd29/roslaunch-ubuntu-34283.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://ubuntu:45321/
ros_comm version 1.16.0

SUMMARY
========
PARAMETERS
* /rosdistro: noetic
* /rosversion: 1.16.0
NODES
```

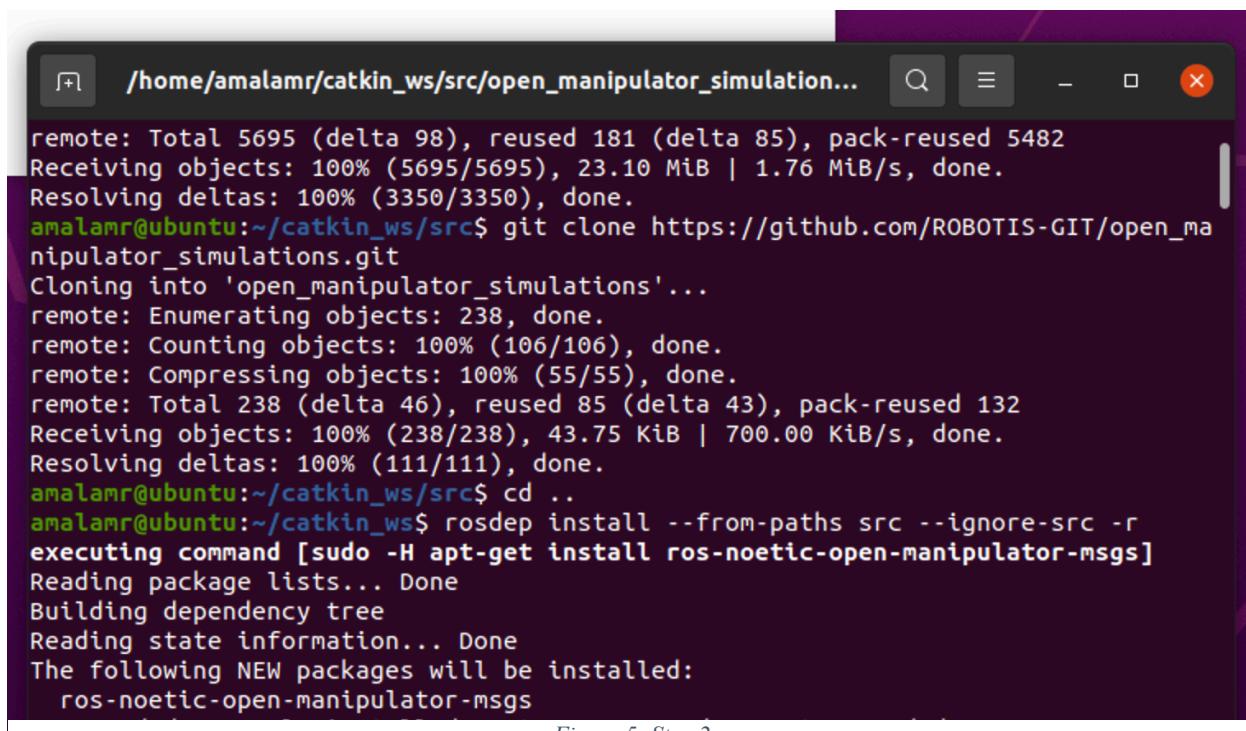
Figure 3: Launching ROS

### 3.1 Launching Gazebo



```
amalamr@ubuntu:~$ sudo apt update
[sudo] password for amalamr:
Get:1 http://security.ubuntu.com/ubuntu focal-security InRelease [114 kB]
Hit:2 http://archive.ubuntu.com/ubuntu focal InRelease
Hit:3 http://packages.microsoft.com/repos/code stable InRelease
Hit:4 http://us.archive.ubuntu.com/ubuntu focal InRelease
Hit:5 http://us.archive.ubuntu.com/ubuntu focal-updates InRelease
Get:6 http://us.archive.ubuntu.com/ubuntu focal-backports InRelease [108 kB]
Hit:7 http://packages.ros.org/ros/ubuntu focal InRelease
Fetched 222 kB in 1s (156 kB/s)
Reading package lists... Done
Building dependency tree
Reading state information... Done
56 packages can be upgraded. Run 'apt list --upgradable' to see them.
amalamr@ubuntu:~$ cd catkin_ws/src
amalamr@ubuntu:~/catkin_ws/src$ git clone https://github.com/ROBOTIS-GIT/open_ma
nipulator.git
Cloning into 'open_manipulator'...
remote: Enumerating objects: 5695, done.
remote: Counting objects: 100% (213/213), done.
remote: Compressing objects: 100% (109/109), done.
```

Figure 6: Step 1



```
remote: Total 5695 (delta 98), reused 181 (delta 85), pack-reused 5482
Receiving objects: 100% (5695/5695), 23.10 MiB | 1.76 MiB/s, done.
Resolving deltas: 100% (3350/3350), done.
amalamr@ubuntu:~/catkin_ws/src$ git clone https://github.com/ROBOTIS-GIT/open_ma
nipulator_simulations.git
Cloning into 'open_manipulator_simulations'...
remote: Enumerating objects: 238, done.
remote: Counting objects: 100% (106/106), done.
remote: Compressing objects: 100% (55/55), done.
remote: Total 238 (delta 46), reused 85 (delta 43), pack-reused 132
Receiving objects: 100% (238/238), 43.75 KiB | 700.00 KiB/s, done.
Resolving deltas: 100% (111/111), done.
amalamr@ubuntu:~/catkin_ws/src$ cd ..
amalamr@ubuntu:~/catkin_ws$ rosdep install --from-paths src --ignore-src -r
executing command [sudo -H apt-get install ros-noetic-open-manipulator-msgs]
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
ros-noetic-open-manipulator-msgs
```

Figure 5: Step 2



```
Setting up ros-noetic-dynamixel-sdk (3.7.51-4focal.20230215.212910) ...
Setting up ros-noetic-dynamixel-workbench-toolbox (2.2.1-1focal.20230215.213538)
...
#All required rosdeps installed successfully
amalamr@ubuntu:~/catkin_ws$ sudo apt install ros-noetic-effort-controllers
Reading package lists... Done
Building dependency tree
Reading state information... Done
The following NEW packages will be installed:
  ros-noetic-effort-controllers
0 upgraded, 1 newly installed, 0 to remove and 56 not upgraded.
Need to get 84.6 kB of archives.
After this operation, 365 kB of additional disk space will be used.
Get:1 http://packages.ros.org/ros/ubuntu focal/main amd64 ros-noetic-effort-controllers amd64 0.21.1-1focal.20230215.232804 [84.6 kB]
Fetched 84.6 kB in 2s (41.0 kB/s)
Selecting previously unselected package ros-noetic-effort-controllers.
(Reading database ... 270962 files and directories currently installed.)
Preparing to unpack .../ros-noetic-effort-controllers_0.21.1-1focal.20230215.232804_amd64.deb ...
Unpacking ros-noetic-effort-controllers (0.21.1-1focal.20230215.232804) ...
Setting up ros-noetic-effort-controllers (0.21.1-1focal.20230215.232804) ...
amalamr@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/amalamr/catkin_ws
```

Figure 8: Step 3

```
[ 95%] Building CXX object open_manipulator/open_manipulator_controller/CMakeFiles/open_manipulator_controller.dir/src/open_manipulator_controller.cpp.o
[100%] Linking CXX executable /home/amalamr/catkin_ws/devel/lib/open_manipulator_controller/open_manipulator_controller
[100%] Built target open_manipulator_controller
amalamr@ubuntu:~/catkin_ws$ rosrun open_manipulator_gazebo open_manipulator_gazebo.launch
RLEException: [open_manipulator_gazebo.launch] is neither a launch file in package [open_manipulator_gazebo] nor is [open_manipulator_gazebo] a launch file name
The traceback for the exception was written to the log file
amalamr@ubuntu:~/catkin_ws$ source devel/setup.bash
amalamr@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/amalamr/catkin_ws
Source space: /home/amalamr/catkin_ws/src
Build space: /home/amalamr/catkin_ws/build
Devel space: /home/amalamr/catkin_ws/devel
Install space: /home/amalamr/catkin_ws/install
#####
##### Running command: "make cmake_check_build_system" in "/home/amalamr/catkin_w
amalamr@ubuntu:~/catkin_ws$
```

Figure 7: Step 4



```
[ 16%] Built target open_manipulator_gazebo_xacro_generated_to-devel_space_
[ 37%] Built target open_manipulator_libs
[ 45%] Built target omx_gripper_sub_publisher
[ 91%] Built target open_manipulator_control_gui
[100%] Built target open_manipulator_controller
amalamr@ubuntu:~/catkin_ws$ rosrun open_manipulator_gazebo open_manipulator_gazebo.launch
... logging to /home/amalamr/.ros/log/8c0bc77a-db0b-11ed-ada7-7b59d5a6cd29/roslaunch-ubuntu-41448.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

xacro: in-order processing became default in ROS Melodic. You can drop the option.
started rosrun server http://ubuntu:36337/
SUMMARY
=====
PARAMETERS
```

Figure 10: Step 5: Finally Launching Gazebo

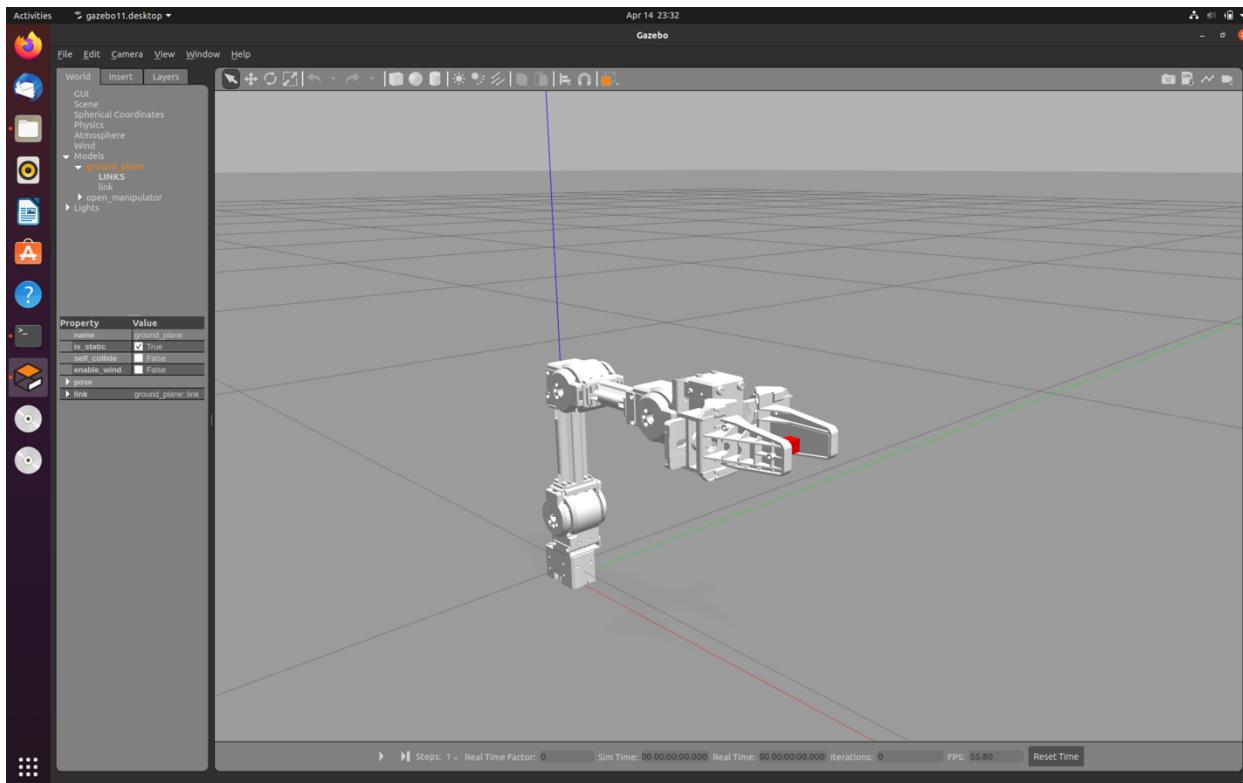


Figure 9: Gazebo Running



### 3.2 Nodes

```
amalamr@ubuntu:~/catkin_ws$ rostopic list
/clock
/gazebo/link_states
/gazebo/model_states
/gazebo/parameter_descriptions
/gazebo/parameter_updates
/gazebo/performance_metrics
/gazebo/set_link_state
/gazebo/set_model_state
/gripper_position/command
/gripper_position/pid/parameter_descriptions
/gripper_position/pid/parameter_updates
/gripper_position/state
/gripper_sub_position/command
/gripper_sub_position/pid/parameter_descriptions
/gripper_sub_position/pid/parameter_updates
/gripper_sub_position/state
/joint1_position/command
/joint2_position/command
/joint3_position/command
/joint4_position/command
/joint_states
/rosout
/rosout_agg
amalamr@ubuntu:~/catkin_ws$ rqt_graph
amalamr@ubuntu:~/catkin_ws$
```

Figure 11: List of the Nodes

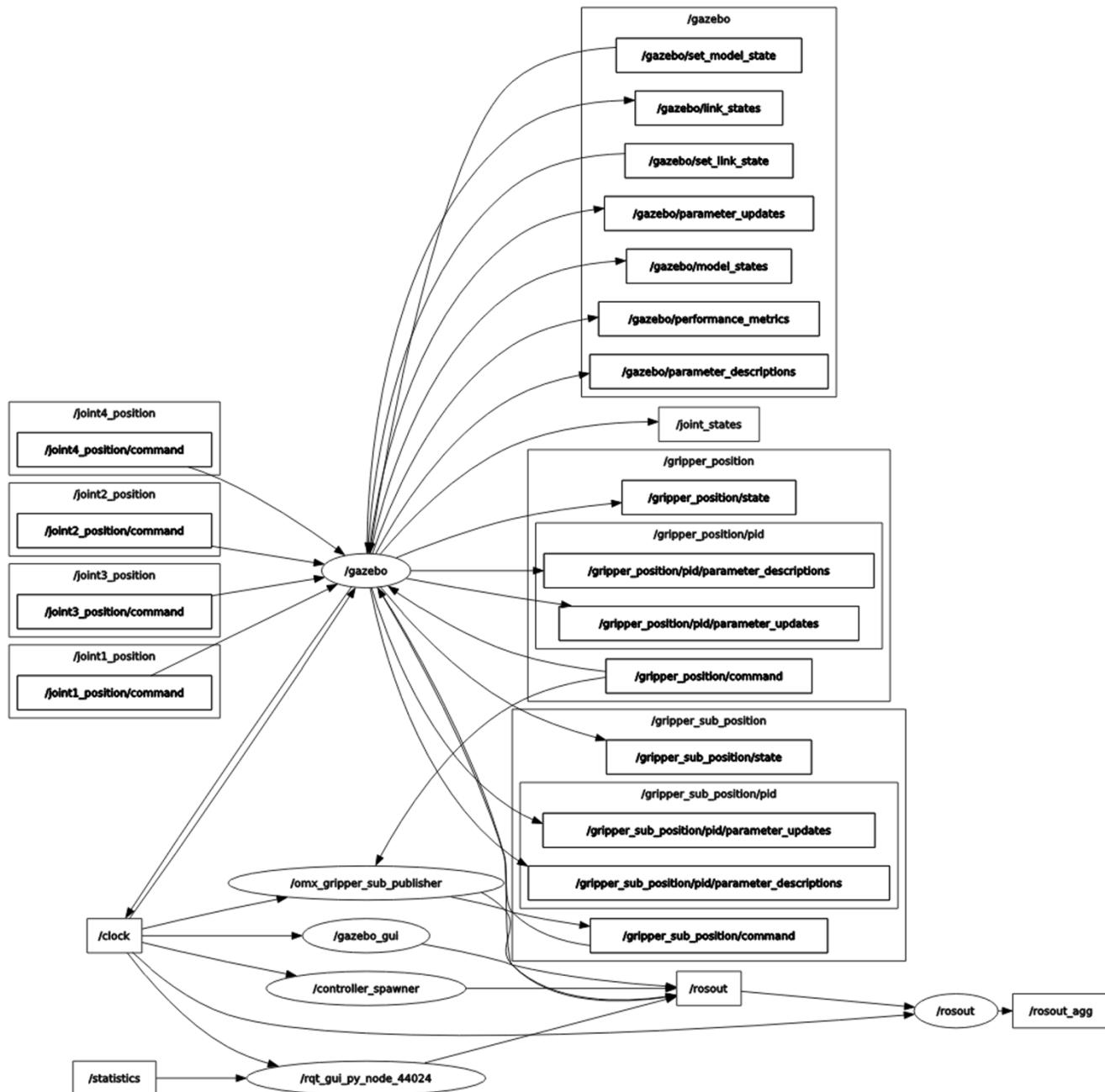


Figure 12: RQT Graph

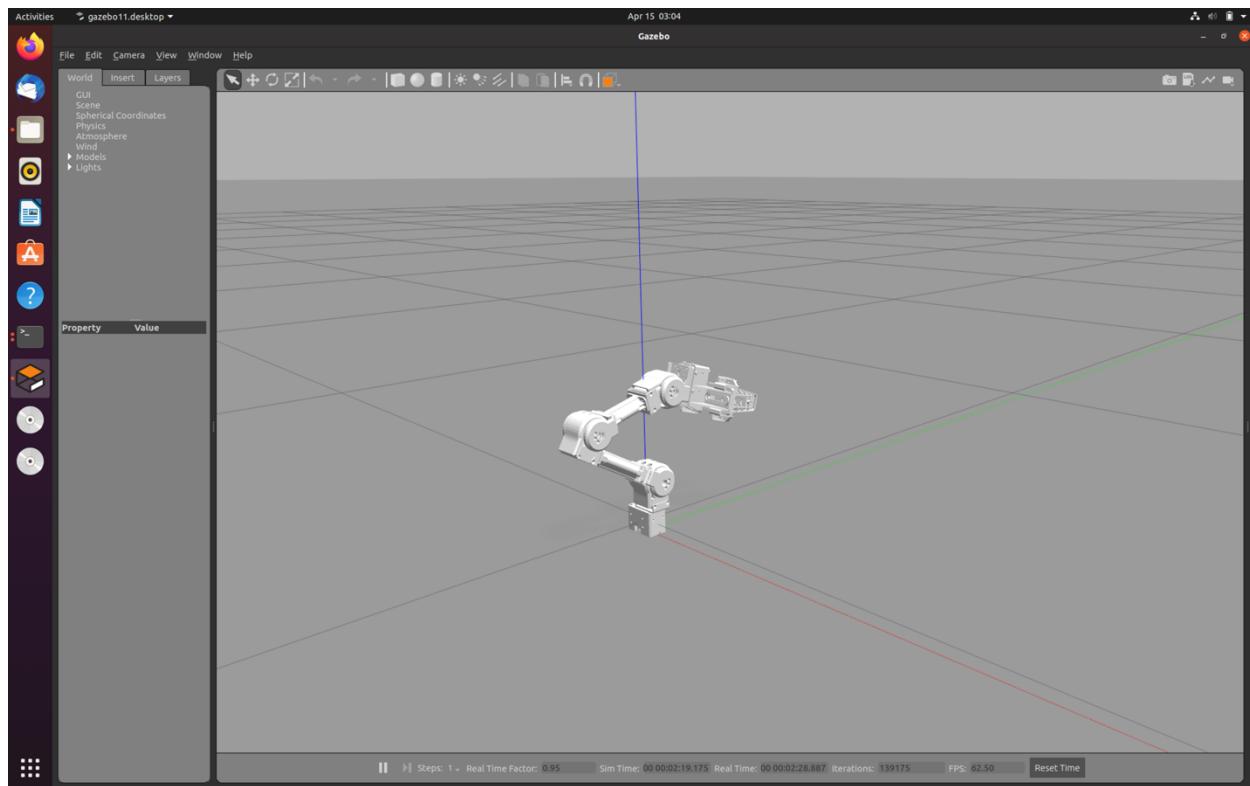


```
amalamr@ubuntu:~/catkin_ws/src/milestone1/src$ python3 publisher.py
```

Figure 13: Launching my Node

```
[INFO] [1681520502.442268, 5.402000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520502.568892, 5.502000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520502.570881, 5.504000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520502.664818, 5.600000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520502.667318, 5.601000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520502.763973, 5.700000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520502.766459, 5.703000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520502.878688, 5.800000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520502.881214, 5.802000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520502.979217, 5.900000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520502.981864, 5.902000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520503.076461, 6.000000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520503.078457, 6.001000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
[INFO] [1681520503.181199, 6.100000]: Robot Position [x y z roll pitch yaw]
[INFO] [1681520503.183352, 6.102000]: [0.012 0.1428 0.1611 1.57 0.2617 1.57]
```

Figure 14: My Node is Running



*Figure 15: Robot Position After Running the Node*

### 3.3 GUI

```
/home/amalamr/catkin_ws/src/open_manipulator/open_mani... /home/amalamr/catki... /home/amalamr/catki... ▾
```

```
amalamr@ubuntu:~/catkin_ws$ roslaunch open_manipulator_controller open_manipulator_controller.launch use_platform:=false
... logging to /home/amalamr/.ros/log/4c6ade5c-db2a-11ed-ada7-7b59d5a6cd29/roslaunch-ubuntu-95146.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://ubuntu:44737/
SUMMARY
```

*Figure 16: Launching GUI in Gazebo Part 1*



```
[ 91%] Built target open_manipulator_control_gui
[100%] Built target open_manipulator_controller
amalamr@ubuntu:~/catkin_ws$ roslaunch open_manipulator_control_gui open_manipulator_control_gui.launch
... logging to /home/amalamr/.ros/log/4c6ade5c-db2a-11ed-ada7-7b59d5a6cd29/roslaunch-ubuntu-95257.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://ubuntu:39535/
```

Figure 18: Launching GUI in Gazebo Part 2

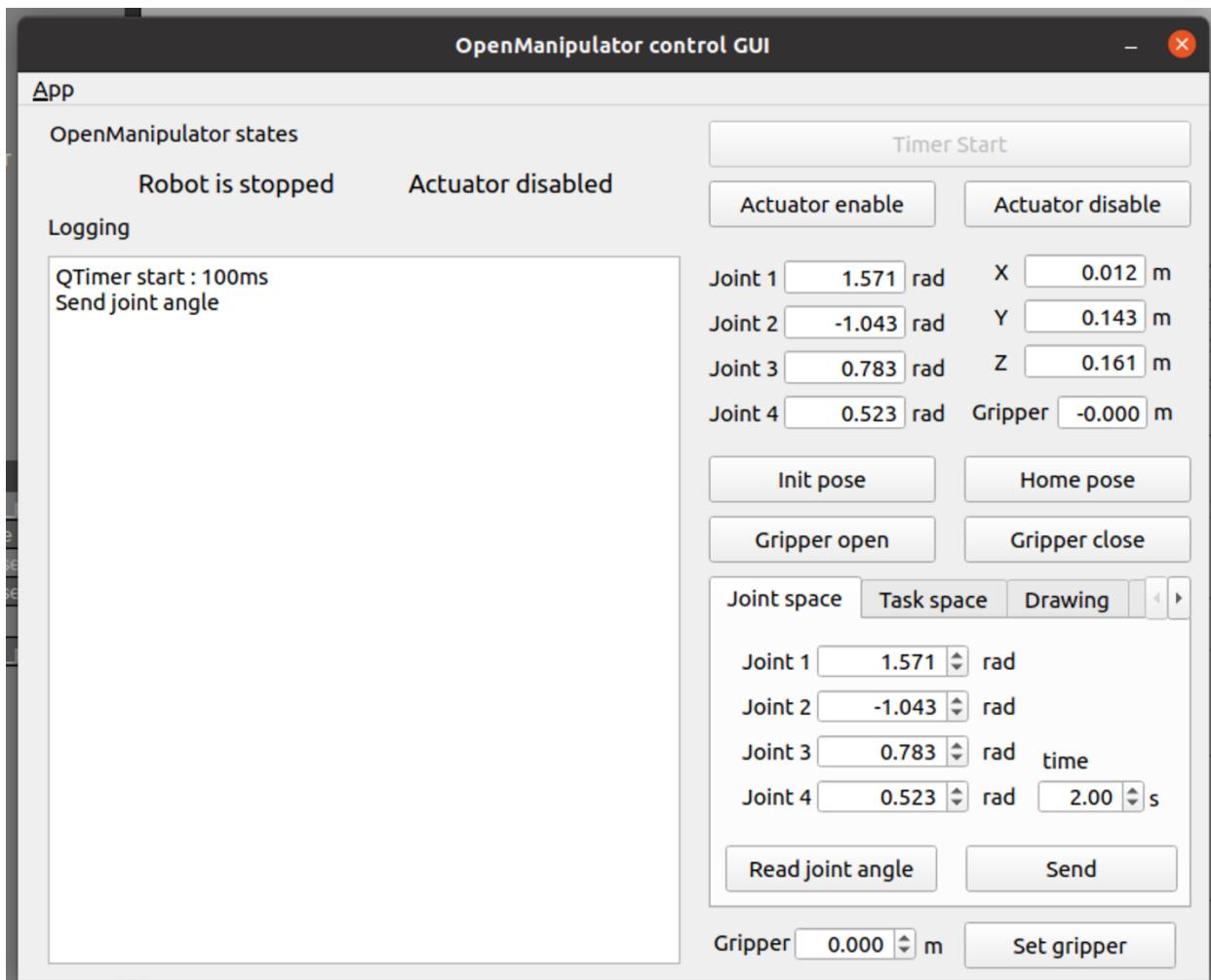


Figure 17: Setting the Joint Position and Sending them

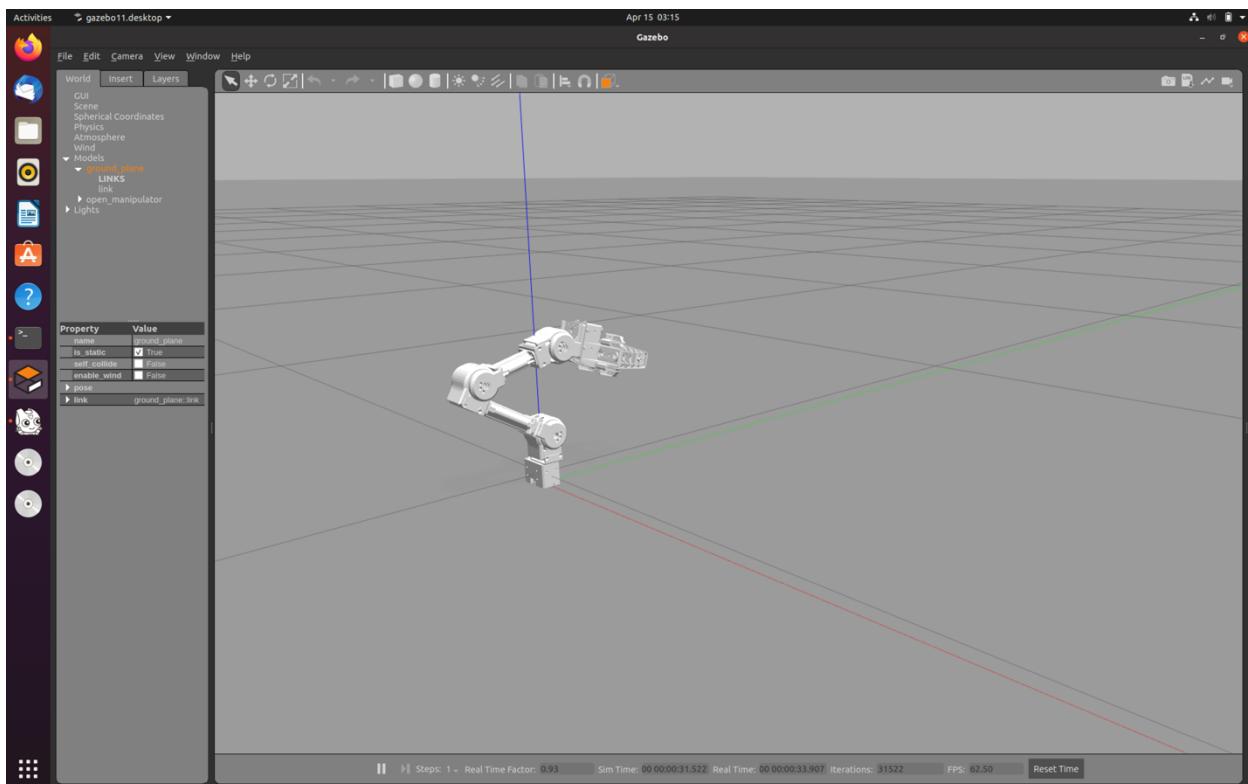


Figure 19: Robot Position After Sending Joint Positions

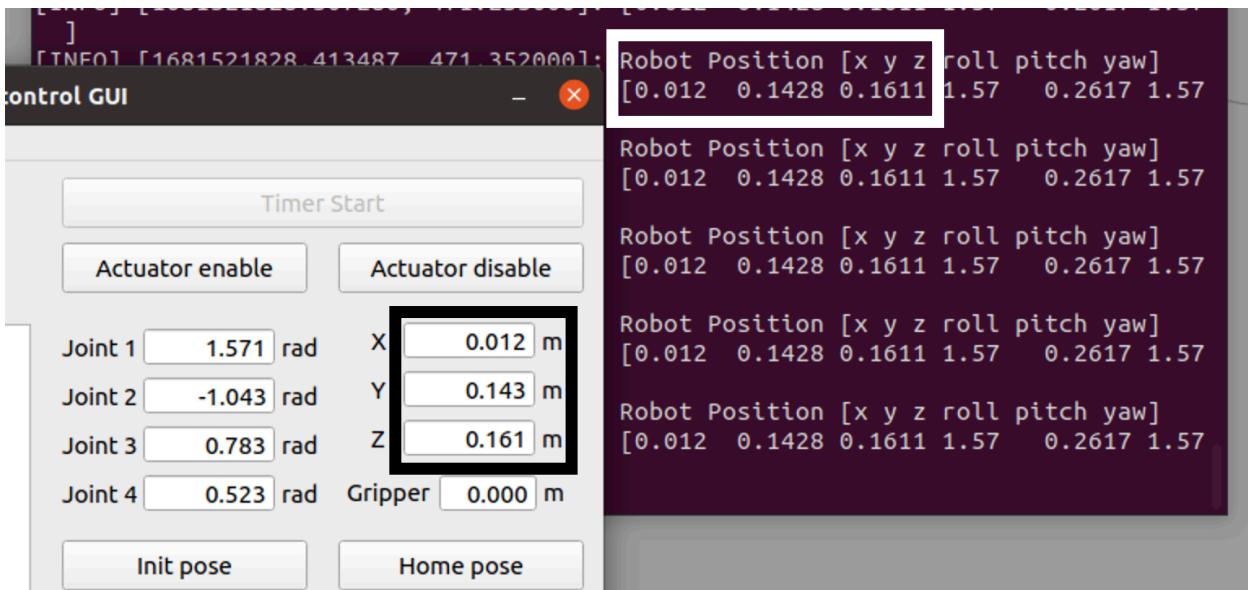


Figure 20: Comparison Between GUI Coordinates and Code Coordinates



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## 4.0 VIDEO LINK

<https://drive.google.com/drive/folders/12GzNeXPt04xlqZa32DG2jnj5VDyOArYm?usp=sharing>