

Group Assignment – Part 2

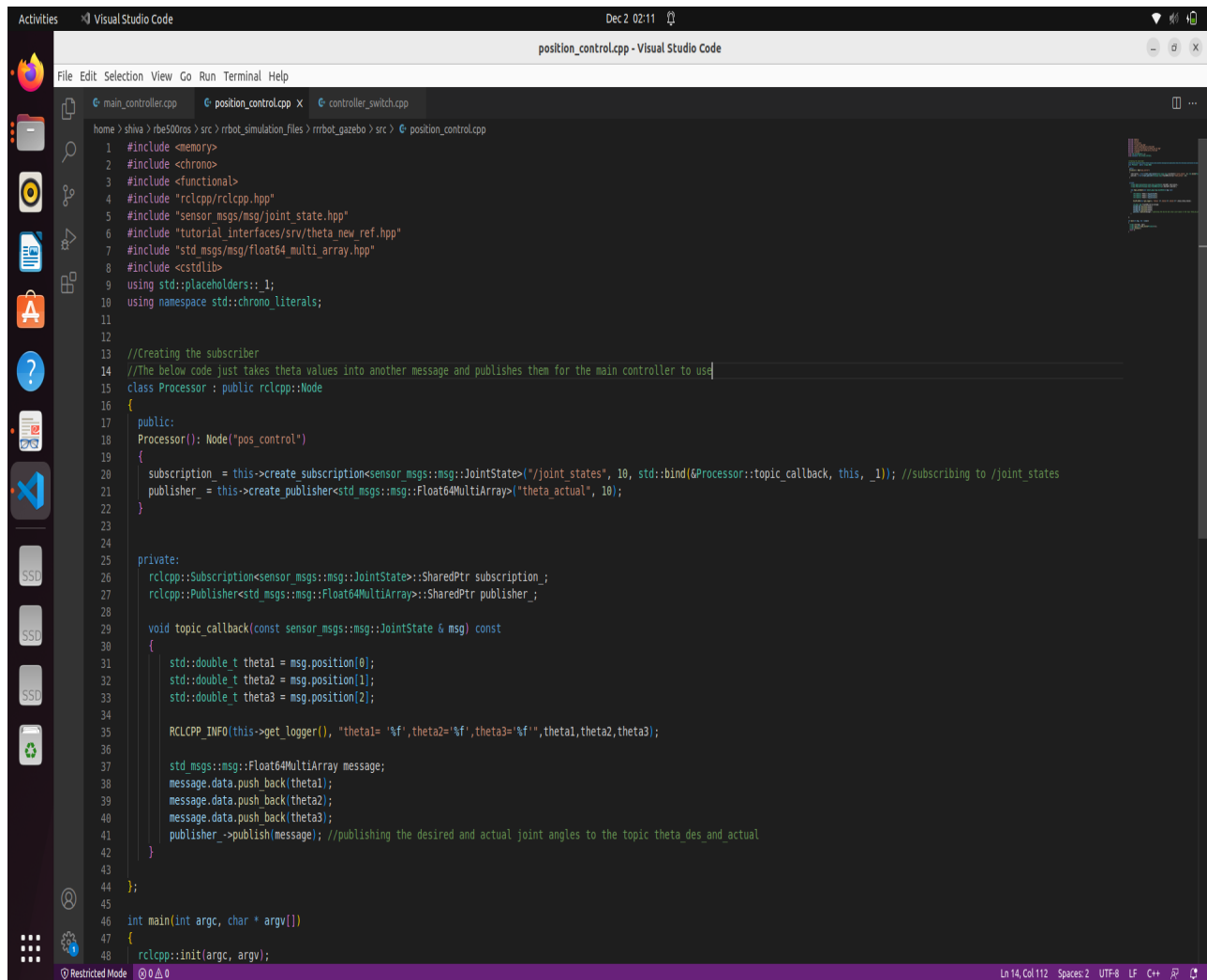
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Chaitanya Sriram Gaddipati

Ethan Wilke

Part 1.) The Code

The “Position control” file consists of a subscriber file that reads and organizes the recorded current positions of the joints and then sends them out in a message format through a publisher. Below is its code. (Please check code comments below for documentation)



```
1 #include <memory>
2 #include <chrono>
3 #include <functional>
4 #include "rclcpp/rclcpp.hpp"
5 #include "sensor_msgs/msg/joint_state.hpp"
6 #include "tutorial_interfaces/srv/theta_new_ref.hpp"
7 #include "std_msgs/msg/float64_multi_array.hpp"
8 #include <cstdlib>
9 using std::placeholders::_1;
10 using namespace std::chrono_literals;
11
12
13 //Creating the subscriber
14 //The below code just takes theta values into another message and publishes them for the main controller to use
15 class Processor : public rclcpp::Node
16 {
17 public:
18     Processor(): Node("pos_control")
19     {
20         subscription_ = this->create_subscription<sensor_msgs::msg::JointState>("/joint_states", 10, std::bind(&Processor::topic_callback, this, _1)); //subscribing to /joint_states
21         publisher_ = this->create_publisher<std_msgs::msg::Float64MultiArray>("theta actual", 10);
22     }
23
24 private:
25     rclcpp::Subscription<sensor_msgs::msg::JointState>::SharedPtr subscription_;
26     rclcpp::Publisher<std_msgs::msg::Float64MultiArray>::SharedPtr publisher_;
27
28     void topic_callback(const sensor_msgs::msg::JointState & msg) const
29     {
30         std::double_t theta1 = msg.position[0];
31         std::double_t theta2 = msg.position[1];
32         std::double_t theta3 = msg.position[2];
33
34         RCLCPP_INFO(this->get_logger(), "theta1= '%f',theta2='%f',theta3='%f'",theta1,theta2,theta3);
35
36         std_msgs::msg::Float64MultiArray message;
37         message.data.push_back(theta1);
38         message.data.push_back(theta2);
39         message.data.push_back(theta3);
40         publisher_->publish(message); //publishing the desired and actual joint angles to the topic theta_des_and_actual
41     }
42
43 };
44
45 int main(int argc, char * argv[])
46 {
47     rclcpp::init(argc, argv);
48 }
```

“Main Controller” takes in the message from the “position_control” node and takes desired joint values through a service. It calculates the joint efforts through PD controllers for each joint. This calculated joint effort for each joint is then sent out through a publisher, eventually being read

from the Gazebo program for the simulation. Below is its code. (Please check code comments below for documentation)

```
main_controller.cpp x position_control.cpp controller_switch.cpp
home > shiva > rbe500ros > src > rrbot_simulation_files > rrbot_gazebo > src > main_controller.cpp
22 class NewProcessor : public rclcpp::Node
23 {
24 public:
25     NewProcessor()
26     : Node("main_control")
27     {
28         //create a service to take desired joint values
29         service_ = this->create_service<tutorial_interfaces::srv::PositionControl>("position_control", std::bind(&NewProcessor::jointref, this, _1));
30     }
31
32 private:
33     //initializing the old error and desired joint values for modification inside the callback function
34     mutable double e1_old;
35     mutable double e2_old;
36     mutable double e3_old;
37     mutable double theta1_des;
38     mutable double theta2_des;
39     mutable double theta3_des;
40
41     void jointref(const std::shared_ptr<tutorial_interfaces::srv::PositionControl::Request> request){
42         //taking desired angle values from the client request from the terminal
43         theta1_des = request->joint1_ref;
44         theta2_des = request->joint2_ref;
45         theta3_des = request->joint3_ref;
46         //subscribing to actual joint angles
47         subscription_1 = this->create_subscription<std_msgs::msg::Float64MultiArray>("theta actual", 10, std::bind(&NewProcessor::topic1_callback, this, _1));
48         publisher_1 = this->create_publisher<std_msgs::msg::Float64MultiArray>("/forward_effort_controller/commands", 10); //publishing joint efforts
49         publisher_2 = this->create_publisher<std_msgs::msg::Float64MultiArray>("/theta_des", 10); //publishing desired joint values for plotting
50     }
```

```
main_controller.cpp x position_control.cpp controller_switch.cpp
home > shiva > rbe500ros > src > rrbot_simulation_files > rrbot_gazebo > src > main_controller.cpp
51
52 void topic1_callback(const std_msgs::msg::Float64MultiArray & msg) const
53 {
54     //extracting the actual joint values
55     std::double_t theta1 = msg.data[0];
56     std::double_t theta2 = msg.data[1];
57     std::double_t theta3 = msg.data[2];
58     RCLCPP_INFO(this->get_logger(), "theta1_des= '%f', theta2_des= '%f', theta3_des= '%f', theta1_des, theta2_des, theta3_des");
59     RCLCPP_INFO(this->get_logger(), "theta1= '%f', theta2= '%f', theta3= '%f', theta1, theta2, theta3");
60
61     //initial joint efforts are set to be zero
62     double joint1_effort = 0;
63     double joint2_effort = 0;
64     double joint3_effort = 0;
65     //steady state error is set to be 0.01
66     double epsilon = 0.01;
67     //initializing error variables
68     double e1, e2, e3, e1_dot, e2_dot, e3_dot;
69     //the sampling time is 100 milliseconds
70     double sampling_time = 0.1;
71     //Setting the proportional and derivative gains
72     //Below are the tuned values
73     double Kp1 = 0.09; //joint 1 proportional gain
74     double Kd1 = 0.09; //joint 1 derivative gain
75     double Kp2 = 0.05; //joint 2 proportional gain
76     double Kd2 = 0.06; //joint 2 derivative gain
77     double Kp3 = 1200; //joint 3 proportional gain
78     double Kd3 = 9; //joint 3 derivative gain
79
80     //creating message for publisher_ to publish efforts
81     std_msgs::msg::Float64MultiArray message;
82     std_msgs::msg::Float64MultiArray message1;
83 }
```

```

83
84 //Calculating joint efforts using PD control parameters set above and calculating joint efforts till all joint values have reached the necessary steady state
85
86 //joint 1
87 if((std::abs(theta1_des - theta1) > epsilon)){
88     e1 = theta1_des - theta1; //calculating error
89     if(std::abs(theta1) < 0.03){ //During the very initial state, as there is no old error, using proportional controller only
90         joint1_effort = Kp1*e1; //effort for joint1
91         e1_old = e1; //updating old error
92     }
93     else{
94         e1_dot = (e1 - e1_old)/sampling_time; //calculating the rate of change of error
95         joint1_effort = Kp1*e1 + Kd1*e1_dot; //effort for joint1 generated using PD controller
96         e1_old = e1; //updating old error
97     }
98 }
99
100 //joint 2
101 if((std::abs(theta2_des - theta2) > epsilon)){
102     e2 = theta2_des - theta2;
103     if(std::abs(theta2) < 0.15){
104         joint2_effort = Kp2*e2;
105         e2_old = e2;
106     }
107     else{
108         e2_dot = (e2 - e2_old)/sampling_time;
109         joint2_effort = Kp2*e2 + Kd2*e2_dot; //effort for joint2
110         e2_old = e2;
111     }
112 }
113
114 //joint 3
115 if((std::abs(theta3_des - theta3) > epsilon)){
116     e3 = theta3_des - theta3;
117     if(std::abs(theta3) < 0.01){
118         joint3_effort = Kp3*e3;
119         e3_old = e3;
120     }
121     else{
122         e3_dot = (e3 - e3_old)/sampling_time;
123         joint3_effort = Kp3*e3 + Kd3*e3_dot; //effort for joint3
124         e3_old = e3;
125     }
126 }
127

```

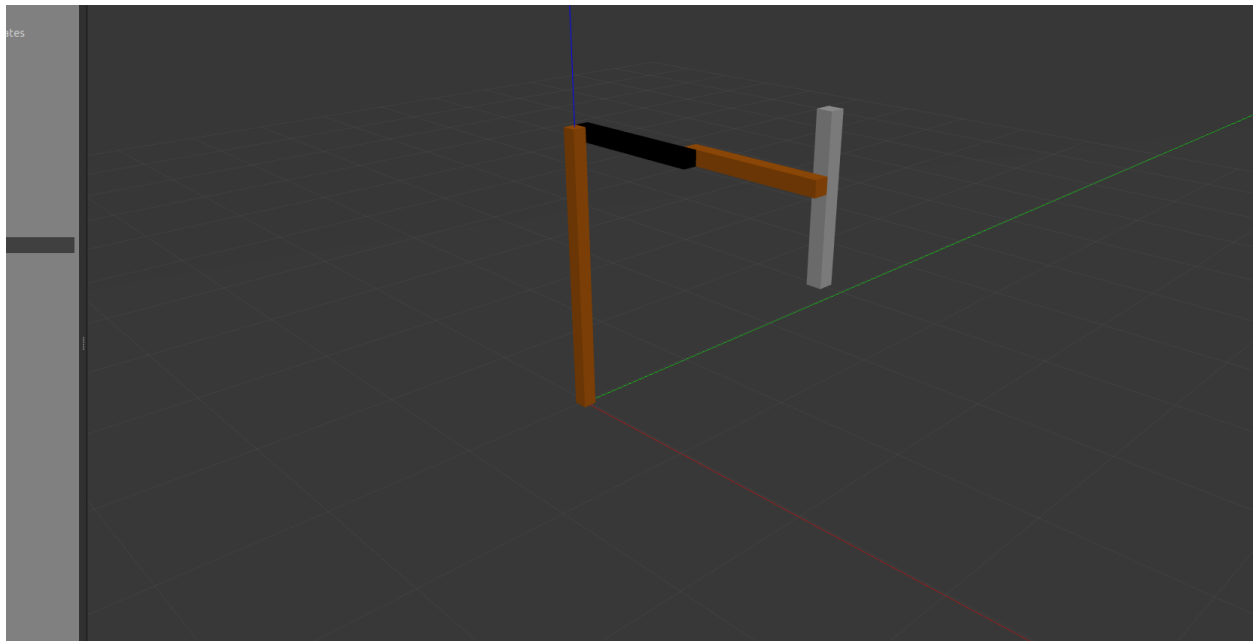
```

127
128 //storing the joint efforts in a message
129 message.data.push_back(joint1_effort);
130 message.data.push_back(joint2_effort);
131 message.data.push_back(joint3_effort);
132 //storing desired joint values in another message
133 message1.data.push_back(theta1_des);
134 message1.data.push_back(theta2_des);
135 message1.data.push_back(theta3_des);
136 RCLCPP_INFO(this->get_logger(), "joint1e= '%f', joint2e= '%f', joint3e= '%f', joint1_effort, joint2_effort, joint3_effort);
137 //publishing joint efforts
138 publisher_1->publish(message);
139 //publishing desired angles taken from the service
140 publisher_2->publish(message1);
141 }
142 rclcpp::Publisher<std_msgs::msg::Float64MultiArray>::SharedPtr publisher_1;
143 rclcpp::Publisher<std_msgs::msg::Float64MultiArray>::SharedPtr publisher_2;
144 rclcpp::Subscription<std_msgs::msg::Float64MultiArray>::SharedPtr subscription_1;
145 rclcpp::Service<tutorial_interfaces::srv::PositionControl>::SharedPtr service_;
146 };
147
148 int main(int argc, char * argv[])
149 {
150     rclcpp::init(argc, argv);
151     rclcpp::spin(std::make_shared<NewProcessor>());
152     rclcpp::shutdown();
153     return 0;
154 }

```

PART 2.) The Results

Initial condition of robot



Joint Position Reference 1

Joint 1 reference value: 0.5

Joint 2 reference value: 1.57

Joint 3 reference value: -0.2

Screenshot attached below for service call

```
shiva@shiva-Inspiron-15-5501:~$101x27
[INFO] [spawner-9]: process started with pid [191587]
[gzserver-1] [WARN] [1669958058.483204390] [controller_manager]: Controller Manager: to switch controllers you need to specify a strictness level of controller_manager_msgs::SwitchController::STRICT (2) or ::BEST_EFFORT (1). Defaulting to ::BEST_EFFORT
[gzserver-1] [WARN] [1669958058.483452769] [controller_manager]: Could not 'activate' controller with name 'forward_effort_controller' because no controller with this name exists
[gzserver-1] [INFO] [1669958059.826047240] [controller_manager]: Loading controller 'forward_effort_controller'
[spawner-9] [INFO] [1669958059.941656775] [spawner_forward_effort_controller]: Loaded forward_effort_controller
[gzserver-1] [INFO] [1669958059.946978132] [controller_manager]: Configuring controller 'forward_effort_controller'
[gzserver-1] [INFO] [1669958059.950531490] [forward_effort_controller]: configure successful
[spawner-9] [WARN] [1669958059.956482276] [spawner_forward_effort_controller]: "--stopped" flag is deprecated use "--inactive" instead
[INFO] [spawner-9]: process has finished cleanly [pid 191587]
[gzserver-1] [WARN] [1669958084.078702270] [controller_manager]: Controller Manager: to switch controllers you need to specify a strictness level of controller_manager_msgs::SwitchController::STRICT (2) or ::BEST_EFFORT (1). Defaulting to ::BEST_EFFORT
[gzserver-1] [WARN] [1669958084.079008166] [controller_manager]: Controller with name 'forward_position_controller' can not be deactivated since it is not active.

shiva@shiva-Inspiron-15-5501:~$100x12
[INFO] [1669956449.569087211] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669956744.759587309] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669957668.592473444] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669957683.763533419] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958058.498167817] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958084.091330439] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$

shiva@shiva-Inspiron-15-5501:~$100x11
shiva@shiva-Inspiron-15-5501:~$ ros2 service call position_control tutorial_interfaces/srv/PositionControl "{joint1_ref: 0.5, joint2_ref: 1.57, joint3_ref: -0.2}"
waiting for service to become available...
requester: making request: tutorial_interfaces.srv.PositionControl_Request(joint1_ref=0.5, joint2_ref=1.57, joint3_ref=-0.2)
```

Graphs generated for a period of 60 seconds with sampling time 0.1 seconds. As we can see, the final values are close to the reference values

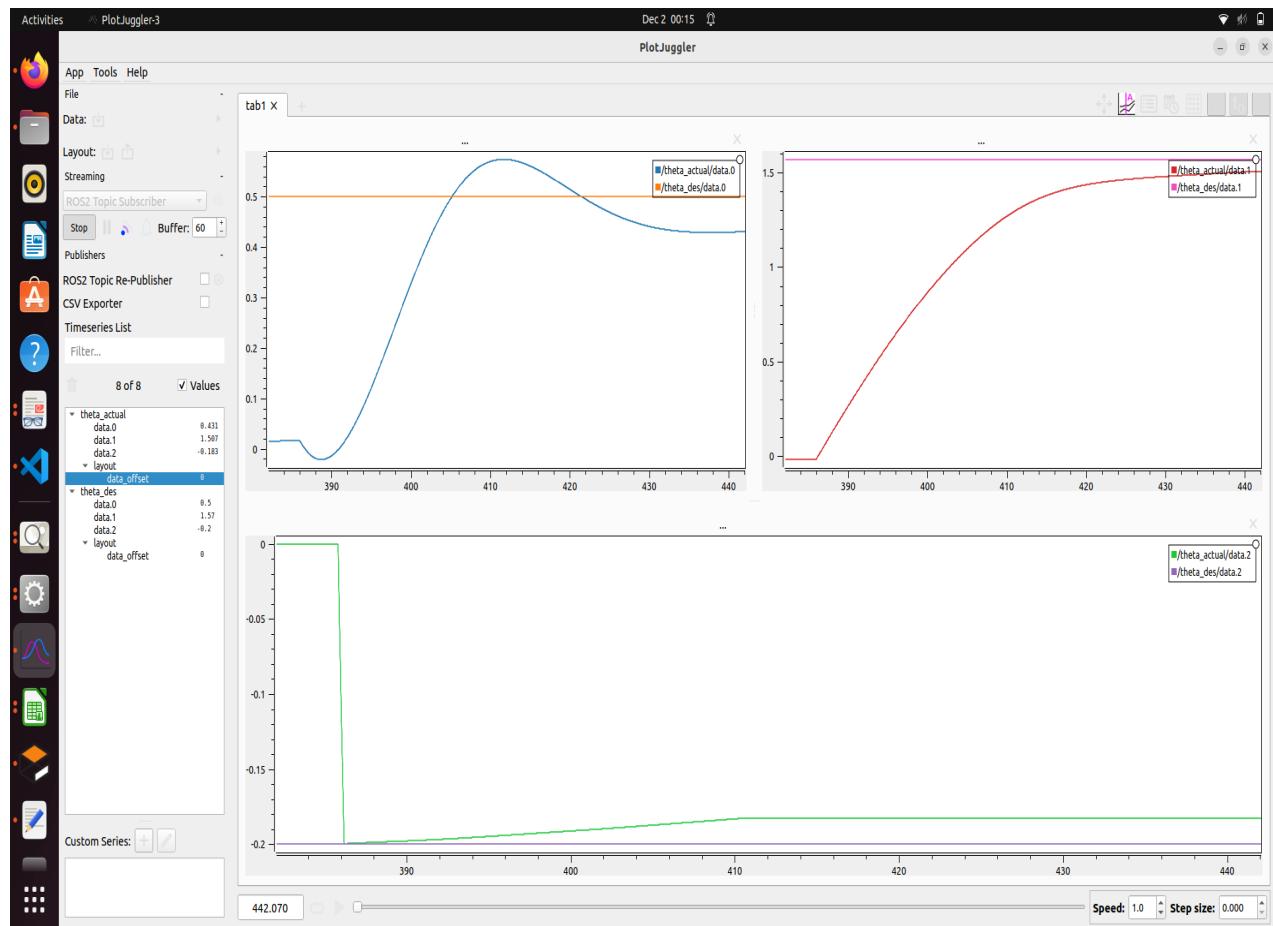
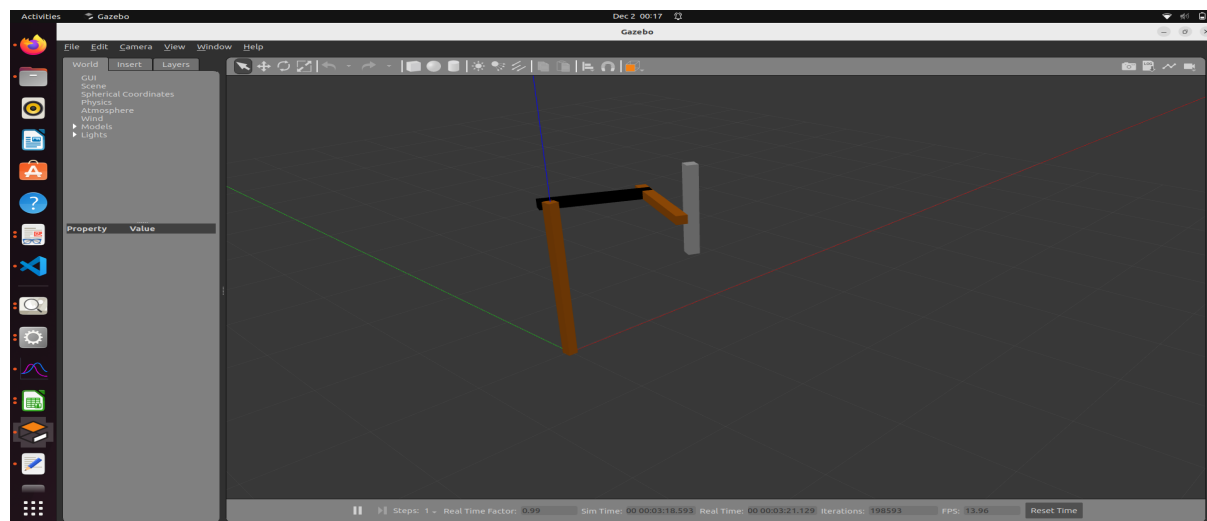


Figure: Joint 1 graph (top left), Joint 2 graph (top right), Joint 3 graph (bottom)

Final condition of the robot



```
[INFO] [1669958330.021971323] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182704'
[INFO] [1669958330.031964982] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182696'
[INFO] [1669958330.042081520] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182688'
[INFO] [1669958330.052412446] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182680'
[INFO] [1669958330.062476379] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182673'
[INFO] [1669958330.072882236] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182665'
[INFO] [1669958330.082488748] [pos_control]: theta1= '0.437412',theta2='1.535859',theta3='-0.182658'
[INFO] [1669958330.092929176] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182651'
[INFO] [1669958330.103623554] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182644'
[INFO] [1669958330.113240730] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182640'
[INFO] [1669958330.123999936] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182637'
[INFO] [1669958330.136258781] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182638'
[INFO] [1669958330.145674786] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182642'
[INFO] [1669958330.155715063] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182650'
[INFO] [1669958330.165449717] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182660'
[INFO] [1669958330.175127440] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182673'
[INFO] [1669958330.185232982] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182687'
[INFO] [1669958330.195386750] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182700'
[INFO] [1669958330.205164553] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182712'
[INFO] [1669958330.215150434] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182720'
[INFO] [1669958330.225021369] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182723'
[INFO] [1669958330.234619848] [pos_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182721'

[INFO] [1669958330.206083213] [main_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182712'
[INFO] [1669958330.206192224] [main_control]: joint1e= '0.005633',joint2e='0.001707',joint3e='-20.744435'
[INFO] [1669958330.215879616] [main_control]: theta1_des= '0.500000',theta2_des='1.570000',theta3_des='-0.200000'
[INFO] [1669958330.216077958] [main_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182720'
[INFO] [1669958330.216181931] [main_control]: joint1e= '0.005633',joint2e='0.001707',joint3e='-20.734951'
[INFO] [1669958330.226014456] [main_control]: theta1_des= '0.500000',theta2_des='1.570000',theta3_des='-0.200000'
[INFO] [1669958330.226227122] [main_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182723'
[INFO] [1669958330.226331252] [main_control]: joint1e= '0.005633',joint2e='0.001707',joint3e='-20.731528'
[INFO] [1669958330.243600444] [main_control]: theta1_des= '0.500000',theta2_des='1.570000',theta3_des='-0.200000'
[INFO] [1669958330.243856462] [main_control]: theta1= '0.437412',theta2='1.535858',theta3='-0.182721'
[INFO] [1669958330.243962012] [main_control]: joint1e= '0.005633',joint2e='0.001707',joint3e='-20.735429'
```

Joint Position Reference 2

Joint 1 reference value: -0.8

Joint 2 reference value: 2.05

Joint 3 reference value: -0.3

Screenshot attached below for service call

```
[INFO] [spawnner-9]: process started with pid 192476
[gzserver-1] [WARN] [1669958400.889385296] [controller_manager]: Controller Manager: to switch controllers you need to specify a strictness level of controller_manager_msgs::SwitchController::STRICT (2) or ::BEST_EFFORT (1). Defaulting to ::BEST_EFFORT
[gzserver-1] [WARN] [1669958400.894608656] [controller_manager]: Could not 'activate' controller with name 'forward_effort_controller' because no controller with this name exists
[gzserver-1] [INFO] [1669958401.182409502] [controller_manager]: Loading controller 'forward_effort_controller'
[spawnner-9] [INFO] [1669958401.281608619] [spawnner_forward_effort_controller]: Loaded forward_effort_controller
[gzserver-1] [INFO] [1669958401.288774931] [controller_manager]: Configuring controller 'forward_effort_controller'
[gzserver-1] [INFO] [1669958401.292844928] [forward_effort_controller]: configure successful
[spawnner-9] [WARN] [1669958401.299767124] [spawnner_forward_effort_controller]: "--stopped" flag is deprecated use "--inactive" instead
[INFO] [spawnner-9]: process has finished cleanly [pid 192476]
[gzserver-1] [WARN] [1669958546.984136755] [controller_manager]: Controller Manager: to switch controllers you need to specify a strictness level of controller_manager_msgs::SwitchController::STRICT (2) or ::BEST_EFFORT (1). Defaulting to ::BEST_EFFORT
[gzserver-1] [WARN] [1669958546.984401422] [controller_manager]: Controller with name 'forward_position_controller' can not be deactivated since it is not active

[INFO] [1669957600.932473444] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669957683.763533419] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958058.498167817] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958084.091330439] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958480.946843672] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958547.000172446] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$

shiva@shiva-Inspiron-15-5501:~$ ros2 service call position_control tutorial_interfaces/srv/PositionControl "{joint1_ref: -0.8, joint2_ref: 2.05, joint3_ref: -0.3}"
waiting for service to become available...
requester: making request: tutorial_interfaces.srv.PositionControl_Request(joint1_ref=-0.8, joint2_ref=2.05, joint3_ref=-0.3)
```

Graphs generated for a period of 60 seconds with sampling time 0.1 seconds. As we can see, the final values are close to the reference values

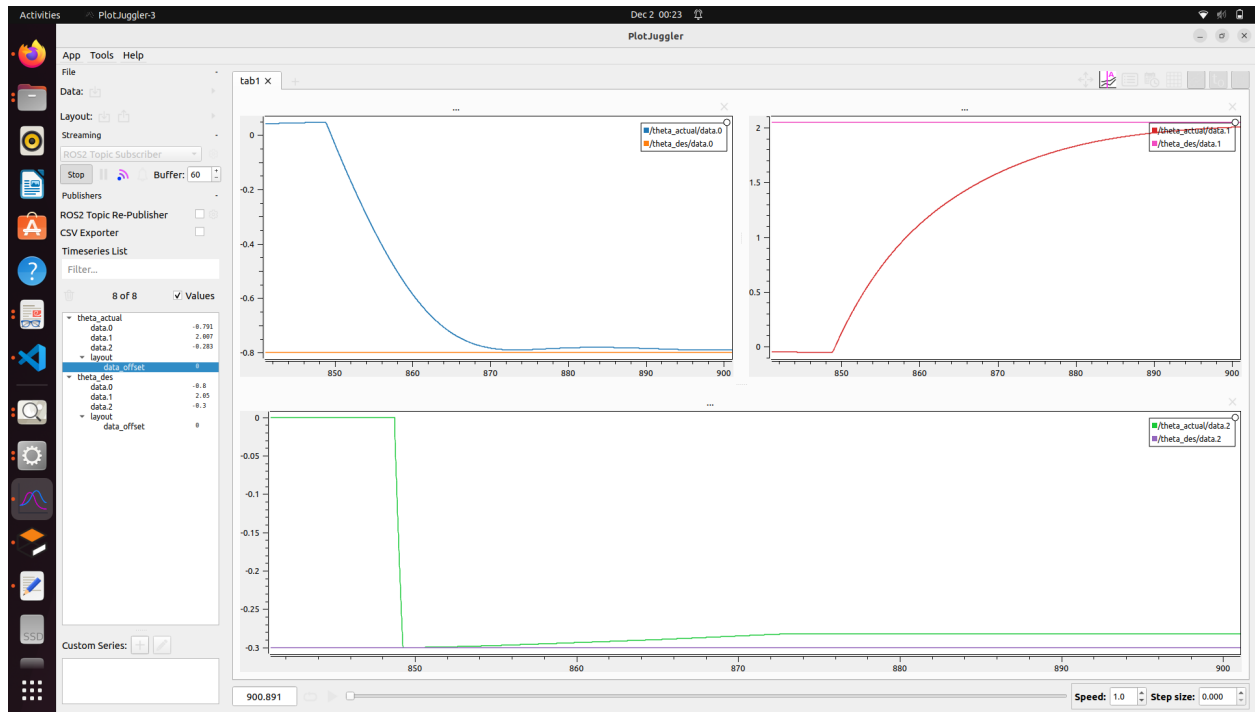
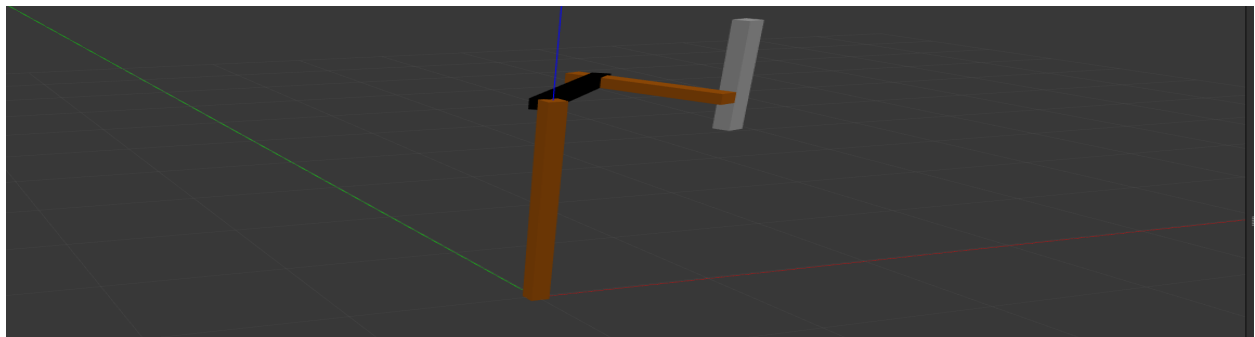


Figure: Joint 1 graph (top left), Joint 2 graph (top right), Joint 3 graph (bottom)

Final condition of the robot



```
[INFO] [1669958721.878955045] [pos_control]: theta1= '-0.790021', theta2= '2.039996', theta3= '-0.282722'
```

```
[INFO] [1669958721.889376843] [pos_control]: theta1= '-0.790021', theta2= '2.039996', theta3= '-0.282730'
```

```
[INFO] [1669958721.899616948] [pos_control]: theta1= '-0.790021', theta2= '2.039996', theta3= '-0.282731'
```

```
[INFO] [1669958721.909671895] [pos_control]: theta1= '-0.790020', theta2= '2.039996', theta3= '-0.282726'
```

```
[INFO] [1669958721.920501351] [pos_control]: theta1= '-0.790020', theta2= '2.039996', theta3= '-0.282717'
```

```
[INFO] [1669958721.930611577] [pos_control]: theta1= '-0.790020', theta2= '2.039996', theta3= '-0.282708'
```

```
[INFO] [1669958721.941009087] [pos_control]: theta1= '-0.790020', theta2= '2.039997', theta3= '-0.282708'
```

```
[INFO] [1669958721.950720825] [pos_control]: theta1= '-0.790019', theta2= '2.039997', theta3= '-0.282691'
```

```
[INFO] [1669958721.960360783] [pos_control]: theta1= '-0.790019', theta2= '2.039997', theta3= '-0.282682'
```

```
[INFO] [1669958721.970054153] [pos_control]: theta1= '-0.790019', theta2= '2.039997', theta3= '-0.282674'
```

```
[INFO] [1669958721.980328385] [pos_control]: theta1= '-0.790019', theta2= '2.039998', theta3= '-0.282666'
```

```
[INFO] [1669958721.989644223] [pos_control]: theta1= '-0.790019', theta2= '2.039998', theta3= '-0.282657'
```

```
[INFO] [1669958722.002668655] [pos_control]: theta1= '-0.790018', theta2= '2.039998', theta3= '-0.282649'
```

```
[INFO] [1669958722.010723805] [pos_control]: theta1= '-0.790018', theta2= '2.039999', theta3= '-0.282642'
```

```
[INFO] [1669958722.021593771] [pos_control]: theta1= '-0.790018', theta2= '2.039999', theta3= '-0.282636'
```

```
[INFO] [1669958722.031155719] [pos_control]: theta1= '-0.790018', theta2= '2.040000', theta3= '-0.282634'
```

```
[INFO] [1669958722.041191361] [pos_control]: theta1= '-0.790018', theta2= '2.040000', theta3= '-0.282634'
```

```
[INFO] [1669958722.052953846] [pos_control]: theta1= '-0.790017', theta2= '2.040001', theta3= '-0.282639'
```

```
[INFO] [1669958722.062868470] [pos_control]: theta1= '-0.790017', theta2= '2.040001', theta3= '-0.282647'
```

```
[INFO] [1669958722.071734040] [pos_control]: theta1= '-0.790017', theta2= '2.040002', theta3= '-0.282659'
```

```
[INFO] [1669958722.054006452] [main_control]: joint1e= '0.000000', joint2e= '0.000000', joint3e= '-20.3336'
```

```
[INFO] [1669958722.063671182] [main_control]: theta1_des= '-0.800000', theta2_des= '2.050000', theta3_des= '-0.300000'
```

```
[INFO] [1669958722.063854708] [main_control]: theta1= '-0.790017', theta2= '2.040001', theta3= '-0.282671'
```

```
[INFO] [1669958722.063935191] [main_control]: joint1e= '0.000000', joint2e= '0.000000', joint3e= '-20.2987'
```

```
[INFO] [1669958722.072494674] [main_control]: theta1_des= '-0.800000', theta2_des= '2.050000', theta3_des= '-0.300000'
```

```
[INFO] [1669958722.072826307] [main_control]: theta1= '-0.790017', theta2= '2.040002', theta3= '-0.282679'
```

```
[INFO] [1669958722.072947312] [main_control]: joint1e= '0.000000', joint2e= '0.000000', joint3e= '-20.8483'
```

```
[INFO] [1669958722.087182898] [main_control]: theta1_des= '-0.800000', theta2_des= '2.050000', theta3_des= '-0.300000'
```

```
[INFO] [1669958722.087414189] [main_control]: theta1= '-0.790017', theta2= '2.040002', theta3= '-0.282673'
```

```
[INFO] [1669958722.087528757] [main_control]: joint1e= '0.000000', joint2e= '0.000000', joint3e= '-20.6885'
```


Joint Position Reference 3

Joint 1 reference value: 1.5

Joint 2 reference value: 1

Joint 3 reference value: -0.1

Screenshot attached below for service call

```
shiva@shiva-Inspiron-15-5501: ~ 101x27
shiva@shiva-Inspiron-15-5501: ~ 100x12
shiva@shiva-Inspiron-15-5501: ~ 100x11

[INFO] [1669958828.017202793] [controller_manager]: Loading controller 'forward_velocity'
[INFO] [1669958828.060235135] [spawner_forward_velocity_controller]: Loaded forward_velocity_controller
[INFO] [1669958828.070530112] [controller_manager]: Configuring controller 'forward_velocity_controller'
[INFO] [1669958828.072107737] [forward_velocity_controller]: configure successful
[WARN] [1669958828.074892409] [spawner_forward_velocity_controller]: "--stopped" flag is deprecated, use "--inactive" instead
mer-8]: process has finished cleanly [pid 193223]
[INFO] [1669958829.568723320] [controller_manager]: Loading controller 'forward_effort'
[INFO] [1669958829.655055475] [spawner_forward_effort_controller]: Loaded forward_effort_controller
[INFO] [1669958829.660395349] [controller_manager]: Configuring controller 'forward_effort_controller'
[INFO] [1669958829.662033843] [forward_effort_controller]: configure successful
[WARN] [1669958829.666349784] [spawner_forward_effort_controller]: "--stopped" flag is deprecated, use "--inactive" instead

[INFO] [1669957683.763533419] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958058.498167817] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958084.091330430] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958480.946843672] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958547.080172446] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$ ros2 run rrrbot_gazebo switch
[INFO] [1669958854.955408754] [rclcpp]: OK
shiva@shiva-Inspiron-15-5501:~$

control "[joint1_ref: 1.5, joint2_ref: 1, joint3_ref: -0.1]"
shiva@shiva-Inspiron-15-5501:~$ ros2 service call position_control tutorial_interfaces/srv/PositionControl "[joint1_ref: 1.5, joint2_ref: 1, joint3_ref: -0.1]"
waiting for service to become available...
requester: making request: tutorial_interfaces.srv.PositionControl_Request(joint1_ref=1.5, joint2_ref=1.0, joint3_ref=-0.1)
```

Graphs generated for a period of 60 seconds with sampling time 0.1 seconds. As we can see, the final values are close to the reference values

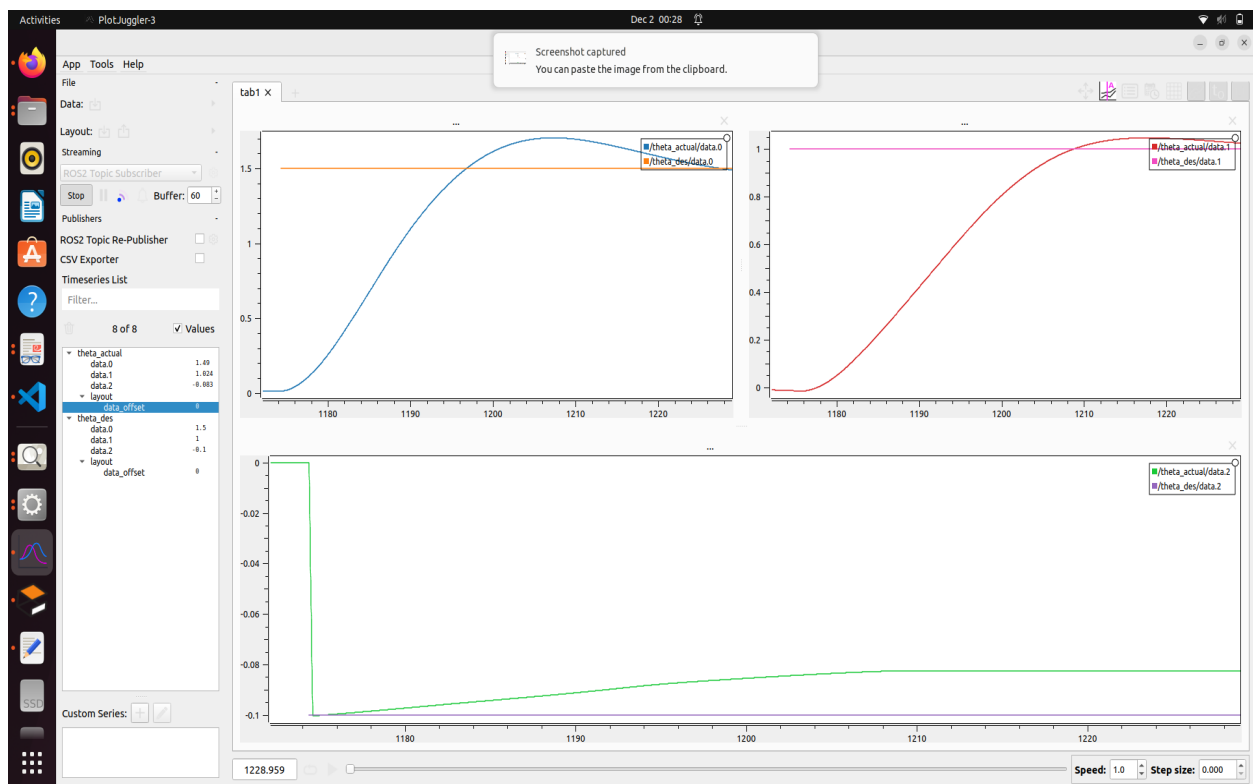


Figure: Joint 1 graph (top left), Joint 2 graph (top right), Joint 3 graph (bottom)

A 3D visualization of a robotic arm in a dark gray environment with a light gray grid floor. The arm consists of a vertical orange pillar, a horizontal orange beam, and a black gripper at the end. A blue line extends from the gripper upwards. A green line and a red line originate from the base of the pillar, extending across the grid floor.

From the above results it can be observed that there is some small steady state error in each joint value despite extensive tuning. This can be reduced further by using PID control instead.

These are the instructions to run the code shown above. Create a new workspace and keep the two packages in the submission file into a src folder. Build the workspace. To use the position control node follow the below commands.

```
ros2 launch rrrbot_gazebo rrobot_world.launch.py
```

II. Open another terminal pane and now switch the controller to effort controller using:

III. Open another terminal pane for service call using:

```
ros2 service call position_control tutorial_interfaces/srv/PositionControl "{joint1_ref: 0.5,  
joint2_ref: 1.57, joint3_ref: -0.2}"
```

IV. In another terminal pane run the controller using

```
ros2 run rrrbot_gazebo pos_control
```

V. In another terminal pane run the main controller using

```
ros2 run rrrbot_gazebo main_control
```

Note: While giving the sample reference joint values make sure the joint3_ref values are negative. This is due to the design of the robot prismatic joint in the urdf file.