Final Project: Joint Space PID Control of RRP robot in ROS

Pranav Moorthy

Krishna Sathwik Durgaraju

Part 1. Inverse kinematics:

Inverse kinematics

The given values from the xacro file are:

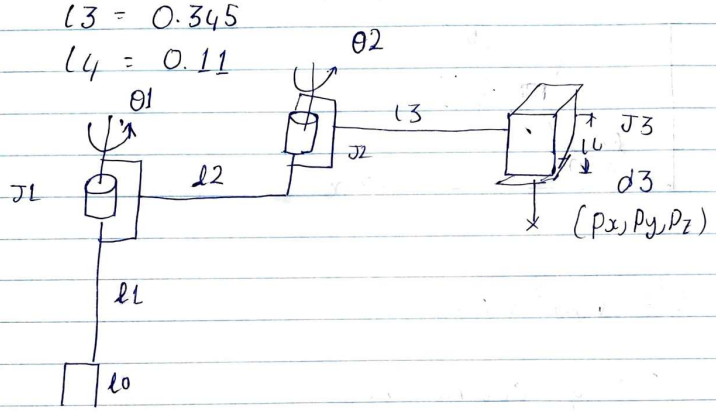
$l0 = 0.05$

$l1 = 0.45$

$l2 = 0.425$

$l3 = 0.345$

$l4 = 0.11$



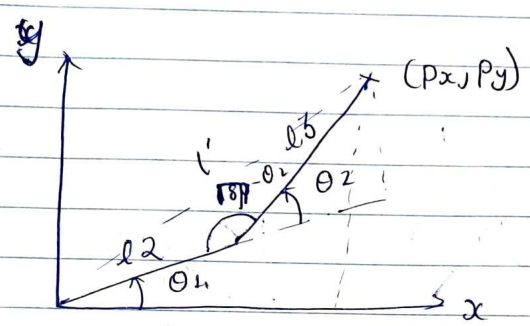
$d3 = (l0 + l1 - l4) - pz$

Substituting values we get

$d3 = (0.05 + 0.45 - 0.11) - pz$

$d3 = 0.39 - pz$

Taking top view we get



$$l' = \sqrt{Px^2 + Py^2}$$

Using cosine rule

$$\cos(\pi - \theta 2) = \frac{l2^2 + l3^2 - l'}{(2 l2 . l3)}$$

$$\cos(\pi - \theta_2) = -\cos\theta 2$$

$$\cos\theta_2 = \frac{l' - (l2^2 + l3^2)}{2(l2 . l3)}$$

Substituting values we get

$$\cos\theta_2 = \frac{P_x^2 + P_y^2 - (0.425)^2 + (0.345)^2}{2 \times (0.425) \times (0.325)}$$

$$\theta_2 = \cos^{-1}\left(\frac{P_x^2 + P_y^2 - 0.29965}{0.29325}\right)$$

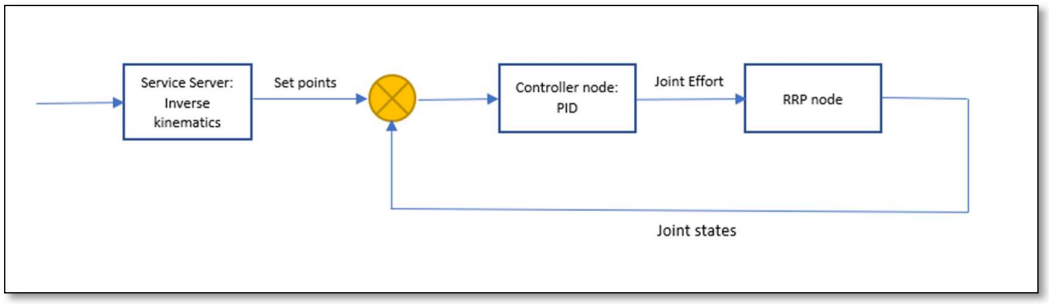
~~$\theta_1 = \tan^{-1}(P_y, P_x) - \tan^{-1}(l_2 \sin\theta_2)$,~~

$$\theta_1 = \tan^{-1}(p_y, p_x) - \tan^{-1}\left(l_3 \sin\theta_2, l_2 + l_3 \cos\theta_2\right)$$

Substituting

$$\theta_1 = \tan^{-1}(p_y, p_x) - \tan^{-1}\left(0.345 \sin\theta_2, 0.425 + 0.345 \cos\theta_2\right)$$

Implementation Block Diagram:



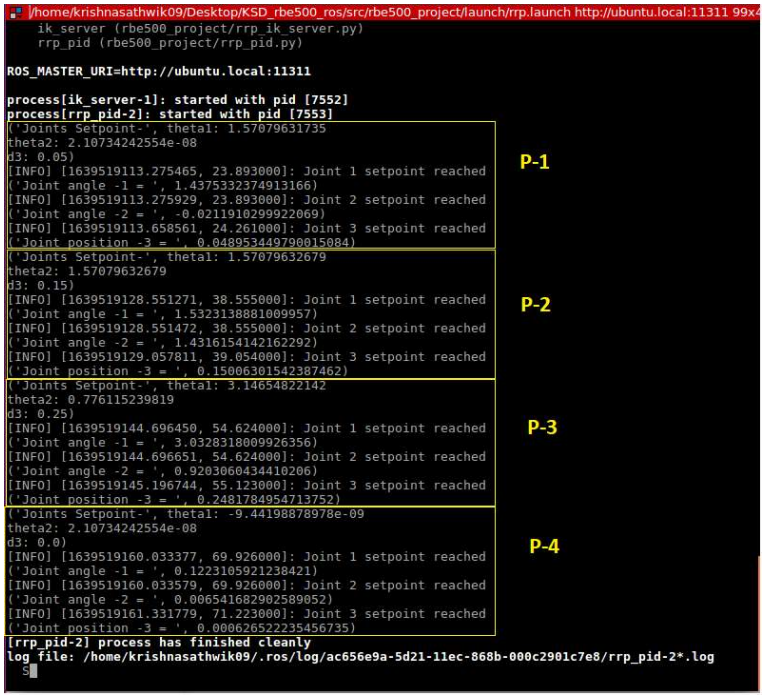
Service Code explanation:

A service named **ik.srv** is created. This service is used to input the desired end effector positions and the required joint angle position acts as a response. The server node waits for a service request from the client node (which is rrp_pid.py). On receiving the service request the server returns the required joint angle positions for all the three joints.

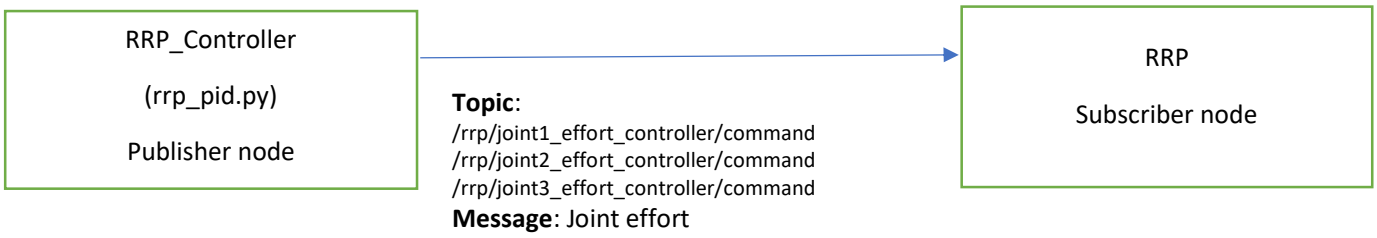
Joint angles:

S.no	End effector Position			Joint angles-Set points		
	x	y	z	θ1	θ2	d3
P1	0	0.77	0.34	1.57	0	0.05
P2	-0.345	0.425	0.24	1.57	1.57	0.15
P3	-0.67	-0.245	0.14	3.14	0.77	0.25
P4	0.77	0	0.39	0	0	0

Joint angles Screenshot:



Part 2. Controller node Implementation:



Code explanation:

1.Created variables and assigned calculated values of joint angle formulas by reading the angles from the server nodes for all the waypoints.

2. Once we read the value of the joint angles, using these values as feedback we implemented the PID controller to make the joints reach the desired position with the help of effort controller topics.

3. Once the position is reached within threshold, for a waypoint, stop the robot for a second and then continue with the loop.

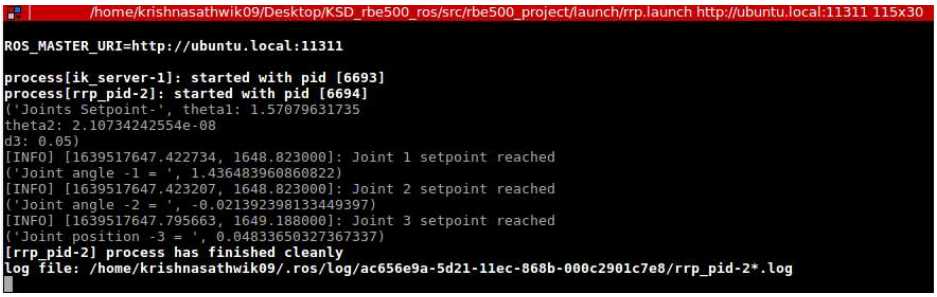
4. Exit gracefully once the task is complete.

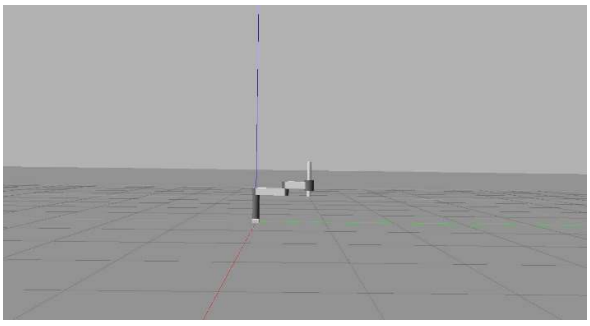
3.Results.

Set Point 1:

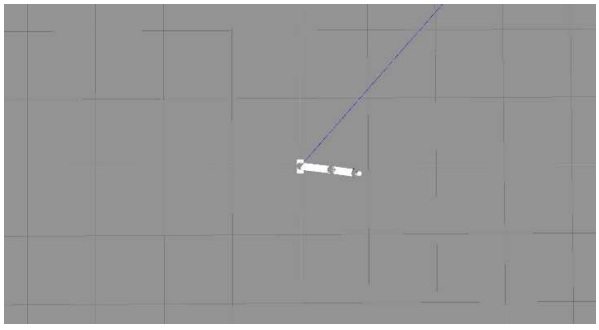
	End effector Position			Joint angles			
	x	**y**	**z**	**θ1**	**θ2**	**d3**	
P1	0	0.77	0.34	1.570	0	0.0500	**Desired Set Point**
				1.436	-0.02	0.0483	**Output**
				0.134	0.02	0.0017	**Error**

Screenshot:





Side view



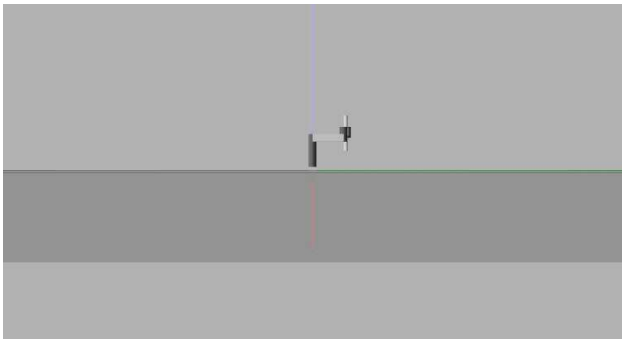
Top view

Set Point 2:

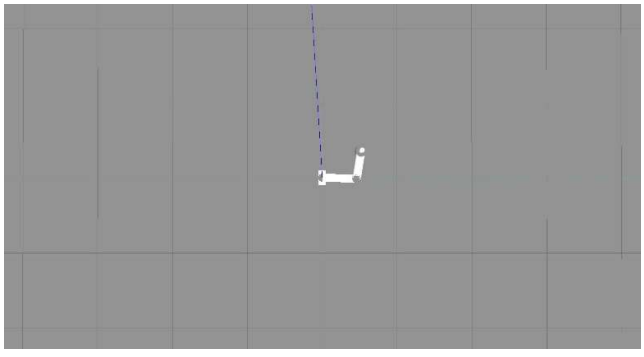
	End effector Position			Joint angles			
	x	y	z	θ1	θ2	d3	
P2	-0.345	0.425	0.24	1.57	1.57	0.15	**Desired Set Point**
				1.54	1.434	0.15	**Output**
				0.03	0.136	0	**Error**

Screenshot:

```
/home/krishnasathwik09/Desktop/KSD_rbe500_ros/src/rbe500_project/launch/rrp.launch http://ubuntu.local:11311 115x30
started roslaunch server http://192.168.43.129:39177/

SUMMARY
========

PARAMETERS
 * /rosdistro: kinetic
 * /rosversion: 1.12.17

NODES
  /
    ik_server (rbe500_project/rrp_ik_server.py)
    rrp_pid (rbe500_project/rrp_pid.py)

ROS_MASTER_URI=http://ubuntu.local:11311

process[ik_server-1]: started with pid [6956]
process[rrp_pid-2]: started with pid [6957]
('Joints Setpoint-', theta1: 1.57079632679
theta2: 1.57079632679
d3: 0.15)
[INFO] [1639518221.453983, 2212.755000]: Joint 1 setpoint reached
('Joint angle -1 = ', 1.5424162446219816)
[INFO] [1639518221.454256, 2212.755000]: Joint 2 setpoint reached
('Joint angle -2 = ', 1.4346532146083373)
[INFO] [1639518221.986616, 2213.268000]: Joint 3 setpoint reached
('Joint position -3 = ', 0.1509586697872298)
[rrp_pid-2] process has finished cleanly
log file: /home/krishnasathwik09/.ros/log/ac656e9a-5d21-11ec-868b-000c2901c7e8/rrp_pid-2*.log
```



Side view

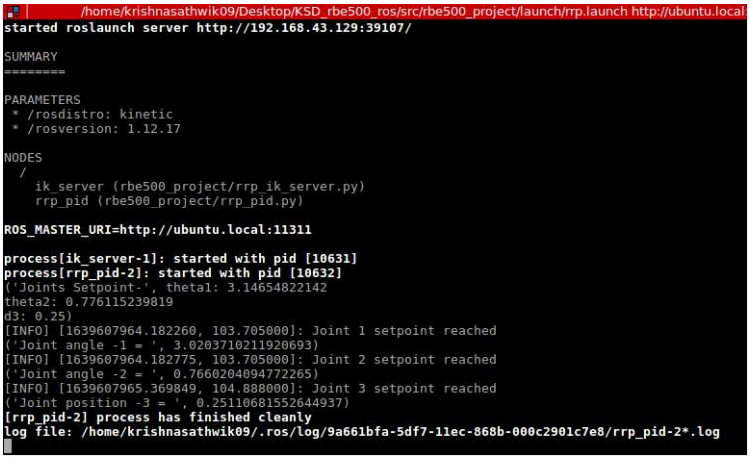


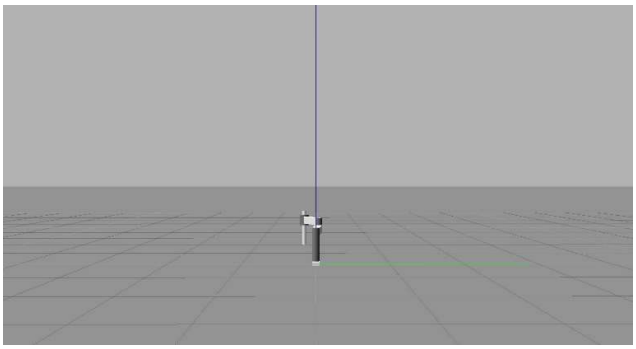
Top view

Set Point 3:

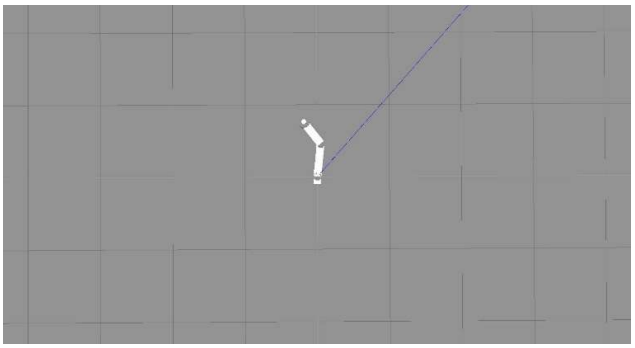
	End effector Position			Joint angles			
	x	y	z	θ1	θ2	d3	
P3	-0.67	-0.245	0.14	3.14	0.77	0.25	Desired Set Point
				3.02	0.76	0.25	Output
				0.12	0.01	0	Error

Screenshots:





Side view

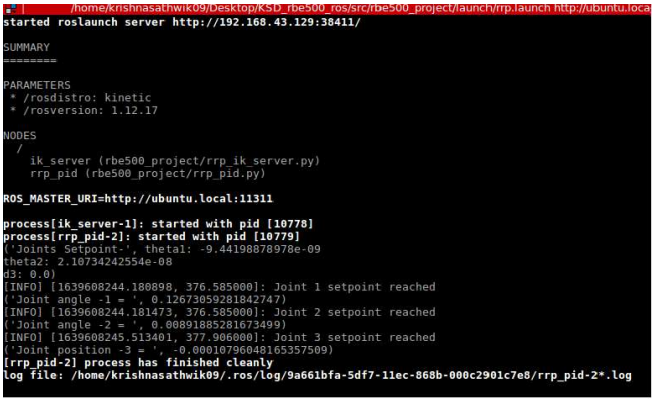


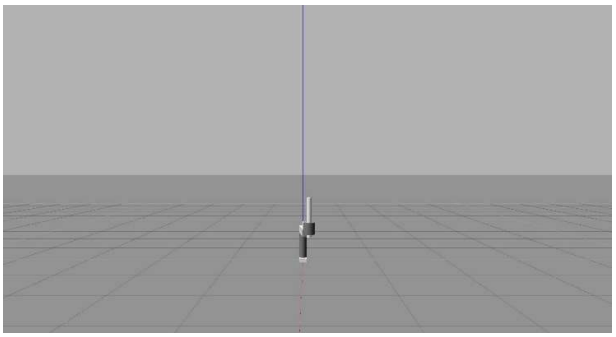
Top view

Set Point 4:

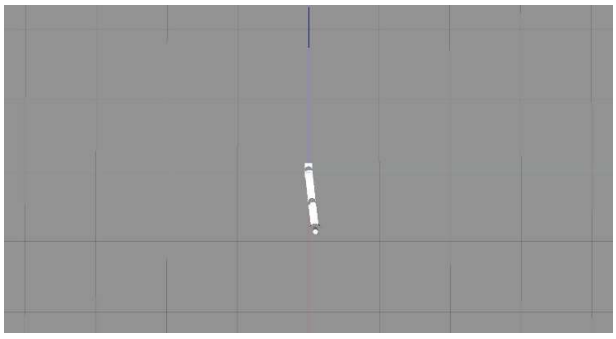
	End effector Position			Joint angles			
	x	y	z	θ1	θ2	d3	
P4	0.77	0	0.39	0	0	0	Desired Set Point
				0.126	0.0089	0	Output
				0.126	0.0089	0	Error

Screenshot:





Side view



Top view