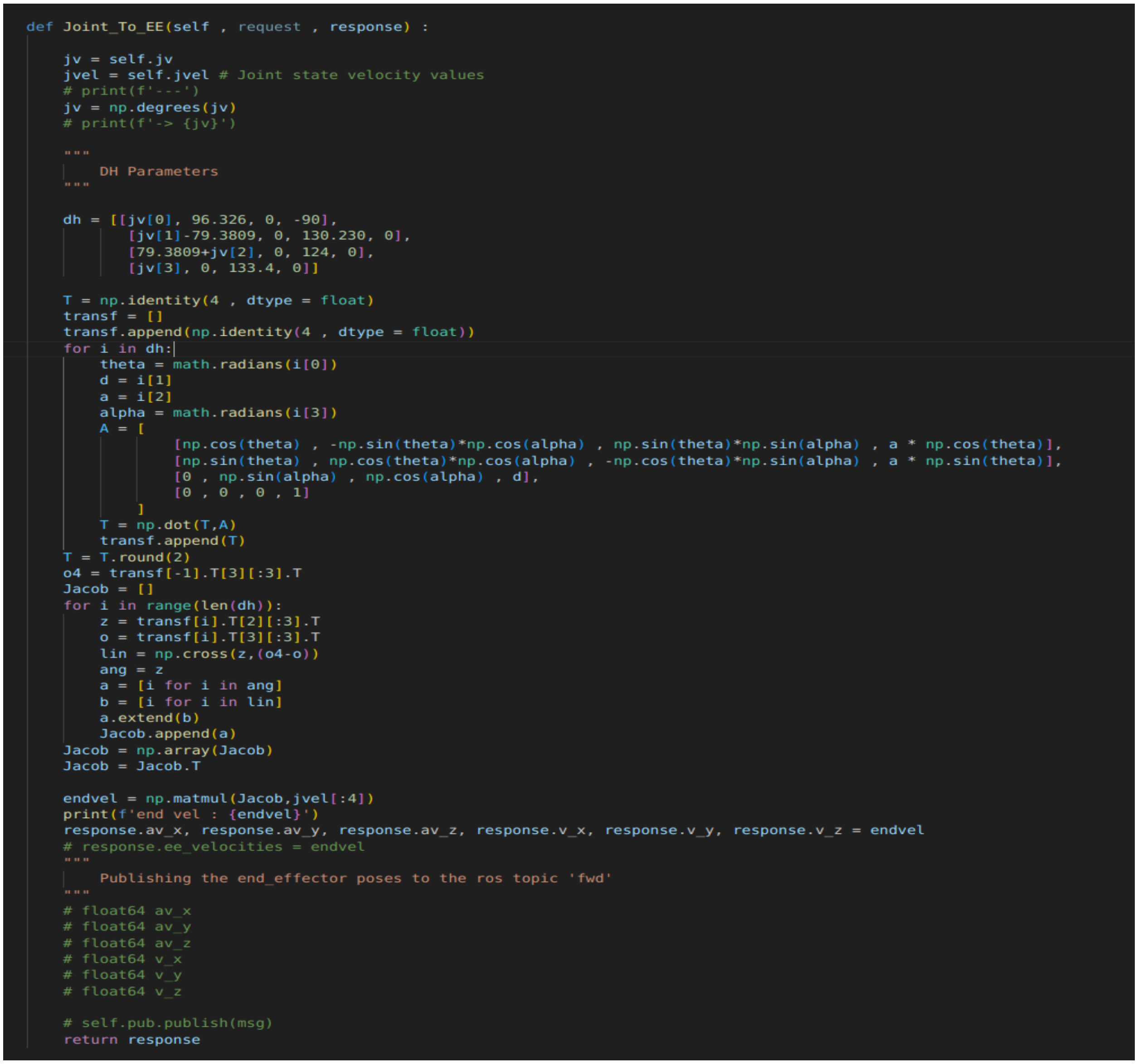
Report RBE500 Group Assignment Part2

Q1:

Problem statement: Create a node with two services, One calculates end effector velocities for the present Joint Velocities and other calculate required joint velocities for the intended end effector velocities.

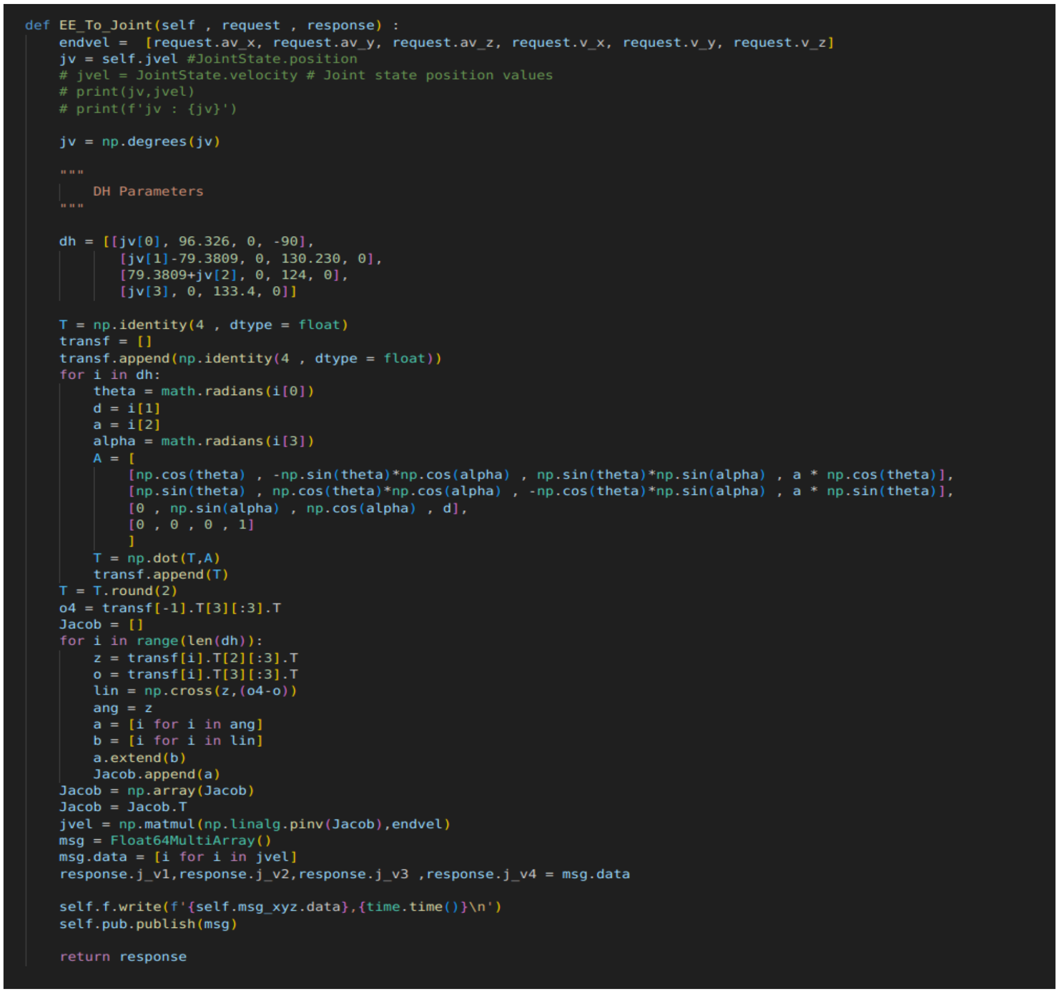
- A node with these requirements is created where a subscriber is used to subscribe Joint state values from corresponding Topic from which joint position and velocity values are retrieved.
- Using Joint positions, The dh parameters are calculated and transformation matrices of each frame with respect to the zeroth frame are calculated. Using these transformation matrices, The Z axis values and origin values are derived using which the jacobian of the robot for that particular pose is calculated.



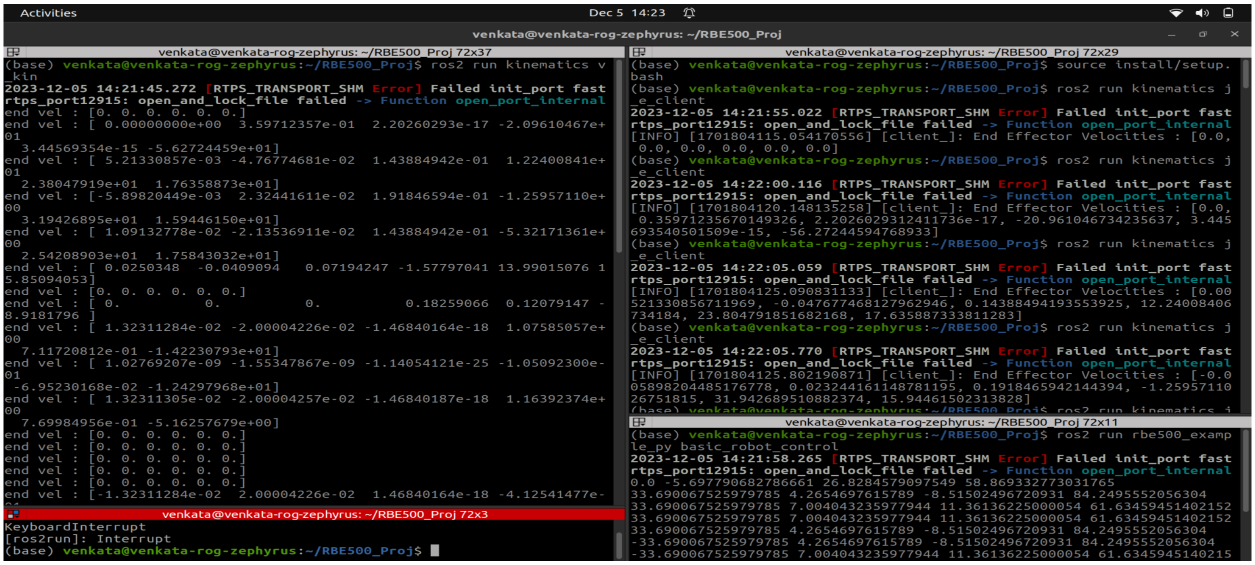
```
def Joint_To_EE(self , request , response) :

    jv = self.jv
    jvel = self.jvel # Joint state velocity values
    # print(f'---')
    jv = np.degrees(jv)
    # print(f'-> {jv}')

    """
        DH Parameters
    """

    dh = [[jv[0], 96.326, 0, -90],
            [jv[1]-79.3809, 0, 130.230, 0],
            [79.3809+jv[2], 0, 124, 0],
            [jv[3], 0, 133.4, 0]]

    T = np.identity(4 , dtype = float)
    transf = []
    transf.append(np.identity(4 , dtype = float))
    for i in dh:
        theta = math.radians(i[0])
        d = i[1]
        a = i[2]
        alpha = math.radians(i[3])
        A = [
                [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 , 1]
            ]
        T = np.dot(T,A)
        transf.append(T)
    T = T.round(2)
    o4 = transf[-1].T[3][:3].T
    Jacob = []
    for i in range(len(dh)):
        z = transf[i].T[2][:3].T
        o = transf[i].T[3][:3].T
        lin = np.cross(z,(o4-o))
        ang = z
        a = [i for i in ang]
        b = [i for i in lin]
        a.extend(b)
        Jacob.append(a)
    Jacob = np.array(Jacob)
    Jacob = Jacob.T

    endvel = np.matmul(Jacob,jvel[:4])
    print(f'end vel : {endvel}')
    response.av_x, response.av_y, response.av_z, response.v_x, response.v_y, response.v_z = endvel
    # response.ee_velocities = endvel
    """
        Publishing the end_effector poses to the ros topic 'fwd'
    """
    # float64 av_x
    # float64 av_y
    # float64 av_z
    # float64 v_x
    # float64 v_y
    # float64 v_z

    # self.pub.publish(msg)
    return response
```

-

- Multiplying Jacobian with joint velocities gives the end effector frame twist for the robot. A client is used to run this method.



```python
def EE_To_Joint(self , request , response) :
    endvel =  [request.av_x, request.av_y, request.av_z, request.v_x, request.v_y, request.v_z]
    jv = self.jvel #JointState.position
    # jvel = JointState.velocity # Joint state position values
    # print(jv,jvel)
    # print(f'jv : {jv}')

    jv = np.degrees(jv)

    """
        DH Parameters
    """

    dh = [[jv[0], 96.326, 0, -90],
           [jv[1]-79.3809, 0, 130.230, 0],
           [79.3809+jv[2], 0, 124, 0],
           [jv[3], 0, 133.4, 0]]

    T = np.identity(4 , dtype = float)
    transf = []
    transf.append(np.identity(4 , dtype = float))
    for i in dh:
        theta = math.radians(i[0])
        d = i[1]
        a = i[2]
        alpha = math.radians(i[3])
        A = [
            [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 , 1]
            ]
        T = np.dot(T,A)
        transf.append(T)
    T = T.round(2)
    o4 = transf[-1].T[3][:3].T
    Jacob = []
    for i in range(len(dh)):
        z = transf[i].T[2][:3].T
        o = transf[i].T[3][:3].T
        lin = np.cross(z,(o4-o))
        ang = z
        a = [i for i in ang]
        b = [i for i in lin]
        a.extend(b)
        Jacob.append(a)
    Jacob = np.array(Jacob)
    Jacob = Jacob.T
    jvel = np.matmul(np.linalg.pinv(Jacob),endvel)
    msg = Float64MultiArray()
    msg.data = [i for i in jvel]
    response.j_v1,response.j_v2,response.j_v3 ,response.j_v4 = msg.data

    self.f.write(f'{self.msg_xyz.data},{time.time()}\n')
    self.pub.publish(msg)

    return response
```



Activities
Dec 5 14:23
venkata@venkata-rog-zephyrus: ~/RBE500_Proj
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x37
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x29
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x11
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x3

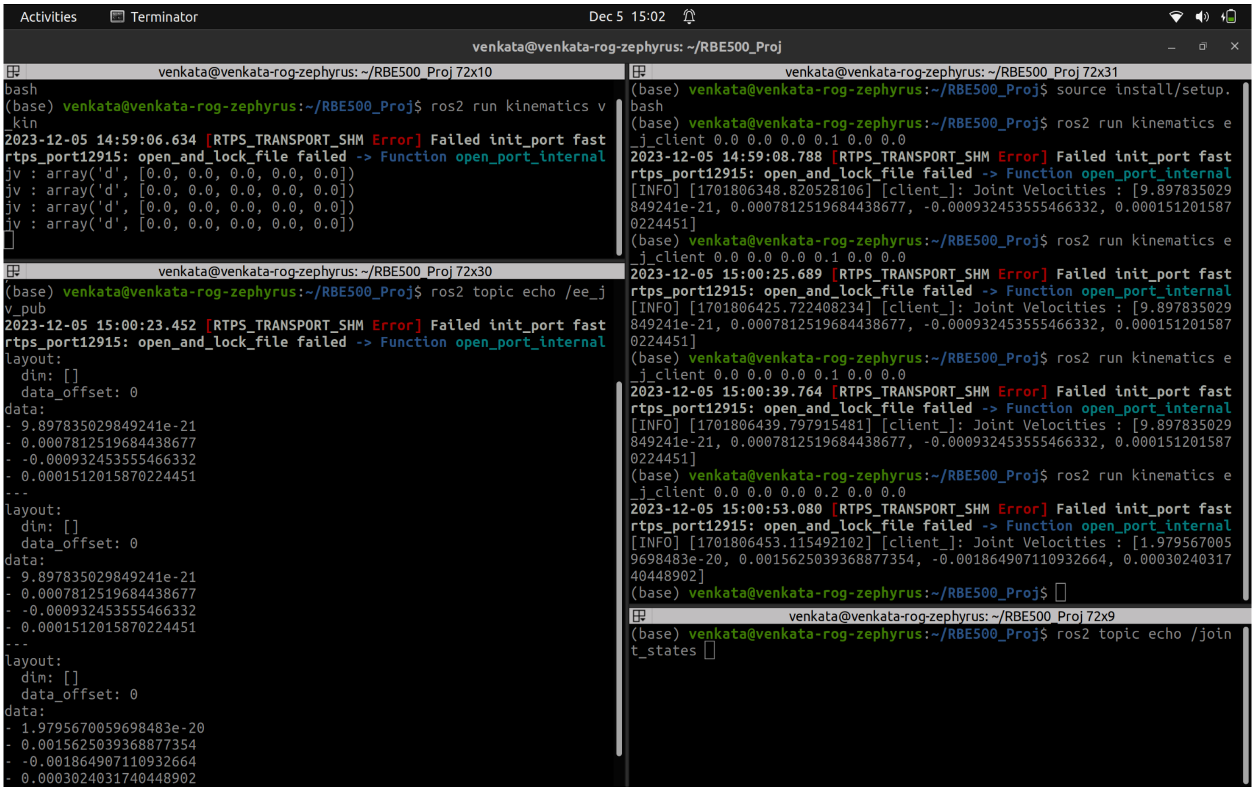
```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics v
_kin
2023-12-05 14:21:45.272 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [ 0.00000000e+00  3.59712357e-01  2.20260293e-17 -2.09610467e+
01
  3.44569354e-15 -5.62724459e+01]
end vel : [ 5.21330857e-03 -4.76774681e-02  1.43884942e-01  1.22400841e+
01
  2.38047919e+01  1.76358873e+01]
end vel : [-5.89820449e-03  2.32441611e-02  1.91846594e-01 -1.25957110e+
00
  3.19426895e+01  1.59446150e+01]
end vel : [ 1.09132778e-02 -2.13536911e-02  1.43884942e-01 -5.32171361e+
00
  2.54208903e+01  1.75843032e+01]
end vel : [ 0.0250348  -0.0409094   0.07194247 -1.57797041 13.99015076 1
5.85094053]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [ 0.          0.          0.          0.18259066  0.12079147 -
8.9181796 ]
end vel : [ 1.32311284e-02 -2.00004226e-02 -1.46840164e-18  1.07585057e+
00
  7.11720812e-01 -1.42230793e+01]
end vel : [ 1.02769207e-09 -1.55347867e-09 -1.14054121e-25 -1.05092300e-
01
 -6.95230168e-02 -1.24297968e+01]
end vel : [ 1.32311305e-02 -2.00004257e-02 -1.46840187e-18  1.16392374e+
00
  7.69984956e-01 -5.16257679e+00]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [0. 0. 0. 0. 0. 0.]
end vel : [-1.32311284e-02  2.00004226e-02  1.46840164e-18 -4.12541477e-
```

```
KeyboardInterrupt
[ros2run]: Interrupt
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ 
```

```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ source install/setup.
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics j
_e_client
2023-12-05 14:21:55.022 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701804115.054170556] [client_]: End Effector Velocities : [0.0,
 0.0, 0.0, 0.0, 0.0, 0.0]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics j
_e_client
2023-12-05 14:22:00.116 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701804120.148135258] [client_]: End Effector Velocities : [0.0,
 0.35971235670149326, 2.2026029312411736e-17, -20.961046734235637, 3.445
693540501509e-15, -56.27244594768933]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics j
_e_client
2023-12-05 14:22:05.059 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701804125.090831133] [client_]: End Effector Velocities : [0.00
521330856711969, -0.047677468127962946, 0.14388494193553925, 12.24008406
734184, 23.804791851682168, 17.635887333811283]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics j
_e_client
2023-12-05 14:22:05.770 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701804125.802190871] [client_]: End Effector Velocities : [-0.0
05898204485176778, 0.023244161148781195, 0.1918465942144394, -1.25957110
26751815, 31.942689510882374, 15.94461502313828]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics j
```

```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run rbe500_examp
le_py basic_robot_control
2023-12-05 14:21:58.265 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
0.0 -5.697790682786661 26.8284579097549 58.869332773031765
33.690067525979785 4.2654697615789 -8.51502496720931 84.2495552056304
33.690067525979785 7.004043235977944 11.36136225000054 61.63459451402152
33.690067525979785 7.004043235977944 11.36136225000054 61.63459451402152
33.690067525979785 4.2654697615789 -8.51502496720931 84.2495552056304
-33.690067525979785 4.2654697615789 -8.51502496720931 84.2495552056304
-33.690067525979785 7.004043235977944 11.36136225000054 61.6345945140215
```

- Another service in this node takes in our input of end effector velocities from the client, applies pseudo inverse of the jacobian and multiplies it with these end effector velocities to derive joint velocities.
- These values are published for subsequent use.



venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x10

```
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics v
_kin
2023-12-05 14:59:06.634 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
jv : array('d', [0.0, 0.0, 0.0, 0.0, 0.0])
jv : array('d', [0.0, 0.0, 0.0, 0.0, 0.0])
jv : array('d', [0.0, 0.0, 0.0, 0.0, 0.0])
jv : array('d', [0.0, 0.0, 0.0, 0.0, 0.0])
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x30

```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 topic echo /ee_j
v_pub
2023-12-05 15:00:23.452 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
layout:
  dim: []
  data_offset: 0
data:
- 9.897835029849241e-21
- 0.0007812519684438677
- -0.000932453555466332
- 0.0001512015870224451
---
layout:
  dim: []
  data_offset: 0
data:
- 9.897835029849241e-21
- 0.0007812519684438677
- -0.000932453555466332
- 0.0001512015870224451
---
layout:
  dim: []
  data_offset: 0
data:
- 1.9795670059698483e-20
- 0.0015625039368877354
- -0.001864907110932664
- 0.0003024031740448902
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x31

```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ source install/setup.
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics e
_j_client 0.0 0.0 0.0 0.1 0.0 0.0
2023-12-05 14:59:08.788 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701806348.820528106] [client_]: Joint Velocities : [9.897835029
849241e-21, 0.0007812519684438677, -0.000932453555466332, 0.000151201587
0224451]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics e
_j_client 0.0 0.0 0.0 0.1 0.0 0.0
2023-12-05 15:00:25.689 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701806425.722408234] [client_]: Joint Velocities : [9.897835029
849241e-21, 0.0007812519684438677, -0.000932453555466332, 0.000151201587
0224451]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics e
_j_client 0.0 0.0 0.0 0.1 0.0 0.0
2023-12-05 15:00:39.764 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701806439.797915481] [client_]: Joint Velocities : [9.897835029
849241e-21, 0.0007812519684438677, -0.000932453555466332, 0.000151201587
0224451]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics e
_j_client 0.0 0.0 0.0 0.2 0.0 0.0
2023-12-05 15:00:53.080 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
[INFO] [1701806453.115492102] [client_]: Joint Velocities : [1.979567005
9698483e-20, 0.0015625039368877354, -0.001864907110932664, 0.00030240317
40448902]
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$
```

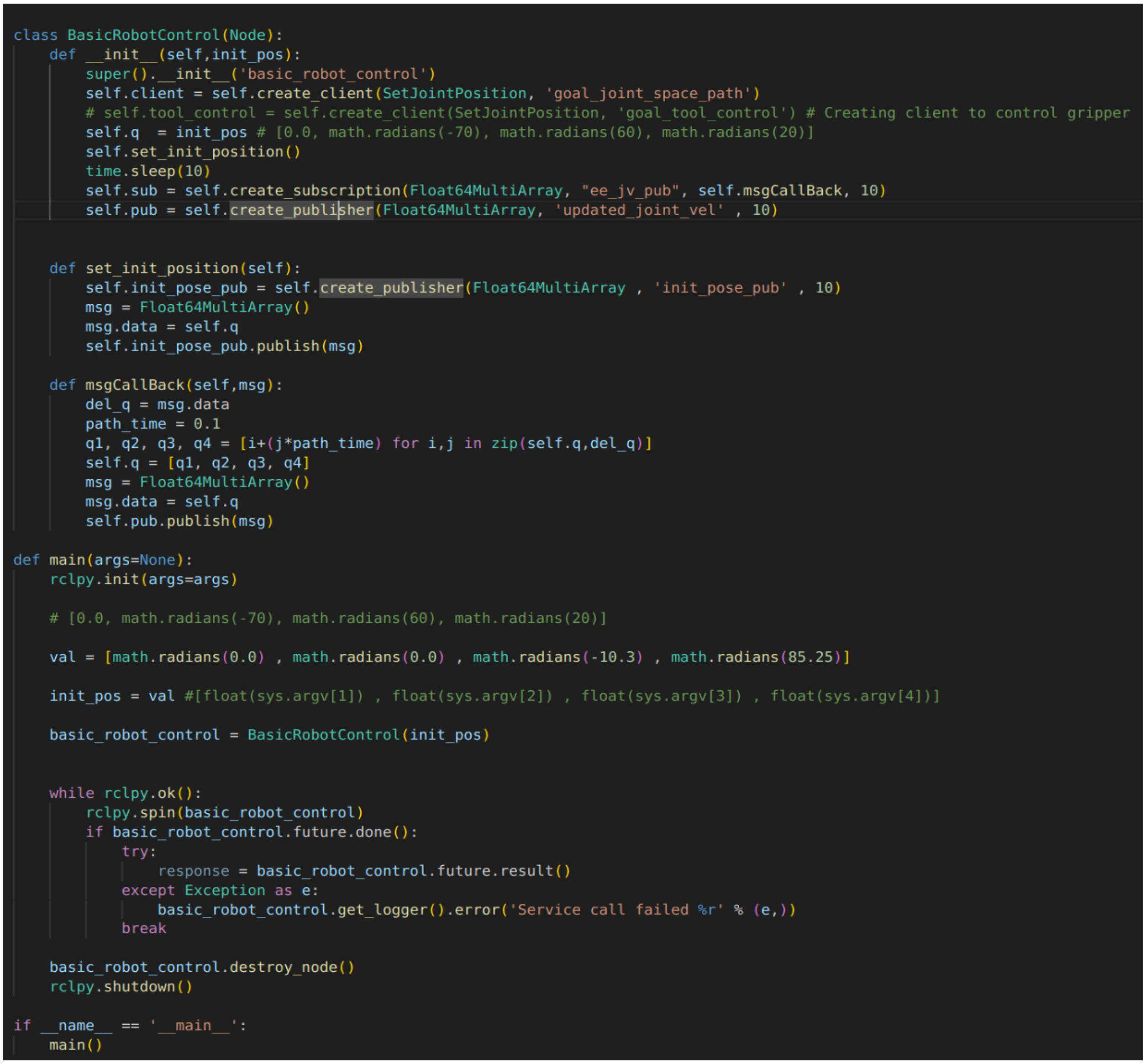
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x9

```
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 topic echo /join
t_states
```

Q2:

Problem Statement: Another node is implemented which subscribes to the above node to take joint velocities and updates the joint state for required twist

- Once the joint velocities are derived from the above node, it is added to the present joint states by multiplying with path time.

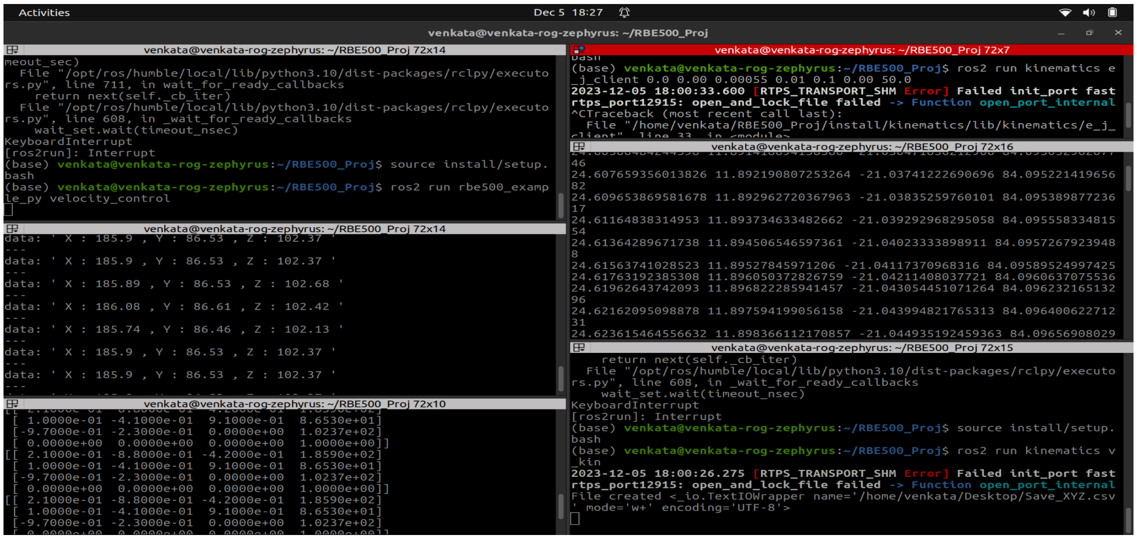


```python
class BasicRobotControl(Node):
    def __init__(self,init_pos):
        super().__init__('basic_robot_control')
        self.client = self.create_client(SetJointPosition, 'goal_joint_space_path')
        # self.tool_control = self.create_client(SetJointPosition, 'goal_tool_control') # Creating client to control gripper
        self.q  = init_pos # [0.0, math.radians(-70), math.radians(60), math.radians(20)]
        self.set_init_position()
        time.sleep(10)
        self.sub = self.create_subscription(Float64MultiArray, "ee_jv_pub", self.msgCallBack, 10)
        self.pub = self.create_publisher(Float64MultiArray, 'updated_joint_vel' , 10)


    def set_init_position(self):
        self.init_pose_pub = self.create_publisher(Float64MultiArray , 'init_pose_pub' , 10)
        msg = Float64MultiArray()
        msg.data = self.q
        self.init_pose_pub.publish(msg)

    def msgCallBack(self,msg):
        del_q = msg.data
        path_time = 0.1
        q1, q2, q3, q4 = [i+(j*path_time) for i,j in zip(self.q,del_q)]
        self.q = [q1, q2, q3, q4]
        msg = Float64MultiArray()
        msg.data = self.q
        self.pub.publish(msg)

def main(args=None):
    rclpy.init(args=args)

    # [0.0, math.radians(-70), math.radians(60), math.radians(20)]

    val = [math.radians(0.0) , math.radians(0.0) , math.radians(-10.3) , math.radians(85.25)]

    init_pos = val #[float(sys.argv[1]) , float(sys.argv[2]) , float(sys.argv[3]) , float(sys.argv[4])]

    basic_robot_control = BasicRobotControl(init_pos)


    while rclpy.ok():
        rclpy.spin(basic_robot_control)
        if basic_robot_control.future.done():
            try:
                response = basic_robot_control.future.result()
            except Exception as e:
                basic_robot_control.get_logger().error('Service call failed %r' % (e,))
            break

    basic_robot_control.destroy_node()
    rclpy.shutdown()

if __name__ == '__main__':
    main()
```

- As the manipulator moves, the jacobian and required joint velocities change and the joint state is updated with this new value.
- These values are published to basic robot control to move the robot.

Q3:

Problem Statement: Move the robot with the intended twist, Save robot's movement using forward kinematics node.

- We took the continuously updated values from the velocity control node referred to in question 2 and published it in a topic. These updated values are feeded to the basic robot control node which gets these updated values constantly and moves the robot to that point within the same path time with which del q is multiplied in the velocity control node to follow the intended velocity. For the robot to move, we need to run the service which calculates joint velocities from intended end effector twist, client which takes the twist as input and give it to service, velocity control node which updates the positions by using del q*sampling time, and basic robot control to move the robot. This is represented in the screenshot below
- 

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x14

```
meout_sec)
  File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executo
rs.py", line 711, in wait_for_ready_callbacks
    return next(self._cb_iter)
  File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executo
rs.py", line 608, in _wait_for_ready_callbacks
    wait_set.wait(timeout_nsec)
KeyboardInterrupt
[ros2run]: Interrupt
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ source install/setup.
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run rbe500_examp
le_py velocity_control
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x14

```
data: ' X : 185.9 , Y : 86.53 , Z : 102.37 '
---
data: ' X : 185.9 , Y : 86.53 , Z : 102.37 '
---
data: ' X : 185.89 , Y : 86.53 , Z : 102.68 '
---
data: ' X : 186.08 , Y : 86.61 , Z : 102.42 '
---
data: ' X : 185.74 , Y : 86.46 , Z : 102.13 '
---
data: ' X : 185.9 , Y : 86.53 , Z : 102.37 '
---
data: ' X : 185.9 , Y : 86.53 , Z : 102.37 '
---
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x10

```
 [ 1.0000e-01 -4.1000e-01  9.1000e-01  8.6530e+01]
 [-9.7000e-01 -2.3000e-01  0.0000e+00  1.0237e+02]
 [ 0.0000e+00  0.0000e+00  0.0000e+00  1.0000e+00]]
[[ 2.1000e-01 -8.8000e-01 -4.2000e-01  1.8590e+02]
 [ 1.0000e-01 -4.1000e-01  9.1000e-01  8.6530e+01]
 [-9.7000e-01 -2.3000e-01  0.0000e+00  1.0237e+02]
 [ 0.0000e+00  0.0000e+00  0.0000e+00  1.0000e+00]]
[[ 2.1000e-01 -8.8000e-01 -4.2000e-01  1.8590e+02]
 [ 1.0000e-01 -4.1000e-01  9.1000e-01  8.6530e+01]
 [-9.7000e-01 -2.3000e-01  0.0000e+00  1.0237e+02]
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x7

```
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics e
_j_client 0.0 0.00 0.00055 0.01 0.1 0.00 50.0
2023-12-05 18:00:33.600 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
^CTraceback (most recent call last):
  File "/home/venkata/RBE500_Proj/install/kinematics/lib/kinematics/e_j_
client", line 33, in <module>
```

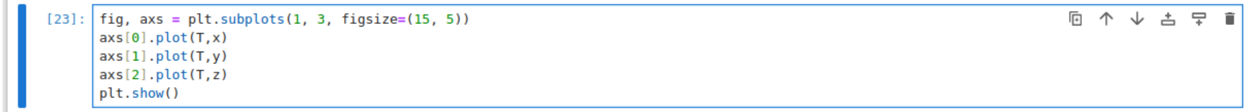
venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x16

```
46
24.607659356013826 11.892190807253264 -21.03741222690696 84.095221419656
82
24.609653869581678 11.892962720367963 -21.03835259760101 84.095389877236
17
24.61164838314953 11.893734633482662 -21.039292968295058 84.095558334815
54
24.61364289671738 11.894506546597361 -21.04023333898911 84.0957267923948
8
24.61563741028523 11.89527845971206 -21.04117370968316 84.09589524997425
24.61763192385308 11.896050372826759 -21.04211408037721 84.09606370755536
24.61962643742093 11.896822285941457 -21.043054451071264 84.09623216513
96
24.62162095098878 11.897594199056158 -21.043994821765313 84.09640062271
31
24.623615464556632 11.898366112170857 -21.044935192459363 84.0965690802
```

venkata@venkata-rog-zephyrus: ~/RBE500_Proj 72x15

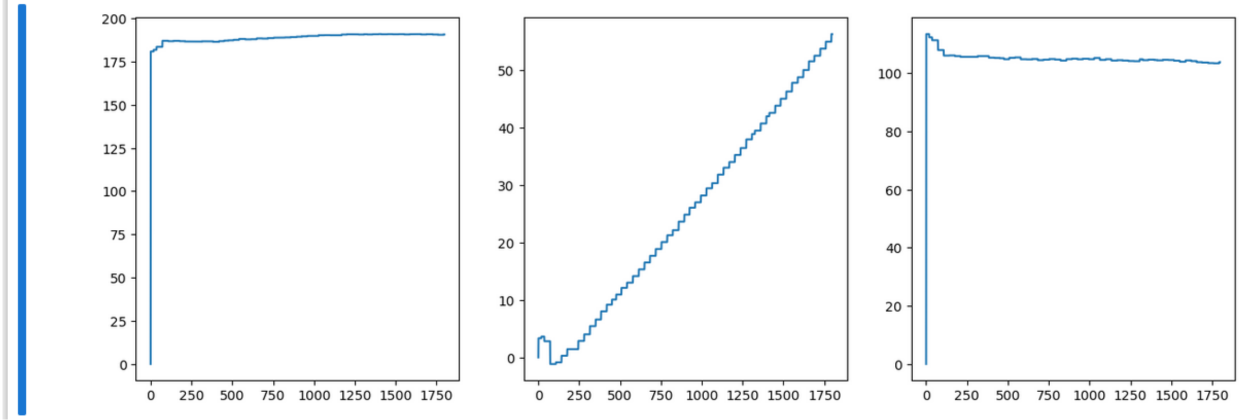
```
    return next(self._cb_iter)
  File "/opt/ros/humble/local/lib/python3.10/dist-packages/rclpy/executo
rs.py", line 608, in _wait_for_ready_callbacks
    wait_set.wait(timeout_nsec)
KeyboardInterrupt
[ros2run]: Interrupt
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ source install/setup.
bash
(base) venkata@venkata-rog-zephyrus:~/RBE500_Proj$ ros2 run kinematics v
_kin
2023-12-05 18:00:26.275 [RTPS_TRANSPORT_SHM Error] Failed init_port fast
rtps_port12915: open_and_lock_file failed -> Function open_port_internal
File created <_io.TextIOWrapper name='/home/venkata/Desktop/Save_XYZ.csv
' mode='w+' encoding='UTF-8'>
```

This is the video of the robot moving is uploaded in canvas, The graphs below shows how robot is moving w.r.t time.



[23]:

```python
fig, axs = plt.subplots(1, 3, figsize=(15, 5))
axs[0].plot(T,x)
axs[1].plot(T,y)
axs[2].plot(T,z)
plt.show()
```



200
175
150
125
100
75
50
25
0
0 250 500 750 1000 1250 1500 1750
50
40
30
20
10
0
0 250 500 750 1000 1250 1500 1750
100
80
60
40
20
0
0 250 500 750 1000 1250 1500 1750