How to control Universal Robot by using ROS2

Version: 2.0, 2021/06/24

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PREFACE

This introduction aims to provide a tutorial about how to control the real Universal Robot by using the Robot Operating System 2 (ROS2). The introduction is compatible across the entire line of UR robots -- from 3 kg to 16 kg payload and includes both the CB3 and the E-series. Especially, a ur_5e robot is used for explanation.

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1. Preliminaries

1.1 ROS 2 distribution

ROS 2 Foxy is highly recommended.

(ROS 2 Foxy Fitzroy, released June 5th, 2020, supported until May 2023)

Installation: https://docs.ros.org/en/foxy/Installation/Ubuntu-Development-Setup.html

1.2 Ubuntu system

To match ROS 2 Foxy distribution, Ubuntu 20.04 is required.

Installation: https://ubuntu.com/download/desktop

2. Introduction

This introduction is based on the official universal robot ROS 2 driver:
https://github.com/UniversalRobots/Universal_Robots_ROS2_Driver

2.1 Download and build ROS 2 packages

Follow the steps below to build the required ROS 2 packages:

Step 1:

```
# source global ROS 2
$ gedit ~/.bashrc
```

At the last line, add "source ~/ros2_foxy/install/local_setup.bash"

```
$ source ~/.bashrc
```

Step 2:

```
# create a new ROS 2 workspace
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ mkdir -p $COLCON_WS/src
```

Step 3:

```
# Pull relevant packages, install dependencies, compile, and source the workspace
$ cd $COLCON_WS
$ git clone https://github.com/UniversalRobots/Universal_Robots_ROS2_Driver.git src/Universal_Robots_ROS2_Driver
$ vcs import src --skip-existing --input src/Universal_Robots_ROS2_Driver/Universal_Robots_ROS2_Driver.repos
$ rosdep install --ignore-src --from-paths src -y -r
$ colcon build --cmake-args -DCMAKE_BUILD_TYPE=Release
$ source install/setup.bash
```

Step 4:

```
# To use MoveIt, some additional packages should be added into workspace
$ cd $COLCON_WS
$ vcs import src --skip-existing --input src/Universal_Robots_ROS2_Driver/MoveIt_Support.repos
$ vcs import src --skip-existing --input src/moveit2/moveit2.repos
$ rosdep install --ignore-src --from-paths src -y -r
$ colcon build --cmake-args -DCMAKE_BUILD_TYPE=Release
$ source install/setup.bash
```

2.2 Hardware setup: setting a ur_5e robot

2.2.1 Preparation

To enable external control of the UR robot from a control PC, you need to install the externalcontrol-1.0.5.urcap which can be found inside the resources folder of this driver:
(`ros_ws_foxy_ur_driver→src→Universal_Robots_ROS2_Driver→ur_robot_driver→resources`)
or download the latest from Universal_Robots_ExternalControl_URCap:
https://github.com/UniversalRobots/Universal_Robots_ExternalControl_URCap/releases
Note: For installing this URCap, a minimal PolyScope version 5.1 (for e-Series) is necessary.

2.2.2 Install an URCap on an e-Series robot

For installing the necessary URCap and creating a program, please see the individual tutorial on how to setup a CB3 robot or how to setup an e-Series robot

To install it you first have to copy it to the robot's programs folder which can be done using a USB stick.

Step 1:
On the welcome screen, click on the hamburger menu in the top-right corner and select `Settings` to enter the robot's setup. Select `System` and then `URCaps` to enter the URCaps installation screen.

Step 2:
Click the little plus sign at the bottom to open the file selector. You should see all URCap files stored inside the robot's programs folder. Select and open the `externalcontrol-1.0.5.urcap` file. Your URCaps view should now show the `External Control` in the list of active URCaps and a notification to restart the robot.

Step 3:
After the reboot you should find the `External Control` in URCaps tag inside Installation.

Step 4:
You should setup the IP address of the external PC which will be running the ROS 2 driver. Note that the robot and the external PC have to be in the same network, ideally in a direct connection with each other to minimize network disturbances. The custom port should be left untouched for now.

Step 5:
To use the new URCaps, create a new program and insert the `External Control` program node into the program tree.

If you click on the `command` tab again, you'll see the settings entered inside the `Installation`. Check that they are correct, and then save the program. Your robot is now ready to be used together with this driver.

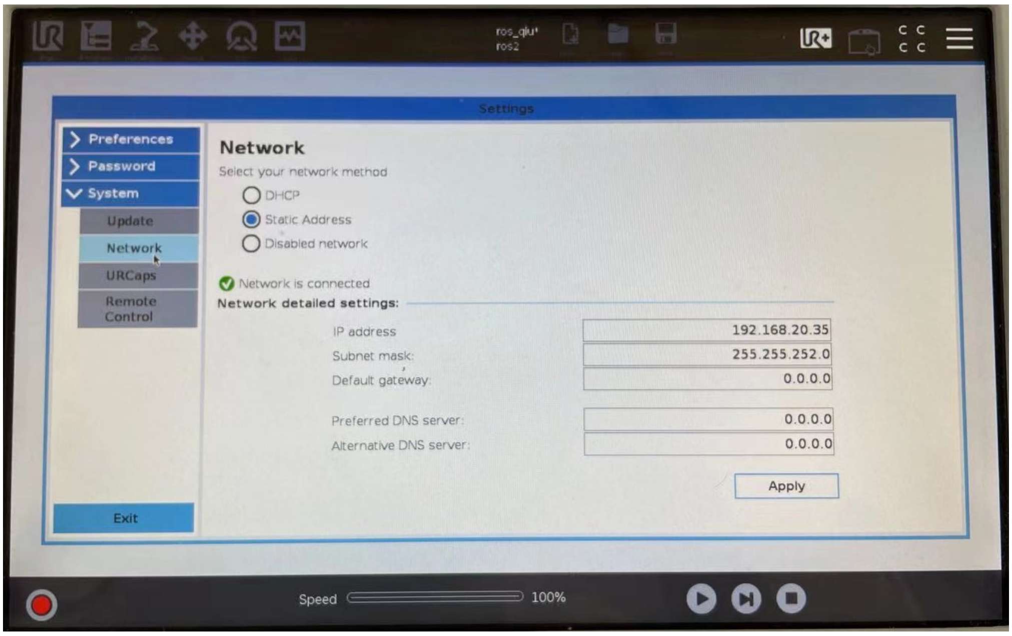
3. Examples

3.1 Preparation

First, the physical connection between the robot and the control PC should be established, e.g., connect the robot and the PC via a net cable.

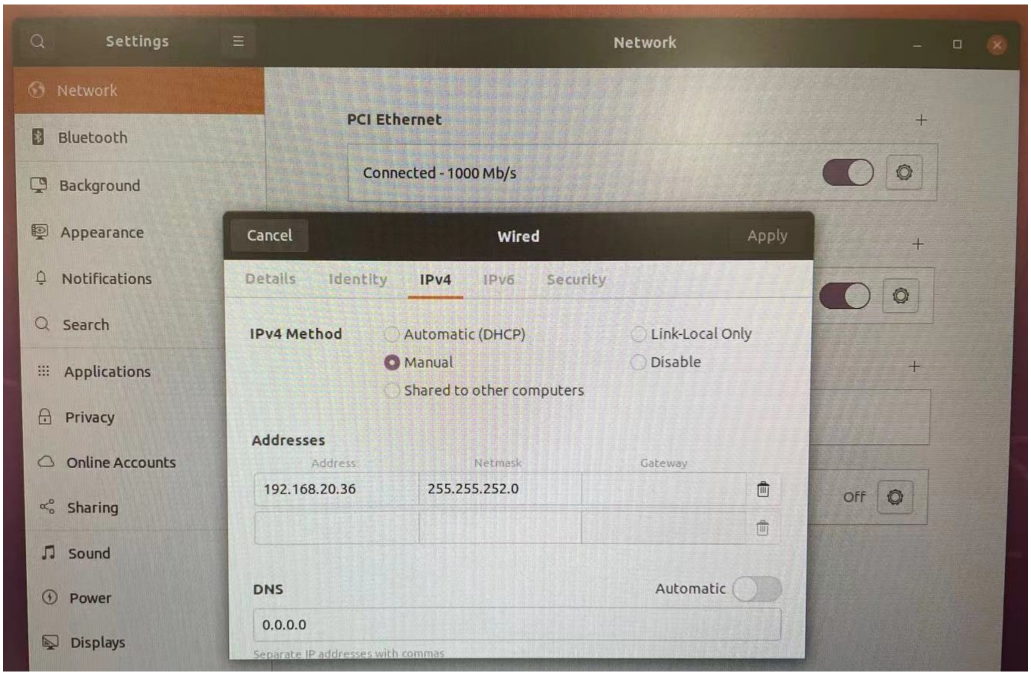
3.1.1 Set IP address of the robot

The IP address of the ur_5e robot is set as: 192.168.20.35.

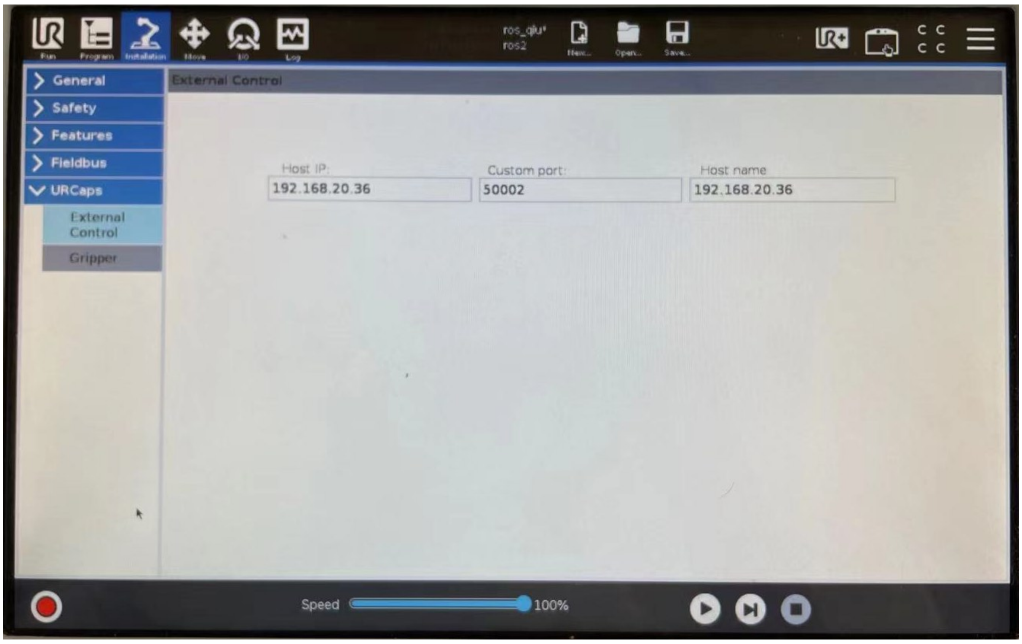


3.1.2 Set IP address of the control PC

First, configure the IP address of the control PC, which is set as: 192.168.20.36.



Second, update the information of `External Control` in `URCaps` in `Installation`.



As shown in the above figure, configure the Host IP and Host name.

3.2 Test joint trajectory controller

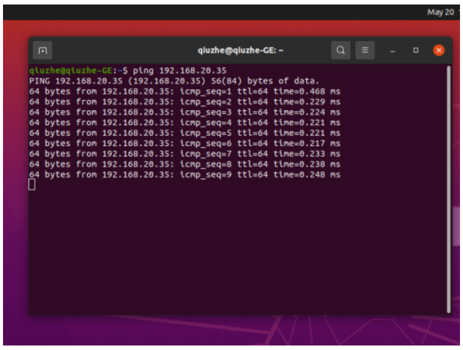
A ur_5e robot is controlled via `joint_trajectory_controller` by using a PC (ROS 2 Foxy with Ubuntu 20.04).

The following steps are recommended:

Step 1:
Power on the ur_5e robot, and confirm the connection between the robot and the PC.
The IP address of the ur_5e robot is set as: 192.168.20.35.
The IP address of the PC is set as: 192.168.20.36.

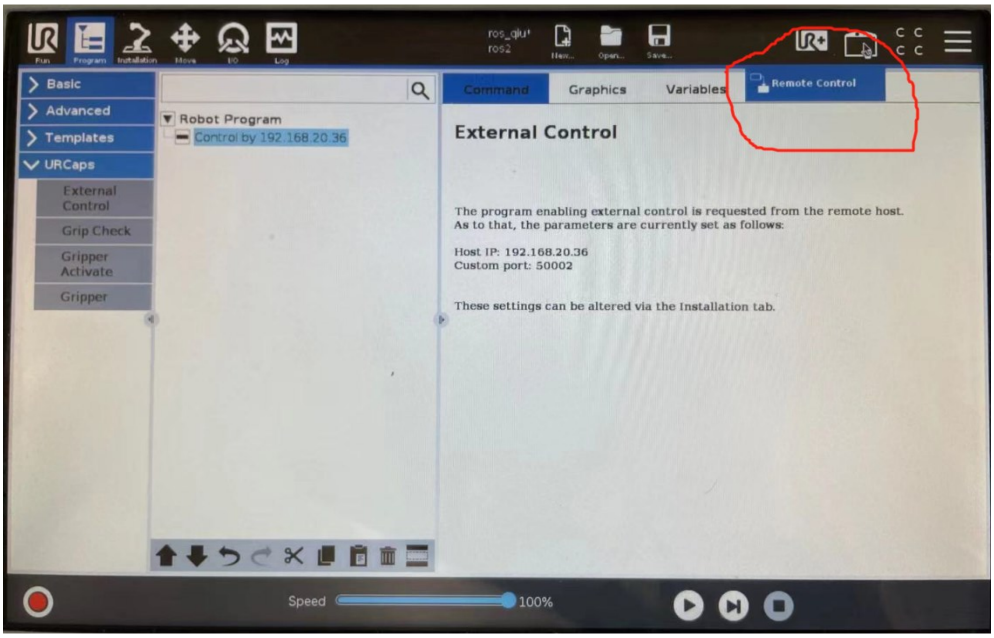
Open Terminal 1:

```
$ ping 192.168.20.35
```



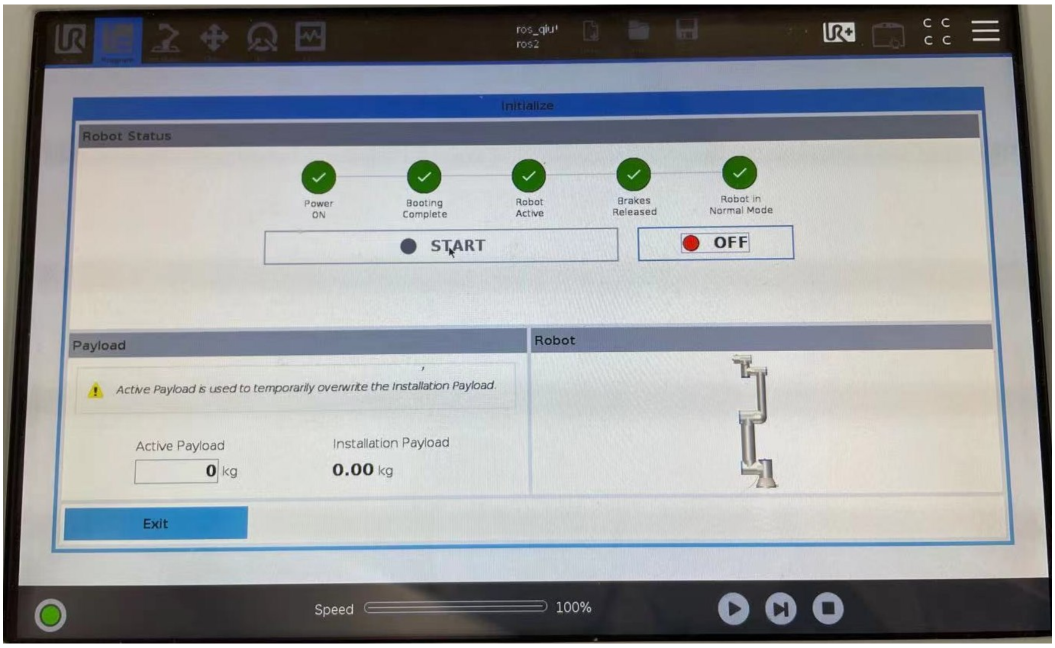
We can see the robot and the PC are successfully connected.

Step 2:
Set the robot control mode to the local control mode by using the teach-pendant.



As shown in the above figure, the local control mode has already set.

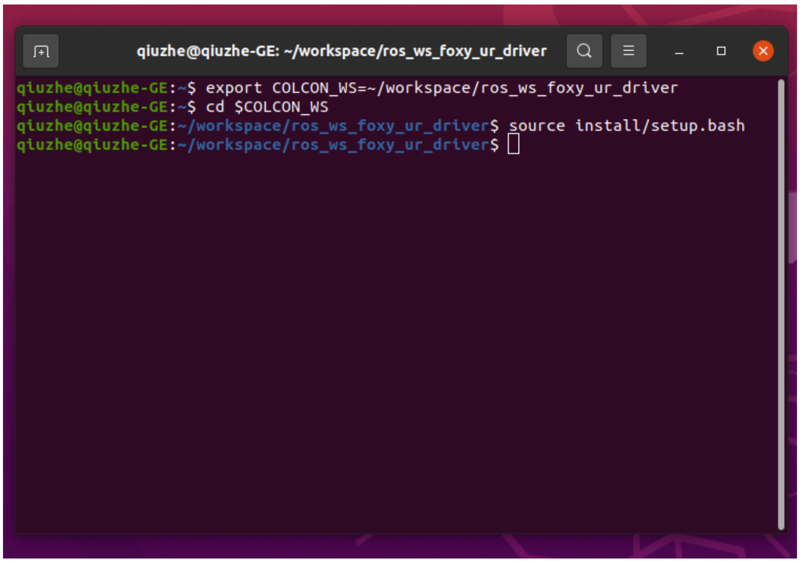
Step 3:
Start the robot.



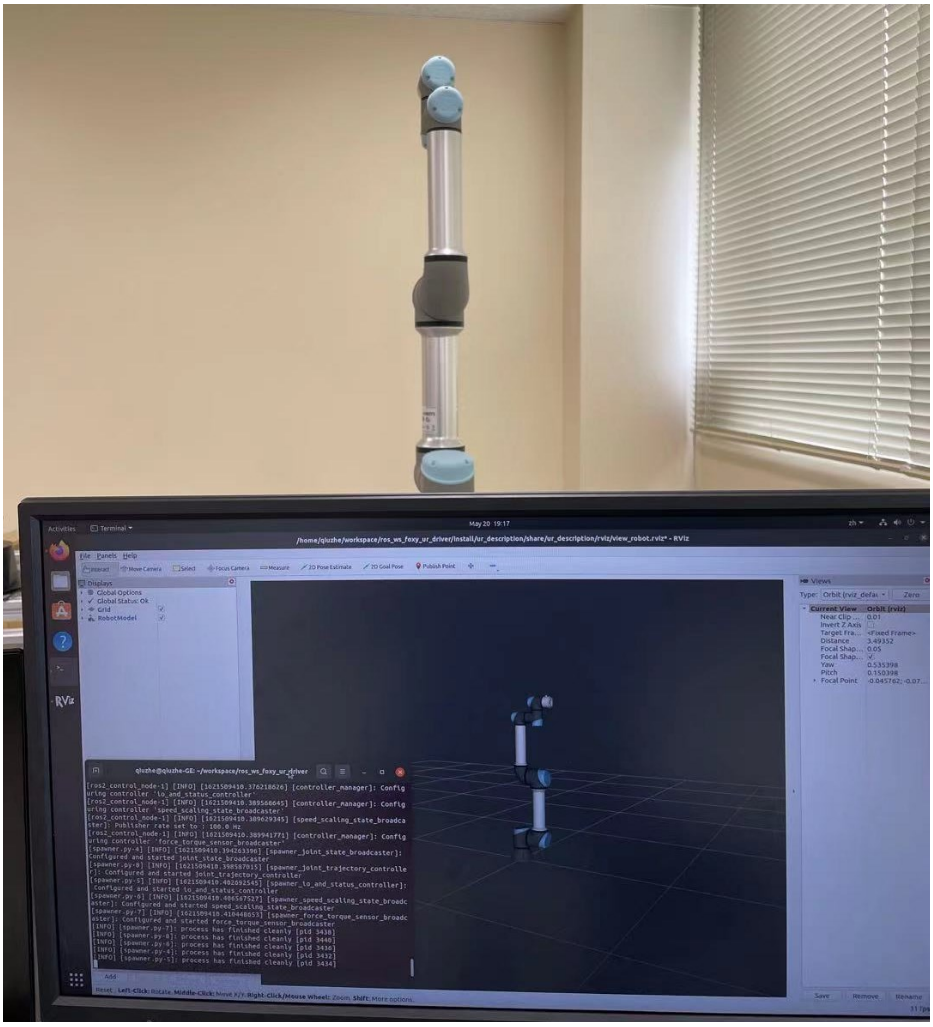
As shown in the above figure, the robot has already started.

Step 4:
Start the robot driver. Remember source the bash file first.
Open Terminal 2:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
```

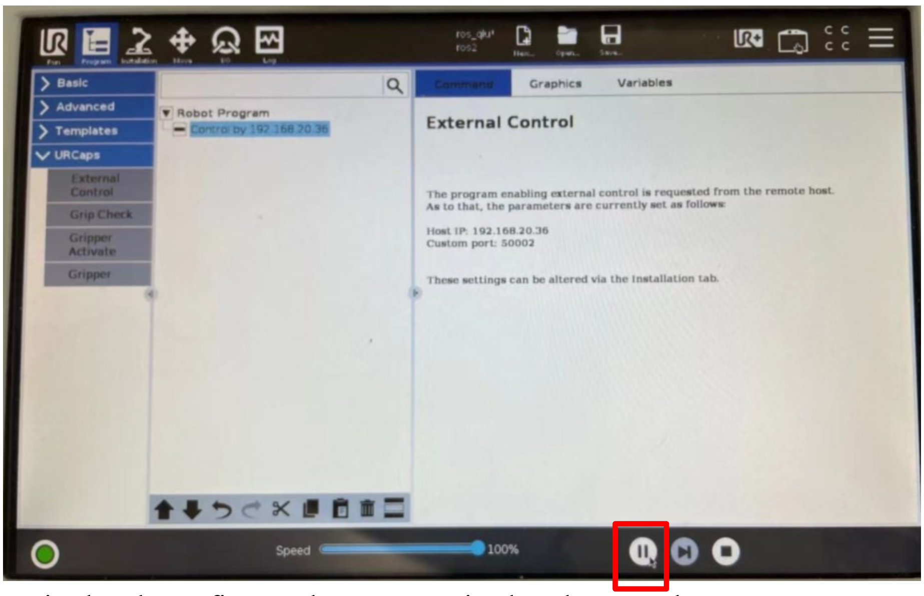



```
$ ros2 launch ur_bringup ur_control.launch.py ur_type:=ur5e robot_ip:=192.168.20.35 launch_rviz:=true
```



As shown in the above figure, the driver is successfully started.

Step 5:
Load Robot Program: External Control, and start it.



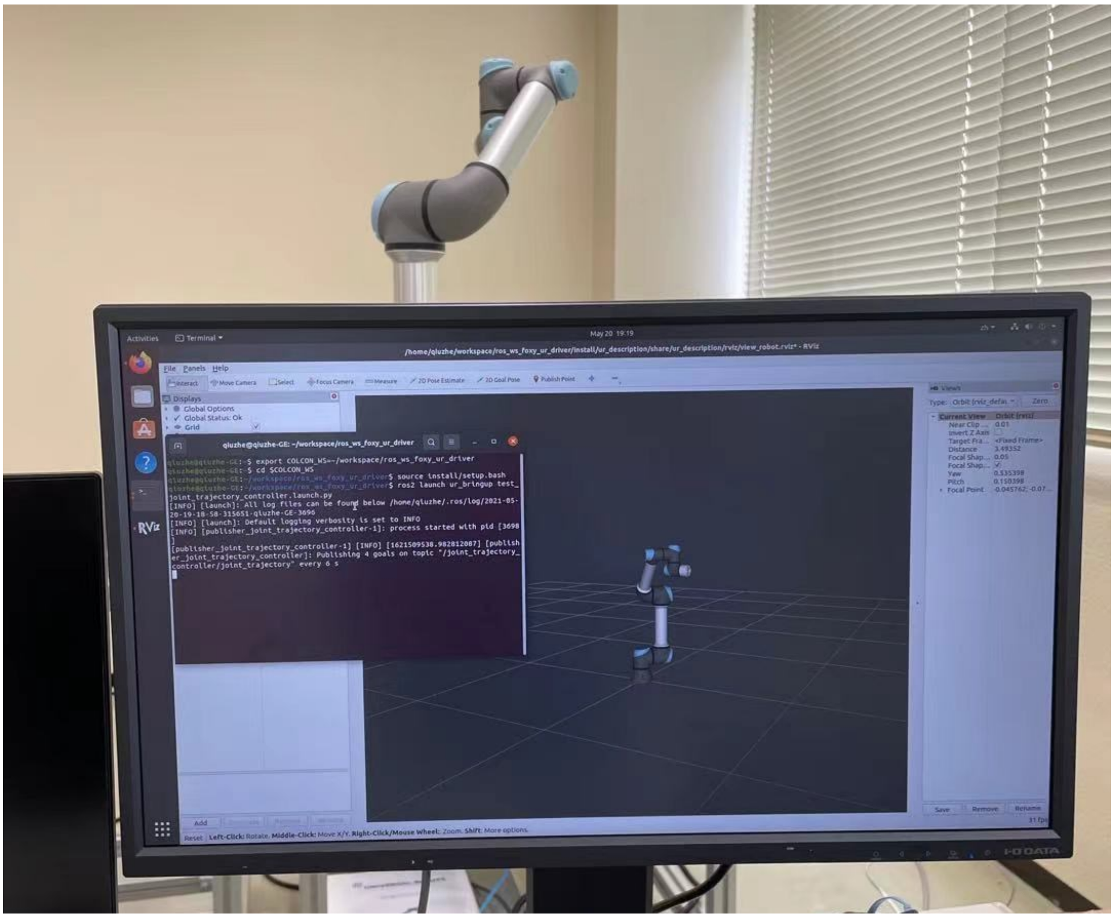
As shown in the above figure, the program is already started.

Step 6:

Start the Joint Trajectory Controller. Remember source the bash file first.

Open Terminal 3:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
$ ros2 launch ur_bringup test_joint_trajectory_controller.launch.py
```



After a few seconds, the robot starts to move.

3.3 Test scaled_joint_trajectory_controller

A ur_5e robot is controlled via `scaled_joint_trajectory_controller` by using a PC (ROS 2 Foxy with Ubuntu 20.04).

The following steps are recommended:

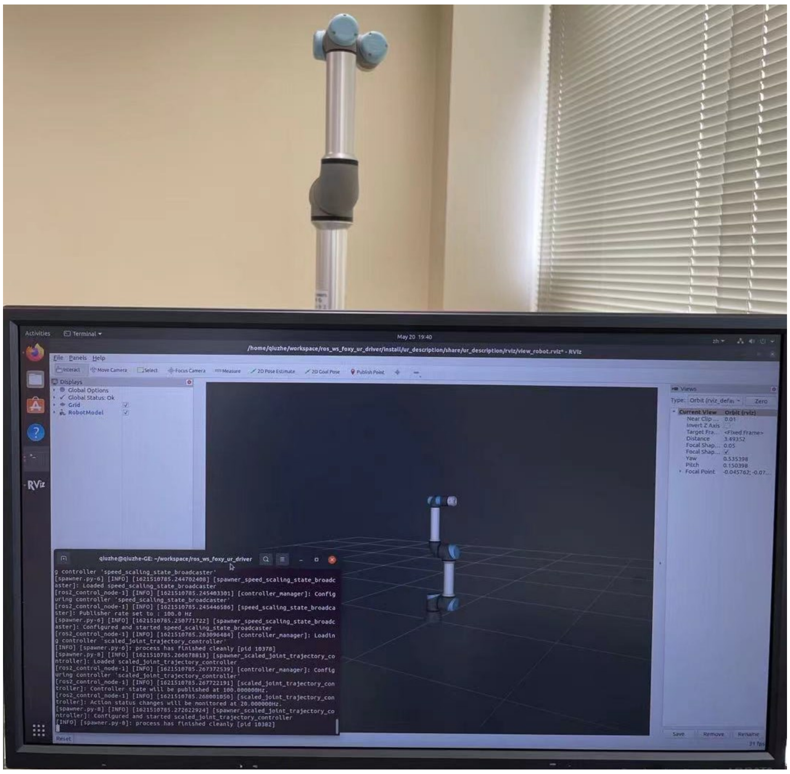
Step 1:
Same as Step 1 of Example 3.2

Step 2:
Same as Step 2 of Example 3.2

Step 3:
Same as Step 3 of Example 3.2

Step 4:
Start the robot driver. Remember source the bash file first.
Open Terminal 2:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
$ ros2 launch ur_bringup ur_control.launch.py ur_type:=ur5e robot_ip:=192.168.20.35 robot_controller:=scaled_joint_trajectory_controller launch_rviz:=true
```

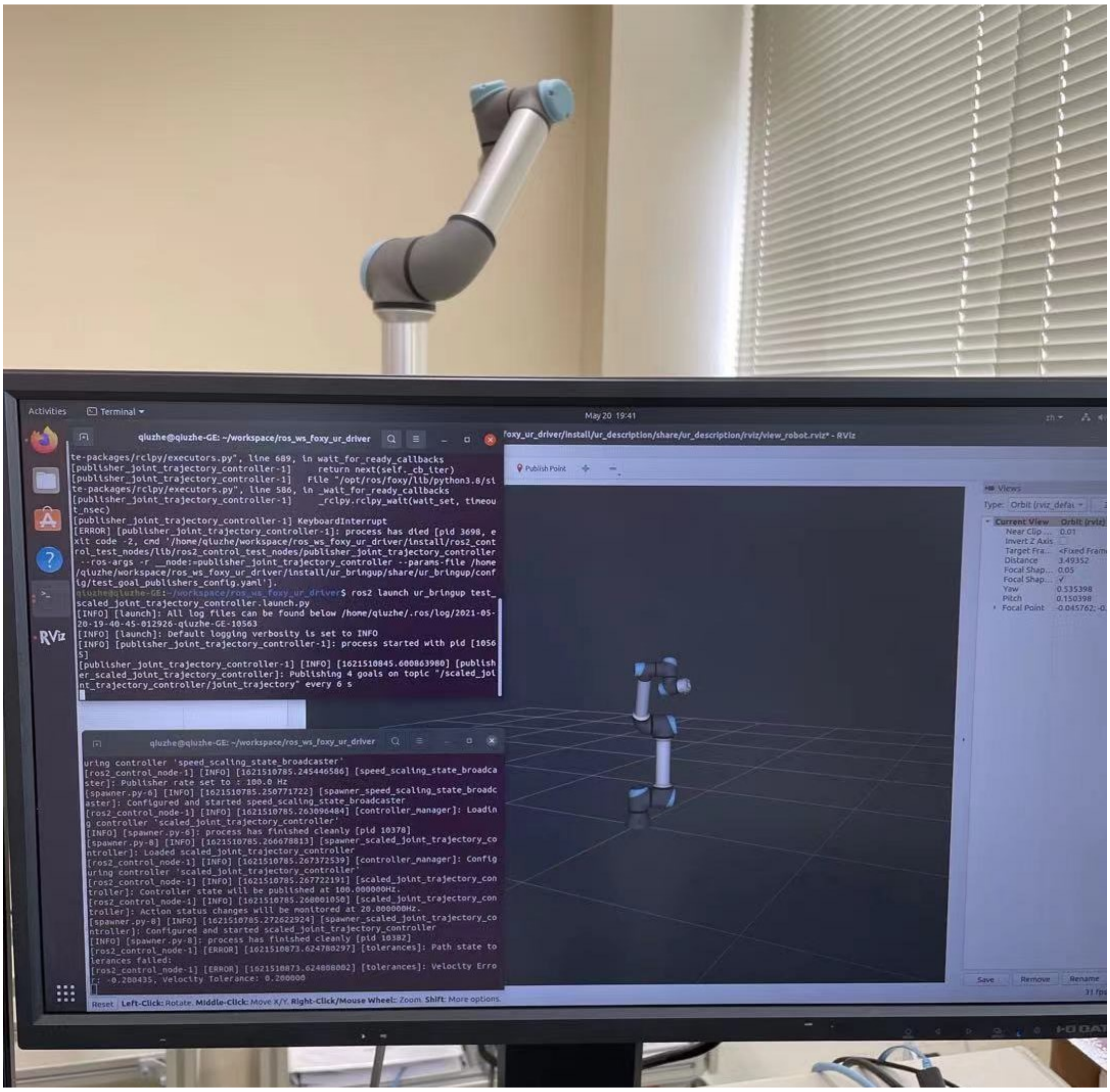


As shown in the above figure, the driver is already started.

Step 5:
Load Robot Program: External Control, and start it. Same as Step 5 of Example 3.2

Step 6:
Start the Scaled Joint Trajectory Controller. Remember source the bash file first.
Open Terminal 3:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
$ ros2 launch ur_bringup test_scaled_joint_trajectory_controller.launch.py
```



After a few seconds, the robot starts to move.

3.4 Test MoveIt plugin

A ur_5e robot is controlled via `MoveIt` by using a PC (ROS 2 Foxy with Ubuntu 20.04).

The following steps are recommended:

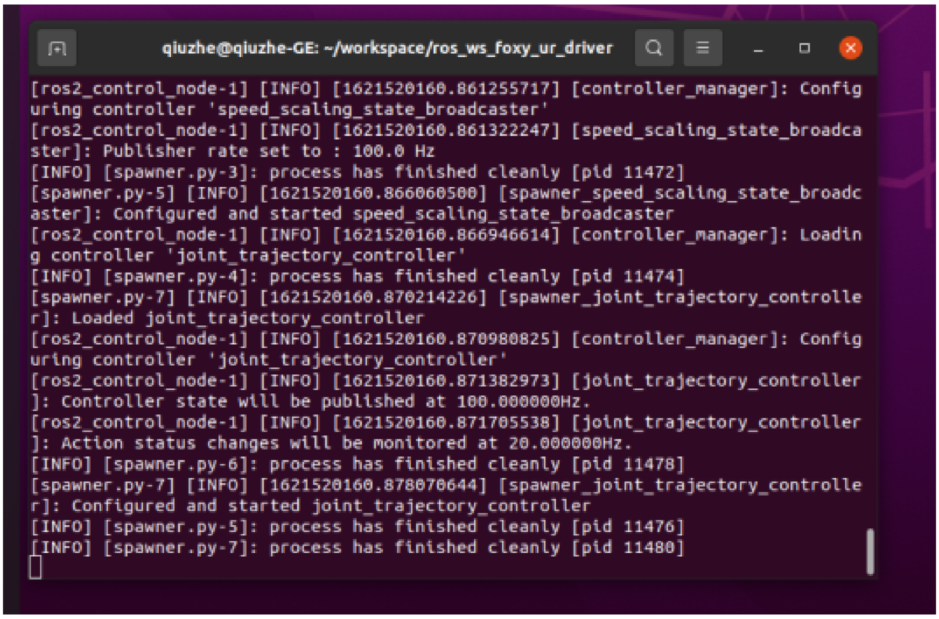
Step 1:
Same as Step 1 of Example 3.2

Step 2:
Same as Step 2 of Example 3.2

Step 3:
Same as Step 3 of Example 3.2

Step 4:
Start the robot driver. Remember source the bash file first.
Open Terminal 2:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
$ ros2 launch ur_bringup ur_control.launch.py ur_type:=ur5e
robot_ip:=192.168.20.35 launch_rviz:=false
```



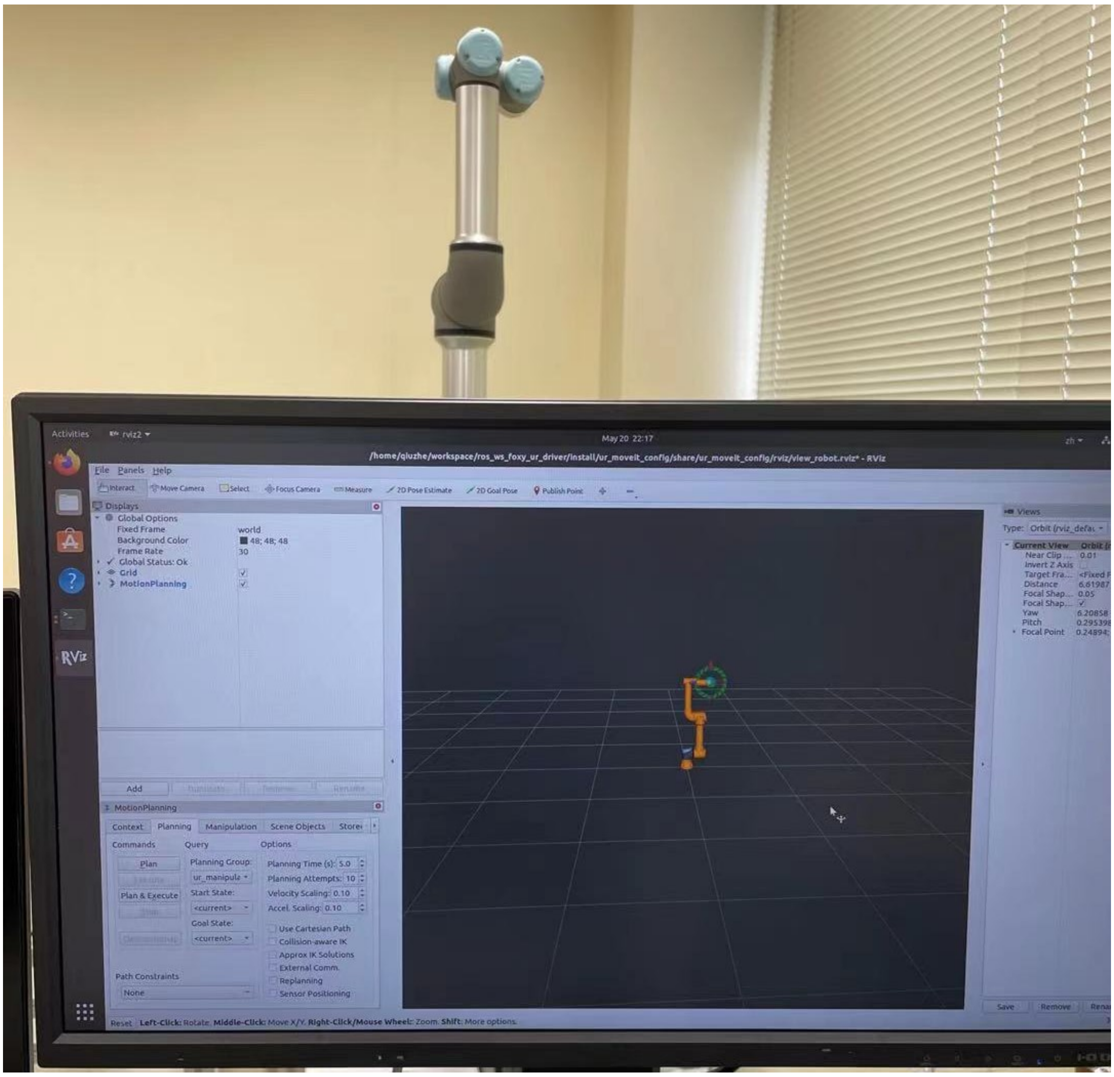
As shown in the above figure, the driver is successfully started.

Step 5:
Load Robot Program: External Control, and start it. Same as Step 5 of Example 3.2

Step 6:

Start the MoveIt example. Remember source the bash file first.
Open Terminal 3:

```
$ export COLCON_WS=~/workspace/ros_ws_foxy_ur_driver
$ cd $COLCON_WS
$ source install/setup.bash
$ ros2 launch ur_bringup ur_moveit.launch.py ur_type:=ur5e
robot_ip:=192.168.20.35 launch_rviz:=true
```



As shown in the above figure, now you can use the MoveIt Plugin in rviz2 to plan and execute trajectories with the robot.

3.5 Modified ROS 2 package of scaled-/joint trajectory controller

A ur_5e robot is controlled via modified `joint_trajectory_controller` by using a PC (ROS 2 Foxy with Ubuntu 20.04). Similarly, the same setting can be applied to the scaled_joint_trajectory_controller for controlling the ur_5e robot.

The following steps are recommended:

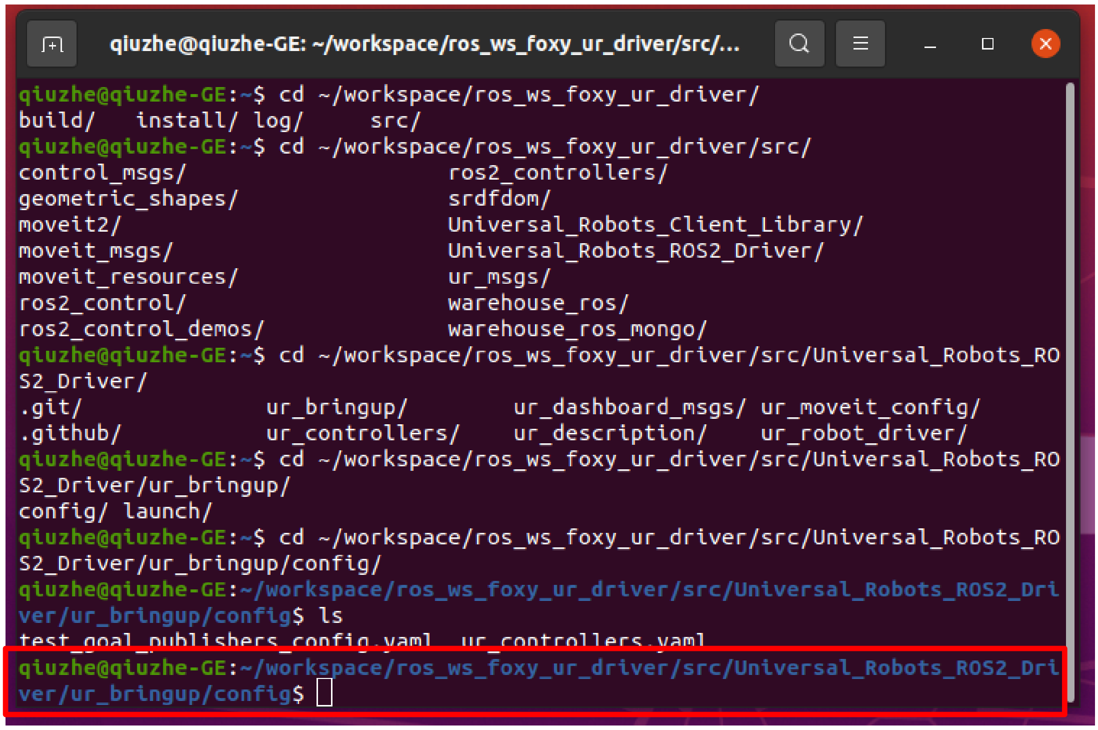
Step 1:

Set desired position of each joint

Open Terminal 1:

Find the controller config file.

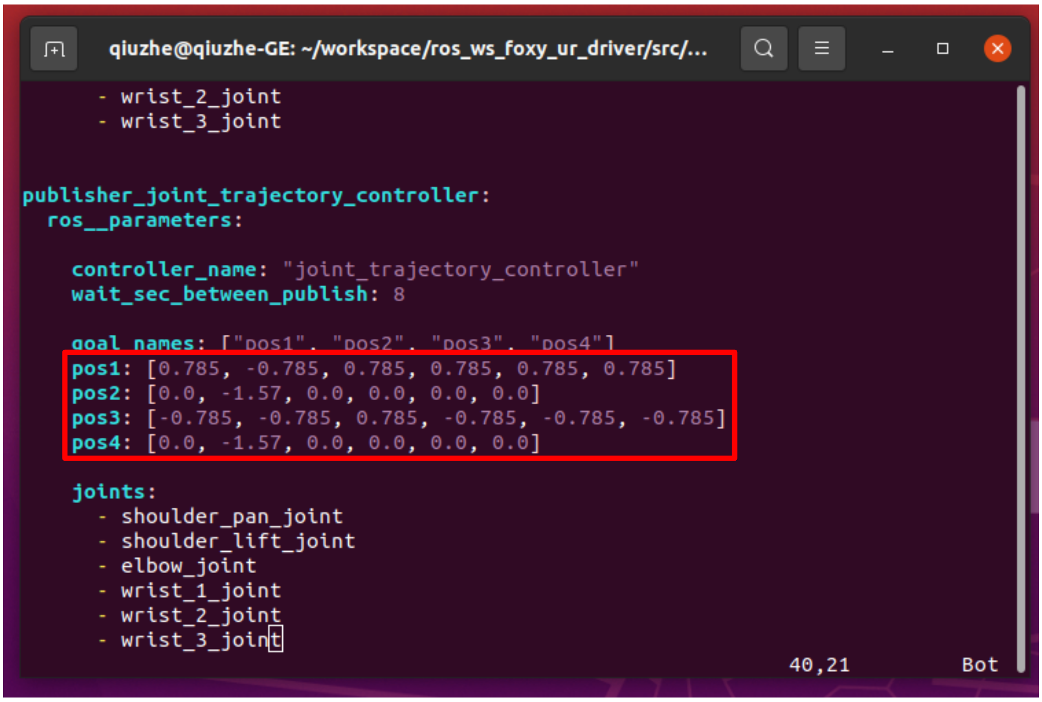
```
$ cd ~ /workspace/ros_ws_foxy_ur_driver/src/Universal_Robots_ROS2_Driver/
ur_bringup/config
```



Modify the controller config file: change desired position of each joint.

```
$ vim test_goal_publishers_config.yaml
```

Six values of "pos" mean the desired position associated with six joints. In addition, "pos1-4" mean four desired joint trajectories for the ur_5e robot.



Step2:

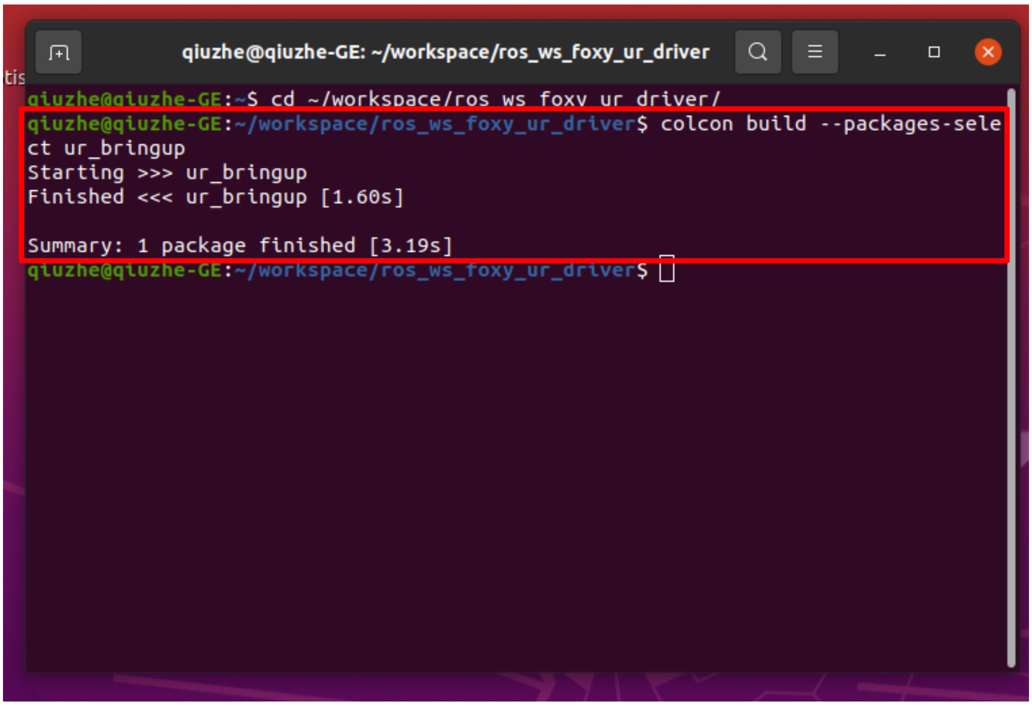
The package should be recompiled after modification

In Terminal 1:

`$ cd ~ /workspace/ros_ws_foxy_ur_driver`

Only compile the modified package to save time

`$ colcon build –packages-select ur_bringup`



Then, refer to Step1 to Step6 of Sec 3.2 to control the ur_5e robot. The performances of the joint trajectory controller are shown as follows.