Linux Programming for Robotics

Open Terminal: alt+ ctrl + t
Close Terminal ctrl+ d

Linux File System:

- How to navigate through a Linux file system
- How to interact with a Linux files system
- How to edit files using Shell (gedit editor)
- Manage access to files (permissions)
- Create simple Linux programs (Bash Scripts)
- Manage execution of Linux programs (processes)
- How to connect to the remote computer of a robot (ssh)
- Perception with ROS

Source: \url{https://www.hostinger.in/tutorials/linux-commands}

pwd
pwd command to find out the path of the current working directory (folder) you're in.

cd
cd command is used to navigate through the Linux files and directories. It requires either the full path or the name of the directory.
cd .. (with space and two dots) to move one directory up
cd (with tilde) to go straight to the home folder
cd- (with a hyphen) to move to your previous directory

ls
ls command is used to view the contents of a directory. By default, this command will display the contents of your current working directory.
ls -R will list all the files in the sub-directories as well

ls -a will show the hidden files
ls -al will list the files and directories with detailed information like the permissions, size, owner, etc.

cat
cat command is used to display the contents of a file on the standard on screen.
cat > filename creates a new file
cat filename1 filename2>filename3 joins two files (1 and 2) and stores the output of them in a new file (3)

cp
cp <file/folder we want to copy> <name of the new file/folder>
cp -r my_scripts/ my_scripts_copy/
cp –help
cp command to copy files from the current directory to a different directory.

mv command
mv command is used to move files and rename files.
To rename files, the Linux command is mv oldname.ext newname.ext
mv <file/folder we want to move> <destination>

mkdir
mkdir command is used to make a new directory
There are extra mkdir commands as well:
mkdir dirName
use the p (parents) option to create a directory in between two existing directories. For example,
mkdir -p Music/2020/Newfile will create the new “2020” file.

rmdir
rmdir command is used to delete a directory. However, rmdir only allows you to delete empty directories.

rm
rm command is used to delete directories and the contents within them. If you only want to delete the directory — as an alternative to rmdir — use rm -r.

touch
touch command allows you to create a blank new file through the Linux command line.
Example: touch /home/newfile.txt

locate

locate command is used to locate a file, just like the search command in Windows. Use -i for case insensitive.
locate -i word1*word2 to search for a file that contains two or more words.

find
find is used to search for files and directories. The difference is, you use the find command to locate files within a given directory.
As an example, find /home/ -name notes.txt command will search for a file called notes.txt within the home directory and its sub directories.
Other variations when using the find are:
To find files in the current directory use, find . -name notes.txt
To look for directories use, \/ -type d -name notes.txt

grep
grep is used to search through all the text in each file.
To illustrate, grep blue notepad.txt will search for the word blue in the notepad file. Lines that contain the searched word will be displayed fully.

sudo
Short for “SuperUser Do”, sudo command is used to perform tasks that require administrative or root permissions.

df
df command to get a report on the system’s disk space usage, shown in percentage and kilo bytes. If you want to see the report in megabytes, type df -m.

du
du (Disk Usage) command is to check how much space a file or a directory takes. However, the disk usage summary will show disk block numbers instead of the usual size format. If you want to see it in bytes, kilobytes, and megabytes, add the -h argument to the command line.

head
head command is used to view the first lines of any text file. By default, it will show the first ten lines, but you can change this number to your liking. For example, if you only want to show the first five lines, type head -n 5 filename.ext.

tail
tail command will display the last ten lines of a text file. For example, tail -n filename.ext

diff

diff command compares the contents of two files line by line. After analyzing the files, it will output the lines that do not match. Programmers often use this command when they need to make program alterations instead of rewriting the entire source code.
The simplest form of this command is diff file1.ext file2.ext

tar
tar command is used to archive multiple files into zip format, with compression being optional.

chmod
chmod is used to change the read, write, and execute permissions of files and directories.
chmod octal file – change the permissions of file to octal, which can be found separately for user, group, and world by adding:
4 – read (r)
2 – write (w)
1 – execute (x)
Examples:
chmod 777 – read, write, execute for all
chmod 755 – rwx for owner, rx for group and world
chmod +x read.py give permission to file read.py for execution.

chown
chown command enables you to change or transfer the ownership of a file to the specified username. For instance, chown linuxuser2 file.ext will make linuxuser2 as the owner of the file.ext.

jobs
jobs command will display all current jobs along with their statuses. A job is basically a process that is started by the shell.

kill
kill is used to terminate unresponsive program. It will send a certain signal to the misbehaving app and instructs the app to terminate itself.
SIGTERM (15) — requests a program to stop running and gives it some time to save all of its progress. If you don't specify the signal when entering the kill command, this signal will be used.
SIGKILL (9) — forces programs to stop immediately. Unsaved progress will be lost.
Besides knowing the signals, you also need to know the process identification number (PID) of the program you want to kill. If you don't know the PID, simply run the command ps ux.

After knowing what signal you want to use and the PID of the program, enter the following syntax:
kill [signal option] PID.

ping
ping command is used to check your connectivity status to a server. For example, by simply entering ping google.com, the command will check whether you're able to connect to Google and also measure the response time.

wget
wget command line is used to download files from the internet. Simply type wget followed by the download link.

uname
uname command, short for Unix Name, will print detailed information about your Linux system like the machine name, operating system, kernel, and so on.

top
top is equivalent to Task Manager in Windows, the top command will display a list of running processes and how much CPU each process uses. It's very useful to monitor system resource usage, especially knowing which process needs to be terminated because it consumes too many resources.

history
When you have been using Linux for a certain period of time, you will quickly notice that you can run hundreds of commands every day. As such, running history command is particularly useful if you want to review the commands you have entered before.

man
man gives the detail of manual instruction of the command. Example man tail will show the manual instruction of the tail command.

echo
echo command is used to move some data into a file. For example, if you want to add the text, "Hello, my name is John" into a file called name.txt, you would type echo Hello, my name is John >> name.txt

zip, unzip
Use the zip command to compress your files into a zip archive, and use the unzip command to extract the zipped files from a zip archive.

hostname

If you want to know the name of your host/network simply type hostname. Adding a -i to the end will display the IP address of your network.

useradd, userdel
Since Linux is a multi-user system, this means more than one person can interact with the same system at the same time. useradd is used to create a new user, while passwd is adding a password to that user's account. To add a new person named John type, useradd John and then to add his password type, passwd 123456789.
To remove a user is very similar to adding a new user. To delete the users account type, userdel UserName

Use the clear command to clean out the terminal if it is getting cluttered with too many past commands.
Try the TAB button to autofill what you are typing.
Ctrl+C and Ctrl+Z are used to stop any command that is currently working. Ctrl+C will stop and terminate the command, while Ctrl+Z will simply pause the command.
If you accidental freeze your terminal by using Ctrl+S, simply undo this with the unfreeze Ctrl+Q.
Ctrl+A moves you to the beginning of the line while Ctrl+E moves you to the end.
You can run multiple commands in one single command by using the ";" to separate them. For example Command1; Command2; Command3. Or use if you only want the next command to run when the first one is successful.

Tab Completion

$ls -l Do
$clear
ctrl + a -beginning of the line
ctrl + e -End of the line
ctrl + ←
ctrl + →
ctrl + u - delete cursor to start
ctrl + k - delete cursor to end
ctrl + shift + c - copy to clipboard
ctrl + shift + v - copy from clipboard
ctrl + r - search command history
ctrl + c - cancel the command
uparrow - previous command
downarrow - next command

Type and note down the operations

$ ls
$ ls -l
long list for more details
$ ls -lh
{command}[options][argument]
$ls -lah /opt
$ls -a - list all
$ls -F list.txt
$man ls
$ls --help
$ls -l --human-readable
q to quit

apropos list - lists all those commands
$file myfile.txt - determines file type
$stat myfile.txt - display ownership
$cd Document/
$pwd - print working directory
$cd .. - previous directory
$cd ~ - goes to home folder

$echo Hello
$echo "Hello"
$cal
$cal 2017
$cal 12 2017
$cal -A 1 12 2021 - after one month
$cal -B 1 12 2021 - before one month
$cal -A 1 -B 1 12 2021 - after and before one month
$cal -y
$date
$date -u - universal time
$date --universal (long names preceded by --)
$history
$!1 - executes first command
$!! - executes previous command
$history -c; history -w clears history
$exit
$echo $PATH - gives the shell script path
$which cal
$which echo

$which which
$cat 1>output.txt - deletes the data written before

standard input - keyboard- 0
standard output - monitor - 1
error - 2

$cat >>output.txt - appends to the data written before
$cat 2>>error.txt - writes the error to error.txt
$cat -k xyz 2>error.txt - writes the error to error.txt
$cat input.txt
"Hello World!"
$cat 0<input.txt
$cat <input.txt
$cat <input.txt 1>output.txt
$tty - gives dev/pts/l
$date 1>date.txt
$cat 0<date.txt --delimiter = " " --fields 1
$date | cut --delimiter = " " --fields 1
$date | cut --delimiter = " " --fields 1 > today.txt
$date | cut >today.txt --delimiter = " " --fields 1
$date | tee full.txt | cut --delimiter = " " --fields 1 > today.txt
tee stores in the file full.txt also pipe helps to store data in today.txt
$date | echo "hello"
$date | xargs echo "hello"
$date | cut --delimiter = " " --fields 1 > today.txt
$date | cut --delimiter = " " --fields 1 | xargs echo

$rm file.txt
$cat file.txt | xargs rm
Aliases - nicknames for pipelines
$cd \texttildelow
$gedit .bash_aliases - shows hidden files

alias getdate = 'date | tee */home/asha/text.txt* | cut --delimiter = " " --fields 1 |
tee /home/asha/date.txt | xargs echo hello'
save - close - open terminal
$getdates

open .bashrc_aliases
add the following lines
alias calmagic = "cal -A 1 -B 1 2021 > */home/asha/thing.txt"*
save and close

ctrl+alt+t
$echo 12 2017 | calmagic

wild cards *

ls *
ls D*
ls Do*
ls *.txt - all that ends with .txt
ls ?.txt - ? single letter.txt
ls ??.txt
ls file[1234567890].txt
ls file*.txt
ls file[0-9]/txt
ls file[A-Z].txt
ls file[0-9][0-9].txt
ls file[0-9][A-Z][a-z].txt
ls file[0-9ABC].txt
cd Desktop/
touch file.txt
touch *~/Documents/asha.txt*
echo "Hello" > hello.txt
mkdir fodername
mkdir ~/Pictures/myPics
mkdir -p myFolder
cd ~/Desktop/
mkdir \{jan, feb, mar\}_\{2020, 2021\}
mkdir \{jan, feb, mar\}_\{2020 .. 2025\}
touch \{jan, feb, mar\}_{2020 .. 2025\}/file\{1 ..10\}.txt
ls \{jan, feb, mar\}_\{2020 .. 2025\}/file\{1 ..10\} > output.txt
touch file\{A,B,C\}.txt
touch file\{A .. C\}.txt

Delete files and Folders
rm
rm asha.txt
rm Documents/asha.txt
touch file\{1 ..3\}.txt
rm *.txt - removes all those ends with .txt
rm file*
rm *2*
rm *.jpg
rm *\[2,3\]*
rm -r folderName

```
mkdir -p folder/file\{1,2,3\}
touch folder/file\{1,2,3\}/file\{1,2,3\}.txt
rm -r folder
rm -ri folder
```

Copy files and Folders

```
cp file1.txt file2.txt
rm file*
. - this folder
.. - previous folder
```

Rename files and folders

```
cd Desktop/
mv oldfile.txt newfile.txt
mv oldfolder newfolder
mv file* newfolder
mv newfolder/ ~ /Documents/
```

```
sudo apt install mlocate
locate *.conf
locate *.CONF
locate -i *.CONF
locate -i --limit 3 *.CONF
locate -S
locate -S >~/Desktop/data.txt
locate -i --limit 3 *.CONF>~/Desktop/list.txt
locate -e .com
locate -e .conf
locate --existing .conf
locate --follow .conf
locate --follow *.conf
locate --existing --follow -i --limit 5 *.conf
touch findme.txt
locate findme.txt
updatedb
man updatedb
sudo updatedb
locate findme.txt
cd ..
locate findme.txt
```

```
cd Desktop/
locate -S
locate -S > data_after.txt
locate --existing --follow findme.txt
find
find /home
find /etc
find /home/asha
cd Desktop/
mkdir asha.txt
mkdir asha
cd asha
touch asha.txt
cd ..
cd asha2
mkdir asha2
cd asha2
find
cd ..
find
cd ~/Documents/
mkdir level1
cd level1/
mkdir level2
cd level2
mkdir level3
cd level3
touch level.txt
cd ~/Documents/
find
find . -maxdepth 1
find . -maxdepth 2
find . -maxdepth 3
find . -maxdepth 4
find .
find . -type f
find . -type d
find . -type d -maxdepth 1
find . -maxdepth 1 -type d
find . -maxdepth 1 -type f
find . -name "5.txt"
find . -name "level3.txt"
find . -name "level4.txt"
find . -name "*.txt"
```

```
find . --maxdepth 3 -name "*.txt"
find . -maxdepth 3 -name "*.txt"
find . -maxdepth 2 -name "*.txt"
find . -maxdepth 2 -name "?.txt"
find . -maxdepth 2 -iname "*.TXT"
find /-type f -size +1000k
find /-type f -size +100k
find / -type f -size +100k
find / -type f -size +1000k
sudo find / -type f -size +1000k
sudo find / -type f -size +1000k |wc -l
sudo find / -type f -size +1000k | wc -l
sudo find / -type f -size +100k | wc -l
find / -type f -size +100k | wc -l
find / -type f -size +100k -size -5M
find / -type f -size -100k -size +5M
find / -type f -size -100k -o -size +5M
find / -type f -size -100k -o -size +5M | wc -l
cd Desktop/
mkdir copy
sudo find / -type  f -size +100k ssize -5M
sudo find / -type  f -size +100k size -5M
sudo find / -type  f -size +100k -size -5M
sudo find / -type  f -size +100k -size -5M |wc -l
sudo find / -type  f -size +100k -size -5M | wc -l
sudo find / -type  f -size +100k -size -5M -exec cp WHT WHERE
sudo find / -type  f -size +100k -size -5M -exec cp {} ~/Desktop/copy
sudo find / -type  f -size +100k -size -5M -exec cp {} ~/Desktop/copy  \;
sudo find / -maxdepth 3 -type  f -size +100k -size -5M -exec cp {}
~/Desktop/copy  \;
cd copy/
ls
cd ..
sudo find / -maxdepth 3 -type  f -size +100k -size -5M -ok cp {}
~/Desktop/copy  \;
touch  haystack/folder{1..500}/files{1..500}.txt
touch haystack/folder{1..500}/files{1..500}.txt
touch haystack/folder${shuf -i 1-500 -n l}/needle.txt
find haystack/ -type f -name "needle.txt"
find haystack/ -type f -name "needle.txt" -exec mv {} ~/Desktop \;


echo "Hello" >file1.txt
echo "there" >file2.txt
```

```
echo "Welcome" >file3.txt
cat file1.txt file2.txt file3.txt
cat file1.txt file2.txt file3.txt > file.txt
cat file.txt
cat file[1-3].txt > file.txt
ls
echo "abc" >>new.txt
echo "def" >>new.txt
cat new.txt
tac new.txt
cat file[1-3].txt | tac
cat file[1-3].txt | tac > reverse.txt
cat file[1-3].txt | rev
cat file[1-3].txt | rev | tac
cat file.txt | head
head file.txt | head -n 2
find | head -n 5
find | head -n 5 | tac
cat /etc/cups/cups-browsed.conf
cat /etc/cups/cups-browsed.conf | wc -l
head -n 20 /etc/cups/cups-browsed.conf | wc -l
head -n 20  /etc/cups/cups-browsed.conf
head -n 20 | cat /etc/cups/cups-browsed.conf
head file.txt | tail -n 2
tail -n 20 cat /etc/cups/cups-browsed.conf | wc -l
tail -n 20 /etc/cups/cups-browsed.conf | wc -l
tail -n 20 /etc/cups/cups-browsed.conf
head -n 1 file.txt | tail -n 1
find  | tail -n 3
find  | tail -n 3 > export.txt
cat export.txt
```

echo "asha" >> file.txt
echo "vihan" >> file.txt
echo "laxmi" >> file.txt

```
sort file.txt > sorted.txt
cat sorted.txt
sort file.txt | tac rev_sorted.txt
sort file.txt | tac > rev_sorted.txt
cat rev_sorted.txt
sort -r file.txt | less (sort the text)
sort -r numbers.txt | less (wrong output )
```

sort -n numbers.txt | less (n- number)
sort -nr numbers.txt | less (nr- number and reverse)
sort number.txt
sort -u number.txt | less (u- unique_
ls -l /etc/
ls -l /etc | head -n 20
ls -l /etc | head -n 20 | sort -k 5n
ls -l /etc | head -n 20 | sort -k 5nr (n number)
ls -l /etc | head -n 20 | sort -k 6hr (h human readable)
ls -l /etc | head -n 20 | sort -k 5hr
ls -lh /etc | head -n 20 | sort -k 5hr
ls -lh /etc | head -n 20 | sort -k 6M (M-month)
ls -lh /etc | head -n 20 | sort -k 6Mr (Mr-Month reverse)
ls -lh /etc | head -n 20 | sort -k 7r
ls -lh /etc | head -n 20 | sort -k 7nr
ls -lh /etc | head -n 20 | sort -k 2n
ls -lh /etc | head -n 20 | sort -k 2nr

echo "hello world" > file.txt
cat file.txt
grep e file.txt (search e)
grep -c e file.txt
wc -l file.txt
grep -i hello file.txt (i case insensitive)
grep -i a file.txt
grep -ic a file.txt
grep -i "hello world" file.txt
grep -iv a file.txt (v search without a)
grep -iv o file.txt
grep -iv h file.txt
grep -cv h file.txt
cat file.txt
grep -i "e" file1.txt file.txt
grep -ci "e" file1.txt file.txt
mkdir file
mv hello.txt hello
mv file.txt file
ls file/ | grep file.txt
ls -F
ls -F /etc | grep -v
ls -F /etc | grep -v / >files.txt
ls -F /etc | grep -v / sort -r > files.txt

ls -F /etc
ls -F /etc | grep magic
ls -F /etc | grep -v magic
ls -F /etc | grep -v magic >files.txt
ls -F /etc | grep -v magic| sort -r >files.txt
ls -F /etc | grep -v/ | sort -r >files.txt
ls -F /etc | grep -v / | sort -r >files.txt
ls -F /etc | grep -v /
man -k print | grep files

Archive and Compressing

ls
ls -lh
tar -cvf archive.tar file1.txt files.txt (c for create)
ls
ls -l | grep .tar
file archive.tar
mv archive.tar new.odt
file new.odt
mv new.odt new.tar
ls
tar -tf new.tar
rm file?.txt
ls
tar -xvf new.tar (x for extract)
ls
gzip new.tar
ls
ls -lh
gunzip new.tar.gz
ls
ls -lh
bzip2 new.tar
ls
ls -lh
bunzip2 new.tar.bz2
ls
zip other.zip file1.txt files.txt
ls
unzip other.zip
rm other.zip new.tar

```
ls
tar -cvf new.tar *.txt
ls
tar -cvzf new.tar.gz *.txt
ls
file new.tar.gz
tar -cvjf new.tar.bz2 *.txt
ls
rm *.txt | tar -xvf new.tar
rm *.txt
ls
tar -xvzf new.tar.gz
tar -xvjf new.tar.bz2
```

Introduction to Editors

Bash Scripting

```
nano our_script.sh
file our_script.sh
nano our_script.sh
which bash
nano our_script.sh

#!/bin/bash

echo "Welcome to bash scripting!!"

mkdir ~/Desktop/files
cd ~/Desktop/files
touch file{1..100}.txt
ls -lh ~/Desktop/files > ~/Desktop/file.log

file our_script.sh
nano our_script.sh
which python3
nano our_script.sh
bash our_script.sh
nano our_script.sh

nano backup.sh
which bash
nano backup.sh
```

```
#!/bin/bash
tar -cvzf backup.tar.gz ~/{Pictures} 2>/dev/null

cd ~
mkdir bin
mv ~/Desktop/backup.sh /bin
mv ~/Desktop/backup.sh ~/bin/
cd ~/bin/
ls
chmod +x backup.sh
nano backup.sh
ls
bash backup.sh
ls
cd ..
nano .bashrc
echo $PATH
backup
nano .bashrc
Add the foolowing line at the end
PATH="$PATH:$HOME/bin"

crontab -e

# 20 11 1 1(JUN) 0(SUN)
  * *  *   *   *      echo "Hello World" >> ~/Desktop/hello.txt

cd Desktop/
ls
cat hello.txt

crontab -e

# m h  dom mon dow   command
# 20 11 1 1(JUN) 0(SUN)
#  * *  *   *   *      echo "Hello World" >> ~/Desktop/hello.txt


#   0,15,30,45 * * * * echo "Hello World" >> ~/Desktop/hello.txt

    */15 * */3 * * echo "Hello World"
    59   23  * JAN,DEC SUN echo "we can"
```

```
cd bin
nano backup.sh

#!/bin/bash

tar -cvzf ~/backup/backup.tar.gz ~/{Desktop,Pictures,Videos} 2>/dev/null

date >> ~/backup/backup.log


ls backup/
backup
bash backup.sh

crontab -e

#    */15 * */3 * * echo "Hello World"
#    59   23  * JAN,DEC SUN echo "we can"

* * * * * bash ~/bin/backup.sh

cat backup.log
uname -o
www.GNU.org
```

Download, install, compile from GNU.org

```
https://ftp.gnu.org/gnu/coreutils/


cd /Documents
cd ~/Documents
ls
file coreutils-9.0.tar.xz
tar -xJf coreutils-9.0.tar.xz
ls
cd coreutils-9.0/
ls
cd src
ls
nano ls.c

add after main() {
```

printf("Hello\n");
ls | less
sudo apt-get install gcc
cd ..
bash configure
ls
sudo apt-get install make
ls
make
sudo make install

reverting back
cd ~/Documents/coreutils-9.0/src
nano ls.c
cd ..
make && sudo make install
www.ubuntu.com
lsb_release -a
uname -m
https://packages.ubuntu.com/focal/
apt-cache search docx
apt-cache search docx | grep text
apt-cache show docx2txt
apt-cache search "web server" | less
apt-cache show apache2
apt-cache search textt
apt-cache show apache2
cd /var/lib/apt/lists
ls
ls | less
ls | less -N
cd ~
apt-cache show gcc
cd /var/lib/apt/lists/
ls | less -N
nano archive.ubuntu.com_ubuntu_dists_focal_main_binary-amd64_Packages

Visual Studio

Open terminal
Install Visual Studio using the command
$sudo snap install --classic code

Refer \url{https://linuxhint.com/install_use_vs_code_ubuntu/} for more details.

Install extensions
1. Python
2. XML
3. Terminal

Python Programming for Robotics

>>python

or

>>python3

```
print("Hello")
print(4)
```

and	del	from	None	True
as	elif	global	nonlocal	try
assert	else	if	not	while
break	except	import	or	with
class	False	in	pass	yield
continue	finally	is	raise	async
def	for	lambda	return	await

+	Addition	1 + 1 = 2
-	Subtraction	2 - 1 = 1
*	Multiplication	2 * 2 = 4
/	Division	5 / 2 = 2
%	Modulus	5 % 2 = 1

=	x = 5	x = 5
+=	x += 3	x = x + 3
-=	x -= 3	x = x – 3
*=	x *= 3	x = x * 3
/=	x /= 3	x = x / 3
%	x %= 3	x = x % 3

Expressions

An expression is a combination of values, variables, and operators. A value all by itself is considered an expression, and so is a variable, so the following are all legal expressions.

Order of operations

When more than one operator appears in an expression, the order of evaluation depends on the rules of precedence. For mathematical operators, Python follows mathematical convention. The acronym PEMDAS is a useful way to remember the rules: Parentheses, Exponentiation, Multiplication and Division.

Modulus operator
The modulus operator works on integers and yields the remainder when the first operand is divided by the second. In Python, the modulus operator is a percent sign (%).

String operations
The + operator works with strings, but it is not addition in the mathematical sense. Instead, it performs concatenation, which means joining the strings by linking them end to end.

Asking the user for input
Sometimes we would like to take the value for a variable from the user via their keyboard. Python provides a built-in function called input that gets input from the keyboard. When this function is called, the program stops and waits for the user to type something. When the user presses Return or Enter, the program resumes and input returns what the user typed as a string.

Comments
For this reason, it is a good idea to add notes to your programs to explain in natural language what the program is doing. These notes are called comments, and in Python they start with the # symbol.

Conditional execution
Boolean expressions
A Boolean expression is an expression that is either true or false. The following examples use the operator ==, which compares two operands and produces True if they are equal and False otherwise:

==	Equal	5 == 5
!=	Not Equal	4 != 5
>>	Greater than	5 >> 4
<	Less than	4 < 5
>=	Greater than or equal to	5 >= 4
<=	Less than or equal to	4 <= 5

if loop

```
i=1
if i==1:
    print('first')
elif 4==4:
    print('second')
elif 3==3:
    print('middle')
else:
    print('last')
```

while loop

```
count = 0
while True:
    print(count)
    count += 1
    if count >= 5:
        break
print("ROS")
```

for loop

```
for x in range(5):
    print(x)
```

```
while (1):
    print('enter a digit')
    num=input()
    var=str(num)
    if (ord(var) in range (48,58)):
        break
print('you entered BCD')
```

```
for x in range(10):
    if x % 2 == 0:
        continue
    print(x)
```

Exception Handling in Python

```
print('num')
num=input()
print('den')
den=input()
try:
    res= int(num)/int(den)
except:
    print("den cannot be 0")
else:
    print(res)
```

Functions

Built-in functions
Python provides a number of important built-in functions that we can use without needing to provide the function definition. The creators of Python wrote a set of functions to solve common problems and included them in Python for us to use.

int
len
max
min
type
float
str

Math functions

```
import math
math.sin()
math.sqrt()
math.log10
```

Random numbers

```
import random
random.random()
```

```
random.randint()


def my_func(num):
    return num*2

seq=[2,3,4,5,6,7]
map(my_func,seq)
a= list(map(my_func,seq))
print(a)


main()

if __name__ == "__main__":
 # execute only if run as a script
        main()
```

Classes

```
class Number:
        def __init__(self, val):
        self.val = val

obj = Number(2)
obj.val
```

Practice the codes from following Libraries:

numpy
matplotlib
math
random

Experiment 2: Introduction ROS2 Programming

Installation:

Step 1:

https://docs.ros.org/en/foxy/Installation/Ubuntu-Install-Debians.html

Step 2:

https://docs.ros.org/en/foxy/Tutorials/Colcon-Tutorial.html

Before creating your first node you need to:

- Create a ROS2 workspace and source it.
- Create a Python package.

ROS organizes the program using packages. A package contains Cpp, Python, setup, compilation, and parameters files. They are:

- package.xml file containing meta-information about the package
- setup.py containing instructions for how to install the package
- setup.cfg is required when a package has executable so that ros2 run can find them
- /<package_name> a directory with the same name as the package, used by ROS2 tools to find the package that contains __init__.py

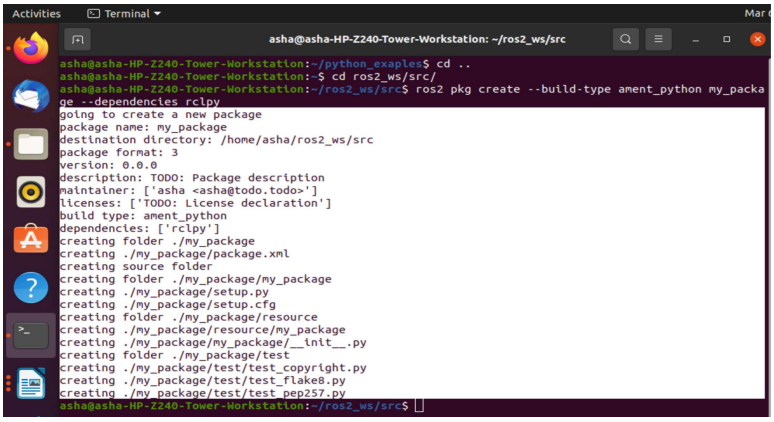
When you want to create packages, you need to work in a particular ROS workspace known as **ROS workspace**. The ROS2 workspace is the directory in your hard disk where your **ROS2. packages reside to be usable by ROS2. Usually, the ROS2 workspace directory is called ros2_ws**

Execute in Terminal #1

```
mkdir -p ~/ros2_ws/src
```

Inside this workspace, there is a directory called **src.** This folder contains all the packages created. Every time you create a package, you have to be in the directory **ros2_ws/src.**

```
cd ~/ros2_ws/src
ros2 pkg create --build-type ament_python my_package --dependencies rclpy
```



ros pkg create <package_name> --build-type ament_python my_package --dependencies <package_dependencies>

The **package_name** is the name of the package you want to create, and **package_dependencies** are the names of other ROS packages that your package depends on.

Execute in Terminal #1

gedit ~/.bashrc

source /opt/ros/foxy/setup.bash
source ~/ros2_ws/install/setup.bash
source /usr/share/colcon_argcomplete/hook/colcon-argcomplete.bash

Execute in Terminal #1

ros2 pkg list
ros2 pkg list | grep my_package

ros2 pkg list: Gives you a list with all packages in your ROS system.

ros2 pkg list | grep my_package: Filters, from all of the packages located in the ROS system, the package is named my_package.

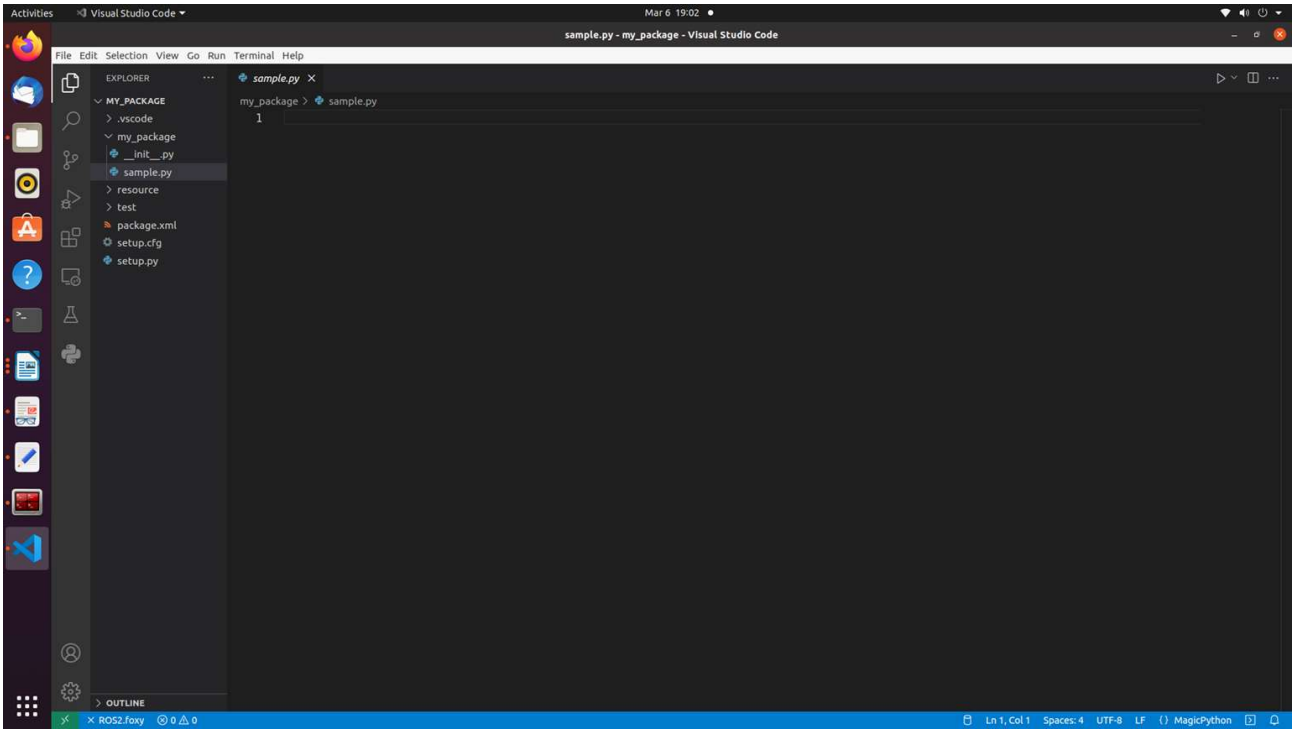
cd ~/ros2_ws
colcon build
colcon build --packages-select <package_name>
colcon build --packages-select my_package

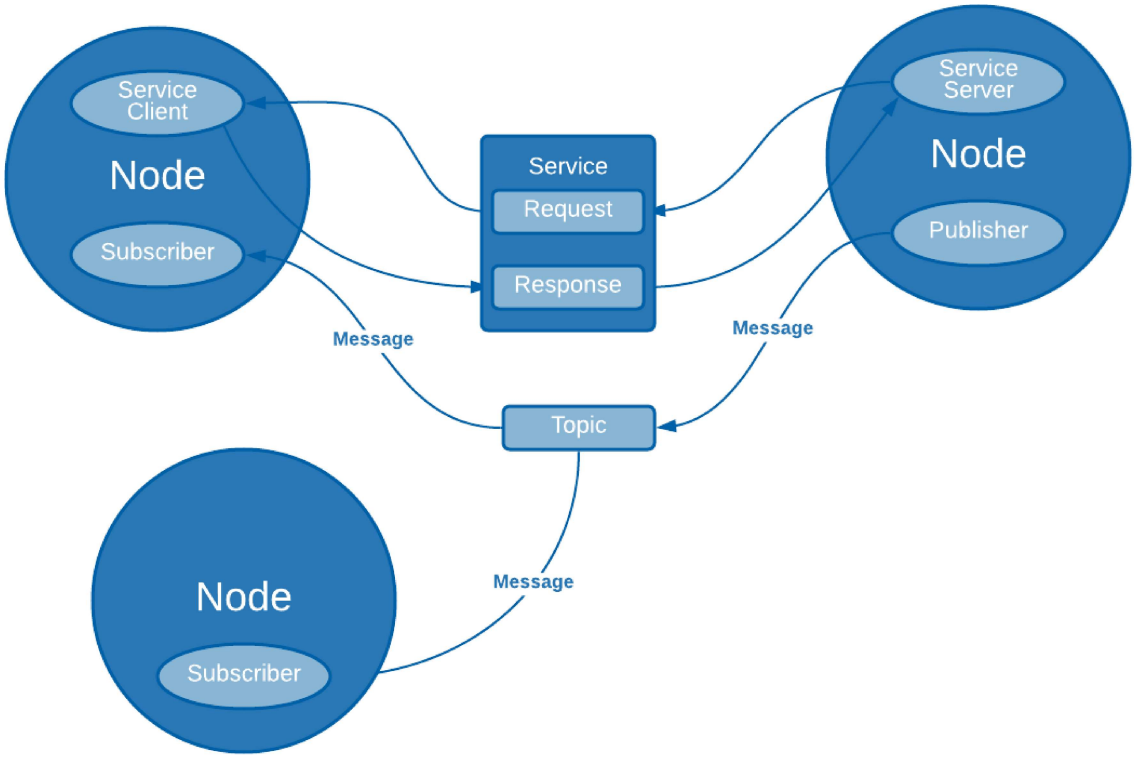
1. Create a Python file that will be executed in the **my_package** (all Python scripts) directory inside **my_package** folder.

Execute in Terminal #1

src/my_package/my_package
touch sample.py
chmod +x sample.py

Right click on the folder my_package and open with Visual Studio Application





Type the following code

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node

class MyNode(Node):  #MIDIFY NAME OF THE CLASS
    def __init__(self):
        # call super() in the constructor in order to initialize the Node object
        # the parameter we pass is the node name
        super().__init__('sample') #MIDIFY NAME OF THE NODE
        # create a timer sending two parameters:
        # - the duration between 2 callbacks (0.2 seeconds)
        # - the timer function (timer_callback)
        self.create_timer(0.2, self.timer_callback)

    def timer_callback(self):
        # print a ROS2 log on the terminal with a great message!
        self.get_logger().info("Congratulation for starting your Robot Operating Syatem
Lab!!")


def main(args=None):
    # initialize the ROS communication
    rclpy.init(args=args)
    # declare the node constructor
    node = MyNode() #MIDIFY NAME OF THE NODE
    # pause the program execution, waits for a request to kill the node (ctrl+c)
    rclpy.spin(node)
    # shutdown the ROS communication
    rclpy.shutdown()


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

Execute in Terminal #2

```
cd ~/ros2_ws/src/my_package
mkdir launch
cd launch
touch my_package_launch_file.launch.py
chmod +x my_package_launch_file.launch.py
```

Type the following in the my_package_launch_file.launch.py

```
from launch import LaunchDescription
from launch_ros.actions import Node
```

```
def generate_launch_description():
    return LaunchDescription([
        Node(
            package='my_package',
            executable='sample',
            output='screen'),
    ])
```

Modify the setup.py file to generate an executable from the Python file you just created.

```
from setuptools import setup
from glob import glob
import os

package_name = 'my_package'

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
        (os.path.join('share', package_name), glob('launch/*')),
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
        'sample = my_package.sample:main'
        ],
    },
)
```

The main objective of this code is to add an entry point to the script you created a few moments ago. To do that, work with a dictionary named entry_points. Inside it, you find an array called console_scripts. Add the node information to generate the executable. The objective of this code is to install the launch files. For example, with the package named "my_package", this will install all the launch files from the launch/folder, into ~/ros2_ws/install/my_python_pkg/share/my_python_pkg/launch/.

```
import os
from glob import glob
```

```
from setuptools import setup
package_name = 'my_package'
setup(

    #code
    ...


    data_files=[
            ('share/ament_index/resource_index/packages',
                ['resource/' + package_name]),
            ('share/' + package_name, ['package.xml']),
            (os.path.join('share', package_name), glob('launch/*.launch.py'))
        ],

    #code

)
```

Compile your package file as was previously explained.

Execute in Terminal #1

```
cd ~/ros2_ws
colcon build
source ~/ros2_ws/install/setup.bash
```

Finally, Now you must execute it. Use the following command that you already know. Execute the roslaunch command in the terminal to launch your program.

Execute in Terminal #1

```
ros2 launch my_package my_package_launch_file.launch.py
```

```
ctrl+C
```

Execute in Terminal #1

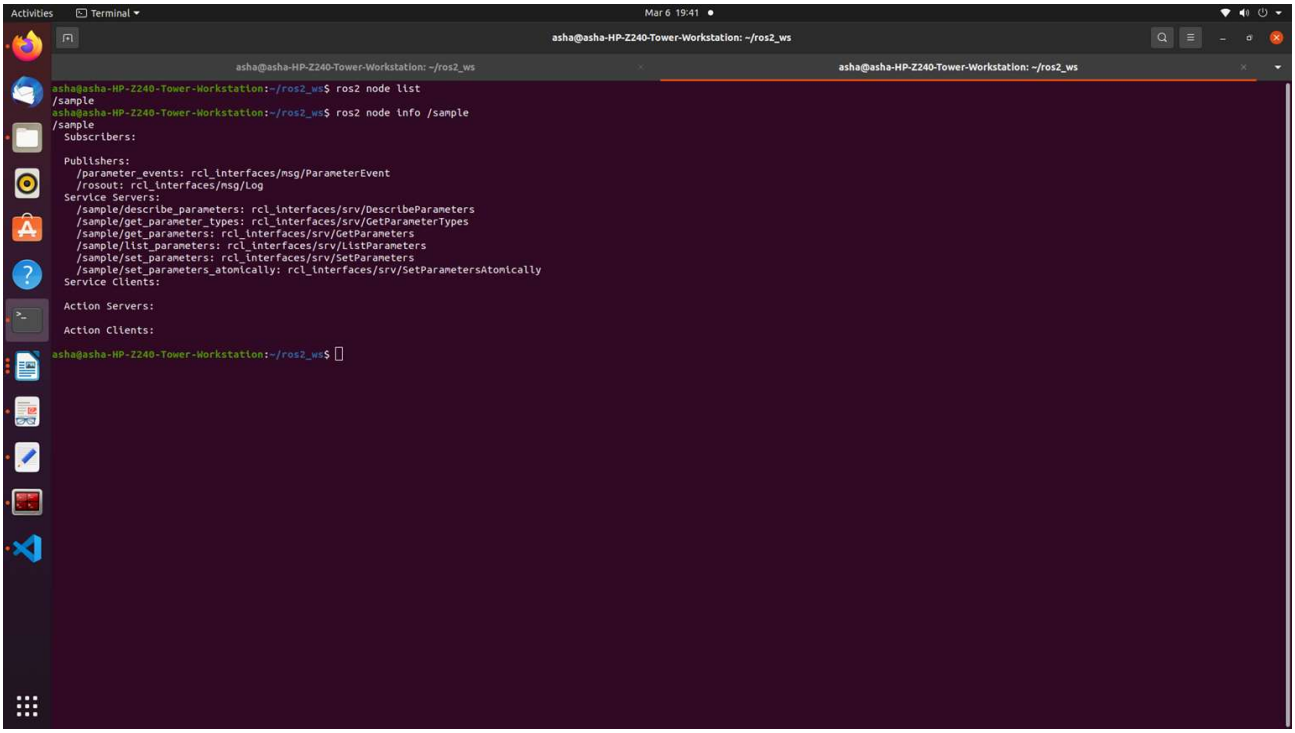
```
ros2 run  my_package sample
```

In main function declare the MyNode class, which you will use to start the node as such. Within this, you have the __init__method and the timer_callback method.
super().__init__('<node_name>')
timer_callback method creates a message with the counter value appended and publishes it to the console with get_logger().info.
self.get_logger().info(""your message to be printed")

Execute in Terminal #2

```
ros2 node list
```

ros2 node info <node_name>
ros2 node info /sample



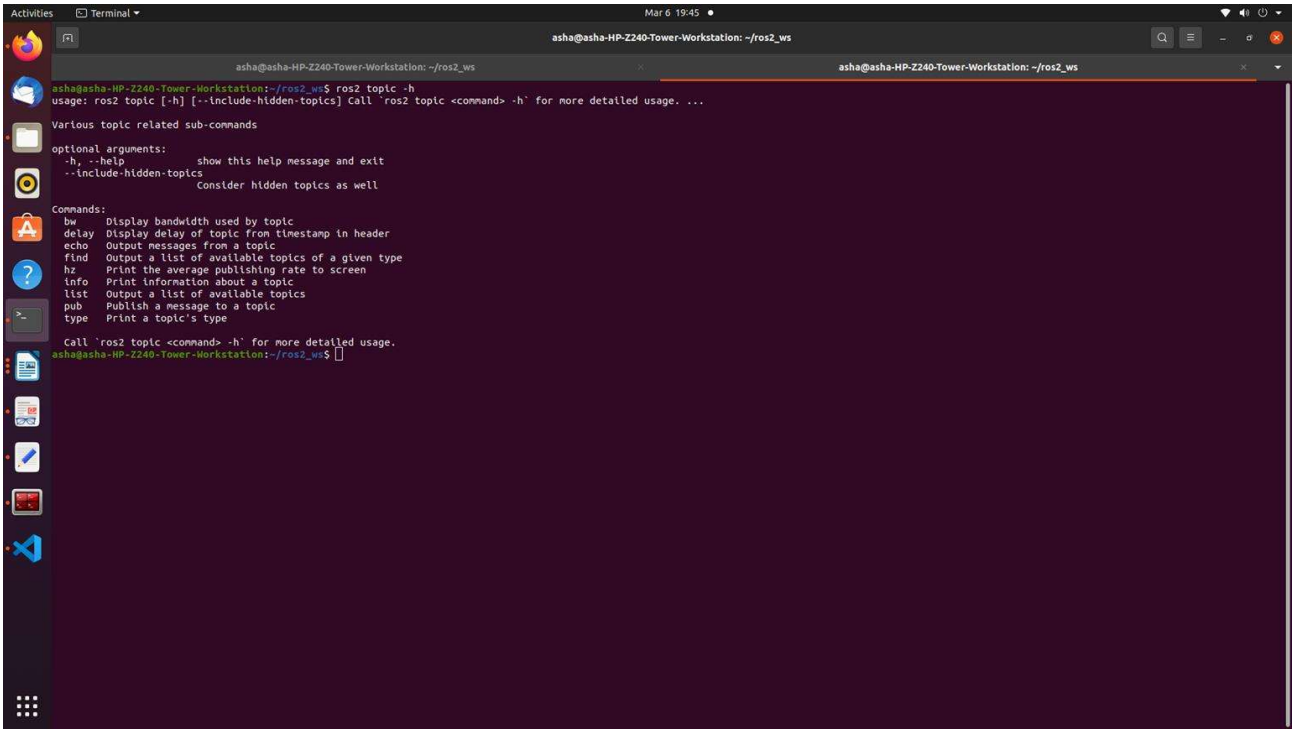
Understanding ROS2 Topics: Publishers & Subscribers

What will you learn about in this unit?

- Topics
- Basic topic commands
- Topic publishers
- Topic subscribers

Execute in Terminal #1

source /opt/ros/foxy/setup.bash
ros2 topic -h



OOP Python Code Template for Nodes

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node


class MyCustomNode(Node): # MODIFY NAME
        def __init__(self):
                super().__init__("node_name") # MODIFY NAME


def main(args=None):
        rclpy.init(args=args)
        node = MyCustomNode() # MODIFY NAME
        rclpy.spin(node)
        rclpy.shutdown()

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

Execute in Terminal #1

```
cd ros2_ws/src/my_package/my_package/
touch robot_publisher.py
chmod +x robot_publisher.py
ros2 interface show example_interfaces/msg/String
```

open the my_package using Visual Studio and edit the file robot_publisher.py

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from example_interfaces.msg import String

class RobotPublisher(Node):

    def __init__(self):
        super().__init__("robot_publisher")
        self.robot_name_="ROBOT"
        self.publisher_ = self.create_publisher(String, "robot_news", 10)
        self.timer_ = self.create_timer(0.5, self.publish_news)
        self.get_logger().info("Node Started")


    def publish_news(self):
        msg = String()
        msg.data = "Hello " + str(self.robot_name_)
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = RobotPublisher()
    rclpy.spin(node)
    rclpy.shutdown()

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

Edit the setup.py

```
from setuptools import setup

package_name = 'my_package '

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
```

```
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
             'sample = my_package.sample:main',
            'robot_publisher = my_package.robot_publisher:main'
        ],
    },
)
```

Execute in Terminal #1

```
colcon build --packages-select my_package –symlink-install
```

Execute in Terminal #2

```
source ~/.bashrc
ros2 run my_package robot_publisher
```

Execute in Terminal #3

```
source ~/.bashrc
ros2 topic echo /robot_news
```

Subscriber node

Execute in Terminal #1

```
cd ros2_ws/src/my_package/my_package /
touch robot_subscriber.py
chmod +x robot_subscriber.py
```

Edit the file robot_subscriber.py using Visual Studio Editor

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from example_interfaces.msg import String

class RobotSubscriber(Node):
    def __init__(self):
        super().__init__("robot_subscriber")
        self.subscriber_ = self.create_subscription(String, "robot_news",
self.callback_robot_news, 10)
        self.get_logger().info("robot_subscriber Node Started")
```

```
    def callback_robot_news(self, msg):
        self.get_logger().info(msg.data)


def main(args=None):
    rclpy.init(args=args)
    node = RobotSubscriber()
    rclpy.spin(node)
    rclpy.shutdown()


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

Edit the setup.py

```
from setuptools import setup
package_name = 'my_package '

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
             'sample = my_package.sample:main',
            "robot_publisher = my_package.robot_publisher:main",
            'robot_subscriber = my_package.robot_subscriber:main'
        ],
    },
)
```

Execute in Terminal #1

```
colcon build --packages-select my_package  --symlink-install
```

Execute in Terminal #2

```
source ~./bashrc
ros2 run my_package robot_publisher
```

Execute in Terminal #3

```
source ~./bashrc
ros2 run my_package robot_subscriber
```

Execute in Terminal #4

```
ros2 node list
ros2 topic list
```

Try: Modify the subscriber code to publish number at 1Hz on the topic /number

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from example_interfaces.msg import String, Int32
global count

class RobotSubscriber(Node):
    def __init__(self):
        super().__init__("robot_subscriber")
        self.count_ = 0
        self.subscriber_ = self.create_subscription(String, "robot_news",
self.callback_robot_news, 10)
        self.publisher_ = self.create_publisher(Int32, "robot_number", 10)
        self.timer_ = self.create_timer(1, self.send_number)
        self.get_logger().info("robot_subscriber and publisher Node Started")

    def callback_robot_news(self, msg):
        self.get_logger().info(msg.data)

    def send_number(self):
        number = Int32()
        number.data = self.count_
        self.count_ +=1
        self.publisher_.publish(number)

def main(args=None):
    rclpy.init(args=args)
    node = RobotSubscriber()
    rclpy.spin(node)
    rclpy.shutdown()


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

Post Lab Exercises - Marks: 4 [CO – 1, LO – 1, 2, 12, PO- 1,2,3, BL – 3,4,5]

Exercise 1: Write a launch file pub_sub.launch.py to run the publisher and subscriber node.
Exercise 2: Create 2 nodes from scratch. First node has 1 publisher, the second has 1 publisher & 1 subscriber.

- The number_publisher node publishes a number on the "/number" topic, with the existing type example_interfaces/msg/Int32.
- The number_counter node subscribes to the "/number" topic. It keeps a counter variable. Every time a new number is received, it's added to the counter. The node also has a publisher on the "/number_count" topic. When the counter is updated, the publisher directly publishes the new value on the topic.

A few hints:

- Check what to put into the example_interfaces/msg/Int32 with the "ros2 interface show" command line tool.
- Use the order as follows: first create the number_publisher node, check that the publisher is working with "ros2 topic". Then create the number_counter, focus on the subscriber. And finally create the last publisher. In the number_counter node, the publisher will publish messages directly from the subscriber callback.

More About Launch File

```
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():
    return LaunchDescription([
        launch_ros.actions.Node(
            package='turtlebot3_teleop',
            executable='teleop_keyboard',
            output='screen'),
    ])
```

```
from launch import LaunchDescription
import launch_ros.actions

def generate_launch_description():
    return LaunchDescription([
        launch_ros.actions.Node(
            package='teleop_twist_keyboard',
            executable='teleop_twist_keyboard',
```

```
        output='screen'),
    ])
```

Within the LaunchDescription object, generate a node where you will provide the following parameters:

1. package='package_name' Name of the package that contains the code of the ROS program to execute
2. executable='cpp_executable_name' Name of the cpp executable file that you want to execute
3. output='type_of_output' Through which channel you will print the output of the program

Create Custom Message

To publish the data that contains multiple data types, one can create a new one.
Create a custom interface in a CMake package and then use it in a Python node.
To create a new message, do the following:

.1 Create a directory in the src folder
.2 Create a directory named **msg** inside your package Inside the directory, create a file named Name_of_message.msg. Modify the CMakeLists.txt file
.3 Modify package.xml file
.4 Compile and source
.5 Use in code

Create an interface to send the Manufacture date of the robot.

Execute in Terminal #1

```
cd ros2_ws/src
ros2 pkg create my_robot_interface
ls
cd my_robot_interface/
rm -rf include/
rm -rf src/
mkdir msg
cd msg
touch ManufactureDate.msg
```

open src with visual studio application:

Enter the following data in ManufactureDate.msg (**It should have the pattern '^[A-Z][A-Za-z0-9]*$')

```
int32 date
string month
int64 year
```

In CmakeLists.txt

Edit two functions inside CMakeLists.txt:

find_package()
This is where all the packages required to COMPILE the messages for the topics, services, and actions go. In package.xml, state them as **build_depend** and **exec_depend**.
find_package(ament_cmake REQUIRED)
find_package(rclcpp REQUIRED)
find_package(std_msgs REQUIRED)
find_package(rosidl_default_generators REQUIRED)

rosidl_generate_interfaces()
This function includes all of the messages for this package (in the msg folder) to be compiled. The function should look similar to the following:
rosidl_generate_interfaces(${PROJECT_NAME}
"msg/ManufactureDate.msg"
)

```
cmake_minimum_required(VERSION 3.5)
project(my_robot_interface)

# Default to C++14
if(NOT CMAKE_CXX_STANDARD)
  set(CMAKE_CXX_STANDARD 14)
endif()

if(CMAKE_COMPILER_IS_GNUCXX OR CMAKE_CXX_COMPILER_ID MATCHES
"Clang")
  add_compile_options(-Wall -Wextra -Wpedantic)
endif()

# find dependencies
find_package(ament_cmake REQUIRED)
find_package(rclcpp REQUIRED)
find_package(std_msgs REQUIRED)
find_package(rosidl_default_generators REQUIRED)

rosidl_generate_interfaces(my_robot_interface
"msg/ManufactureDate.msg"
)


ament_package()
```

Modify package.xml

Add the following lines to the package.xml
<build_depend**>**rosidl_default_generators**</**build_depend**>**
<exec_depend>rosidl_default_runtime</exec_depend>
<member_of_group**>**rosidl_interface_packages**</**member_of_group**>**

```
<?xml version="1.0"?>
<?xml-model href="http://download.ros.org/schema/package_format3.xsd"
schematypens="http://www.w3.org/2001/XMLSchema"?>
<package format="3">
  <name>my_robot_interface</name>
  <version>0.0.0</version>
  <description>TODO: Package description</description>
  <maintainer email="asha@todo.todo">asha</maintainer>
  <license>TODO: License declaration</license>

  <buildtool_depend>ament_cmake</buildtool_depend>

  <depend>rclcpp</depend>
  <depend>std_msgs</depend>
  <build_depend>rosidl_default_generators</build_depend>
  <exec_depend>rosidl_default_runtime</exec_depend>
  <member_of_group>rosidl_interface_packages</member_of_group>

  <test_depend>ament_lint_auto</test_depend>
  <test_depend>ament_lint_common</test_depend>

  <export>
    <build_type>ament_cmake</build_type>
  </export>
</package>
```

Execute in Terminal #1

```
cd ~/ros2_ws
colcon build --packages-select my_robot_interface
cd install/my_robot_interface/lib/python3.8/site-packages/my_robot_interface/msg
```

This executes this bash file that sets, among other things, the newly generated messages created through the colcon build. If you don't do this, it might give you an import error, saying it doesn't find the message generated.

```
source install/setup.bash
ros2 interface show my_robot_interface/msg/ManufactureDate
```

Modify robot_publisher.py to transmit the manufacturing date to the subscriber node

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from my_robot_interface.msg import ManufactureDate

class RobotDatePublisher(Node):

    def __init__(self):
        super().__init__("robot_date_publisher")
        self.robot_name_="ROBOT"
        self.publisher_ = self.create_publisher(ManufactureDate,
"robot_manufacturing_date", 10)
        self.timer_ = self.create_timer(0.5, self.publish_news)
        self.get_logger().info("Node Started")


    def publish_news(self):
        msg = ManufactureDate()
        msg.date = 12
        msg.month = "March"
        msg.year = 2022
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = RobotDatePublisher()
    rclpy.spin(node)
    rclpy.shutdown()

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

Execute in Terminal #1

```
colcon build --packages-select my_package
```

Execute in Terminal #2

```
ros2 run my_package robot_publisher
```

Execute in Terminal #3

```
ros2 run my_package robot_subscriber
```

Edit package.xml

```
 <depend>rclpy</depend>
 <depend>example_interfaces</depend>
 <depend>my_robot_interface</depend>
```

Edit robot_subscriber.py code

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from my_robot_interface.msg import ManufactureDate

class RobotDateSubscriber(Node):
    def __init__(self):
        super().__init__("robot_date_subscriber")
        self.subscriber_ = self.create_subscription(ManufactureDate,
"robot_manufacturing_date", self.callback_robot_news, 10)
        self.get_logger().info("robot_subscriber Node Started")

    def callback_robot_news(self, msg):
        information ="Manufacturing Date of the ROBOT is " + str(msg.date) + " " +
str(msg.month) + " " + str(msg.year)
        self.get_logger().info(information)


def main(args=None):
    rclpy.init(args=args)
    node = RobotDateSubscriber()
    rclpy.spin(node)
    rclpy.shutdown()


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

Experiment 3: TurtleSim Programming, Publisher, Subscriber, Services, Actions

Recap:

Setup for launch files:

- Create a new package
- Create a launch/ folder at the root of the package.
- Configure CMakeLists.txt to install files from this launch/ folder.
- Create any number of files you want inside the launch/ folder, ending with .launch.py.

Run a launch file:

- use “colcon build” to install the file.
- source your environment
- launch file with “ros2 launch <package> <name_of_the_file>

First try to design the application by yourself. Don’t write code! Just take a piece of paper and make the design. What nodes should you create? How do the nodes communicate between each other? Which functionality should you add, and where to put them? Etc.

- Directly start on your own (Use the template to start with)
- Work step by step on each functionality/communication.

Client – Server Nodes

Execute in Terminal #1
ros2 interface show example_interfaces/srv/AddTwoInts

Execute in Terminal #1
```
cd ros2_ws/src/my_package/my_package
touch add_two_ints_server.py
chmod +x add_two_ints_server.py
```

Edit add_two_ints_server.py in visual studio editor

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
```

```
from example_interfaces.srv import AddTwoInts

class AddTwoIntsServerNode(Node):
    def __init__(self):
        super().__init__("add_two_ints_server")
        self.server_ = self.create_service(AddTwoInts, "add_two_ints",
self.callback_add_two_ints)
        self.get_logger().info("Add two ints server has been started")

    def callback_add_two_ints(self, request, response):
        response.sum = request.a + request.b
        self.get_logger().info(str(request.a)+ " + " + str(request.b) + " = " +
str(response.sum))
        return response

def main(args=None):
        rclpy.init(args=args)
        node = AddTwoIntsServerNode()
        rclpy.spin(node)
        rclpy.shutdown()

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

Add executable name in setup.py

```
 entry_points={
        'console_scripts': [
        'sample = my_package.sample:main',
        'robot_publisher = my_package.robot_publisher:main',
        'robot_subscriber = my_package.robot_subscriber:main',
        'add_two_ints_server = my_package.add_two_ints_server:main'
        ],
```

Execute in Terminal #1

```
colcon build –packages-select my_package
```

Execute in Terminal #2

```
ros2 run my_package add_two_ints_server
```

Execute in Terminal #3

```
ros2 service call /add_two_ints example_interfaces/srv/AddTwoInts "{a: 3, b: 4}"
```

Ctrl + C in all terminal windows.

Execute in Terminal #1

```
cd ros2_ws/src/my_package/my_package/
touch add_two_ints_client.py
chmod +x add_two_ints_client.py
```

Edit add_two_ints_client.py using visual studio editor

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from example_interfaces.srv import AddTwoInts
from functools import partial


class AddTwoIntClientNode(Node):
    def __init__(self):
        super().__init__("add_two_ints_client")
        self.call_add_two_int_server(6, 7)

    def call_add_two_int_server(self, a, b):
        client = self.create_client(AddTwoInts, "add_two_ints")
        while not client.wait_for_service(1.0):
            self.get_logger().warn("Waiting for Server Add Two Ints")
        request = AddTwoInts.Request()
        request.a = a
        request.b = b
        future = client.call_async(request)
        future.add_done_callback(
            partial(self.callback_call_two_ints, a=a, b=b))

    def callback_call_two_ints(self, future, a, b):
        try:
            response = future.result()
            self.get_logger().info(str(a) + " + " + str(b) + " = " + str(response.sum))

        except Exception as e:
            self.get_logger().error("Service call failed %r" % (e,))


def main(args=None):
    rclpy.init(args=args)
    node = AddTwoIntClientNode()
    rclpy.spin(node)
    rclpy.shutdown()


if __name__ == "__main__":
```

```
    main()
```

Add executable name in setup.py

```
entry_points={
        'sample = my_package.sample:main',
        'robot_publisher = my_package.robot_publisher:main',
        'robot_subscriber = my_package.robot_subscriber:main',
        'add_two_ints_server = my_package.add_two_ints_server:main',
        'add_two_ints_client = my_package.add_two_ints_client:main'
        ],
```

Execute in Terminal #1

```
colcon build --packages-select my_package –symlink-install
```

Execute in Terminal #2

```
ros2 run my_package add_two_int_server
```

Execute in Terminal #3

```
ros2 run my_package add_two_ints_client
```

Execute in Terminal #4

```
ros2 node list
```

Execute in Terminal #5

```
ros2 service list
ros2 service type /add_two_ints
ros2 interface show example_interfaces/srv/AddTwoInts
ros2 service call /add_two_int example_interfaces/srv/AddTwoInts
ros2 service call /add_two_int example_interfaces/srv/AddTwoInts "{a: 3, b: 4}"
rqt
plugins→services→service caller
service - /add_two_ints
Enter the values under Expression for a and b
Click call
```

Response is viewed in the second window

Exercise 1: Create a service-client operation to reset the counter value in the number_counter nodes.

The node “number_publisher” publishes a number on the /”number” topic.

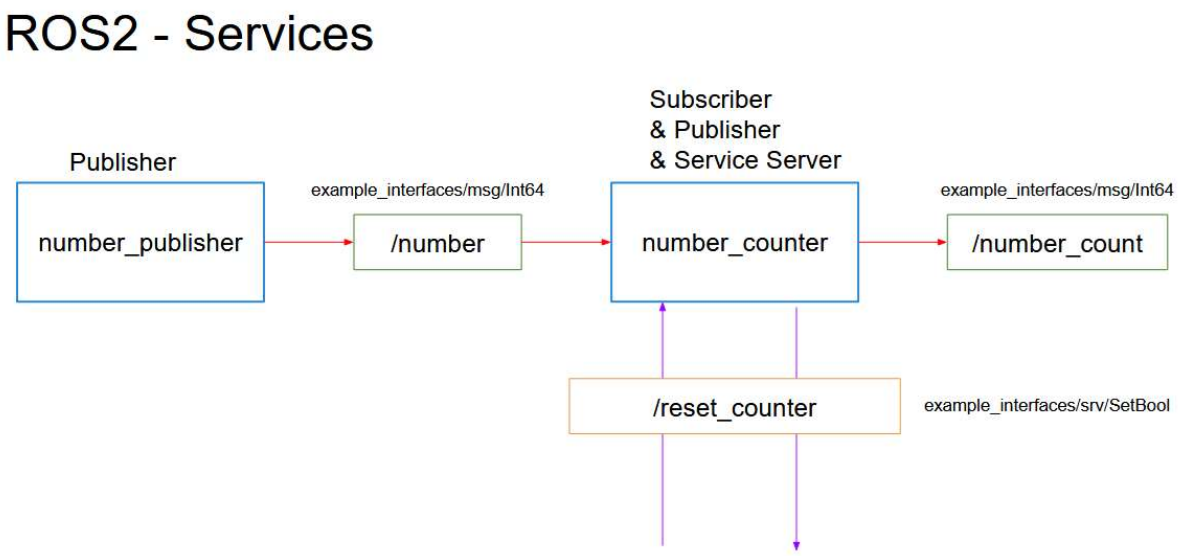
The node “number_counter” gets the number, adds it to a counter, and publishes the counter on the “/number_count” topic.

Add the following ros2 services

Add a functionality to reset the counter to zero:

- Create a service server inside the “number_counter” node.
- Service name: “/reset_counter”
- Service type: example_interfaces/srv/SetBool. Use “ros2 interface show” to discover what’s inside!
- When the server is called, you check the boolean data from the request. If true, you set the counter variable to 0.

We will then call the service directly from the command line. You can also decide - for more practice - to create your own custom node to call this “/reset_counter” service.



Add a functionality to reset the counter to zero:

- Create a service server inside the “number_counter” node.
- Service name: “/reset_counter”
- Service type: example_interfaces/srv/SetBool. Use “ros2 interface show” to discover what’s inside!
- When the server is called, you check the boolean data from the request. If true, you set the counter variable to 0.

We will then call the service directly from the command line. You can also decide - for more practice - to create your own custom node to call this “/reset_counter” service.

```
#!/usr/bin/env python3
```

```
import rclpy
from rclpy.node import Node
from example_interfaces.msg import Int64
from example_interfaces.srv import SetBool

class NumberCounterNode(Node):
    def __init__(self):
        super().__init__("number_counter")
        self.counter_ = 0
        self.number_count_publisher_ = self.create_publisher(Int64, "number_count", 10)
        self.number_subscriber_ = self.create_subscription(Int64, "number",
self.callback_number, 10)
        self.reset_counter_service_ = self.create_service(SetBool, "reset_counter",
self.callback_reset_counter)
        self.get_logger().info("Node started")


    def callback_number(self, msg):
        self.counter_ += msg.data
        new_msg = Int64()
        new_msg.data = self.counter_
        self.number_count_publisher_.publish(new_msg)
        self.get_logger().info(str(self.counter_))

    def callback_reset_counter(self, request, response):
        if request.data:
            self.counter_ = 0
            response.success = True
            response.message = "Counter is reset"
        else:
            response.success = False
            response.message = "Counter is not reset"
        return response


def main(args=None):
        rclpy.init(args=args)
        node = NumberCounterNode()
        rclpy.spin(node)
        rclpy.shutdown()

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

Execute in Terminal #1

```
ros2 interface show example_interfaces/srv/SetBool
```

Execute in Terminal #1

```
cd ros2_ws/
colcon build --packages-select my_package
```

Execute in Terminal #1

```
ros2 run my_package number_publisher
```

Execute in Terminal #2

```
ros2 run my_package number_counter
```

Execute in Terminal #3

```
ros2 topic list
ros2 topic echo /number_count
```

Execute in Terminal #4

```
ros2 service call /reset_counter example_interfaces/srv/SetBool "{data: False}"
ros2 service call /reset_counter example_interfaces/srv/SetBool "{data: True}"
```

Custom Services

```
cd ros2_ws/src/my_robot_interface
mkdir srv
cd srv
touch SetDate.srv
```

SetDate.srv

```
string robot_name
int64 date
---
bool success
```

Change CmakeLists.txt as

```
rosidl_generate_interfaces(my_robot_interface
"msg/ManufactureDate.msg"
"srv/SetDate.srv"
)
```

```
colcon build –packages-select my_robot_interface
```

Change robot_publisher.py code as

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from my_robot_interface.msg import ManufactureDate
from my_robot_interface.srv import SetDate

class RobotDatePublisher(Node):

    def __init__(self):
        super().__init__("robot_date_publisher")
```

```
        self.robot_name_="ROBOT"
        self.publisher_ = self.create_publisher(ManufactureDate,
"robot_manufacturing_date", 10)
        self.timer_ = self.create_timer(0.5, self.publish_news)
        self.set_date_ = self.create_service(SetDate, "set_date", self.callback_set_date)
        self.get_logger().info("Node Started")

    def callback_set_date(self, request, response):
        name = request.robot_name
        date = request.date

        if (name =="ROBOT") and (date==12):
            response.success = True
        else:
            response.success = False
        return response

    def publish_news(self):
        msg = ManufactureDate()
        msg.date = 12
        msg.month = "March"
        msg.year = 2022
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = RobotDatePublisher()
    rclpy.spin(node)
    rclpy.shutdown()

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

Execute in Terminal #1

colcon build –packages-select my_package

Execute in Terminal #1

ros2 run my_package robot_publisher

Execute in Terminal #2

ros2 service list

ros2 service call /set_date my_robot_interface/srv/SetDate "{name: "ROBOT", date: 12}"

change robot_subscriber.py code as

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from example_interfaces.msg import String, Int32
```

```
from my_robot_interface.msg import ManufactureDate
from my_robot_interface.srv import SetDate
from functools import partial

class RobotDateSubscriber(Node):
    def __init__(self):
        super().__init__("robot_date_subscriber")
        self.subscriber_ = self.create_subscription(ManufactureDate,
"robot_manufacturing_date", self.callback_robot_news, 10)
        self.get_logger().info("robot_subscriber Node Started")

    def callback_robot_news(self, msg):
        information ="Manufacturing Date of the ROBOT is " + str(msg.date) + " " +
str(msg.month) + " " + str(msg.year)
        self.get_logger().info(information)
        self.check_date_server("ROBOT", 12)

    def check_date_server(self, robot_name, date):
        client = self.create_client(SetDate, "set_date")
        while not client.wait_for_service(1.0):
            self.get_logger().warn("Waiting for Server")
        request = SetDate.Request()
        request.robot_name = robot_name
        request.date = date
        future = client.call_async(request)
        future.add_done_callback(partial(self.callback_date_response,
robot_name=robot_name, date=date))

    def callback_date_response(self, future, robot_name, date):
        try:
            response = future.result()
            self.get_logger().info(str(response.success))
        except Exception as e:
            self.get_logger().error("Service call failed %r" % (e,))

def main(args=None):
    rclpy.init(args=args)
    node = RobotDateSubscriber()
    rclpy.spin(node)
    rclpy.shutdown()


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

Execute in Terminal #1

```
ros2 run colcon build --packages-select my_package
```

Execute in Terminal #2

```
ros2 run my_package robot_publisher
```

Execute in Terminal #3

ros2 run my_package robot_subscriber

TurtleSim Programming

Execute in Terminal #1

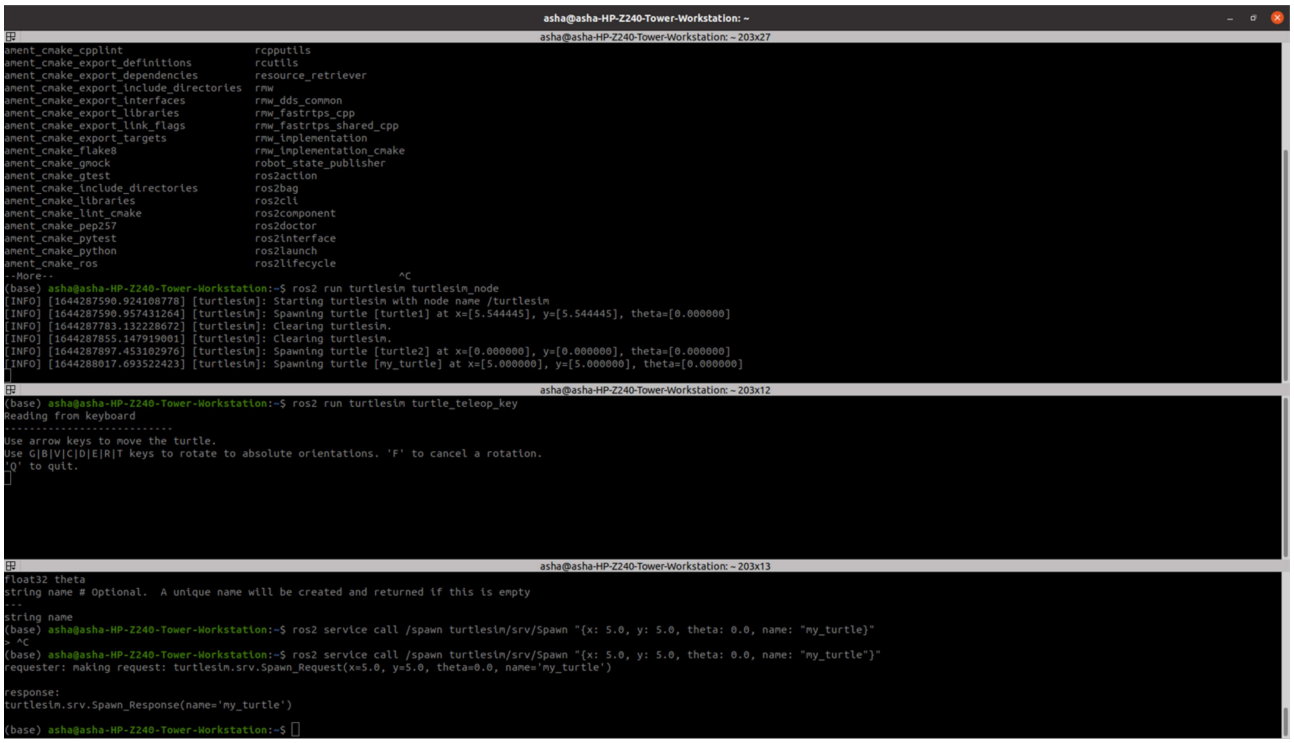
ros2 run turtlesim turtlesim_node

Execute in Terminal #2

ros2 run turtlesim turtle_teleop_key

Execute in Terminal #3

ros2 service list
ros2 service type /clear
ros2 interface show std_srvs/srv/Empty
ros2 service call /clear std_srvs/srv/Empty
ros2 service type /spawn
ros2 interface show turtlesim/srv/Spawn
ros2 service call /spawn turtlesim/srv/Spawn
ros2 service call /spawn turtlesim/srv/Spawn "{x: 5.0, y: 5.0, theta: 0.0, name: "my_turtle"}"



ROS2 interfaces:

https://github.com/ros2/example_interfaces
https://github.com/ros2/common_interfaces

You will use 3 nodes:

- The turtlesim_node from the turtlesim package

- A custom node to control the turtle (named “turtle1”) which is already existing in the turtlesim_node. This node can be called turtle_controller.
- A custom node to spawn turtles on the window. This node can be called turtle_spawner.

Execute in Terminal #1

```
cd ~/ros2_ws/src/my_package/my_package
```

Execute in Terminal #2

```
touch turtle_controller.py
chmod + turtle_controller.py
```

Open src with Visual Studio Application

Enter the code in turtle_controller.py

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from turtlesim.msg import Pose
from geometry_msgs.msg import Twist
import math


class TurtleControllerNode(Node):
    def __init__(self):
        super().__init__("turtle_controller")
        self.target_x = 8.0
        self.target_y = 4.0
        self.pose_ = None
        self.cmd_vel_publisher_ = self.create_publisher(Twist, "turtle1/cmd_vel", 10)
        self.pose_subscriber_ = self.create_subscription(Pose, "turtle1/pose",
self.callback_turtle_pose, 10)
        self.control_loop_timer_ = self.create_timer(0.01, self.control_loop)

    def callback_turtle_pose(self,msg):
        self.pose_ = msg


    def control_loop(self):
        if self.pose_ == None:
            return
        dist_x = self.target_x - self.pose_.x
```

```
        dist_y = self.target_y - self.pose_.y
        distance = math.sqrt(dist_x * dist_x + dist_y * dist_y)
        msg = Twist()
        if distance > 0.5:
            msg.linear.x = distance
            goal_theta = math.atan2(dist_y, dist_x)
            diff = goal_theta - self.pose_.theta

            if diff > math.pi:
                diff -= 2*math.pi
            elif diff < -math.pi:
                diff += 2*math.pi

            msg.angular.z = diff
        else:
            msg.linear.x = 0.0
            msg.angular.z = 0.0

        self.cmd_vel_publisher_.publish(msg)


def main(args=None):
    rclpy.init(args=args)
    node = TurtleControllerNode()
    rclpy.spin(node)
    rclpy.shutdown()


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

Modify entry_points setup.py as

```
entry_points={
        'console_scripts': [
        'sample = my_package.sample:main',
        'robot_publisher = my_package.robot_publisher:main',
        'robot_subscriber = my_package.robot_subscriber:main',
        'turtlesim_controller = my_package.turtle_controller:main'
        ],
    },
```

)

Modify he package.xml as

```
<depend>rclpy</depend>
<depend>example_interfaces</depend>
<depend>my_robot_interface</depend>
<depend>turtlesim</depend>
```

Execute in Terminal #1

```
ros2 run turtlesim turtlesim_node
```

Execute in Terminal #2

```
colcon build --packages-select my_package --symlink-install
```

Execute in Terminal #3

```
ros2 run my_package turtlesim_controller
```

Execute in Terminal #4

```
ros2 service list
ros2 service type /spawn
ros2 interface show turtlesim/srv/Spawn
```

Execute in Terminal #1

```
cd ros2_ws/my_robot_interface/srv
touch  MoveLocation.srv
```

Edit MoveLocation.srv

```
float32 loc_x
float32 loc_y
---
float32 distance
```

Change CmakeLists.txt as

```
rosidl_generate_interfaces(my_robot_interface
"msg/ManufactureDate.msg"
"srv/SetDate.srv"
"srv/MoveLocation.srv"
)
```

Execute in Terminal #1

```
cd ~/ros2_ws
colcon build –packages-select my_robot_interface
```

Send the service request to find the distance between current location and new location.

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from turtlesim.msg import Pose
from geometry_msgs.msg import Twist
from my_robot_interface.srv import MoveLocation
import math


class TurtleControllerNode(Node):
    def __init__(self):
        super().__init__("turtle_controller")
        self.target_x = 9.0
        self.target_y = 9.0
        self.pose_ = None
        self.cmd_vel_publisher_ = self.create_publisher(Twist, "turtle1/cmd_vel", 10)
        self.pose_subscriber_ = self.create_subscription(Pose, "turtle1/pose",
self.callback_turtle_pose, 10)
        self.control_loop_timer_ = self.create_timer(0.01, self.control_loop)
        self.servce_ = self.create_service(MoveLocation, "move_location",
self.callback_get_distance)
    def callback_turtle_pose(self,msg):
        self.pose_ = msg



    def control_loop(self):
        if self.pose_ == None:
            return
        dist_x = self.target_x - self.pose_.x
        dist_y = self.target_y - self.pose_.y
        distance = math.sqrt(dist_x * dist_x + dist_y * dist_y)
        msg = Twist()
        if distance > 0.5:
            msg.linear.x = distance
            goal_theta = math.atan2(dist_y, dist_x)
            diff = goal_theta - self.pose_.theta

            if diff > math.pi:
                diff -= 2*math.pi
            elif diff < -math.pi:
                diff += 2*math.pi

            msg.angular.z = diff
        else:
            msg.linear.x = 0.0
```

```
            msg.angular.z = 0.0

        self.cmd_vel_publisher_.publish(msg)

    def callback_get_distance(self, request, response):
        x = request.loc_x - self.pose_.x
        y = request.loc_y - self.pose_.y

        response.distance = math.sqrt(x * x + y * y)
        return response


def main(args=None):
    rclpy.init(args=args)
    node = TurtleControllerNode()
    rclpy.spin(node)
    rclpy.shutdown()


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

Execute in Terminal #1

```
colcon build –packages-select my_package
```

Execute in Terminal #2

```
ros2 run turtlesim turtlesim_node
```

Execute in Terminal #3

```
ros2 run my_package turtlesim_controller
```

Execute in Terminal #1

```
ros2 service call /move_location my_robot_interface/srv/MoveLocation "{loc_x: 5.0, loc_y: 5.0}"
```

Exercise2: Create two new files named movement_server.py and movement_client.py.

1. Create a directory named **srv** inside my_robot_interface package
2. Inside this directory, create a file named **MyCustomServiceMessage**.srv

```
string move  # Signal to define movement
             # "Turn right" to make the robot turn in right direction.
             # "Turn left" to make the robot turn in left direction.
             # "Stop" to make the robot stop the movement.
---
bool success
```

3. Modify CMakeLists.txt file
4. Modify package.xml file
5. Compile and source

6 Use in code

```
ros2 interface show my_robot_interface/srv/MyCustomServiceMessage
```

Action Server – Action Client Nodes

Execute in Terminal #1

```
cd ~/ros2_ws/src/my_robot_interface
mkdir action
touch Navigate2D.action

#Goal
int32 secs
---
#Result
string status
---
#Feedback
string feedback
```

package.xml

```
  <depend>rclcpp</depend>
  <depend>std_msgs</depend>
  <depend>action_msgs</depend>
```

CMakeLists.txt

```
rosidl_generate_interfaces(my_robot_interface
"msg/ManufactureDate.msg"
"srv/SetDate.srv"
"srv/MoveLocation.srv"
"action/Navigate2D.action"
)
```

Execute in Terminal #1

```
colcon build –packages-select my_robot_interface
```

Execute in Terminal #1

```
cd ~/ros2_ws/src/my_package/my_package
touch  action_client.py
chmod +x  action_client.py

import rclpy
from rclpy.action import ActionClient
from rclpy.node import Node
from rclpy.executors import MultiThreadedExecutor
from my_robot_interface.action import Navigate2D
```

```
class MyActionClient(Node):
    def __init__(self):
        super().__init__('action_client')
        self._action_client = ActionClient(self, Navigate2D, "navigate")

    def send_goal(self, secs):
        goal_msg = Navigate2D.Goal()
        goal_msg.secs = secs
        self._action_client.wait_for_server()
        self._send_goal_future = self._action_client.send_goal_async(goal_msg,
self.feedback_callback)
        self._send_goal_future.add_done_callback(self.goal_response_callback)

    def goal_response_callback(self, future):
        goal_handle = future.result()
        if not goal_handle.accepted:
            self.get_logger().info('Goal rejected')
            return
        self.get_logger().info('Goal accepted')
        self._get_result_future = goal_handle.get_result_async()
        self._get_result_future.add_done_callback(self.get_result_callback)

    def get_result_callback(self, future):
        result = future.result().result
        self.get_logger().info('Result: {0}'.format(result.status))
        rclpy.shutdown()

    def feedback_callback(self, feedback_msg):
        feedback = feedback_msg.feedback
        self.get_logger().info('Received feedback: {0}'.format(feedback.feedback))

def main(args=None):
    rclpy.init(args=args)
    action_client = MyActionClient()
    future = action_client.send_goal(5)
    executor = MultiThreadedExecutor()
    rclpy.spin(action_client, executor=executor)

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

Execute in Terminal #1

```
cd ~/ros2_ws/src/my_package/my_package
touch  action_server.py
chmod +x  action_server.py
```

Edit the file action_server.py

```
#!/usr/bin/env python3
```

```
import rclpy
from rclpy.node import Node
from turtlesim.msg import Pose
from geometry_msgs.msg import Twist
from rclpy.action import ActionServer
import time
from my_robot_interface.action import Navigate2D


class NavigateAction(Node):
    def __init__(self):
        super().__init__("action_server")
        self.action_server_ = ActionServer(
            self, Navigate2D, "navigate", self.navigate_callback)
        self.cmd = Twist()
        self.publisher_ = self.create_publisher(Twist, "turtle1/cmd_vel", 10)

    def navigate_callback(self, goal_handle):
        self.get_logger().info('Executing goal...')
        feedback_msg = Navigate2D.Feedback()
        feedback_msg.feedback = "Moving to the left ..."
        for i in range(1, goal_handle.request.secs):
            self.get_logger().info(feedback_msg.feedback)
            goal_handle.publish_feedback(feedback_msg)
            self.cmd.linear.x = 0.3
            self.cmd.angular.z = 0.3
            self.publisher_.publish(self.cmd)
            time.sleep(1)
        goal_handle.succeed()
        self.cmd.linear.x = 0.0
        self.cmd.angular.z = 0.0
        self.publisher_.publish(self.cmd)
        feedback_msg.feedback = "Finished action server. Robot moved during 5 seconds"
        result = Navigate2D.Result()
        result.status = feedback_msg.feedback
        return result


def main(args=None):
    rclpy.init(args=args)
    node = NavigateAction()
    rclpy.spin(node)
    rclpy.shutdown()


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

Edit CmakeLists.txt

```
  entry_points={
```

```
'console_scripts': [
'sample = my_package.sample:main',
'robot_publisher = my_package.robot_publisher:main',
'robot_subscriber = my_package.robot_subscriber:main',
'add_two_int_server = my_package.add_two_int_server:main',
'add_two_ints_client = my_package.add_two_ints_client:main',
'turtlesim_controller = my_package.turtle_controller:main',
'action_client = my_package.action_client:main',
'action_server = my_package.action_server:main'
],
```

Execute in Terminal #1

```
ros2 run turtlesim turtlesim_node
```

Execute in Terminal #2

```
ros2 run my_package action_client
```

Execute in Terminal #3

```
ros2 run my_package action_server
```

Introduction to URDF: Mobile Robot Design and Control

Install the necessary packages required
Execute in Terminal #1

```
sudo apt-get install ros-foxy-teleop-twist-keyboard
sudo apt-get install ros-foxy-joint-state-publisher*

sudo apt install gazebo11 libgazebo11-dev
sudo apt install ros-foxy-gazebo-ros-pkgs
sudo apt install ros-foxy-robot-state-publisher*
```

Execute in Terminal #1

```
cd ros2_ws/src
ros2 pkg create lab4 --build-type ament_python --dependencies rclpy
cd src/lab4/
mkdir urdf
mkdir launch
cd urdf
touch three_wheeled_robot.urdf
```

```
<?xml version="1.0" ?>

<robot name = "three_wheeled_robot">

    <link name="base">
        <visual>
        <geometry>
            <box size="0.75 0.4 0.1"/>
        </geometry>
        <material name="gray">
            <color rgba=".2 .2 .2 1" />
        </material>
        </visual>

        <inertial>
            <mass value="1" />
            <inertia ixx="0.01" ixy="0.0" ixz="0" iyy="0.01" iyz="0" izz="0.01" />
        </inertial>

        <collision>
        <geometry>
            <box size="0.75 0.4 0.1"/>
        </geometry>
        </collision>

    </link>

    <link name="wheel_right_link">
        <inertial>
                <mass value="2" />
                <inertia ixx="0.01" ixy="0.0" ixz="0"
                iyy="0.01" iyz="0" izz="0.01" />
        </inertial>

        <visual>
            <geometry>
              <cylinder radius="0.15" length="0.1"/>
            </geometry>
            <material name="white">
            <color rgba="1 1 1 1"/>
            </material>
        </visual>

        <collision>
            <geometry>
              <cylinder radius="0.15" length="0.1"/>
            </geometry>
          <contact_coefficients mu="1" kp="1e+13" kd="1.0"/>
        </collision>
    </link>
```

```
<joint name="wheel_right_joint" type="continuous">
    <origin xyz="0.2 0.25 0.0" rpy="1.57 0.0 0.0"/>
    <parent link="base"/>
    <child link="wheel_right_link"/>
    <axis xyz="0.0 0.0 1.0"/>
</joint>



<link name="wheel_left_link">
    <inertial>
        <mass value="2" />
        <inertia ixx="0.01" ixy="0.0" ixz="0"
            iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
          <cylinder radius="0.15" length="0.1"/>
      </geometry>
      <material name="white">
        <color rgba="1 1 1 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
          <cylinder radius="0.15" length="0.1"/>
      </geometry>
      <contact_coefficients mu="1" kp="1e+13" kd="1.0"/>
    </collision>
</link>

<joint name="wheel_left_joint" type="continuous">
    <origin xyz="0.2 -0.25 0.0" rpy="1.57 0.0 0.0"/>
    <parent link="base"/>
    <child link="wheel_left_link"/>
    <axis xyz="0.0 0.0 1.0"/>
</joint>



<link name="caster">
    <inertial>
            <mass value="1" />
            <inertia ixx="0.01" ixy="0.0" ixz="0"
            iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
```

```
      <sphere radius=".08" />
    </geometry>
    <material name="white" />
  </visual>

  <collision>
    <origin/>
    <geometry>
      <sphere radius=".08" />
    </geometry>
  </collision>
</link>

<joint name="caster_joint" type="continuous">
  <origin xyz="-0.3 0.0 -0.07" rpy="0.0 0.0 0.0"/>
  <axis xyz="0 0 1" />
  <parent link="base"/>
  <child link="caster"/>
</joint>

<link name="camera">
  <inertial>
        <mass value="0.1" />
        <inertia ixx="0.01" ixy="0.0" ixz="0"
        iyy="0.01" iyz="0" izz="0.01" />
  </inertial>

  <visual>
    <geometry>
      <box size="0.1 0.1 0.05"/>
    </geometry>
    <material name="white">
      <color rgba="1 1 1 1"/>
    </material>
  </visual>

  <collision>
    <geometry>
       <box size="0.1 0.1 0.05"/>
    </geometry>
  </collision>
</link>

<joint name="camera_joint" type="fixed">
  <origin xyz="-0.35 0 0.01" rpy="0 0.0 3.14"/>
  <parent link="base"/>
  <child link="camera"/>
  <axis xyz="0.0 0.0 1.0"/>
</joint>

<link name="lidar">
```

```
    <inertial>
            <mass value="0.5" />
            <inertia ixx="0.01" ixy="0.0" ixz="0"
            iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
        <cylinder radius="0.1" length="0.05"/>
      </geometry>
      <material name="white">
        <color rgba="1 1 1 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
          <box size="0.1 0.1 0.1"/>
      </geometry>
    </collision>
</link>

<joint name="lidar_joint" type="fixed">
    <origin xyz="-0.285 0 0.075" rpy="0 0.0 1.57"/>
    <parent link="base"/>
    <child link="lidar"/>
    <axis xyz="0.0 0.0 1.0"/>

</joint>

<!--http://wiki.ros.org/simulator_gazebo/Tutorials/ListOfMaterials-->
<gazebo reference="base">
    <material>Gazebo/WhiteGlow</material>
</gazebo>
<gazebo reference="wheel_left_link">
    <material>Gazebo/SkyBlue</material>
</gazebo>
<gazebo reference="wheel_right_link">
    <material>Gazebo/SkyBlue </material>
</gazebo>
<gazebo reference="caster">
    <material>Gazebo/Grey</material>
</gazebo>
<gazebo reference="lidar">
    <material>Gazebo/Blue</material>
</gazebo>
<gazebo reference="camera">
    <material>Gazebo/Red</material>
</gazebo>
```

```
<!-- differential robot-->
<gazebo>
   <plugin filename="libgazebo_ros_diff_drive.so" name="gazebo_base_controller">
     <odometry_frame>odom</odometry_frame>
     <commandTopic>cmd_vel</commandTopic>
     <publish_odom>true</publish_odom>
     <publish_odom_tf>true</publish_odom_tf>
     <update_rate>15.0</update_rate>

     <left_joint>wheel_left_joint</left_joint>
     <right_joint>wheel_right_joint</right_joint>

     <wheel_separation>0.5</wheel_separation>
     <wheel_diameter>0.3</wheel_diameter>
     <max_wheel_acceleration>0.7</max_wheel_acceleration>
     <max_wheel_torque>8</max_wheel_torque>
     <robotBaseFrame>base</robotBaseFrame>
   </plugin>
</gazebo>

<!-- camera plugin-->
<gazebo reference="camera">
  <sensor type="camera" name="camera1">
    <visualize>true</visualize>
    <update_rate>30.0</update_rate>
    <camera name="head">
      <horizontal_fov>1.3962634</horizontal_fov>
      <image>
        <width>800</width>
        <height>800</height>
        <format>R8G8B8</format>
      </image>
      <clip>
        <near>0.02</near>
        <far>300</far>
      </clip>
    </camera>
    <plugin name="camera_controller" filename="libgazebo_ros_camera.so">
      <alwaysOn>true</alwaysOn>
      <updateRate>60.0</updateRate>
      <cameraName>/camera1</cameraName>
      <imageTopicName>image_raw</imageTopicName>
      <cameraInfoTopicName>info_camera</cameraInfoTopicName>
      <frameName>camera</frameName>
      <hackBaseline>0.07</hackBaseline>
    </plugin>
  </sensor>
</gazebo>

<!--lidar plugin-->
```

```
    <gazebo reference="lidar">
      <sensor name="lidar" type="ray">
       <visualize>true</visualize>
        <update_rate>12.0</update_rate>
        <plugin filename="libgazebo_ros_ray_sensor.so" name="gazebo_lidar">
        <output_type>sensor_msgs/LaserScan</output_type>
        <frame_name>lidar</frame_name>
        </plugin>
        <ray>
          <scan>
            <horizontal>
              <samples>360</samples>
              <resolution>1</resolution>
              <min_angle>0.00</min_angle>
              <max_angle>3.14</max_angle>
            </horizontal>
          </scan>
          <range>
            <min>0.120</min>
            <max>3.5</max>
            <resolution>0.015</resolution>
          </range>
        </ray>
      </sensor>
    </gazebo>

</robot>
```

```
cd ..
cd launch
touch gazebo.launch.py
```

```
from launch import LaunchDescription
from launch_ros.actions import Node
from launch.actions import  ExecuteProcess
def generate_launch_description():
    urdf = '/home/asha/ros2_ws/src/lab4/urdf/three_wheeled_robot.urdf'
    return LaunchDescription([

        Node(
            package='robot_state_publisher',
            executable='robot_state_publisher',
            name='robot_state_publisher',
            output='screen',
            arguments=[urdf]),
        Node(
            package='joint_state_publisher',
            executable='joint_state_publisher',
            name='joint_state_publisher',
            arguments=[urdf]),
#  Gazebo related stuff required to launch the robot in simulation
```

```
        ExecuteProcess(
            cmd=['gazebo', '--verbose', '-s', 'libgazebo_ros_factory.so'],
            output='screen'),
        Node(
            package='gazebo_ros',
            executable='spawn_entity.py',
            name='urdf_spawner',
            output='screen',
            arguments=["-topic", "/robot_description", "-entity", "lab4 "])
    ])
```

touch rviz.launch.py

```
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():
    urdf = '/home/asha/ros2_ws/src/lab4/urdf/three_wheeled_robot.urdf'
    # rviz_config_file=os.path.join(package_dir,'config.rviz')

    return LaunchDescription([
        Node(
            package='robot_state_publisher',
            executable='robot_state_publisher',
            name='robot_state_publisher',
            output='screen',
            arguments=[urdf]),
        Node(
            package='joint_state_publisher_gui',
            executable='joint_state_publisher_gui',
            name='joint_state_publisher_gui',
            arguments=[urdf]),

        Node(
        package='rviz2',
        executable='rviz2',
        name='rviz2',
        # arguments=['-d',rviz_config_file],
        output='screen'),


    ])
```

Edit the setup.py file as

```
from setuptools import setup
import os
from glob import glob
package_name = 'lab4 '
```

```
setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
          (os.path.join('share', package_name), glob('urdf/*')),
          (os.path.join('share', package_name), glob('launch/*'))
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
        ],
    },
)
```

Execute in Terminal #1

```
colcon build --packages-select lab4
ros2 launch lab4 rviz.launch.py
```

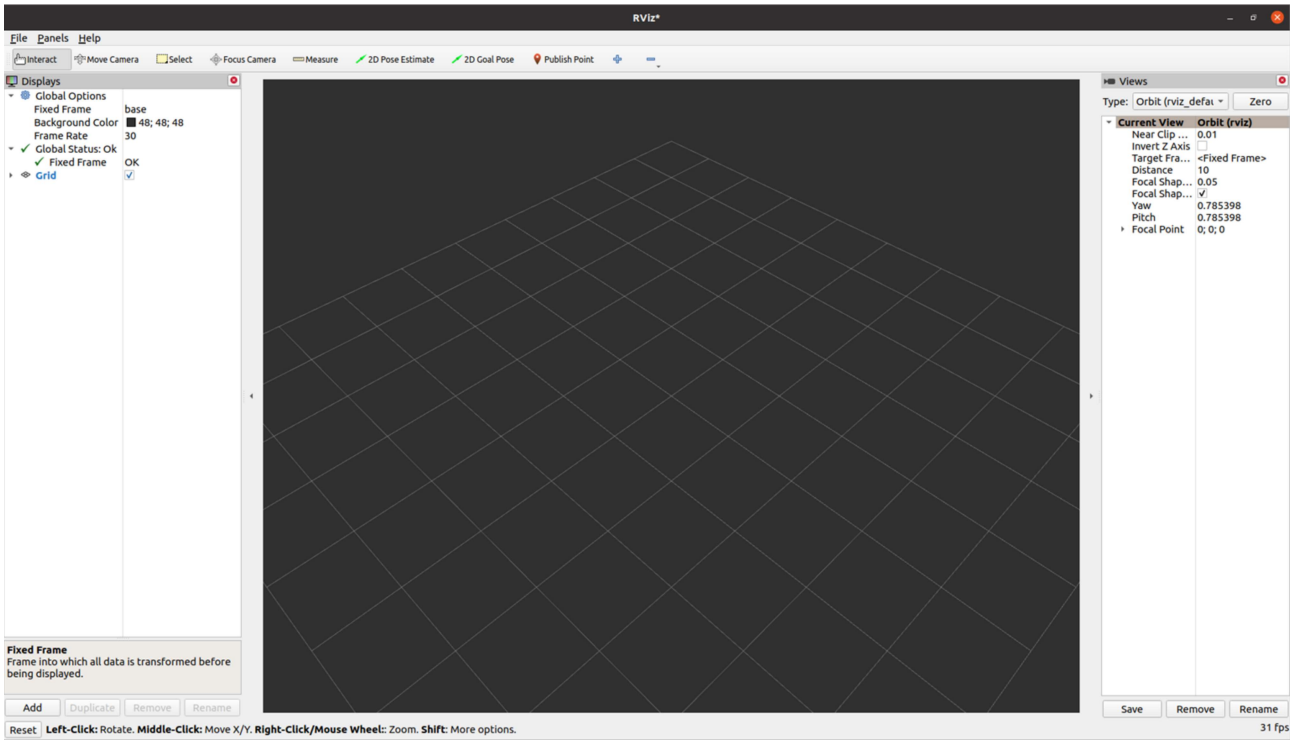
Execute in Terminal #2

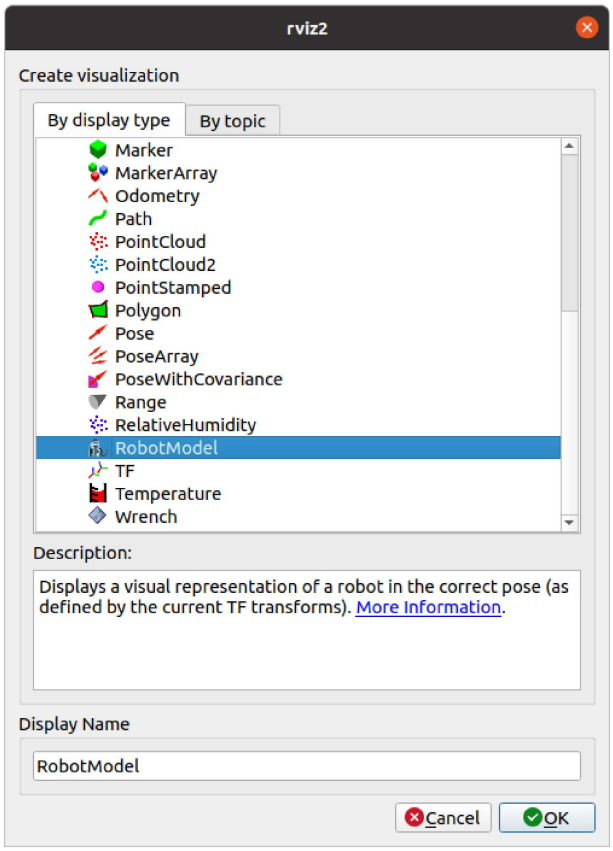
```
killall gzserver
ros2 launch lab4 gazebo.launch.py
```

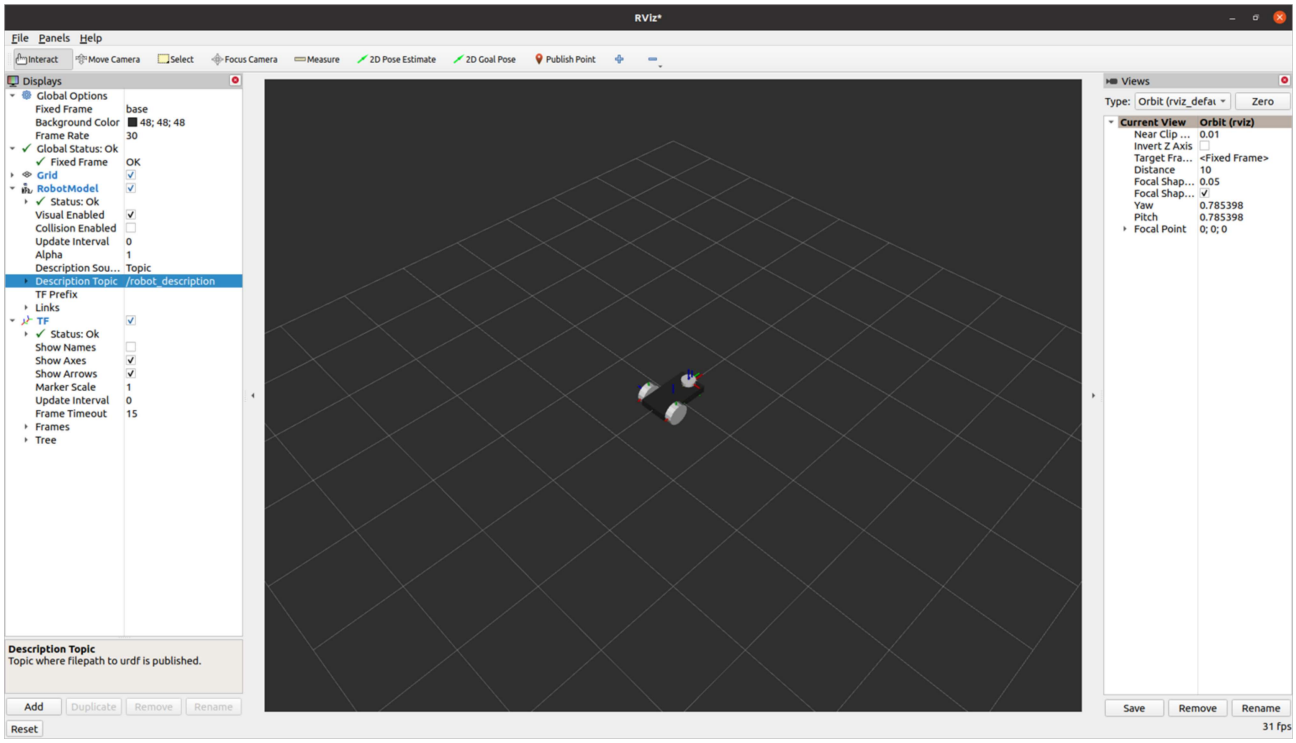
Execute in Terminal #3

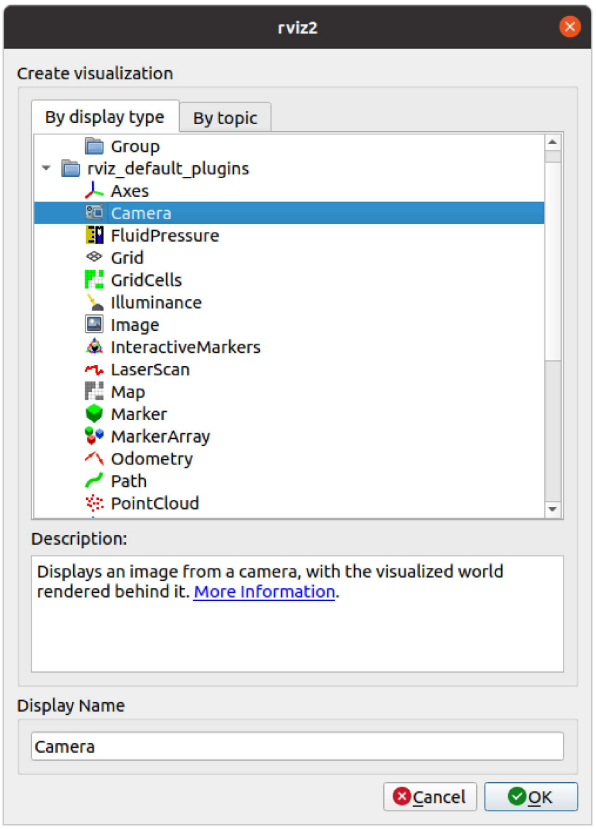
```
ros2 run teleop_twist_keyboard teleop_twist_keyboard
```

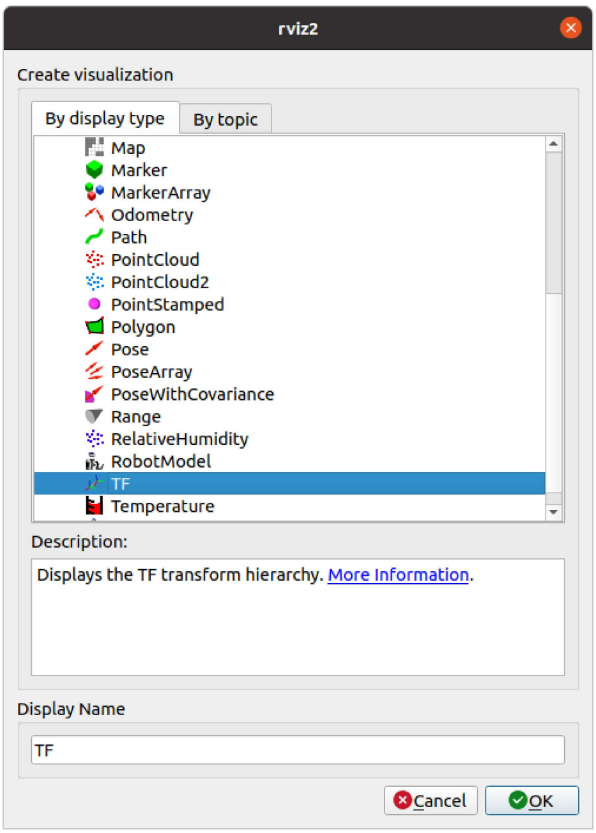
Do these changes in the rviz window:

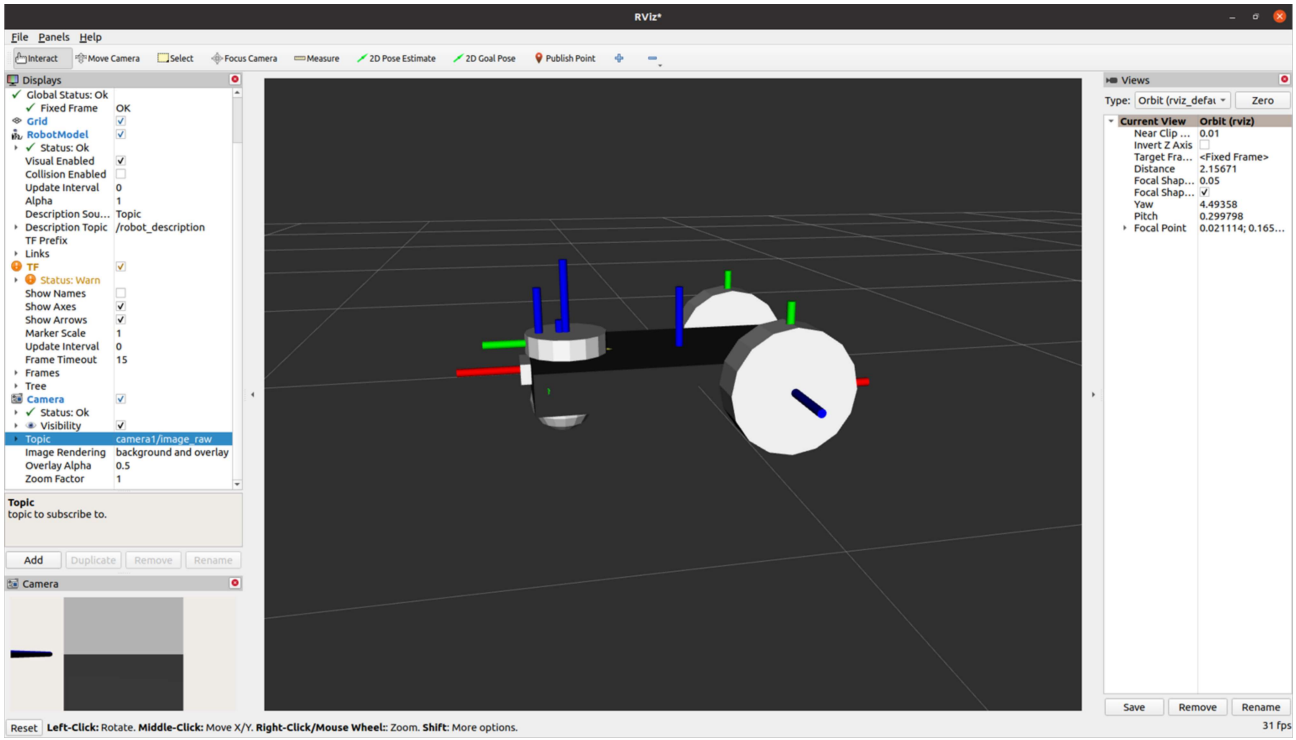

RViz*
File Panels Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Goal Pose
Publish Point
Displays
Global Options
Fixed Frame base
Background Color 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
Fixed Frame
Frame into which all data is transformed before being displayed.
Add
Duplicate
Remove
Rename
Views
Type: Orbit (rviz_defau
Zero
Current View Orbit (rviz)
Near Clip ... 0.01
Invert Z Axis
Target Fra... <Fixed Frame>
Distance 10
Focal Shap... 0.05
Focal Shap...
Yaw 0.785398
Pitch 0.785398
Focal Point 0; 0; 0
Save
Remove
Rename
Reset
Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps

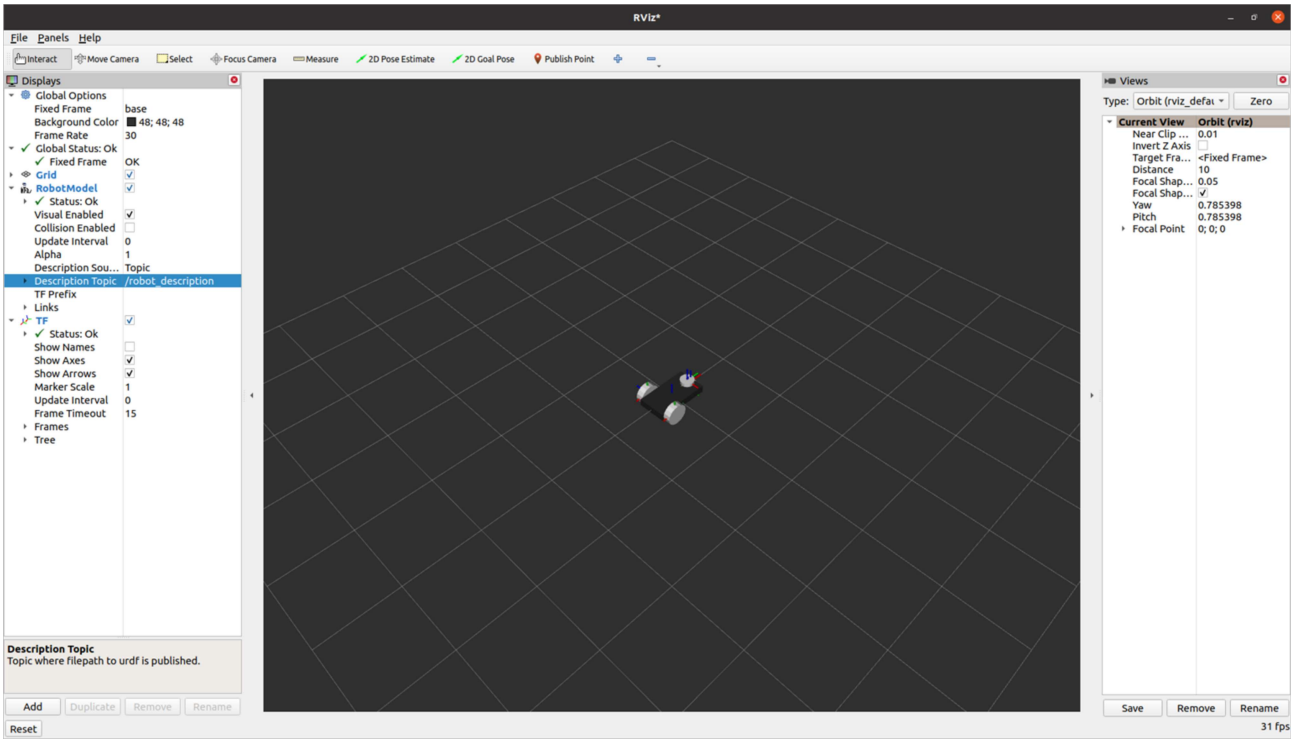

rviz2
Create visualization
By display type
By topic
Marker
MarkerArray
Odometry
Path
PointCloud
PointCloud2
PointStamped
Polygon
Pose
PoseArray
PoseWithCovariance
Range
RelativeHumidity
RobotModel
TF
Temperature
Wrench
Description:
Displays a visual representation of a robot in the correct pose (as defined by the current TF transforms). More Information.
Display Name
RobotModel
Cancel
OK

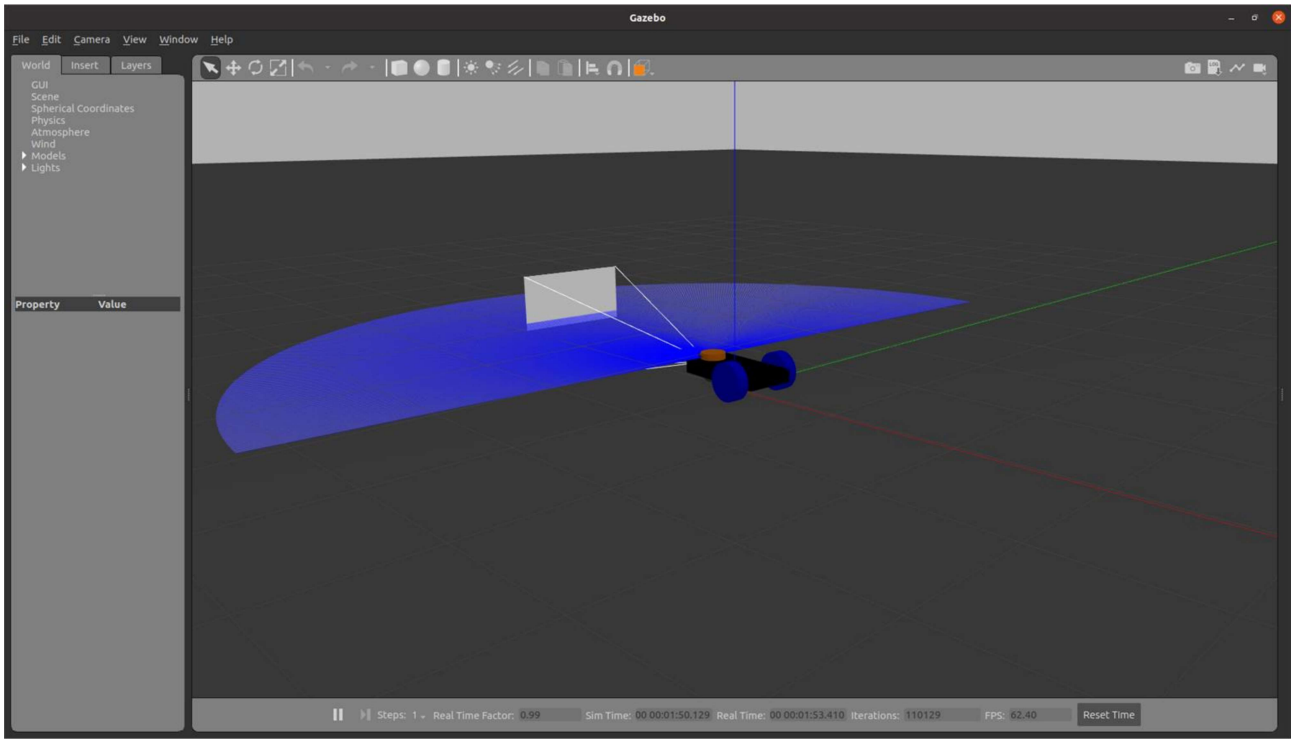

RViz*
File
Panels
Help
Interact
Move Camera
Select
Focus Camera
Measure
2D Pose Estimate
2D Goal Pose
Publish Point
Displays
Global Options
Fixed Frame
base
Background Color
48; 48; 48
Frame Rate
30
Global Status: Ok
Fixed Frame
OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval
0
Alpha
1
Description Sou...
Topic
Description Topic
/robot_description
TF Prefix
Links
TF
Status: Ok
Show Names
Show Axes
Show Arrows
Marker Scale
1
Update Interval
0
Frame Timeout
15
Frames
Tree
Description Topic
Topic where filepath to urdf is published.
Add
Duplicate
Remove
Rename
Reset
Views
Type:
Orbit (rviz_defax
Zero
Current View
Orbit (rviz)
Near Clip ...
0.01
Invert Z Axis
Target Fra...
<Fixed Frame>
Distance
10
Focal Shap...
0.05
Focal Shap...
Yaw
0.785398
Pitch
0.785398
Focal Point
0; 0; 0
Save
Remove
Rename
31 fps

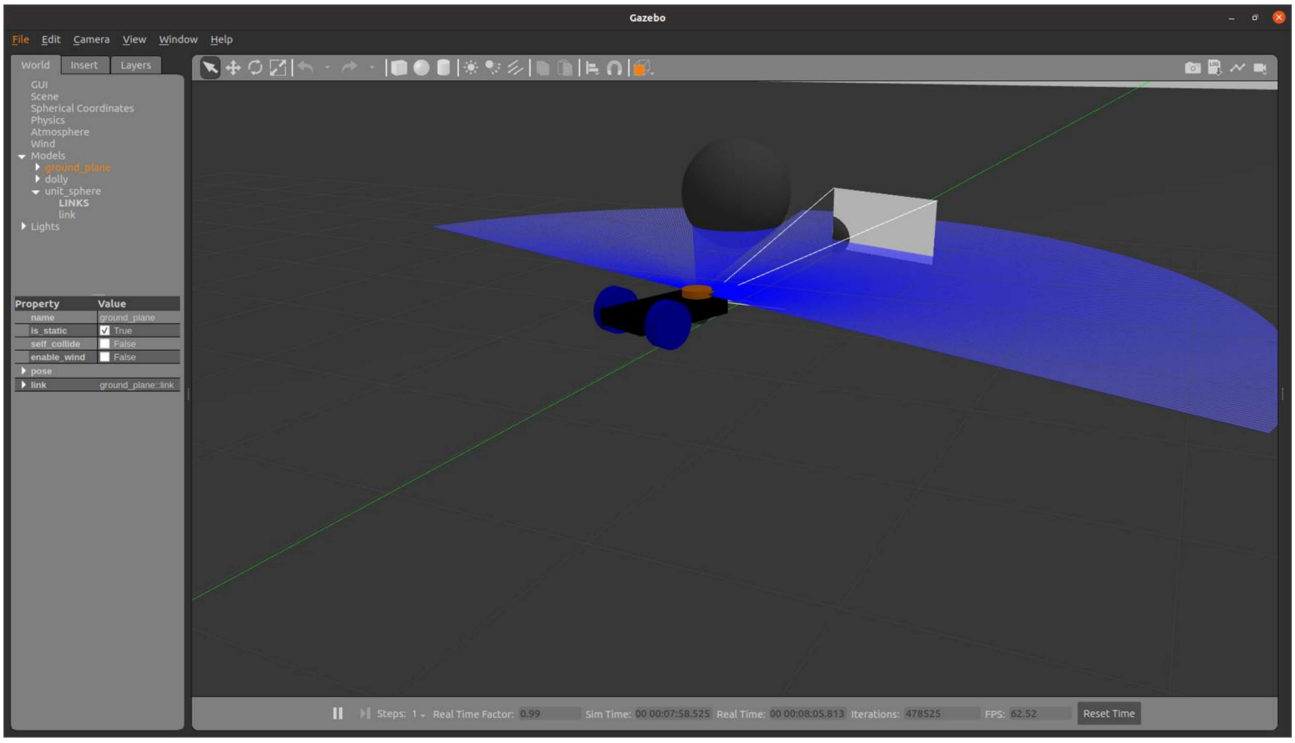

rviz2
Create visualization
By display type
By topic
Group
rviz_default_plugins
Axes
Camera
FluidPressure
Grid
GridCells
Illuminance
Image
InteractiveMarkers
LaserScan
Map
Marker
MarkerArray
Odometry
Path
PointCloud
Description:
Displays an image from a camera, with the visualized world rendered behind it. More Information.
Display Name
Camera
Cancel
OK


rviz2
Create visualization
By display type
By topic
Map
Marker
MarkerArray
Odometry
Path
PointCloud
PointCloud2
PointStamped
Polygon
Pose
PoseArray
PoseWithCovariance
Range
RelativeHumidity
RobotModel
TF
Temperature
Description:
Displays the TF transform hierarchy. More Information.
Display Name
TF
Cancel
OK


RVIz*
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Goal Pose Publish Point
Displays
Global Status: Ok
Fixed Frame OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval 0
Alpha 1
Description Sou... Topic
Description Topic /robot_description
TF Prefix
Links
TF
Status: Warn
Show Names
Show Axes
Show Arrows
Marker Scale 1
Update Interval 0
Frame Timeout 15
Frames
Tree
Camera
Status: Ok
Visibility
Topic camera1/image_raw
Image Rendering background and overlay
Overlay Alpha 0.5
Zoom Factor 1
Topic
topic to subscribe to.
Add Duplicate Remove Rename
Camera
Views
Type: Orbit (rviz_defa Zero
Current View Orbit (rviz)
Near Clip ... 0.01
Invert Z Axis
Target Fra... <Fixed Frame>
Distance 2.15671
Focal Shap... 0.05
Focal Shap...
Yaw 4.49358
Pitch 0.299798
Focal Point 0.021114; 0.165...
Save Remove Rename
Reset Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps


RVIz*
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Goal Pose Publish Point
Displays
Global Options
Fixed Frame base
Background Color 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval 0
Alpha 1
Description Sou... Topic
Description Topic /robot_description
TF Prefix
Links
TF
Status: Ok
Show Names
Show Axes
Show Arrows
Marker Scale 1
Update Interval 0
Frame Timeout 15
Frames
Tree
Description Topic
Topic where filepath to urdf is published.
Add Duplicate Remove Rename
Views
Type: Orbit (rviz_defa Zero
Current View Orbit (rviz)
Near Clip ... 0.01
Invert Z Axis
Target Fra... <Fixed Frame>
Distance 10
Focal Shap... 0.05
Focal Shap...
Yaw 0.785398
Pitch 0.785398
Focal Point 0; 0; 0
Save Remove Rename
Reset
31 fps


Gazebo
File Edit Camera View Window Help
World Insert Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
Lights
Property Value
Steps: 1 Real Time Factor: 0.99 Sim Time: 00 00:01:50.129 Real Time: 00 00:01:53.410 Iterations: 110129 FPS: 62.40
Reset Time


Gazebo
File Edit Camera View Window Help
World Insert Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
ground_plane
dolly
unit_sphere
LINKS
link
Lights
Property Value
name ground_plane
is_static True
self_collide False
enable_wind False
pose
link ground_plane::link
Steps: 1 Real Time Factor: 0.99 Sim Time: 00 00:07:58.525 Real Time: 00 00:08:05.813 Iterations: 478525 FPS: 62.52
Reset Time

sudo apt-get install python3-pip
pip3 install transforms3d

Edit move_robot.py

```
#!/usr/bin/env python3
import rclpy
from rclpy.node import Node
from geometry_msgs.msg import Twist
from nav_msgs.msg import Odometry
import transforms3d
import math


class GotoGoalNode(Node):
    def __init__(self):
        super().__init__("move_robot")
        self.target_x = 2
        self.target_y = 2
        self.publisher = self.create_publisher(Twist, "cmd_vel", 10)
        self.subscriber = self.create_subscription(Odometry, "odom", self.control_loop, 10)

    def control_loop(self, msg):

        dist_x = self.target_x - msg.pose.pose.position.x
        dist_y = self.target_y - msg.pose.pose.position.y
        print('current position: {}
{}'.format(msg.pose.pose.position.x,msg.pose.pose.position.y))
        distance = math.sqrt(dist_x * dist_x + dist_y * dist_y)
        print('distance : {}'.format(round(distance, 3)))


        goal_theta = math.atan2(dist_y, dist_x)
        quat = msg.pose.pose.orientation
        roll, pitch, yaw = transforms3d.euler.quat2euler([quat.w,quat.x,quat.y,quat.z])
        diff = math.pi - round(yaw, 2) + round(goal_theta, 2)
        print('yaw: {}'.format(round(yaw, 2)))
        print('target angle: {}'.format(round(goal_theta, 2)))

        if diff > math.pi:
            diff -= 2*math.pi
        elif diff < -math.pi:
            diff += 2*math.pi
        print('orientation : {}'.format(round(diff, 2)))

        vel = Twist()

        if abs(diff) > 0.2:
            vel.linear.x = 0.0
            vel.angular.z = 0.4*round(diff, 2)
```

```
        else:
            if abs(distance) > 0.2:
                vel.linear.x = 0.3*round(distance, 3)
                vel.angular.z = 0.0

            else:
                vel.linear.x = 0.0
                vel.angular.z = 0.0

        print('speed : {}'.format(vel))
        self.publisher.publish(vel)


def main(args=None):
    rclpy.init(args=args)
    node = GotoGoalNode()
    rclpy.spin(node)
    rclpy.shutdown()


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

Execute in Terminal #1

```
colcon build --packages-select lab4
ros2 launch lab4 rviz.launch.py
```

Execute in Terminal #2

```
killall gzserver
ros2 launch lab4 gazebo.launch.py
```

Execute in Terminal #3

```
ros2 run lab4 controller
```

Edit setup.py

```
 entry_points={
        'console_scripts': [
            'controller = lab4.move_robot:main'
        ],
```

Exercise 1: Write a python code to move the robot to along the wall using the laser scan data.

Exercise 2: Modify the URDF code to change to 4 wheeled robot and run the program.

MANIPULATOR DESIGN AND CONTROL

http://wiki.ros.org/urdf/Tutorials/Adding%20Physical%20and%20Collision%20Properties%20to%20a%20URDF%20Model

Execute in Terminal #1

```
sudo apt-get install ros-foxy-teleop-twist-keyboard
sudo apt-get install ros-foxy-joint-state-publisher*
sudo apt-get install ros-foxy-joint-trajectory-controller
sudo apt-get install ros-foxy-controller-manager
sudo apt install ros-foxy-gazebo-*
sudo apt install ros-foxy-gazebo-msgs
sudo apt install ros-foxy-gazebo-ros
sudo apt install ros-foxy-gazebo-ros2-control-demos
sudo apt install ros-foxy-ros2 control
sudo apt install ros-foxy-ros2-control
sudo apt install ros-foxy-ros2-controllers
sudo apt install ros-foxy-ros2controlcli
sudo apt install ros-foxy-xacro
sudo apt install ros-foxy-gazebo-dev
sudo apt install ros-foxy-gazebo-plugins
```

```
cd ros2_ws/src/urdf_tutorial/urdf
touch manipulator.urdf
```

```
<?xml version="1.0"?>
<robot name="arm">

    <link name="world"/>
    <link name="base_link">
        <visual>
            <geometry>
                <cylinder length="0.05" radius="0.2"/>
            </geometry>
            <material name="Black">
                <color rgba="0 0 0 1"/>
            </material>
            <origin rpy="0 0 0" xyz="0 0 0.025"/>
        </visual>

        <collision>
            <geometry>
                <cylinder length="0.05" radius="0.2"/>
            </geometry>
            <origin rpy="0 0 0" xyz="0 0 0.025"/>
```

```
    </collision>

    <inertial>
        <origin rpy="0 0 0" xyz="0 0 0.025"/>
        <mass value="5.0"/>
        <inertia ixx="0.0135" ixy="0.0" ixz="0.0" iyy="0.0135" iyz="0.0" izz="0.05"/>
    </inertial>
</link>

<joint name="fixed" type="fixed">
    <parent link="world"/>
    <child link="base_link"/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_1">
    <visual>
        <geometry>
            <cylinder length="0.5" radius="0.08"/>
        </geometry>
        <material name="blue">
            <color rgba="0 0 0.8 1"/>
        </material>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
    </visual>

    <collision>
        <geometry>
            <cylinder length="0.5" radius="0.08"/>
        </geometry>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
    </collision>

    <inertial>
        <origin rpy="0 0 0" xyz="0 0 0.25"/>
        <mass value="5.0"/>
        <inertia ixx="0.107" ixy="0.0" ixz="0.0" iyy="0.107" iyz="0.0" izz="0.0125"/>
    </inertial>

</link>

<joint name="joint_1" type="continuous">
    <axis xyz="0 0 1"/>
    <parent link="base_link"/>
    <child link="link_1"/>
    <origin rpy="0 0 0" xyz="0.0 0.0 0.05"/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_2">
    <inertial>
```

```
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="2.0"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
      <geometry>
      <cylinder length="0.1" radius="0.08"/>
      </geometry>
      <material name="Red">
        <color rgba="1 0 0 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
        <cylinder length="0.1" radius="0.08"/>
      </geometry>
    </collision>
  </link>

  <joint name="joint_2" type="continuous">
    <axis xyz="0 0 1"/>
    <parent link="link_1"/>
    <child link="link_2"/>
    <origin rpy="0 1.5708 0" xyz="0.0 -0.005 0.58"/>
    <limit lower="-0.25" upper="3.34" effort="10" velocity="0.5"/>
    <dynamics damping="10" friction="1.0"/>
  </joint>

  <link name="link_3">
    <inertial>
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="0.01"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
    </inertial>

    <visual>
      <geometry>
      <cylinder length="0.4" radius="0.05"/>
      </geometry>
      <material name="blue">
        <color rgba="0.5 0.5 0.5 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
        <cylinder length="0.4" radius="0.05"/>
      </geometry>
    </collision>
```

```
</link>

<joint name="joint_3" type="fixed">
   <parent link="link_2"/>
   <child link="link_3"/>
   <origin rpy="1.57 0 0" xyz="0.0 0.2 0 "/>
   <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_4">
   <inertial>
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="0.01"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
   </inertial>

   <visual>
      <geometry>
      <cylinder length="0.1" radius="0.06"/>
      </geometry>
      <material name="Red">
         <color rgba="1 0 0 1"/>
      </material>
   </visual>

   <collision>
      <geometry>
         <cylinder length="0.1" radius="0.06"/>
      </geometry>
   </collision>

</link>

<joint name="joint_4" type="continuous">
   <parent link="link_3"/>
   <child link="link_4"/>
   <origin rpy="1.57 0 0" xyz=" 0 0 -0.25"/>
   <axis xyz=" 0 0 1"/>
   <limit lower="-1.92" upper="1.92" effort="10" velocity="0.5"/>
   <dynamics damping="10" friction="1.0"/>
</joint>

<link name="link_5">
   <inertial>
      <origin rpy="0 0 0" xyz="0 0 0.2"/>
      <mass value="0.01"/>
      <inertia ixx="0.027" ixy="0.0" ixz="0.0" iyy="0.027" iyz="0.0" izz="0.0025"/>
   </inertial>

   <visual>
      <geometry>
```

```
        <cylinder length="0.3" radius="0.03"/>
        </geometry>
        <material name="yello">
            <color rgba="0 1 0.5 1"/>
        </material>
        </visual>

    <collision>
        <geometry>
            <cylinder length="0.3" radius="0.03"/>
        </geometry>
    <dynamics damping="0.0" friction="0.0"/>

    </collision>
</link>

<joint name="joint_5" type="fixed">
    <parent link="link_4"/>
    <child link="link_5"/>
    <origin rpy="1.57 0 0" xyz="0.0 -0.2 0 "/>
    <dynamics damping="10" friction="1.0"/>
</joint>

<gazebo reference="base_link">
    <material>Gazebo/Black</material>
</gazebo>

<gazebo reference="link_1">
    <material>Gazebo/White</material>
</gazebo>

<gazebo reference="link_3">
    <material>Gazebo/White</material>
</gazebo>

<gazebo reference="link_2">
    <material>Gazebo/Blue</material>
</gazebo>

<gazebo reference="link_4">
    <material>Gazebo/Blue</material>
</gazebo>

<gazebo reference="link_5">
    <material>Gazebo/White</material>
</gazebo>



<gazebo>
<plugin filename="libgazebo_ros2_control.so" name="gazebo_ros2_control">
```

```
        <robot_sim_type>gazebo_ros2_control/GazeboSystem</robot_sim_type>

<parameters>/home/asha/ros2_ws/src/urdf_tutorial/config/control.yaml</parameters>
    </plugin>
    </gazebo>

    <ros2_control name="GazeboSystem" type="system">
        <hardware>
        <plugin>gazebo_ros2_control/GazeboSystem</plugin>
    </hardware>


    <joint name="joint_1">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">0.0</param>
    </joint>
    <joint name="joint_2">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">-1.57</param>
    </joint>
    <joint name="joint_4">
        <command_interface name="position">
        <param name="min">-3.14</param>
        <param name="max">3.14</param>
        </command_interface>
        <state_interface name="position"/>
        <param name="initial_position">0.0</param>
    </joint>

    </ros2_control>

</robot>
```

```
cd ..
cd launch
touch arm_rviz.launch.py
```

```
from launch import LaunchDescription
from launch_ros.actions import Node
import os
```

```
def generate_launch_description():

    urdf_file = urdf = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/manipulator.urdf'



    joint_state_publisher_node = Node(
        package="joint_state_publisher_gui",
        executable="joint_state_publisher_gui",
    )
    robot_state_publisher_node = Node(
        package="robot_state_publisher",
        executable="robot_state_publisher",
        output="both",
        arguments=[urdf_file]
    )
    rviz_node = Node(
        package="rviz2",
        executable="rviz2",
        name="rviz2",
        output="log"
    )

    nodes_to_run = [
        joint_state_publisher_node,
        robot_state_publisher_node,
        rviz_node
    ]

    return LaunchDescription(nodes_to_run)
```

touch arm_gazebo.launch.py

```
import os
from launch import LaunchDescription
from launch.actions import ExecuteProcess
from launch_ros.actions import Node

def generate_launch_description():
    urdf_file = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/manipulator.urdf'

    return LaunchDescription(
        [
            ExecuteProcess(
                cmd=["gazebo","-s","libgazebo_ros_factory.so",],
                output="screen",
            ),
            Node(
                package="gazebo_ros",
                executable="spawn_entity.py",
```

```
            arguments=["-entity","urdf_tutorial","-b","-file", urdf_file],
        ),
        Node(
            package="robot_state_publisher",
            executable="robot_state_publisher",
            output="screen",
            arguments=[urdf_file],
        ),


    ]
)
```

```
cd ~/ros2_ws/src/urdf_tutorial
mkdir config
cd config
touch control.yaml
```

```
controller_manager:
  ros__parameters:
    update_rate: 100
    joint_state_broadcaster:
      type: joint_state_broadcaster/JointStateBroadcaster
    joint_trajectory_controller:
      type: joint_trajectory_controller/JointTrajectoryController

joint_trajectory_controller:
  ros__parameters:
    joints:
      - joint_1
      - joint_2
      - joint_4

    command_interfaces:
      - position

    state_interfaces:
      - position

    state_publish_rate: 50.0
    action_monitor_rate: 20.0

    allow_partial_joints_goal: false
    open_loop_control: true
    constraints:
      stopped_velocity_tolerance: 0.01
      goal_time: 0.0
      joint1:
        trajectory: 0.05
        goal: 0.03
```

touch arm_control.launch.py
Edit arm_control.launch.py

```
import os
from launch import LaunchDescription
from launch.actions import ExecuteProcess, IncludeLaunchDescription,
RegisterEventHandler
from launch_ros.actions import Node
from launch.event_handlers import OnProcessExit
from launch.launch_description_sources import PythonLaunchDescriptionSource
from ament_index_python.packages import get_package_share_directory

import xacro

def generate_launch_description():

    urdf_file = '/home/asha/ros2_ws/src/lab5/urdf/manipulator.urdf'
    controller_file = '/home/asha/ros2_ws/src/lab5/config/control.yaml'
    robot_description = {"robot_description": urdf_file}

    gazebo = IncludeLaunchDescription(
        PythonLaunchDescriptionSource([os.path.join(
            get_package_share_directory('gazebo_ros'), 'launch'), '/gazebo.launch.py']),
    )

    doc = xacro.parse(open(urdf_file))
    xacro.process_doc(doc)
    params = {'robot_description': doc.toxml()}

    node_robot_state_publisher = Node(
        package='robot_state_publisher',
        executable='robot_state_publisher',
        output='screen',
        parameters=[params]
    )

    spawn_entity = Node(package='gazebo_ros', executable='spawn_entity.py',
        arguments=["-entity","lab5","-b","-file", urdf_file],
        output='screen'
    )

    load_joint_state_controller = ExecuteProcess(
        cmd=['ros2', 'control', 'load_controller', '--set-state', 'start',
             'joint_state_broadcaster'],
        output='screen'
    )

    load_joint_trajectory_controller = ExecuteProcess(
        cmd=['ros2', 'control', 'load_controller', '--set-state', 'start',
```

```
            'joint_trajectory_controller'],
        output='screen'
    )

    return LaunchDescription(
        [
            RegisterEventHandler(
                event_handler=OnProcessExit(
                    target_action=spawn_entity,
                    on_exit=[load_joint_state_controller],
                )
            ),

            RegisterEventHandler(
                event_handler=OnProcessExit(
                    target_action=load_joint_state_controller,
                    on_exit=[load_joint_trajectory_controller],
                )
            ),

            gazebo,

            node_robot_state_publisher,

            spawn_entity,

            Node(
                package="controller_manager",
                executable="ros2_control_node",
                parameters=[robot_description, controller_file],
                output="screen"
            )
        ]
    )
```

Add extensions in Visual Studio

ros
ros snippet
xml
xml tools
urdf
xml complete
icons

Execute in Terminal #1

```
colcon build --packages-select urdf_tutorial
```

Execute in Terminal #1

ros2 launch urdf_tutorial arm_rviz.launch.py

Execute in Terminal #2

ros2 launch urdf_tutorial arm_gazebo.launch.py

Execute in Terminal #3

ros2 launch urdf_tutorial arm_control.launch.py

cd ros2_ws/src/urdf_tutorial/urdf_tutorial/

touch controller.py

chmod +x controller.py

```
#!/usr/bin/env python3

import rclpy
from rclpy.node import Node
from builtin_interfaces.msg import Duration
from trajectory_msgs.msg import JointTrajectory, JointTrajectoryPoint

class TrajectoryPublisher(Node):

    def __init__(self):
        super().__init__('trajectory_node')
        topic_ = "/joint_trajectory_controller/joint_trajectory"
        self.publisher_ = self.create_publisher(JointTrajectory, topic_, 10)
        self.timer_ = self.create_timer(1,self.timer_callback)
        self.joints = ['joint_1', 'joint_2', 'joint_4']
        self.goal_ =[1.5, 0.5, 1.2]


    def timer_callback(self):
        msg = JointTrajectory()
        msg.joint_names = self.joints
        point = JointTrajectoryPoint()
        point.positions = self.goal_
        point.time_from_start = Duration(sec=2)
        msg.points.append(point)
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = TrajectoryPublisher()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

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

Edit setup.py as

```
from setuptools import setup
import os
from glob import glob
package_name = 'urdf_tutorial'

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
          (os.path.join('share', package_name), glob('urdf/*')),
          (os.path.join('share', package_name), glob('launch/*')),
          (os.path.join('share', package_name), glob('config/*'))


    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
            'controller = urdf_tutorial.controller:main'
        ],
    },
)
```

Execute in Terminal #1

```
colcon build --packages-select urdf_tutorial
```

Execute in Terminal #1

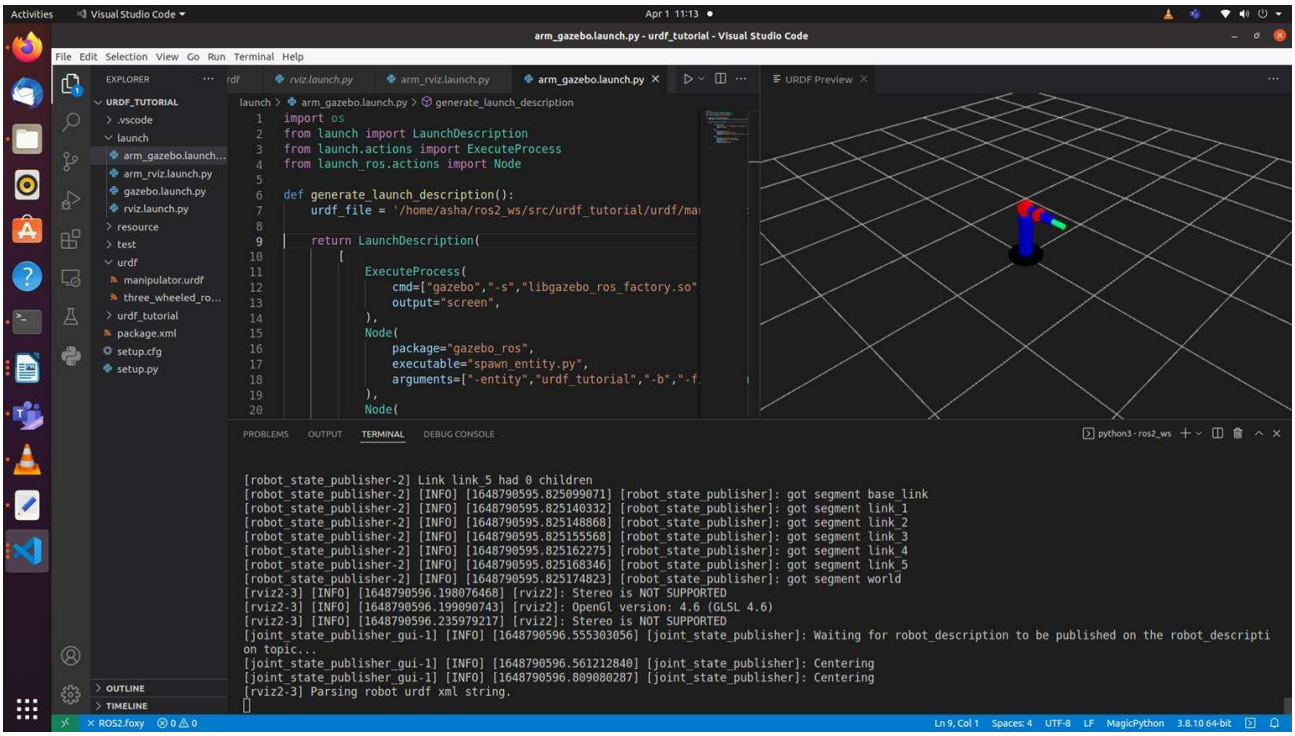
```
ros2 launch urdf_tutorial arm_rviz.launch.py
```

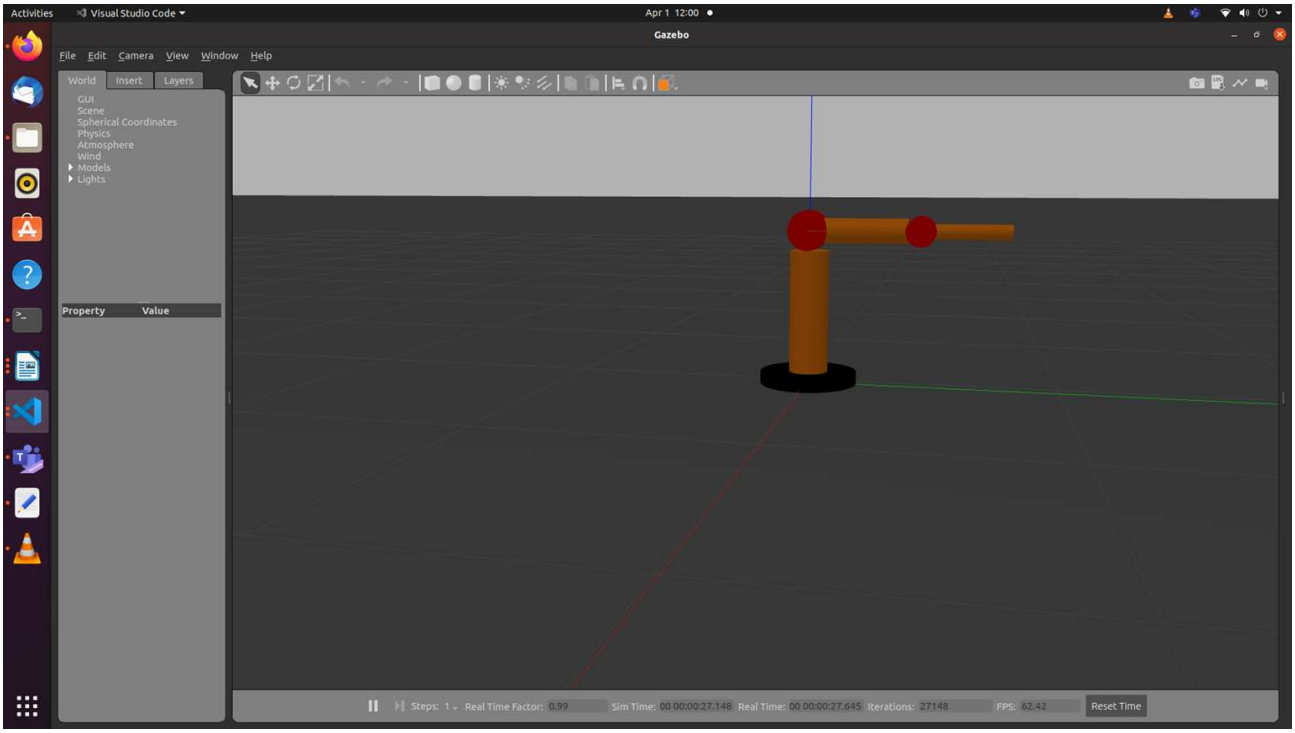
Execute in Terminal #2

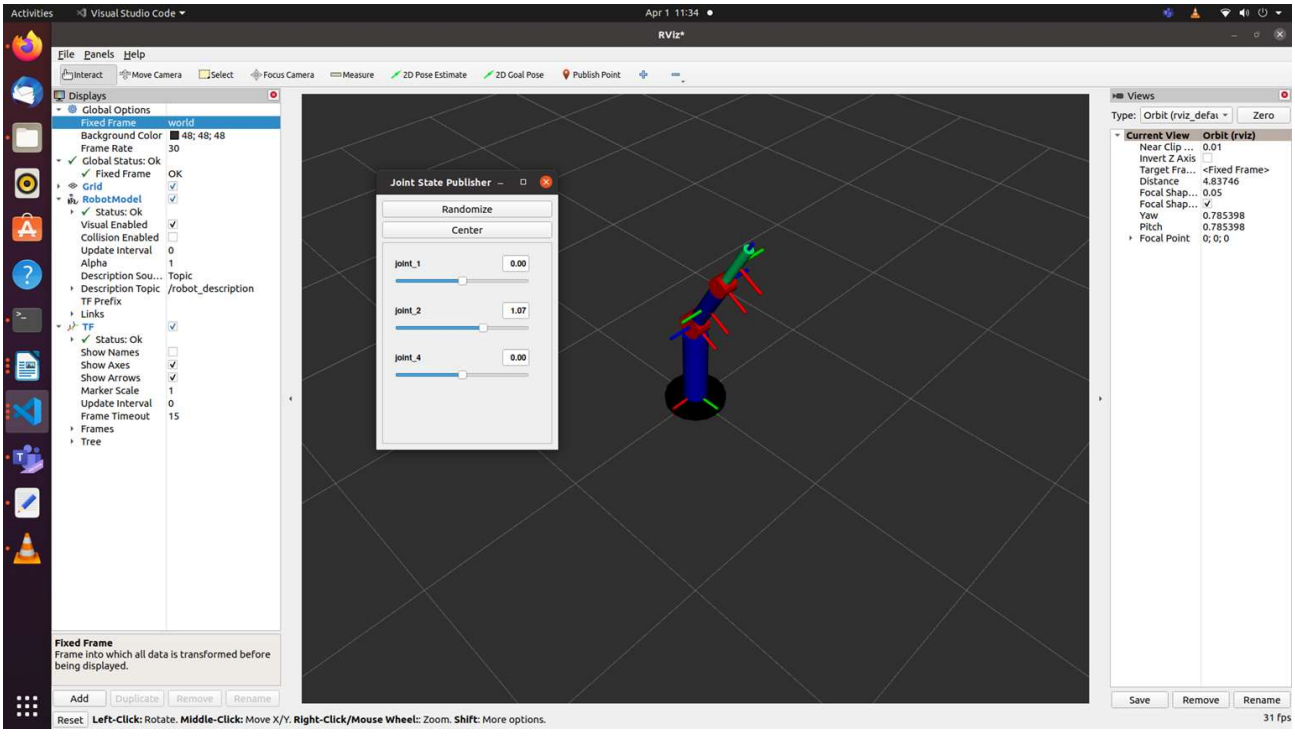
```
ros2 launch urdf_tutorial arm_control.launch.py
```

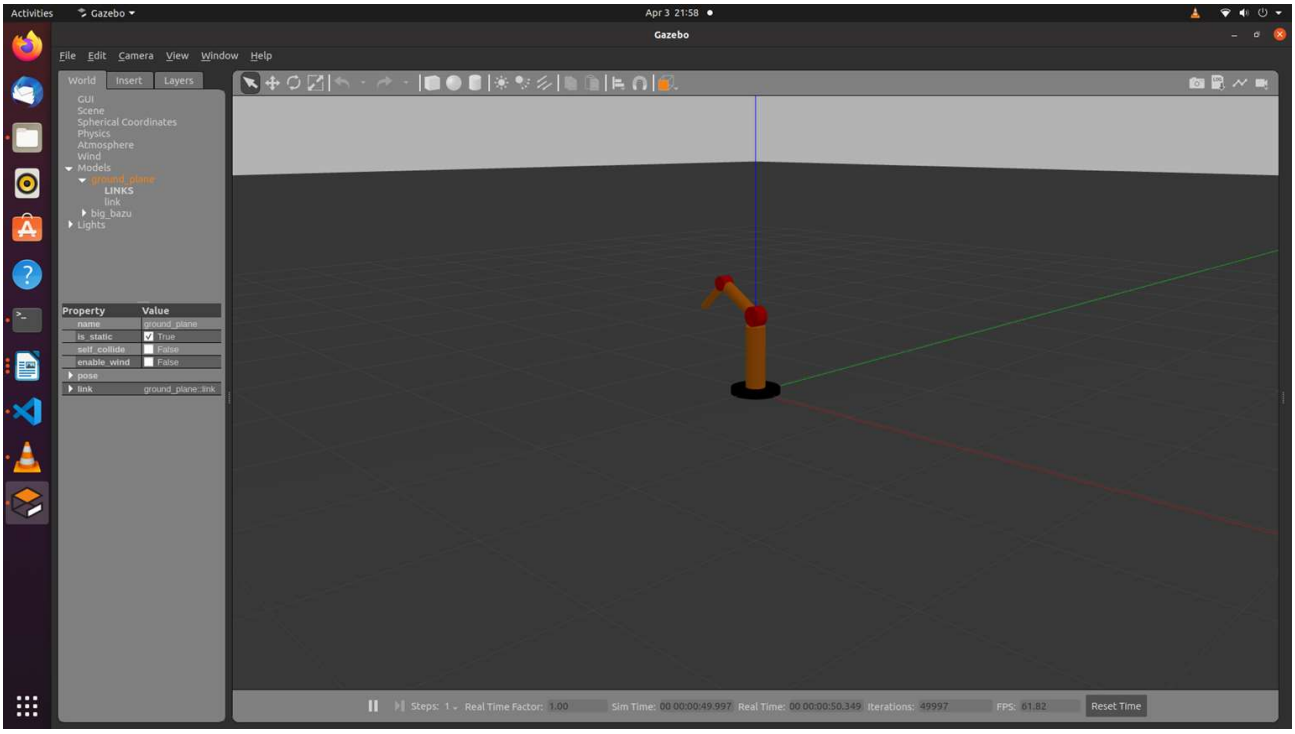
Execute in Terminal #3

```
ros2 run urdf_tutorial controller
```


Activities
Visual Studio Code
Apr 1 11:13
arm_gazebo.launch.py - urdf_tutorial - Visual Studio Code
File Edit Selection View Go Run Terminal Help
EXPLORER
URDF_TUTORIAL
.vscode
launch
arm_gazebo.launch...
arm_rviz.launch.py
gazebo.launch.py
rviz.launch.py
resource
test
urdf
manipulator.urdf
three_wheeled_ro...
urdf_tutorial
package.xml
setup.cfg
setup.py
rviz.launch.py
arm_rviz.launch.py
arm_gazebo.launch.py
URDF Preview
launch > arm_gazebo.launch.py > generate_launch_description
import os
from launch import LaunchDescription
from launch.actions import ExecuteProcess
from launch_ros.actions import Node
def generate_launch_description():
urdf_file = '/home/asha/ros2_ws/src/urdf_tutorial/urdf/ma
return LaunchDescription(
[
ExecuteProcess(
cmd=["gazebo","-s","libgazebo_ros_factory.so"
output="screen",
),
Node(
package="gazebo_ros",
executable="spawn_entity.py",
arguments=["-entity","urdf_tutorial","-b","-f
),
Node(
PROBLEMS
OUTPUT
TERMINAL
DEBUG CONSOLE
python3 - ros2_ws
[robot_state_publisher-2] Link link_5 had 0 children
[robot_state_publisher-2] [INFO] [1648790595.825099071] [robot_state_publisher]: got segment base_link
[robot_state_publisher-2] [INFO] [1648790595.825140332] [robot_state_publisher]: got segment link_1
[robot_state_publisher-2] [INFO] [1648790595.825148868] [robot_state_publisher]: got segment link_2
[robot_state_publisher-2] [INFO] [1648790595.825155568] [robot_state_publisher]: got segment link_3
[robot_state_publisher-2] [INFO] [1648790595.825162275] [robot_state_publisher]: got segment link_4
[robot_state_publisher-2] [INFO] [1648790595.825168346] [robot_state_publisher]: got segment link_5
[robot_state_publisher-2] [INFO] [1648790595.825174823] [robot_state_publisher]: got segment world
[rviz2-3] [INFO] [1648790596.198076468] [rviz2]: Stereo is NOT SUPPORTED
[rviz2-3] [INFO] [1648790596.199090743] [rviz2]: OpenGl version: 4.6 (GLSL 4.6)
[rviz2-3] [INFO] [1648790596.235979217] [rviz2]: Stereo is NOT SUPPORTED
[joint_state_publisher_gui-1] [INFO] [1648790596.555303056] [joint_state_publisher]: Waiting for robot_description to be published on the robot_descripti
on topic...
[joint_state_publisher_gui-1] [INFO] [1648790596.561212840] [joint_state_publisher]: Centering
[joint_state_publisher_gui-1] [INFO] [1648790596.809080287] [joint_state_publisher]: Centering
[rviz2-3] Parsing robot urdf xml string.
OUTLINE
TIMELINE
ROS2.foxy
0 0
Ln 9, Col 1
Spaces: 4
UTF-8
LF
MagicPython
3.8.10 64-bit


Activities
Visual Studio Code
Apr 1 12:00
Gazebo
File Edit Camera View Window Help
World Insert Layers
GUI
Scene
Spherical Coordinates
Physics
Atmosphere
Wind
Models
Lights
Property Value
Steps: 1 Real Time Factor: 0.99 Sim Time: 00 00:00:27.148 Real Time: 00 00:00:27.645 Iterations: 27148 FPS: 62.42
Reset Time


Activities
Visual Studio Code
Apr 1 11:34
RViz*
File Panels Help
Interact Move Camera Select Focus Camera Measure 2D Pose Estimate 2D Goal Pose Publish Point
Displays
Global Options
Fixed Frame world
Background Color 48; 48; 48
Frame Rate 30
Global Status: Ok
Fixed Frame OK
Grid
RobotModel
Status: Ok
Visual Enabled
Collision Enabled
Update Interval 0
Alpha 1
Description Sou... Topic
Description Topic /robot_description
TF Prefix
Links
TF
Status: Ok
Show Names
Show Axes
Show Arrows
Marker Scale 1
Update Interval 0
Frame Timeout 15
Frames
Tree
Fixed Frame
Frame into which all data is transformed before being displayed.
Add Duplicate Remove Rename
Joint State Publisher
Randomize
Center
joint_1 0.00
joint_2 1.07
joint_4 0.00
Views
Type: Orbit (rviz_defa
Zero
Current View Orbit (rviz)
Near Clip ... 0.01
Invert Z Axis
Target Fra... <Fixed Frame>
Distance 4.83746
Focal Shap... 0.05
Focal Shap...
Yaw 0.785398
Pitch 0.785398
Focal Point 0; 0; 0
Save Remove Rename
Reset Left-Click: Rotate. Middle-Click: Move X/Y. Right-Click/Mouse Wheel:: Zoom. Shift: More options.
31 fps



ROS2 parameters:

Parameters help to provide the values while running the code.

ros2 param list

Edit the controller.py

```
#!/usr/bin/env python3


#colcon build --packages-select urdf_tutorial
#ros2 run urdf_tutorial controller --ros-args -p end_location:=[3.5,1.5,-1.2]

import rclpy
from rclpy.node import Node
from builtin_interfaces.msg import Duration
from trajectory_msgs.msg import JointTrajectory, JointTrajectoryPoint
```

```
class TrajectoryPublisher(Node):

    def __init__(self):
        super().__init__('trajectory_node')
        topic_ = "/joint_trajectory_controller/joint_trajectory"
        self.joints = ['joint_1', 'joint_2', 'joint_4']
        #self.goal_ =[1.5, 0.5, 1.2]
        self.declare_parameter("joint_angles", [1.5, 0.5, 1.2])
        self.goal_=self.get_parameter("joint_angles").value
        self.publisher_ = self.create_publisher(JointTrajectory, topic_, 10)
        self.timer_ = self.create_timer(1,self.timer_callback)



    def timer_callback(self):
        msg = JointTrajectory()
        msg.joint_names = self.joints
        point = JointTrajectoryPoint()
        point.positions = self.goal_
        point.time_from_start = Duration(sec=2)
        msg.points.append(point)
        self.publisher_.publish(msg)

def main(args=None):
    rclpy.init(args=args)
    node = TrajectoryPublisher()
    rclpy.spin(node)
    node.destroy_node()
    rclpy.shutdown()

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

Execute in Terminal #1

```
#colcon build --packages-select urdf_tutorial
```

Execute in Terminal #2

```
ros2 launch urdf_tutorial arm_control.launch.py
ros2 control load_controller --set-state start joint_state_broadcaster
ros2 control load_controller --set-state start joint_trajectory_controller
```

Execute in Terminal #3

```
#ros2 run urdf_tutorial controller --ros-args -p joint_angles:=[3.5,1.5,-1.2]
```

Exercise 1: Replicate the process for UR5e robot given its urdf file.

Exercise 2: Write a python code to move the manipulator to end location using inverse kinematics.

Viva Questions: Compute the inertia parameters for the each block used in the three_wheeled_robot and manipulator.

References

https://docs.ros.org/en/foxy/Tutorials/URDF/Using-URDF-with-Robot-State-Publisher.html

https://github.com/benbongalon/ros2-urdf-tutorial/tree/master/urdf_tutorial

https://github.com/cra-ros-pkg/robot_localization/tree/foxy-devel

https://github.com/ros/robot_state_publisher/tree/foxy

https://github.com/ros/joint_state_publisher/tree/foxy

http://gazebosim.org/tutorials?tut=ros_urdf

Lab6: ROS2 Perception – Line Follower

- How to use OpenCV in ROS2
- How to follow a line
- How to find different elements based on color
- Track multiple paths and decide
- Create a basic PID for the line following

OpenCV is the most extensive and complete library for image recognition. With it, you can work with images like never before: applying filters, post-processing, and working with images in any way you want. OpenCV is not a ROS2 library, but it's been integrated nicely into ROS with http://wiki.ros.org/cv_bridge. This package allows the ROS imaging topics to use the OpenCV image variable format.

For example, OpenCV images come in BGR image format, while regular ROS images are in the more standard RGB encoding. OpenCV_bridge provides a nice feature to convert between them. Also, there are many other functions to transfer images to OpenCV variables transparently.

If gazebo is stuck use the following command
killall -9 gzserver
sudo apt install libopencv-dev python3-opencv

cd ros2_ws/src
ros2 pkg create lab6 --build-type ament_python --dependencies rclpy std_msgs
cd ..
colcon build
open lab6 with visual studio application
create urdf folder
create a file car.urdf inside the urdf folder

```
<?xml version="1.0" ?>

<robot name = "car">

   <link name="base">
      <visual>
      <geometry>
         <box size="0.75 0.4 0.1"/>
      </geometry>
      <material name="pink">
```

```
      <color rgba="1 0 1 1" />
    </material>
    </visual>

    <inertial>
      <mass value="1" />
      <inertia ixx="0.01" ixy="0.0" ixz="0" iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <collision>
    <geometry>
      <box size="0.75 0.4 0.1"/>
    </geometry>
    </collision>

</link>

<link name="wheel_right_link">
    <inertial>
          <mass value="2" />
          <inertia ixx="0.01" ixy="0.0" ixz="0"
          iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
        <cylinder radius="0.15" length="0.1"/>
      </geometry>
      <material name="blue">
      <color rgba="0 0 1 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
        <cylinder radius="0.15" length="0.1"/>
      </geometry>
     <contact_coefficients mu="1" kp="1e+13" kd="1.0"/>
    </collision>
</link>

<joint name="wheel_right_joint" type="continuous">
    <origin xyz="0.2 0.25 0.0" rpy="1.57 0.0 0.0"/>
    <parent link="base"/>
    <child link="wheel_right_link"/>
    <axis xyz="0.0 0.0 1.0"/>
</joint>



<link name="wheel_left_link">
```

```
    <inertial>
       <mass value="2" />
       <inertia ixx="0.01" ixy="0.0" ixz="0"
          iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
         <cylinder radius="0.15" length="0.1"/>
      </geometry>
      <material name="blue">
        <color rgba="0 0 1 1"/>
      </material>
    </visual>

    <collision>
      <geometry>
         <cylinder radius="0.15" length="0.1"/>
      </geometry>
      <contact_coefficients mu="1" kp="1e+13" kd="1.0"/>
    </collision>
</link>

<joint name="wheel_left_joint" type="continuous">
    <origin xyz="0.2 -0.25 0.0" rpy="1.57 0.0 0.0"/>
    <parent link="base"/>
    <child link="wheel_left_link"/>
    <axis xyz="0.0 0.0 1.0"/>
</joint>



<link name="caster">
    <inertial>
          <mass value="1" />
          <inertia ixx="0.01" ixy="0.0" ixz="0"
          iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
      <geometry>
        <sphere radius=".08" />
      </geometry>
      <material name="white" />
    </visual>

    <collision>
      <origin/>
      <geometry>
        <sphere radius=".08" />
      </geometry>
```

```
    </collision>
</link>

<joint name="caster_joint" type="continuous">
    <origin xyz="-0.3 0.0 -0.07" rpy="0.0 0.0 0.0"/>
    <axis xyz="0 0 1" />
    <parent link="base"/>
    <child link="caster"/>
</joint>

<link name="camera">
    <inertial>
        <mass value="0.5" />
        <inertia ixx="0.01" ixy="0.0" ixz="0"
        iyy="0.01" iyz="0" izz="0.01" />
    </inertial>

    <visual>
        <geometry>
            <box size="0.1 0.1 0.1"/>
        </geometry>
        <material name="red">
            <color rgba="1 0 0 1"/>
        </material>
    </visual>

    <collision>
        <geometry>
            <box size="0.1 0.1 0.1"/>
        </geometry>
    </collision>
</link>


<joint name="camera_joint" type="fixed">
    <origin xyz="-0.32 0 0.1" rpy="0 0.0 3.14"/>
    <parent link="base"/>
    <child link="camera"/>
    <axis xyz="0.0 0.0 1.0"/>
</joint>




<!--http://wiki.ros.org/simulator_gazebo/Tutorials/ListOfMaterials-->
<gazebo reference="base">
    <material>Gazebo/WhiteGlow</material>
</gazebo>
<gazebo reference="wheel_left_link">
    <material>Gazebo/SkyBlue</material>
```

```
</gazebo>
<gazebo reference="wheel_right_link">
    <material>Gazebo/SkyBlue </material>
</gazebo>
<gazebo reference="caster">
    <material>Gazebo/Grey</material>
</gazebo>
<gazebo reference="camera">
    <material>Gazebo/Blue</material>
</gazebo>



<!-- differential robot-->
<gazebo>
    <plugin filename="libgazebo_ros_diff_drive.so" name="gazebo_base_controller">
      <odometry_frame>odom</odometry_frame>
      <commandTopic>cmd_vel</commandTopic>
      <publish_odom>true</publish_odom>
      <publish_odom_tf>true</publish_odom_tf>
      <update_rate>15.0</update_rate>

      <left_joint>wheel_left_joint</left_joint>
      <right_joint>wheel_right_joint</right_joint>

      <wheel_separation>0.5</wheel_separation>
      <wheel_diameter>0.3</wheel_diameter>
      <max_wheel_acceleration>0.7</max_wheel_acceleration>
      <max_wheel_torque>8</max_wheel_torque>
      <robotBaseFrame>base</robotBaseFrame>
    </plugin>
</gazebo>

<!-- camera plugin-->

<gazebo reference="camera">
    <sensor type="camera" name="camera1">
      <visualize>true</visualize>
      <update_rate>30.0</update_rate>
      <camera name="head">
        <horizontal_fov>1.3962634</horizontal_fov>
        <image>
          <width>512</width>
          <height>512</height>
          <format>R8G8B8</format>
        </image>
        <clip>
          <near>0.02</near>
          <far>500</far>
        </clip>
      </camera>
```

```
      <plugin name="camera_controller" filename="libgazebo_ros_camera.so">
        <alwaysOn>true</alwaysOn>
        <updateRate>0.0</updateRate>
        <cameraName>/camera</cameraName>
        <imageTopicName>image_raw</imageTopicName>
        <cameraInfoTopicName>camera_info</cameraInfoTopicName>
        <frameName>camera_link</frameName>
        <hackBaseline>0.07</hackBaseline>
      </plugin>
    </sensor>
    <material>Gazebo/Blue</material>
  </gazebo>

</robot>
```

Create a launch folder
Create a launch file rviz.launch.py

```
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch_ros.actions import Node

def generate_launch_description():
    package_dir = '/home/asha/ros2_ws/src/lab6/urdf'
    urdf = os.path.join(package_dir,'car.urdf')

    return LaunchDescription([
        Node(
            package='robot_state_publisher',
            executable='robot_state_publisher',
            name='robot_state_publisher',
            output='screen',
            arguments=[urdf]),

        Node(
            package='joint_state_publisher_gui',
            executable='joint_state_publisher_gui',
            name='joint_state_publisher_gui',
            arguments=[urdf]),

        Node(
            package='rviz2',
            executable='rviz2',
            name='rviz2',
            output='screen'),
        ])
```

Create a launch folder
Create a launch file gazebo.launch.py inside the launch folder

```
import os
from ament_index_python.packages import get_package_share_directory
from launch import LaunchDescription
from launch.actions import DeclareLaunchArgument, ExecuteProcess
from launch.substitutions import LaunchConfiguration
from launch_ros.actions import Node
from launch.launch_description_sources import PythonLaunchDescriptionSource

def generate_launch_description():
  urdf = '/home/asha/ros2_ws/src/lab6/urdf/car.urdf'
  return LaunchDescription([
    #   publishes TF for links of the robot without joints
        Node(
            package='robot_state_publisher',
            executable='robot_state_publisher',
            name='robot_state_publisher',
            output='screen',
            arguments=[urdf]),
       # publish TF for Joints only links
        Node(
            package='joint_state_publisher',
            executable='joint_state_publisher',
            name='joint_state_publisher',
            output='screen',
            ),
        # open gazebo
        ExecuteProcess(
            cmd=['gazebo', '--verbose', '-s', 'libgazebo_ros_factory.so'],
            output='screen'),
        Node(
            package='gazebo_ros',
            executable='spawn_entity.py',
            name='urdf_spawner',
            output='screen',
            arguments=["-topic", "/robot_description", "-entity", "lab6"])
  ])
```

- **Height and width**: These are the dimensions in camera pixels. In this case, it's 512 **x 512**.
- **Encoding**: How these pixels are encoded. This means what each value in the data array will mean. In this case, it's **rgb8**. This means that the data values will be a color value represented as red/green/blue in 8-bit integers.
- **Data**: The image data.

Terminal 1:
ros2 launch lab6 rviz.launch.py
ros2 launch lab6 gazebo.launch.py

ctrl + c to kill the rviz and gazebo window

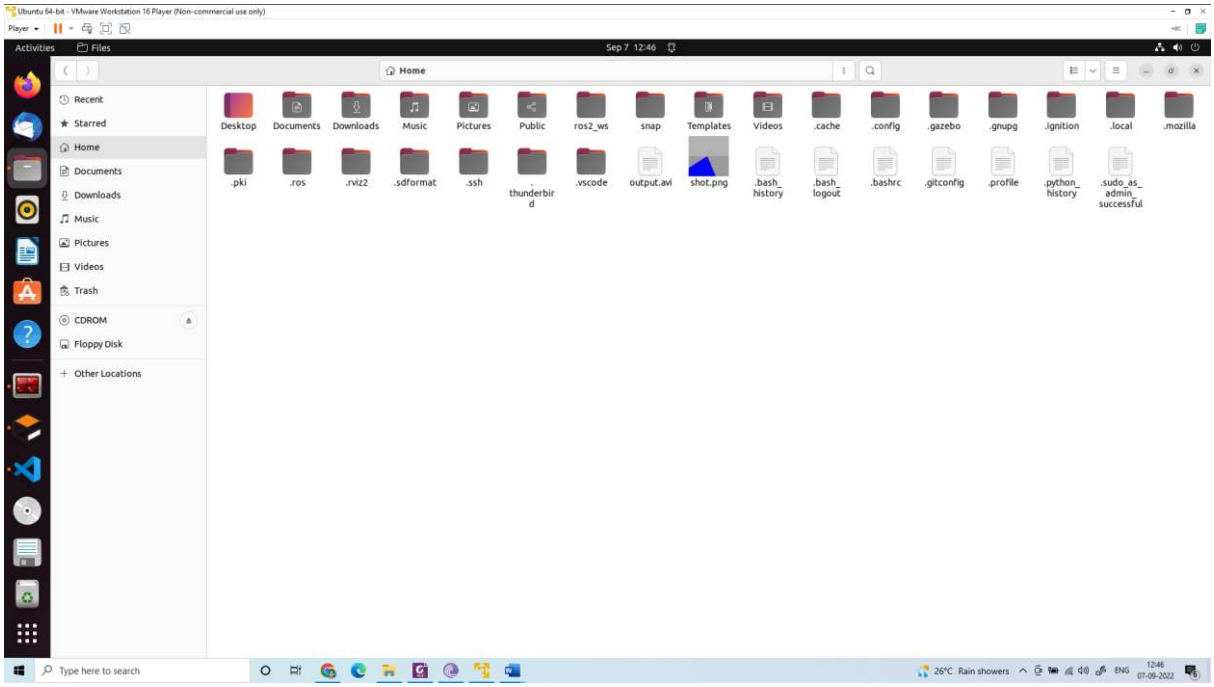
create a file capture_image.py inside the lab 6 folder

```
import rclpy
import cv2
from rclpy.node import Node
from cv_bridge import CvBridge
from sensor_msgs.msg import Image

class Capture(Node):
  def __init__(self):
    super().__init__('video_subscriber')
    self.subscriber =
self.create_subscription(Image,'/camera1/image_raw',self.process_data,10)
    self.out =
#cv2.VideoWriter('/home/asha/output.avi',cv2.VideoWriter_fourcc('M','J','P','G'), 10,
(512,512))
    self.bridge = CvBridge()

  def process_data(self, data):

    frame = self.bridge.imgmsg_to_cv2(data)
    self.out.write(frame)
    self.img = cv2.imwrite('/home/asha/shot.png', frame)
    cv2.imshow("output", frame)
    cv2.waitKey()
    cv2.destroyAllWindows()


def main(args=None):
  rclpy.init(args=args)
  node = Capture()
  rclpy.spin(node)
  rclpy.shutdown()

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

Terminal 1:
ros2 launch lab6 gazebo.launch.py
draw a line and place the robot on the line (insert→yellow line)

Terminal 2:
ros2 run lab6 capture

Press ctrl + c to capture the image of the road

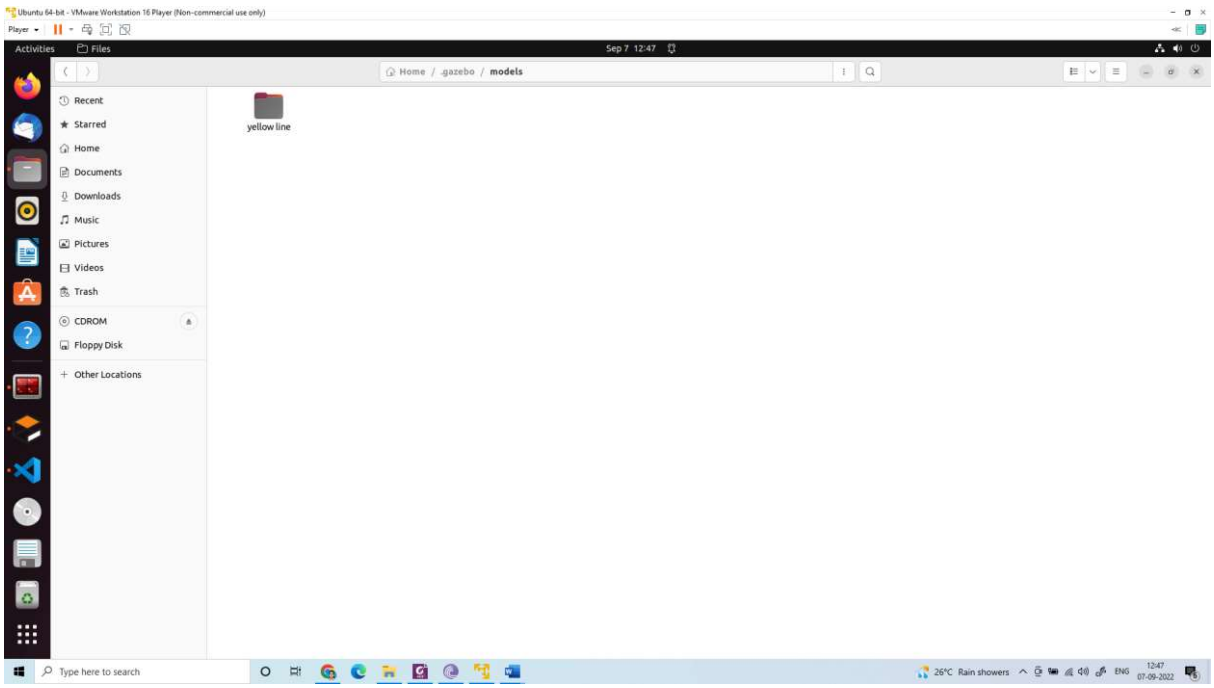


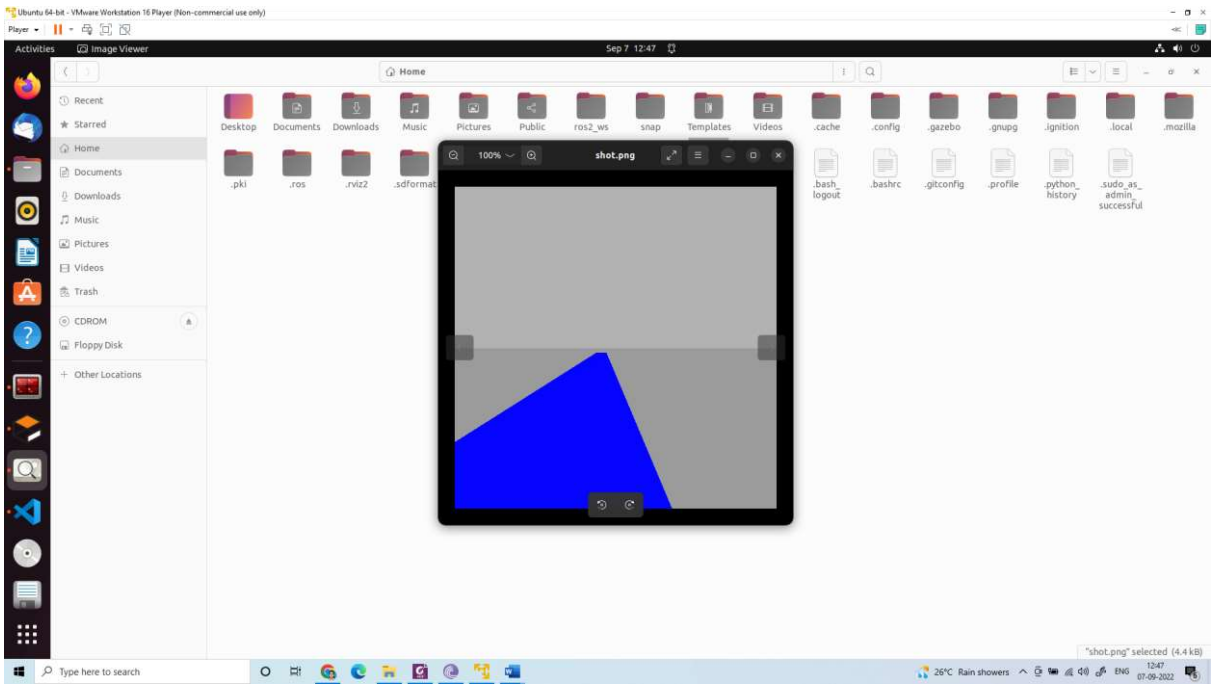
create a file extract_road.py inside the lab 6 folder

```
import cv2
import numpy

image = cv2.imread('/home/asha/shot.png')

def mouse(event,x,y,flags,param):
        if event==cv2.EVENT_LBUTTONDOWN:
                h=image[y,x,0]
                s=image[y,x,1]
                v=image[y,x,2]
                print("H:",h)
                print("S:",s)
                print("V:",v)

cv2.namedWindow('mouse')
cv2.setMouseCallback('mouse',mouse)


cv2.imshow("original image", image)
cv2.imshow("mouse", image)
cv2.waitKey(0)
cv2.destroyAllWindows()


light_line = numpy.array([250,0,0])
dark_line = numpy.array([255,10,10])
mask = cv2.inRange(image, light_line,dark_line)
cv2.imshow('mask', mask)
cv2.waitKey(0)
```

```
cv2.destroyAllWindows()

canny= cv2.Canny(mask,30,5)
cv2.imshow('edge', canny)
cv2.waitKey(0)
cv2.destroyAllWindows()
print(canny.shape)

r1=200;c1=0
img = canny[r1:r1+200,c1:c1+512]
cv2.imshow('crop', img)
cv2.waitKey(0)
cv2.destroyAllWindows()

edge=[]
row =150

for i in range (512):
    if(img[row,i]==255):
        edge.append(i)
print(edge)


if(len(edge)==4):
    left_edge=edge[0]
    right_edge=edge[2]
    print(edge)
if(len(edge)==3):
    if(edge[1]-edge[0] > 5):
        left_edge=edge[0]
        right_edge=edge[1]
    else:
        left_edge=edge[0]
        right_edge=edge[2]

road_width=(right_edge-left_edge)
frame_mid = left_edge + (road_width/2)
mid_point = 512/2
img[row,int(mid_point)]=255
print(mid_point)
error=mid_point-frame_mid

if(error < 0):
    action="Go Right"
else :
    action="Go Left"

print("error", error)


img[row,int(frame_mid)]=255
```

```
print("mid point of the frame", frame_mid)


f_image = cv2.putText(img, action, (50,50), cv2.FONT_HERSHEY_SIMPLEX, 1,
(255,0,0), 1, cv2.LINE_AA)
cv2.imshow('final image',f_image)
cv2.waitKey(0)
cv2.destroyAllWindows()
```





Create a line_follow.py inside the folder lab 6

```
#!/usr/bin/env python3

import sys
import cv2
import numpy
import rclpy
from rclpy.node import Node
from cv_bridge import CvBridge
from sensor_msgs.msg import Image
from geometry_msgs.msg import Twist

class LineFollower(Node):
    def __init__(self):
        super().__init__('line_follower')
        self.bridge = CvBridge()
        self.subscriber =
self.create_subscription(Image,'/camera1/image_raw',self.process_data, 10)
        self.publisher = self.create_publisher(Twist, '/cmd_vel', 40)
        timer_period = 0.2
        self.timer = self.create_timer(timer_period, self.send_cmd_vel)
        self.velocity=Twist()
        self.empty = False
        self.error = 0
        self.action=""
        self.get_logger().info("Node Started!")

    def send_cmd_vel(self):

        if(self.empty):
            self.velocity.linear.x=0.0
            self.velocity.angular.z= 0.0
            self.action="Stop"

        else:
            if(self.error > 0):
                self.velocity.linear.x=0.1
                self.velocity.angular.z=0.1
                self.action="Go Left"
            elif(self.error < 0):
                self.velocity.linear.x=0.1
                self.velocity.angular.z=-0.1
                self.action="Go Right"
            elif(self.error==0):
                self.velocity.linear.x=0.1
                self.velocity.angular.z= 0.0
                self.action="Go Straight"
```

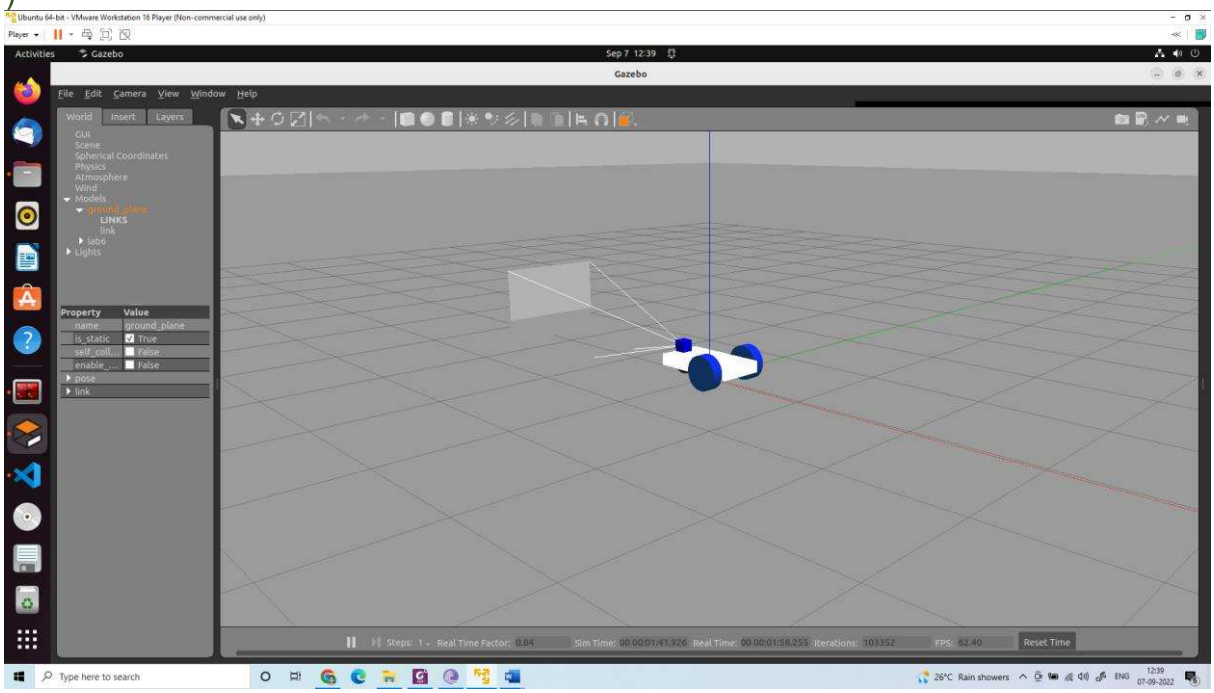
```
    self.publisher.publish(self.velocity)


## Subscriber Call Back

def process_data(self, data):
    self.get_logger().info("Image Received!")
    frame = self.bridge.imgmsg_to_cv2(data)
    light_line = numpy.array([250,0,0])
    dark_line = numpy.array([255,10,10])
    mask = cv2.inRange(frame, light_line,dark_line)
    cv2.imshow('mask', mask)


    canny= cv2.Canny(mask,30,5)
    cv2.imshow('edge', canny)


    r1=200;c1=0
    img = canny[r1:r1+200,c1:c1+512]
    cv2.imshow('crop', img)


    edge=[]
    row =150

    for i in range(512):
        if(img[row,i]==255):
            edge.append(i)
    print(edge)

    if(len(edge)==0):
        left_edge=512//2
        right_edge=512//2
        self.empty = True

    if(len(edge)==1):
        if edge[0]>512//2:
            left_edge=0
            right_edge=edge[0]
            self.empty = False
        else:
            left_edge=edge[0]
            right_edge=512
            self.empty = False


    if(len(edge)==2):
        left_edge=edge[0]
```

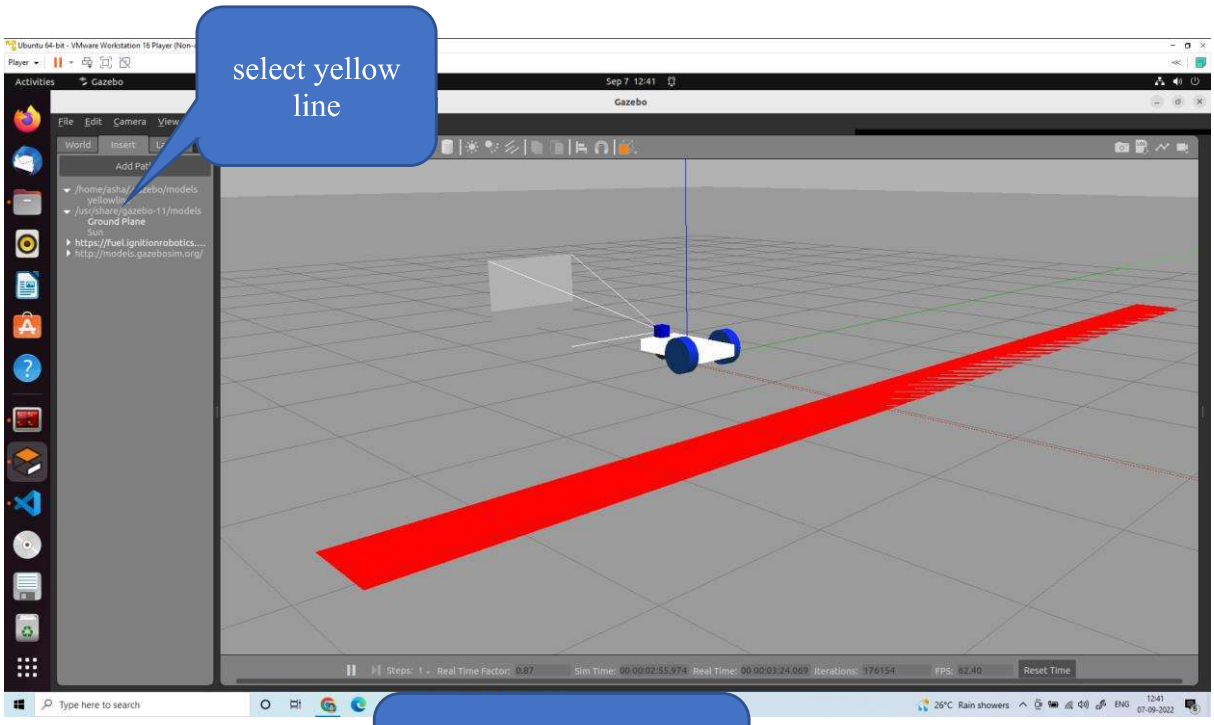
```
            right_edge=edge[1]
            self.empty = False

        if(len(edge)==3):
            if(edge[1]-edge[0]>5):
                left_edge=edge[0]
                right_edge=edge[1]
                self.empty = False
            else:
                left_edge=edge[0]
                right_edge=edge[2]
                self.empty = False

        if(len(edge)==4):
            left_edge=edge[0]
            right_edge=edge[2]
            self.empty = False

        if(len(edge)>=5):
            left_edge=edge[0]
            right_edge=edge[len(edge)-1]
            self.empty = False


        road_width=(right_edge-left_edge)
        frame_mid = left_edge + (road_width/2)
        mid_point = 512/2
        img[row,int(mid_point)]=255
        print(mid_point)
        self.error=mid_point-frame_mid
        img[row,int(frame_mid)]=255
        print(self.action)
        f_image = cv2.putText(img, self.action, (100,100), cv2.FONT_HERSHEY_SIMPLEX,
1, (255,0,), 2, cv2.LINE_AA)

def main(args=None):
  rclpy.init(args=args)
  node = LineFollower()
  rclpy.spin(node)
  rclpy.shutdown()

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

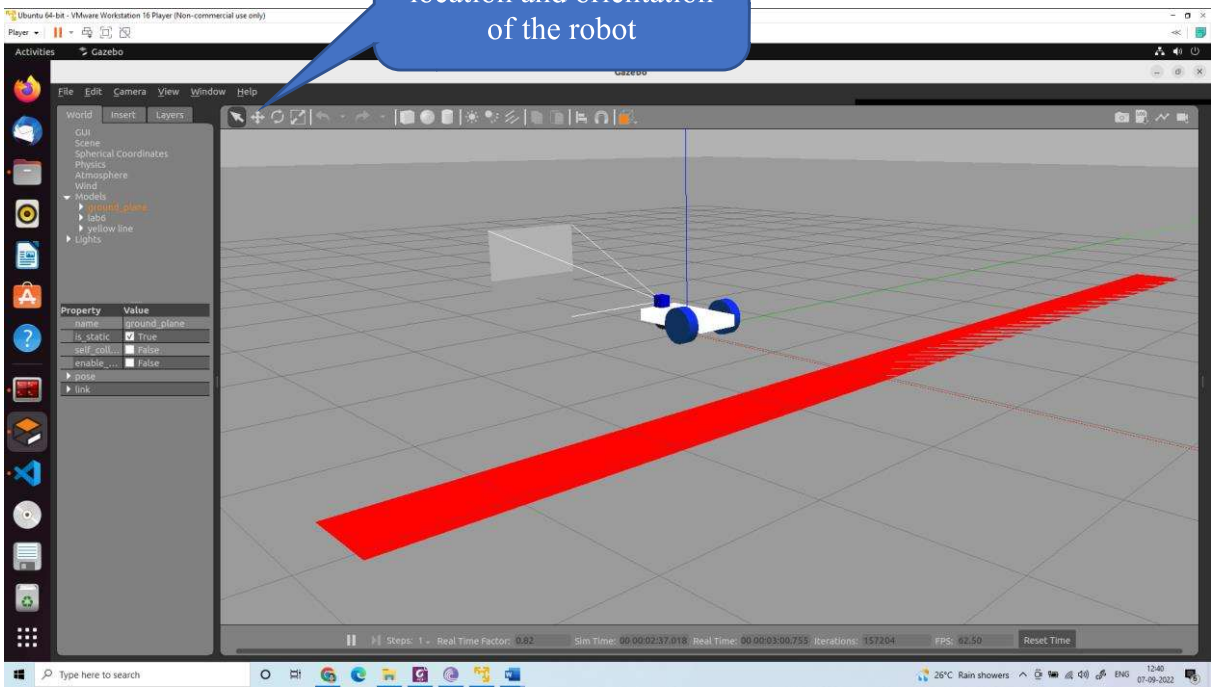
edit setup.py file

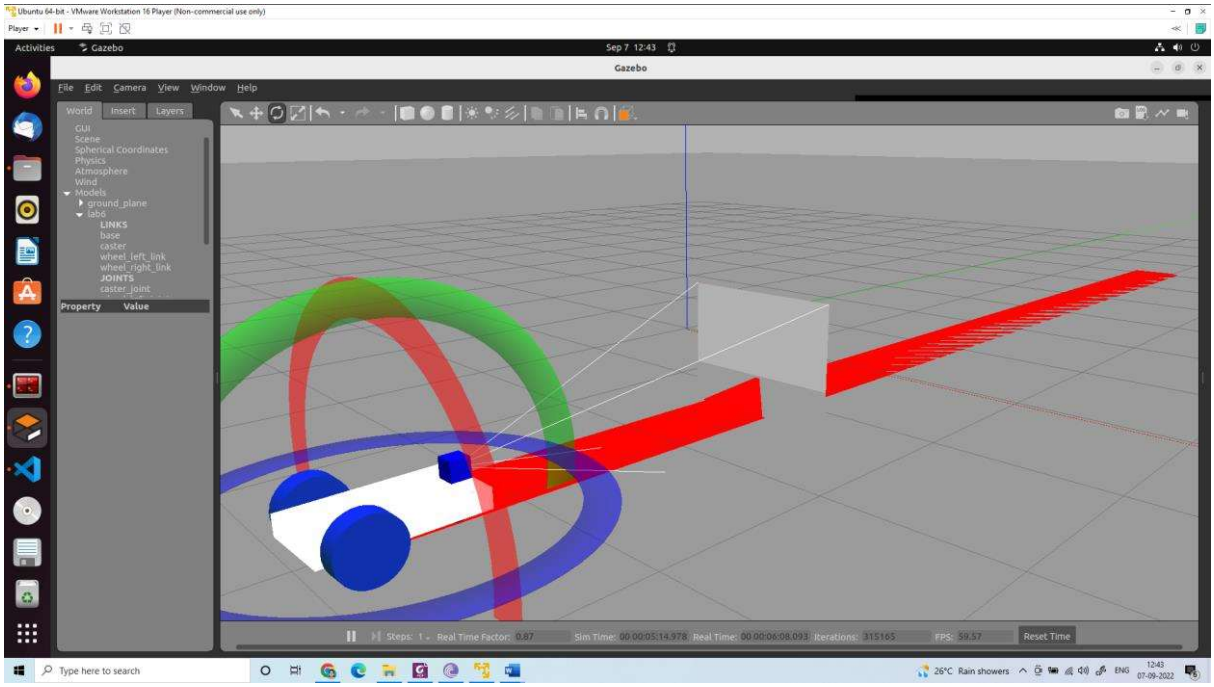
```
from setuptools import setup
import os
```

```
from glob import glob

package_name = 'lab6'

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
        (os.path.join('share', package_name), glob('launch/*')),
        (os.path.join('share', package_name), glob('urdf/*'))
    ],
    install_requires=['setuptools'],
    zip_safe=True,
    maintainer='asha',
    maintainer_email='asha.cs12@gmail.com',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
            'capture = lab6.capture_image:main',
            'line = lab6.line_follow:main'
        ],
    },
)
```




select yellow line

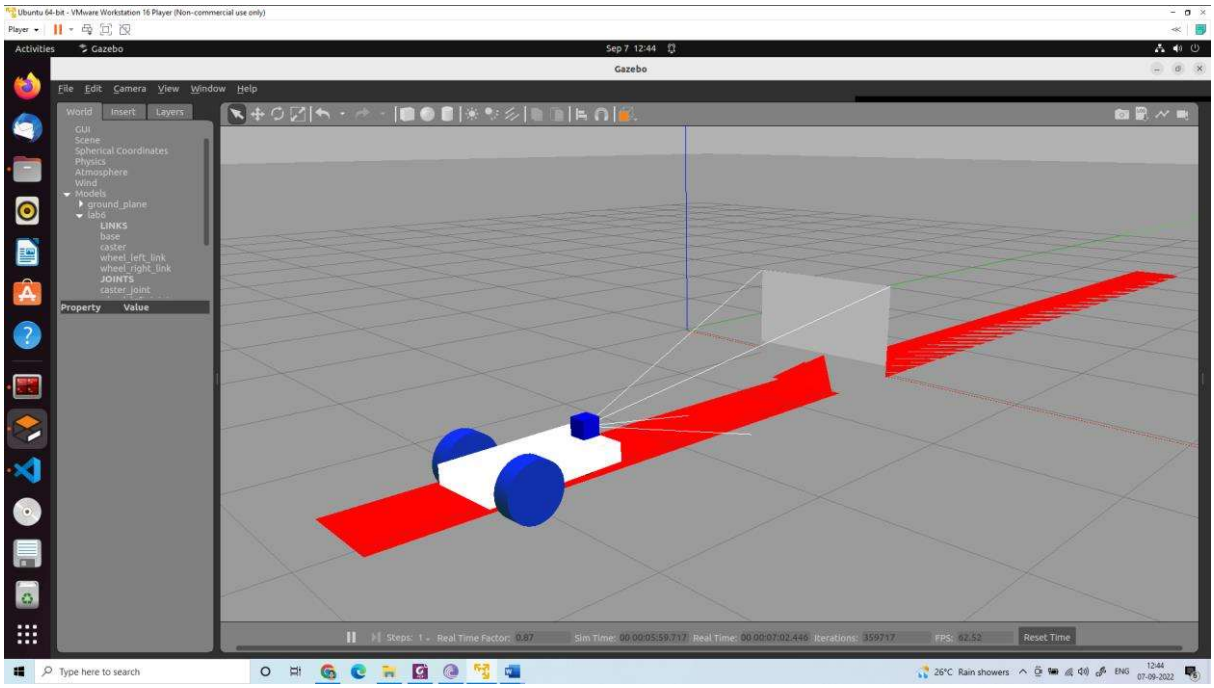

Use these to change the location and orientation of the robot

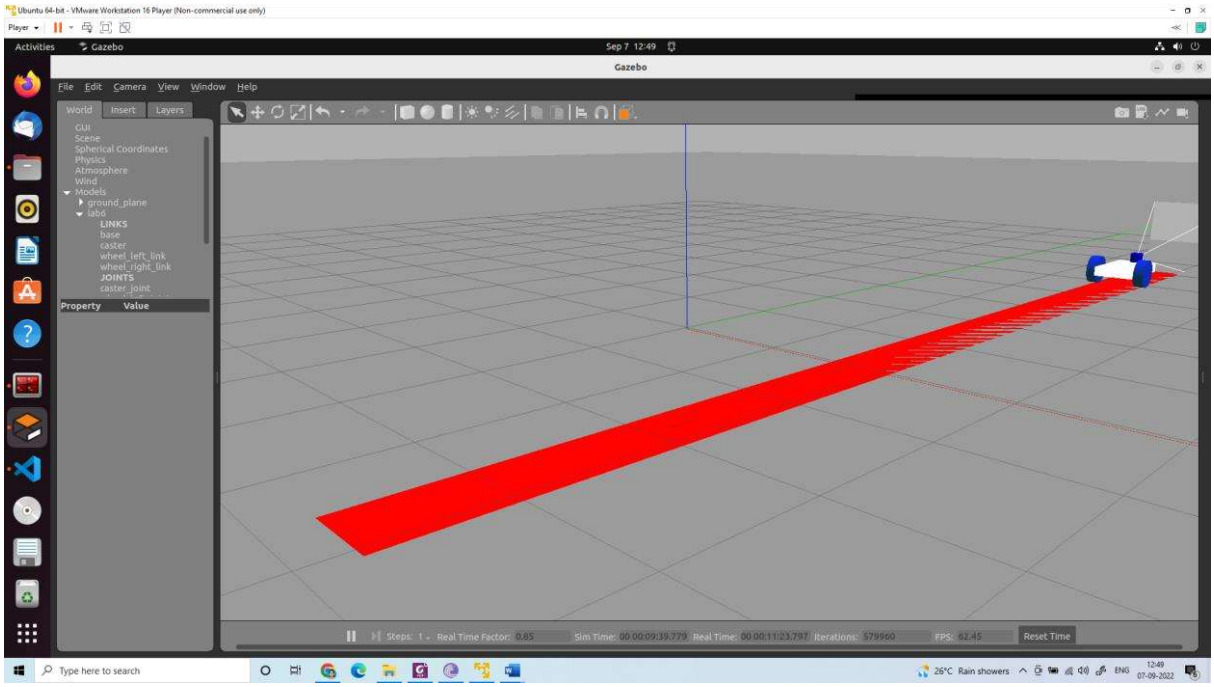


Terminal 1:
ros2 launch lab6 gazebo.launch.py

Terminal 2:
ros2 topic list

Terminal 3:
ros2 run lab6 line





Create a red line

Create a world folder
Create a yellow line folder
Supplementary material:

Create a model.config

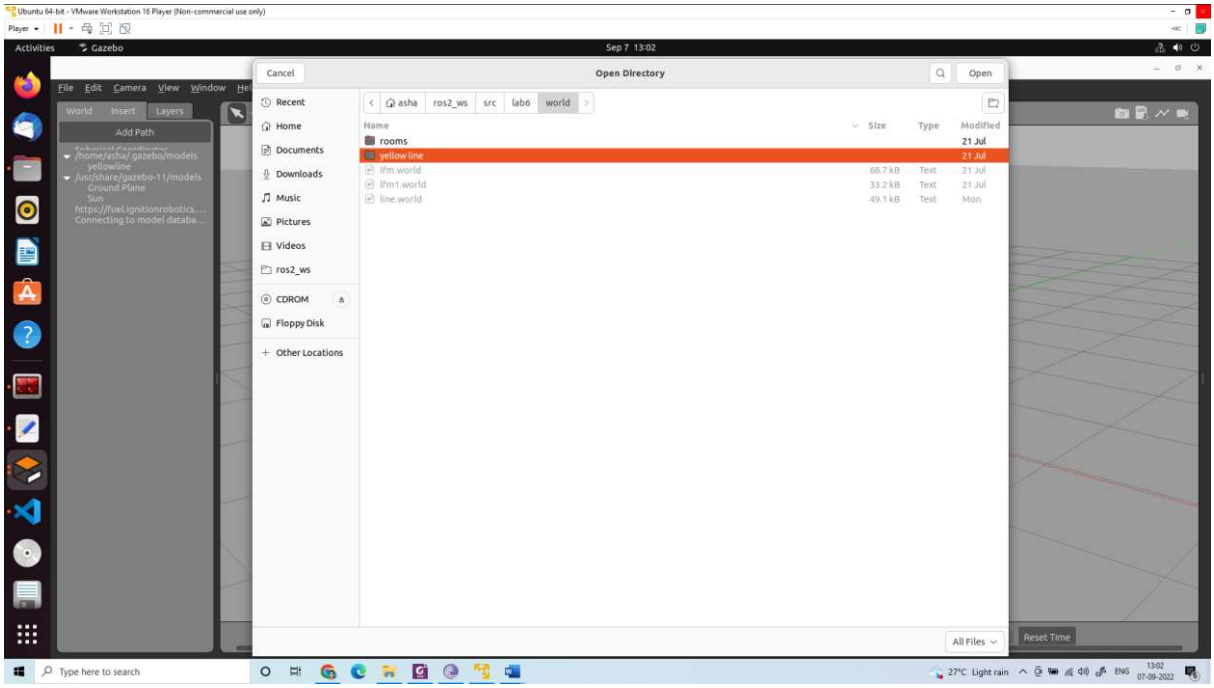
```
<?xml version="1.0" ?>
<model>
    <name>yellowline</name>
    <version>1.0</version>
    <sdf version="1.6">model.sdf</sdf>
    <author>
        <name></name>
        <email></email>
    </author>
    <description></description>
</model>
```

Create a model.sdf

```
<?xml version="1.0"?>
<sdf version="1.6">
<model name="yellow line">
  <static>true</static>
    <link name="link_ground">
      <collision name="collision">
```

```
      <geometry>
        <plane>
          <normal>0 0 1</normal>
          <size>0.1 3.2</size>
        </plane>
      </geometry>

      <surface>
        <friction>
          <ode>
            <mu>100</mu>
            <mu2>50</mu2>
          </ode>
        </friction>
      </surface>
    </collision>
    <visual name="visual_ground">
      <cast_shadows>false</cast_shadows>
      <geometry>
        <plane>
          <normal>0 0 1</normal>
          <size>0.5 10</size>
        </plane>
      </geometry>
     <material>
        <script>
          <uri>file://media/materials/scripts/gazebo.material</uri>
          <name>Gazebo/Red</name>
        </script>
      </material>
    </visual>
  </link>
 </model>
</sdf>
```

Copy the folder into /home/asha/.gazebo/models/
In the gazebo window (gazebo)
Insert→/home/asha/.gazebo/models/→yellow line→all files
close gazebo (killall 9 gzserver) and open again (gazebo)



Insert→/home/asha/.gazebo/models/→yellow line

Exercise: Write a code to track the red ball in the gazebo simulation.

ROS2 control for Turtlebot 2

sudo apt-get install ros-foxy-teleop-twist-keyboard
sudo apt-get install ros-foxy-joint-state-publisher
sudo apt-get install ros-foxy-xacro
sudo apt-get install ros-foxy-kobuki-*

ros2 launch turtlebot_interface interface.launch.py
ros2 run teleop_twist_keyboard teleop_twist_keyboard
sudo apt-get update && sudo apt-get upgrade -y && sudo apt-get dist-upgrade -y

Open Terminal

hostname -I
or ifconfig

note down the IP address

From a remote computer you can connect to turtlebot Laptop

Using PuTTY (in windows)

Reminna (in Ubuntu)

ssh username@ipaddress (in terminal)

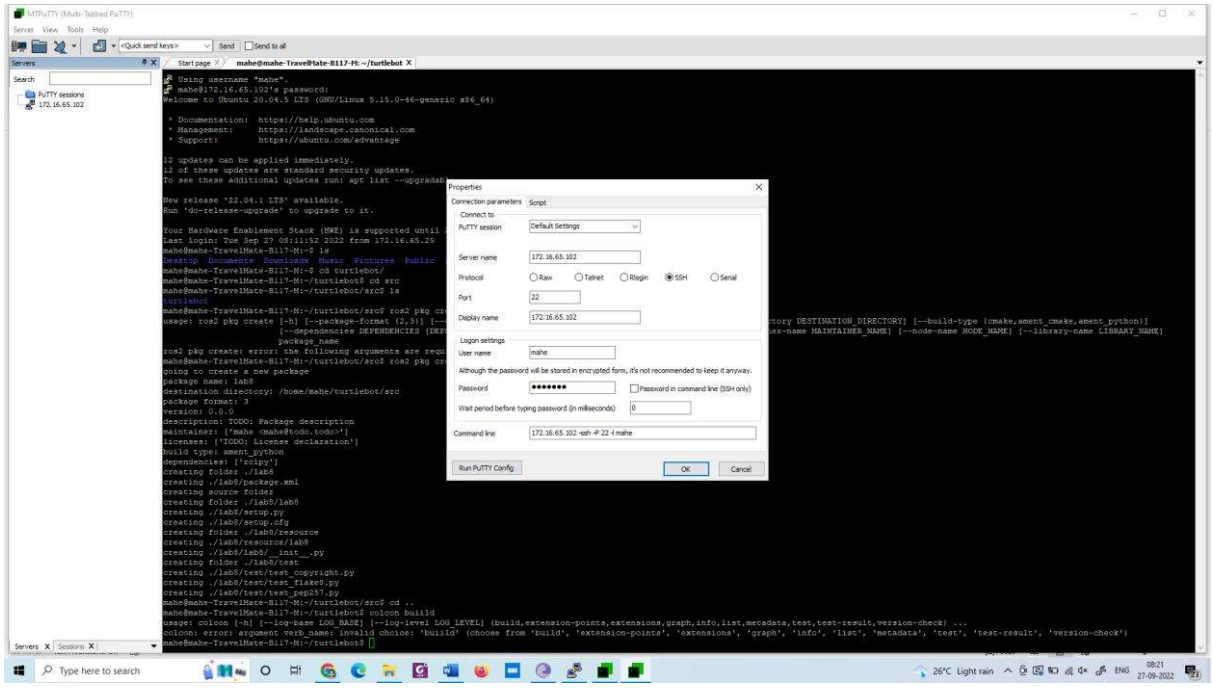
Connect camera USB and Kubuki USB and switch on Kubuki.
Switch on the netbook.
Use Remmina to connect to turtlebot from Ubuntu/mtputty from windows
See that the turtlebot laptop and remote laptop are connected to same WiFi
Find the address of netbook placed on turtlebot
Open terminal and type
$ifconfig
Copy the address inet addr: ----(For example 172.16.65.109)
Open Remmina
Establish SSH connection
Type Name (for example turtlebot)
Server Name: 172.16.65.109
User name: mahe or robolab
Password:robolab

Open the terminal and type

$ ros2 launch turtlebot_interface interface.launch.py

Open another terminal and type

$ ros2 run teleop_twist_keyboard teleop_twist_keyboard



cd turtlebot
cd src
ros2 pkg create lab8 –build-type ament_python –dependencies rclpy
cd ..
colcon build
Open lab8 using visual studio
Create a python file move_robot.py inside lab8 folder

```
#!/usr/bin/env python
import rclpy
from geometry_msgs.msg import Twist
from nav_msgs.msg import Odometry
from rclpy.node import Node
import sys



class MoveRobot(Node):
    def __init__(self):
        super().__init__("move_robot")
```

```
        self.lin_vel = 0.1
        self.ang_vel = 0.0
        self.distance = 1.0
        self.publisher = self.create_publisher(Twist, "/cmd_vel", 10)
        self.subscriber = self.create_subscription(Odometry, "odom", self.control_loop,
10)

    def control_loop(self, msg):
        X=msg.pose.pose.position.x
        print("position", X)
        vel = Twist()
        if abs(X) < self.distance:
            vel.linear.x = self.lin_vel
            vel.angular.z = 0.0
        else:
            vel.linear.x = 0.0
            vel.angular.z = 0.0
        print('speed : {}'.format(vel))
        self.publisher.publish(vel)

def main(args=None):
    rclpy.init(args=args)
    node = MoveRobot()
    rclpy.spin(node)
    rclpy.shutdown()


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

Edit setup.py as follows

```
from setuptools import setup

package_name = 'gotogoal'

setup(
    name=package_name,
    version='0.0.0',
    packages=[package_name],
    data_files=[
        ('share/ament_index/resource_index/packages',
            ['resource/' + package_name]),
        ('share/' + package_name, ['package.xml']),
    ],
    install_requires=['setuptools'],
```

```
    zip_safe=True,
    maintainer='mahe',
    maintainer_email='mahe@todo.todo',
    description='TODO: Package description',
    license='TODO: License declaration',
    tests_require=['pytest'],
    entry_points={
        'console_scripts': [
            'move = lab8.move_robot:main'
        ],
    },
)
```

```
cd ~/turtlebot/
colcon build
```

Terminal 1:

```
ros2 launch turtlebot_interface interface.launch.py
```

Terminal 2:

```
ros2 topic list
```

Terminal 2:

```
ros2 run lab8 move
```

Example 2:

```
#!/usr/bin/env python
import rclpy
from geometry_msgs.msg import Twist
from nav_msgs.msg import Odometry
from rclpy.node import Node
import math
import time
from std_srvs.srv import Empty
import sys



class MoveRobot(Node):
    def __init__(self):
        super().__init__("move_robot")
        self.lin_vel = 0.1
        self.ang_vel = 0.0
        self.distance = 1.0
        self.publisher = self.create_publisher(Twist, "/cmd_vel", 10)
        self.move(0.1,5,True)
        time.sleep(2)
```

```
        self.rotate(30,125,False)
        self.stop()

    def move(self, speed, time, is_forward):
        t0= self.get_clock().now()
         self.velocity = Twist()
         if(is_forward):
              self.velocity.linear.x = abs(speed)
              self.get_logger().info("Turtlebot moving forward")

         else:
             self.velocity.linear.x =-abs(speed)
             self.get_logger().info("Turtlebot moving backward")
             t1= self.get_clock().now()
             if (t1-t0)>time:
                  self.get_logger().info("Time closed")
                  self.get_logger().warn("Stopping the robot")
                  self.velocity.linear.x =0

         self.publisher.publish(self.velocity)

def stop(self):
        self.velocity = Twist()
         self.velocity.linear.x=0
         self.publisher.publish(self.velocity)

def rotate(self, ang_speed_deg,relative,speed_deg,clockwise):
self.velocity = Twist()
         self.velocity.linear.x=0
         ang_speed=math.radians(abs(ang_speed_deg))
         if(clockwise):
                self.velocity.angular.z=-abs(ang_speed)
         else:
                self.velocity.angular.z=abs(ang_speed)
        angle_moved = 0
        t0= self.get_clock().now()
        while(True):
                self.publisher.publish(self.velocity)
                self.get_logger().info("Turtlebot ratates")
                t1= self.get_clock().now()
                current_ang = (t1-t0)*ang_speed_degree
                if(current_ang > relative_speed_deg):
                        self.get_logger().info("Reached")
                        break
         self.velocity.angular.z=0
         self.publisher.publish(self.velocity)
```

```
def main(args=None):
    rclpy.init(args=args)
    node = MoveRobot()
    rclpy.spin(node)
    rclpy.shutdown()

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

UR5 control using ROS2

sudo apt-get update && sudo apt-get upgrade -y && sudo apt-get dist-upgrade -y

sudo apt-get install python3-colcon-ros

sudo apt-get install python3-colcon-bash

sudo apt update && sudo apt install curl gnupg2 lsb-release

sudo curl -sSL https://raw.githubusercontent.com/ros/rosdistro/master/ros.key -o /usr/share/keyrings/ros-archive-keyring.gpg

echo "deb [arch=$(dpkg --print-architecture) signed-by=/usr/share/keyrings/ros-archive-keyring.gpg] http://packages.ros.org/ros2/ubuntu $(source /etc/os-release && echo $UBUNTU_CODENAME) main" | sudo tee /etc/apt/sources.list.d/ros2.list > /dev/null

sudo apt update

sudo apt-get upgrade

sudo apt install ros-foxy-desktop
sudo apt install ros-foxy-moveit
sudo apt install ros-foxy-ros2-control
sudo apt install ros-foxy-rqt-service-caller
sudo apt install ros-foxy-warehouse-ros-mongo

mkdir ur5
cd ur5
mkdir ros2
cd ros2
mkdir src
cd src

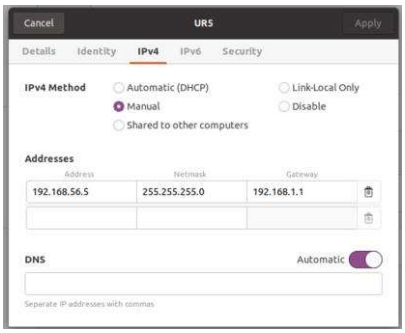
git clone --recurse-submodules -j8 https://github.com/ashacs2/ur5_interface.git -b ros2
git clone --recurse-submodules -j8 https://github.com/ashacs2/ur5_ros2_interface.git -b ros2
gedit ~/.bashrc
source ~/ur5/ros2/install/setup.bash

cd ur5/ros2/

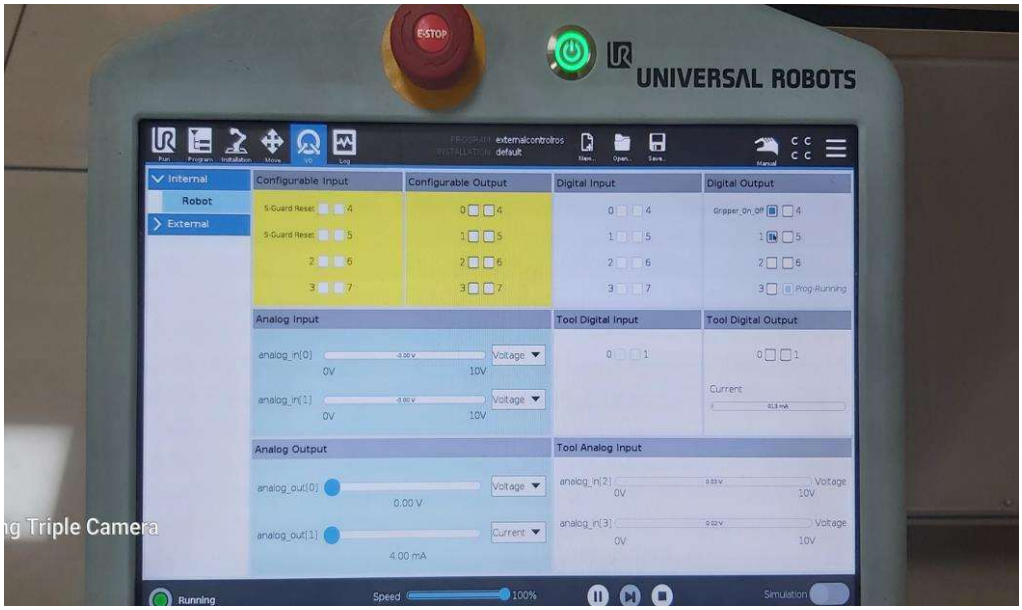
rosdep install --from-paths src --ignore-src -r -y

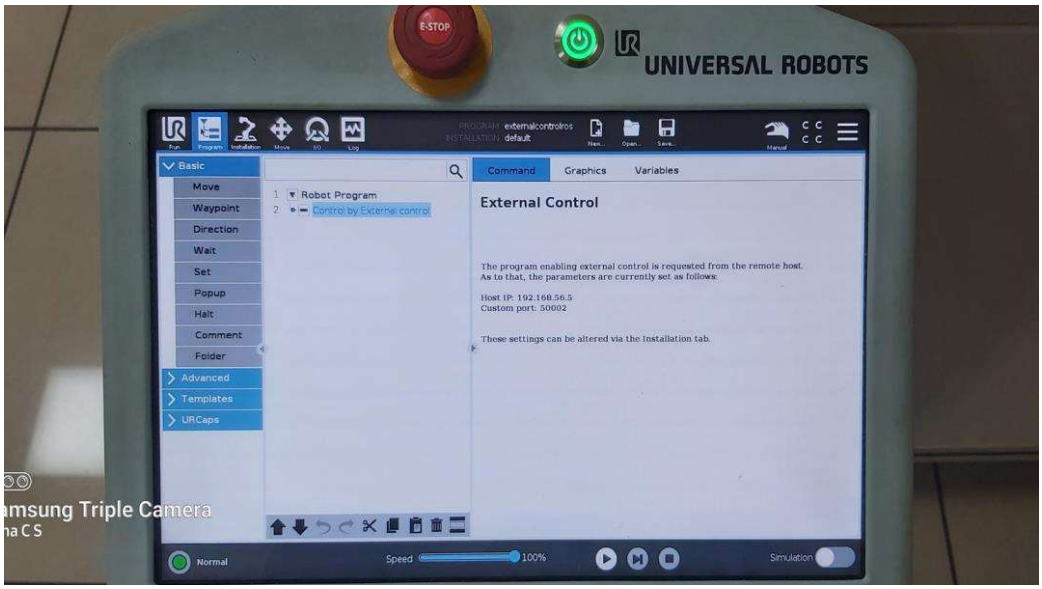
cd ..
colcon build --symlink-install --cmake-args -
DCMAKE_EXPORT_COMPILE_COMMANDS=1

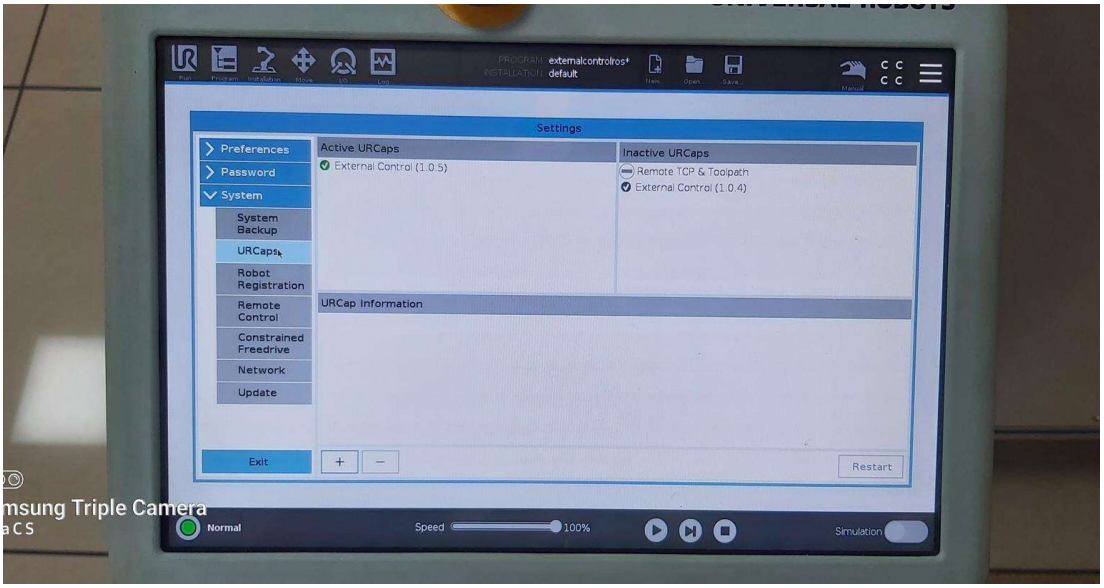
Connect an ethernet cable from UR5 to PC.

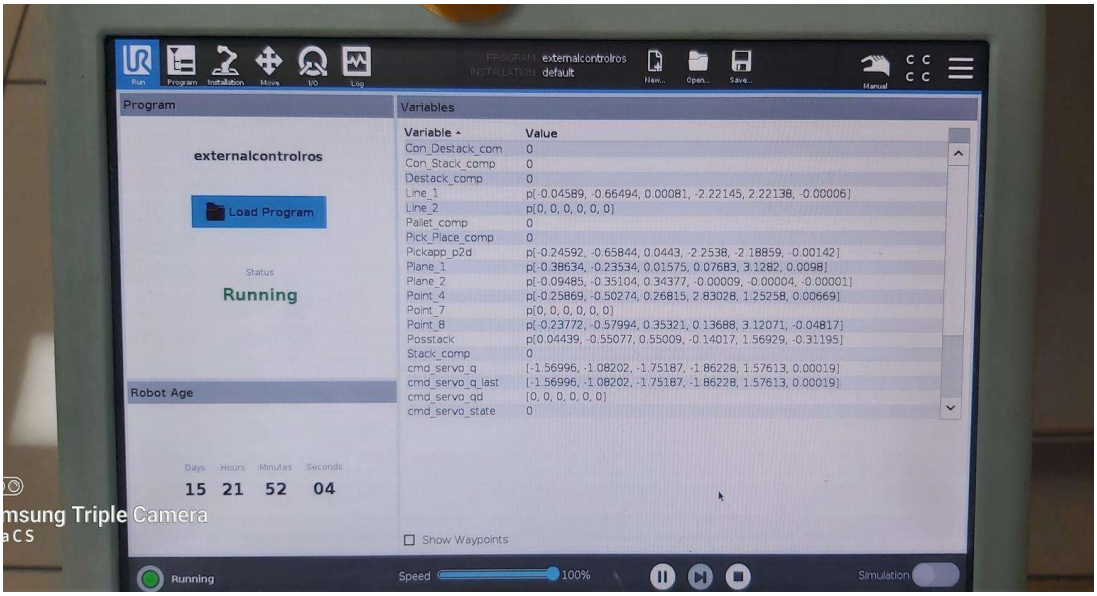


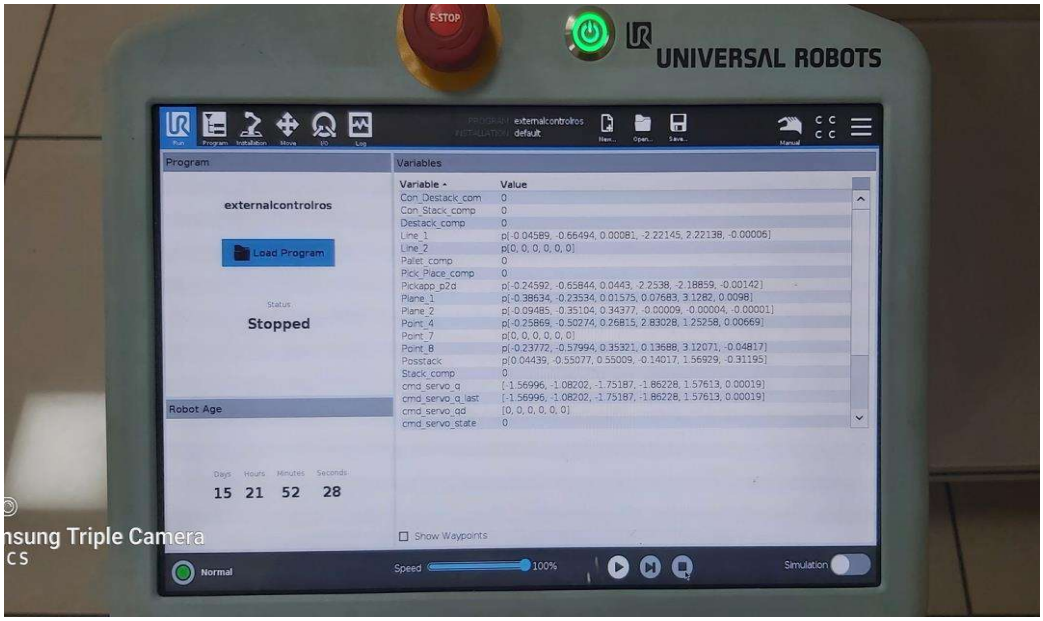
Settings in Teach Pendent:

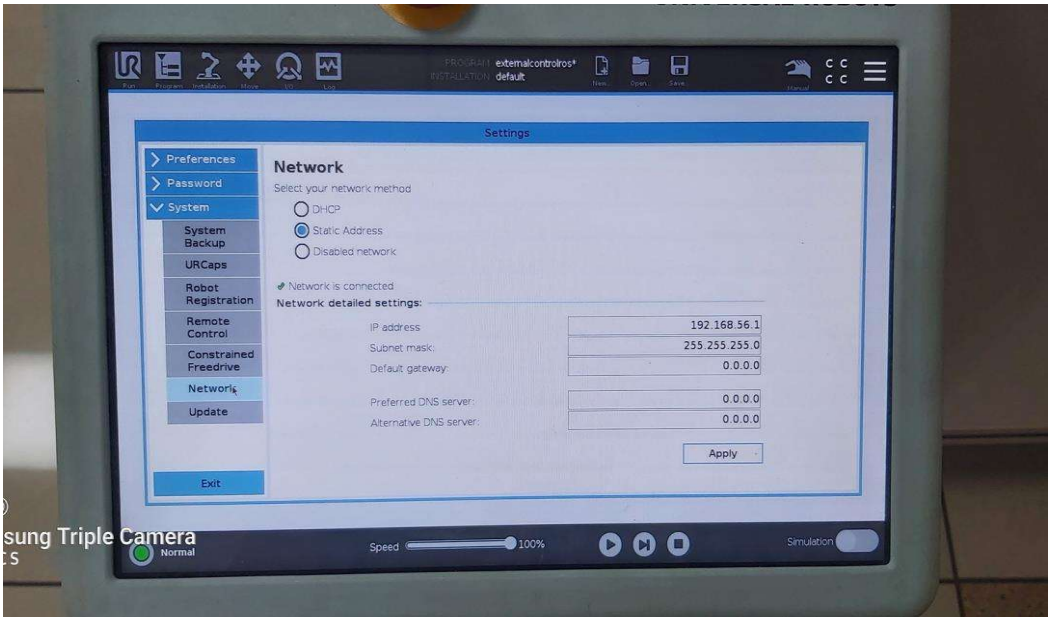


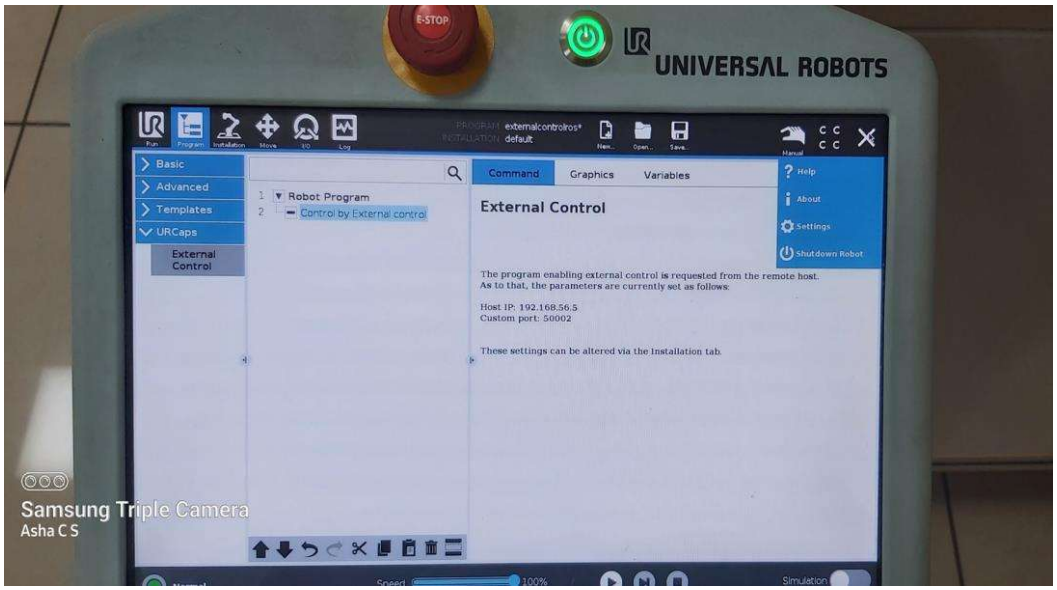

E-STOP
UNIVERSAL ROBOTS
Basic
Move
Waypoint
Direction
Wait
Set
Popup
Halt
Comment
Folder
Advanced
Templates
URCaps
Robot Program
Control by External control
Command
Graphics
Variables
External Control
The program enabling external control is requested from the remote host.
As to that, the parameters are currently set as follows:
Host IP: 192.168.56.5
Custom port: 50002
These settings can be altered via the Installation tab.
Normal
Speed
100%
Simulation


Settings
Preferences
Password
System
System Backup
URCaps
Robot Registration
Remote Control
Constrained Freedrive
Network
Update
Active URCaps
External Control (1.0.5)
Inactive URCaps
Remote TCP & Toolpath
External Control (1.0.4)
URCap Information
Exit
Restart
Normal
Speed
100%
Simulation

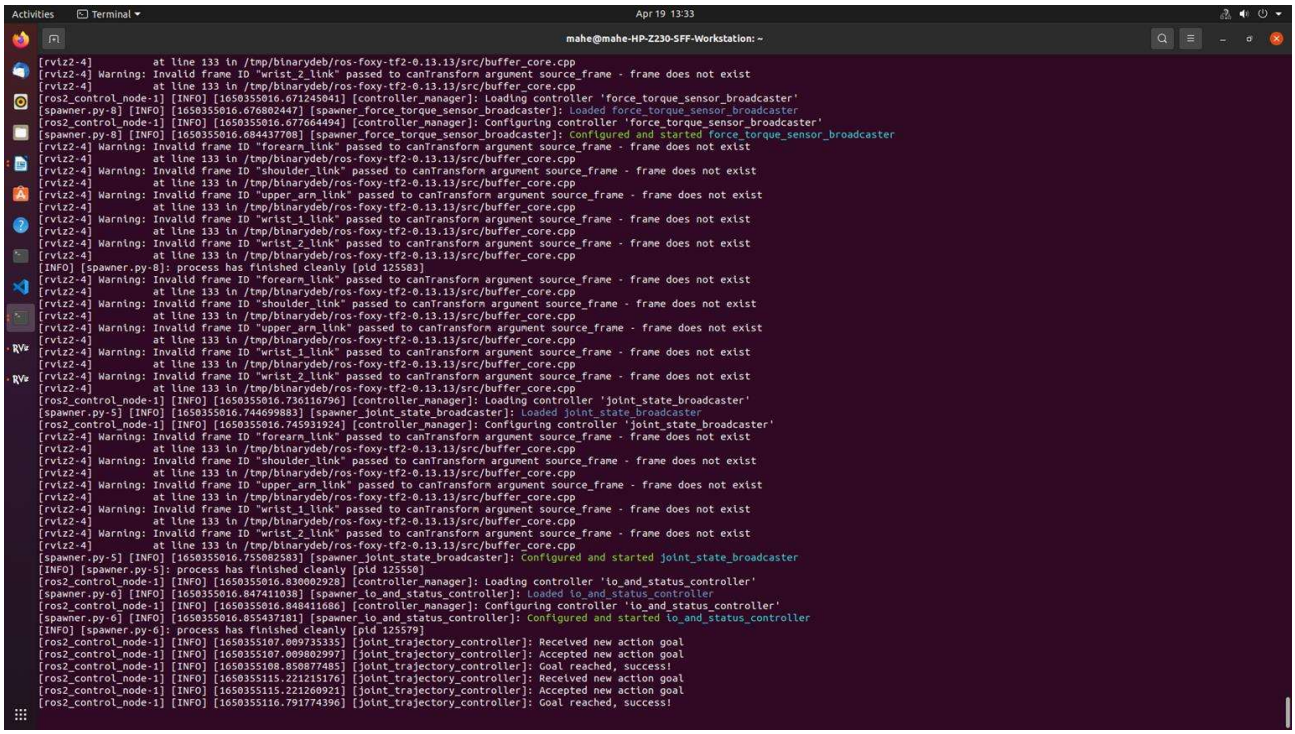

Run
Program
Installation
Move
I/O
Log
PROGRAM externalcontrolros
INSTALLATION default
New...
Open...
Save...
Manual
Program
externalcontrolros
Load Program
Status
Running
Robot Age
Days Hours Minutes Seconds
15 21 52 04
Variables
Variable
Value
Con_Destack_com 0
Con_Stack_comp 0
Destack_comp 0
Line_1 p[-0.04589, -0.66494, 0.00081, -2.22145, 2.22138, -0.00006]
Line_2 p[0, 0, 0, 0, 0, 0]
Pallet_comp 0
Pick_Place_comp 0
Pickapp_p2d p[-0.24592, -0.65844, 0.0443, -2.2538, -2.18859, -0.00142]
Plane_1 p[-0.38634, -0.23534, 0.01575, 0.07683, 3.1282, 0.0098]
Plane_2 p[-0.09485, -0.35104, 0.34377, -0.00009, -0.00004, -0.00001]
Point_4 p[-0.25869, -0.50274, 0.26815, 2.83028, 1.25258, 0.00669]
Point_7 p[0, 0, 0, 0, 0, 0]
Point_8 p[-0.23772, -0.57994, 0.35321, 0.13688, 3.12071, -0.04817]
Posstack p[0.04439, -0.55077, 0.55009, -0.14017, 1.56929, -0.31195]
Stack_comp 0
cmd_servo_q [-1.56996, -1.08202, -1.75187, -1.86228, 1.57613, 0.00019]
cmd_servo_q_last [-1.56996, -1.08202, -1.75187, -1.86228, 1.57613, 0.00019]
cmd_servo_qd [0, 0, 0, 0, 0, 0]
cmd_servo_state 0
Show Waypoints
Running
Speed 100%
Simulation

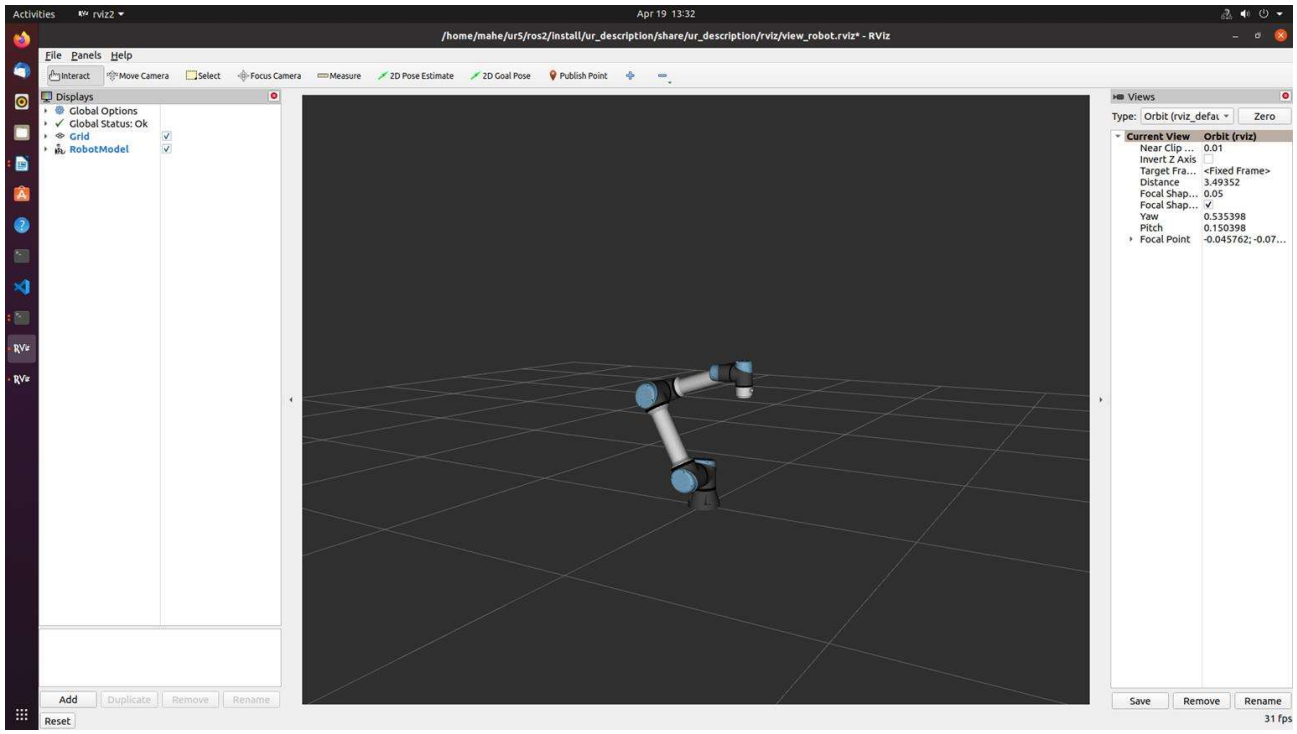

E-STOP
UNIVERSAL ROBOTS
Program
externalcontrolros
Load Program
Status
Stopped
Robot Age
Days Hours Minutes Seconds
15 21 52 28
Variables
Variable
Value
Con_Destack_com 0
Con_Stack_comp 0
Destack_comp 0
Line_1 p[-0.04589, -0.66494, 0.00081, -2.22145, 2.22138, -0.00006]
Line_2 p[0, 0, 0, 0, 0, 0]
Pallet_comp 0
Pick_Place_comp 0
Pickapp_p2d p[-0.24592, -0.65844, 0.0443, -2.2538, -2.18859, -0.00142]
Plane_1 p[-0.38634, -0.23534, 0.01575, 0.07683, 3.1282, 0.0098]
Plane_2 p[-0.09485, -0.35104, 0.34377, -0.00009, -0.00004, -0.00001]
Point_4 p[-0.25869, -0.50274, 0.26815, 2.83028, 1.25258, 0.00669]
Point_7 p[0, 0, 0, 0, 0, 0]
Point_8 p[-0.23772, -0.57994, 0.35321, 0.13688, 3.12071, -0.04817]
Posstack p[0.04439, -0.55077, 0.55009, -0.14017, 1.56929, -0.31195]
Stack_comp 0
cmd_servo_q [-1.56996, -1.08202, -1.75187, -1.86228, 1.57613, 0.00019]
cmd_servo_q_last [-1.56996, -1.08202, -1.75187, -1.86228, 1.57613, 0.00019]
cmd_servo_qd [0, 0, 0, 0, 0, 0]
cmd_servo_state 0
Show Waypoints
Normal
Speed 100%
Simulation


PROGRAM externalcontrolros*
INSTALLATION default
Settings
Preferences
Password
System
System Backup
URCaps
Robot Registration
Remote Control
Constrained Freedrive
Network
Update
Exit
Network
Select your network method
DHCP
Static Address
Disabled network
Network is connected
Network detailed settings:
IP address: 192.168.56.1
Subnet mask: 255.255.255.0
Default gateway: 0.0.0.0
Preferred DNS server: 0.0.0.0
Alternative DNS server: 0.0.0.0
Apply
Normal
Speed 100%
Simulation



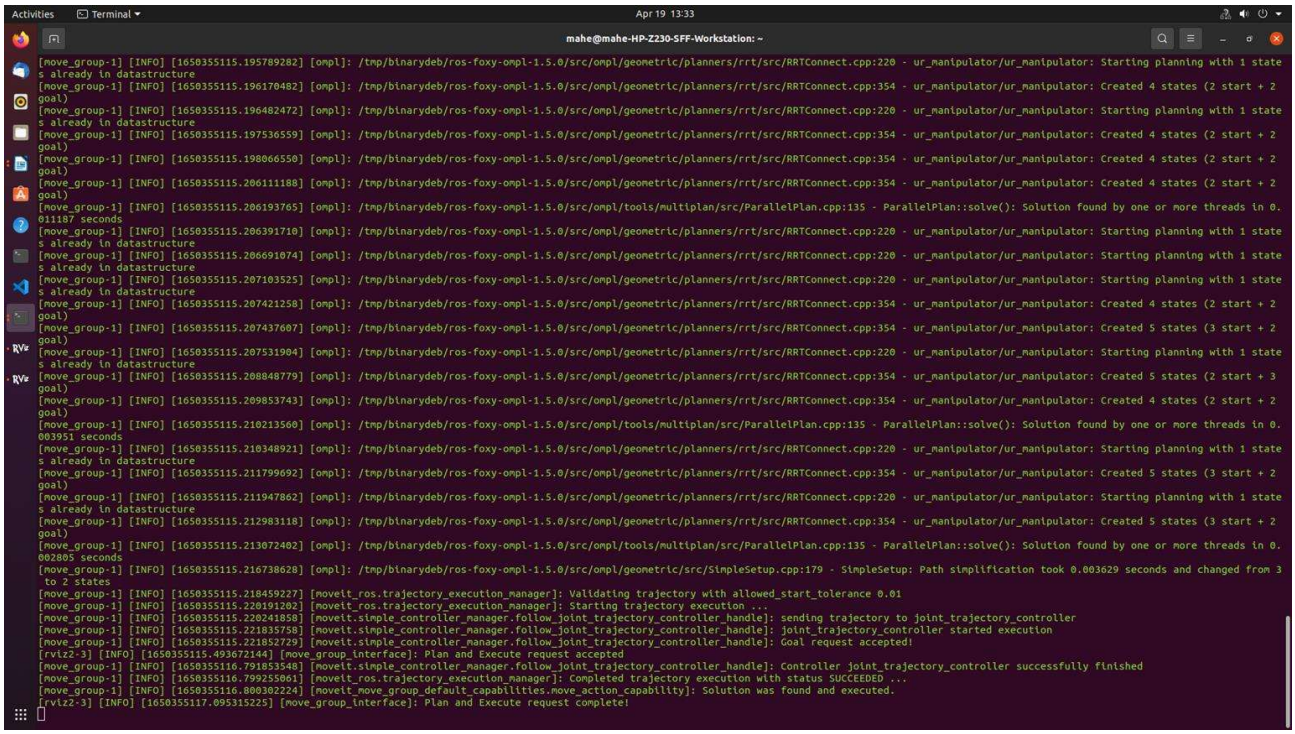
ros2 launch ur_bringup ur5e.launch.py robot_ip:=192.168.56.1

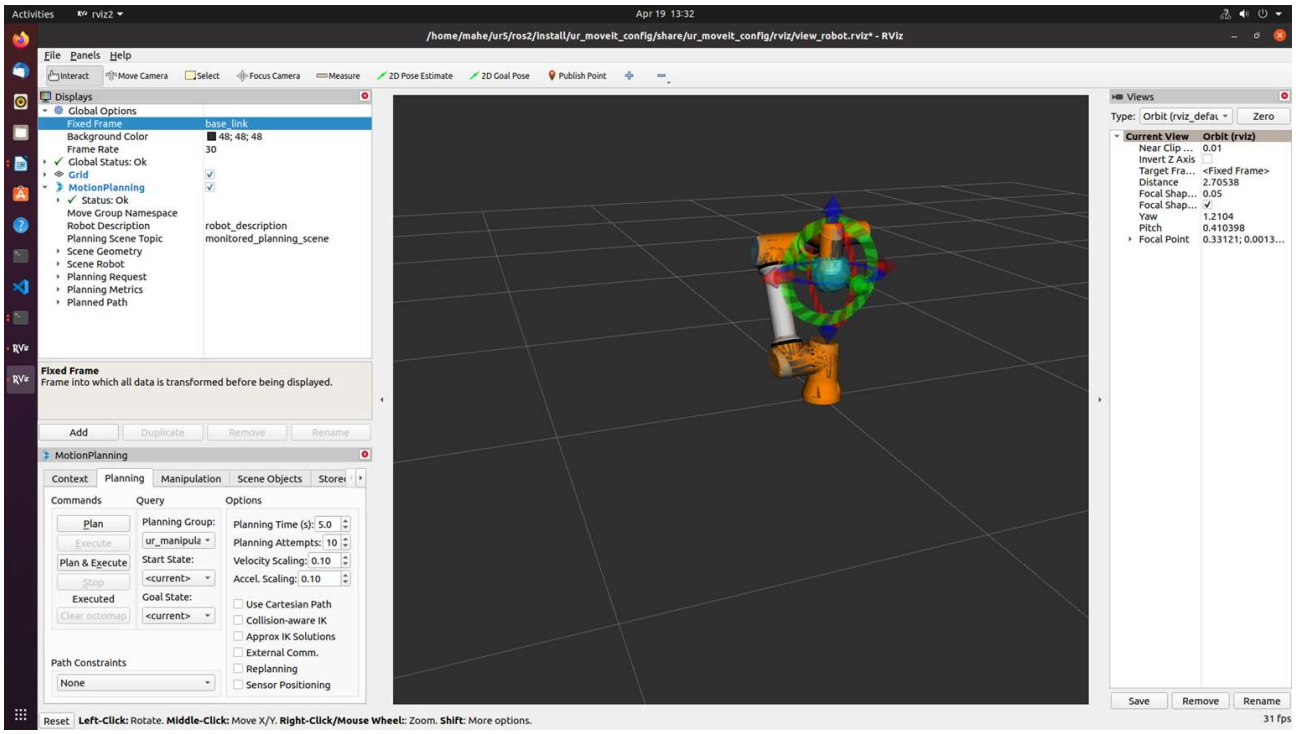




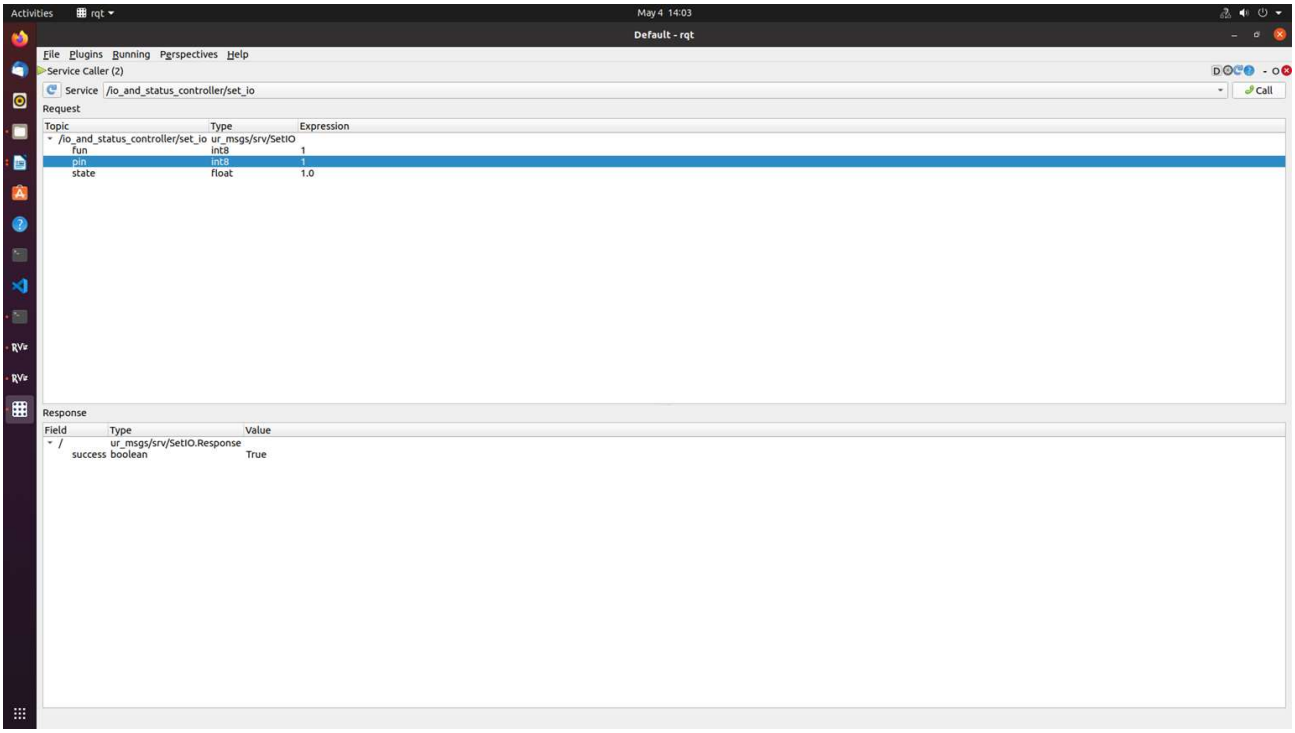
Set in manual mode (1234)
Open externalcontrolros program
Run the program

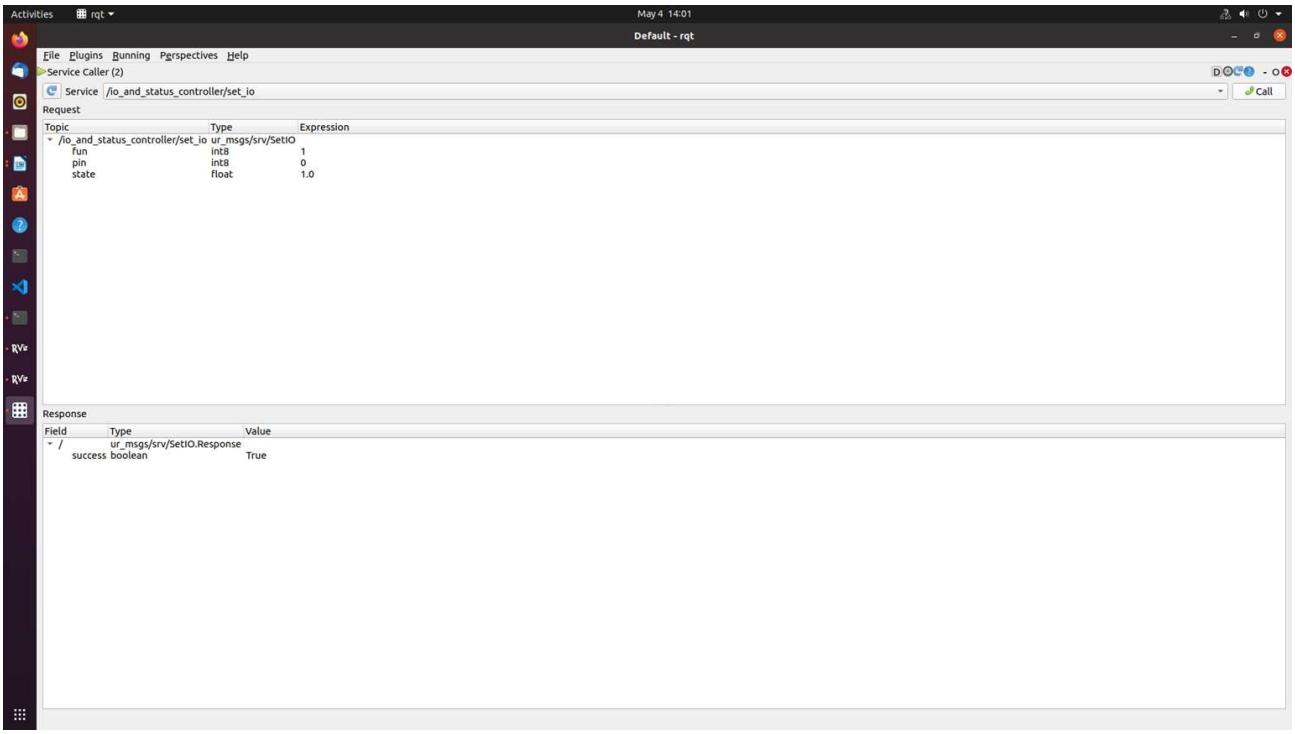
ros2 launch ur_bringup ur_moveit.launch.py ur_type:=ur5e robot_ip:=192.168.56.1

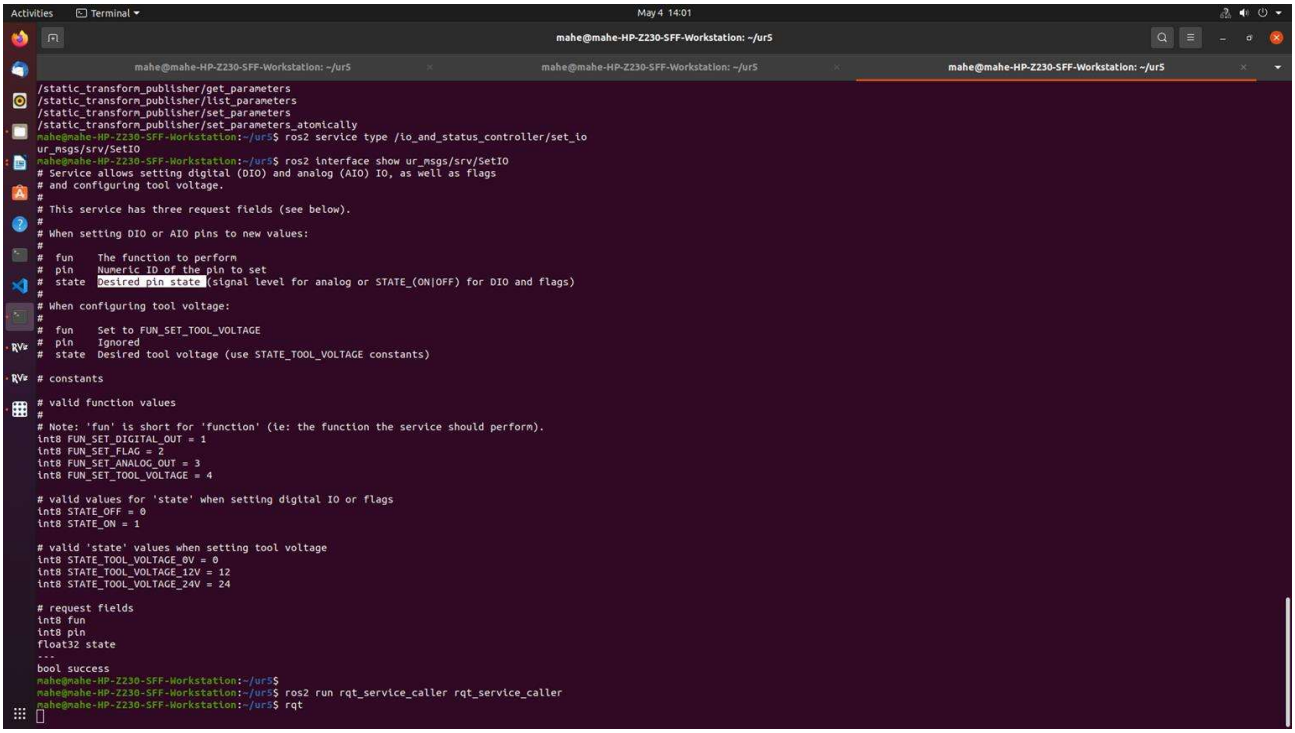




type >>
rqt
plugins→service caller
select io_and_status_controller/set_io
set the pin as 0 for gripper
state as 1.0 to set the gripper off
state as 0.0 to set the gripper off


Activities
rqt
May 4 14:03
Default - rqt
File Plugins Running Perspectives Help
Service Caller (2)
Service /io_and_status_controller/set_io
Call
Request
Topic Type Expression
/io_and_status_controller/set_io ur_msgs/srv/SetIO
fun int8 1
pin int8 1
state float 1.0
Response
Field Type Value
/ ur_msgs/srv/SetIO.Response
success boolean True


Activities
rqt
May 4 14:01
Default - rqt
File Plugins Running Perspectives Help
Service Caller (2)
Service /io_and_status_controller/set_io
Call
Request
Topic Type Expression
/io_and_status_controller/set_io ur_msgs/srv/SetIO
fun int8 1
pin int8 0
state float 1.0
Response
Field Type Value
/ ur_msgs/srv/SetIO.Response
success boolean True



Edit test_goal_publishers_config file as

```
publisher_scaled_joint_trajectory_controller:
  ros__parameters:

    controller_name: "scaled_joint_trajectory_controller"
    wait_sec_between_publish: 6

    goal_names: ["pos1", "pos2", "pos3", "pos4"]
    pos1: [-1.76, -2.129, -1.117, -1.483, 1.57, 0.1745]
    pos2: [-1.76, -2.3911, -1.448, -0.8726, 1.57, 0.17]
    pos3: [-1.76, -2.129, -1.117, -1.483, 1.57, 0.1745]
    pos4: [-1.76, -2.3911, -1.448, -0.8726, 1.57, 0.17]

    joints:
      - shoulder_pan_joint
      - shoulder_lift_joint
      - elbow_joint
      - wrist_1_joint
      - wrist_2_joint
      - wrist_3_joint
```

```
    check_starting_point: true
    starting_point_limits:
      shoulder_pan_joint: [-3.14,3.14]
      shoulder_lift_joint: [-3.14,3.14]
      elbow_joint: [-3.14,3.14]
      wrist_1_joint: [-3.14,3.14]
      wrist_2_joint: [-3.14,3.14]
      wrist_3_joint: [-3.14,3.14]

publisher_joint_trajectory_controller:
  ros__parameters:

    controller_name: "joint_trajectory_controller"
    wait_sec_between_publish: 6

    goal_names: ["pos1", "pos2", "pos3", "pos4"]
    pos1: [-1.76, -2.129, -1.117, -1.483, 1.57, 0.1745]
    pos2: [-1.76, -2.3911, -1.448, -0.8726, 1.57, 0.17]
    pos3: [-1.76, -2.129, -1.117, -1.483, 1.57, 0.1745]
    pos4: [-1.76, -2.3911, -1.448, -0.8726, 1.57, 0.17]

    joints:
      - shoulder_pan_joint
      - shoulder_lift_joint
      - elbow_joint
      - wrist_1_joint
      - wrist_2_joint
      - wrist_3_joint

    check_starting_point: true
    starting_point_limits:
      shoulder_pan_joint: [-3.14,3.14]
      shoulder_lift_joint: [-3.14,3.14]
      elbow_joint: [-3.14,3.14]
      wrist_1_joint: [-3.14,3.14]
      wrist_2_joint: [-3.14,3.14]
      wrist_3_joint: [-3.14,3.14]


cd ur5
colcon build –packages-select ur_bringup
ros2 launch ur_bringup test_joint_trajectory_controller.launch.py
```