

# Linux Basics Introduction

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Linux is an open-source operating system whose kernel was created by Linus Torvalds in 1991.

Many companies and organizations develop their own Linux distributions based on the Linux operating system, such as Google, Red Hat, Ubuntu, etc.

Currently, the ROS system mainly runs on the Ubuntu operating system, which is based on the Debian Linux distribution.

Therefore, if you want to deeply learn and practice robotics, it's best to install the Ubuntu operating system on your computer using [WSL](#), or a virtual machine like [VirtualBox](#) or [VMware](#).

More importantly, most current artificial intelligence environments are based on the Ubuntu operating system, so for learning and practicing robotics, it's best to work in an Ubuntu environment.

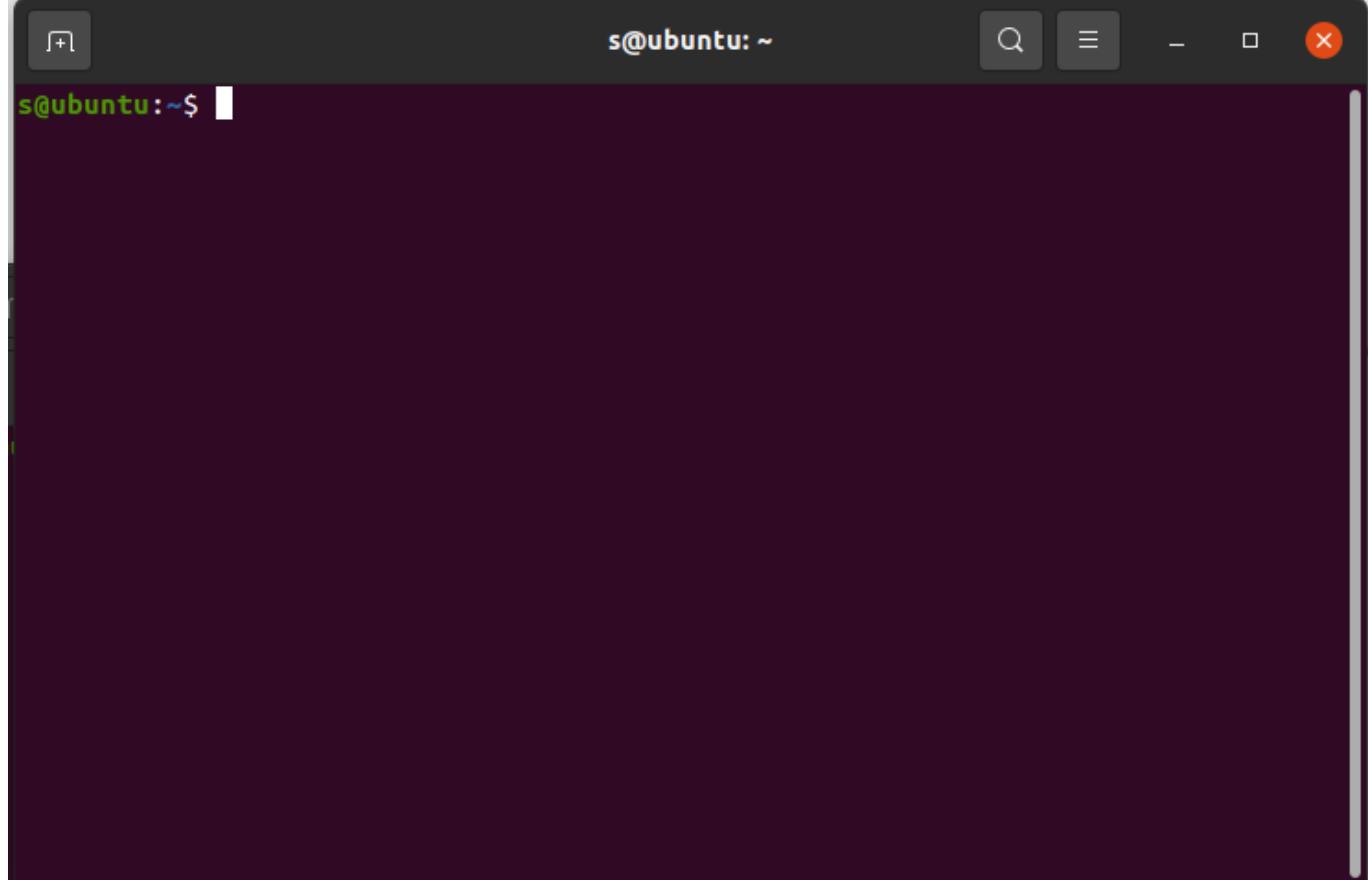
## Terminal

First, we need to understand one thing: the terminal.

The terminal is a text interface where users can input commands, and the operating system will execute corresponding operations based on the commands entered by the user.

In the Ubuntu operating system, the terminal is a very important tool. Users can execute various commands in the terminal, such as installing software, configuring the system, running programs, etc.

Press the ctrl key, alt key, and t key simultaneously to summon a terminal interface:



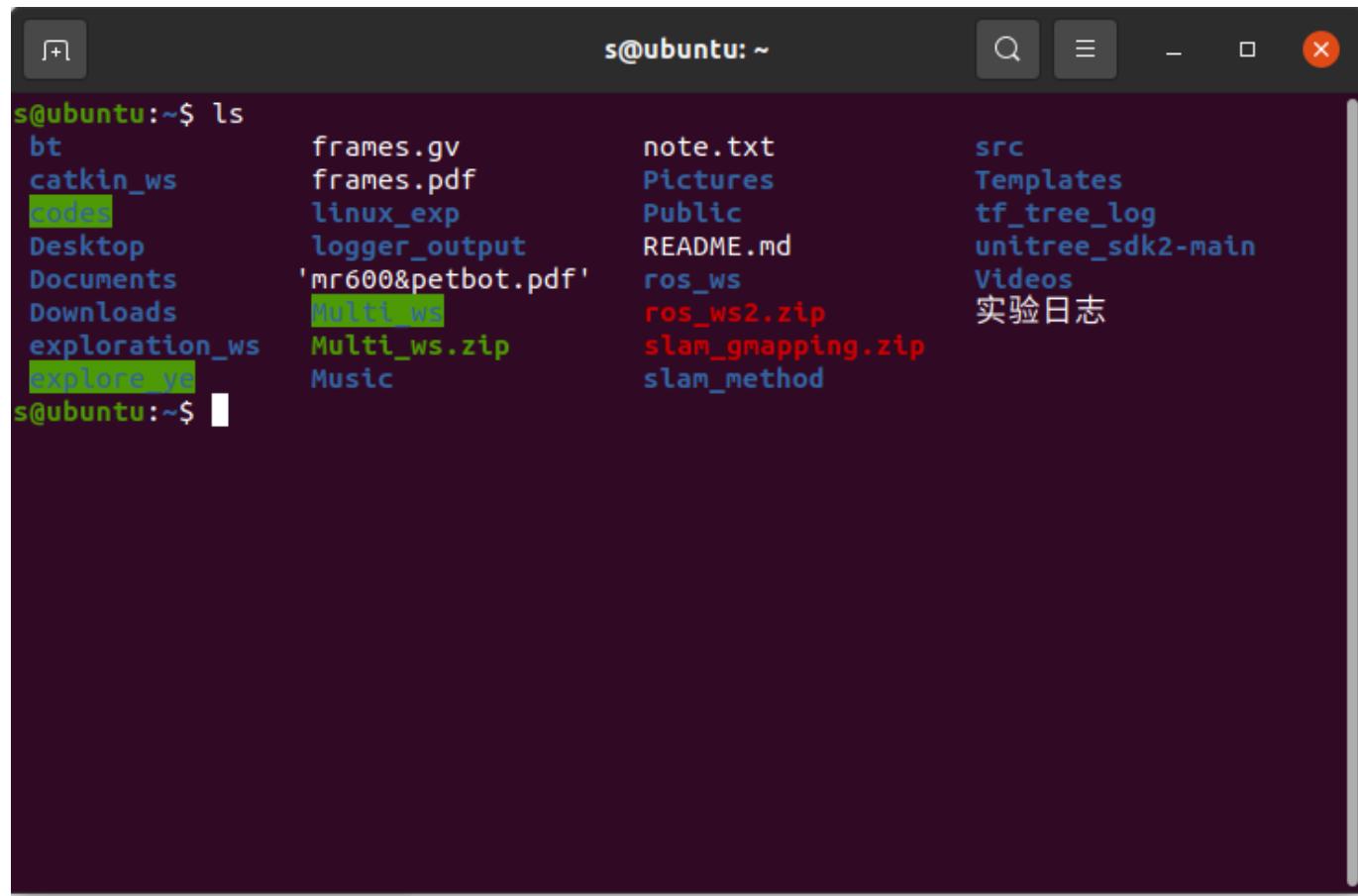
In this image, s is the username, the part after the @ separator is the hostname ubuntu, : is a separator symbol, and ~ represents the current user's home directory, which is also the current path where the terminal is located.

You can input some commands in this black box to perform corresponding operations. For example, input the ls command to list the files and folders in the current directory.

Or input the cd command to switch the current directory. For example, input

```
cd ~/
```

to switch to the current user's home directory, which is the default path when opening the terminal.



The screenshot shows a terminal window titled 's@ubuntu: ~'. The terminal displays the output of the 'ls' command, listing various files and directories in the user's home directory. The files listed include 'bt', 'catkin\_ws', 'codes', 'Desktop', 'Documents', 'Downloads', 'exploration\_ws', 'explore ye', 'frames.gv', 'frames.pdf', 'linux\_exp', 'logger\_output', "'mr600&petbot.pdf'", 'Multi\_ws', 'Multi\_ws.zip', 'Music', 'note.txt', 'Pictures', 'Public', 'README.md', 'ros\_ws', 'ros\_ws2.zip', 'slam\_gmapping.zip', 'slam\_method', 'src', 'Templates', 'tf\_tree\_log', 'unitree\_sdk2-main', 'Videos', and '实验日志'. The file 'Multi\_ws' is highlighted in green, while the directory 'Multi\_ws.zip' is highlighted in red. The terminal prompt 's@ubuntu:~\$' is visible at the bottom.

## Linux Basic Commands Mini-Experiment (Follow Step by Step)

### Experiment Safety Notice (Very Important)

In this experiment, you will encounter **commands that actually modify files and directories**. Please read carefully:

- **rm and mv directly delete or move files**
- **rm -rf is extremely dangerous; once the path is wrong, data cannot be recovered**
- **This experiment only allows operations under ~ (your home directory)**
- **It is strictly forbidden to execute rm -rf in system directories such as /, /home, /usr**

- You will be responsible for repair or compensation costs if the system is damaged due to misoperation

Feel free to ask questions if you don't understand

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## I. Experiment Objectives

Through a complete mini-experiment, master the following:

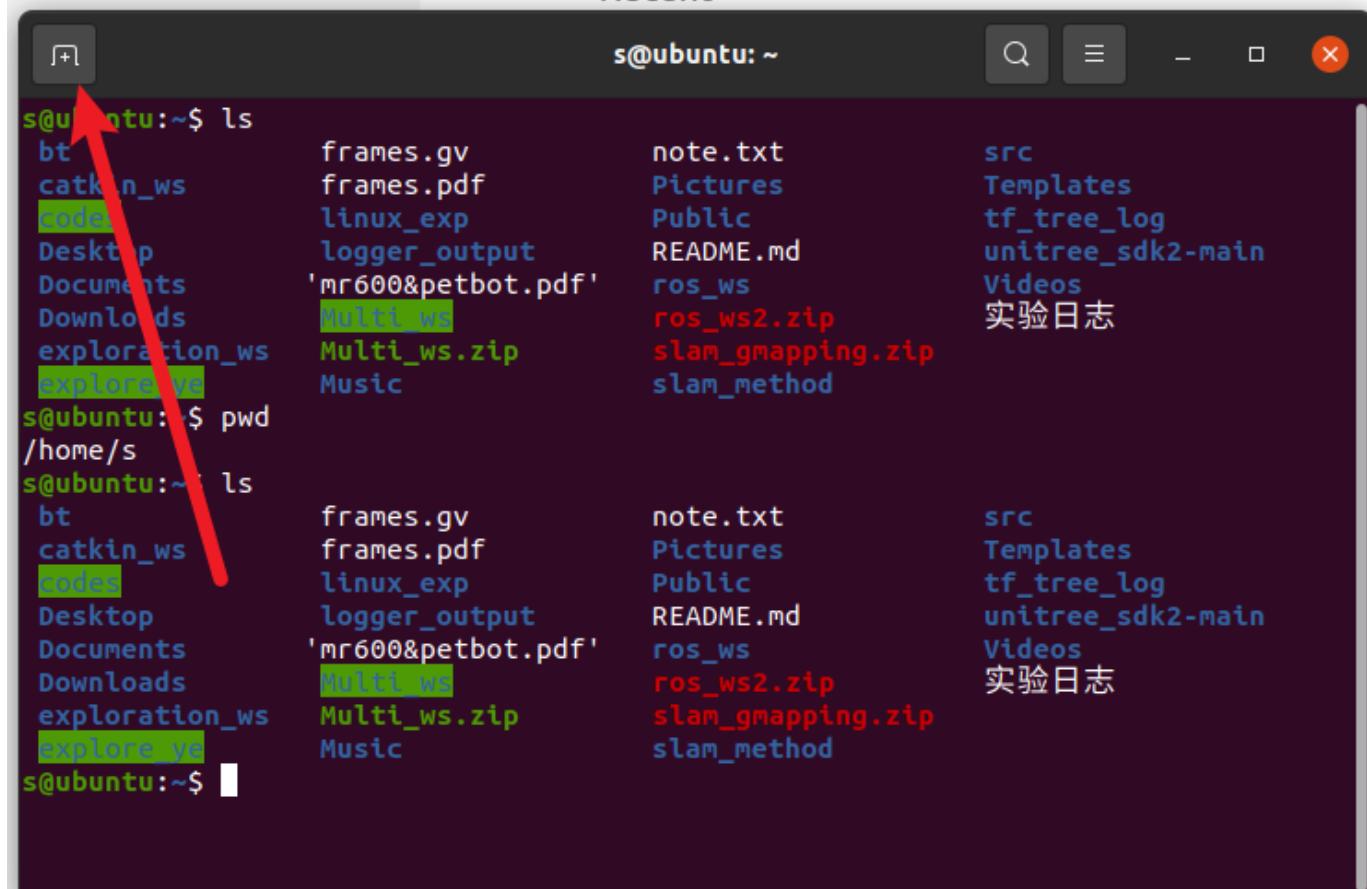
- **Path concepts** in the Linux terminal
  - Common file/directory operation commands: `ls` `mkdir` `touch` `cp` `mv` `rm` `find` `cat`
  - Using `gedit` to create and edit files
  - Using different methods to execute Python programs, understanding:
    - Relative paths
    - Absolute paths
    - `~` (home directory)
  - Understanding basic system and network commands: `ping`, `top`
  - Learning to execute a **complete automation script**
- 

### Tips

**Copy and Paste:** To copy in the terminal, use `ctrl + shift + c`. To paste, use `ctrl + shift + v`. If you press `ctrl + v` in the terminal, invisible characters will appear, and you'll need to press backspace twice to delete them.

**Closing Programs:** In the terminal, close programs using `ctrl + c`, and force terminate programs using `ctrl + z`.

**Adding a New Terminal:** Click the plus sign to add a new terminal:



```
s@ubuntu:~$ ls
bt frames.gv note.txt src
catkin_ws frames.pdf Pictures Templates
codes linux_exp Public tf_tree_log
Desktop logger_output README.md unitree_sdk2-main
Documents 'mr600&petbot.pdf'
Downloads Multi_ws ros_ws Videos
exploration_ws Multi_ws.zip slam_gmapping.zip 实验日志
explore ye Music slam_method

s@ubuntu:~$ pwd
/home/s
s@ubuntu:~$ ls
bt frames.gv note.txt src
catkin_ws frames.pdf Pictures Templates
codes linux_exp Public tf_tree_log
Desktop logger_output README.md unitree_sdk2-main
Documents 'mr600&petbot.pdf'
Downloads Multi_ws ros_ws Videos
exploration_ws Multi_ws.zip slam_gmapping.zip 实验日志
explore ye Music slam_method

s@ubuntu:~$
```

## II. Experiment 1: Manual Operations

### 1. Check Current Location

Confirm you are currently in your **user directory (~)**.

```
pwd
ls
```

```
s@ubuntu:~$ pwd
/home/s
s@ubuntu:~$ ls
bt frames.gv note.txt src
catkin_ws frames.pdf Pictures Templates
codes linux_exp Public tf_tree_log
Desktop logger_output README.md unitree_sdk2-main
Documents 'mr600&petbot.pdf'
Downloads Multi_ws ros_ws Videos
exploration_ws Multi_ws.zip slam_gmapping.zip 实验日志
explore ye Music slam_method
```

### 2. Create Experiment Workspace

```
mkdir linux_exp  
cd linux_exp  
ls
```

You can observe that the path before the \$ symbol has changed.

```
s@ubuntu:~$ cd linux_exp  
s@ubuntu:~/linux_exp$ ls  
s@ubuntu:~/linux_exp$
```

---

### 3. Create Files and Directories

In Windows, we use right-click to create files/folders, and in the terminal, we have corresponding commands:

```
mkdir src  
touch note.txt  
ls
```

```
s@ubuntu:~/linux_exp$ mkdir src  
s@ubuntu:~/linux_exp$ touch note.txt  
s@ubuntu:~/linux_exp$ ls  
note.txt  src  
s@ubuntu:~/linux_exp$
```

---

### 4. Use gedit to Create a Python File

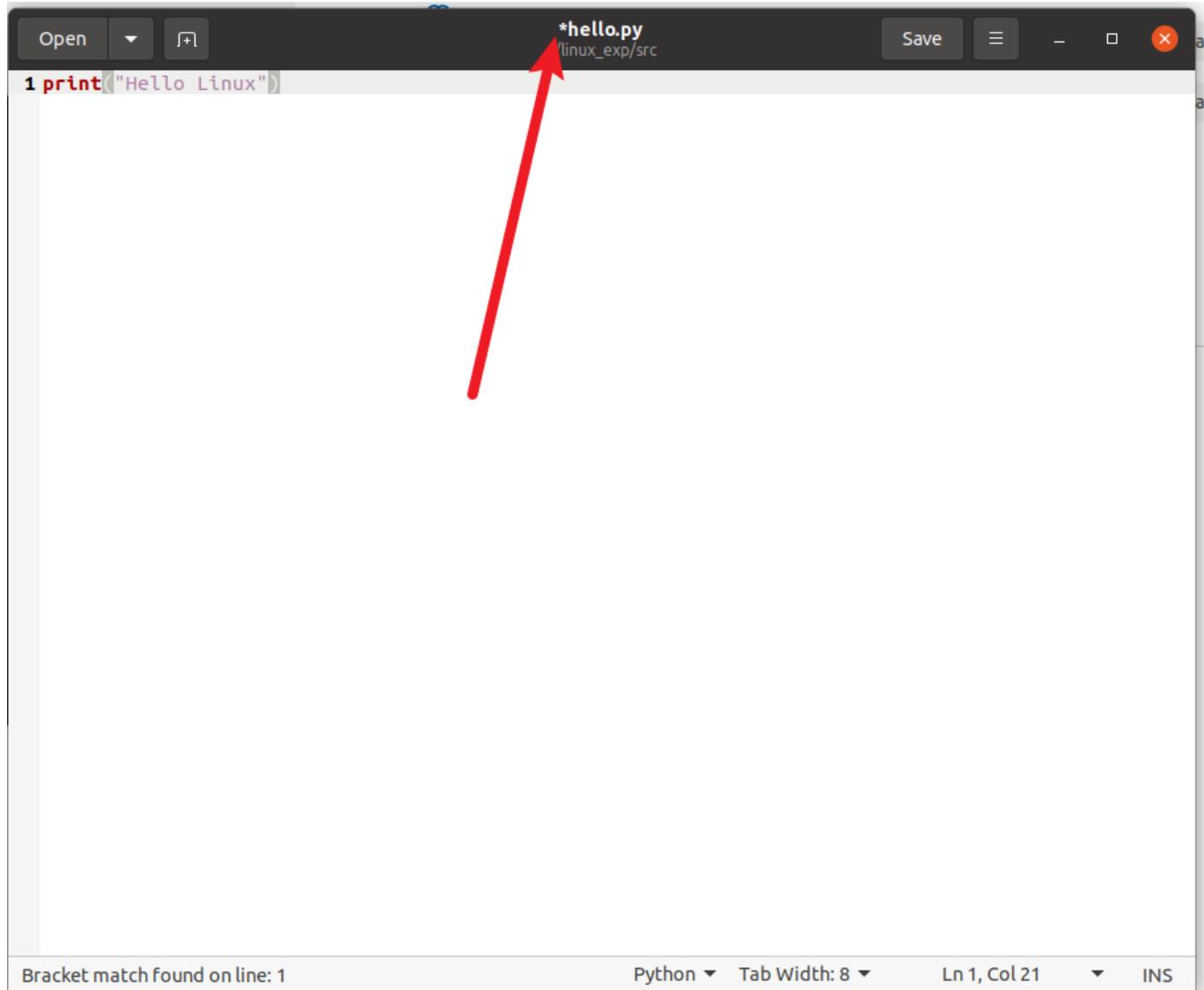
gedit is a text editor:

```
gedit src/hello.py
```

In the opened editor, input and save:

```
print("Hello Linux")
```

The effect is shown below:



A screenshot of a code editor window. The title bar shows the file name as `*hello.py` and the path as `/linux_exp/src`. The editor contains a single line of Python code: `1 print("Hello Linux")`. A large red arrow points from the bottom left towards the asterisk (\*) in the title bar, highlighting it. The status bar at the bottom of the editor displays the message "Bracket match found on line: 1" on the left, and "Python Tab Width: 8 Ln 1, Col 21 INS" on the right.

Note that you need to save with **ctrl + s**. The \* symbol here indicates there are unsaved modifications.

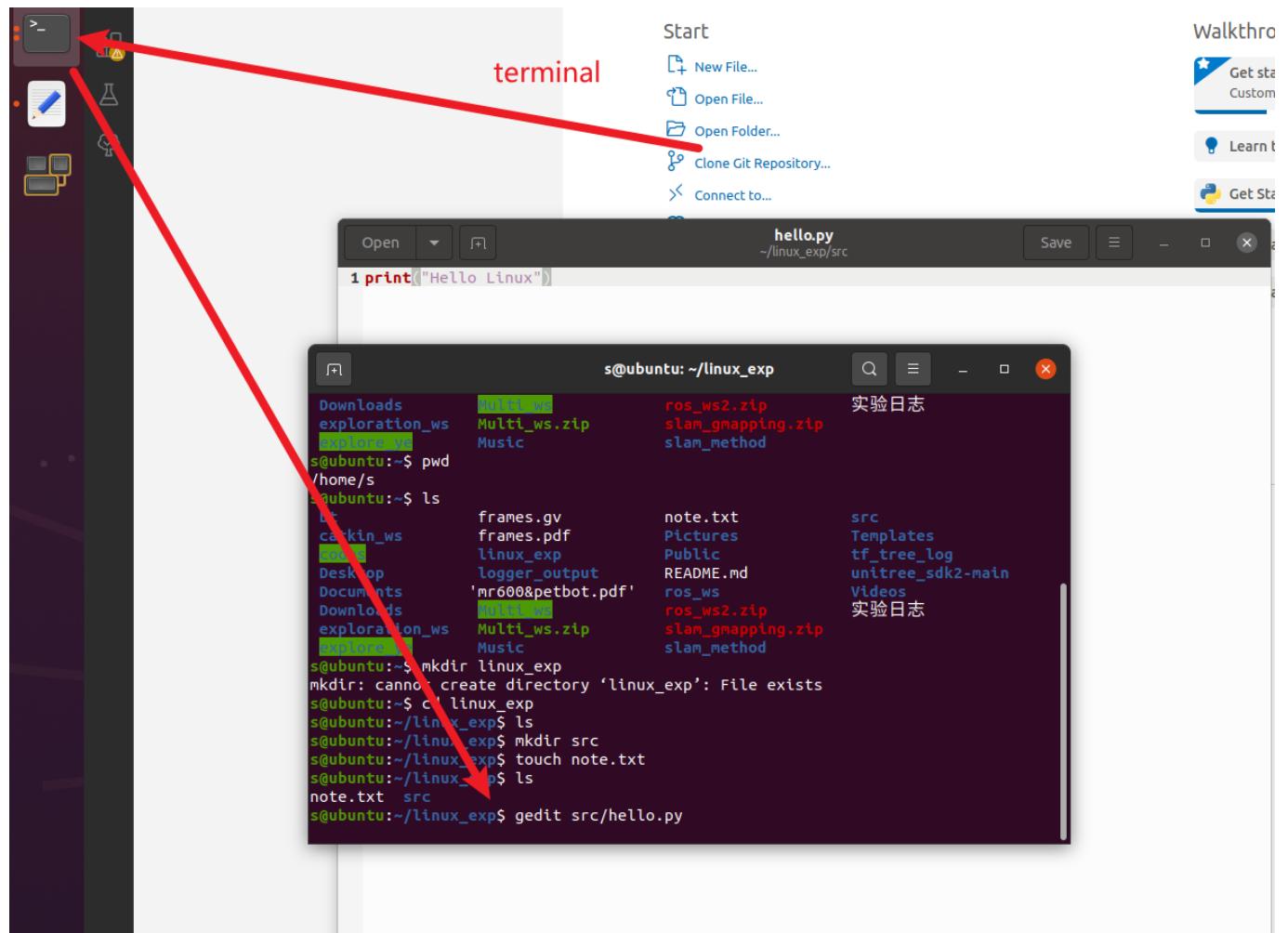
After saving, the effect is as shown:

The screenshot shows a code editor window with the following details:

- Title Bar:** The title bar displays "hello.py" and the path "~/linux\_exp/src".
- Code Area:** The main area contains the Python code:

```
1 print("Hello Linux")
```
- Toolbar:** The top toolbar includes "Open", "Save", and other standard file operations.
- Status Bar:** The bottom status bar shows "Python" as the language mode, "Tab Width: 8", "Ln 1, Col 21", and "INS" for insert mode.

Click the terminal icon on the left.



You can see that below the gedit command, there is no new place to input commands. This is because the gedit text editor is running. You can press **ctrl** and **c** simultaneously in the terminal to close it.

```
s@ubuntu:~/linux_exp$ gedit src/hello.py
^C
s@ubuntu:~/linux_exp$
```

## 5. Use find to Search for Files

We can search for files we want in folders

```
find ~ -name "hello.py"
```

```
s@ubuntu:~/linux_exp$ find ~ -name "hello.py"
/home/s/linux_exp/src/hello.py
```

You can observe the path of this file. It starts with **/**, meaning this is an absolute path.

## 6. View File Contents

```
cat src/hello.py
```

```
s@ubuntu:~/linux_exp$ cat src/hello.py
print("Hello Linux")
s@ubuntu:~/linux_exp$
```

## 7. Copy, Move, Delete Files (Use Caution)

Copy

```
cp src/hello.py hello_copy.py
ls
```

Move/Rename

```
mv hello_copy.py hello_moved.py
ls
```

Delete

```
rm hello_moved.py
ls
```

You can observe the effects of these commands on files.

Note: **Do not use `rm -rf /` or randomly delete directories**

## III. Experiment 2: Execute Python, Understand Paths

Make sure you are still in the `~/linux_exp` directory:

```
pwd
```

```
s@ubuntu:~/linux_exp$ pwd
/home/s/linux_exp
s@ubuntu:~/linux_exp$
```

**Method 1: Relative Path**

```
python3 src/hello.py
```

---

**Method 2: Home Path**

```
python3 ~/linux_exp/src/hello.py
```

---

**Method 3: Absolute Path**

```
python3 /home/<username>/linux_exp/src/hello.py
```

Please replace `<username>` with the current terminal username, which is the string before @

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**Reflection**

- Why do all three methods work?
  - After you `cd ~`, which ones will still work?
- 

**IV. Experiment 3: System and Network Commands (Observation Only)****View Processes (Press q to exit)**

```
top
```

```

top - 14:01:41 up 29 min, 1 user, load average: 0.01, 0.06, 0.17
Tasks: 351 total, 1 running, 349 sleeping, 0 stopped, 1 zombie
%CPU(s): 0.0 us, 2.2 sy, 0.0 ni, 97.8 id, 0.0 wa, 0.0 hi, 0.0 si, 0.0 st
MiB Mem : 3780.0 total, 194.6 free, 2025.5 used, 1559.9 buff/cache
MiB Swap: 2048.0 total, 2025.0 free, 23.0 used. 1375.6 avail Mem

PID USER PR NI VIRT RES SHR S %CPU %MEM TIME+ COMMAND
 841 root 20 0 316268 7540 6300 S 5.9 0.2 0:05.92 vmtoolsd
 2534 s 20 0 347060 133184 81780 S 5.9 3.4 0:13.71 Xorg
 5967 s 20 0 15216 3896 3132 R 5.9 0.1 0:00.03 top
    1 root 20 0 169624 12228 7676 S 0.0 0.3 0:05.47 systemd
    2 root 20 0 0 0 0 S 0.0 0.0 0:00.06 kthreadd
    3 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 rcu_gp
    4 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 rcu_par+
    5 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 slub_fl+
    6 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 netns
    8 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 kworker+
   10 root 0 -20 0 0 0 I 0.0 0.0 0:00.00 mm_perc+
   11 root 20 0 0 0 0 S 0.0 0.0 0:00.00 rcu_tas+
   12 root 20 0 0 0 0 S 0.0 0.0 0:00.00 rcu_tas+
   13 root 20 0 0 0 0 S 0.0 0.0 0:00.03 ksoftirq+
   14 root 20 0 0 0 0 I 0.0 0.0 0:01.29 rcu_sch+
   15 root rt 0 0 0 0 S 0.0 0.0 0:00.01 migrati+
   16 root -51 0 0 0 0 S 0.0 0.0 0:00.00 idle_in+

```

### Test Network (Ctrl + C to stop)

Sometimes we use this command to test whether the host can access the internet.

```
ping baidu.com
```

```
s@ubuntu:~/linux_exp$ ping baidu.com
PING baidu.com (111.63.65.247) 56(84) bytes of data.
64 bytes from 111.63.65.247 (111.63.65.247): icmp_seq=1 ttl=128 time=44.7 ms
64 bytes from 111.63.65.247 (111.63.65.247): icmp_seq=2 ttl=128 time=44.1 ms
64 bytes from 111.63.65.247 (111.63.65.247): icmp_seq=3 ttl=128 time=44.8 ms
64 bytes from 111.63.65.247 (111.63.65.247): icmp_seq=4 ttl=128 time=44.1 ms
64 bytes from 111.63.65.247 (111.63.65.247): icmp_seq=5 ttl=128 time=42.8 ms
^C
--- baidu.com ping statistics ---
5 packets transmitted, 5 received, 0% packet loss, time 4008ms
rtt min/avg/max/mdev = 42.768/44.077/44.766/0.721 ms
s@ubuntu:~/linux_exp$
```

## V. Experiment 4: One-Click Automation Script (Key Point)

We can write a script to automatically get today's weather in Shenzhen from the internet and execute the Python code we wrote above.

### ① Create Script File

```
cd ~/linux_exp  
gedit run_linux_exp.sh
```

Write the following content and save:

```
#!/bin/bash

echo "==== Linux Basic Experiment Script: Automatically Execute Python File ==="
python3 ~/linux_exp/src/hello.py

echo "==== Linux Basic Experiment Script: Get Today's Weather ==="
# Define the city to query (can be modified to your city, such as Beijing,
Shanghai, Guangzhou; supports Chinese and English)
CITY="Shenzhen"

# Output prompt information
echo =====
echo "      Today's Weather Query (from wttr.in)"
echo =====

# Get weather information from wttr.in and format output
curl -s "wttr.in/${CITY}?format=3" # Minimal output (City: Weather Temperature)
# Script completion prompt
echo -e "\n====="
echo "      Query Complete"
echo ====="
```



```
run_linux_exp.sh
~/linux_exp

1 #!/bin/bash
2
3 echo "==== Linux 基础实验脚本：自动执行Python 文件 ==="
4 python3 ~/linux_exp/src/hello.py
5
6 echo "==== Linux 基础实验脚本：获取当天气 ==="
7 # 定义要查询的城市（可修改为你的城市，如北京、上海、Guangzhou，支持中英文）
8 CITY="深圳"
9
10 # 输出提示信息
11 echo "====="
12 echo "      今日天气查询 (来自 wttr.in) "
13 echo "====="
14
15 # 从wttr.in获取天气信息并格式化输出
16 curl -s "wttr.in/${CITY}?format=3" # 极简输出 (城市：天气 温度)
17 # 脚本结束提示
18 echo -e "\n====="
19 echo "          查询完成"
20 echo "====="

sh ▾ Tab Width: 8 ▾ Ln 20, Col 46 ▾ INS
```

## ② Add Execute Permission

```
chmod +x run_linux_exp.sh
```

## ③ Execute Script

```
./run_linux_exp.sh
```

```
s@ubuntu:~/linux_exp$ chmod +x run_linux_exp.sh
s@ubuntu:~/linux_exp$ ./run_linux_exp.sh
== Linux 基础实验脚本：自动执行Python 文件 ==
Hello Linux
== Linux 基础实验脚本：获取当天气 ==
=====
    今日天气查询（来自 wttr.in）
=====
深圳: ☀ +23 °C
=====
    查询完成
=====
s@ubuntu:~/linux_exp$ █
```

We can see that scripts are particularly powerful tools that can accomplish many tasks through Linux commands.

---

## VI. Experiment Summary

In this experiment, you actually used and understood:

### ❖ Three Path Writing Methods

- **Absolute path** /home/<username>/linux\_exp/src/hello.py
- **Relative path** src/hello.py
- **Home path** ~/linux\_exp/src/hello.py

### ⌚ Whether a command succeeds depends on: where you are + how you write the path

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## VII. Checklist (Self-Check)

- I know what `pwd` does
- I won't randomly use `rm -rf`
- I can understand every line of commands in the script
- I understand why the same Python file can be executed in multiple ways

## VIII. Linux Command Learning Resources

- [linux-command-manual](#)
- [geeksforgeeks - Linux Commands](#)
- [The Linux command line for beginners](#)

# Experiment 2: ROS Basics and Communication Mechanisms

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## 1. Experiment Objectives

- Understand the concept of ROS Nodes

- Master the Topic publish-subscribe mechanism
- Understand the role of the ROS Master

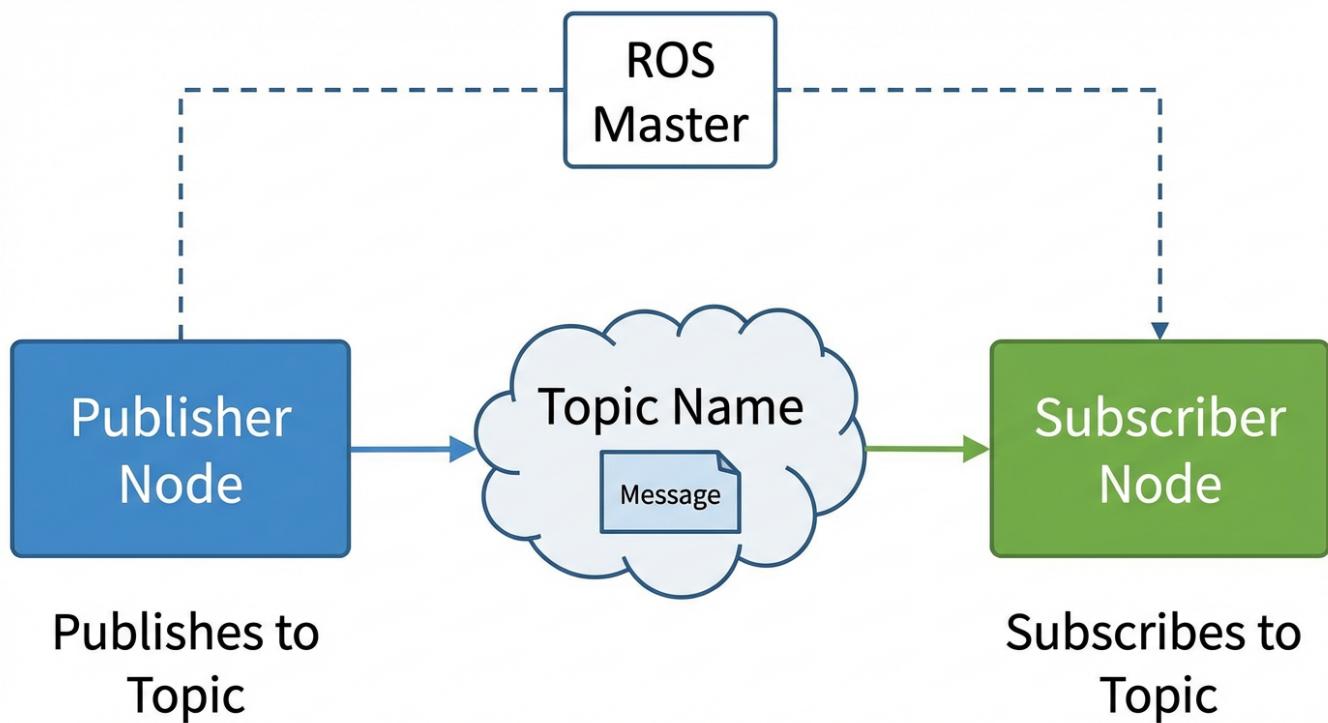
## 2. Core ROS Concepts

### 2.1 Basic Components

- **Node** : The basic operational unit of a ROS system; each node performs a specific task.
- **Topic** : A named channel for communication between nodes.
- **Master** : Provides coordination services for communication between nodes (requires `roscore`).

### 2.2 Node Communication

The most common way nodes communicate is based on topics. A publisher node names a topic and publishes messages to it. Another subscriber node subscribes to that topic.



## 3. Experiment Steps

First, download the course code repository from GitHub and rename it to `catkin_ws`.

```
git clone https://github.com/AB-pixel-pixel/Embodied-AI-Exploration-Lab1.git
mv Embodied-AI-Exploration-Lab1 catkin_ws
cd catkin_ws
```

### Experiment 2.1: Running two isolated programs

```
cd ~/catkin_ws/src/ros_course_examples/simulation_demo
python3 controller.py
```

```
# Terminal 2: Run Motor  
cd ~/catkin_ws/src/ros_course_examples/simulation_demo  
python3 motor.py
```

Execution result shown in the figure:

The image shows two terminal windows side-by-side. Both windows have a dark background and light-colored text. The top window's title bar reads "s@ubuntu: ~/catkin\_ws/src/ros\_course\_examples/simulation...". The bottom window's title bar also reads "s@ubuntu: ~/catkin\_ws/src/ros\_course\_examples/simulation...". Both windows show command-line output from Python scripts.

**Top Terminal Output:**

```
s@ubuntu:~$ cd ~/catkin_ws/src/ros_course_examples/simulation_demo
s@ubuntu:~/catkin_ws/src/ros_course_examples/simulation_demo$ python3 controller.py
Controller started.
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
^OPController: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
Controller: I want the robot to move to (1.0, 1.0). sending command 'forward'...
```

**Bottom Terminal Output:**

```
s@ubuntu:~$ cd ~/catkin_ws/src/ros_course_examples/simulation_demo
s@ubuntu:~/catkin_ws/src/ros_course_examples/simulation_demo$ python3 motor.py
Motor started.
Motor: Current position is (0.0, 0.0). Waiting for commands...
Motor: Current position is (0.0, 0.0). Waiting for commands...
Motor: Current position is (0.0, 0.0). Waiting for commands...
Motor: Current position is (0.0, 0.0). Waiting for commands...
```

**Observation :** The two programs run independently and cannot communicate with each other.

Close these two programs now.

## Experiment 2.2: Implementing Node Communication using ROS

We have already encapsulated the code into ROS nodes, the files are as follows:

`src/ros_course_examples/nodes/motor_node.py` and  
`src/ros_course_examples/nodes/controller_node.py`.

As long as we start these two nodes, we can achieve node communication based on the ROS framework.

First, perform compilation.

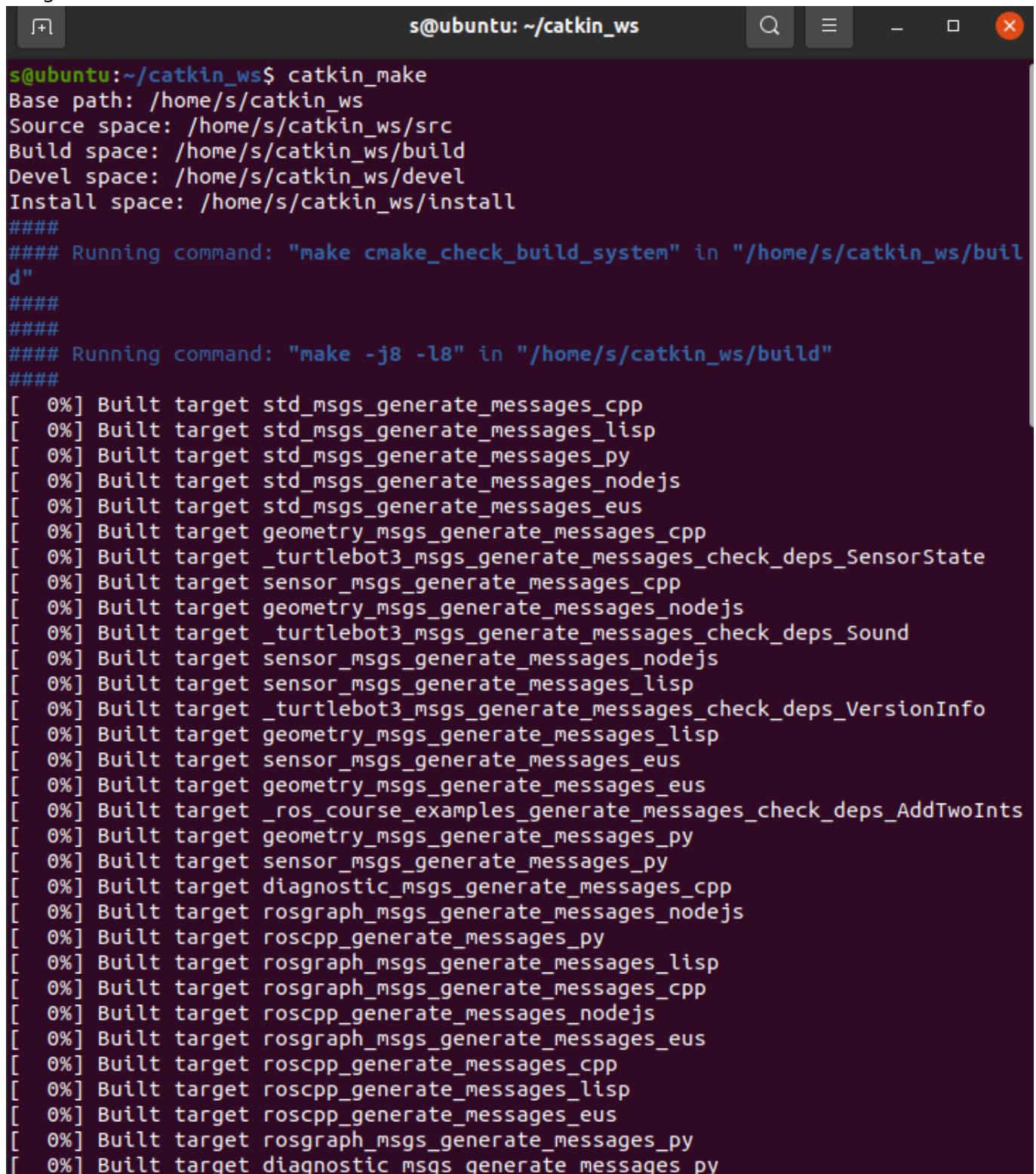
In Terminal 1: Compile the ROS workspace.

We use the `catkin_make` command to compile ROS packages. Its functions are:

- Compile source code: Compile C++ source files into executables, mark Python scripts as executable.
- Handle dependencies: Automatically resolve and link dependencies between packages.
- Generate configuration files: Create environment configuration scripts such as `devel/setup.bash`.
- Build message types: Compile custom msg, srv, and action files.

```
cd ~/catkin_ws
catkin_make
```

Rough schematic:



```
s@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/s/catkin_ws
Source space: /home/s/catkin_ws/src
Build space: /home/s/catkin_ws/build
Devel space: /home/s/catkin_ws/devel
Install space: /home/s/catkin_ws/install
#####
##### Running command: "make cmake_check_build_system" in "/home/s/catkin_ws/build"
#####
#####
##### Running command: "make -j8 -l8" in "/home/s/catkin_ws/build"
#####
[ 0%] Built target std_msgs_generate_messages_cpp
[ 0%] Built target std_msgs_generate_messages_lisp
[ 0%] Built target std_msgs_generate_messages_py
[ 0%] Built target std_msgs_generate_messages_nodejs
[ 0%] Built target std_msgs_generate_messages_eus
[ 0%] Built target geometry_msgs_generate_messages_cpp
[ 0%] Built target _turtlebot3_msgs_generate_messages_check_deps_SensorState
[ 0%] Built target sensor_msgs_generate_messages_cpp
[ 0%] Built target geometry_msgs_generate_messages_nodejs
[ 0%] Built target _turtlebot3_msgs_generate_messages_check_deps_Sound
[ 0%] Built target sensor_msgs_generate_messages_nodejs
[ 0%] Built target sensor_msgs_generate_messages_lisp
[ 0%] Built target _turtlebot3_msgs_generate_messages_check_deps_VersionInfo
[ 0%] Built target geometry_msgs_generate_messages_lisp
[ 0%] Built target sensor_msgs_generate_messages_eus
[ 0%] Built target geometry_msgs_generate_messages_eus
[ 0%] Built target _ros_course_examples_generate_messages_check_deps_AddTwoInts
[ 0%] Built target geometry_msgs_generate_messages_py
[ 0%] Built target sensor_msgs_generate_messages_py
[ 0%] Built target diagnostic_msgs_generate_messages_cpp
[ 0%] Built target rosgraph_msgs_generate_messages_nodejs
[ 0%] Built target roscpp_generate_messages_py
[ 0%] Built target rosgraph_msgs_generate_messages_lisp
[ 0%] Built target rosgraph_msgs_generate_messages_cpp
[ 0%] Built target roscpp_generate_messages_nodejs
[ 0%] Built target rosgraph_msgs_generate_messages_eus
[ 0%] Built target roscpp_generate_messages_cpp
[ 0%] Built target rosgraph_msgs_generate_messages_lisp
[ 0%] Built target roscpp_generate_messages_eus
[ 0%] Built target rosgraph_msgs_generate_messages_py
[ 0%] Built target diagnostic_msgs_generate_messages_py
```

After execution it will:

- Compile code in the build/ directory.
- Output results to the devel/ directory.
- Generate environment variables usable by ROS.

Terminal 1: Start the ROS Master node.

The `roscore` command can start the Master node:

- Function: Manages registration and discovery of all nodes.

- Role: Allows Publishers and Subscribers to find each other.
- Analogy: Like a central server, connecting nodes.
- **Note: During the experiment, we do not close the terminal running roscore.**

```
roscore
```

```
s@ubuntu:~/catkin_ws$ roscore
... logging to /home/s/.ros/log/c3669880-e08f-11f0-8de9-0b6678ff4937/roslaunch-ubuntu-10449.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://ubuntu:39677/
ros_comm version 1.17.4

SUMMARY
=====

PARAMETERS
* /rosdistro: noetic
* /rosversion: 1.17.4

NODES

auto-starting new master
process[master]: started with pid [10464]
ROS_MASTER_URI=http://ubuntu:11311/

setting /run_id to c3669880-e08f-11f0-8de9-0b6678ff4937
process[rosout-1]: started with pid [10482]
started core service [/rosout]
```

Grant execution permissions to the node code:

```
cd ~/catkin_ws/src/ros_course_examples/nodes/
chmod +x motor_node.py
chmod +x controller_node.py
```

```
s@ubuntu:~/catkin_ws/src/ros_course_examples/scripts$ cd ~/catkin_ws/src/ros_course_examples/nodes/
s@ubuntu:~/catkin_ws/src/ros_course_examples/nodes$ chmod +x motor_node.py
s@ubuntu:~/catkin_ws/src/ros_course_examples/nodes$ chmod +x controller_node.py
s@ubuntu:~/catkin_ws/src/ros_course_examples/nodes$
```

## Start Communication Demo

Since we need to use the ROS framework, we need to use ROS commands to start the code instead of simply using python commands.

This is the `rosrun` command:

- Function: Run a node within a ROS package.
- Features: Simple, direct, suitable for testing or debugging.
- Example usage:

```
# rosrun <ros package name> <executable file name>
rosrun turtlesim turtlesim_node
```

- If the executable file requires arguments, they can also follow directly: rosrun pkg exe arg1 arg2 ...

Terminal 2: Start the motor node.

**Note:** source devel/setup.bash helps ros commands find corresponding executable files.

```
cd ~/catkin_ws
source devel/setup.bash
rosrun ros_course_examples motor_node.py
```

You will see that this node (program) is waiting for information, and its position does not change.

```
s@ubuntu:~/catkin_ws$ source devel/setup.bash
s@ubuntu:~/catkin_ws$ rosrun ros_course_examples motor_node.py
[INFO] [1766558552.909377]: Motor: Ready to receive commands. Initial Position: (0.00, 0.00)
```

Terminal 3: Start the controller node. Next, let's control it.

```
cd ~/catkin_ws
source devel/setup.bash
rosrun ros_course_examples controller_node.py
```

Observing the terminal, we can discover that it is constantly sending commands:

```
s@ubuntu:~/catkin_ws$ rosrun ros_course_examples controller_node.py
[INFO] [1766559022.809927]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559023.811670]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559024.811996]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559025.812015]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559026.811545]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559027.811822]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559028.812258]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
```

Return to view Terminal 2 (Motor node).

```
s@ubuntu:~/catkin_ws$ rosrun ros_course_examples motor_node.py
[INFO] [1766559078.039613]: Motor: Ready to receive commands. Initial Position: (0.00, 0.00)
[INFO] [1766559078.816648]: Motor: Executing command. Current Position: (0.10, 0.10)
[INFO] [1766559079.816708]: Motor: Executing command. Current Position: (0.20, 0.20)
[INFO] [1766559080.815000]: Motor: Executing command. Current Position: (0.30, 0.30)
[INFO] [1766559081.814704]: Motor: Executing command. Current Position: (0.40, 0.40)
[INFO] [1766559082.815514]: Motor: Executing command. Current Position: (0.50, 0.50)
```

**Observed:** The Controller sends speed commands, and the Motor receives them and updates the position.

---

However, wouldn't it be too complicated to enter a command line every time a program is started?

ROS provides a unified startup configuration mechanism that can start multiple nodes with one click; this is the **roslaunch** command.

**roslaunch:**

- Function: Start multiple nodes at once through .launch files.
- Set parameters for nodes, for example, setting parameters for relevant planning algorithms according to the size of the robot.
- Remap topics, suitable for changing communication relationships without changing code.
- Set namespaces, suitable for multiple robots using the same code.
- Launch files are usually located in the launch/ directory of the package (not mandatory, but convention).
- Example:

```
# rosrun <ros package name> <launch file name within package>
roslaunch turtlesim turtlesim_demo.launch
```

Close Terminal 2 and Terminal 3, execute in Terminal 3:

```
cd ~/catkin_ws
source devel/setup.bash
roslaunch ros_course_examples ros_communication_demo.launch
```

You can observe that both nodes have started.

```
s@ubuntu:~/catkin_ws$ roslaunch ros_course_examples ros_communication_demo.launch
... logging to /home/s/.ros/log/c3669880-e08f-11f0-8de9-0b6678ff4937/roslaunch-ubuntu-12682.log
Checking log directory for disk usage. This may take a while.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://ubuntu:42997/

SUMMARY
=====
PARAMETERS
  * /rosdistro: noetic
  * /rosversion: 1.17.4

NODES
/
  controller_node (ros_course_examples/controller_node.py)
  motor_node (ros_course_examples/motor_node.py)

ROS_MASTER_URI=http://localhost:11311

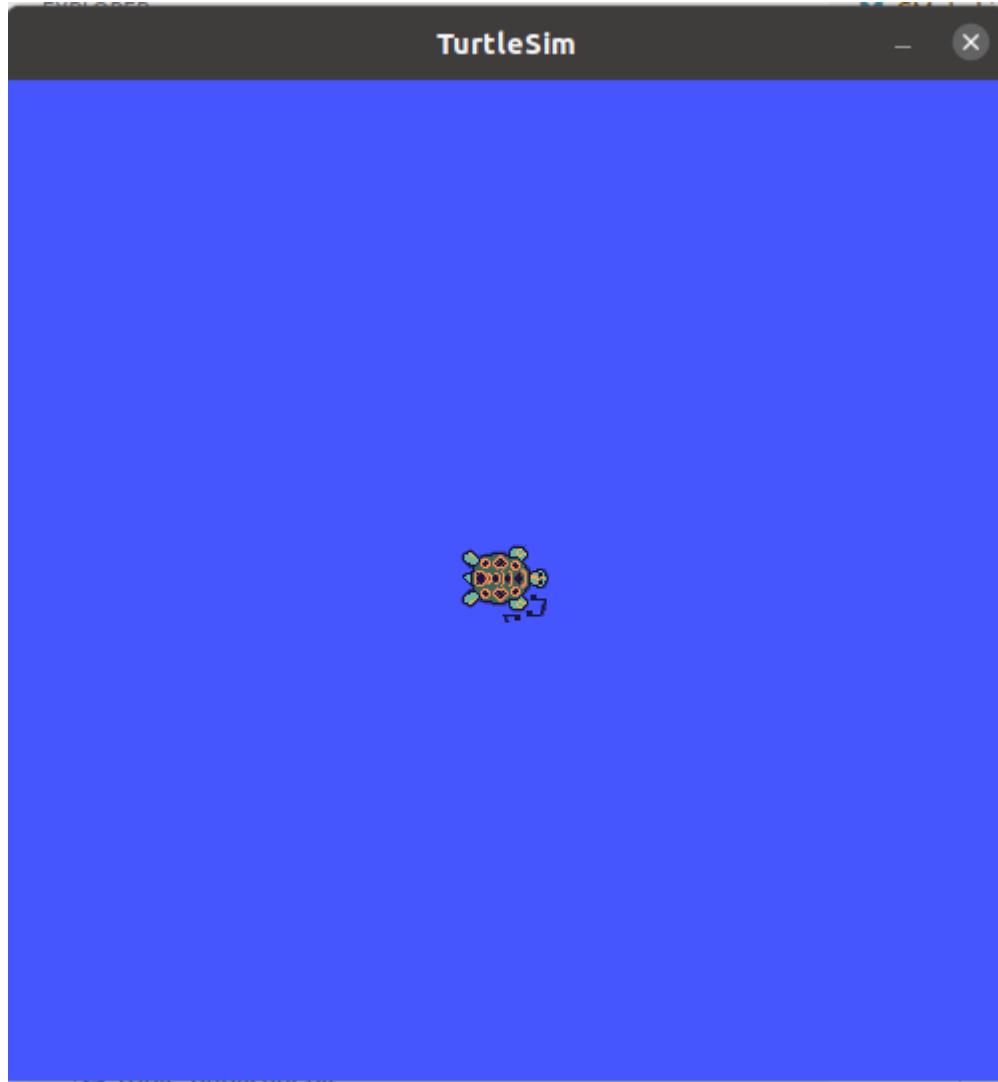
process[motor_node-1]: started with pid [12703]
process[controller_node-2]: started with pid [12704]
[INFO] [1766559238.780645]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559238.875874]: Motor: Ready to receive commands. Initial Position: (0.00, 0.00)
[INFO] [1766559239.783281]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559239.785221]: Motor: Executing command. Current Position: (0.10, 0.10)
[INFO] [1766559240.783177]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559240.787180]: Motor: Executing command. Current Position: (0.20, 0.20)
[INFO] [1766559241.782647]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559241.786413]: Motor: Executing command. Current Position: (0.30, 0.30)
[INFO] [1766559242.782789]: Controller: Sending command to move to (100,100). Linear X: 0.10, Linear Y: 0.10
[INFO] [1766559242.786200]: Motor: Executing command. Current Position: (0.40, 0.40)
```

Before proceeding to the following experiments, you can close this program first (**Note: do not close the terminal running roscore**).

## Experiment 2.3: TurtleSim Communication Experiment

Terminal 2: Start Turtle Simulation

```
rosrun turtlesim turtlesim_node
```

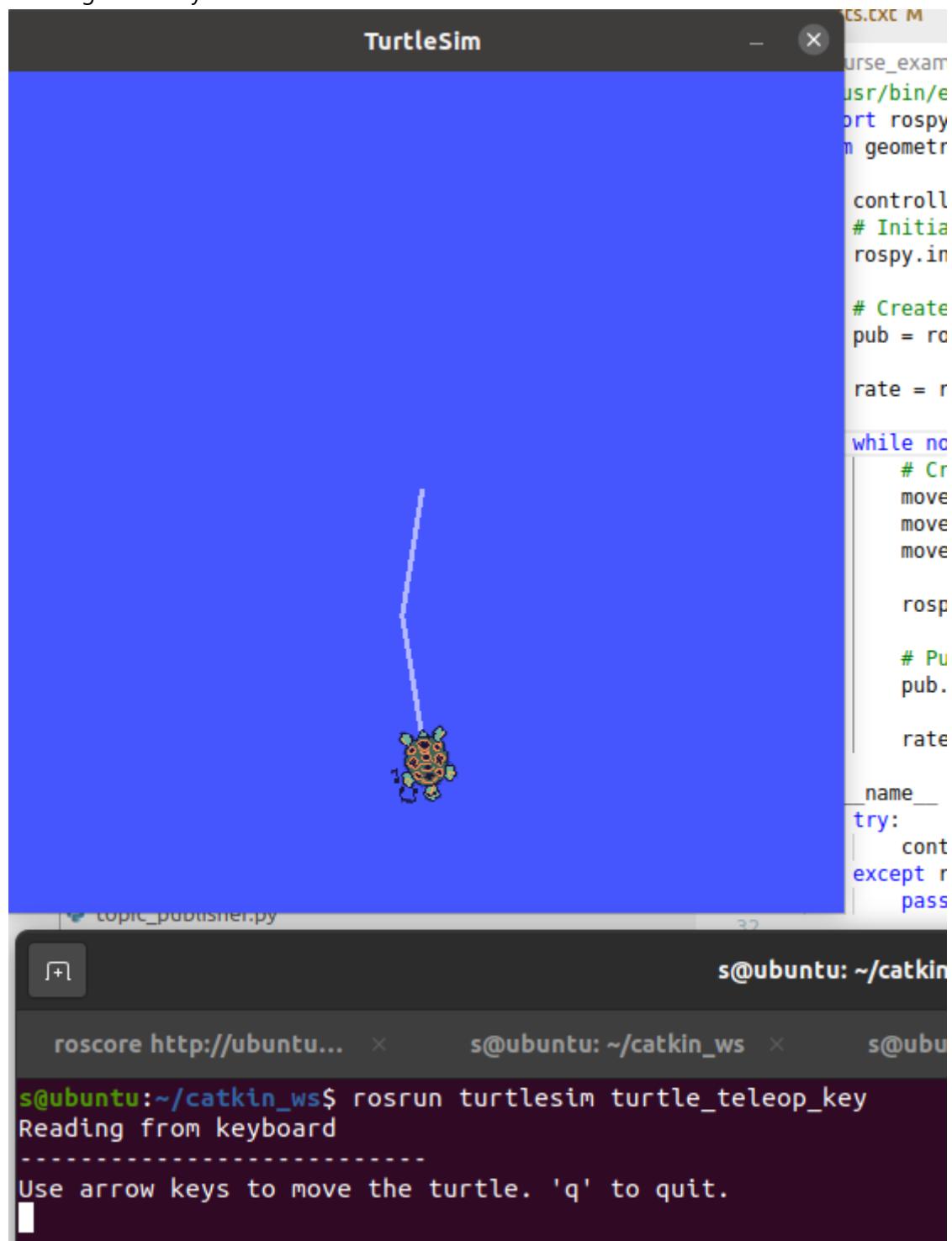


Terminal 3: Start Keyboard Control

```
roslaunch turtlesim turtle_teleop_key
```

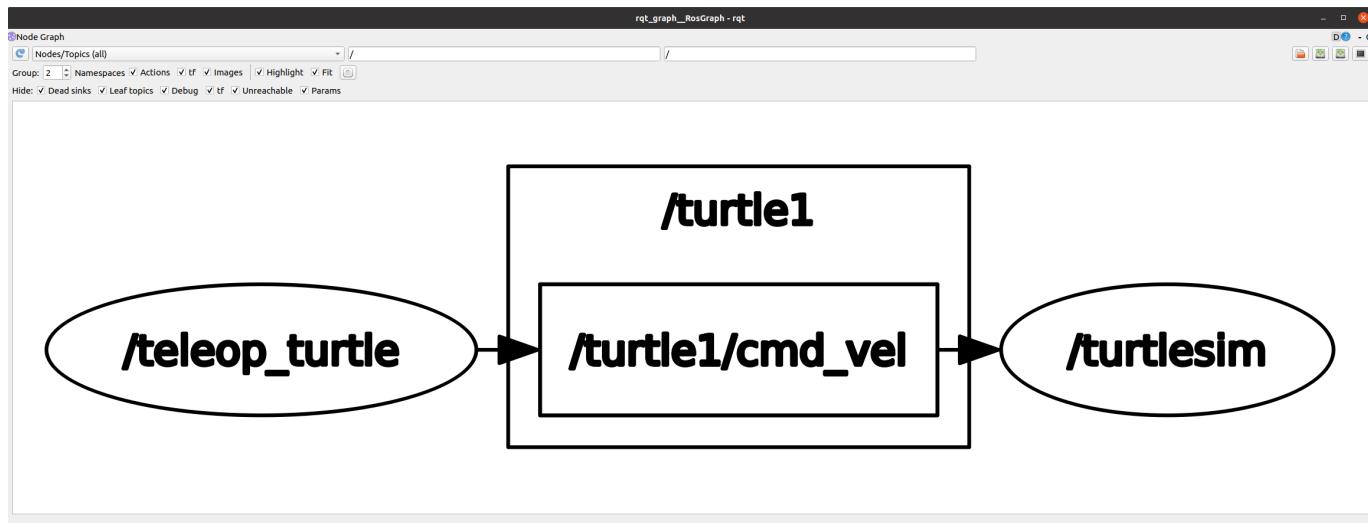
```
s@ubuntu:~/catkin_ws$ roslaunch turtlesim turtle_teleop_key
Reading from keyboard
-----
Use arrow keys to move the turtle. 'q' to quit.
```

Pressing arrow keys in Terminal 3 can control the turtle movement.



Terminal 4: Visualize Communication Graph

```
rqt_graph
```



### Communication Process Analysis :

1. **turtle\_teleop\_key** node listens for keyboard input.
2. Publishes speed commands to the **/turtle1/cmd\_vel** topic.
3. The information published to the topic is linear speed and angular speed; the message type is **geometry\_msgs/Twist**.
4. **turtlesim\_node** subscribes to **/turtle1/cmd\_vel**.
5. Receives speed commands and executes movement.

### Experiment 2.4: Viewing Topic Information

All the above information can be observed through ROS commands.

```
# List all topics
rostopic list
```

```
# View topic information
rostopic info /turtle1/cmd_vel
```

```
# View message type definition
rosmsg show geometry_msgs/Twist
```

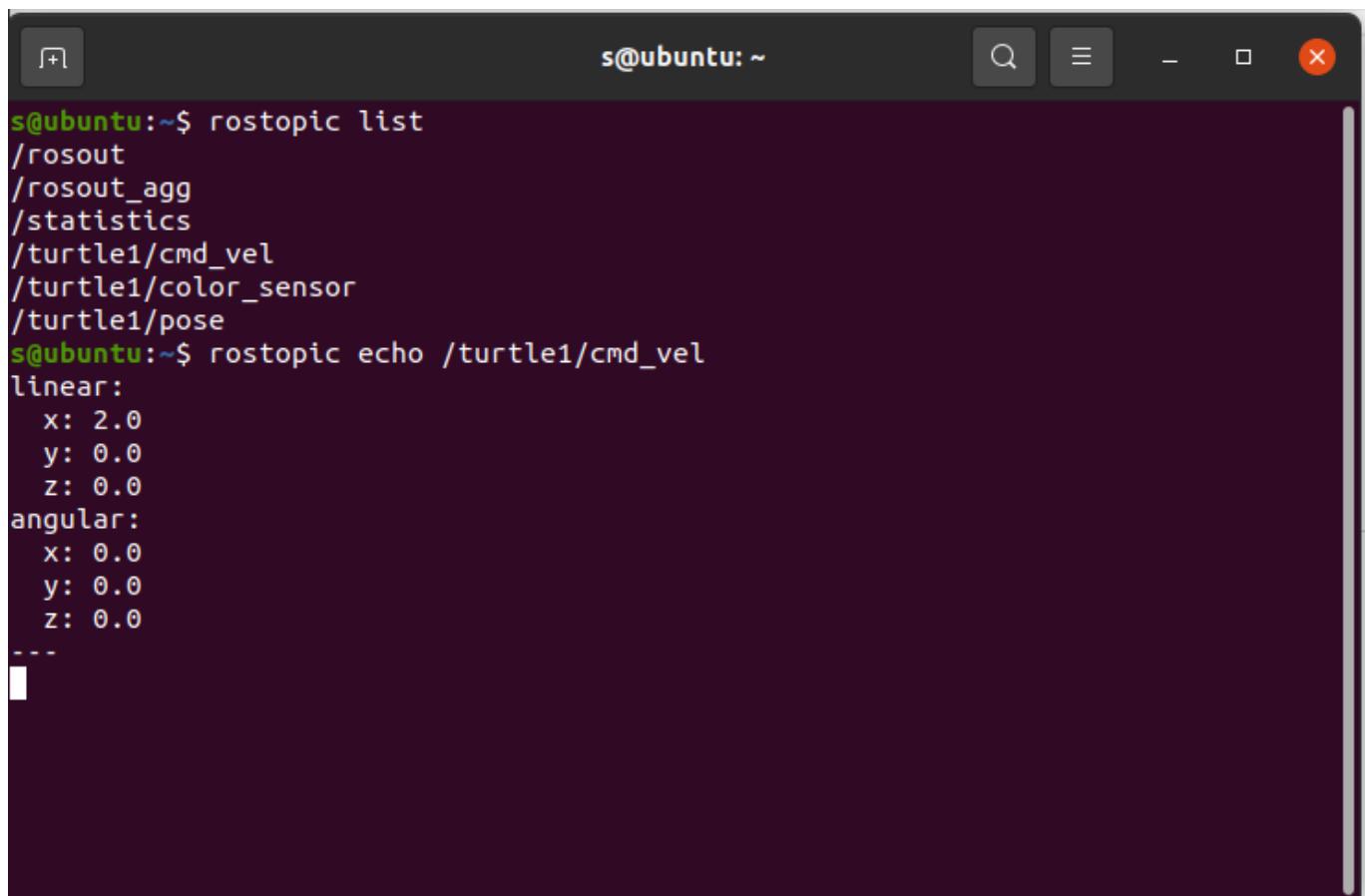
```
s@ubuntu:~/catkin_ws$ rostopic list
/rosout
/rosout_agg
/statistics
/turtle1/cmd_vel
/turtle1/color_sensor
/turtle1/pose
s@ubuntu:~/catkin_ws$ rostopic info /turtle1/cmd_vel
Type: geometry_msgs/Twist

Publishers:
* /teleop_turtle (http://ubuntu:35033/)

Subscribers:
* /turtlesim (http://ubuntu:45585/)
* /rostopic_13061_176659884503 (http://ubuntu:39697/)

s@ubuntu:~/catkin_ws$ rosmsg show geometry_msgs/Twist
geometry_msgs/Vector3 linear
  float64 x
  float64 y
  float64 z
geometry_msgs/Vector3 angular
  float64 x
  float64 y
  float64 z
```

```
# View topic data
rostopic echo /turtle1/cmd_vel
```



A screenshot of a terminal window titled "s@ubuntu: ~". The window shows the output of two commands: "rostopic list" and "rostopic echo /turtle1/cmd\_vel". The "rostopic list" command shows a list of topics including "/rosout", "/rosout\_agg", "/statistics", "/turtle1/cmd\_vel", "/turtle1/color\_sensor", and "/turtle1/pose". The "rostopic echo" command displays the current state of the "/turtle1/cmd\_vel" topic, which is a "Twist" message. The message consists of two "Vector3" fields: "linear" and "angular". The "linear" field has values x: 2.0, y: 0.0, z: 0.0. The "angular" field also has values x: 0.0, y: 0.0, z: 0.0. A vertical scrollbar is visible on the right side of the terminal window.

```
s@ubuntu:~$ rostopic list
/rosout
/rosout_agg
/statistics
/turtle1/cmd_vel
/turtle1/color_sensor
/turtle1/pose
s@ubuntu:~$ rostopic echo /turtle1/cmd_vel
linear:
  x: 2.0
  y: 0.0
  z: 0.0
angular:
  x: 0.0
  y: 0.0
  z: 0.0
---
```

# Experiment 3: Gazebo Simulation Environment

---

## 1. Experiment Objectives

- Master the use of the Gazebo simulator
- Learn to load and save simulation worlds
- Understand the World file structure
- Master the loading of robot models
- Message Type

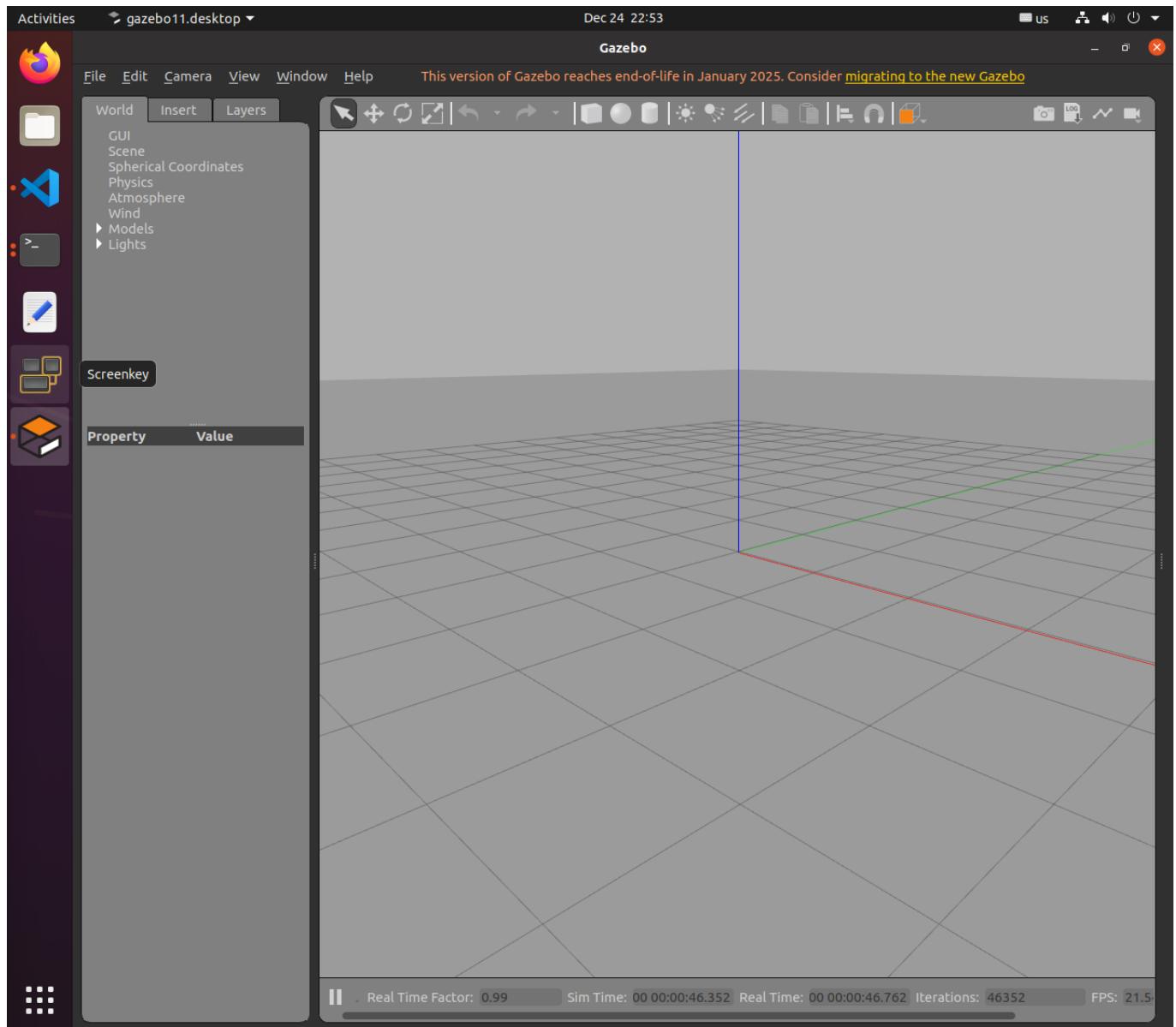
## 2. Gazebo Core Functions

- **Physics Engine** : Simulates real physical laws (gravity, collisions, friction).
- **Sensor Simulation** : LiDAR, cameras, IMU, etc.
- **ROS Integration** : Seamless communication with ROS.
- **Visualization** : 3D scene rendering.

## 3. Experiment Steps

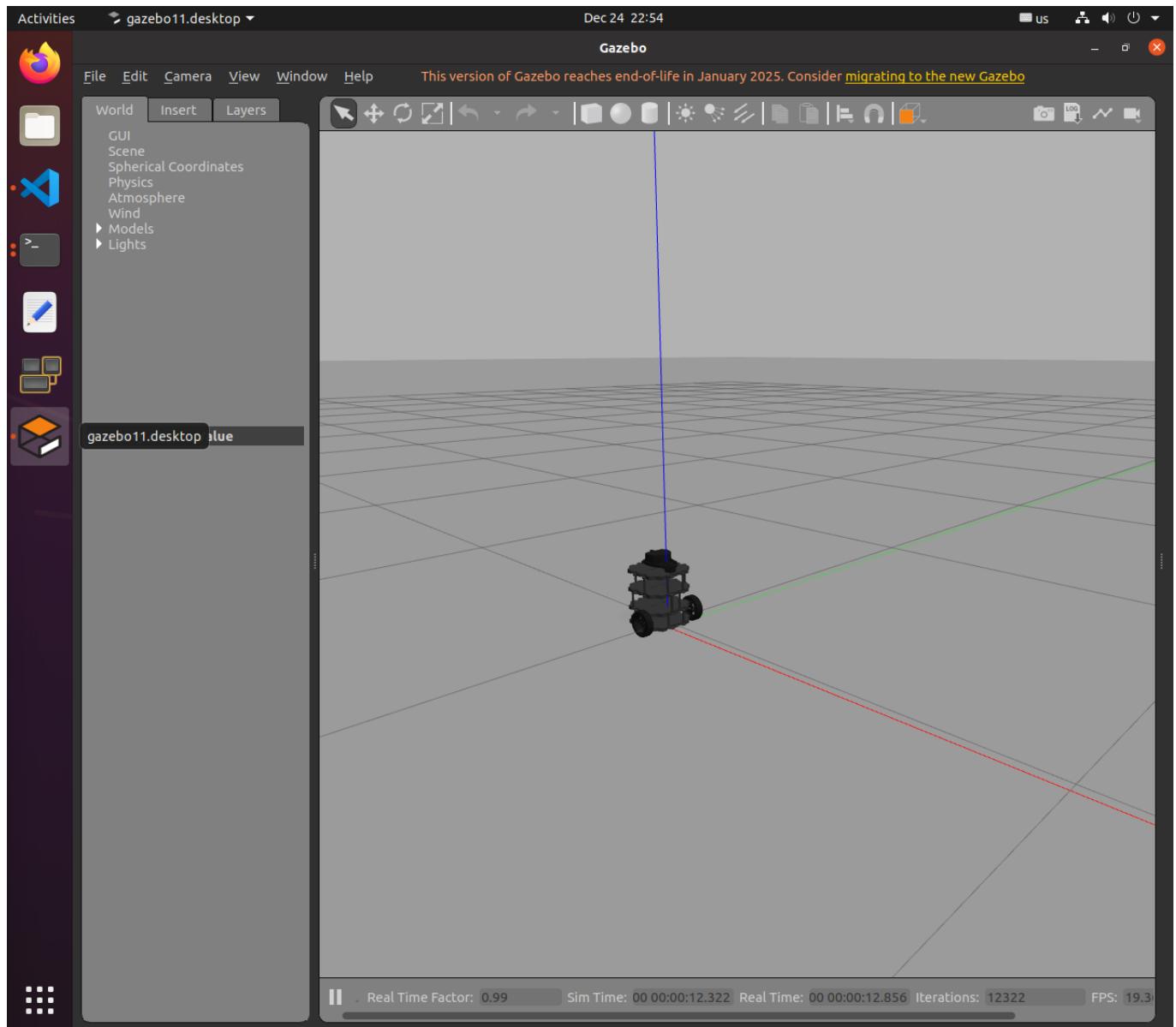
### 3.1 Start Empty World

```
gazebo
```



Or start using ROS

```
source ~/catkin_ws/devel/setup.bash
export TURTLEBOT3_MODEL=waffle
roslaunch turtlebot3_gazebo turtlebot3_empty_world.launch
```



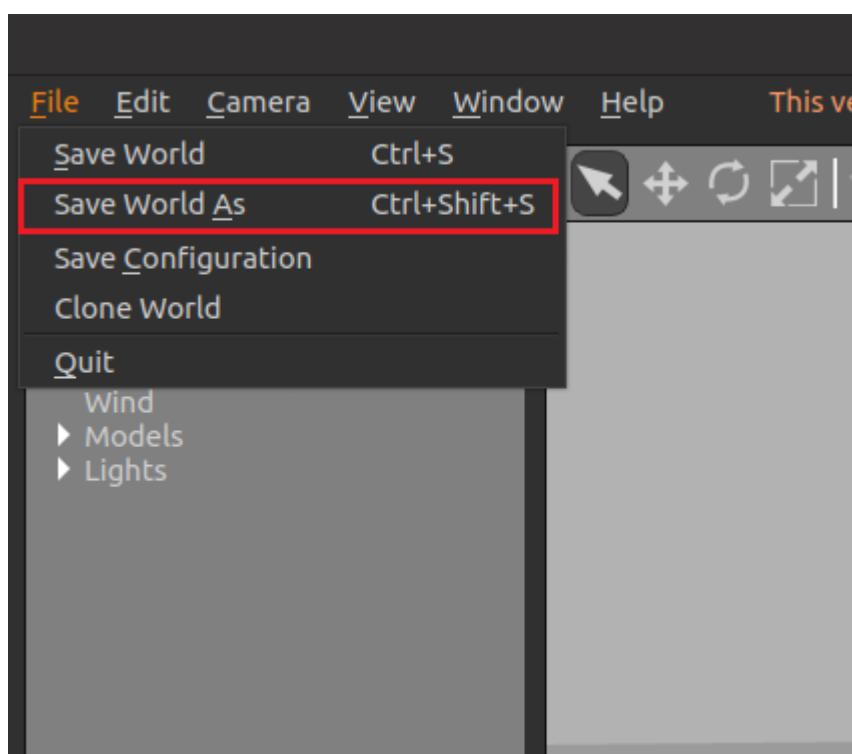
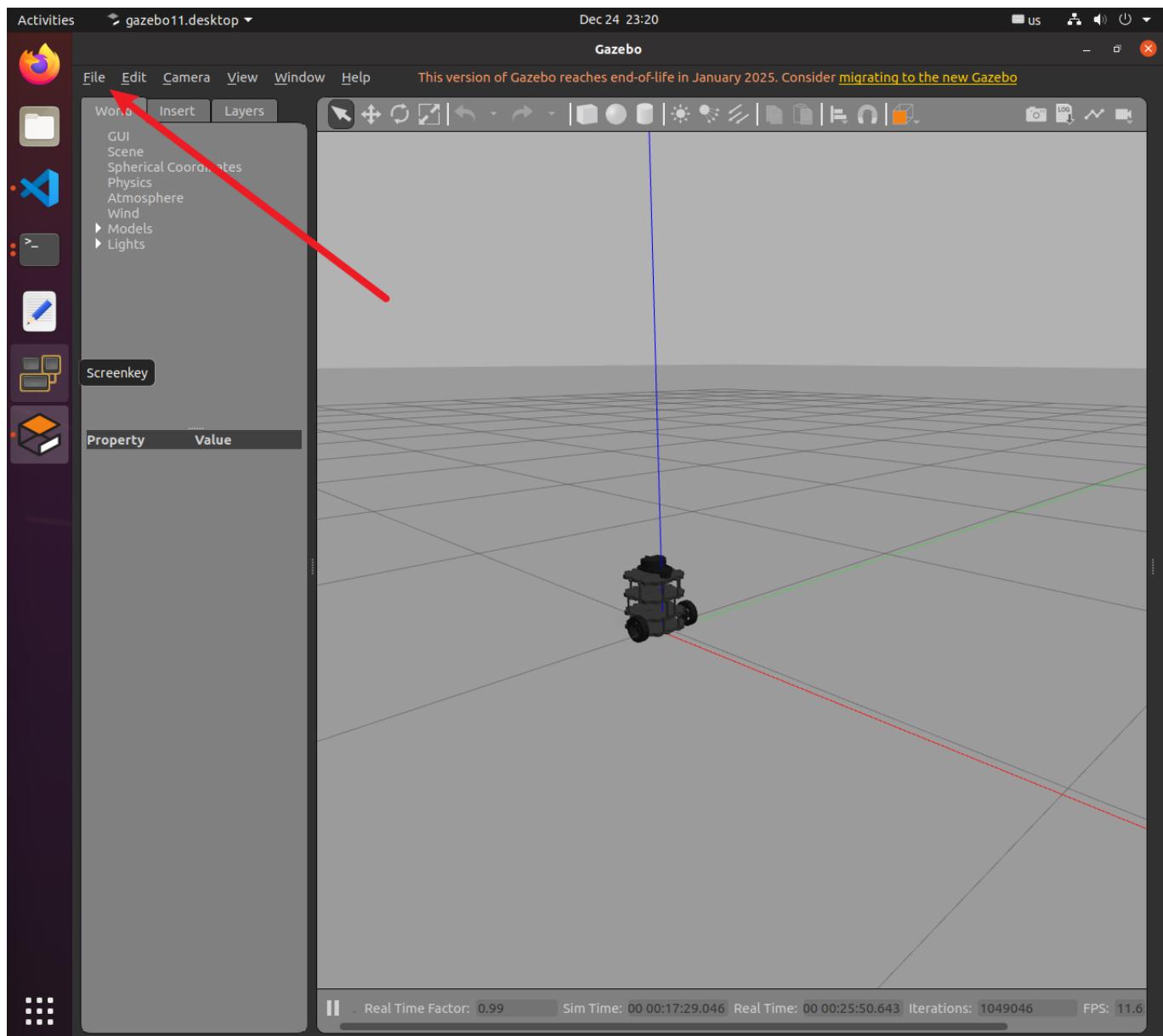
## 3.2 Build Custom Scene

1. **Insert Models** : Drag objects from the left panel into the scene.

2. **Adjust Parameters** :

- Position (x, y, z): Position coordinates
- Orientation (roll, pitch, yaw): Attitude angles
- Scale: Zoom size

1. **Save World** : [File -> Save World As -> my\\_world.world](#)

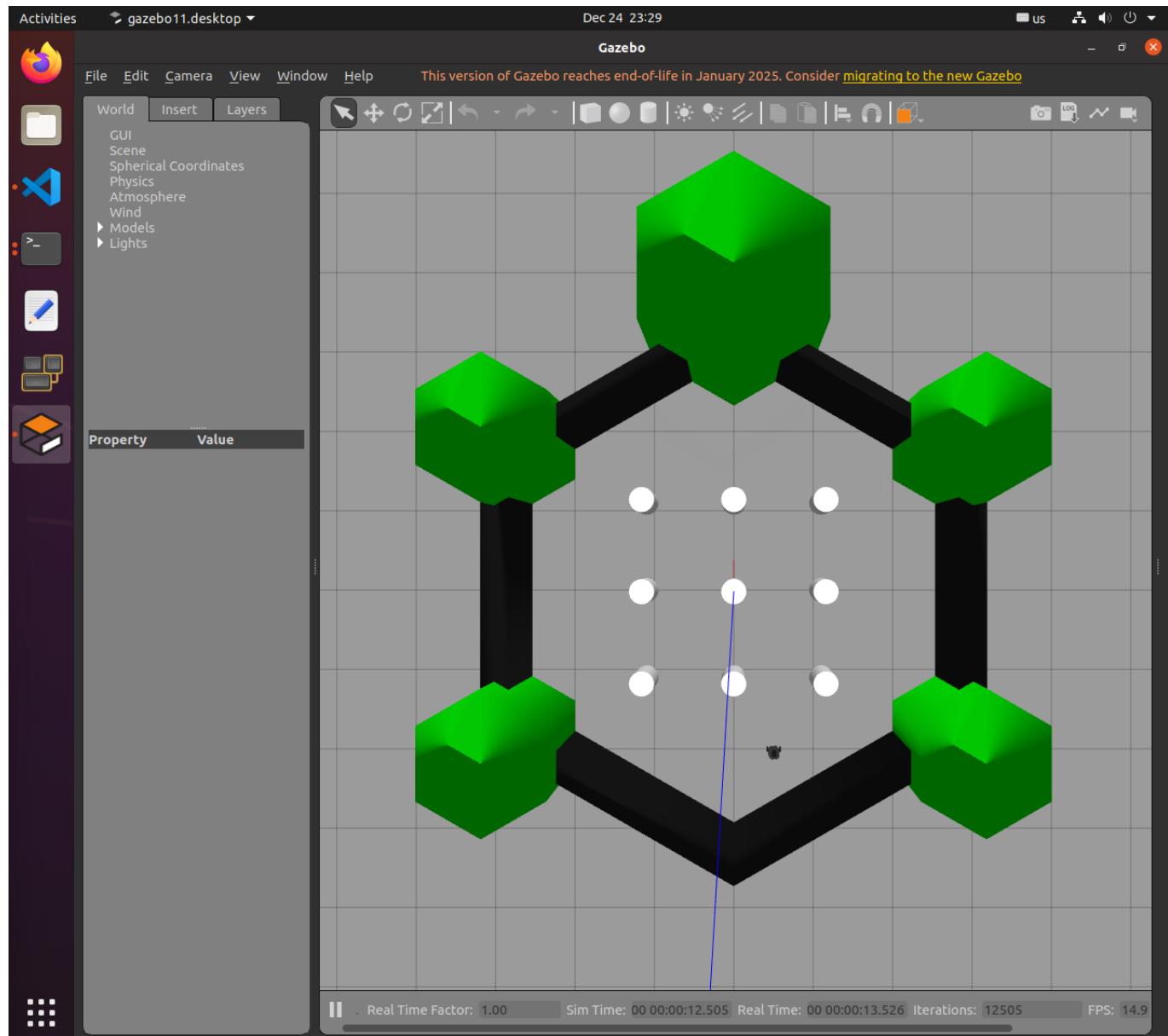


### 3.3 Load Custom World

```
gazebo my_world.world
```

#### Method 2: ROS launch file

```
source ~/catkin_ws/devel/setup.bash
export TURTLEBOT3_MODEL=waffle
roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

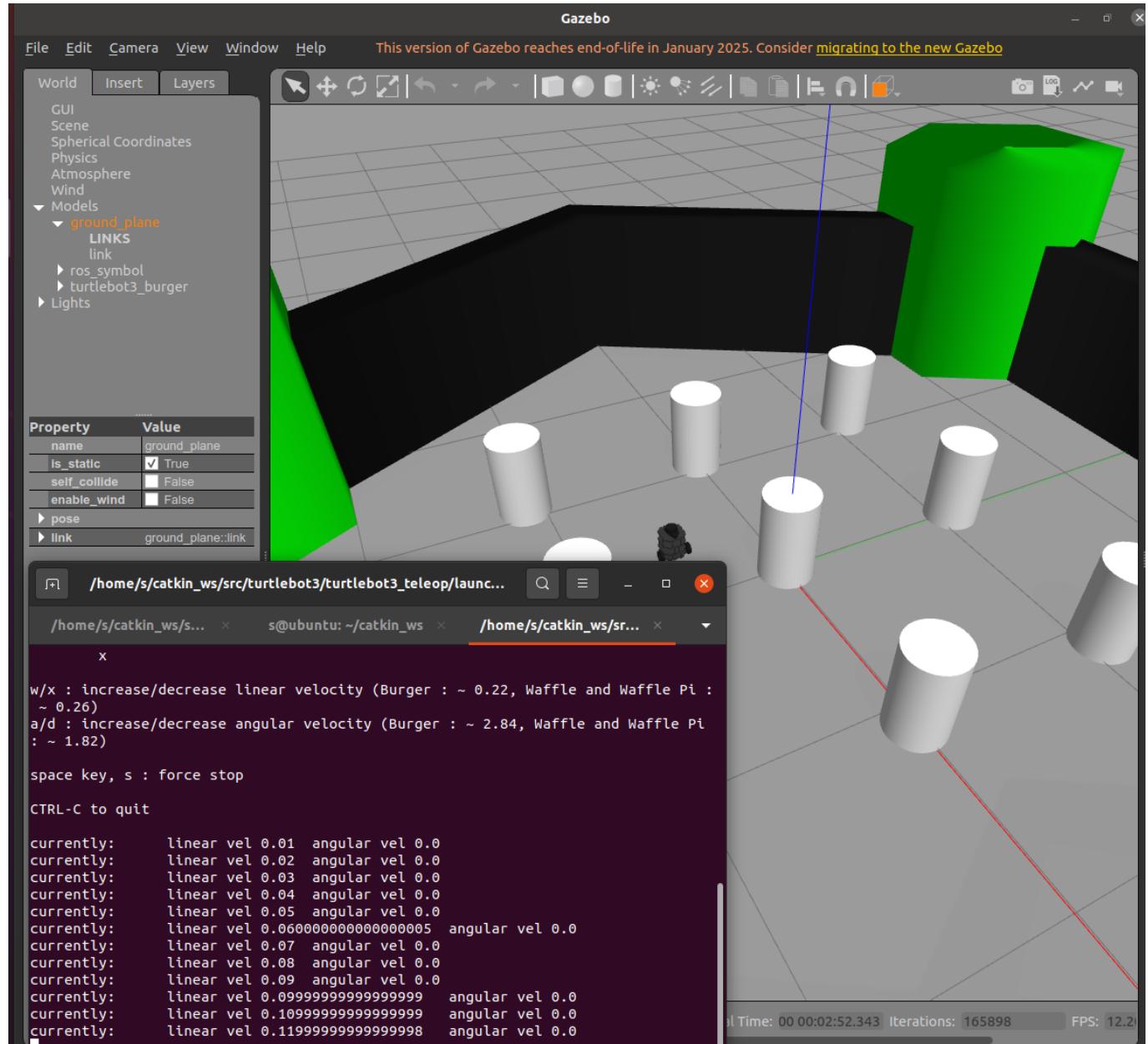


### 3.4 Control Robot Movement

```
source ~/catkin_ws/devel/setup.bash
export TURTLEBOT3_MODEL=waffle
roslaunch turtlebot3_teleop turtlebot3_teleop_key.launch
```

## Operating Instructions :

- **W/A/S/D or Arrow Keys:** Control movement
- **X:** Stop
- **Q/Z:** Increase/decrease speed



## Experiment 4: RViz Visualization

### 1. Experiment Objectives

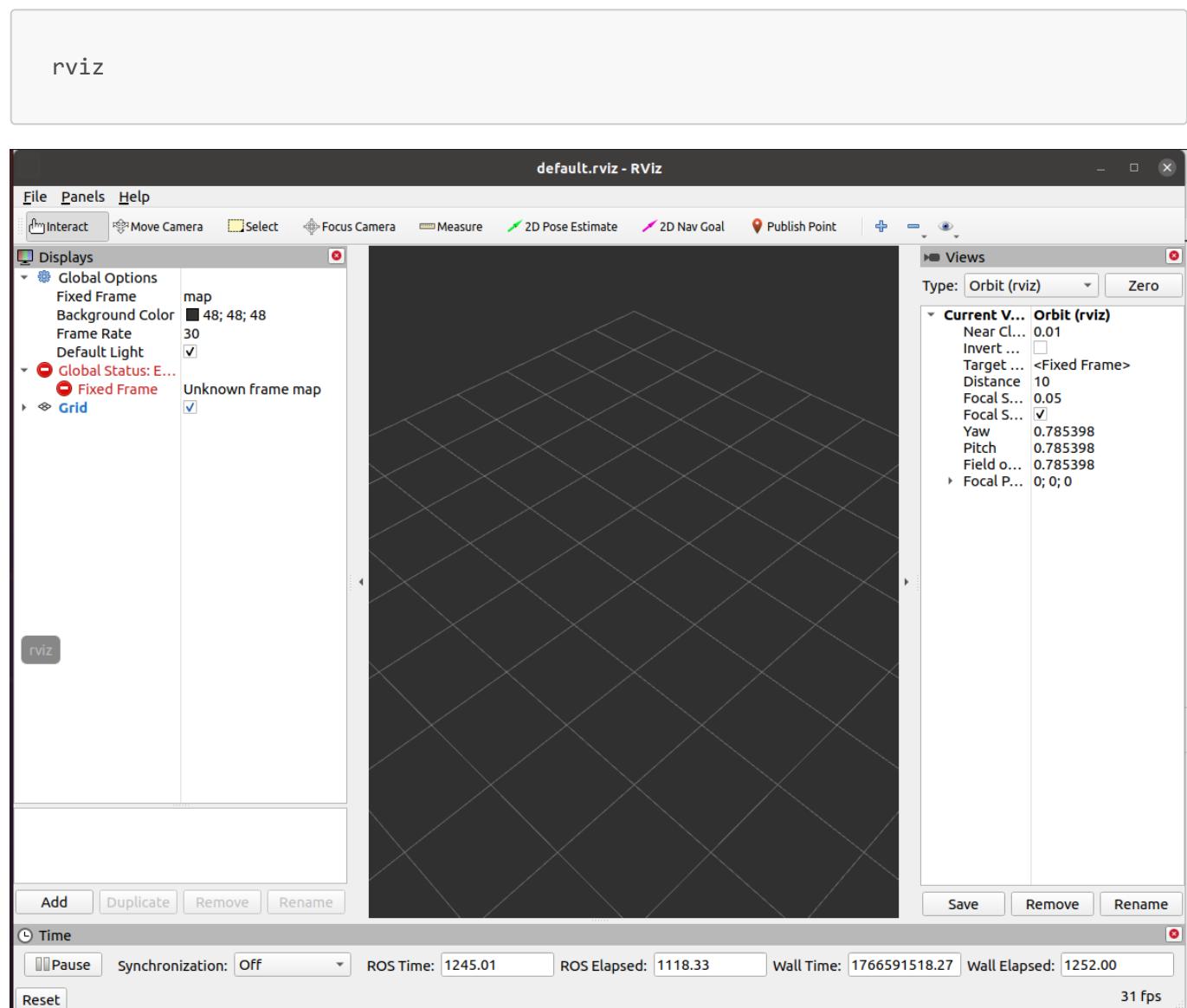
- Master the use of the RViz visualization tool
- Learn to add and configure display items
- Understand visual representation of sensor data
- Master interface interaction and viewpoint control

## 2. Data Types Displayable by RViz

- **Robot Model** : 3D robot model
- **LaserScan** : LiDAR scan data
- **PointCloud2** : 3D point cloud data
- **TF** : Coordinate system transformation relationships
- **Image** : Camera images
- **Odometry** : Odometry trajectory
- **Path** : Planned path
- **Map** : Occupancy grid map

## 3. Introduction to RViz Startup Methods

Start directly



### 3.1 Basic RViz Interface Operations

#### Viewpoint Control

- **Left mouse drag** : Rotate view

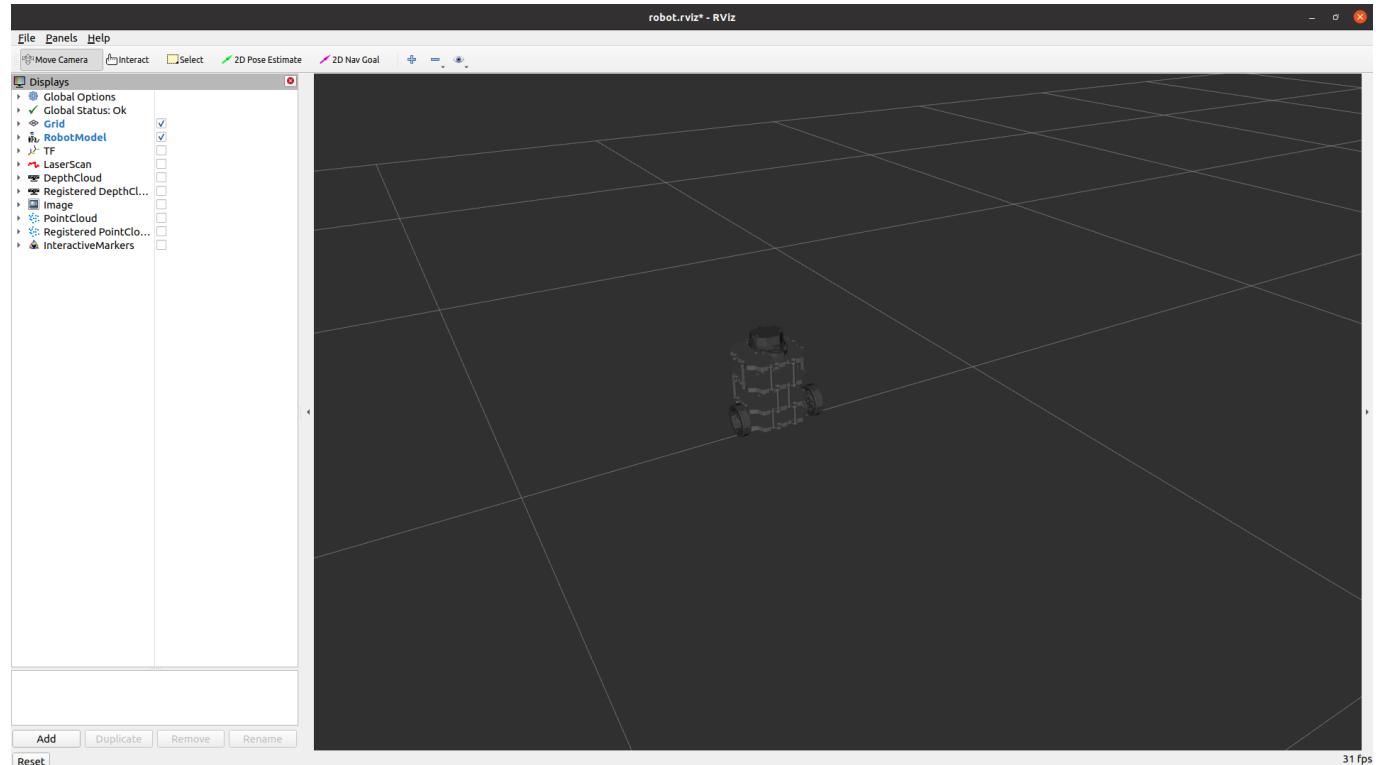
- **Mouse wheel** : Zoom view
- **Shift + Left drag** : Pan view
- **Shift + Wheel** : Pan up/down
- **Middle mouse drag** : Pan (some systems)

## 4. Experiment Steps

### 4.1 Start Simulation and Visualization

```
# Terminal 1: Start gazebo
source ~/catkin_ws/devel/setup.bash
roslaunch turtlebot3_gazebo turtlebot3_world.launch
```

```
# Terminal 2: Start RViz
source ~/catkin_ws/devel/setup.bash
roslaunch turtlebot_rviz_launchers view_robot.launch
```



### 4.2 Detailed Steps to Add Display Items (Display)

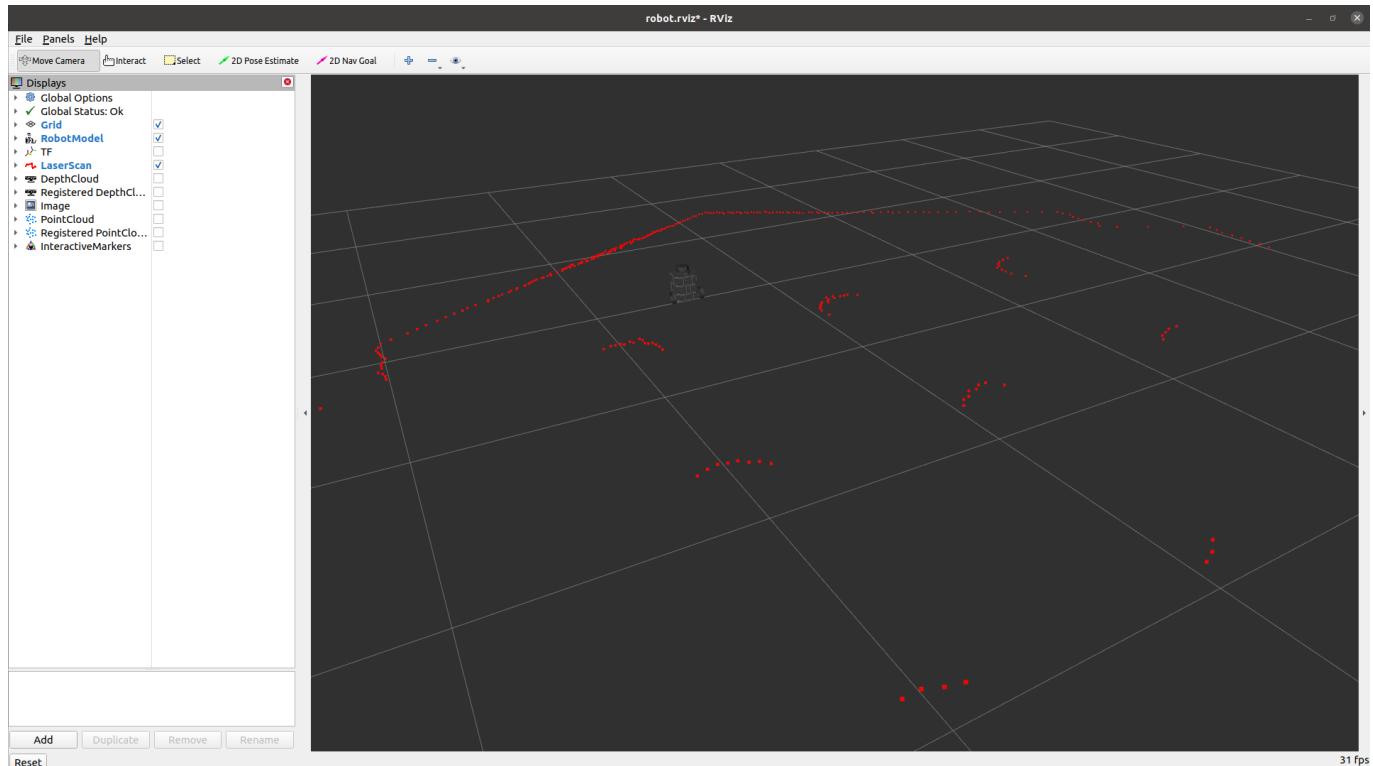
**Example 1: Adding LiDAR Data (Or just check the LaserScan box, like if the rviz launch already configured rviz)**

1. Click the "**Add**" button in the bottom left corner.
2. Select the "**By display type**" tab in the pop-up window.
3. Find and double-click "**LaserScan**".
4. Expand "**LaserScan**" in the left Displays panel.

## 5. Configure parameters:

```
Topic: /scan          # Click dropdown to select /scan
Size (m): 0.05       # Adjust point size
Style: Points         # Display style
Color Transformer: Intensity # Color map
```

## 6. Observe red scan points displaying obstacle positions.



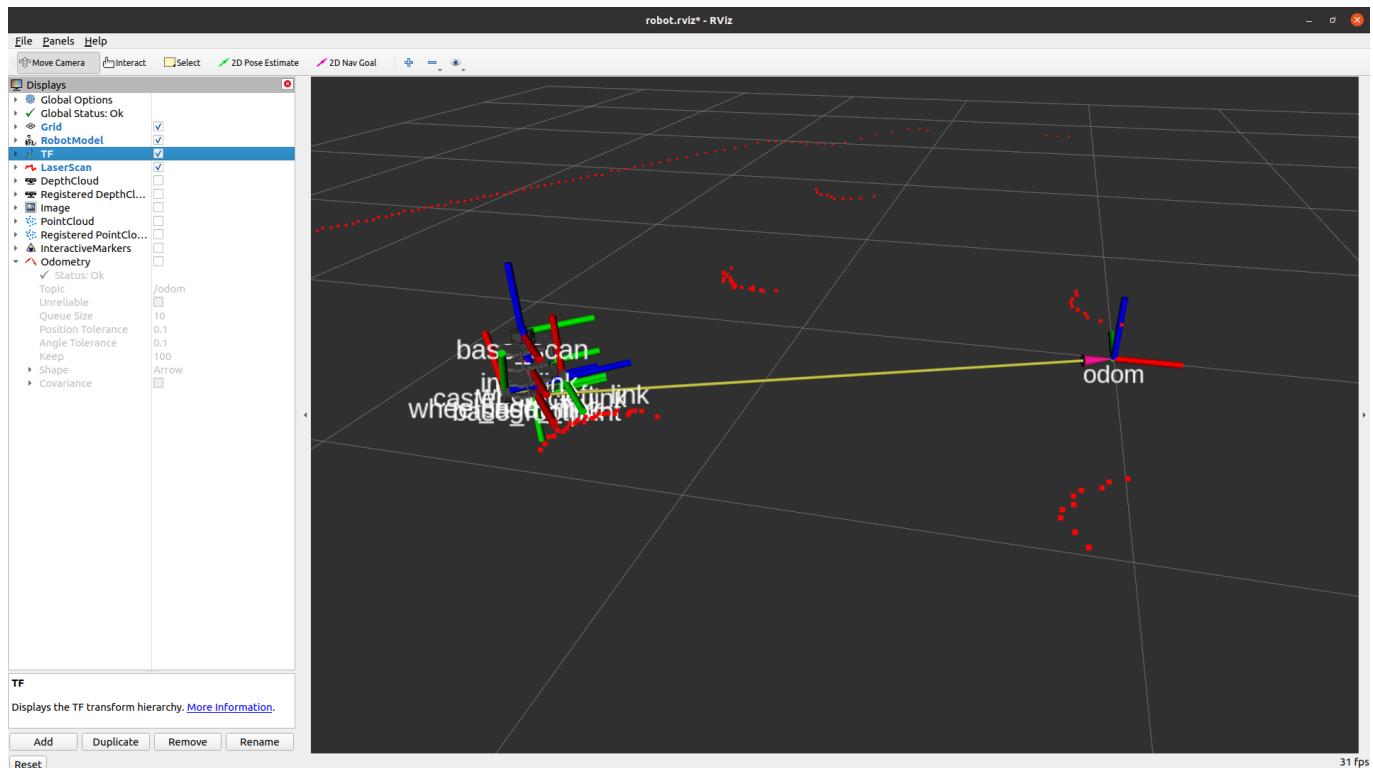
## Example 2: Adding Coordinate Systems (TF)

1. Click "Add" -> Select "TF" .

2. Configure parameters:

```
Show Axes          # Show axes
Show Arrows         # Show arrows
Marker Scale: 0.5  # Adjust axes size
Update Interval: 0 # Update interval (0=fastest)
```

3. Observe red, green, and blue arrows (representing X/Y/Z axes).



### 4.3 Configuration Table for Common Display Items

Display Type	Recommended Topic	Function	Key Parameters
<b>RobotModel</b>	(Default)	Displays 3D robot model	Robot Description: <code>robot_description</code>
<b>LaserScan</b>	<code>/scan</code>	LiDAR scan data	Size: <code>0.05</code> , Style: Points
<b>Odometry</b>	<code>/odom</code>	Odometry trajectory	Keep: <code>100</code> , Shape: Arrow
<b>TF</b>	(No setting needed)	Coordinate system relationships	Show Names: , Marker Scale: <code>0.5</code>
<b>Map</b>	<code>/map</code>	Occupancy grid map	Color Scheme: map

### 4.4 Adjust Fixed Frame (Reference Coordinate System)

#### What is Fixed Frame?

- The display of all data in RViz requires a reference coordinate system.
- Different scenarios require selecting different Fixed Frames.

#### Selection Suggestions

Scenario	Fixed Frame	Effect
Observing robot movement	<code>odom</code>	Viewpoint follows robot
Debugging sensors	<code>base_link</code>	Viewpoint locked onto the robot

#### Setting Method

1. Expand "Global Options" at the top.
2. Click the "Fixed Frame" dropdown menu.
3. Select `odom`.

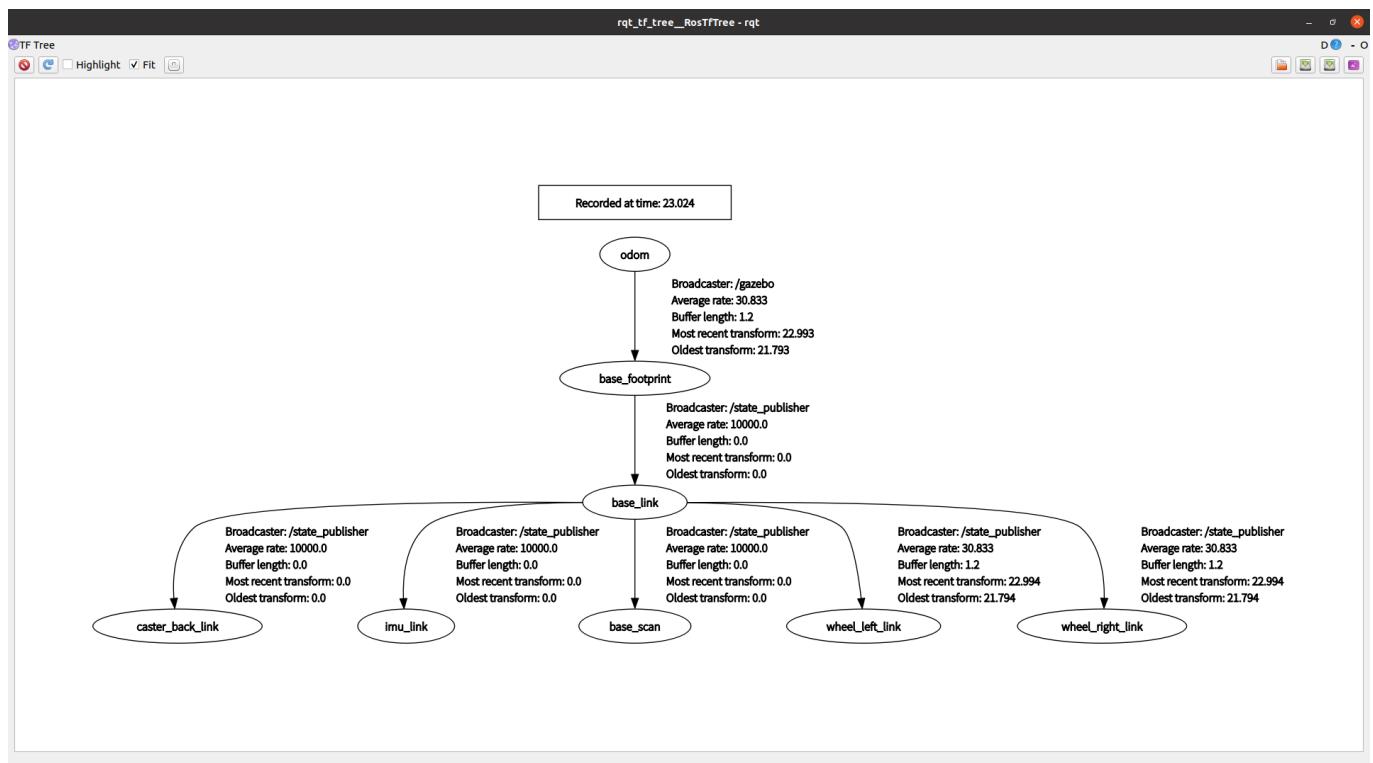
**Note :** If Fixed Frame is set incorrectly, all display items will turn gray or not show.

## 4.5 View TF Tree

### Command to view TF tree diagram

```
rosrun rqt_tf_tree rqt_tf_tree
```

### View TF Transforms



## 6. Common Troubleshooting

Issue	Cause	Solution
Display items turn red/gray	Topic not published	<code>rostopic list</code> Check if topic exists
Cannot see robot model	Fixed Frame error	Change to <code>odom</code> or <code>base_link</code>
Laser data does not show	Wrong Topic selected	Confirm it is <code>/scan</code>
TF shows "No transform"	TF tree incomplete	Check <code>rosrun tf view_frames</code>

## Suggestions for After-class Practice

- Practice Linux command-line operations more.

- Try modifying sample code parameters and observe the effects.
- Use `rqt_graph` and `rostopic` tools to analyze the system.
- Read the official ROS Wiki documentation.

## Recommended Resources

- [ROS Wiki](#)
- [Gazebo Tutorials](#)
- [TF Tutorials](#)