Bash Terminal Basic Commands

Command	Output
ls	List directory contents
echo	Prints text to the terminal window
touch	Creates a file
mkdir	Create a directory
pwd	Print working directory
cd	Change directory
mv	Move or rename directory
less	view the contents of a text file
cat	Read a file, create a file, and concatenate files
chmod	Sets the file permissions flag on a file or folder

ROS Basics

Difficulty: Beginner

The **Robot Operating System (ROS)** is a set of software libraries and tools for building robot applications. From drivers to state-of-the-art algorithms, and with powerful developer tools, ROS has what you need for your next robotics project. And it’s all open source.

These tutorials are a collection of step-by-step instructions meant to steadily build skills.

The best way to approach the tutorials is to walk through them for the first time in order, as they build off of each other and are not meant to be comprehensive documentation.

Catkin Workspace

- **catkin** is the official build system of ROS and the successor to the original ROS build system, rosbuild.
- **catkin** combines CMake macros and Python scripts to provide some functionality on top of CMake’s normal workflow.
- catkin was designed to be more conventional than rosbuild, allowing for better distribution of packages, better cross-compiling support, and better portability.

src

- the `src` folder contains the source code of catkin packages. This is where you can extract/checkout/clone source code for the packages you want to build.
- Each folder within the `src` folder contains one or more catkin packages. This folder should remain unchanged by configuring, building, or installing.
- The root of the `src` folder contains a symbolic link to catkin’s boiler-plate ‘toplevel’ CMakeLists.txt file. This file is invoked by CMake during the configuration of the catkin projects in the workspace. It can be created by calling `catkin_init_workspace` in the `src` folder directory. When we execute the `catkin_make` command from the workspace folder, it checks inside the `src` folder and builds each package.

build

- The `build` folder is where CMake is invoked to `build` the catkin packages in the `src` folder.
- CMake and catkin keep their cache information and other intermediate files here.

- The `build` folder does not have to be contained within the workspace nor does it have to be outside of the `src` folder, but this is recommended.

devel

- The development folder (or `devel` folder) is where built targets are placed before installed.
- The way targets are organized in the `devel` folder is the same as their layout when they are installed.
- This provides a useful testing and development environment which does not require invoking the installation step.
- The location of the `devel` folder is controlled by a catkin specific CMake variable called `CATKIN_DEVEL_PREFIX`, and it defaults to build/devel folder.
- This is the default behavior because it might be confusing to CMake users if they invoked CMake in a `build` folder and that modified things outside of the current directory.
- It is recommended, however, to set the `devel` folder directory to be a peer of the `build` folder directory.

```
source ~/<workspace_name>/devel/setup.bash
```

Create a Catkin Workspace

1. Open up the terminal `shortcut key: ctrl+alt+t`.
2. Create the root workspace directory. You can name your directory anything we are using `workspace` as the name this time.

```
cd ~/
mkdir -p ~/workspace/src
cd workspace
```

3. Run the following command:

```
catkin_make
```

4. The `catkin_make` command is a convenience tool for working with catkin workspaces. Running it the first time in your workspace, it will create a `CMakeLists.txt` link in your `src` folder.
5. Additionally, if you look in your current directory you should now have a 'build' and 'devel' folder.

```
ls
```

6. Now to make your workspace visible to ROS. Source the setup file in the devel directory.

```
source ~/workspace/devel/setup.bash
```

By doing this, all the packages that you create inside the `src` folder will be visible to ROS. s 7. This `setup.bash` file of your workspace must be source everytime when you want to use ROS packages created inside this workspace.

8. To make sure your workspace is properly overlayed by the setup script, make sure ROS_PACKAGE_PATH environment variable includes the directory you're in.

```
echo $ROS_PACKAGE_PATH
/home/youruser/workspace/src:/opt/ros/noetic/share
```

ROS Package

- ROS Packages according to ROS Wiki

> Software in ROS is organized in packages. A package might contain ROS nodes, a ROS-independent library, a dataset, configuration files, a third-party piece of software, or anything else that logically constitutes a useful module. The goal of these packages it to provide this useful functionality in an easy-to-consume manner so that software can be easily reused. In general, ROS packages follow a "Goldilocks" principle: enough functionality to be useful, but not too much that the package is heavyweight and difficult to use from other software.

Reference

1. Packages

Create a ROS Package

- This tutorial will demonstrate how to use the `catkin_create_pkg` script to create a new catkin package, and what you can do with it after it has been created.

1. First, navigate to the source space directory of the catkin workspace you've created.

```
cd ~/workspace/src
```

2. Now, use the catkin_create_pkg script to create a new package called pkg_ros_basics which depends on std_msgs, roscpp, and rospy:

```
catkin_create_pkg pkg_ros_basics std_msgs rospy roscpp
```

   - This will create a beginner_tutorials folder which contains a `package.xml` and a `CMakeLists.txt`, which have been partially filled out with the information you gave `catkin_create_pkg`.
   - `catkin_create_pkg` requires that you give it a `package_name` and optionally a list of dependencies on which that package depends:

```
catkin_create_pkg <package_name> [depend1] [depend2] [depend3]
```

3. Now, you need to build the packages in the catkin workspace:

```
cd ~/workspace
catkin_make
```

- Inside the package, there are `src` folder, `package.xml`, `CMakeLists.txt`, and the `include` folders.
  - **CMakeLists.txt**: This file has all the commands to build the ROS source code inside the package and create the executable. For more information about CMakeLists visit here.
  - **package.xml**: This is an XML file. It mainly contains the package dependencies, information, and so forth.
  - **src**: The source code of ROS packages are kept in this folder.

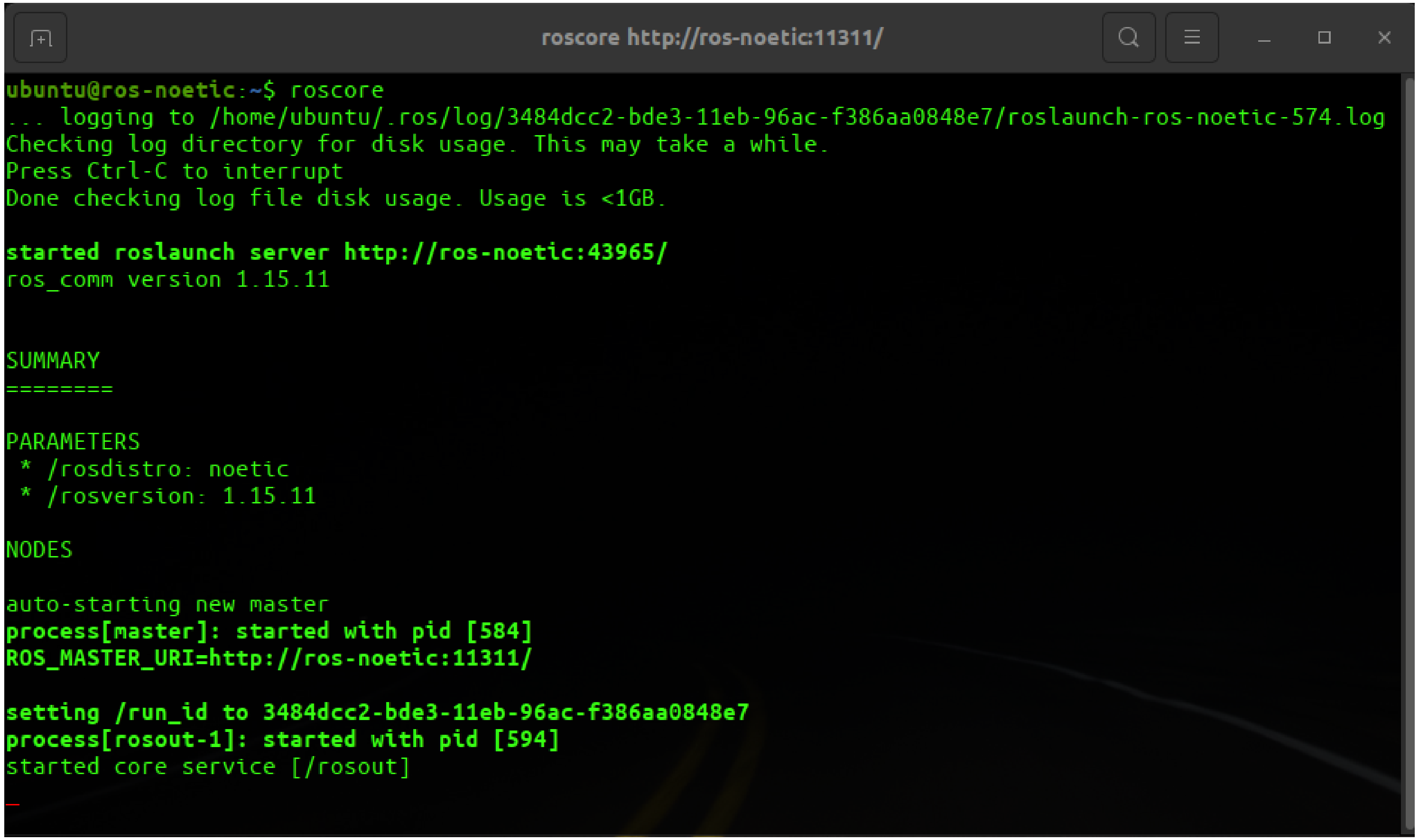
ROS Master

- The `ROS Master` provides naming and registration services to the rest of the nodes in the ROS system.
- As you know ROS Nodes are building blocks of any ROS Application. A single ROS Application may have multiple ROS Nodes which communicate with each other.
- The role of the ROS Master is to enable individual ROS nodes to locate one another.
- Once these nodes have located each other they communicate with each other peer-to-peer.
- You can say, communication is established between nodes by the ROS Master. So, without `ROS Master` running ROS Nodes can not communicate with each other.

Start ROS Master

To start `ROS Master` you just have to enter the following command in the terminal.

```
roscore
```



`roscore` is a collection of nodes and programs that are pre-requisites of a ROS-based system. You must have a roscore running in order for ROS nodes to communicate.

So roscore will start the following:

1. ROS Master
2. ROS Parameter Server
3. `rosout` Logging Node

In the preceding output, you can see information about the computer, parameter which list the name (noetic) and version number of ROS distribution, and some other information.

Reading Assignment

1. ROS Wiki - Master
2. ROS Wiki - roscore

Introducing ROS using turtlesim

- In this section, we will learn about `ROS Nodes`, `ROS Topics` and `ROS Services` using turtlesim examples.
- Commands will be directly executed from the bash terminal.

Configuring your ROS environment

Goal: This tutorial will show you how to prepare your ROS environment.

Prerequisites

Before starting these tutorials please complete installation as described in the ROS installation instructions.

Managing Your Environment

During the installation of ROS, you will see that you are prompted to source one of several setup.*sh files, or even add this ‘sourcing’ to your shell startup script. This is required because ROS relies on the notion of combining spaces using the shell environment. This makes developing against different versions of ROS or against different sets of packages easier.

If you are ever having problems finding or using your ROS packages make sure that you have your environment properly setup. A good way to check is to ensure that environment variables like ROS_ROOT and ROS_PACKAGE_PATH are set:

```
$ printenv | grep ROS
```

```
ROS_VERSION=1
ROS_PYTHON_VERSION=3
ROS_PACKAGE_PATH=/home/ubuntu/workspace/src:/opt/ros/noetic/share
ROSLISP_PACKAGE_DIRECTORIES=/home/ubuntu/workspace/devel/share/common-lisp
ROS_ETC_DIR=/opt/ros/noetic/etc/ros
ROS_MASTER_URI=http://localhost:11311
ROS_ROOT=/opt/ros/noetic/share/ros
ROS_DISTRO=noetic
```

If they are not then you might need to 'source' some setup.*sh files.

```
$ source /opt/ros/noetic/setup.bash
```

> **NOTE**: You will need to run this command on every new shell you open to have access to the ROS commands, unless you add this line to your .bashrc.

To add this line to .bashrc run this command:

```
echo "source /opt/ros/noetic/setup.bash" >> ~/.bashrc
```

To undo this (to change to another distro) in Linux and macOS, locate your system's shell startup script and remove the appended source command.

Summary

The ROS development environment needs to be correctly configured before use. This can be done in two ways: either sourcing the setup files in every new shell you open, or adding the source command to your startup script.

If you ever face any problems locating or using packages with ROS, the first thing you should do is check your environment variables and ensure they are set to the version and distro you intended.

Introducing turtlesim and rqt

Goal: Install and use the turtlesim package and rqt tools to prepare for upcoming tutorials.

Background

Turtlesim is a lightweight simulator for learning ROS. It illustrates what ROS does at the most basic level, to give you an idea of what you will do with a real robot or robot simulation later on.

rqt is a GUI tool for ROS. Everything done in rqt can be done on the command line, but it provides an easier, more user-friendly way to manipulate ROS elements.

This tutorial touches on core ROS concepts, like the separation of nodes, topics, and services. All of these concepts will be elaborated on in later tutorials; for now, you will simply set up the tools and get a feel for them.

Prerequisites

The previous tutorial, Configuring your ROS environment, will show you how to set up your environment.

Tasks

1 Start rosmaster

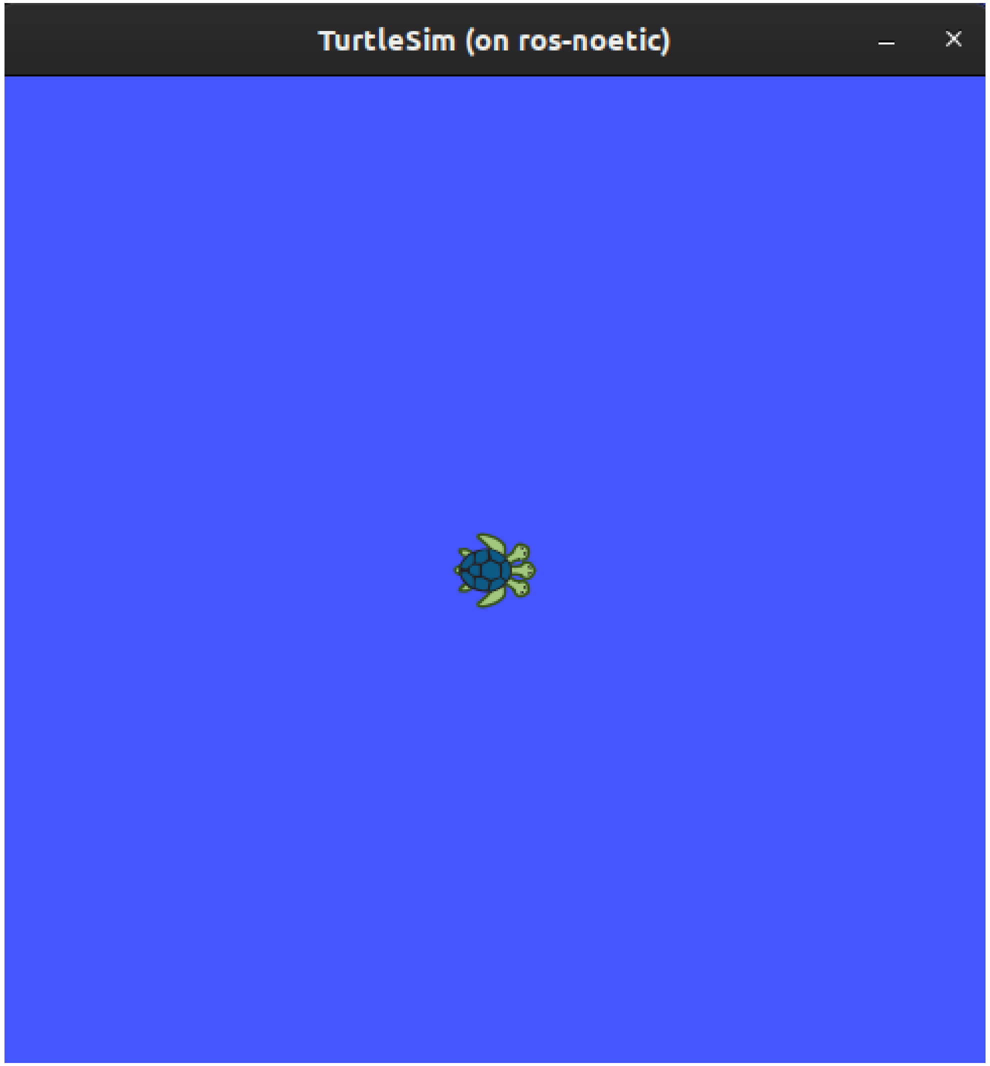
```
roscore
```

2 Start turtlesim

To start turtlesim, enter the following command in your terminal:

```
rosrun turtlesim turtlesim_node
```

The simulator window should appear, with a random turtle in the center.



In the terminal under the command, you will see messages from the node:

```
[ INFO] [1622133713.331795042]: Starting turtlesim with node name /turtlesim
[ INFO] [1622133713.335199049]: Spawning turtle [turtle1] at x=[5.544445], y=
[5.544445], theta=[0.000000]
```

Here you can see your default turtle's name is `turtle1`, and the default coordinates where it spawns.

3 Use turtlesim

Open a new terminal and source ROS again.

Now you will run a new node to control the turtle in the first node:

```
rosrun turtlesim turtle_teleop_key
```

At this point you should have four windows open: a terminal running `roscore`, a terminal running `turtlesim_node`, a terminal running `turtle_teleop_key` and the turtlesim window. Arrange these windows so that you can see the turtlesim window, but also have the terminal running `turtle_teleop_key` active so that you can control the turtle in turtlesim.

Use the arrow keys on your keyboard to control the turtle. It will move around the screen, using its attached "pen" to draw the path it followed so far.

> **Note**: Pressing an arrow key will only cause the turtle to move a short distance and then stop. This is because, realistically, you wouldn't want a robot to continue carrying on an instruction if, for example, the operator lost the connection to the robot.

You can see the nodes and their associated services, topics using the list command:

```
rosnode list
rostopic list
rosservice list
```

You will learn more about these concepts in the coming tutorials. Since the goal of this tutorial is only to get a general overview of turtlesim, we will use rqt (a graphical user interface for ROS) to look at services a little closer.

4 Run rqt

Open a new terminal to run `rqt`:

```
rqt
```

After running rqt the first time, the window will be blank. No worries; just select Plugins > Services > Service Caller from the menu bar at the top.

> **Note**: It may take some time for rqt to locate all the plugins itself. If you click on Plugins, but don't see Services or any other options, you should close rqt, enter the command `rqt --force-discover` in your terminal.

Use the refresh button to the left of the **Service** dropdown list to ensure all the services of your turtlesim node are available.

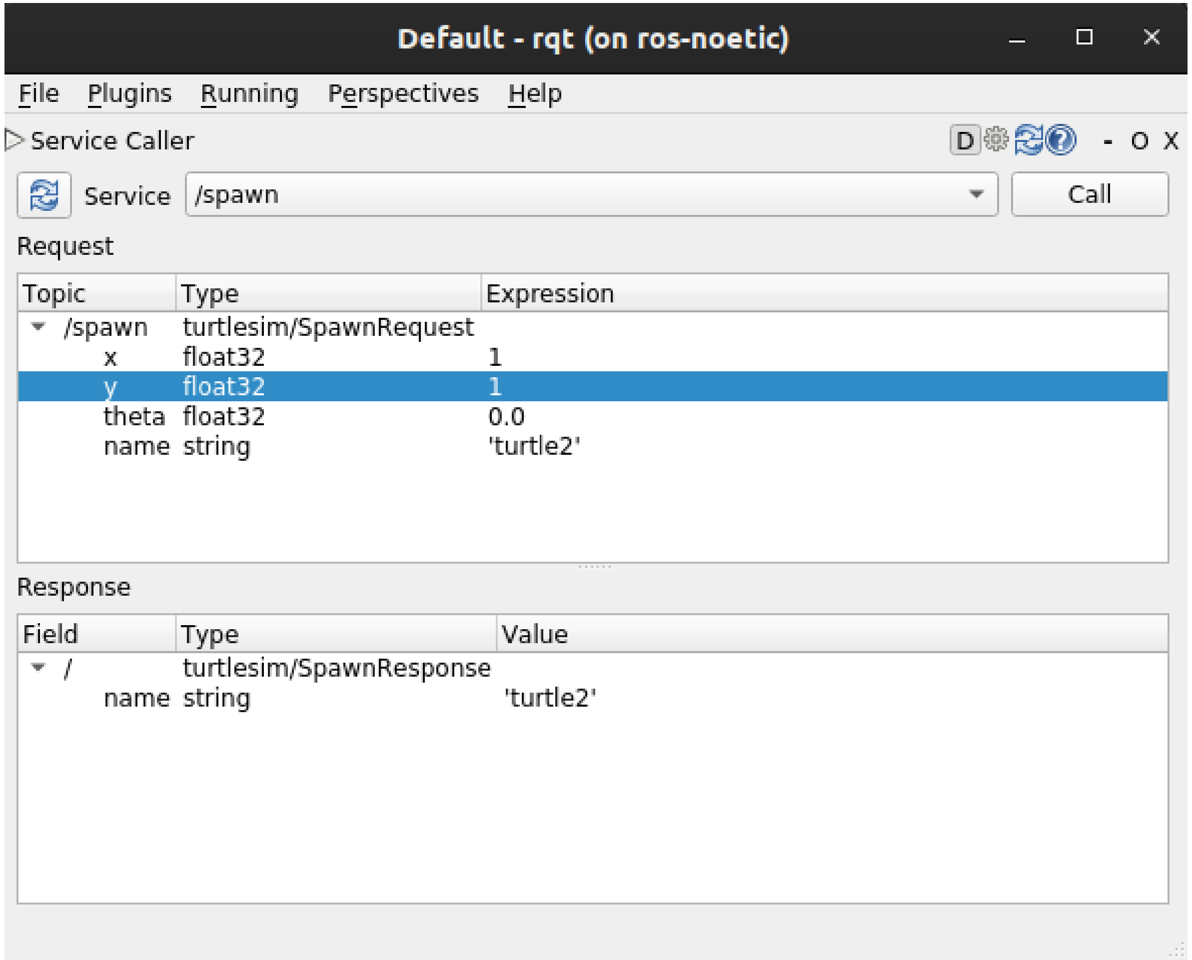
Click on the Service dropdown list to see turtlesim's services, and select the `/spawn` service.

4.1 Try the spawn service

Let's use rqt to call the `/spawn` service. You can guess from its name that `/spawn` will create another turtle in the turtlesim window.

Give the new turtle a unique name, like `turtle2` by double-clicking between the empty single quotes in the Expression column. You can see that this expression corresponds to the **name** value, and is of type **string**.

Enter new coordinates for the turtle to spawn at, like `x = 1.0` and `y = 1.0`.



> **Note**: If you try to spawn a new turtle with the same name as an existing turtle, like your default `turtle1`, you will get an error message in the terminal running `turtlesim_node`:

```
[ERROR] [1622134917.034342076]: A turtled named [turtle1] already exists
```

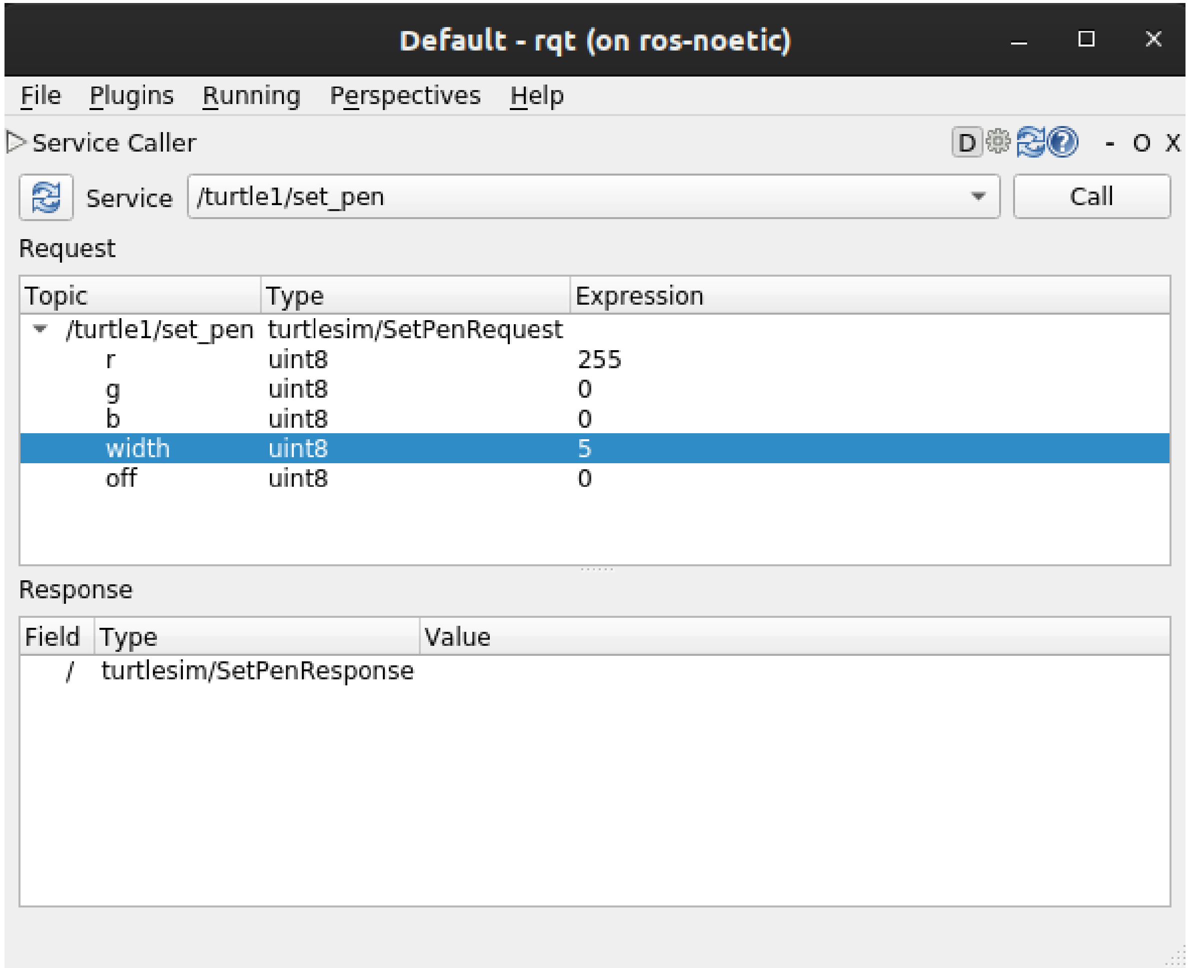
To spawn turtle2, you have to call the service by clicking the **Call** button on the upper right side of the rqt window.

You will see a new turtle (again with a random design) spawn at the coordinates you input for **x** and **y**.

If you refresh the service list in rqt, you will also see that now there are services related to the new turtle, `/turtle2/…`, in addition to `/turtle1/…`.

4.2 Try the set_pen service

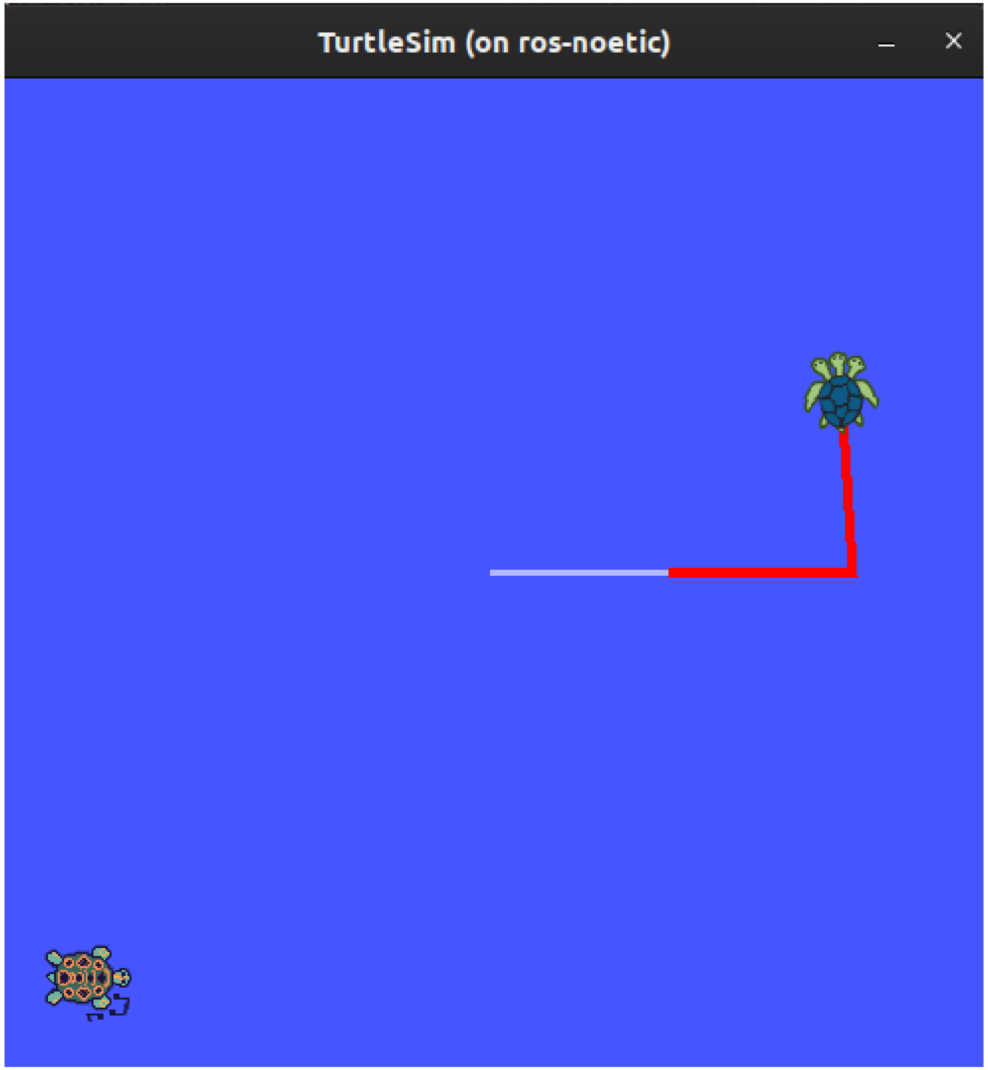
Now let's give turtle1 a unique pen using the `/set_pen` service:



The values for **r**, **g** and **b**, between 0 and 255, will set the color of the pen turtle1 draws with, and **width** sets the thickness of the line.

To have turtle1 draw with a distinct red line, change the value of **r** to 255, and the value of width to **5**. Don't forget to call the service after updating the values.

If you return to the terminal where `turtle_teleop_node` is running and press the arrow keys, you will see turtle1's pen has changed.



You've probably noticed that there's no way to move turtle2. You can accomplish this by remapping turtle1's `cmd_vel` topic onto turtle2.

5 Remapping

In a new terminal, source ROS, and run:

```
rosrun turtlesim turtle_teleop_key __name:=turtle2 --ros-args --remap
turtle1/cmd_vel:=turtle2/cmd_vel
```

> **Note**: Notice that __name:=turtle2 starts the node with name `turtle2`. This avoids conflicts if we start two nodes with same name.

Now you can move turtle2 when this terminal is active, and turtle1 when the other terminal running the `turtle_teleop_key` is active.

Close turtlesim

To stop the simulation, you can simply close the terminal windows where you ran `turtlesim_node` and `turtle_teleop_key`. If you want to keep those terminals open, but end the simulation, you can enter Ctrl + C in the turtlesim_node terminal, and q in the teleop terminal.

Summary

Using turtlesim and rqt is a great way to learn the core concepts of ROS.

Understanding ROS nodes

Goal: Learn about the function of nodes in ROS, and the tools to interact with them.

Background

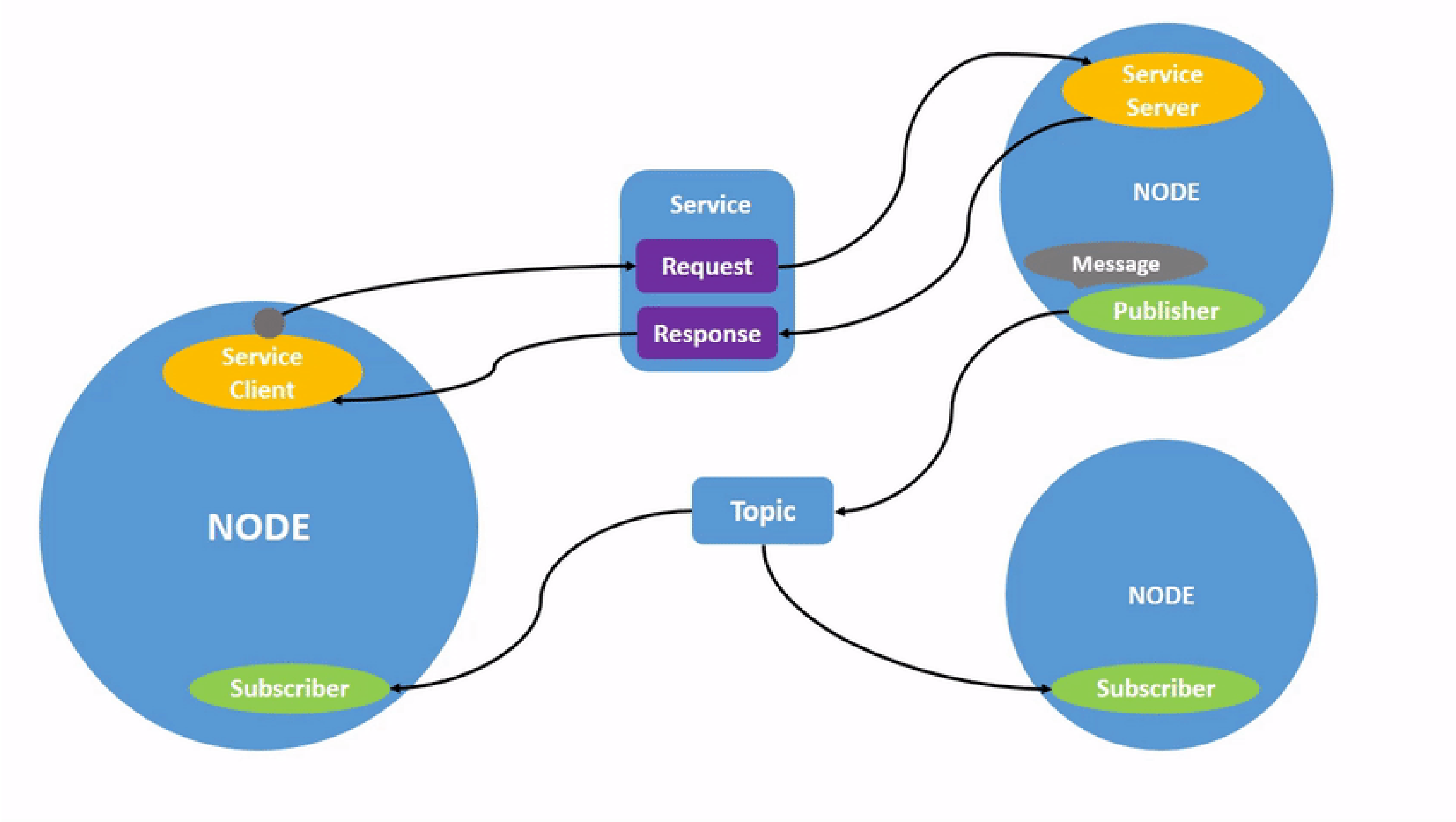
1 The ROS graph

Over the next few tutorials, you will learn about a series of core ROS concepts that make up what is referred to as the “ROS graph”.

The ROS graph is a network of ROS elements processing data together at one time. It encompasses all executables and the connections between them if you were to map them all out and visualize them.

2 Nodes in ROS

Each node in ROS should be responsible for a single, module purpose (e.g. one node for controlling wheel motors, one node for controlling a laser range-finder, etc). Each node can send and receive data to other nodes via topics, services, actions, or parameters.



A full robotic system is comprised of many nodes working in concert.

Prerequisites

As always, don't forget to source ROS in every new terminal you open. Also, run `roscore` in a separate terminal.

Tasks

1 rosrun

The command `rosrun` launches an executable from a package.

```
rosrun <package_name> <executable_name>
```

To run turtlesim, open a new terminal, and enter the following command:

```
rosrun turtlesim turtlesim_node
```

Here, the package name is `turtlesim` and the executable name is `turtlesim_node`.

We still don't know the node name, however. You can find node names by using `rosnode list`

2 rosnode list

`rosnode list` will show you the names of all running nodes. This is especially useful when you want to interact with a node, or when you have a system running many nodes and need to keep track of them.

Open a new terminal while turtlesim is still running in the other one, and enter the following command:

```
rosnode list
```

The terminal will return the node name:

```
/rosout
/turtlesim
```

Open another new terminal and start the teleop node with the command:

```
rosrun turtlesim turtle_teleop_key
```

Here, we are searching the `turtlesim` package again, this time for the executable named `turtle_teleop_key`.

Return to the terminal where you ran `rosnode list` and run it again. You will now see the names of two active nodes:

```
/rosout
/teleop_turtle
/turtlesim
```

2.1 Remapping

Remapping allows you to reassign default node properties, like node name, topic names, service names, etc., to custom values. In the last tutorial, you used remapping on `turtle_teleop_key` to change the default turtle being controlled.

Now, lets reassign the name of our `/turtlesim` node. In a new terminal, run the following command:

```
rosrun turtlesim turtlesim_node __name:=my_turtle
```

Since you're calling `rosrun` on turtlesim again, another turtlesim window will open. However, now if you return to the terminal where you ran `rosnode list`, and run it again, you will see three node names:

```
/my_turtle
/rosout
/teleop_turtle
/turtlesim
```

3 rosnode info

Now that you know the names of your nodes, you can access more information about them with:

```
rosnode info <node_name>
```

To examine your latest node, `my_turtle`, run the following command:

```
rosnode info /my_turtle
```

`rosnode info` returns a list of subscribers, publishers, services, and actions (the ROS graph connections) that interact with that node. The output should look like this:

```
Node [/my_turtle]
Publications:
 * /rosout [rosgraph_msgs/Log]
 * /turtle1/color_sensor [turtlesim/Color]
 * /turtle1/pose [turtlesim/Pose]

Subscriptions:
 * /turtle1/cmd_vel [geometry_msgs/Twist]

Services:
 * /clear
 * /kill
 * /my_turtle/get_loggers
 * /my_turtle/set_logger_level
 * /reset
 * /spawn
 * /turtle1/set_pen
 * /turtle1/teleport_absolute
 * /turtle1/teleport_relative


contacting node http://ros-noetic:44953/ ...
Pid: 878
Connections:
 * topic: /rosout
    * to: /rosout
    * direction: outbound (40097 - 10.104.247.68:60584) [18]
    * transport: TCPROS
 * topic: /turtle1/cmd_vel
    * to: /teleop_turtle (http://ros-noetic:44321/)
    * direction: inbound (58058 - ros-noetic:47853) [17]
    * transport: TCPROS
```

Now try running the same command on the `/teleop_turtle node`, and see how its connections differ from `my_turtle`.

You will learn more about ROS graph connection concepts in the upcoming tutorials.

Summary

A node is a fundamental ROS element that serves a single, modular purpose in a robotics system.

In this tutorial, you utilized nodes created from the `turtlesim` package by running the executables `turtlesim_node` and `turtle_teleop_key`.

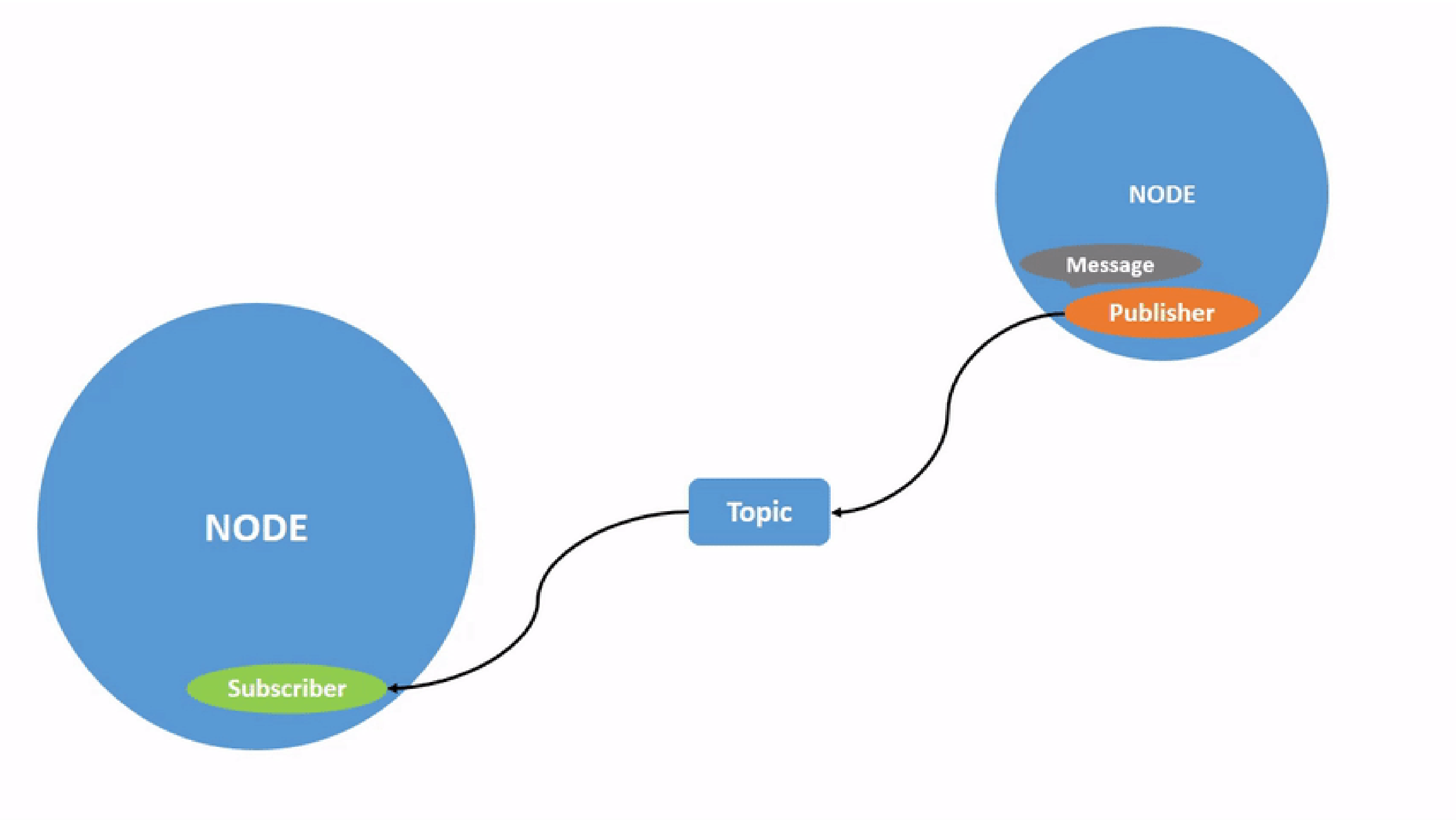
You learned how to use `rosnode list` to discover active node names and `rosnode info` to introspect on a single node. These tools are vital to understanding the flow of data in a complex, real-world robot system.

Understanding ROS topics

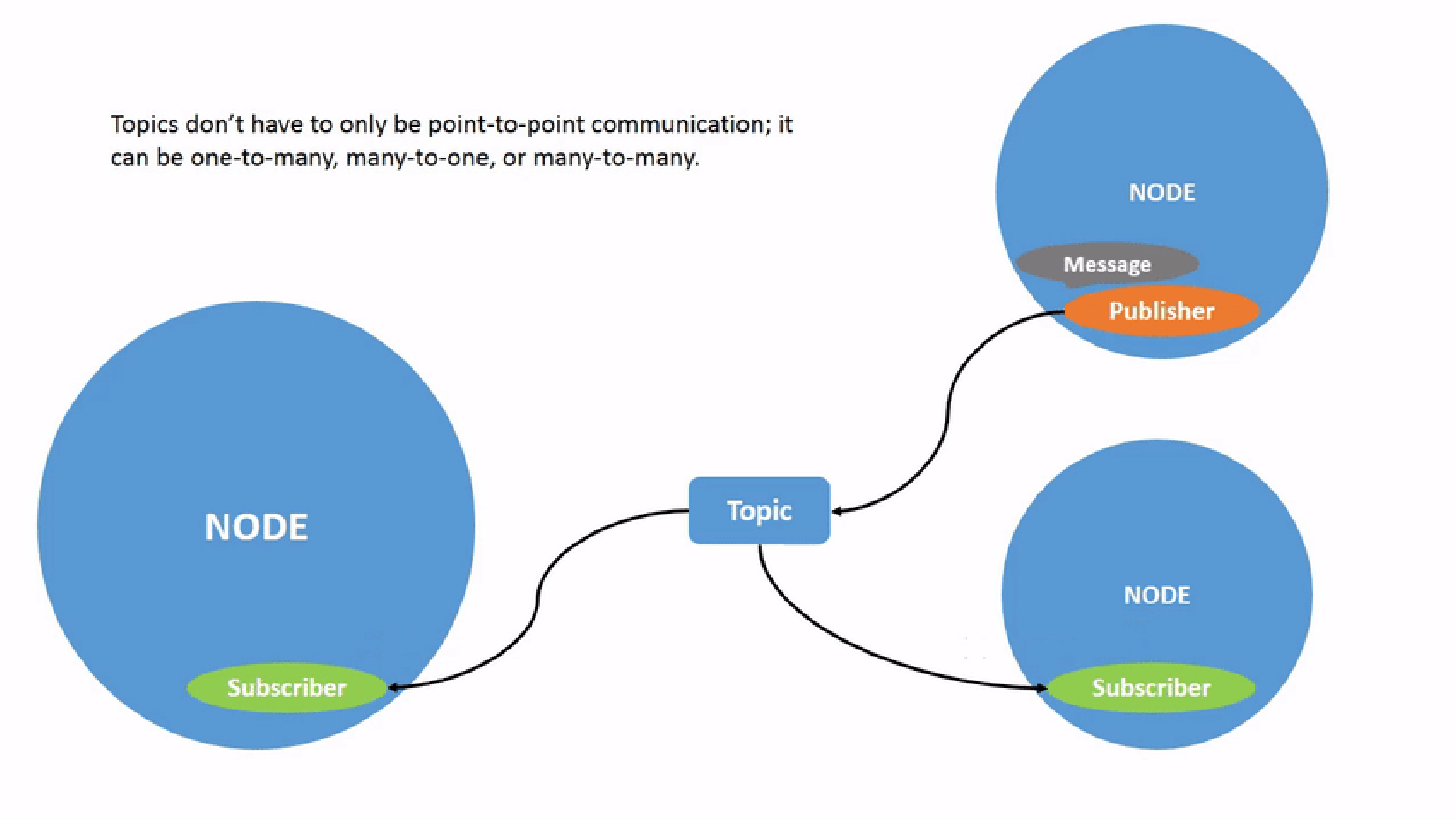
Goal: Use rqt_graph and command line tools to introspect ROS topics.

Background

ROS breaks complex systems down into many modular nodes. Topics are a vital element of the ROS graph that act as a bus for nodes to exchange messages.



A node may publish data to any number of topics and simultaneously have subscriptions to any number of topics.



Topics are one of the important ways that data moves between nodes, and therefore between different parts of the system.

Prerequisites

As always, don't forget to source ROS 2 in every new terminal you open. Run `roscore` in a separate terminal.

Tasks

1 Setup

By now you should be comfortable starting up turtlesim.

Open a new terminal and run:

```
rosrun turtlesim turtlesim_node
```

Open another terminal and run:

```
rosrun turtlesim turtle_teleop_key
```

Recall from the [previous tutorial] that the names of these nodes are `/turtlesim` and `/teleop_turtle` by default.

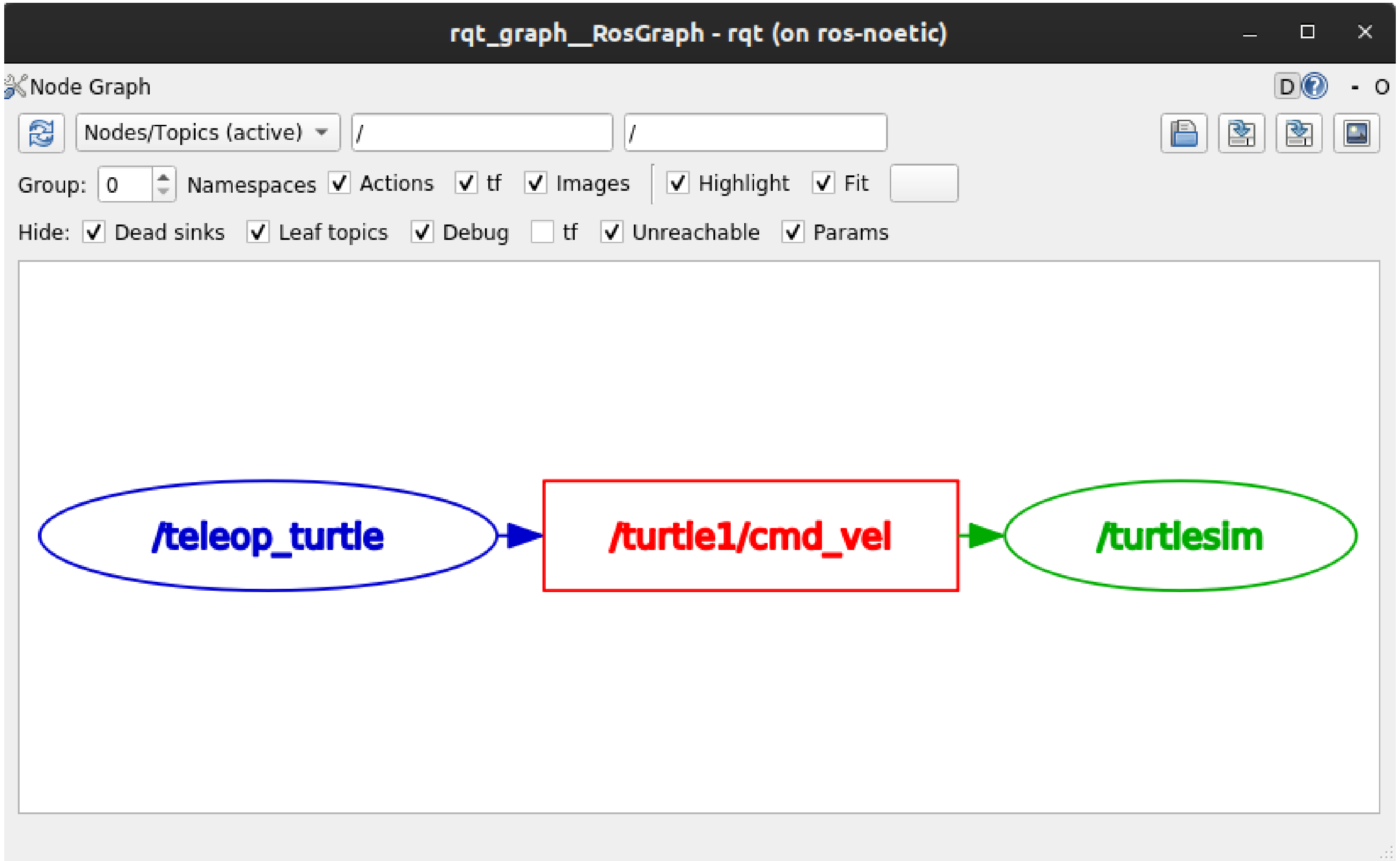
2 rqt_graph

Throughout this tutorial, we will use `rqt_graph` to visualize the changing nodes and topics, as well as the connections between them.

To run rqt_graph, open a new terminal and enter the command:

```
rqt_graph
```

You can also open `rqt_graph` by opening rqt and selecting **Plugins** > **Introspection** > **Nodes Graph**.



You should see the above nodes and topic. If you hover your mouse over the topic in the center, you'll see the color highlighting like in the image above.

The graph is depicting how the `/turtlesim` node and the `/teleop_turtle` node are communicating with each other over a topic. The `/teleop_turtle` node is publishing data (the keystrokes you enter to move the turtle around) to the `/turtle1/cmd_vel` topic, and the `/turtlesim` node is subscribed to that topic to receive the data.

The highlighting feature of **rqt_graph** is very helpful when examining more complex systems with many nodes and topics connected in many different ways.

`rqt_graph` is a graphical introspection tool. Now we'll look at some command line tools for introspecting topics.

rostopic list

Running the `rostopic list` command in a new terminal will return a list of all the topics currently active in the system:

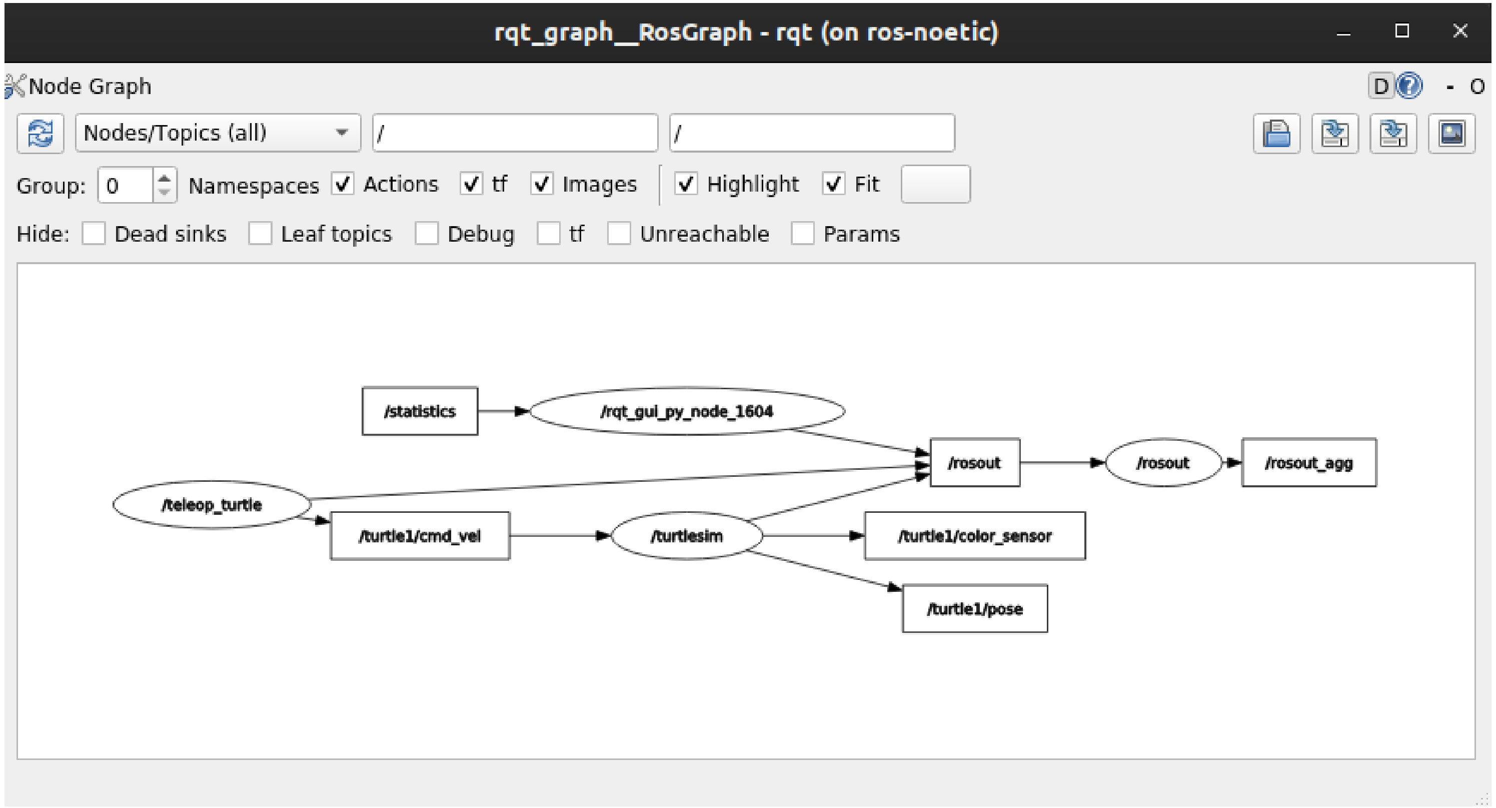
```
/rosout
/rosout_agg
/statistics
/turtle1/cmd_vel
/turtle1/color_sensor
/turtle1/pose
```

Topics have names and types. These attributes, particularly the type, are how nodes know they're talking about the same information as it moves over topics. To show the topic type run this command:

```
rostopic type /turtle1/cmd_vel
```

```
geometry_msgs/Twist
```

If you're wondering where all these topics are in rqt_graph, you can uncheck all the boxes under Hide:



For now, though, leave those options checked to avoid confusion.

4 rostopic echo

To see the data being published on a topic, use:

```
rostopic echo <topic_name>
```

Since we know that `/teleop_turtle` publishes data to `/turtlesim` over the `/turtle1/cmd_vel` topic, let's use echo to introspect on that topic:

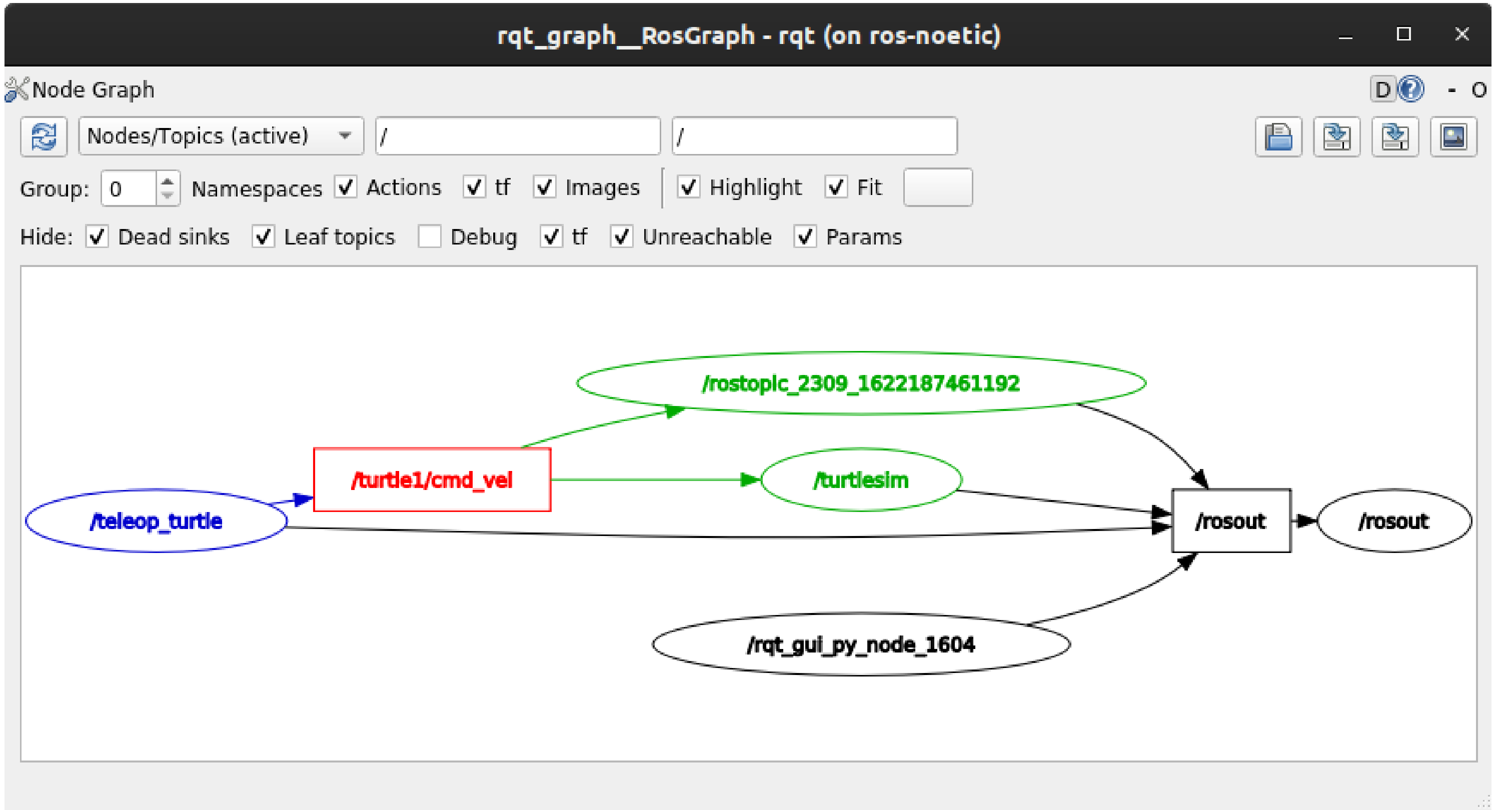
```
rostopic echo /turtle1/cmd_vel
```

At first, this command won't return any data. That's because it's waiting for `/teleop_turtle` to publish something.

Return to the terminal where `turtle_teleop_key` is running and use the arrows to move the turtle around. Watch the terminal where your `echo` is running at the same time, and you'll see position data being published for every movement you make:

```
linear:
  x: 2.0
  y: 0.0
  z: 0.0
angular:
  x: 0.0
  y: 0.0
  z: 0.0
---
```

Now return to rqt_graph and uncheck the Debug box.



`/rostopic_2309_1622187461192` is the node created by the `echo` we just ran (the number will change). Now you can see that the publisher is publishing data over the `cmd_vel` topic, and two subscribers are subscribed.

5 rostopic info

Topics don't have to only be point-to-point communication; it can be one-to-many, many-to-one, or many-to-many.

Another way to look at this is running:

```
rostopic info /turtle1/cmd_vel
```

Which will return:

```
Type: geometry_msgs/Twist

Publishers:
 * /teleop_turtle (http://ros-noetic:44037/)

Subscribers:
 * /turtlesim (http://ros-noetic:44297/)
 * /rostopic_2309_1622187461192 (http://ros-noetic:45255/)
```

6 rosmsg show

Nodes send data over topics using messages. Publishers and subscribers must send and receive the same type of message to communicate.

The topic types we saw earlier after running `rostopic type <topic-name>` let us know what type of messages each topic can send. Recall that the `cmd_vel` topic has the type:

```
geometry_msgs/Twist
```

This means that in the package `geometry_msgs` there is a message called `Twist`.

Now we can run `rosmsg show .msg on this type to learn its details, specifically, what structure of data the message expects.

```
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
```

This tells you that the `/turtlesim` node is expecting a message with two vectors, `linear` and `angular`, of three elements each. If you recall the data we saw `/teleop_turtle` passing to `/turtlesim` with the `echo` command, it's in the same structure:

```
linear:
  x: 2.0
  y: 0.0
  z: 0.0
angular:
  x: 0.0
  y: 0.0
  z: 0.0
---
```

rostopic pub

Now that you have the message structure, you can publish data onto a topic directly from the command line using:

```
rostopic pub <topic_name> <msg_type> '<args>'
```

The `'<args>'` argument is the actual data you'll pass to the topic, in the structure you just discovered in the previous section.

It's important to note that this argument needs to be input in YAML syntax. Input the full command like so:

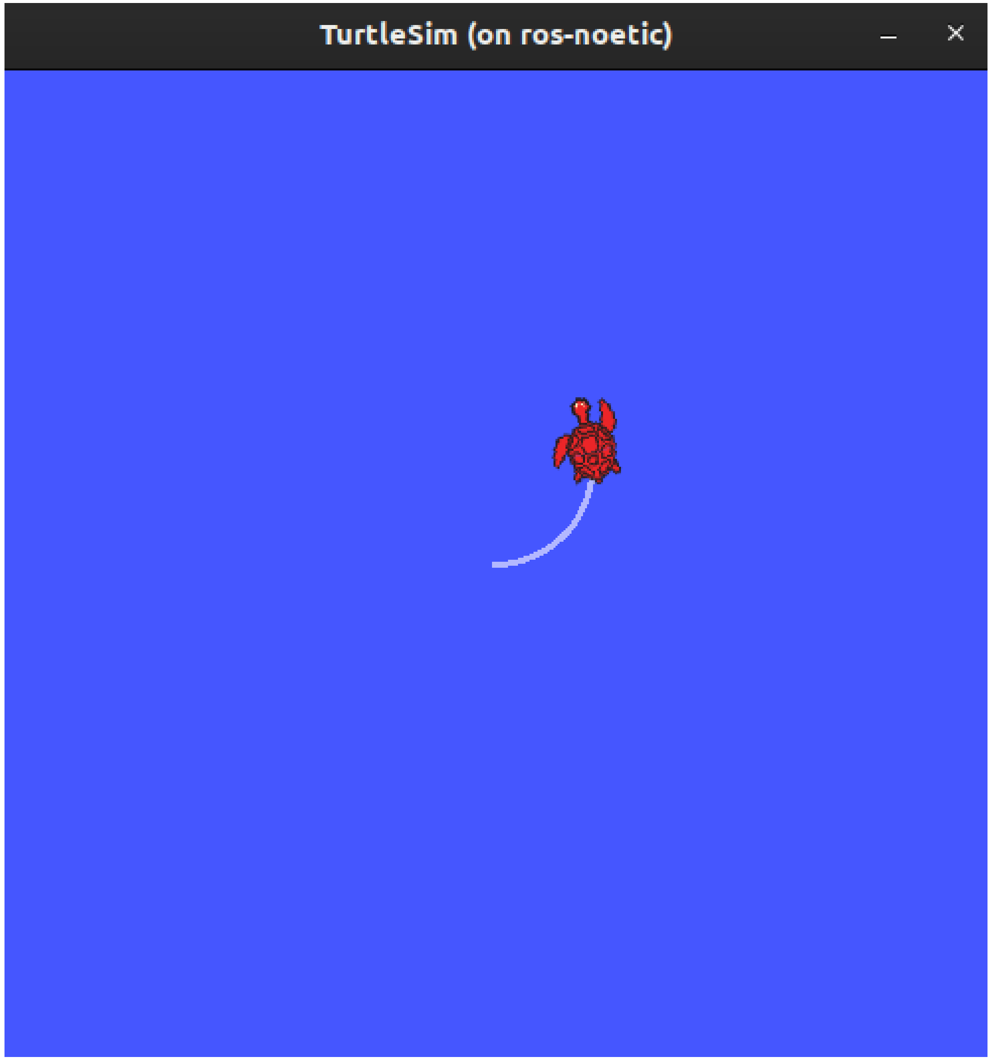
```
rostopic pub -1 /turtle1/cmd_vel geometry_msgs/Twist "{linear: {x: 2.0, y: 0.0, z: 0.0}, angular: {x: 0.0, y: 0.0, z: 1.8}}"
```

`-1` is an optional argument meaning "publish one message then exit".

You will receive the following message in the terminal:

```
publishing and latching message for 3.0 seconds
```

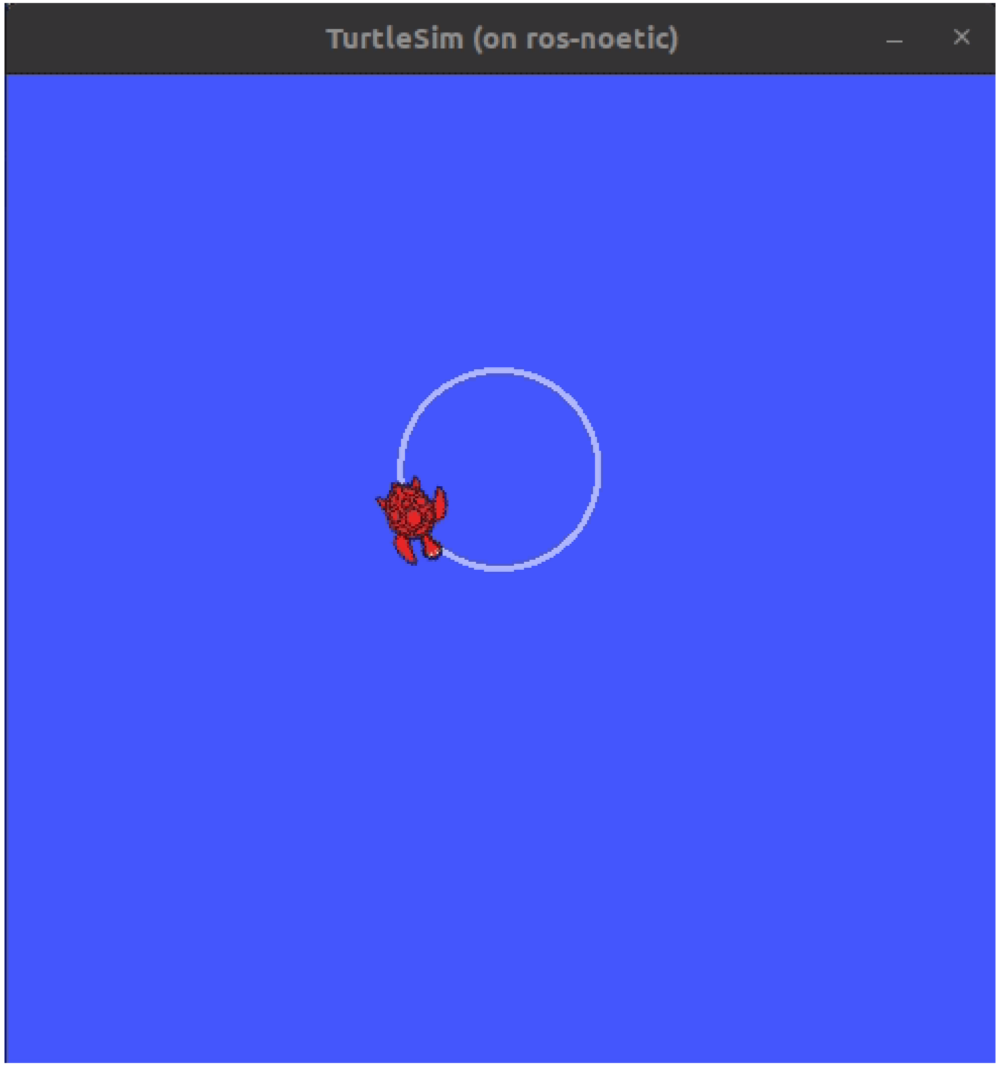
And you will see your turtle move like so:



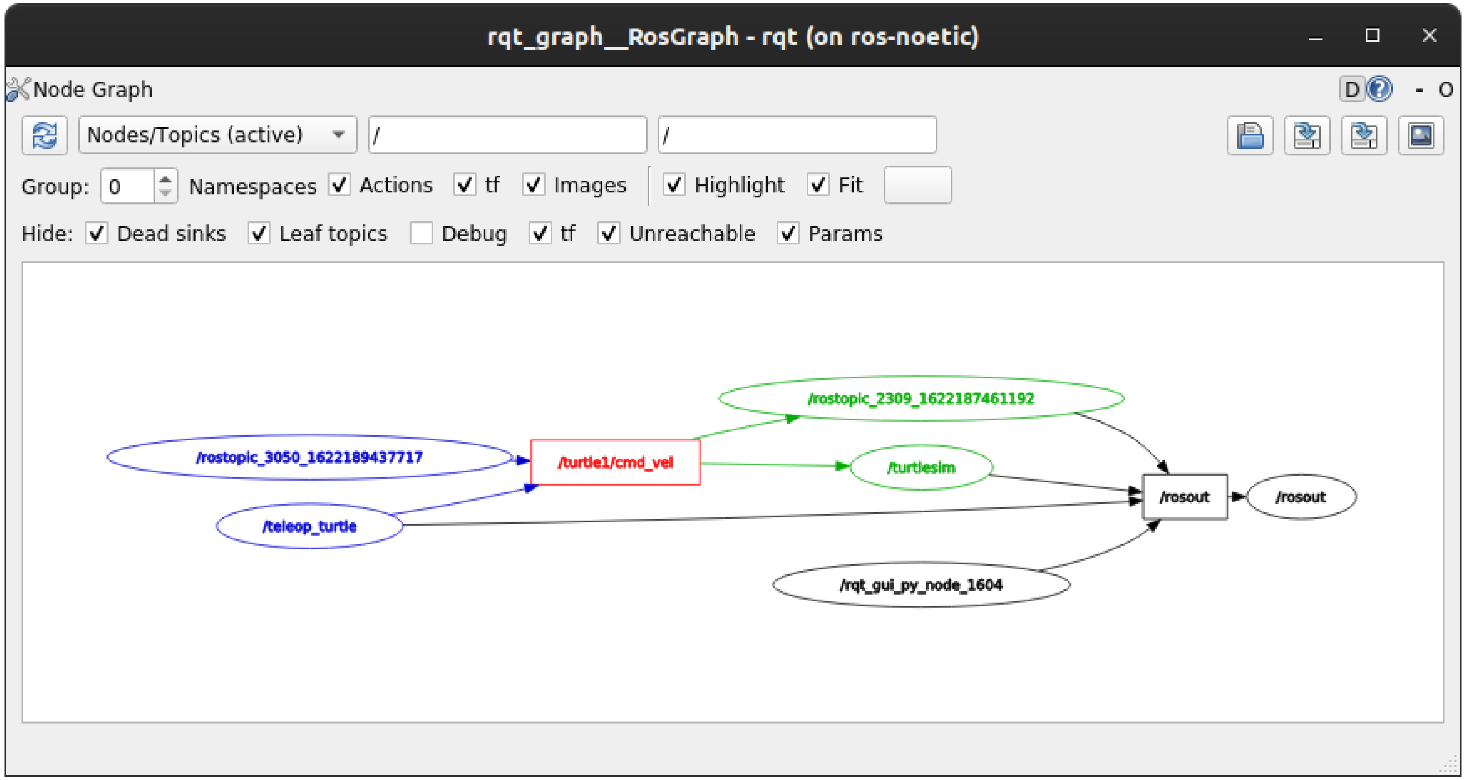
The turtle (and commonly the real robots which it is meant to emulate) require a steady stream of commands to operate continuously. So, to get the turtle to keep moving, you can run:

```
rostopic pub -r 1 /turtle1/cmd_vel geometry_msgs/Twist "{linear: {x: 2.0, y: 0.0, z: 0.0}, angular: {x: 0.0, y: 0.0, z: 1.8}}"
```

The difference here is the removal of the `-1` option and the addition of the `--rate 1` option, which tells `rostopic pub` to publish the command in a steady stream at 1 Hz.

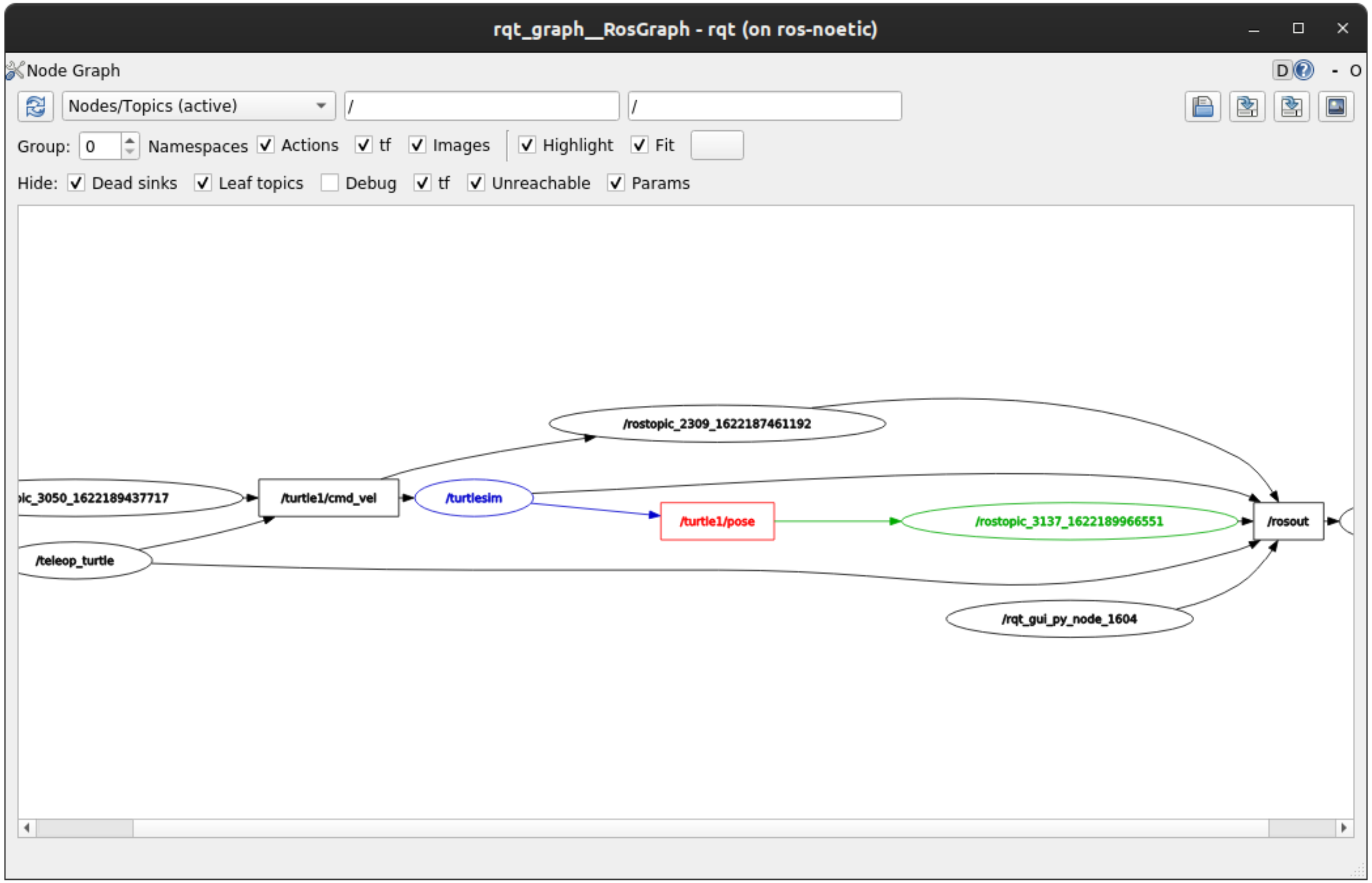


You can refresh **rqt_graph** to see what's happening graphically. You will see the `rostopic pub ...` node (`/rostopic_3050_1622189437717`) is publishing over the `/turtle1/cmd_vel` topic, and is being received by both the `rostopic echo ...` node (`/rostopic_2309_1622187461192`) and the `/turtlesim node` now.



Finally, you can run `echo` on the `pose` topic and recheck rqt_graph:

```
rostopic echo /turtle1/pose
```



In this case, `/turtlesim` is now publishing to the `pose` topic, and a new `echo` node is subscribed.

8 rostopic hz

For one last introspection on this process, you can report the rate at which data is published using:

```
rostopic hz /turtle1/pose
```

It will return data on the rate at which the `/turtlesim` node is publishing data to the `pose` topic.

```
average rate: 62.527
    min: 0.015s max: 0.017s std dev: 0.00041s window: 62
```

Recall that you set the rate of `turtle1/cmd_vel` to publish at a steady 1 Hz using `rostopic pub -r 1`. If you run the above command with `turtle1/cmd_vel` instead of `turtle1/pose`, you will see an average reflecting that rate.

9 Clean up

At this point you'll have a lot of nodes running. Don't forget to stop them, either by closing the terminal windows or entering `Ctrl+C` in each terminal.

Summary

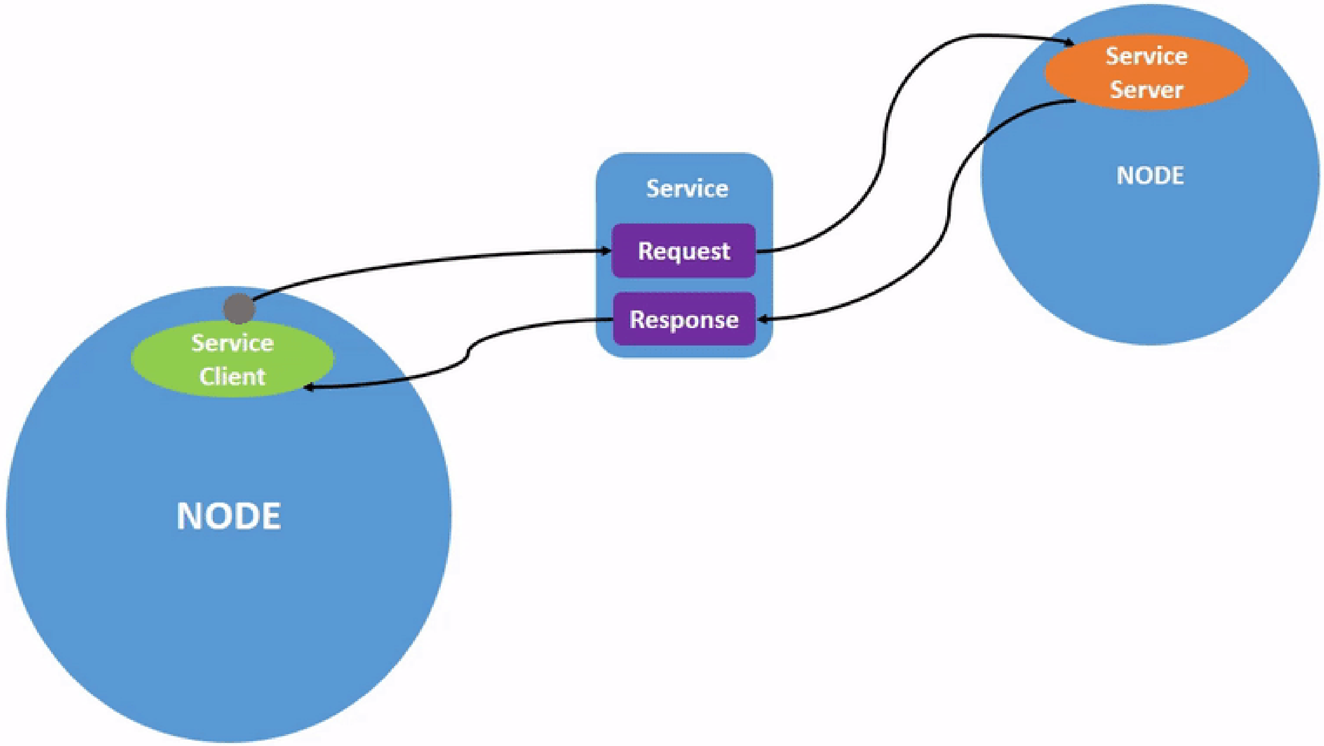
Nodes publish information over topics, which allows any number of other nodes to subscribe to and access that information. In this tutorial you examined the connections between several nodes over topics using rqt_graph and command line tools. You should now have a good idea of how data moves around a ROS system.

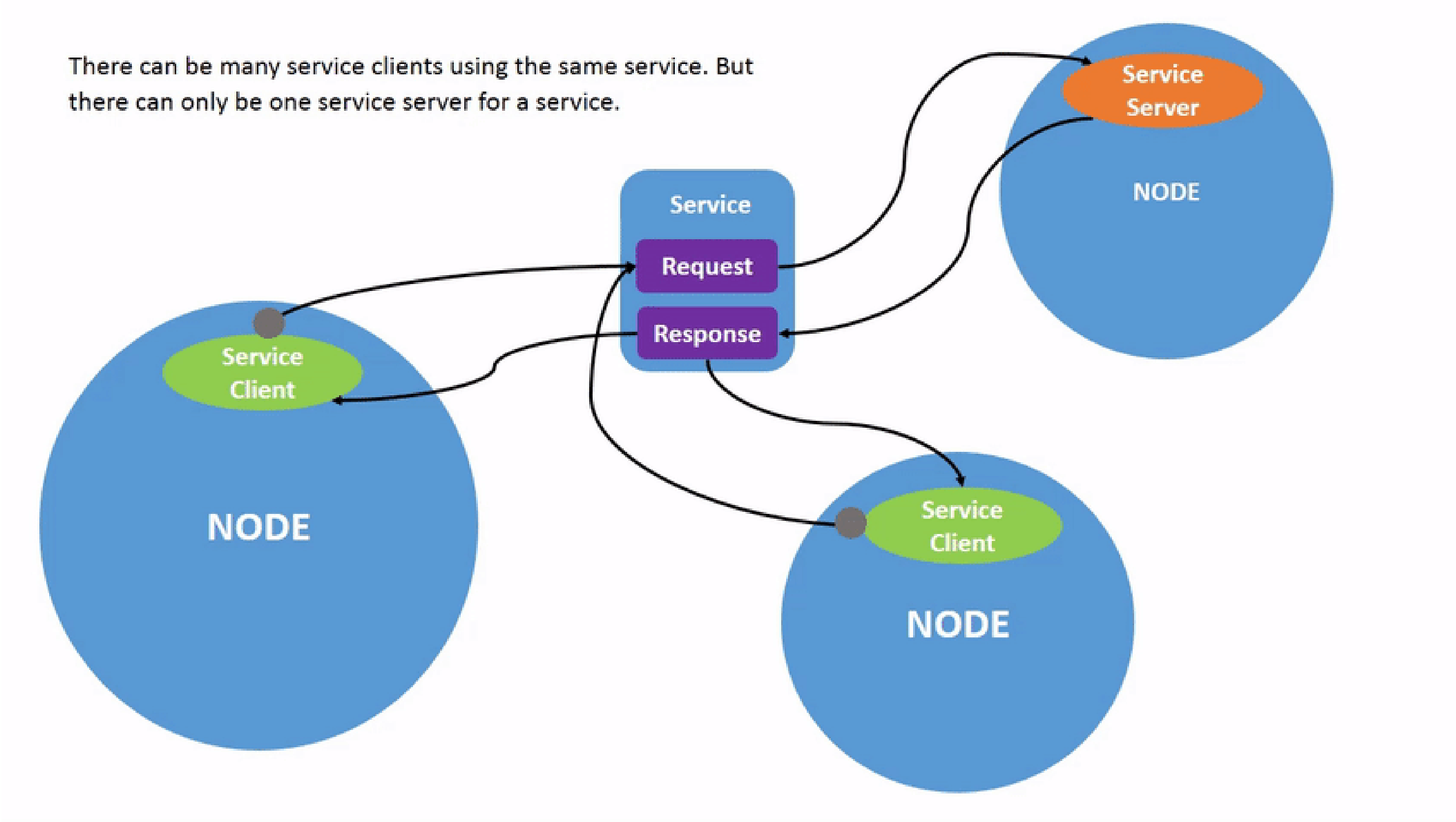
Understanding ROS Services

Goal: Learn about services in ROS using command line tools.

Background

Services are another method of communication for nodes in the ROS graph. Services are based on a call-and-response model, versus topics' publisher-subscriber model. While topics allow nodes to subscribe to data streams and get continual updates, services only provide data when they are specifically called by a client.


Service
Server
NODE
Service
Request
Response
Service
Client
NODE



Prerequisites

As always, don't forget to source ROS in every new terminal you open.

Run `roscore` in a separate terminal.

Tasks

1 Setup

Start up the two turtlesim nodes, `/turtlesim` and `/teleop_turtle`.

Open a new terminal and run:

```
rosrun turtlesim turtlesim_node
```

Open another terminal and run:

```
rosrun turtlesim turtle_teleop_key
```

2 rosservice list

Running the `rosservice list` command in a new terminal will return a list of all the services currently active in the system:

```
/clear
/kill
/reset
/rosout/get_loggers
/rosout/set_logger_level
/spawn
/teleop_turtle/get_loggers
/teleop_turtle/set_logger_level
/turtle1/set_pen
/turtle1/teleport_absolute
/turtle1/teleport_relative
/turtlesim/get_loggers
/turtlesim/set_logger_level
```

For now, let's focus on the turtlesim-specific services, `/clear`, `/kill`, `/reset`, `/spawn`, `/turtle1/set_pen`, `/turtle1/teleport_absolute`, and `/turtle1/teleport_relative`. You may recall interacting with some of these services using rqt in the `[“Introducing turtlesim and rqt” tutorial.

3 rosservice type

Services have types that describe how the request and response data of a service is structured. Service types are defined similarly to topic types, except service types have two parts: one message for the request and another for the response.

To find out the type of a service, use the command:

```
rosservice type <service_name>
```

Let's take a look at turtlesim's `/clear` service. In a new terminal, enter the command:

```
rosservice type /clear
```

Which should return:

```
std_srvs/Empty
```

The `Empty` type means the service call sends no data when making a request and receives no data when receiving a response.

4 rosservice find

If you want to find all the services of a specific type, you can use the command:

```
rosservice find <type_name>
```

For example, you can find all the `Empty` typed services like this:

```
rosservice find std_srvs/Empty
```

Which will return:

```
/clear
/reset
```

5 rossrv show

You can call services from the command line, but first you need to know the structure of the input arguments.

```
rossrv show <type_name>
```

To run this command on the `/clear` service's type, `Empty`:

```
rossrv show std_srvs/Empty
```

Which will return:

```
---
```

The `---` separates the request structure (above) from the response structure (below). But, as you learned earlier, the `Empty` type doesn't send or receive any data. So, naturally, its structure is blank.

Let's introspect a service with a type that sends and receives data, like `/spawn`. From the results of `rosservice list` and `rosservice type`, we know `/spawn`'s type is `turtlesim/Spawn`.

To see the arguments in a `/spawn` call-and-request, run the command:

```
rossrv show turtlesim/Spawn
```

Which will return:

```
float32 x
float32 y
float32 theta
string name
---
string name
```

The information above the `---` line tells us the arguments needed to call `/spawn`. `x`, `y` and `theta` determine the location of the spawned turtle, and `name` is clearly optional.

The information below the line isn't something you need to know in this case, but it can help you understand the data type of the response you get from the call.

6 rosservice call

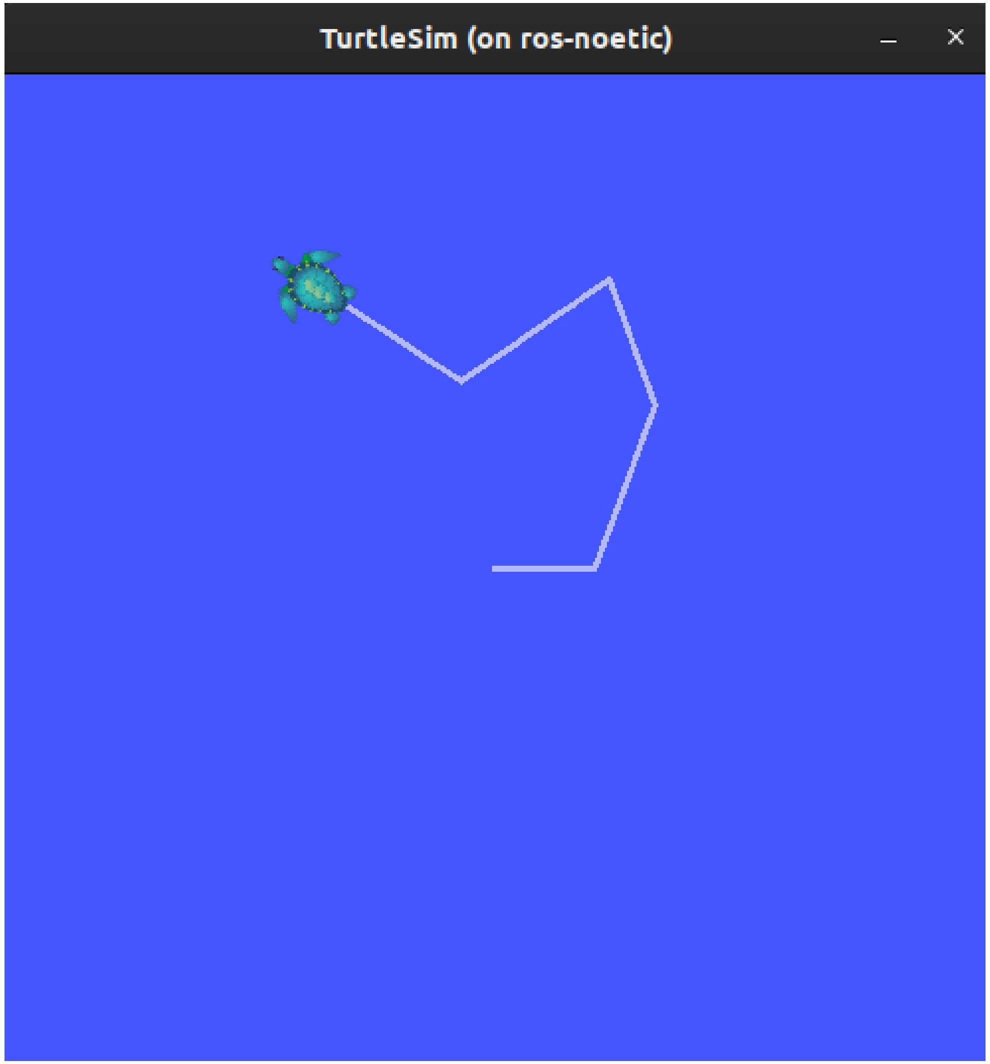
Now that you know what a service type is, how to find a service's type, and how to find the structure of that type's arguments, you can call a service using:

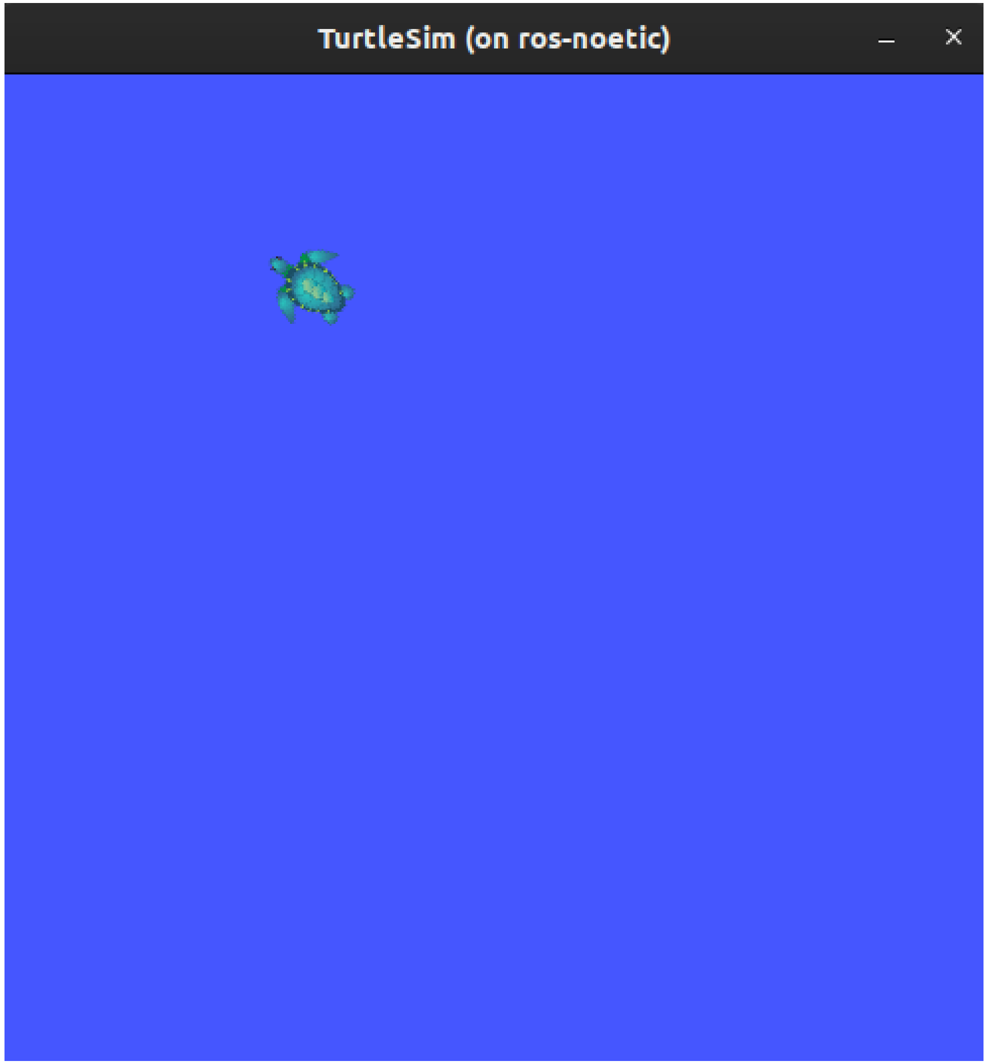
```
rosservice call <service_name> <arguments>
```

The `<arguments>` part is optional. For example, you know that `Empty` typed services don't have any arguments:

```
rosservice call /clear
```

This command will clear the turtlesim window of any lines your turtle has drawn.





Now let's spawn a new turtle by calling `/spawn` and inputting arguments. Input `<arguments>` in a service call from the command-line need to be in YAML syntax.

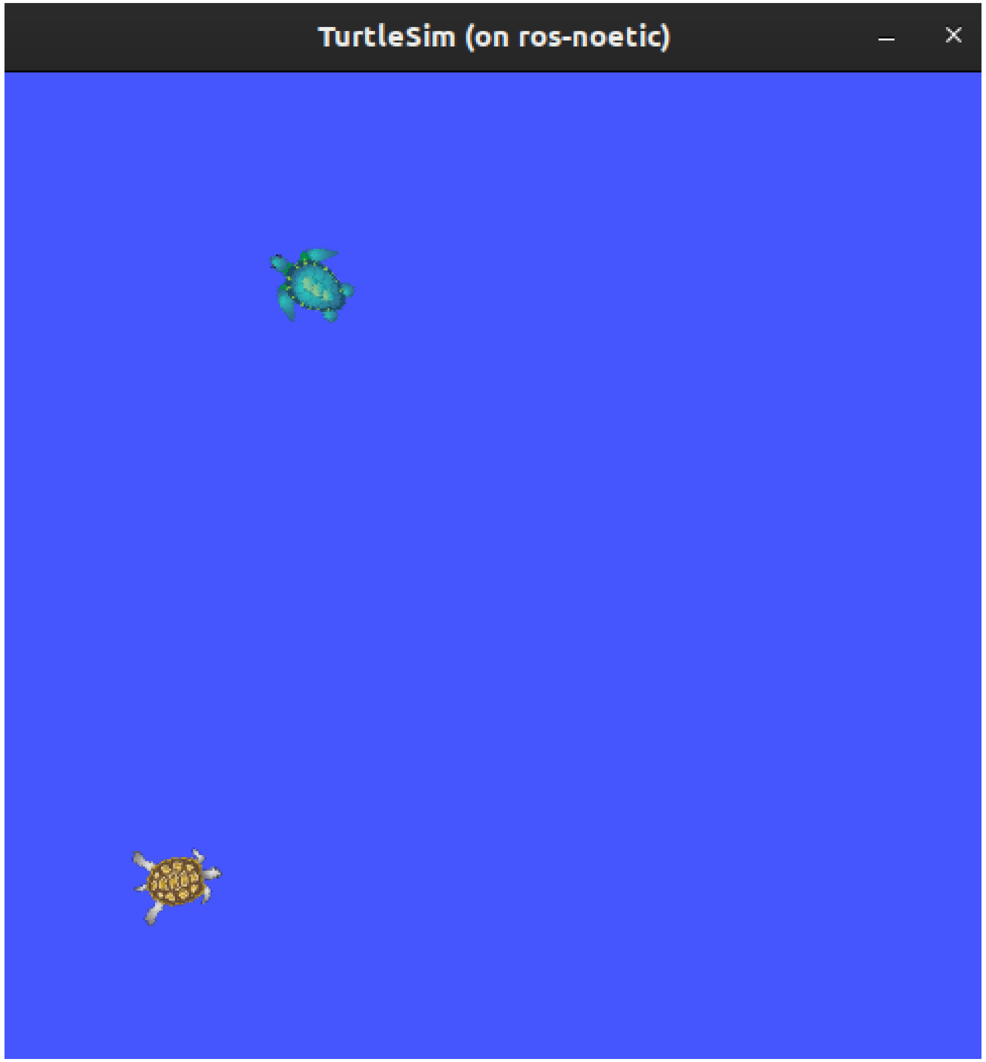
Enter the command:

```
rosservice call /spawn "{x: 2, y: 2, theta: 0.2, name: ''}"
```

You will get this output on terminal:

```
name: "turtle2"
```

Your turtlesim window will update with the newly spawned turtle right away:



Summary

Nodes can communicate using services in ROS. Unlike a topic - a one way communication pattern where a node publishes information that can be consumed by one or more subscribers - a service is a request/response pattern where a client makes a request to a node providing the service and the service processes the request and generates a reponse.

You generally don’t want to use a service for continuous calls; topics or even actions would be better suited.

In this tutorial you used command line tools to identify, elaborate on, and call services.

ROS Parameter Server

- You can think Parameter Server as a space where all the necessary data that needs to be shared among various ROS Nodes is stored.
- Parameter Server runs inside ROS Master.
- ROS Nodes can view and even modify data stored in the Parameter Server.
- Typically Parameter Server is used to store configuration parameters.

Reading Assignment

1. ROS Wiki - Parameter Server

Load Parameters using YAML file

In this section we will learn how to load your own parameters in ROS Parameter Server using a YAML File.

Steps

1. Navigate to `pkg_ros_basics`.

   ```
   cd ~/workspace/src/pkg_ros_basics
   ```

   OR

   ```
   roscd pkg_ros_basics
   ```

   > **NOTE**: `roscd` will work only if you have sourced `setup.bash` of your catkin workspace.

   ---

2. Create a `config` folder for your Python scripts and navigate into the folder.

   ```
   mkdir config
   cd config
   ```

3. Create a configuration YAML file called `config_my.yaml`.

   ```
   touch config_my.yaml
   ```

4. Open the script in any text-editor and start editing.

```
gedit config_my.yaml
```

5. Now fill your config file.

```
# Comment: config_my.yaml Configuration
details:
    name:
        first: "Heisenberg" # First Name
        last: "White" # Last Name
     contact:
         address: "ABQ Street, ABQ" # Address
         phone: 77777     # Contact
```

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- ROS Build system will create a Python Dictionary called `details`.
- This dictionary will have two keys,
    1. Dictionary `name`
    2. Dictionary `contact`
- In your ROS Node you can use `rospy` to get parameters stored in this `config_my` dictionary.

```
param_config_my = rospy.get_param('details')

first_name = param_config_my['name']['first']
phone = param_config_my['contact']['phone']
```

6. Now if you want to load the parameters defined in the YAML file you have to first start the ROS Parameter Server.

   Open up a new terminal and enter the following.

   ```
   roscore
   ```

7. Now load your parameters.

   ```
   rosparam load config_my.yaml
   ```

8. Now get the list of parameters loaded in your ROS Parameter Server.

   ```
   rosparam list
   ```

   Output:

   ```
   /details/contact/address
   /details/contact/phone
   /details/name/first
   /details/name/last
   /rosdistro
   /roslaunch/uris/host_ros_noetic__35261
   /rosversion
   /run_id
   ```

   Here you can see the first four parameters are loaded from our `config_my.yaml` file.

9. Now to view the content of any parameter do the following.

```
rosparam get /details/contact/phone
```

Output:

```
77777
```

This is the value which we defined in the `config_my.yaml` file.

Example #1: ROS Node to Get and Set Parameters

Aim

To write a ROS Node to read `config_my.yaml` file loaded in ROS Parameter Server (done here), print it on the console and modify the phone number.

Code

`node_param_get_set.py`

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

import rospy


def main():

    # 1. Make the script a ROS Node.
    rospy.init_node('node_param_get_set', anonymous=True)

    # 2. Read from Parameter Server
    rospy.loginfo("Reading from Parameter Server.")


    param_config_my = rospy.get_param('details')    # Get all the parameters inside
'details'

    # Store the parameters in variables
    first_name = param_config_my['name']['first']
    last_name = param_config_my['name']['last']
    address = param_config_my['contact']['address']
    phone = param_config_my['contact']['phone']

    # Print the parameters
    rospy.loginfo(">> First Name: {}".format(first_name))
    rospy.loginfo(">> Last Name: {}".format(last_name))
    rospy.loginfo(">> Address: {}".format(address))
    rospy.loginfo(">> Phone: {}".format(phone))

    # 3. Modify the Phone Number

    rospy.set_param('/details/contact/phone', 55555)        # Modify only Phone Number
in Parameter Server
    new_phone = rospy.get_param('/details/contact/phone')   # Get only Phone Number
from Parameter Server
    rospy.loginfo(">> New Phone: {}".format(new_phone))     # Print the new Phone
Number
```

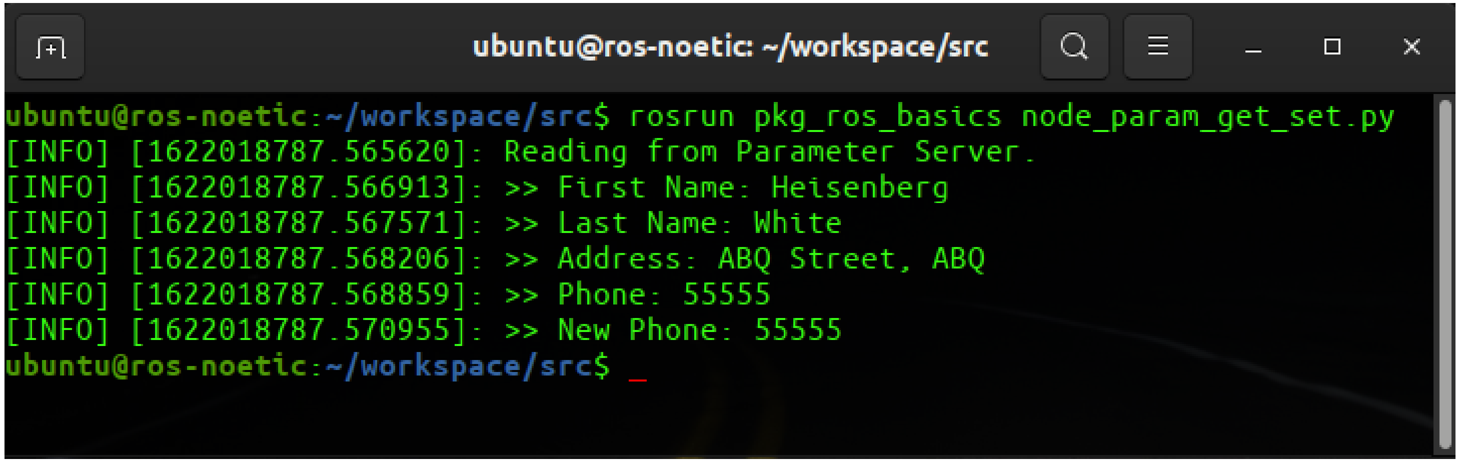
```python
if __name__ == '__main__':
    try:
        main()
    except rospy.ROSInterruptException:
        pass
```

Download

NOTE: Make sure you make the `pkg_ros_basics node_param_get_set.py` script executable.

Output:

```
rosrun pkg_ros_basics node_param_get_set.py
```



- The code is self-explanatory.
- If you are not able to understand the code feel free to seek help from us.

Create a ROS Node

In this section we will learn how to create a ROS Node inside `pkg_ros_basics` ROS Package which we created in the previous section.

1. Navigate to `pkg_ros_basics`.

   ```
   cd ~/catkin_ws/src/pkg_ros_basics
   ```

   OR

   ```
   roscd pkg_ros_basics
   ```

   NOTE: `roscd` will work only if you have sourced `setup.bash` of your catkin workspace.

2. Create a `scripts` folder for your Python scripts and navigate into the folder.

   ```
   mkdir scripts
   cd scripts
   ```

3. Create a Python script called `node_hello_ros.py`.

   ```
   touch node_hello_ros.py
   ```

4. Open the script in any text-editor and start editing.

   ```
   gedit node_hello_ros.py
   ```

5. First line of all your Python ROS scripts should be the following shebang

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

6. Now write a ROS Node to print `Hello World!` on the console.

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

import rospy


def main():

# 1. Make the script a ROS Node.
rospy.init_node('node_hello_ros', anonymous=True)

# 2. Print info on console.
rospy.loginfo("Hello World!")

# 3. Keep the node alive till it is killed by the user.
rospy.spin()


if __name__ == '__main__':
    try:
        main()
    except rospy.ROSInterruptException:
        pass
```

7. Now you have to make this script an executable.

```
sudo chmod +x node_hello_ros.py
```

8. Now in order to run your ROS Node,

    1. Open up a terminal and run ROS Master.

    ```
    roscore
    ```

    2. Once the roscore is up running, open a new termminal and run the ROS Node.

    ```
    rosrun pkg_ros_basics node_hello_ros.py
    ```

    NOTE: This command will work only if you have sourced `setup.bash` of your catkin workspace either manually or using `.bashrc`.

9. You should get some output like this,

```
[INFO] [1601277063.968749]: Hello World!
```

ROS Launch Files

- In the previous sections you must have noticed that we need to use `roscore` command to start ROS Master and Parameter Server, `rosrun` command to run a ROS Node, `rosparam load` command to load parameters etc.
- This is a tedious process to manually run nodes and load parameters.
- Launch files provides the capability to do all these stuff using a single command.
- The idea is to mention all the nodes that you want to run, all the config file that you want to load etc. in a single file which you can run using `roslaunch` command.

Reading Assignment

1. ROS Wiki - roslaunch

Create a ROS Launch File

roslaunch Command

- `roslaunch` is a tool for easily launching multiple ROS nodes locally and remotely via SSH.
- It includes options to automatically respawn processes that have already died. `roslaunch` takes in one or more XML configuration files (with the .launch extension) that specify the parameters to set and nodes to launch.
- Usage:

  ```
  roslaunch <package> file.launch
  ```

  `<package>` is nothing but the package name which you have created using `catkin_create_pkg` command or used any other package.

Steps to create a launch file

1. After creating a package, create a folder in the package names as a `launch` folder to store all the launch files in that folder.

   ```
   cd ~/catkin_ws/src/<package>
   mkdir launch
   ```

2. Here we can create launch files by running this command by going into the `launch` directory, we can keep any name for the launch file,

```
cd launch
touch filename.launch
```

Now you can edit your launch file by adding different nodes that you have to run simultaneously.

Steps to add a ROS node in the launch file

1. Launch files always starts with

```
<launch>
```

and end with

```
</launch>
```

2. Now to add any executable file which we have seen in the rosrun_command section, we have to add this line,

```
<node pkg="name_of_package" type="name_of_executable.py" name="name_of_executable"
output="screen"/>
```

   - `pkg` is the package name which you have created
   - `type` is the name of executable file

- `name` is the name of the node which is created in that executable
- `output` means it will print the data given to the roslog command

Steps to load Config YAML file in ROS Parameter Server

- You can use `rosparam` tag to load the YAML file.

```
<rosparam file ="$(find name_of_package)/config/config.yaml" command="load"/>
```

  - `name_of_package` is the name of your ROS package.
  - `config.yaml` is the name of your configuration file.

Steps to add a Shell Script in the launch file

- You can use `node` tag to run any shell script using launch file

```
<node pkg="name_of_package" type="shell_script.sh" name="shell_script"
output="screen">
        <param name="cmd" value="$(find name_of_package)/launch/shell_script.sh"/>
</node>
```

  - `name_of_package` is the name of your ROS package.
  - `shell_script.sh` is the name of your configuration file.
  - `/launch/shell_script.sh` is the location of the shell script inside your ROS Package folder.

Example #1: Launch two ROS Nodes

Aim

- To launch `talker` and `listener` node present in `rospy_tutorials` package.
- For this create a `chatter.launch` file and save it in the `launch` folder inside `pkg_ros_basics` package.

> **NOTE**: To install `rospy_tutorials` package in your system you can run `sudo apt-get install ros-noetic-ros-tutorials` this command.

Once installed, you can use `listener` python script and talker executable written in C++ present in `rospy_tutorials` package.

Code

`chatter.launch`

```
<launch>
  <node name="talker" pkg="rospy_tutorials" type="talker" output="screen"/>
  <node name="listener" pkg="rospy_tutorials" type="listener.py" output="screen"/>
</launch>
```

Download

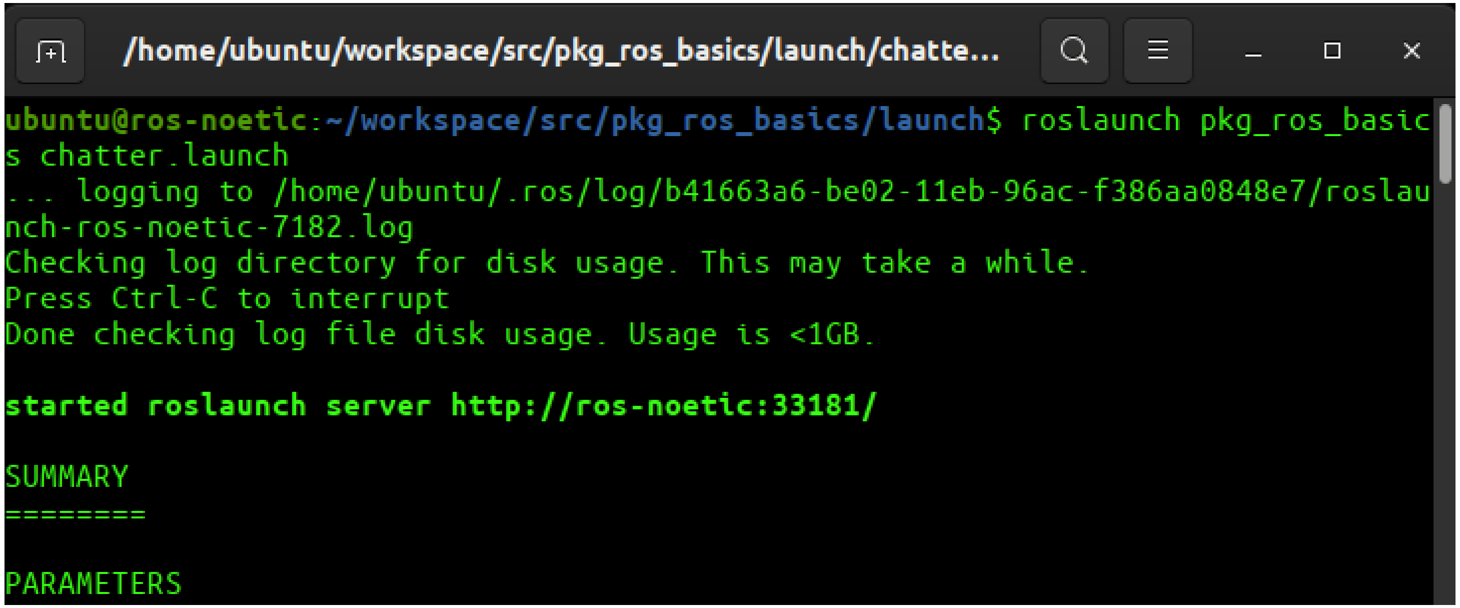
- Here first `talker.cpp` file (for cpp file we dont need to add .cpp extension) has been included with the node name as talker and also set output as screen so you can see the output from talker node.
- Next we have added `listener.py` which has node name as listener and here also we have set output as screen.

Run Command

Now run these command to run the launch file,

```
roslaunch pkg_ros_basics chatter.launch
```

Output



```
 * /rosdistro: noetic
 * /rosversion: 1.15.11

NODES
  /
    listener (rospy_tutorials/listener.py)
    talker (rospy_tutorials/talker)

auto-starting new master
process[master]: started with pid [7190]
ROS_MASTER_URI=http://localhost:11311

setting /run_id to b41663a6-be02-11eb-96ac-f386aa0848e7
process[rosout-1]: started with pid [7200]
started core service [/rosout]
process[talker-2]: started with pid [7203]
process[listener-3]: started with pid [7208]
[INFO] [1622020439.788241]: hello world 1622020439.7881696
[INFO] [1622020439.888438]: hello world 1622020439.888326
[INFO] [1622020439.889578]: /listenerI heard hello world 1622020439.888326
[INFO] [1622020439.988409]: hello world 1622020439.98831
[INFO] [1622020439.989609]: /listenerI heard hello world 1622020439.98831
[INFO] [1622020440.088431]: hello world 1622020440.0883195
[INFO] [1622020440.089766]: /listenerI heard hello world 1622020440.0883195
[INFO] [1622020440.188427]: hello world 1622020440.1883142
[INFO] [1622020440.189786]: /listenerI heard hello world 1622020440.1883142
[INFO] [1622020440.288435]: hello world 1622020440.2883193
[INFO] [1622020440.289813]: /listenerI heard hello world 1622020440.2883193
[INFO] [1622020440.388428]: hello world 1622020440.3883164
[INFO] [1622020440.389766]: /listenerI heard hello world 1622020440.3883164
```

Example #2: Launch Turtle in Forest

Aim

- To write a launch file to run `turtlesim_node` node and `turtle_teleop_key` node present in `turtlesim` package.
- While launching the `turtlesim_node` make sure to change the background colour of the simulator from blue to forest green.
- Name the launch file `turtlesim.launch` and save it in `launch` folder inside `pkg_ros_basics` package.

Code

`turtlesim.launch`

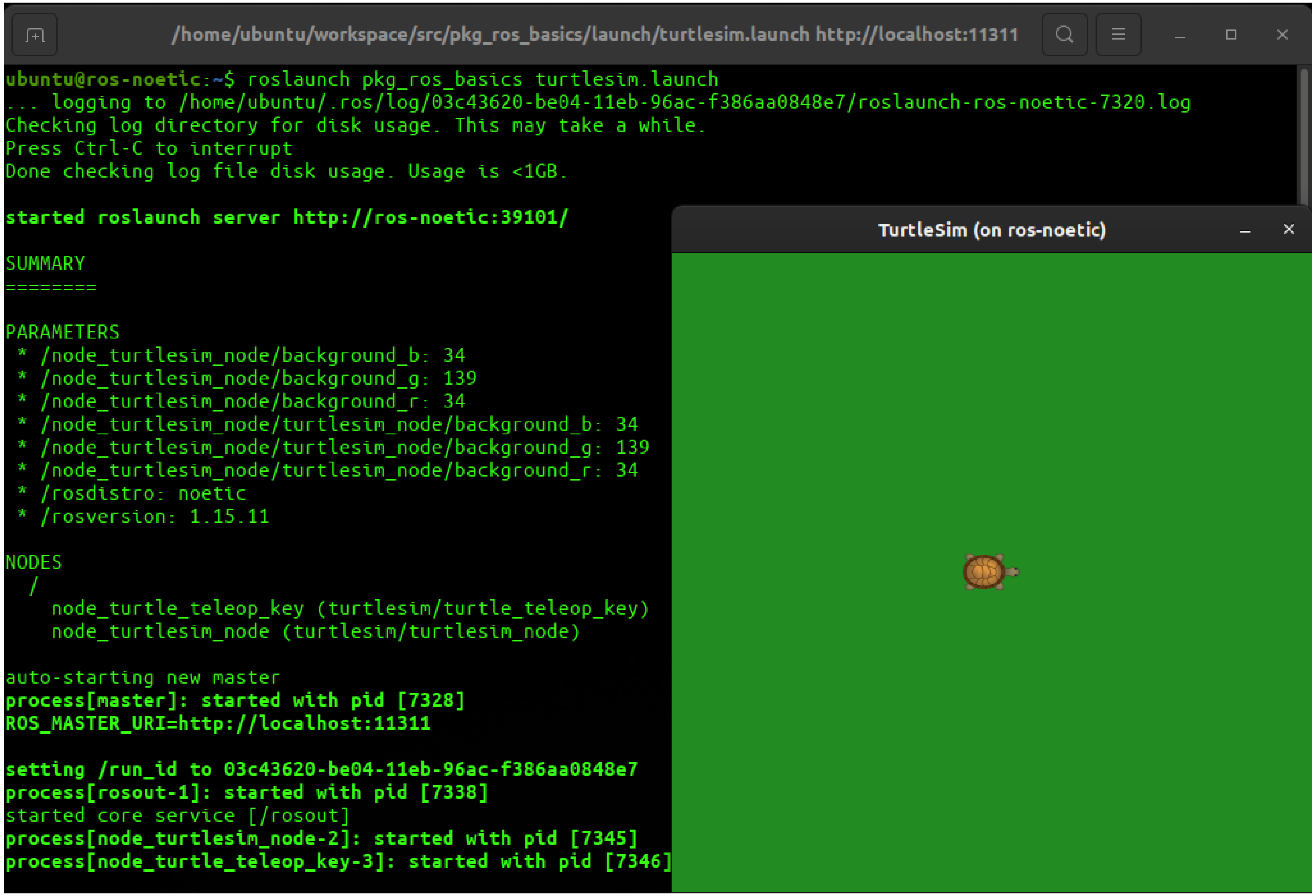
```
<launch>

    <node pkg="turtlesim" type="turtlesim_node" name="node_turtlesim_node">
        <param name="/background_r" value="34" />
        <param name="/background_g" value="139" />
        <param name="/background_b" value="34" />
    </node>

    <node pkg="turtlesim" type="turtle_teleop_key" name="node_turtle_teleop_key" />

</launch>
```

Download

Run Command

```
roslaunch pkg_ros_basics turtlesim.launch
```

Output



- The code is self-explanatory. - If you are not able to understand the code feel free to seek help from us.

ROS with Gazebo

Difficulty: Intermediate

This page is just to quick overview of the simulation and visualization tools in ROS.

> **Note**: ROS and Gazebo together are a great combination to simulate how your algoirthm would work in real time scenarios.

Gazebo Simulator

- Robot simulation is an essential tool in every roboticist's toolbox.
- A robust physics engine, high-quality graphics, and convenient programmatic and graphical interfaces, makes Gazebo a top Choice for 3D Simulator.

.world File: The file used to describe a collection of objects (such as buildings, tables, and lights), and global parameters including the sky, ambient light, and physics properties.

Reference

1. Gazebo Tutorials

RViz

- Visualizing sensor information is an important part in developing and debugging controllers.
- Rviz is a powerful 3D visualization tool in ROS that will hep you do exactly that.
- It allows the user to view the simulated robot model, log sensor information from the robot's sensors, and replay the logged sensor information.

Reference

1. ROS Wiki: RViz
2. Gazebo: Visualization and logging

URDF

- The Unified Robot Description Format (URDF) contains a number of XML specifications for robot models, sensors, scenes, etc.
- It describes the position of all the joints, sensors, type of joints, structure of the robot base, arm etc.

Reference

1. ROS Wiki: URDF overview
2. ROS Wiki: URDF Tutorials

XACRO

- Xacro (XML Macros) Xacro is an XML macro language.
- With xacro, you can construct shorter and more readable XML files by using macros that expand to larger XML expressions.
- Xacro is useful when the structure of the robot is complex so instead of describing the whole structure in an urdf we can divide the structure in small parts and call those macro files in the main xacro file.
- Xacros also make it easier to define common structures. For example, let’s say the robot has 2 wheels, we just need to make macros of a cylindrical structure(wheels), call it in the main xacro file and then define 2 different joints using the same structure but giving different joint location.

Reference

1. ROS Wiki: Using Xacro to Clean Up a URDF File
2. ROS Wiki: Xacro overview

Gazebo Plugins

- A Gazebo plugin needs to be added to your URDF that actually parses the transmission tags and loads the appropriate hardware interfaces and controller manager.
- Plugins basically replicate exact architecture of the sensors in use or the control system used to control the movement of the robot.

What are Transmission Tags?

- Transmission tags are used to link actuators to joints.
- If the transmission tags the joints won't move in Gazebo and they will be considered as stationary objects.
- We need to define transmission for every dynamic(moving) joint.

Reference

1. Gazebo tutorials: ROS Control

Gazebo Simulator

Gazebo is a 3D dynamic simulator with the ability to accurately and efficiently simulate populations of robots in complex indoor and outdoor environments. While similar to game engines, Gazebo offers physics simulation at a much higher degree of fidelity, a suite of sensors, and interfaces for both users and programs.

Features

- multiple physics engines,
- a rich library of robot models and environments,
- a wide variety of sensors,
- convenient programmatic and graphical interfaces

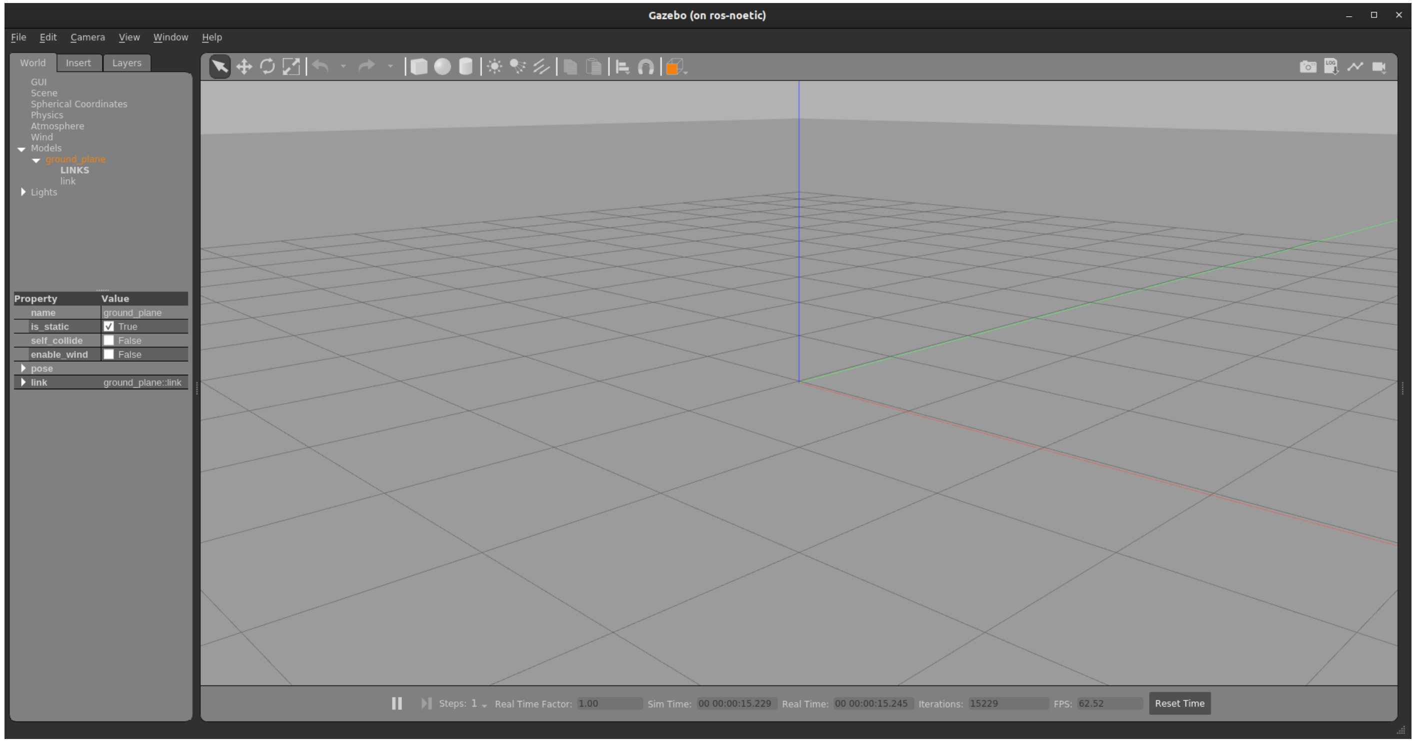
Understanding the GUI

To get a brief overview of the GUI of gazebo, open this link.

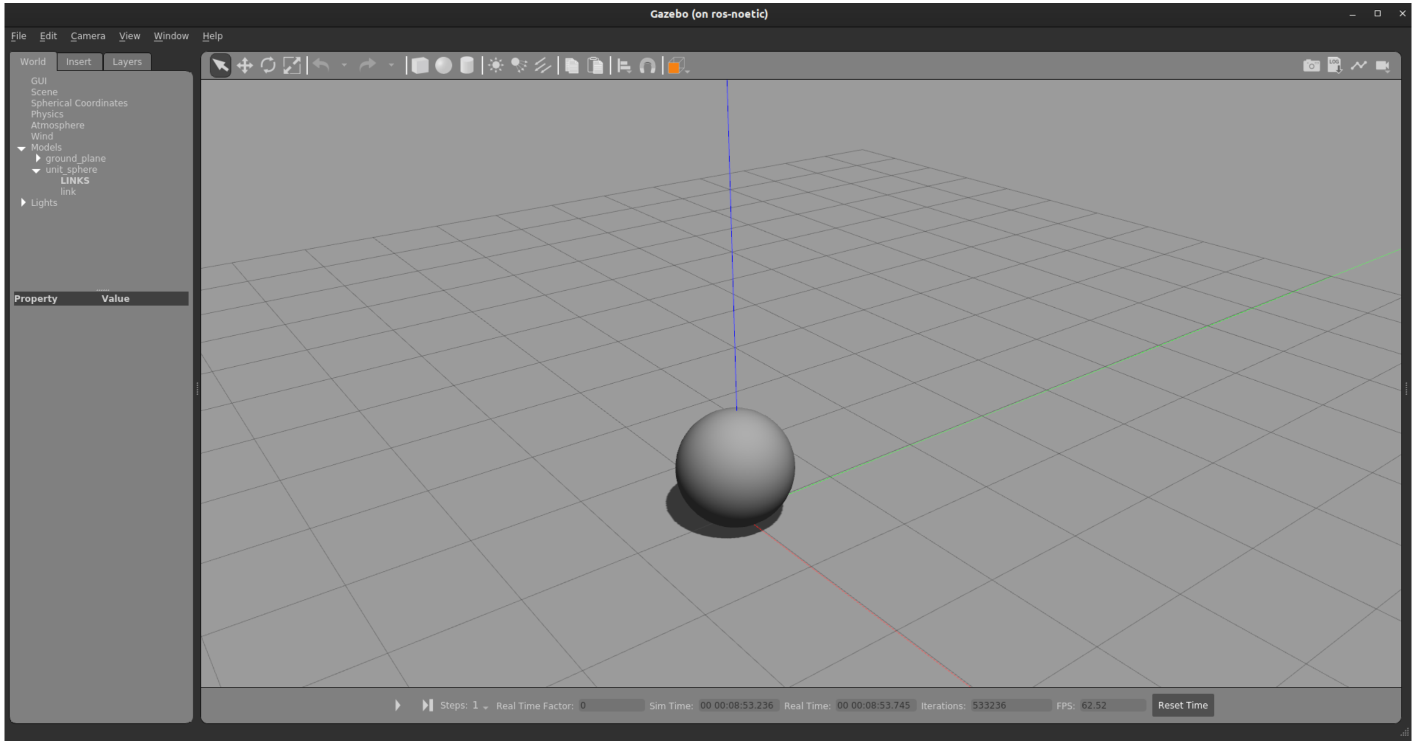
Adding models to Simulator

1. Let's first open a gazebo simulator environment.

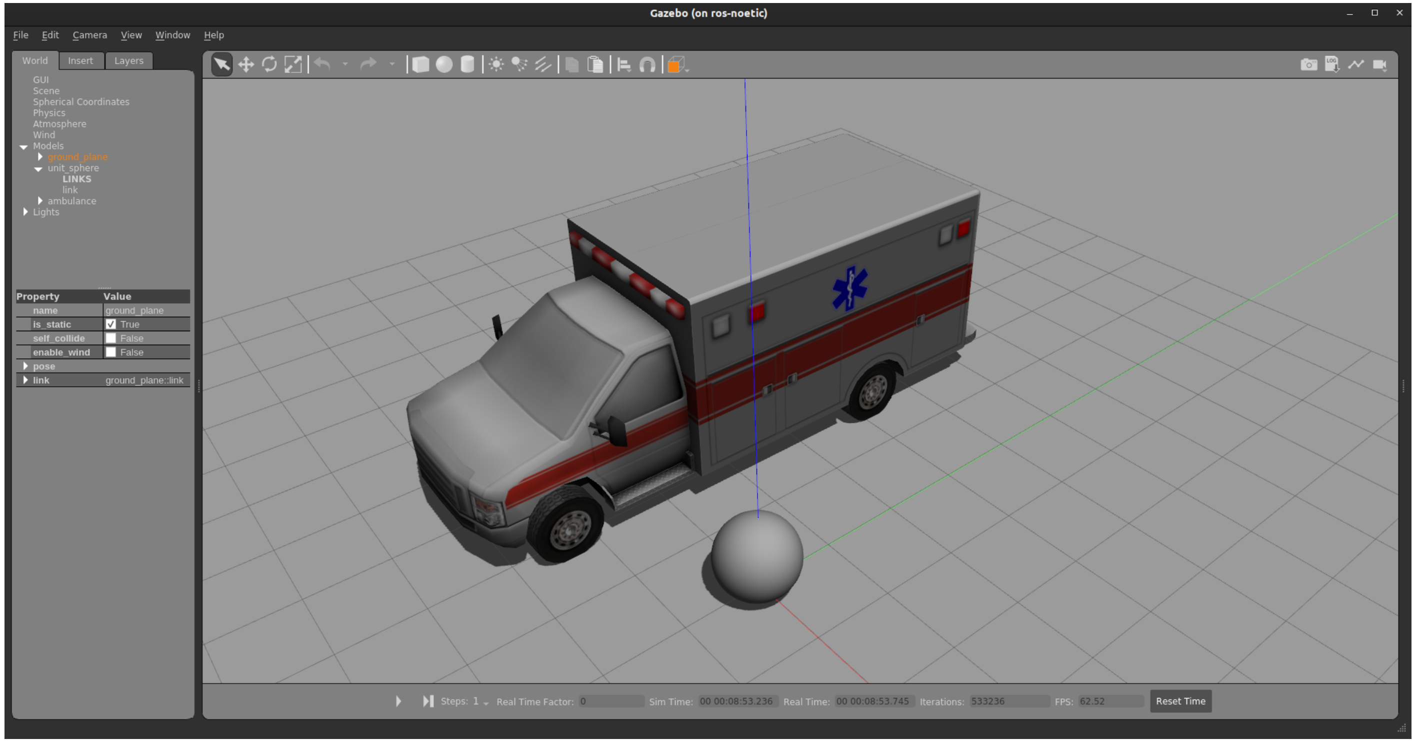
```
roslaunch gazebo_ros empty_world.launch
```



2. You can add primitive shapes like cube, sphere and sphere from upper toolbar.



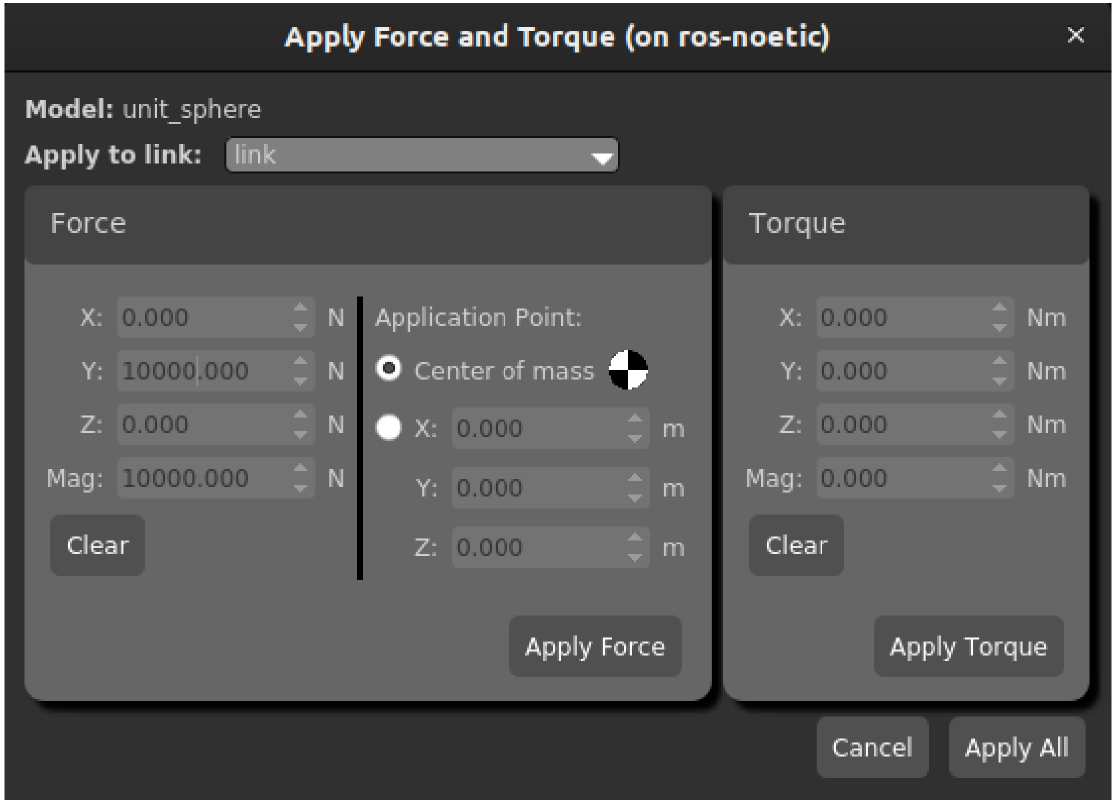
3. You can also add some other models by going to `Insert` on the left panel. Let's try adding `Ambulance` to the scene which is under `http://models.gazebosim.org/`. *It can take some time to download and load.*



4. You can also add some other custom models saved on you hard disk by adding path.

Applying force/torque to a model

First, select sphere. Right-click on it and select apply force/torque. Fill in the details as shown below.



Note: Don't forget to click on play button to start the simulation.

Now click on apply force. You can see the force being applied. Notice that the force is applied for **1ms**, so we've provided such high force for such a small ball to increase the impulse.

RViz

- RViz is short for `ROS Visualization`.
- It is a 3D visualization software tool for robots, sensors, and algorithms.
- It enables you to see the robot's perception of its world (real or simulated).
- The purpose of rviz is to enable you to visualize the state of a robot. It uses sensor data to try to create an accurate depiction of what is going on in the robot's environment.

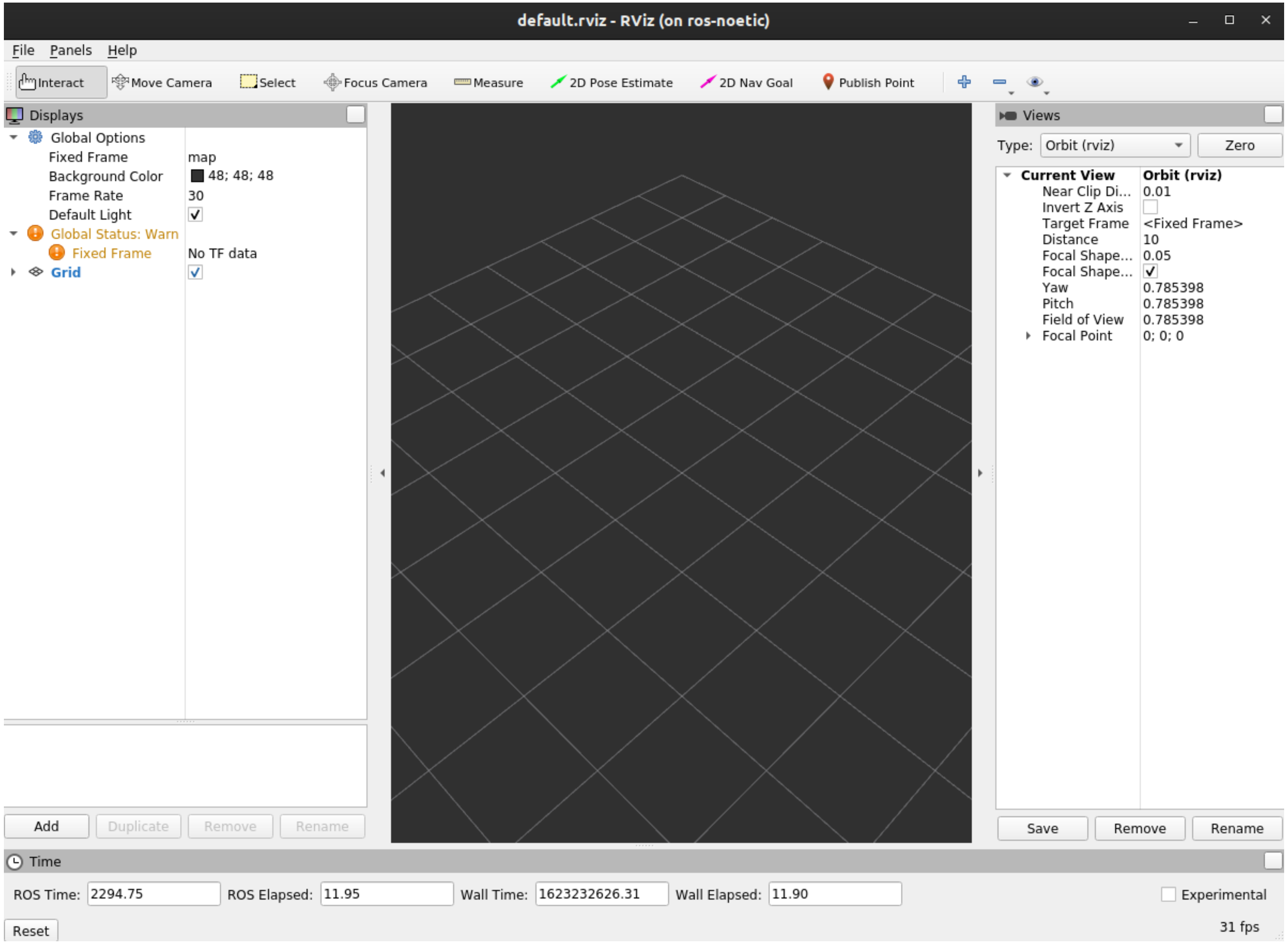
To launch rviz, type the following command in your terminal:

```
roscore
```

And in a different terminal tab, type:

```
rosrun rviz rviz
```

Here is the screen you should see when you launch rviz:



The left panel is the Displays panel. It has a list of plugins. These plugins enable you to view sensor data and robot state information. To add a plugin, you would click the Add button on the bottom left of the window.

Difference between RViz and Gazebo

The difference between the two can be summed up in the following excerpt from Morgan Quigley (one of the original developers of ROS) in his book *Programming Robots with ROS*:

“rviz shows you what the robot thinks is happening, while Gazebo shows you what is really happening.”

- `gazebo` shows the simulated environment in which a robot is placed.
- `rviz` shows the same environment through the eyes of a robot with the help of sensors.

Note: To get more familiar with the RViz tool, check out the tutorial videos in this link.

ROS Exercises

- This section contains tasks based on `ROS Noetic`.
- Make sure you've configured `ROS` and `ROS Workspace` properly before proceeding further.

All the best!!!

Task 0

Welcome to Task 0 !!!

The aim of this task is to make you familiar with rostopics and rosservices. You need to install the mentioned software & libraries by running the provided instructions in the **provided sequence only**; and if any error occurs at any step, please do **not** proceed unless the error has been rectified from your end.

Problem Statement

- The objective of this task is to spawn two turtles in a **turtlesim** window and make one turtle follow another.

Note: The name of turtles should be `turtle1` and `turtle2` respectively with `turtle2` following `turtle1`. `turtle1` should be spawned at default coordinates (5.544445, 5.544445, 0) and `turtle2` at (1.0, 1.0, 0.0).

- You can do this by creating a node name, `node_catch_the_turtle` with a python script, `node_catch_the_turtle.py`.

Optional:

- Change the color of the pen of turtles.
  - **turtle1**
    - `r: 255`
    - `g: 255`
    - `b: 0`
    - `width: 5`
  - **turtle2**
    - `r: 255`
    - `g: 0`
    - `b: 0`
    - `width: 4`
- Change the background to **forestgreen**.
  - `background_r: 34`

- `background_g: 139`
- `background_b: 34`

Procedure

1. First, create a package name `pkg_task0`, within your catkin workspace. Once done, compile and source the packages.

```
cd ~/workspace
catkin_make
source devel/setup.bash
```

1. Within this package, you should have a `scripts` folder inside which you'll create a python script, named `node_catch_the_turtle.py`.

Note: Fill the script with proper programming ethics. Doing this will help us understand your code better and quicker than usual.

---

1. After completing the python script. Make it executable, if it isn't already. To do that, enter the following code.

```
chmod +x ~/workspace/src/pkg_task0/scripts/node_catch_the_turtle.py
```

1. Before executing make sure that `roscore` is running along with `turtlesim_node`. You can either run them in separate terminals or simply create a `task0.launch` file inside the `~/workspace/src/pkg_task0/launch/` folder. Launch file can run multiple nodes unlike a python/cpp script. Run the launch file, enter,

```
roslaunch pkg_task0 task0.launch
```

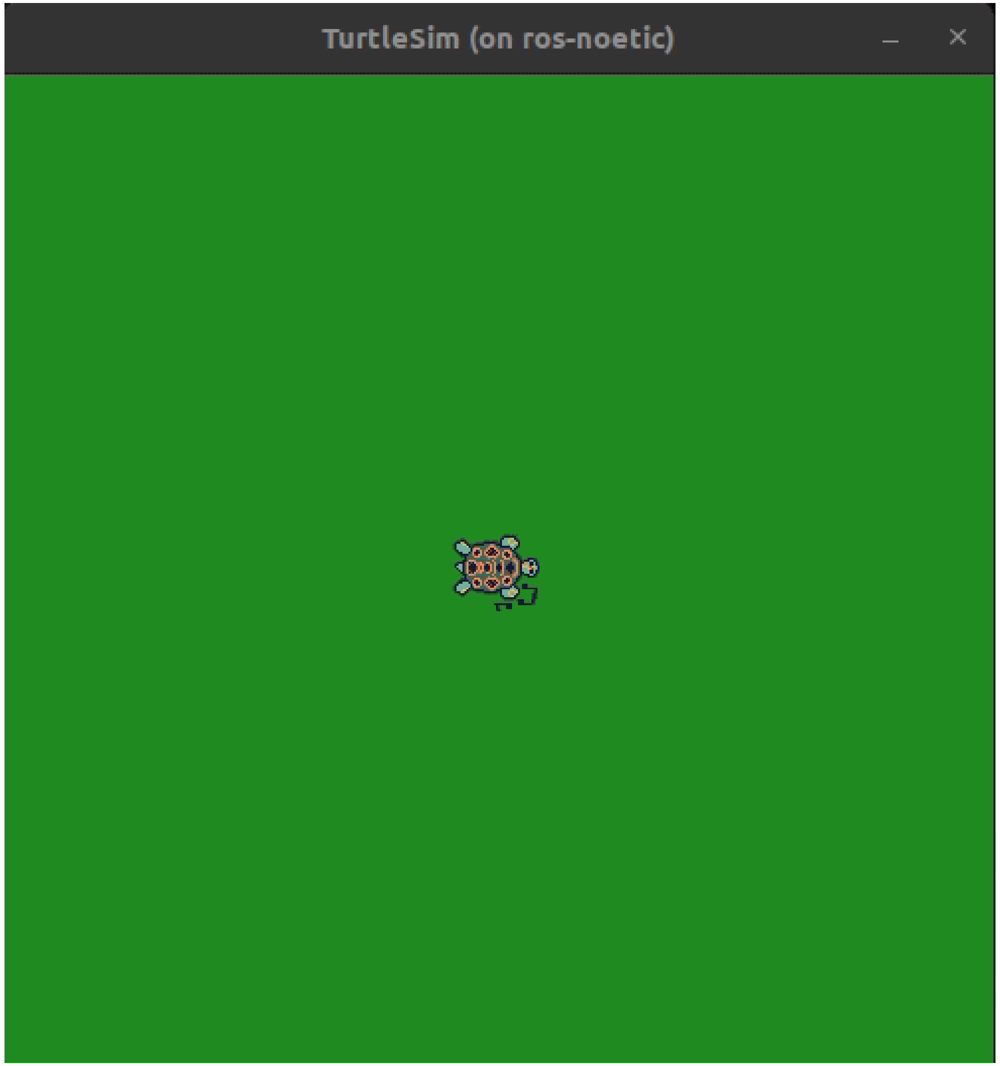
- This should run these processes in parallel.
    - roscore
    - turtlesim_node
    - turtle_teleop_key
    - node_catch_the_turtle.py

Hints

- You can use linear velocity as well as angular velocity with some combination to get this done.
- Keep tracking the distance travelled so as to know when to stop.

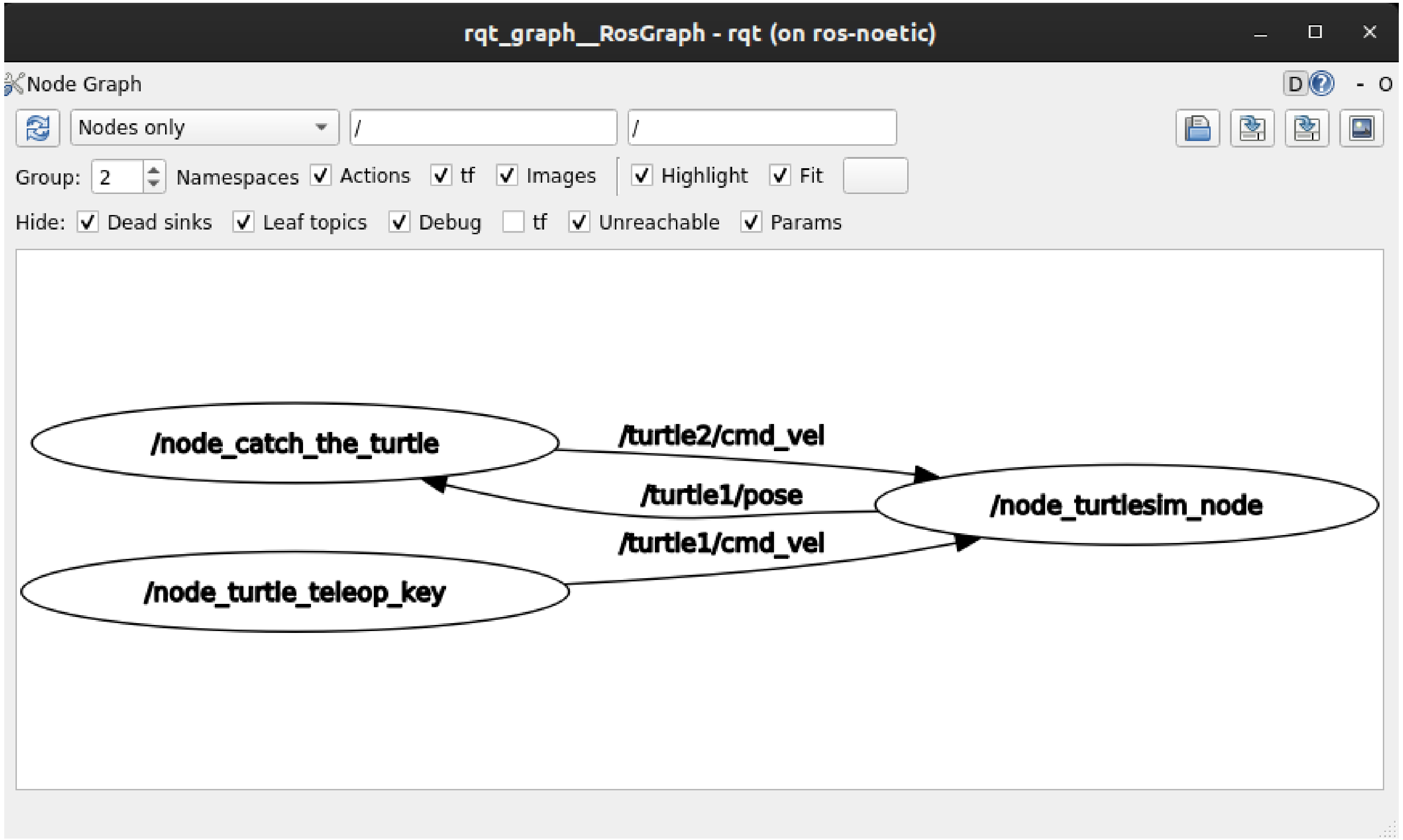
Expected Output

- The following videos can be considered as a valid output.



Note: First, let `turtle2` reach `turtle1` then only move `turtle1`.

- To know whether the nodes are talking to each other as expected one can use the command `rqt_graph`. Below, you can find an expected graph for this task.



- Your terminal should look like this at the startup of roslaunch server.

```
ubuntu@ros-noetic:~$ roslaunch pkg_task0 turtle-task.launch
... logging to /home/ubuntu/.ros/log/6f7d513a-c084-11eb-9883-a5ac155eafae/roslaunch-
ros-noetic-10780.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://ros-noetic:34763/

SUMMARY
========

PARAMETERS
 * /node_turtlesim_node/background_b: 34
 * /node_turtlesim_node/background_g: 139
 * /node_turtlesim_node/background_r: 34
 * /rosdistro: noetic
 * /rosversion: 1.15.11

NODES
  /
    node_catch_the_turtle (pkg_task0/node_catch_the_turtle.py)
    node_turtle_teleop_key (turtlesim/turtle_teleop_key)
    node_turtlesim_node (turtlesim/turtlesim_node)

auto-starting new master
process[master]: started with pid [10788]
ROS_MASTER_URI=http://localhost:11311

setting /run_id to 6f7d513a-c084-11eb-9883-a5ac155eafae
process[rosout-1]: started with pid [10798]
started core service [/rosout]
process[node_turtlesim_node-2]: started with pid [10801]
process[node_turtle_teleop_key-3]: started with pid [10805]
process[node_catch_the_turtle-4]: started with pid [10807]
Reading from keyboard
---------------------------
Use arrow keys to move the turtle. 'q' to quit.
[ INFO] [1622296061.324015602]: Starting turtlesim with node name /node_turtlesim_node
```

```
[ INFO] [1622296061.328553969]: Spawning turtle [turtle1] at x=[5.544445], y=
[5.544445], theta=[0.000000]
[ INFO] [1622296061.657708547]: Spawning turtle [turtle2] at x=[1.000000], y=
[1.000000], theta=[0.000000]
```

Recording Logs

- ROS allows us to record a log of the messages that occurred in a given time period. This is like recording a data stream. The ROS utility which does this is called rosbag, and the command to capture the data is `rosbag record`.
- Create a folder called bag_files in your package as a save destination for the bag files.
- You can run the rosbag record command separately on the command line. But to not loose any data you will have to start recording precisely at the same moment your turtle starts moving. Hence it is a much more preferable option to include the rosbag recording in your launch file itself.
- Add the following lines to your launch file to have the rosbag record run in parallel with your task. Some parameters are explained below:

```
    <arg name="record" default="false"/>
    <arg name="duration" default="100"/>
    <arg name="rec_name" default="turtle_record.bag"/>

    <group if="$(arg record)">
        <node name="rosbag_record_turtle" pkg="rosbag" type="record"
            args="record -O $(find pkg_task0)/bag_files/$(arg rec_name) --
duration=$(arg duration) --chunksize=10 /turtle1/cmd_vel /turtle1/pose
/turtle2/cmd_vel /turtle2/pose" output="screen" />
    </group>
```

Note: Make sure you have added these line before `</launch>` line. And the 3 nodes, the turtlesim, teleop_key and your python script node, are already present within this launch file, for desire recording.

- The `arg_name` tags are roslaunch parameters, meaning they can be called while calling your roslaunch file, for example:

```
roslaunch pkg_task0 task0.launch record:=true rec_name:=my_turtle.bag
```

- This command will..
  - Start recording.
  - Should start turtlesim and turtle_teleop_key node.
  - Should start your python script node.
  - And name the resultant bag file as **my_turtle.bag**.

while still retaining the default value (in seconds) for the duration parameter.

Thus using these parameters along with your launch file will record a bag file of appropriate `duration`. Also, Make sure that the task is completed within the recording duration. **If not then shorten the duration during which you run turtle1 using teleop_key.**

- If the rosbag has started, the message:

```
process[rosbag_record_turtle-5]: started with pid [1056]
```

will appear on your terminal within the roslaunch output window.

> **Note**: bag files with the same name will be overwritten by the rosbag utility without a prompt/warning. Make sure you provide proper name for each iteration if you want to save them all.

Submission Instructions

In total 3 things needs to uploaded to iLearn for submission.

1. A short video of expected output (of your solution).
2. Your package `pkg_task0` which should include these files.

```
pkg_task0
├── bag_files
│   └── turtle_record.bag
├── CMakeLists.txt
├── launch
│   └── turtle-task.launch
├── package.xml
└── scripts
    └── node_catch_the_turtle.py

3 directories, 5 files
```

Take special care of the naming.

3. Bag files as showing in recording logs section.

Task on UR5e

UR5e Gazebo Simulation - Pick and Place