Tutorial 1: Getting Started

Part 1: Launch Your First Robot

Duration: 15 minutes

This section provides a brief introduction to what it's like to use ROS 2. We will launch a pre-built software stack using the "turtlebot" platform and demonstrate how the robot performs mapping in a simulation environment.

At the end of this tutorial, you would hopefully be able to build your own "turtlebot" simulator leveraging different ROS2 packages.

1.1. Make sure you Install All Necessary Packages.

```
sudo apt install ros-humble-navigation2 ros-humble-nav2-bringup

sudo apt install ros-humble-turtlebot3*
```

1.2. Lauch the Robot in Simulator

```
ros2 launch turtlebot3_gazebo turtlebot3_world.launch.py
```

Open up a new terminal for the control keys.

```
ros2 run turtlebot3_teleop teleop_keyboard
```

Once you finish this, please do not close anything. Drive the robot around and wait for the others.

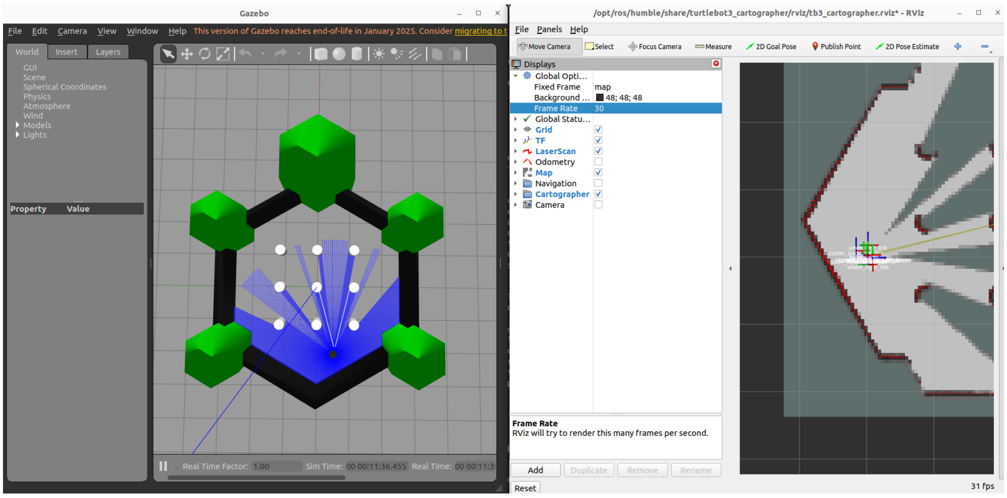
Part 2: RVIZ and SLAM

Duration: 15 minutes

2.1. Introduction

2.1.1. RVIZ and Gazebo

In robotic development, you will face a diverse range of data types, some include robot position frames, 2D lidar arrays, 3d point clouds and many more.



RViz is a powerful **3D visualization tool** in ROS that allows users to view and interact with complex robotic data in real time. It provides a graphical interface to visualize information such as sensor inputs (e.g., LiDAR, cameras), robot models, maps, and navigation paths. This helps developers and researchers better understand and debug the behavior of their robot systems by making abstract data intuitive and accessible.

RVIZ vs Gazebo: You may ask, if we already have RViz, why do we need Gazebo? Well, RViz is primarily a visualization tool—it shows you what the robot perceives, such as sensor data, map information, and planned paths. However, what the robot "sees" doesn't always reflect the actual dynamics of the real world. Gazebo, on the other hand, is a full-featured simulation environment that models the physical world. It can simulate physics, friction, collisions, and sensor noise, providing a more realistic and interactive testing ground for robotic algorithms before deploying them to real hardware.

2.1.2. SLAM

Localization determines the robot's position (x, y, θ) within a known map.

Mapping constructs a representation of the environment given known poses.

SLAM (Simultaneous Localization and Mapping) aims to estimate both the map m and the robot's trajectory $x_{1:t}$ from sensor data $z_{1:t}$ and control inputs $u_{1:t}$, i.e.,

$$ p(x_{1:t}, m \mid z_{1:t}, u_{1:t}) $$

2.2. Launch RVIZ and SLAM

To Launch your slam algorithm:

```
ros2 launch turtlebot3_cartographer cartographer.launch.py
use_sim_time:=True
```

```diff
+ TODO1: After you have launched RVIZ, please drive the robot around the
Simulated World to create your own map.

+ TODO2: Next, press "add" key on the bottom of the left hand panel to add
a sensor of your choice.
```

Part 3: Ros2 Basics

Duration: 30 minutes

3.1. What is ROS2?

- ROS (Robot Operating System) is a flexible, modular middleware framework that enables communication, coordination, and control among components in a robotic system.
- ROS2 is very vauge and does not really relate to robot when first using it.
- Rather than giving you a cake you can add dressing on, ROS2 feels more like here is a cow, some wheat, go make a cake.

3.2. All Components in ROS2

ROS2 Concept	Minecraft Analogy	Description
Node	A player	Performs a specific task like moving, sensing, or reacting.
Topic	A redstone signal line or chat channel that allows for communication between players	Used for one-way communication between nodes.
Publisher	Dispenser or redstone clock	Sends out messages/data on a topic.
Subscriber	Pressure plate or observer block	Listens for and reacts to messages on a topic.
Message	Item, chat message, or redstone signal	The actual data being passed between nodes.
Service	Command block with `/tp` or `/give`	Provides a request-response interaction.
Action	A sequence of commands (e.g., finding treasure)	Long-running task that gives feedback and can be cancelled.
Launch File	Setup script or command block chain	Spawns and connects multiple components at once.
TF (Transform)	Coordinate system of each player or structure	Tracks positions and orientations relative to each other.
RVIZ	Minimap or map mod	Visualizes positions, environment layout, and sensor data.
Gazebo	Modded Minecraft world with physics (e.g., gravity tweaks, slime blocks)	Simulates real-world physics and interactions.

```
+ TODO3: Try coming up with an analogy of your own?
```

3.3. A Unified Framework

```
flowchart TD
    NodeA["Node A (Publisher)"]
    DDS["DDS"]
    NodeB["Node B (Subscriber)"]

    NodeA -->|Message| DDS --> NodeB
```

1. **Node:** A chunk of code that is written by User which will perform a specific task or specific sequence of tasks.

2. **Data Distribution Service:** This is a communication pipeline that is able to interface with all of our code. DDS allows for Nodes to communicate with each other using three main ways:

    - Publisher/Subscriber
    - Services
    - Actions

Part 4: Build Your First ROS2 Package

Duration: 15 minutes

4.1. Converting Code into executable objects with Colcon Build:

4.1.1. What is colcon?

Colcon is the official build tool for ROS 2 that automates building, testing, and managing workspaces with multiple interdependent packages.

4.1.2. What does colcon build do?

`colcon build` is a command used in ROS 2 to compile all the packages inside your workspace's `src/` directory. It scans the source code, resolves dependencies, and builds each package in the correct order. The results are stored in the `build/`, `install/`, and `log/` directories. The `build/` folder contains temporary files used during compilation, `install/` holds the final executable and configuration files, and `log/` keeps logs from the build process. Running `colcon build` is an essential step that prepares your ROS 2 packages to be run or launched in a robot system.

```
colcon build --symlink-install
```

`--symlink-install` tells `colcon` to create symbolic links to your source files instead of copying them, allowing instant updates without rebuilding.

4.2. ROS2 Workspace:

A ROS 2 workspace is a directory structure where you develop, build, and organize multiple ROS 2 packages together.

The `src` folder in ros should be the only place that you put in your development code, you should not be needing to modify `build`, `install` or `log` folder.

A common thing to attempt when facing `catkin build` errors or other strange `build errors` is to delete the `build`, `install` and `log` folder and build again.

```
ros2_ws/
├── src/           # Your code and imported package go here
│   ├── package 1/
│   └── package 2/
├── build/         # (autogenerated by `colcon build`)
├── install/       # (autogenerated by `colcon build`)
└── log/           # (autogenerated by `colcon build`)
```

4.3. ROS2 Package Structure:

You can choose to structure your ros2 package in a variety of different ways. Common templates are provided below:

4.3.1. ROS2 C Package

```
my_cpp_pkg/
├── CMakeLists.txt           # CMake build instructions
├── package.xml              # Package metadata
├── src/                     # C++ source files
│   └── my_node.cpp
├── include/                 # C++ header files
│   └── my_cpp_pkg/
│       └── my_node.hpp
└── launch/                  # (Optional) Launch files
    └── my_launch.py
```

You can create this package template using:

```
ros2 pkg create my_cpp_pkg --build-type ament_cmake --dependencies rclcpp
```

4.3.2. ROS2 Python Package - Python Make

```
my_python_pkg/
├── package.xml              # Package metadata
├── setup.py                 # Python build script
├── setup.cfg                # (Optional) Build config
├── resource/
│   └── my_python_pkg        # Empty file for ROS 2
├── my_python_pkg/           # Python module directory (must match package
name)
│   ├── __init__.py
│   └── my_node.py
└── launch/                  # (Optional) Launch files
    └── my_launch.py
```

You can create this package template using:

```
ros2 pkg create my_python_pkg --build-type ament_python --dependencies
rclpy
```

4.3.3. ROS2 Python Package - cMake

```
my_python_pkg/
├── package.xml              # Package metadata
├── CMakeLists.txt           # Uses ament_cmake to install Python scripts
├── resource/
│   └── my_python_pkg        # Required for ament indexing
├── my_python_pkg/           # Python package (must match name)
│   ├── __init__.py
│   └── my_node.py
└── launch/
    └── my_launch.py
```

You can create this package template using:

```
ros2 pkg create my_cmake_python_pkg --build-type ament_cmake --dependencies
rclpy
```

4.4. Create Your First Package:

Please do not be intimidated by the level of complexity above, in this course you will be writing a very minimal amount of code.

While different developers have different package preferences, in this tutorial we will be using the template of `python_ament_cmake`, as doing so would allow us to incooporate both `python` and `c` code in the same package. Giving us a bit more diversity and making it more user-friendly for everyone.

1. Please create your own package and assign a package name to your robot. Please make sure you are inside your `src` repository.

```
ros2 pkg create [package_name] --build-type ament_cmake --dependencies
rclpy
```

2. Add a launch folder into your package

```
cd [package_name]
```

```
mkdir launch
```

3. Build your empty package in your main Workspace. Navigate back using the command below.

```
cd ..
```

4. Now source and visualize your package.

```
source install.setup.bash
```

```
ros2 pkg list
```

Homework:

Duration: 20 minutes

```
+ TODO4: Can you now try to create a publisher and subscriber of your own
please?

+ TODO5: Visualize your topics using `ros2 topic list`
```

Use the reference link to help you: https://docs.ros.org/en/humble/Tutorials/Beginner-Client-Libraries/Writing-A-Simple-Py-Publisher-And-Subscriber.html