IA712: Mobile Robotics

Lecture 3: System Integration

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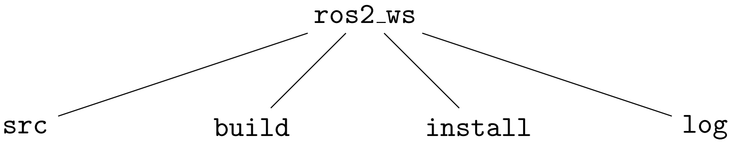
What is a Workspace?

A ROS 2 **workspace** is a directory containing the source code for your (custom) ROS 2 packages.
⟹ The place where you develop, build, and install your own robotics software!

A typical workspace (`ros2_ws`) has the following structure:

- `/src`: Source space. ▷ Place your ROS 2 packages here.
- `/build`: Build space. ▷ The build tool, `colcon`, uses this for intermediate files. You rarely interact with it directly.
- `/install`: Install space. ▷ After a successful build, the compiled programs, libraries, and launch files are placed here, ready to be used.
- `/log`: Log space. ▷ Contains logs from the build process for debugging.

What is a Workspace?



The Build Tool

`colcon` (**col**lective **con**struction): The standard command-line tool to build ROS 2 packages.

Core command:

To build all packages in your workspace, you navigate to the root of the workspace and run:

```
cd ~/ros2_ws/
colcon build
```

- `colcon` **automatically** discovers all the packages in the `src` directory.
- It resolves the **dependencies** between packages.
- It builds them in the correct **order**.
- It places the final **executables** and other files into the `install` directory.

Important: You must run `colcon build` from the **root** of the workspace, not from the `src` directory.

What is a Package?

A **package** is the fundamental unit of software organization in ROS 2.

It's a directory containing everything related to a specific piece of functionality.

A package can contain:

- ROS 2 nodes (C++ or Python source code)
- Launch files
- Configuration files
- Custom message/service/action definitions
- A `package.xml` file (metadata)
- A build file (`CMakeLists.txt` or `setup.py`)

What is a Package?

Packages are created using the `ros2 pkg create` command:

```
# Example for a Python package
ros2 pkg create --build-type ament_python my_package_name
```

- ament: A collection of build **rules and tools** for building, testing, and installing ROS 2 packages.
- colcon: Use the rules defined by ament to execute the build process.

The Manifest

Every ROS 2 package **must** contain a `package.xml` file, which defines the package's properties.

$\Longrightarrow$ Package's "ID card"!

Key Information in `package.xml`:

- `<name>`: The unique name of the package.
- `<version>`: The version number of the package.
- `<description>`: A brief summary of what the package does.
- `<maintainer>`: The person responsible for the package.
- `<license>`: The software license (e.g., Apache 2.0, MIT).
- `<build_depend>`: Dependencies needed to *build* the package.
- `<exec_depend>`: Dependencies needed to *run* the package.

Important: Correctly defining dependencies is crucial for `colcon` to build the workspace successfully.

Why Version Control?

How do you manage code, especially in a team?

Without Version Control

- `nav_node.py`
- `nav_node_working.py`
- `nav_node_final.py`
- `nav_node_final_v2.py`
- Zipping files and sending them via email
- Who changed what, and when?
- How to revert a change that broke everything?

With Version Control

- A complete history of every change.
- The ability to revert to any previous state.
- **Branching**: Work on new features without breaking the main code.
- **Collaboration**: Merge changes from multiple people reliably.
- It's the professional standard for all software development!

The Basic Git Workflow

Git is a distributed version control system.

Your packages in `ros2_ws/src` should be Git repositories.

Typical solo workflow:

1. **git add <files>**: Stage your changes for commit.
2. **git commit -m "Message"**: Save a snapshot of your changes to the local history.
   ⟹ A good message explains *why* you made the change.
3. **git push**: Upload your commits to a remote server like GitHub.
4. **git pull**: Download changes from the remote server.

The Basic Git Workflow

The most important file: `.gitignore`

- Your repository should only track **source code**.
- The `build`, `install`, and `log` directories are generated and should **not** be tracked.

```
# Add this to a .gitignore file in your workspace root
build/
install/
log/
```

Collaboration with GitHub

GitHub hosts your remote Git repositories and provides powerful collaboration tools.

The Pull Request (PR) workflow:

1. **Create a Branch**: Make a new branch for your feature (e.g., `feature/add-lidar-filter`).
2. **Push the Branch**: Push your commits to this new branch on GitHub.
3. **Open a Pull Request**: From GitHub, request to merge your new branch into the main branch (`main` or `master`).
4. **Review and Discuss**: Team members can review your code, suggest changes, and discuss the implementation directly on the PR.
5. **Merge**: Once approved, the changes are merged into the main branch.

We will use this workflow for the final course project.

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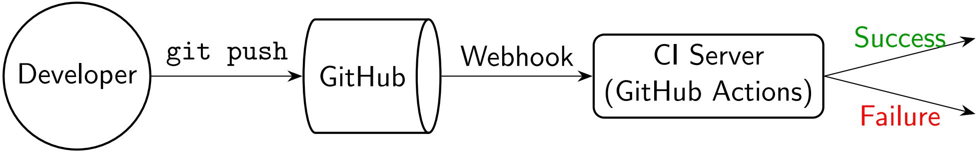
What is Continuous Integration?

Continuous Integration (CI) is the practice of automating the build and testing of code every time a team member commits changes to version control.



Core Idea: Catch integration bugs early and automatically.

$\Longrightarrow$ Your `main` branch should **always** build successfully.

A CI Workflow for ROS 2 with GitHub Actions

GitHub Actions is a CI/CD platform integrated into GitHub.

Define workflows in YAML files inside a `.github/workflows` directory in your repository.

A typical ROS 2 CI workflow when a developer opens a Pull Request:

1. A virtual machine running Ubuntu is automatically started.
2. ROS 2 Humble is installed.
3. Your repository's source code is checked out.
4. Dependencies from your `package.xml` files are installed using `rosdep`.
5. The entire workspace is built with `colcon build`.
6. Automated tests are run with `colcon test`.
7. A ✓ (success) or x (failure) is reported on the Pull Request.

This prevents merging code that breaks the system.

The Development Workflow

The standard workflow for developing with your own packages is:

1. Create a workspace directory (e.g., `ros2_ws/src`).
2. Create or clone your package(s) inside the `src` directory.
3. Navigate to the workspace root (`ros2_ws`).
4. Run `colcon build` to compile your packages.
5. **Source the local setup file**: `source install/setup.bash`.
6. Run your nodes or launch files.

Sourcing is very essential: Sourcing your local `install/setup.bash` file tells the ROS 2 environment where to find your newly built executables and packages.

Overlays and Underlays

Sourcing files creates a layered environment:

- **Underlay:** The base ROS 2 installation you sourced first (e.g., `/opt/ros/humble/setup.bash`).
  $\Longrightarrow$ It provides all the standard packages.
- **Overlay:** Your local workspace (`/ros2_ws/install/setup.bash`).
  $\Longrightarrow$ When you source this *after* the underlay, it adds your custom packages on top.

Overlays and Underlays

Overlay

Your Workspace (`ros2_ws`)

Underlay

Base ROS 2 Install (`/opt/ros/humble`)

The system will prioritize executables from the Overlay. $\Longrightarrow$ This allows you to use your own modified version of a package over the default one.

The Problem with `ros2 run`

For a real robot, you might need to start 10, 20, or even more nodes at once:

- Camera driver
- LiDAR driver
- Motor controller
- Localization node
- Path planner node
- ...and many more.

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Solution:

ROS 2 Launch System. $\Longrightarrow$ Launch files allow you to start and configure an entire system of multiple nodes with a single command.

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Example: Python Launch File

Launch files are typically written in Python.

⟹ Allow for programmatic and flexible system startups.

File: `my_package/launch/turtlesim.launch.py`

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

def generate_launch_description():
return LaunchDescription([
  Node(
  package='turtlesim',
  executable='turtlesim_node',
  name='sim'
  ),
  Node(
  package='turtlesim',
  executable='turtle_teleop_key',
  name='teleop'
  )
])
```

This file describes a system with two nodes. To run it, you use the command:

```
ros2 launch my_package turtlesim.launch.py
```

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The Role of a Hardware Driver

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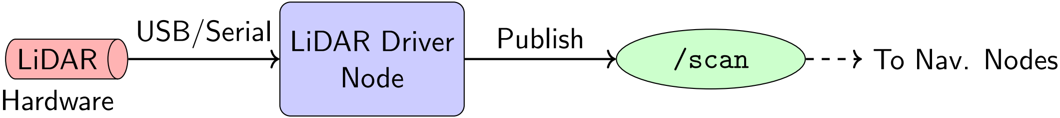

- The driver node reads raw data from the hardware (e.g., via a USB serial port).
- It converts this raw data into a standard ROS 2 message type (e.g., `sensor_msgs/msg/LaserScan`).
- It publishes this standardized message onto a topic for the rest of the system to use.

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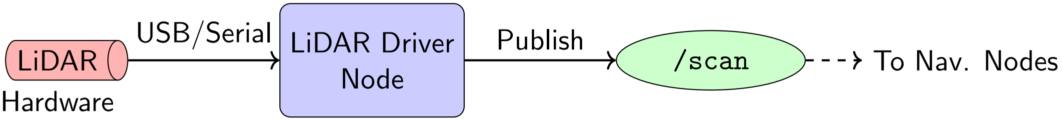

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Benefit? $\implies$ *Your navigation code doesn't need to know which brand of LiDAR you are using.*

Questions?

Next: Practical Work 3 - ROS 2 Intermediate Level