



ROS-Industrial Basic Developer's Training Class

October 2021



Southwest Research Institute





Session 1:

ROS Basics



Southwest Research Institute





Outline



- Intro to ROS
- ROS Workspaces & Colcon
- Installing packages (existing)
- Packages (create)
- Nodes
- Messages / Topics





An Introduction to ROS



(Image taken from Willow Garage's "What is ROS?" presentation)





ROS1 and ROS2



- ROS1 has been around since 2008
 - Uses custom TCP/IP middleware
- ROS2 is a ground-up reimaging of ROS
 - Started in 2014
 - Built on DDS, middleware proven in industry
 - Now on 6th named release



This class will focus on
ROS2





ROS1 and ROS2



- Community is currently in transition!
 - Final ROS1 release (Noetic) is out (EOL in 2025)
 - All critical features are now supported in ROS2
- ROS-Industrial will take time to transition
 - Many breaking changes / conceptual differences
 - Vision is industrial robots will become native ROS devices





ROS Versions



ROS 1



Box Turtle

Mar 2010

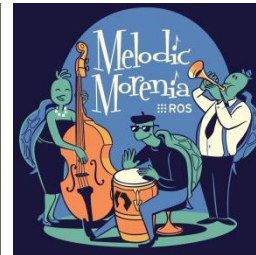
...

...



Lunar

2017 - 2019



Melodic

2018 - 2023



Noetic

2020 - 2025



EOL



ROS 2



Ardent

Dec 2018

...

...



Foxy (LTS)

2020 - 2023



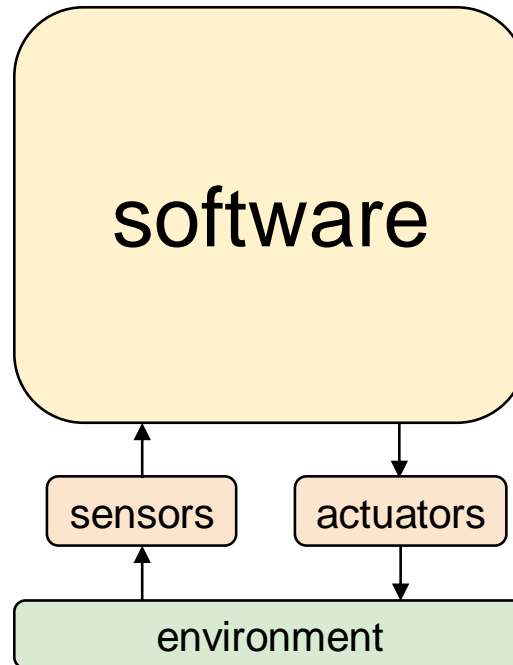
Galactic

2021 - 2022





ROS : The Big Picture



All robots are:

Software connecting Sensors to Actuators
to interact with the Environment

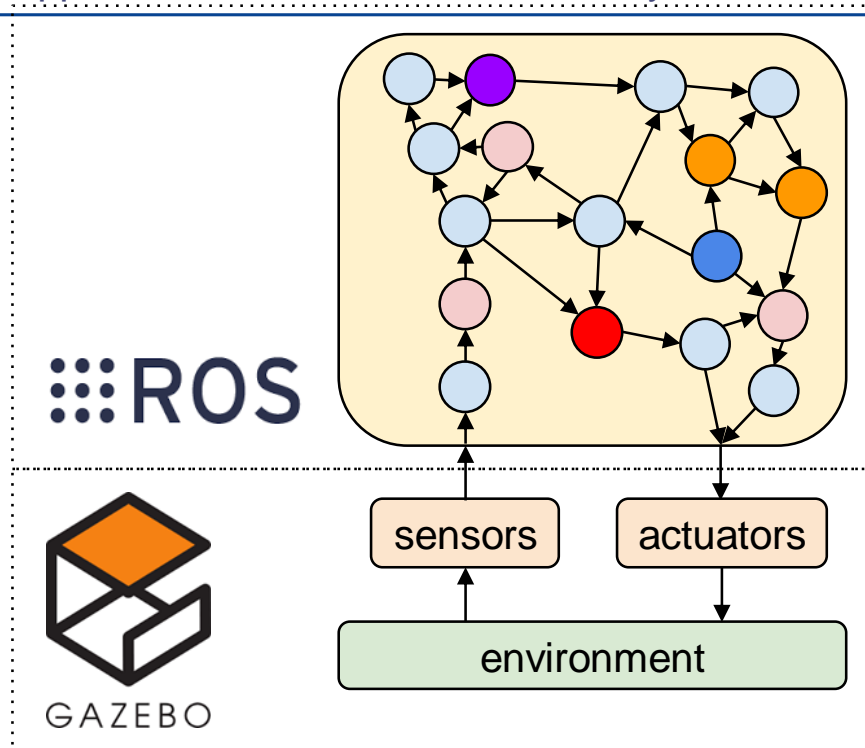


(Adapted from Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics" presentation)





ROS : The Big Picture



- Break Complex Software into Smaller Pieces
- Provide a framework, tools, and interfaces for distributed development
- Encourage re-use of software pieces
- Easy transition between simulation and hardware

(Adapted from Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics" presentation)

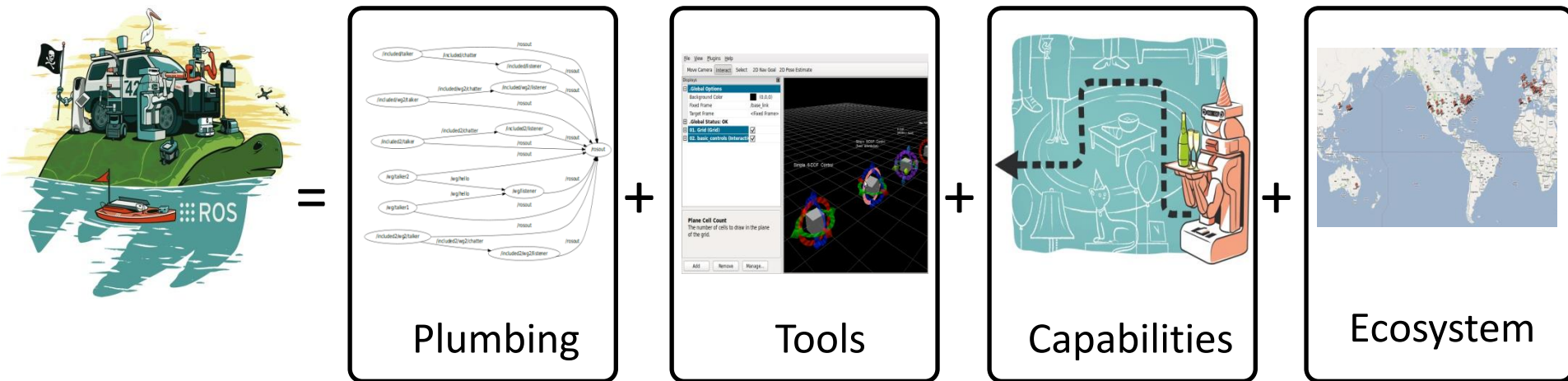




What is ROS?



ROS is...

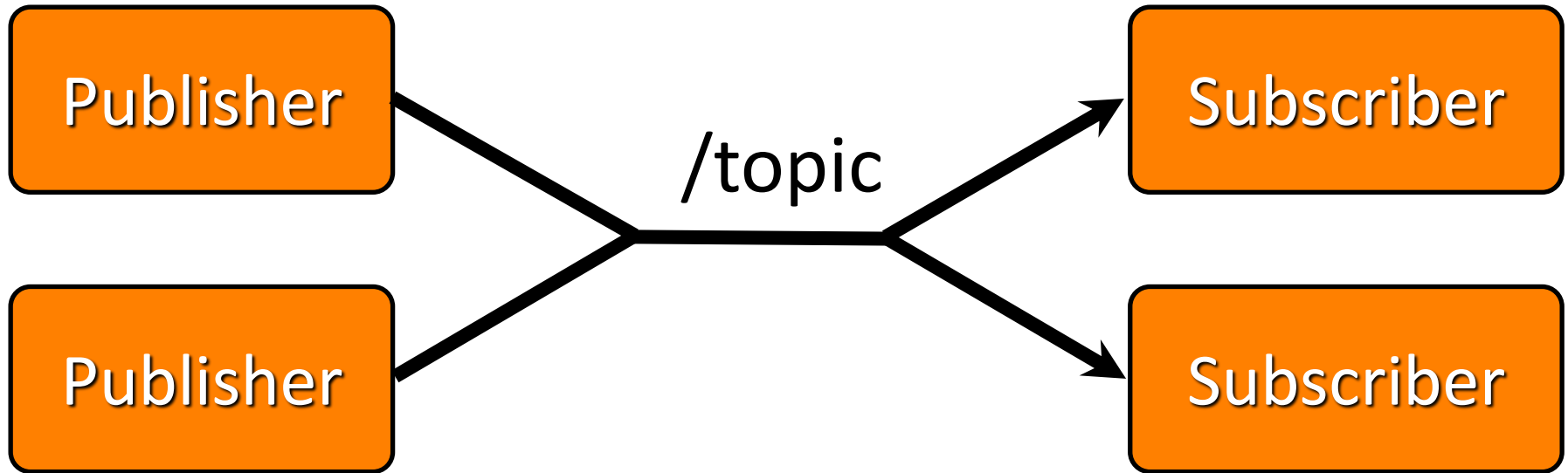


(Adapted from Willow Garage's "What is ROS?" Presentation)





ROS is... plumbing





ROS Plumbing : Drivers



- 2d/3d cameras
- laser scanners
- robot actuators
- inertial units
- audio
- GPS
- joysticks
- etc.

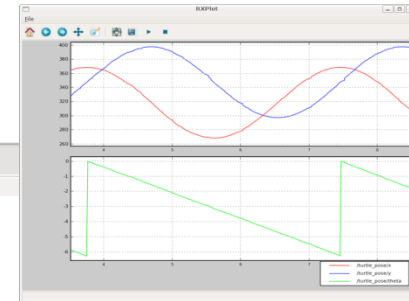
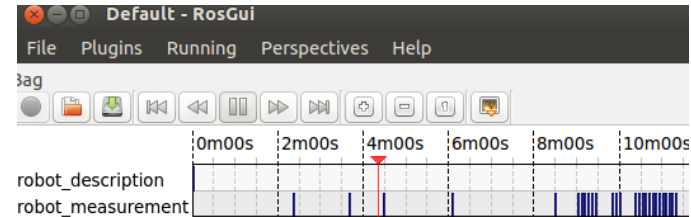
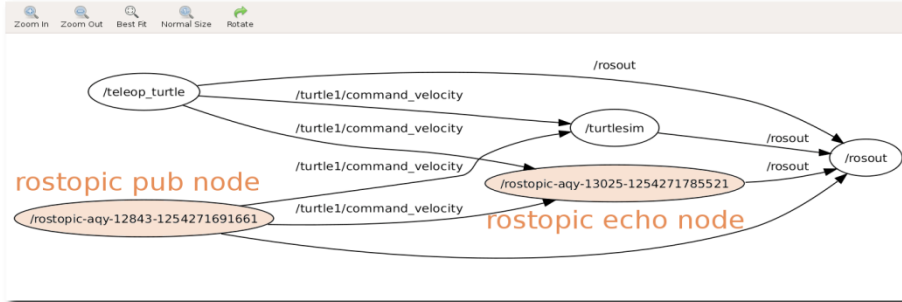


(Adapted from Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics" presentation)

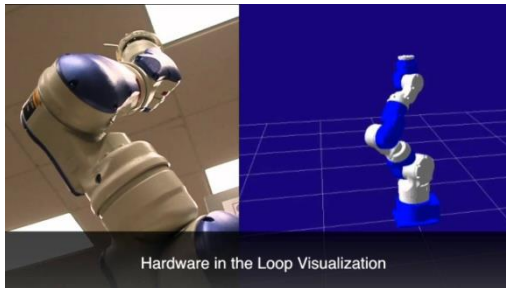




ROS is ...Tools



1345842179.913s Aug



Hardware in the Loop Visualization

- logging/plotting
- graph visualization
- diagnostics
- visualization

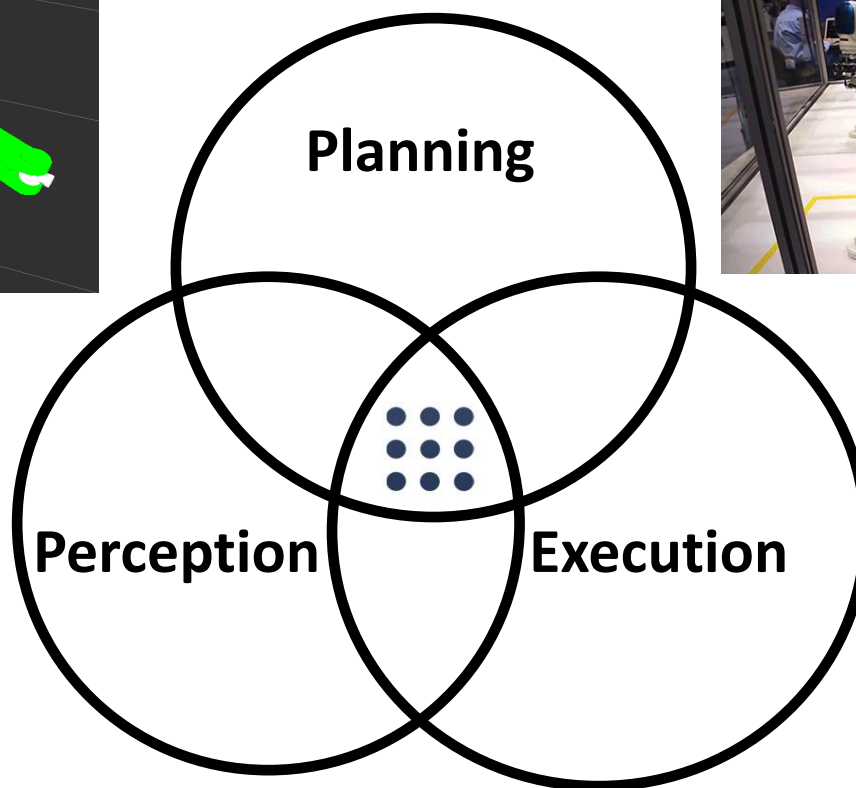
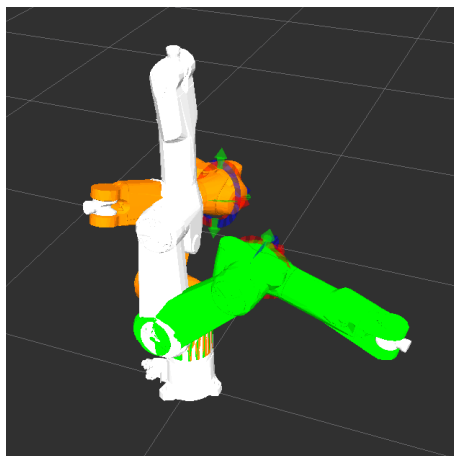
Message	Severity	Topic
#12 The input topic '/narrow_stereo/left/image_raw' is not yet advertised	Warn	/narrow_s
#10 The input topic '/narrow_stereo/right/image_raw' is not yet advertised	Warn	/narrow_s
#11 The input topic '/narrow_stereo/left/camera_info' is not yet advertised	Warn	/narrow_s
#8 The input topic '/narrow_stereo/right/camera_info' is not yet advertised	Warn	/narrow_s
#9 The input topic '/narrow_stereo/left/camera_info' is not yet advertised	Warn	/narrow_s
#7 Holding arms	Info	/arm_hol
#18 The input topic '/wide_stereo/right/camera_info' is not yet advertised	Warn	/wide_ste
#16 The input topic '/wide_stereo/left/camera_info' is not yet advertised	Warn	/wide_ste
#17 The input topic '/wide_stereo/right/image_raw' is not yet advertised	Warn	/wide_ste
#6 The input topic '/wide_stereo/left/image_raw' is not yet advertised	Warn	/wide_ste
#5 Moving torso up	Info	/arm_hol

(Adapted from Willow Garage's "What is ROS?" Presentation)





ROS is...Capabilities

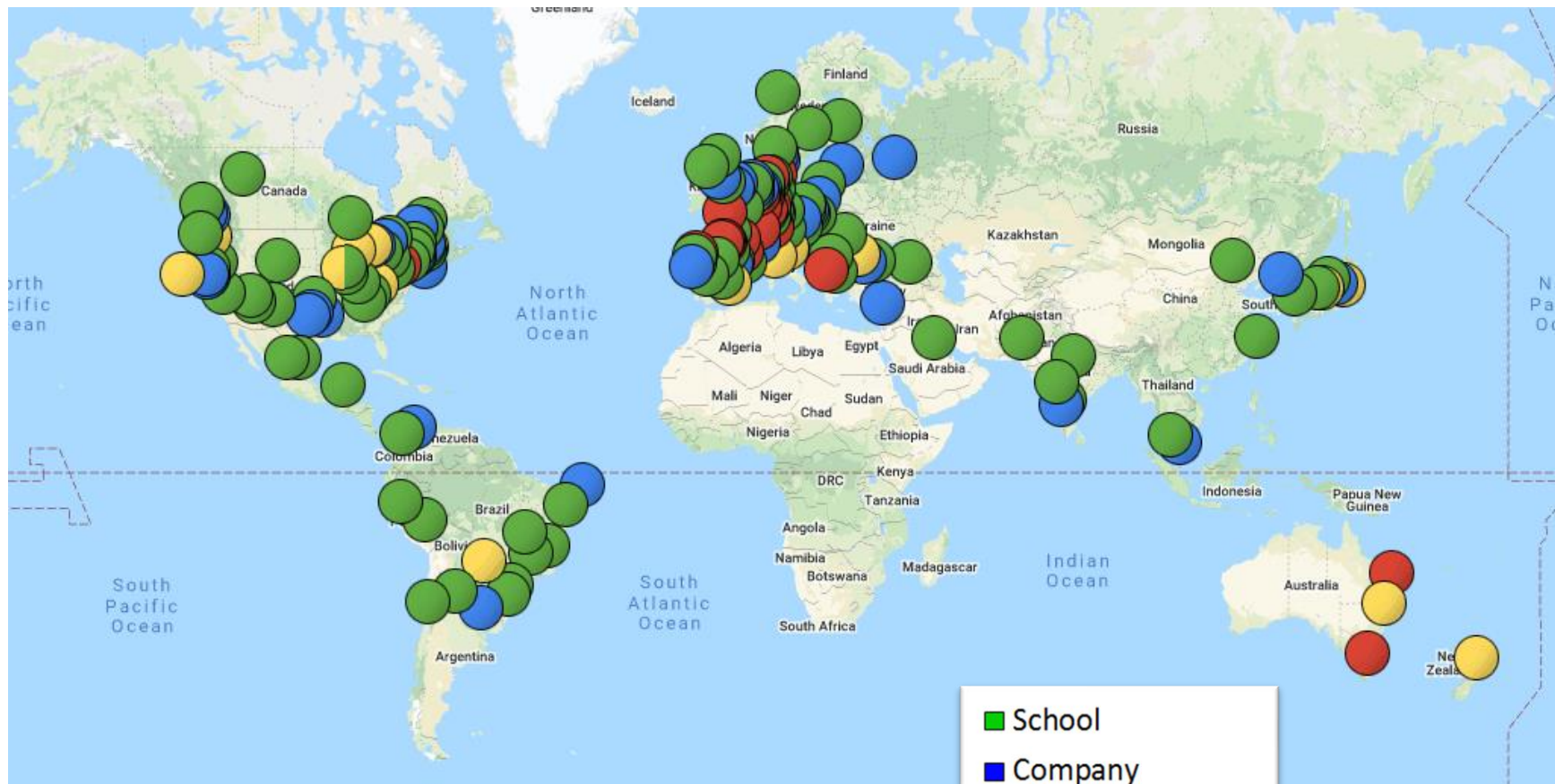


(Adapted from Willow Garage's "What is ROS?" Presentation)





ROS is... an Ecosystem



<http://metrorobots.com/rosmap.html>

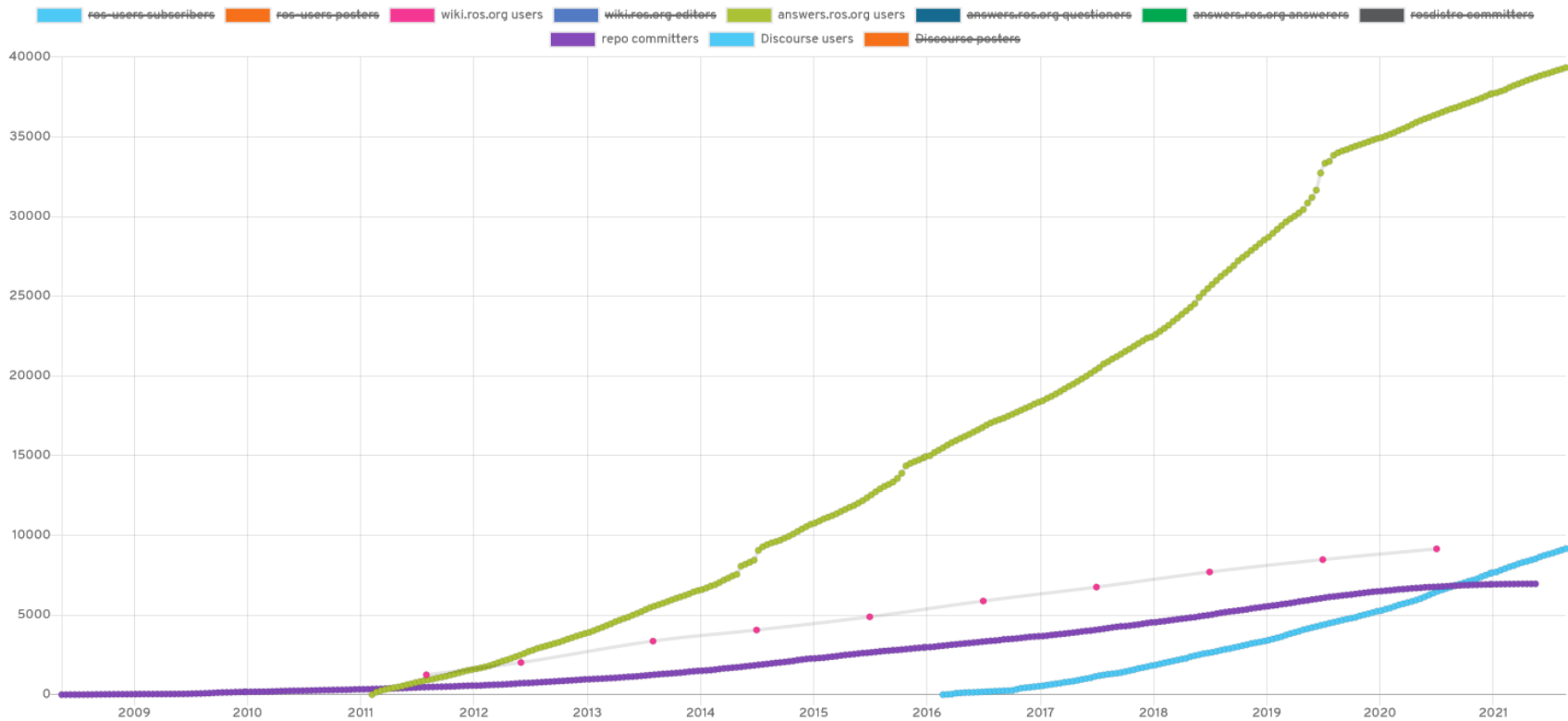




ROS is a growing Ecosystem



Number of ROS Users



A collection of different metrics for measuring the number of users in the ROS community.



<https://metrics.ros.org/>





ROS is International



unique wiki visitors Jul 2020

1.	China	39,080 (19.26%)
2.	United States	31,853 (15.70%)
3.	Japan	16,766 (8.26%)
4.	Germany	14,521 (7.16%)
5.	South Korea	12,583 (6.20%)
6.	India	10,700 (5.27%)
7.	Taiwan	5,904 (2.91%)
8.	United Kingdom	4,150 (2.05%)
9.	France	3,994 (1.97%)
10.	Singapore	3,881 (1.91%)
11.	Canada	3,748 (1.85%)
12.	Italy	3,590 (1.77%)
13.	Hong Kong	3,509 (1.73%)
14.	Spain	2,936 (1.45%)
15.	Russia	2,820 (1.39%)

visitors per million people

1. Singapore: 683
2. Hong Kong: 475
3. Taiwan: 252
4. South Korea: 244
5. Germany: 175
- ...
9. USA: 96

(<http://wiki.ros.org/Metrics> "Community Metrics Report" August 2020)





ROS is a Repository



only includes publicly released code!



(From Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics")



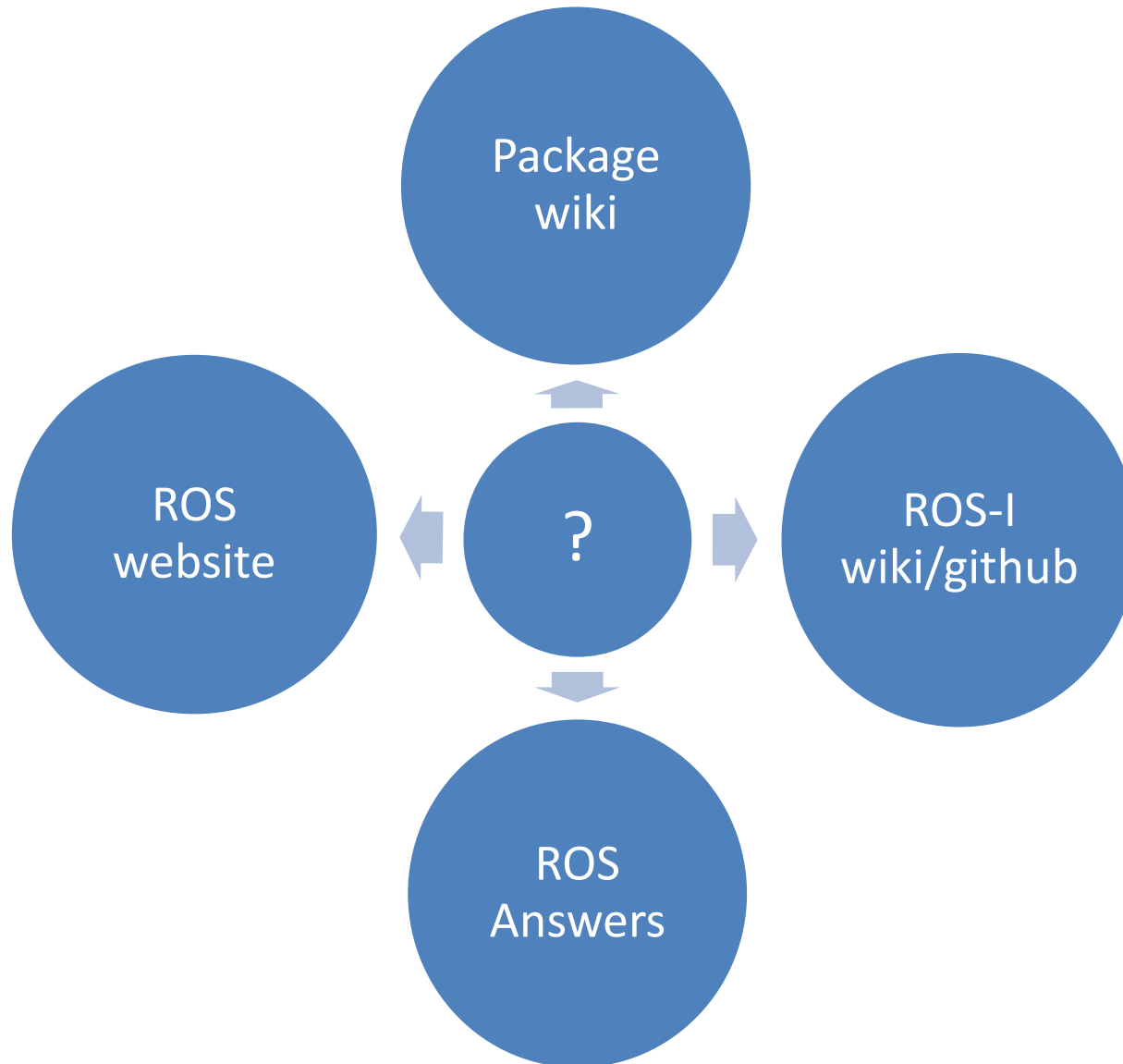


- ROS uses **platform-agnostic** methods for most communication
 - DDS, TCP/IP Sockets, XML, etc.
- Can intermix programming languages
 - Current 1st Tier support: C, C++, Python
 - We will be using C++ for our exercises





ROS Resources





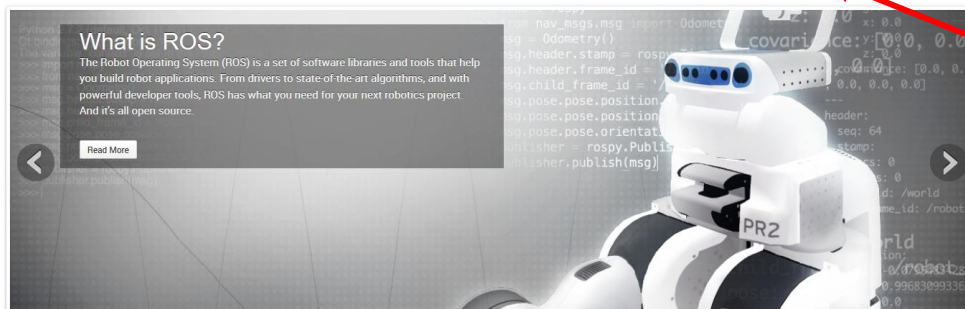
ROS.org Website




<http://ros.org>

ROS


[About](#) [Why ROS?](#) [Getting Started](#) [Get Involved](#) [Blog](#)





ROS Foxy Fitzroy
Foxy Fitzroy is the latest ROS 2 LTS release. It's supported on Ubuntu, Focal, macOS and Windows 10. Get Foxy Fitzroy now!

[Download](#)



ROS Noetic Ninjemys
ROS Noetic Ninjemys is latest ROS 1 LTS Release targeted at the Ubuntu 20.04 (Focal) release, though other systems are supported to varying degrees.

[Download](#)

[Wiki](#)
Find tutorials and learn more

[ROS Answers](#)
Ask questions. Get answers

[Forums](#)
Hear the latest discussions

ROS1
but still relevant

- Install Instructions
- ROS Answers
- Forums (Discourse)





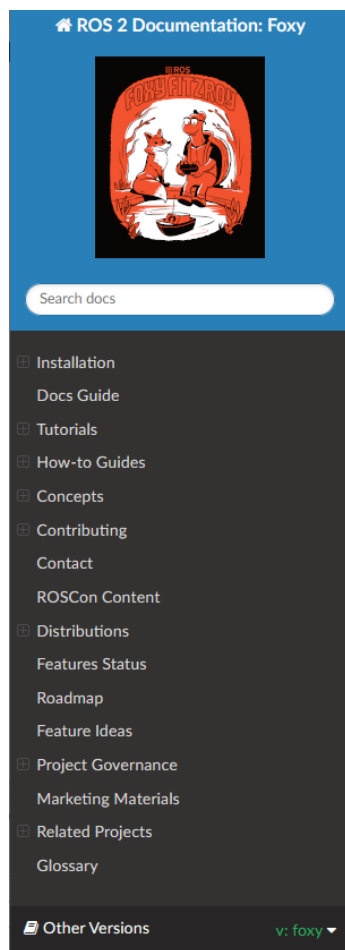
ROS2 Documentation



<http://docs.ros.org>

- Install
- Tutorials
- Concepts

...



» ROS 2 Documentation

[Edit on GitHub](#)

You're reading the documentation for an older, but still supported, version of ROS 2. For information on the latest version, please have a look at [Galactic](#).

ROS 2 Documentation

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.

Since ROS was started in 2007, a lot has changed in the robotics and ROS community. The goal of the ROS 2 project is to adapt to these changes, leveraging what is great about ROS 1 and improving what isn't.

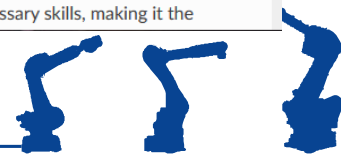
Here you will find the official documentation on **ROS 2**, the newest version of ROS.

If you're looking for documentation on ROS 1 (i.e., ROS as it has existed for several years, and what you might be using right now), check the [ROS wiki](#).

Where to start

Newcomers and experienced ROS users should consult this overview of our user-centric content to find what they're looking for.

- [Installation](#) pages will help you setup ROS 2 for the first time. You can choose your platform as well as the installation type and distribution that suits your needs.
- The [Docs Guide](#) explains the ROS 1 and ROS 2 documentation infrastructure. It is helpful in understanding where specific resources live, how to ask questions, and which sites are maintained.
- [Tutorials](#) walk you through small projects and sample usage of ROS 2, so you can learn the ropes by actually using the tools. They are organized by progression of necessary skills, making it the





ROS Package Index



<http://index.ros.org>

ROS Index index

ABOUT INDEX DOC CONTRIBUTE STATS Search ROS

Home > ROS 2 Overview

Index

ROS 2 Overview

ROS 2 Documentation

[EDIT ON GITHUB](#)

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.

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- [Tutorials](#) walk you through learning ROS 2, whether you're learning from scratch or looking for

FOXY ELOQUENT DASHING NOETIC MELODIC

rclcpp package from rclcpp repo

[rclcpp](#) [rclcpp_action](#) [rclcpp_components](#) [rclcpp_lifecycle](#)

GITHUB-RS2-RCLCPP

Overview 0 Assets 20 Dependencies 0 Tutorials

Package Summary

Tags No category tags.

Version 0.8.4

License Apache License 2.0

Build type [AMENT_CMAKE](#)

Use [RECOMMENDED](#)

Repository Summary

Checkout URI <https://github.com/ros2/rclcpp.git>

VCS Type [git](#)

VCS Version [eloquent](#)

Last Updated [2020-06-26](#)

Dev Status [MAINTAINED](#)

CI status [No Continuous Integration](#)

Package Description

The ROS client library in C++.

Additional Links

No additional links.

Maintainers

Dirk Thomas

Authors

No additional authors.

- Install Instructions
- Tutorials
- Package Info
- Still NEW – see ROS1 Wiki





Package Wiki



<http://wiki.ros.org/<packageName>>

tf

electric fuerte groovy hydro **indigo** jade Documentation Status

[geometry](#): [angles](#) | [eigen_conversions](#) | [kdl_conversions](#) | [tf](#) | [tf_conversions](#)

Package Summary

✓ Released ✓ Continuous integration ✓ Documented

tf is a package that lets the user keep track of multiple coordinate frames over time. tf maintains the relationship between coordinate frames in a tree structure buffered in time, and lets the user transform points, vectors, etc between any two coordinate frames at any desired point in time.

- Maintainer status: maintained
- Maintainer: Tully Foote <tfoote AT osrfoundation DOT org>
- Author: Tully Foote, Eitan Marder-Eppstein, Wim Meeussen
- License: BSD
- Source: git <https://github.com/ros/geometry.git> (branch: indigo-devel)

Contents

1. What does tf do? Why should I use tf?
2. Paper
3. Tutorials
4. Code API Overview
5. Frequently asked questions
6. Command Line Tools

Package Links

[Code API](#)
[Msg/Srv API](#)
[Tutorials](#)
[Troubleshooting](#)
[FAQ](#)
[Changelog](#)
[Change List](#)
[Roadmap](#)
[Reviews](#)

Dependencies (15)
Used by (275)
Jenkins jobs (7)

7.2 change_notifier

change_notifier listens to /tf and periodically republishes any transforms that have changed by a give /tf_changes topic.

7.2.1 Subscribed Topics

/tf (tf/tfMessage)
Transform tree.

7.2.2 Published Topics

/tf_changes (tf/tfMessage)
Reduced transform tree.

7.2.3 Parameters

~polling_frequency (float, default: 10.0)

Frequency (hz) at which to check for any changes to the transform tree.

~translational_update_distance (float, default: 0.1)

Minimum distance between the origin of two frames for the transform to be considered changed.

~angular_update_distance (float, default: 0.1)

Minimum angle between the rotation of two frames for the transform to be considered changed.

- Description / Usage
- Tutorials
- Code / Msg API
- Source-Code Link
- Bug Reporting

“ROS1 Only”

But still relevant for most packages





ROS Answers



<http://answers.ros.org>

The screenshot shows the ROS Answers homepage. At the top, there's a search bar and navigation links. Below the search bar, a list of questions is displayed, each with a title, tags, and statistics (votes, answers, views). The questions include:

- How to save static transforms in bag files?
- pcl 1.72 Installation question
- freenect_launch with Kinect
- Problem using serial write
- schunk_svh_driver : Can't locate node svh_controller in package schunk_svh_driver
- Broken url in tutorial

On the right side, there's a 'Contributors' section showing a grid of user avatars and a 'Tag search' section with a search bar and a list of tags.

The screenshot shows a specific question page on ROS Answers. The question is titled 'How can I use Motoman stack with ROS Indigo?'. It has 1 answer and 1 follower. The answer is provided by user 'gvdhoorn' and includes a detailed explanation and code snippets for building the Motoman ROS nodes. The code snippets are:

```
cd ~/path/to/your/catkin_ws/src
# checkout the desired version of the motoman repository.
# if you'd rather use the development versions, use '-b hydro-devel' or '-b indigo-devel'.
git clone -b hydro https://github.com/ros-industrial/motoman.git
# we need to make sure you have all dependencies installed.
# this step should install 'industrial_robot_client' for you
cd ..
roscpp install --from-paths src --ignore-src --no-deps indigo
# now build
catkin_make
```

The answer concludes with: 'This should successfully build the Motoman ROS nodes. You'll still have to set up your controller, but those steps are identical to the Hydro version (see motoman_driver/Tutorials on the ROS wiki)'.

- Quick responses to Good Questions
- Search by text or tag
- Don't re-invent the wheel!





ROS is a Community



- No Central “Authority” for Help/Support
 - Many users can provide better (?) support
 - ROS-I Consortium can help fill that need
- Most ROS-code is open-source
 - can be reviewed / improved by everyone
 - we count on **YOU** to help ROS grow!





What is ROS to you?



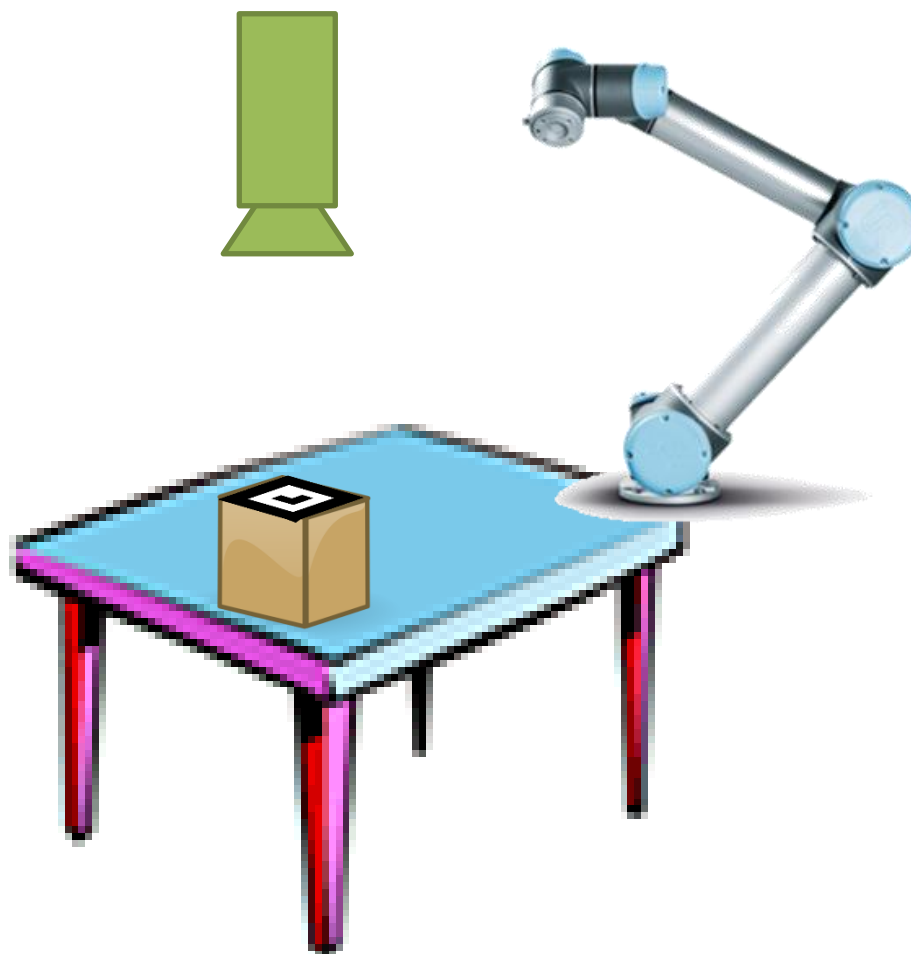
Training Goals:

- Show you ROS as a software framework
- Show you ROS as a tool for problem solving
- Apply course concepts to a sample application
- Ask lots of questions and break things.



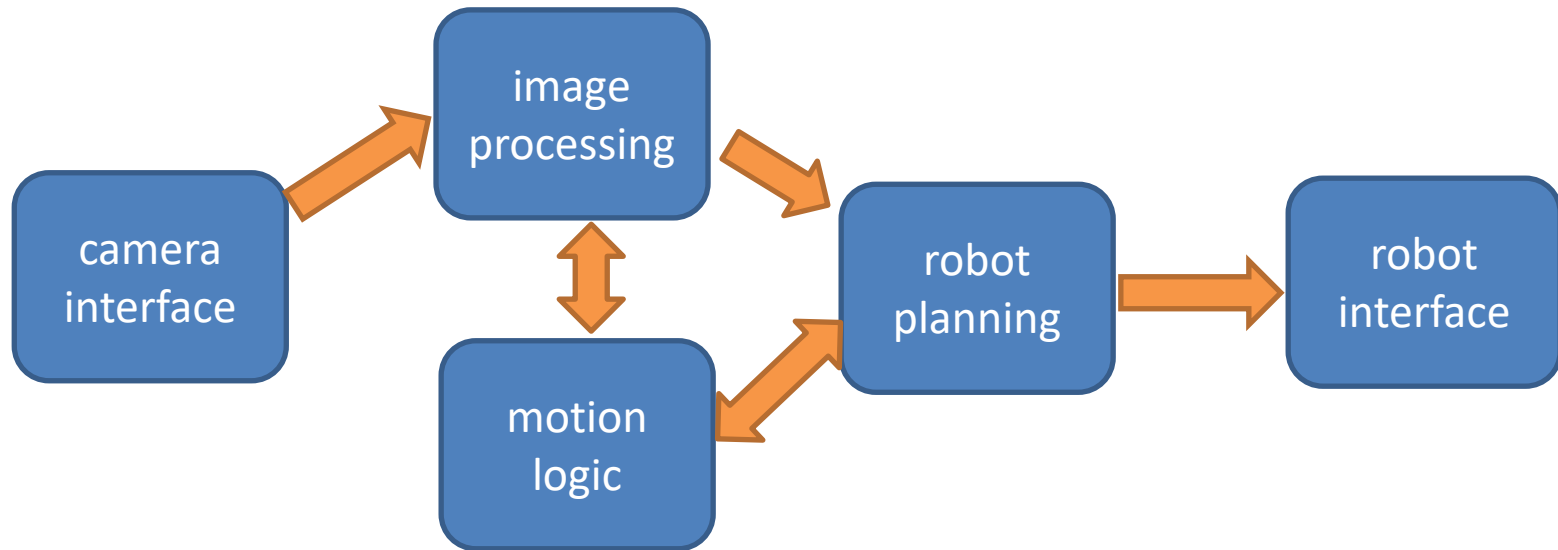


Scan & Plan “Application”





ROS Architecture: Nodes

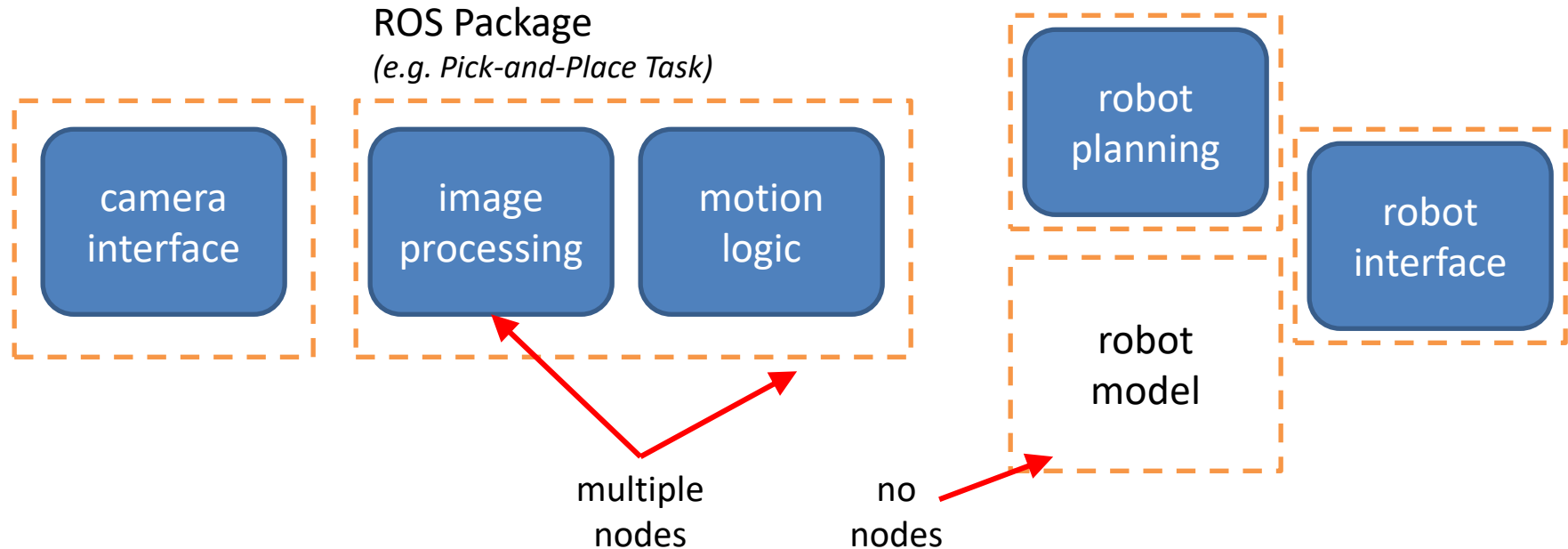


- A **Node** is a *standalone* piece of functionality
 - Most communication happens **between** nodes
 - Nodes can run on many different **devices**
 - Often one node per process, but not always





ROS Architecture: Packages

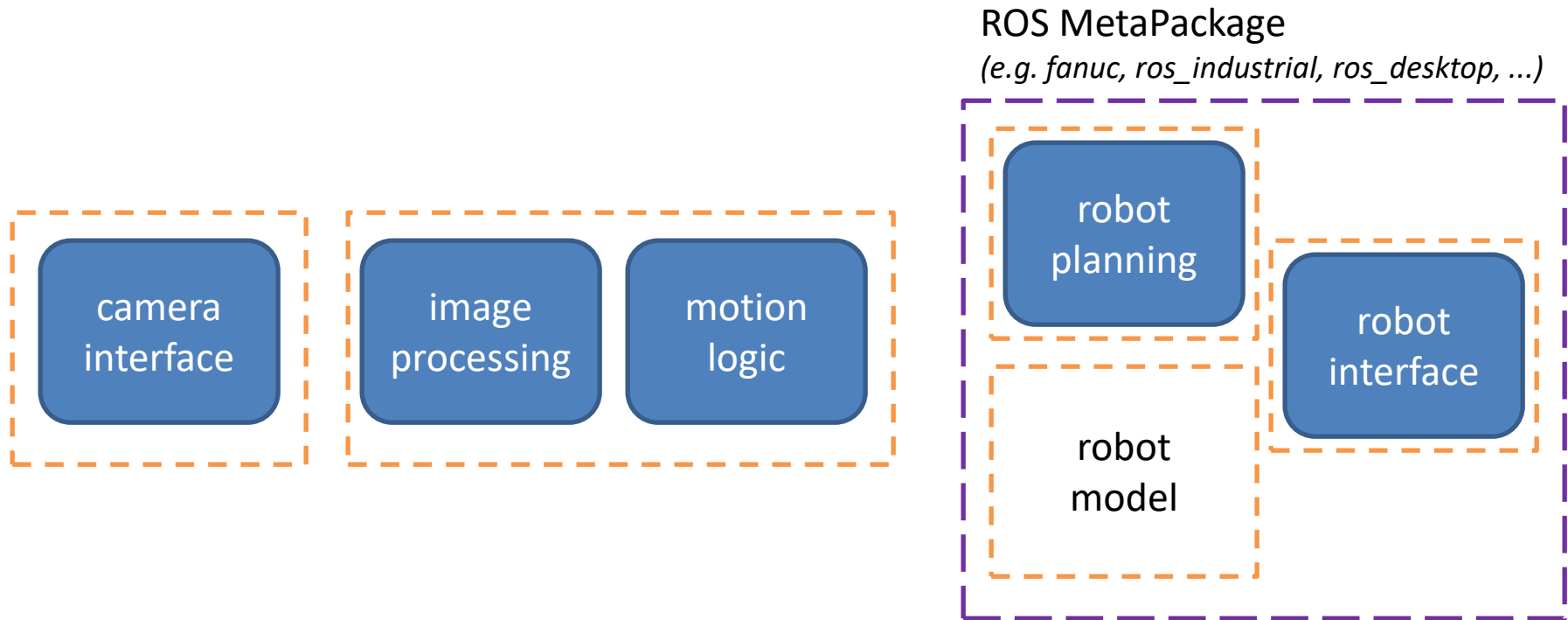


- **ROS Packages** are groups of related nodes/data
 - Files grouped in a single **directory**, with key **metafiles**
 - Many ROS commands are **package-oriented**





ROS Architecture: MetaPkg



- Some “**MetaPackages**” don’t have any content
 - Only dependency references to other packages
 - Mostly for convenient install/deployment

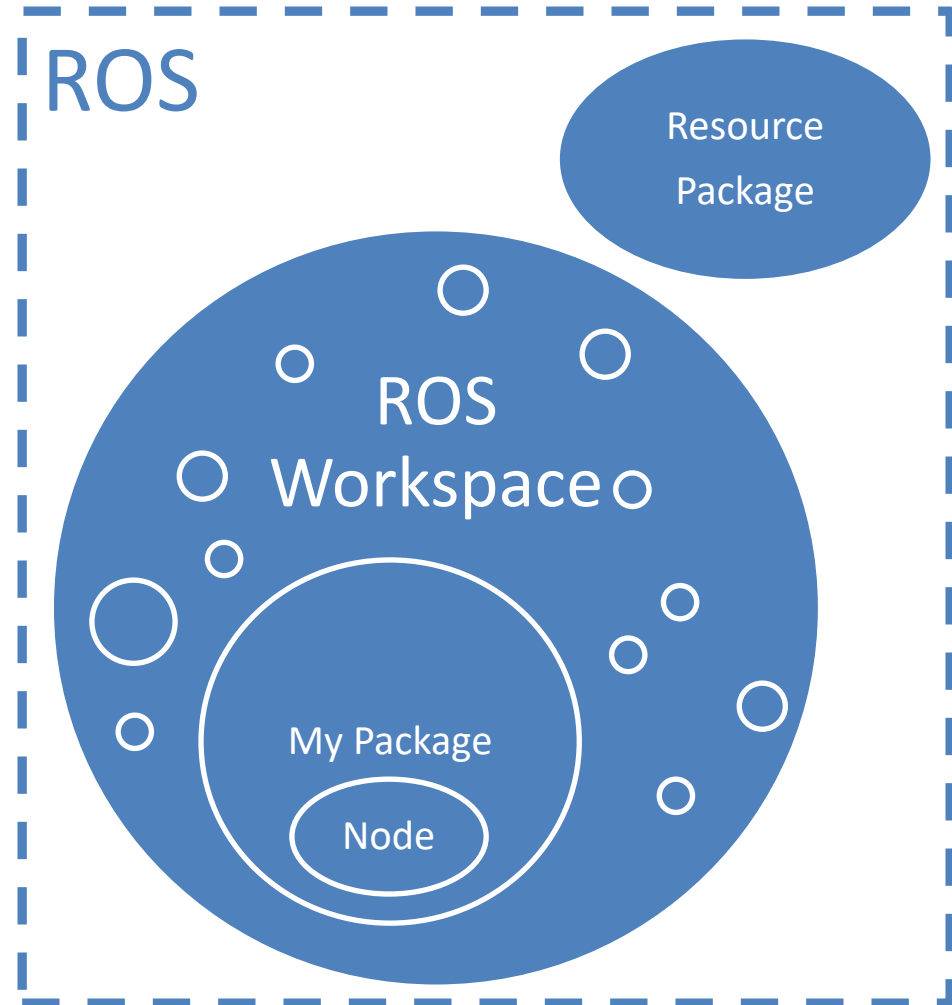




Day 1 Progression



- ☐ Install ROS
- ☐ Create Workspace
- ☐ Add “resources”
- ☐ Create Package
- ☐ Create Node
 - ☐ Basic ROS Node
 - ☐ Interact with other nodes
 - ☐ Messages
 - ☐ Services
- ☐ Run Node
 - ☐ `ros2 run`
 - ☐ `ros2 launch`





Installing ROS





Getting ROS2



<https://index.ros.org/doc/ros2/Installation/Foxy/>



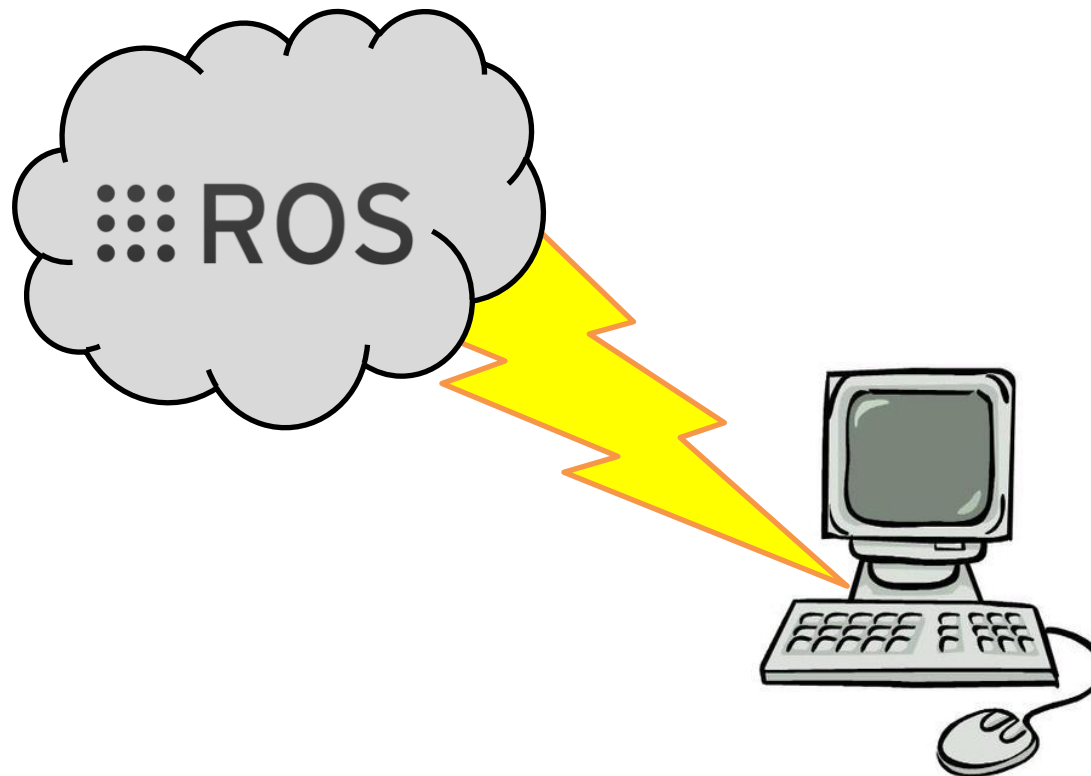


Exercise 1.0



Exercise 1.0

Basic ROS Install/Setup





Day 1 Progression



✓ Install ROS (check install)

☐ Create Workspace

☐ Add “resources”

☐ Create Package

☐ Create Node

☐ Basic ROS Node

☐ Interact with other nodes

☐ Messages

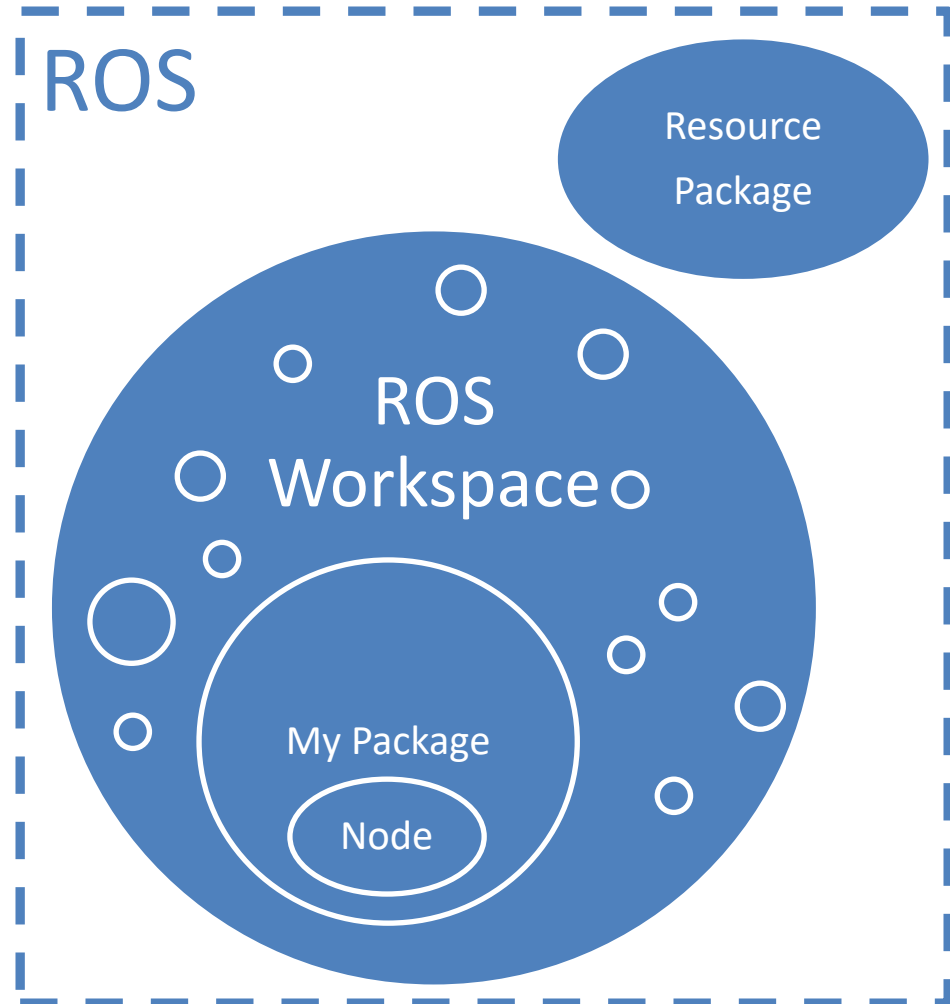
☐ Services

☐ Run Node

☐ `ros2 run`

☐ `ros2 launch`

ROS





Creating a ROS Workspace

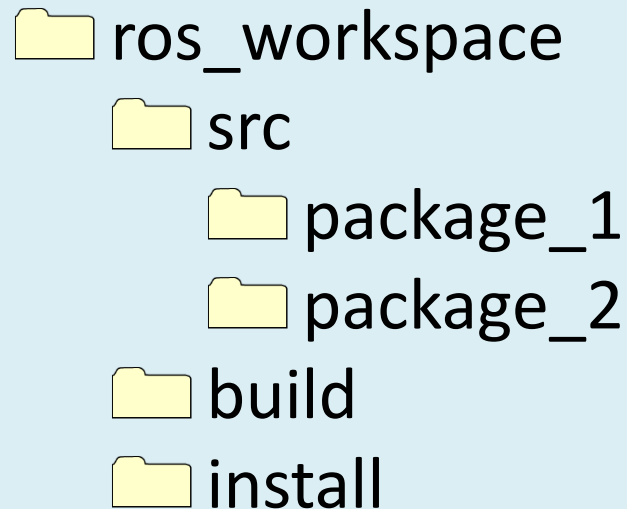




ROS Workspace



- ROS uses a specific directory structure:
 - each “project” typically gets its own **workspace**
 - all packages/source files go in the **src** directory
 - temporary build-files are created in **build**
 - results are placed in **install**





Build System



- ROS2 uses the **ament** build system
 - based on CMake
 - cross-platform (Ubuntu, Windows, embedded...)
 - simplifies depending on packages and exporting outputs to other packages





Build System



- ROS2 also uses the **colcon** build tool
 - Pure Python framework
 - Generates the workspace outputs:
 - Finds all packages in the src directory
 - Defines the build order based on dependencies
 - Invokes the build system for each package
 - CMake/Ament for C++ packages
 - Setuptools for pure Python packages
 - Can build ROS1 packages
 - but some packages may prefer to be built with the ROS1-legacy “catkin” build tools.





Colcon Build Process



Setup (one-time)

1. Create a workspace (arbitrary name and location)
 - `ros_ws`
 - `src` sub-directory must be created manually
 - `build`, `install` directories created automatically
2. Download/create **packages** in `src` subdir

Compile-Time

1. Run `colcon build` from the workspace root
2. Run `source install/setup.bash` to make this workspace visible to ROS





Colcon Build Notes



Colcon Build

- Always run from the workspace root
- Source workspaces of any dependencies before running build.
 - e.g. `source /opt/ros/foxy/setup.bash`
- Can chain multiple workspaces together:
 - `base foxy -> pcl_ws -> my_ws`
- Don't run from a terminal where you have "sourced" this workspace's setup file (can cause circular issues).
- Best Practice: Use a dedicated terminal window for building.
 - Don't do anything in that terminal window other than colcon build.

Source install/setup.bash

- Remember to source this setup file in EACH new terminal
- No need to also source the underlays' setup files
- May need to re-source after adding new packages
- Can add to `~/.bashrc` to automate this step
 - not recommended if using multiple ROS distros or working on multiple projects in parallel

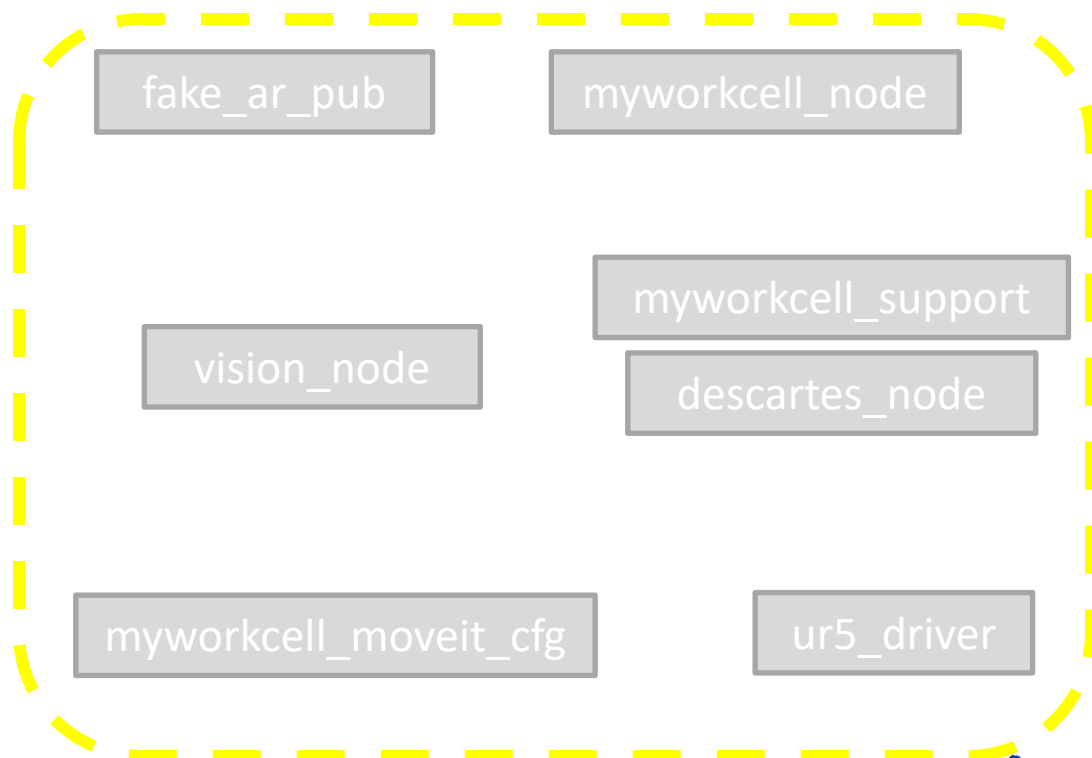
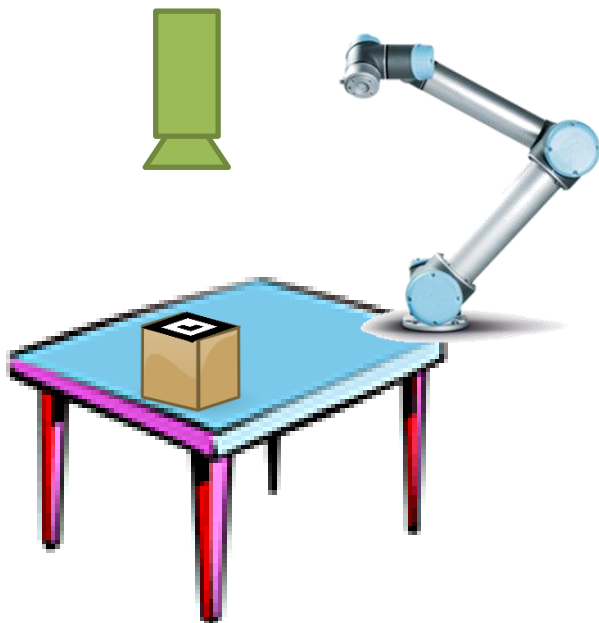




Exercise 1.1

Exercise 1.1

Create a ROS Workspace

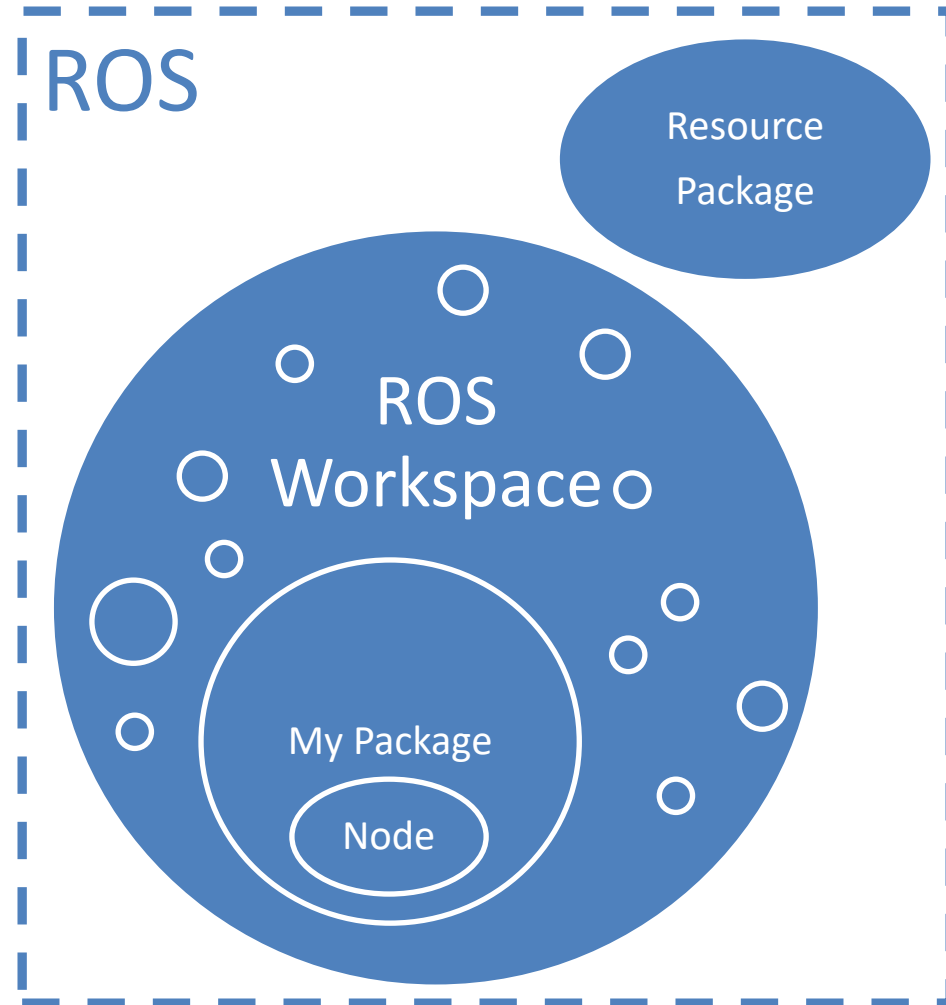




Day 1 Progression



- ✓ Install ROS
- ✓ Create Workspace
- ☐ Add “resources”
- ☐ Create Package
- ☐ Create Node
 - ☐ Basic ROS Node
 - ☐ Interact with other nodes
 - ☐ Messages
 - ☐ Services
- ☐ Run Node
 - ☐ `ros2 run`
 - ☐ `ros2 launch`





Add 3rd-Party Packages (a.k.a. “Resource” Packages)





Install options



Debian Packages

- Nearly “automatic”
- Recommended for end-users
- Stable
- Easy

Source Repositories

- Access “latest” code
- Most at Github.com
- More effort to setup
- Unstable*

Can mix both options, as needed





Finding the Right Package



- ROS Website (<http://index.ros.org>)
 - Search for known packages
- ROS Answers (<http://answers.ros.org>)
 - When in doubt... ask someone!





Install using Debian Packages



```
sudo apt install ros-foxy-package
```

↑ ↑ ↑ ↑ ↑ ↑

admin manage install all ROS pkgs ROS ROS package
permissions ".deb" new ".deb" start with `ros-` distribution name

Use "-" not "_"

- Fully automatic install:
 - Download .deb package from central ROS repository
 - Copies files to standard locations (`/opt/ros/foxy/...`)
 - Also installs any other required dependencies
- `sudo apt-get remove ros-<distro>-<package>`
 - Removes software (but not dependencies!)





Installing from Source



- Find GitHub repo
- Clone repo into your workspace src directory

```
cd ros_ws/src  
git clone http://github.com/user/repo.git
```

- Build your catkin workspace

```
cd ros_ws  
colcon build
```

- Now the package and its resources are available to you

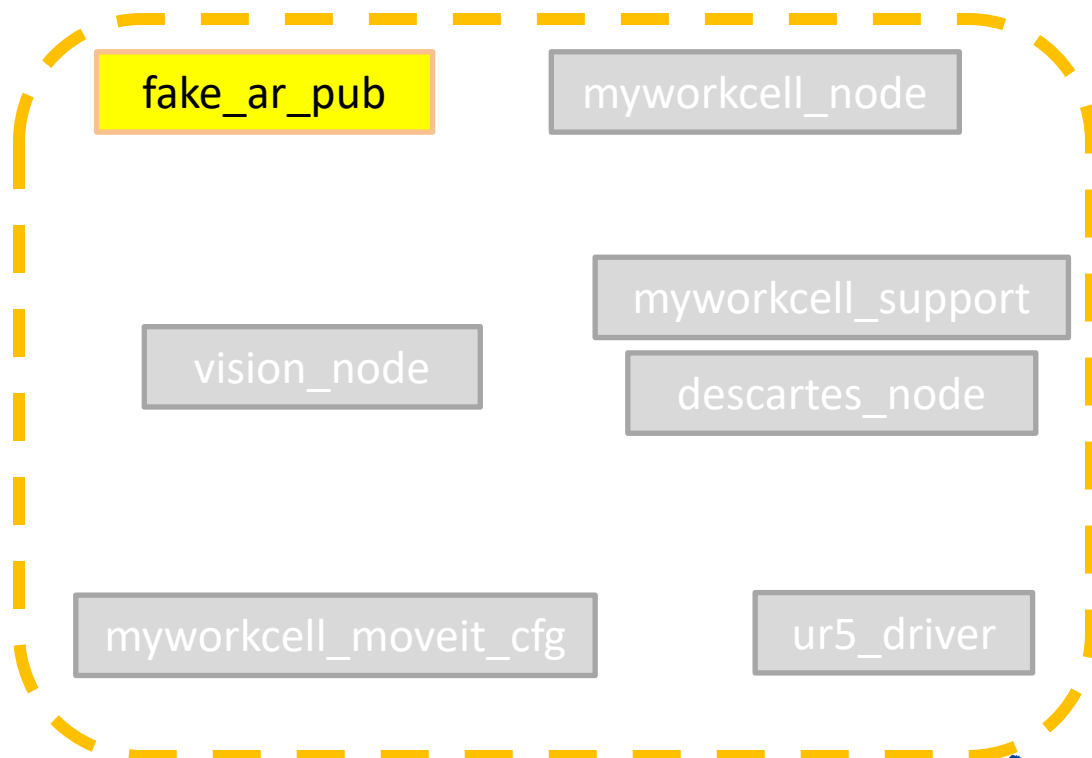
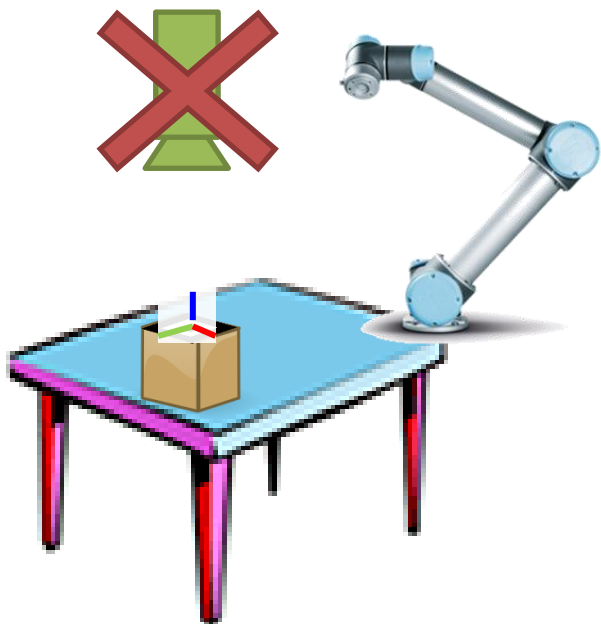




Exercise 1.2

Exercise 1.2

Install “resource” packages

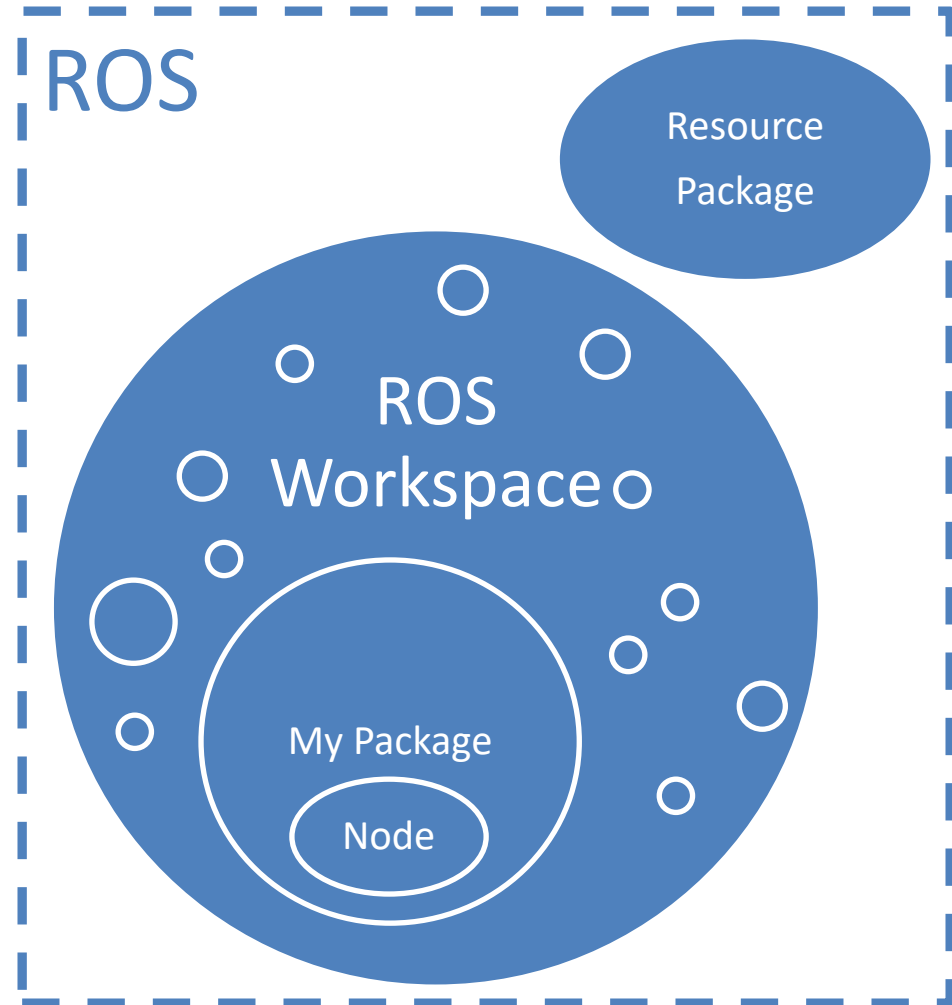




Day 1 Progression



- ✓ Install ROS
- ✓ Create Workspace
- ✓ Add “resources”
- ☐ Create Package
- ☐ Create Node
 - ☐ Basic ROS Node
 - ☐ Interact with other nodes
 - ☐ Messages
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 - ☐ `ros2 run`
 - ☐ `ros2 launch`





ROS Packages

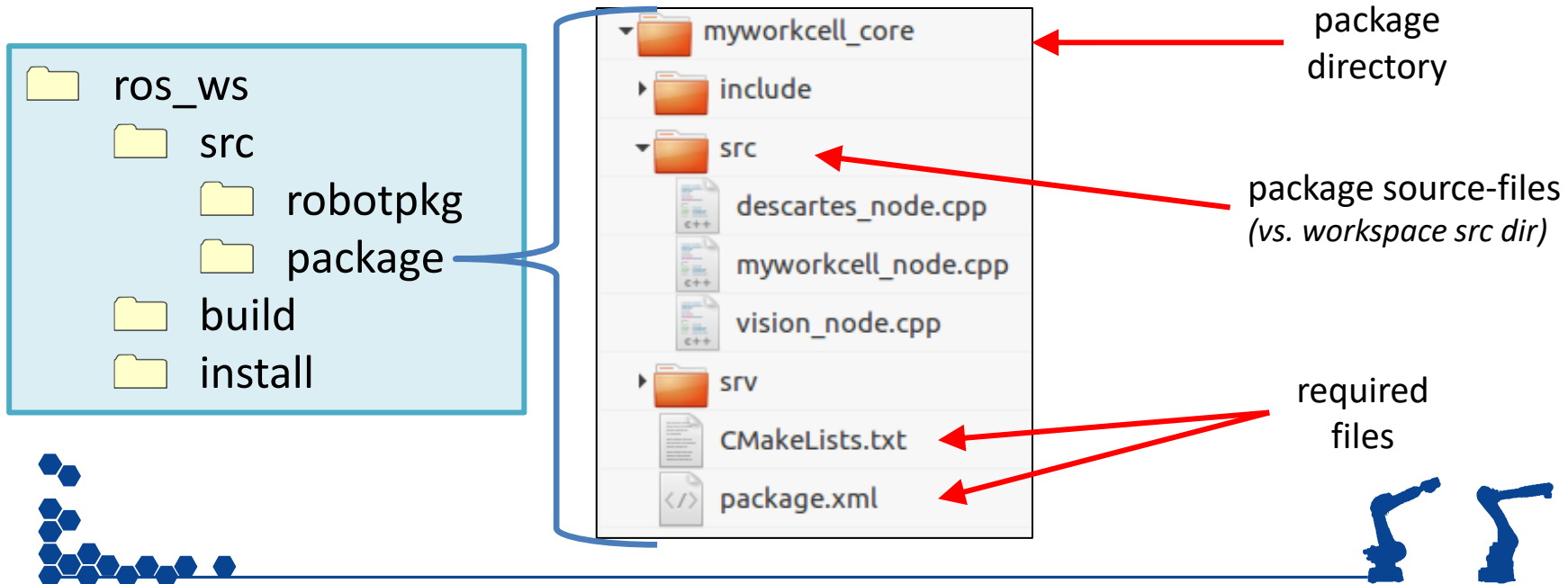




ROS Package Contents



- ROS components are organized into **packages**
- Packages contain several **required files**:
 - `package.xml`
 - **metadata** for ROS: package name, description, dependencies, ...
 - `CMakeLists.txt`
 - **build rules** for catkin





package.xml



- Metadata: name, description, author, license ...

```
<?xml version="1.0"?>
<package format="2">
  <name>myworkcell_core</name>
  <version>0.0.0</version>
  <description>The myworkcell_core package</description>

  <!-- One maintainer tag required, multiple allowed, one person per tag -->
  <!-- Example: -->
  <!-- <maintainer email="jane.doe@example.com">Jane Doe</maintainer> -->
  <maintainer email="ros-industrial@todo.todo">ros-industrial</maintainer>

  <!-- One license tag required, multiple allowed, one license per tag -->
  <!-- Commonly used license strings: -->
  <!--   BSD, MIT, Boost Software License, GPLv2, GPLv3, LGPLv2.1, LGPLv3 -->
  <license>TODO</license>

  <!-- Url tags are optional, but multiple are allowed, one per tag -->
  <!-- Optional attribute type can be: website, bugtracker, or repository -->
  <!-- Example: -->
  <!-- <url type="website">http://wiki.ros.org/myworkcell_core</url> -->

  <!-- Author tags are optional, multiple are allowed, one per tag -->
  <!-- Authors do not have to be maintainers, but could be -->
  <!-- Example: -->
  <!-- <author email="jane.doe@example.com">Jane Doe</author> -->

  <buildtool_depend>catkin</buildtool_depend>
  <build_depend>message_generation</build_depend>
  <exec_depend>message_runtime</exec_depend>
  <depend>roscpp</depend>
  <depend>geometry_msgs</depend>
</package>
```





- Metadata: name, description, author, license ...
- Dependencies:
 - Common
 - `<buildtool_depend>`: Needed to **build** itself. (Typically ***ament_cmake***)
 - `<build_depend>`: Needed to **build** this package.
 - `<exec_depend>`: Needed to **run** code in this package.
 - `<depend>`: Needed to **build**, **export**, and **execution** dependency.
 - Uncommon
 - `<build_export_depend>`: Needed to **build against** this package.
 - `<test_depend>`: Only ***additional*** dependencies for unit tests.
 - `<doc_depend>`: Needed to generate documentation.





- Provides **rules** for **building software**
 - template file contains many examples

```
add_executable(myNode src/myNode.cpp src/widget.cpp)
```

Builds program `myNode`, from `myNode.cpp` and `widget.cpp`

```
ament_target_dependencies(myNode rclcpp std_msgs)
```

Links node `myNode` to dependency headers and libraries

```
install(TARGETS myNode DESTINATION lib/${PROJECT_NAME})
```

Copies nodes/libraries to workspace's "install" directory





- **ros2 pkg**

- `ros2 pkg create package_name`

- Create a new package, including template files*

- Common options (not required, but will help pre-fill templates):*

- `--build-type ament_cmake`

- `--node-name my_node`

- `--dependencies dep_pkg_1 dep_pkg_2`

- `ros2 pkg prefix package_name`

- Show directory where `package_name` is installed*

- `ros2 pkg list`

- List all ros packages installed (this is a BIG LIST!)*

- `ros2 pkg xml package_name`

- Show the `package.xml` file of `package_name`*





Create New Package



```
ros2 pkg create mypkg --node-name mynode  
--dependencies dep1 dep2
```

Easiest way to start a new package

- create directory, required template files
- `mypkg` : name of package to be created
- `mynode` : name of node (main executable)
- `dep1/2` : dependency package names
 - automatically added to `CMakeLists` and `package.xml`
 - can manually add additional dependencies later

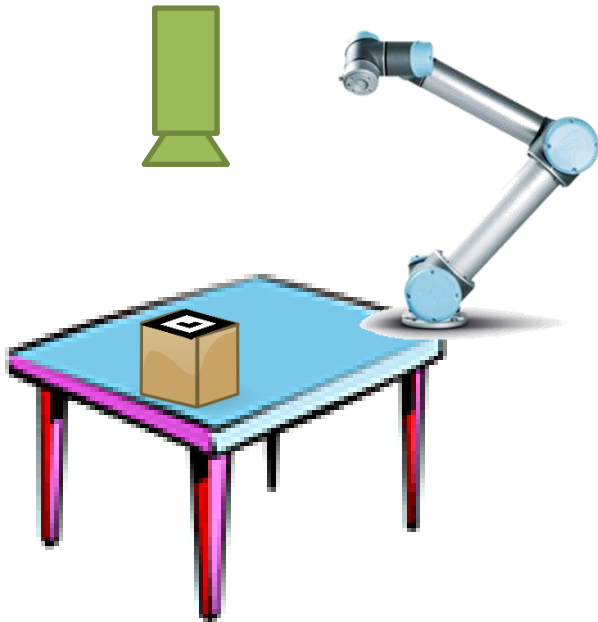




Exercise 1.3.1

Exercise 1.3.1

Create Package

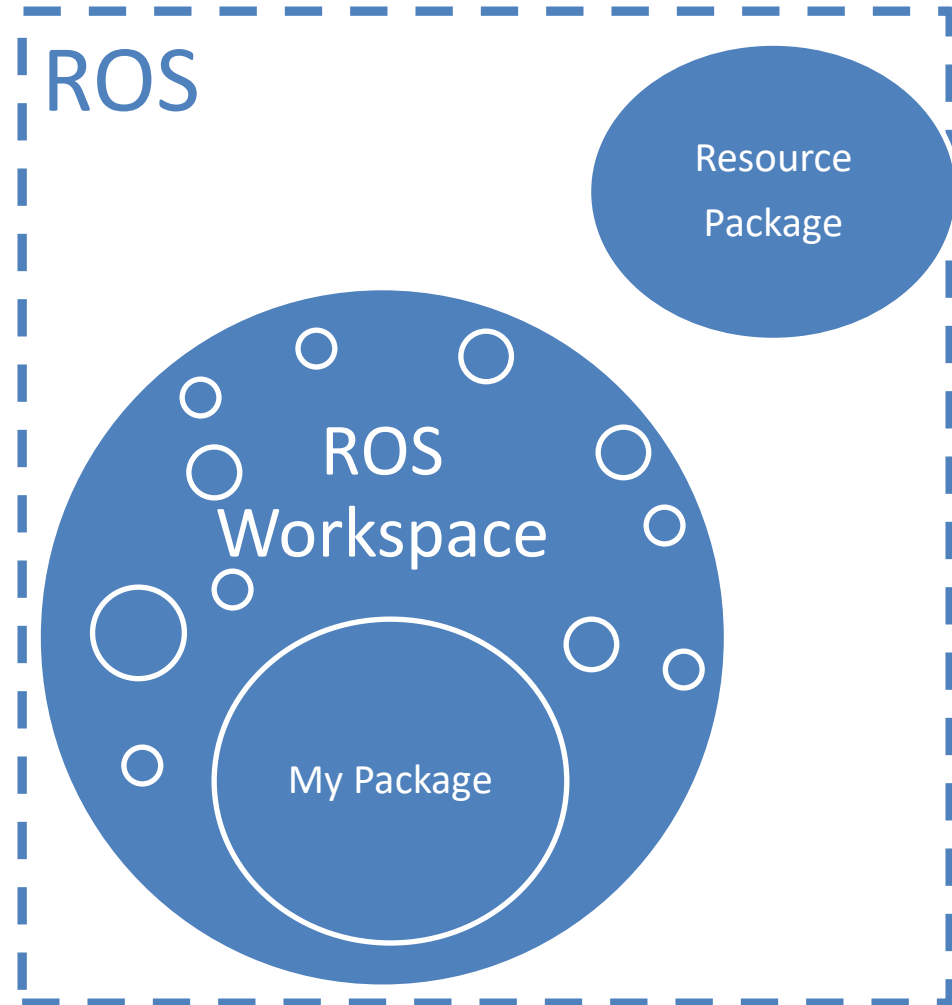




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ROS Nodes





A Simple C++ ROS Node



Simple C++ Program

```
#include <iostream>

int main(int argc, char* argv[])
{

    std::cout << "Hello World!";

    return 0;
}
```

Simple C++ ROS2 Node

```
#include <rclcpp/rclcpp.h>

int main(int argc, char* argv[])
{
    rclcpp::init(argc, argv);
    auto node = make_shared<rclcpp::Node>("hello");

    RCLCPP_INFO(node->get_logger(), "Hello World!");

    return 0;
}
```





ROS2 Node Commands

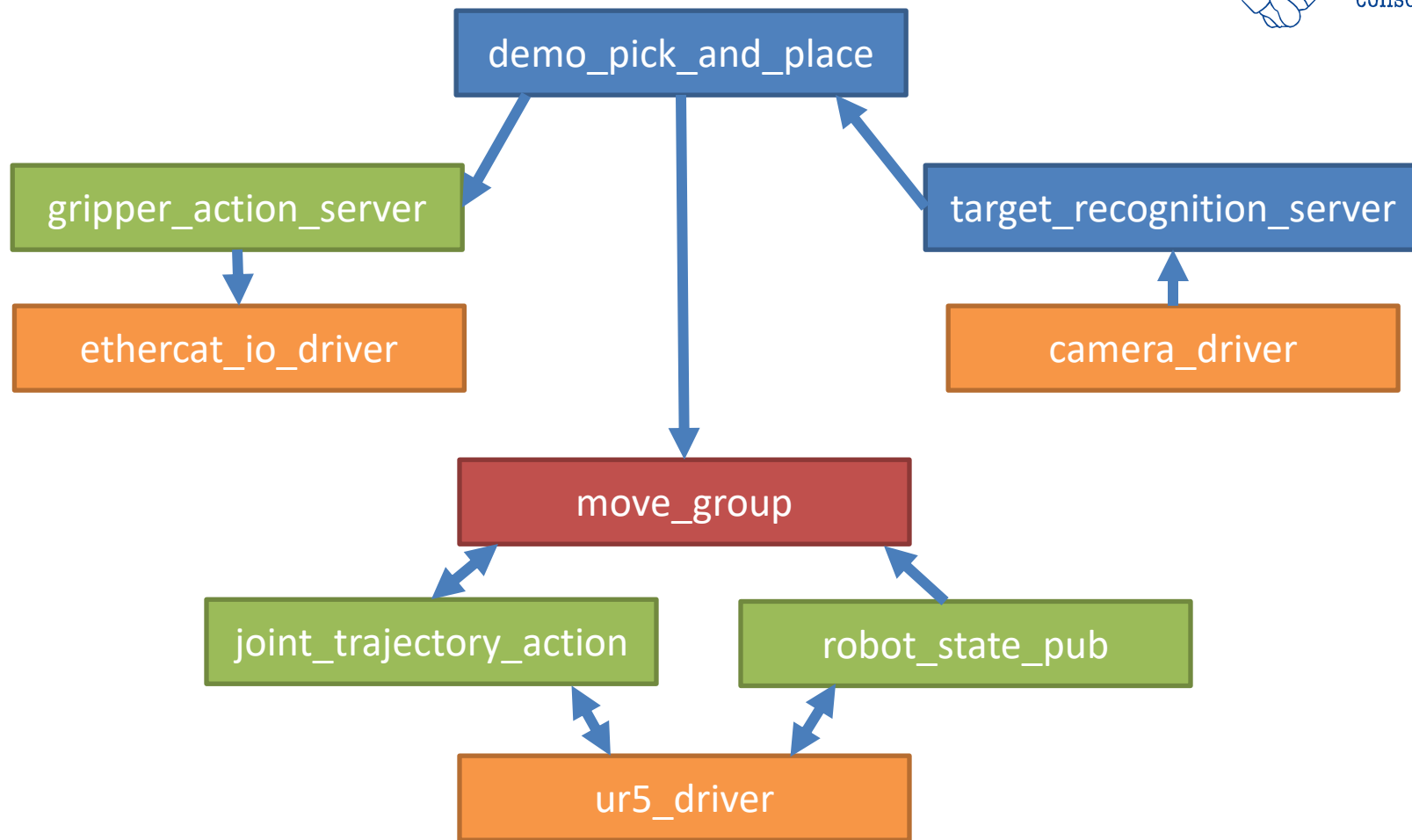


- `ros2 run package_name node_name`
execute ROS node
- **ros2 node**
 - `ros2 node list`
View running nodes
 - `ros2 node info node_name`
View node details (publishers, subscribers, services, etc.)





“Real World” – Nodes



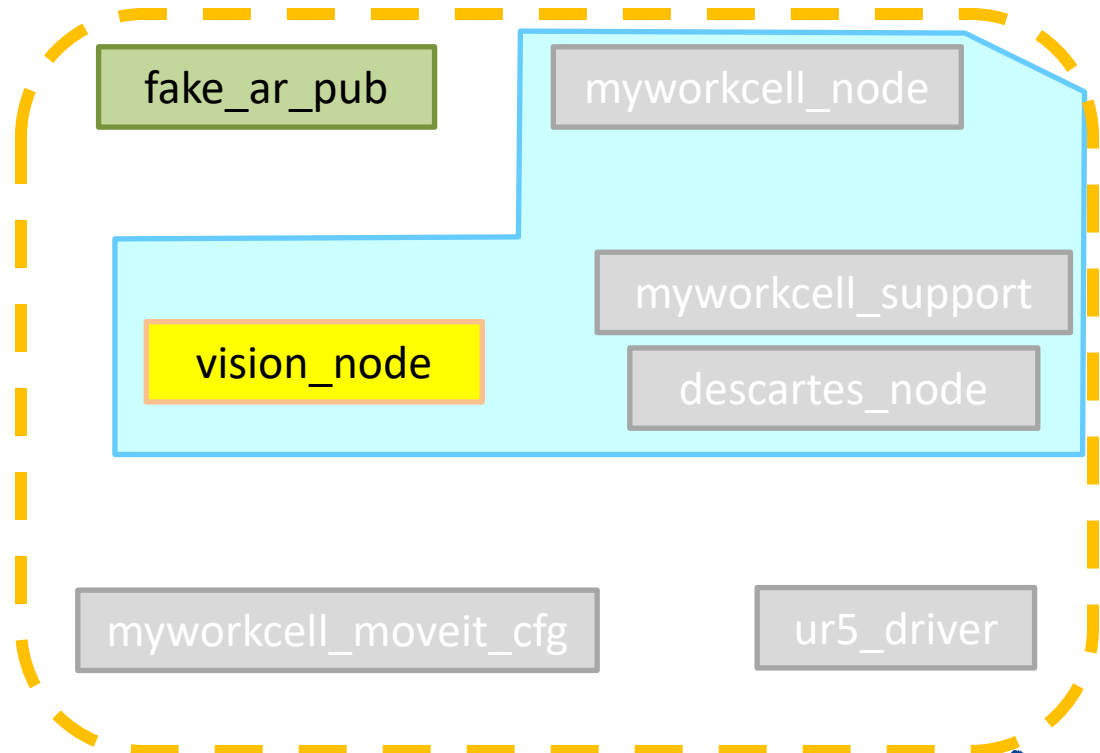
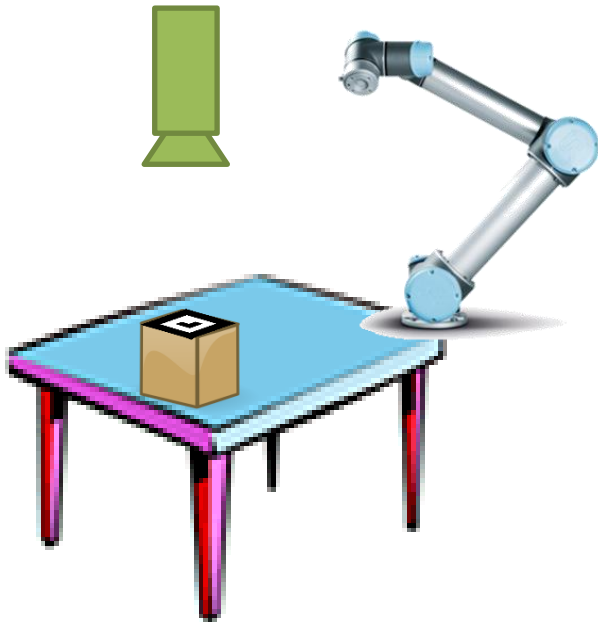


Exercise 1.3.2

Exercise 1.3.2

Create a Node:

*In myworkcell_core package
called vision_node*

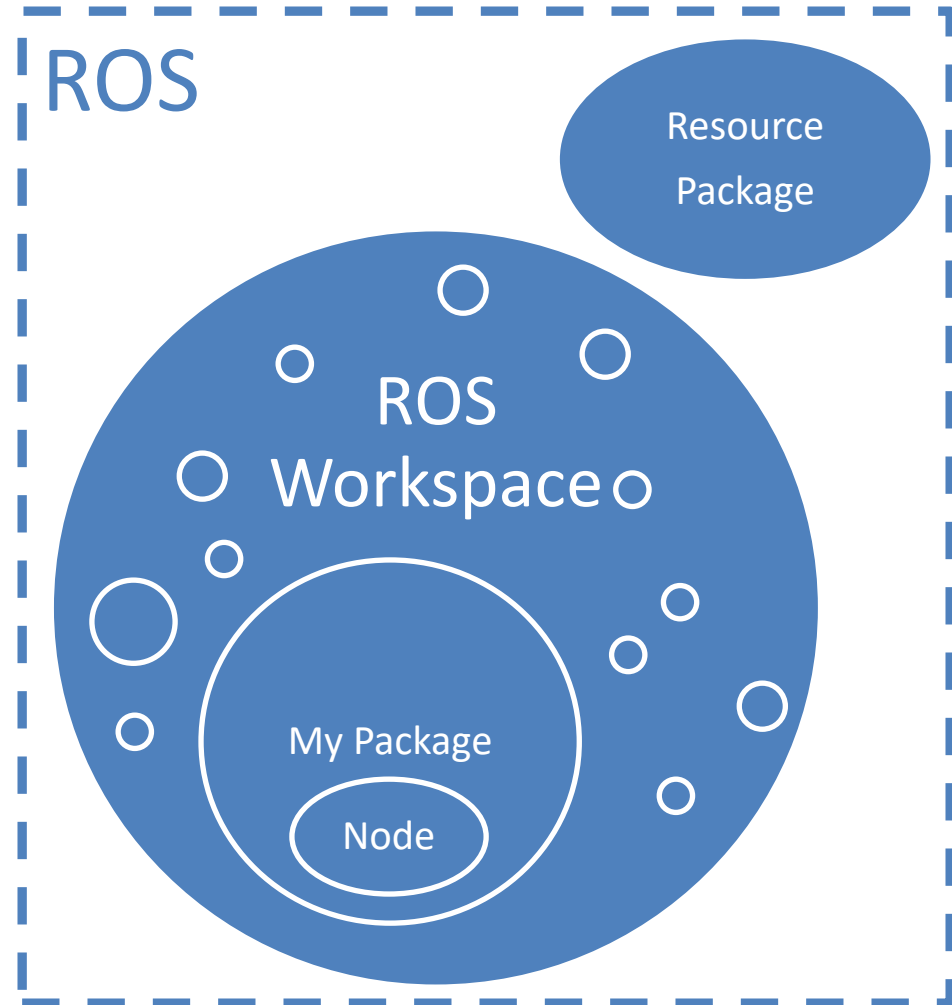




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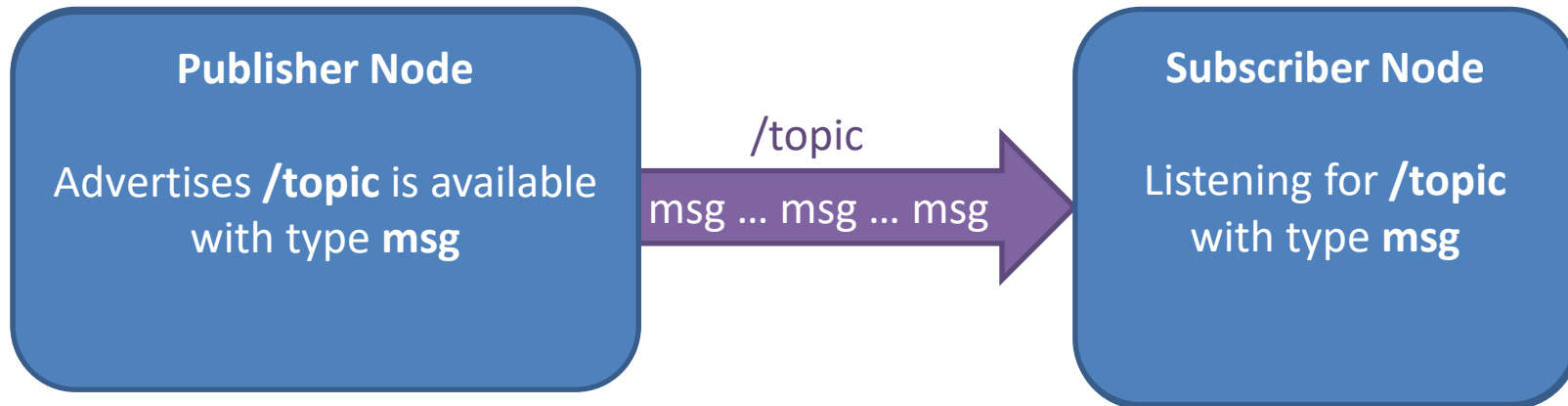


Topics and Messages





Topics are for **Streaming Data**

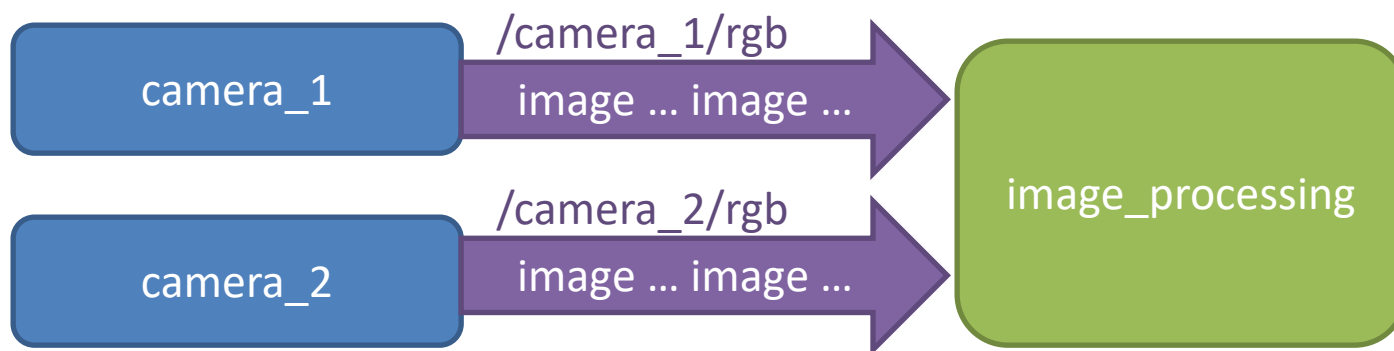




Topics vs. Messages

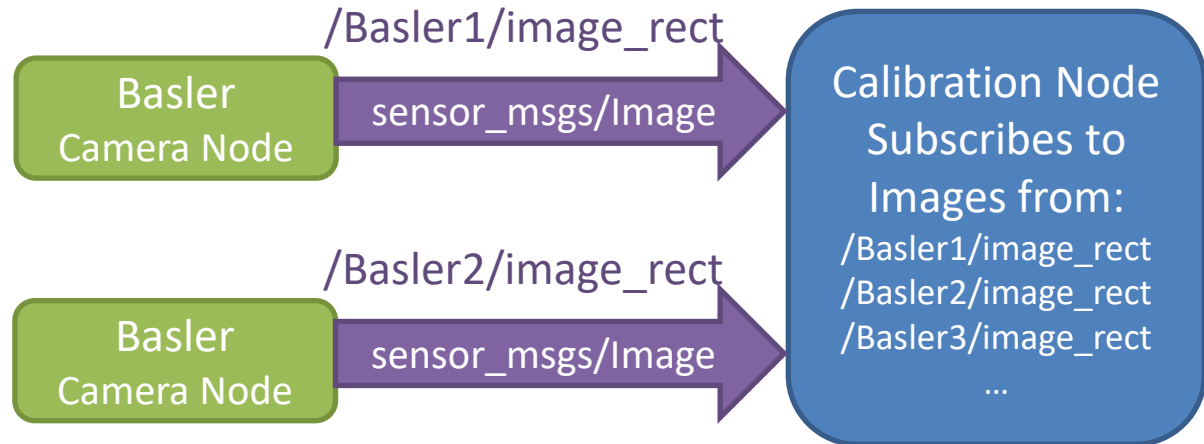


- Topics are **channels**, Messages are **data types**
 - Different topics can use the same Message type





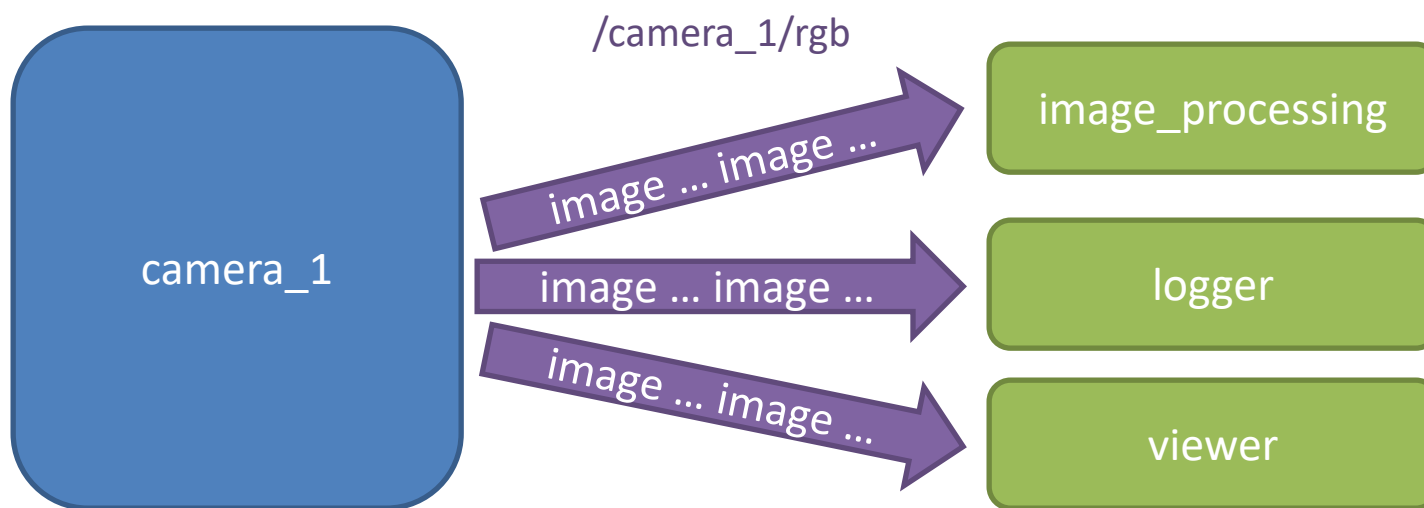
Practical Example





Multiple Pub/Sub

- Many nodes can pub/sub to same topic
 - comms are direct node-to-node





Topics : Details



- Each **Topic** is a stream of **Messages**:
 - sent by **publisher(s)**, received by **subscriber(s)**
- Messages are **asynchronous**
 - publishers don't know if anyone's listening
 - messages may be dropped
 - subscribers are event-triggered (by incoming messages)
- Typical Uses:
 - Sensor Readings: camera images, distance, I/O
 - Feedback: robot status/position
 - Open-Loop Commands: desired position





Quality of Service



- All ROS2 comms define a “Quality of Service” (QoS)
 - History/Depth - buffer N prior messages
 - Reliability - retry or discard dropped messages?
 - Durability - cache messages for late-joining subscribers?
 - Deadline - expected interval between messages
 - etc.
- All participants in a topic must have compatible QoS
 - Publishers - maximum QoS they can provide
 - Subscribers - minimum QoS they require
 - e.g. “reliable” subscriber won’t connect to “best-effort” publisher





QoS Profiles



- ROS provides default QoS profiles for different comms types.
 - Use these defaults, tweak them, or define your own application-specific QoS.
- Default Profile (messages) queue=10, reliable, volatile
- Services Profile queue=10, reliable, volatile
- Sensor Profile queue=5, best-effort, volatile
- Parameters Profile queue=1000, reliable, volatile





ROS Messages Types



- Similar to C structures
- Standard data primitives
 - Boolean: `bool`
 - Integer: `int8`, `int16`, `int32`, `int64`
 - Unsigned Integer: `uint8`, `uint16`, `uint32`, `uint64`
 - Floating Point: `float32`, `float64`
 - String: `string`
- Fixed length arrays: `bool[16]`
- Variable length arrays: `int32[]`
- Other: Nest message types for more complex data structure





- All Messages are defined by a **.msg** file

PathPosition.msg

comment → # A 2D position and orientation

other Msg type → std_msgs/Header header

```
float64 x      # X coordinate
float64 y      # Y coordinate
float64 angle  # Orientation
```

data type field name

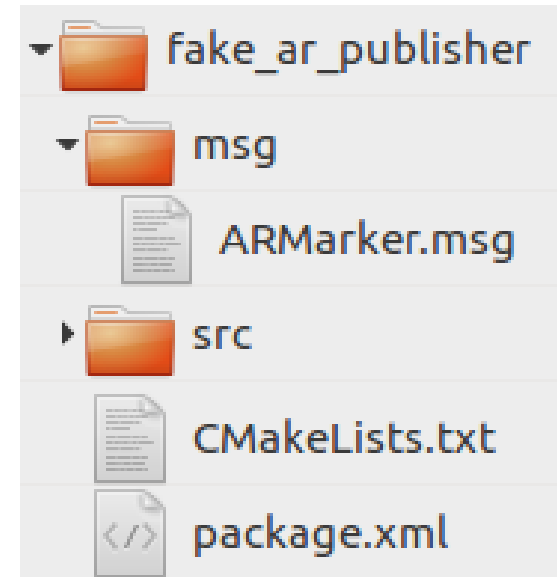




Custom ROS Messages



- Custom message types are defined in `msg` subfolder of packages
- Modify `CMakeLists.txt` to enable message generation.





- Lines needed to generate custom msg types

```
find_package(rosidl_default_generators  
REQUIRED)
```

```
rosidl_generate_interfaces(  
  msg/CustomMsg.msg  
  DEPENDENCIES ...)
```





package.xml



```
<build_depend> roslint_default_generators </build_depend>
```

```
<exec_depend>roslint_default_runtime</exec_depend>
```

```
<member_of_group>roslint_interface_packages</member_of_group>
```





ROS Interface Commands



These commands show info about known ROS message types (+ services/actions, discussed later)

- `ros2 interface list`
 - Show all ROS message types currently available
- `ros2 interface package <package>`
 - Show all ROS message types in package <package>
- `ros2 interface show <package>/<message_type>`
 - Show the structure of the given message type





ROS Topic Commands



- `ros2 topic list`
 - List all topics currently subscribed to and/or publishing
- `ros2 topic type <topic>`
 - Show the message type of the topic
- `ros2 topic info <topic>`
 - Show topic message type, subscribers, publishers, etc.
- `ros2 topic echo <topic>`
 - Echo messages published to the topic to the terminal
- `ros2 topic find <message_type>`
 - Find topics of the given message type

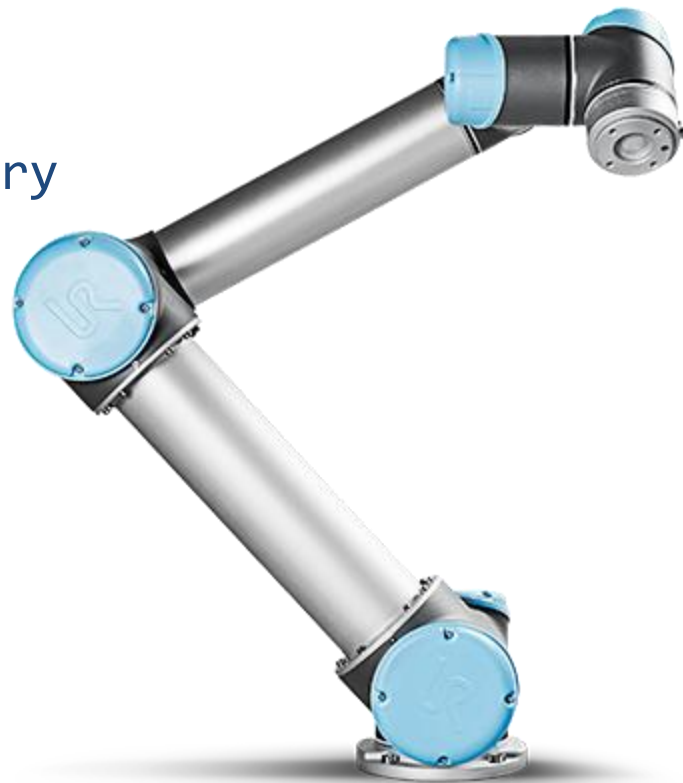




“Real World” – Messages



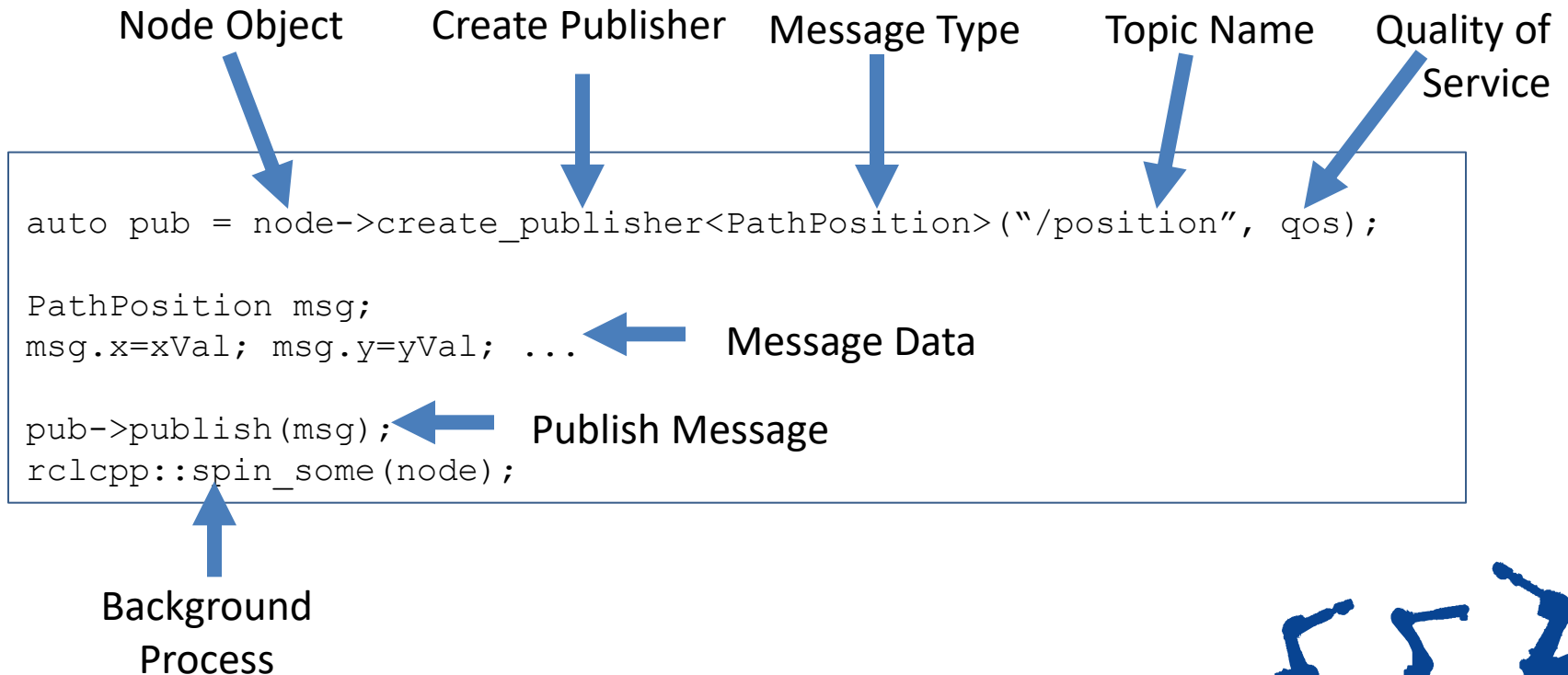
- Use *rqt_msg* to view:
 - sensor_msgs/JointState
 - trajectory_msgs/JointTrajectory
 - sensor_msgs/Image
 - rcl_interfaces/Log





- **Topic Publisher**

- Advertises available topic (*Name, Data Type, QoS*)
- Populates message data
- Periodically publishes new data





- **Topic Subscriber**
 - Defines callback function
 - Listens for available topic (*Name, Data Type, QoS*)

Callback Function



Message Type



Message Data (IN)



```
void msg_callback(const PathPosition& msg) {  
    RCLCPP_INFO_STREAM(node->get_logger(), "Received msg: " << msg);  
}  
  
auto sub = node->create_subscription("/topic", qos, msg_callback);
```

Server Object



Service Name



Callback Ref

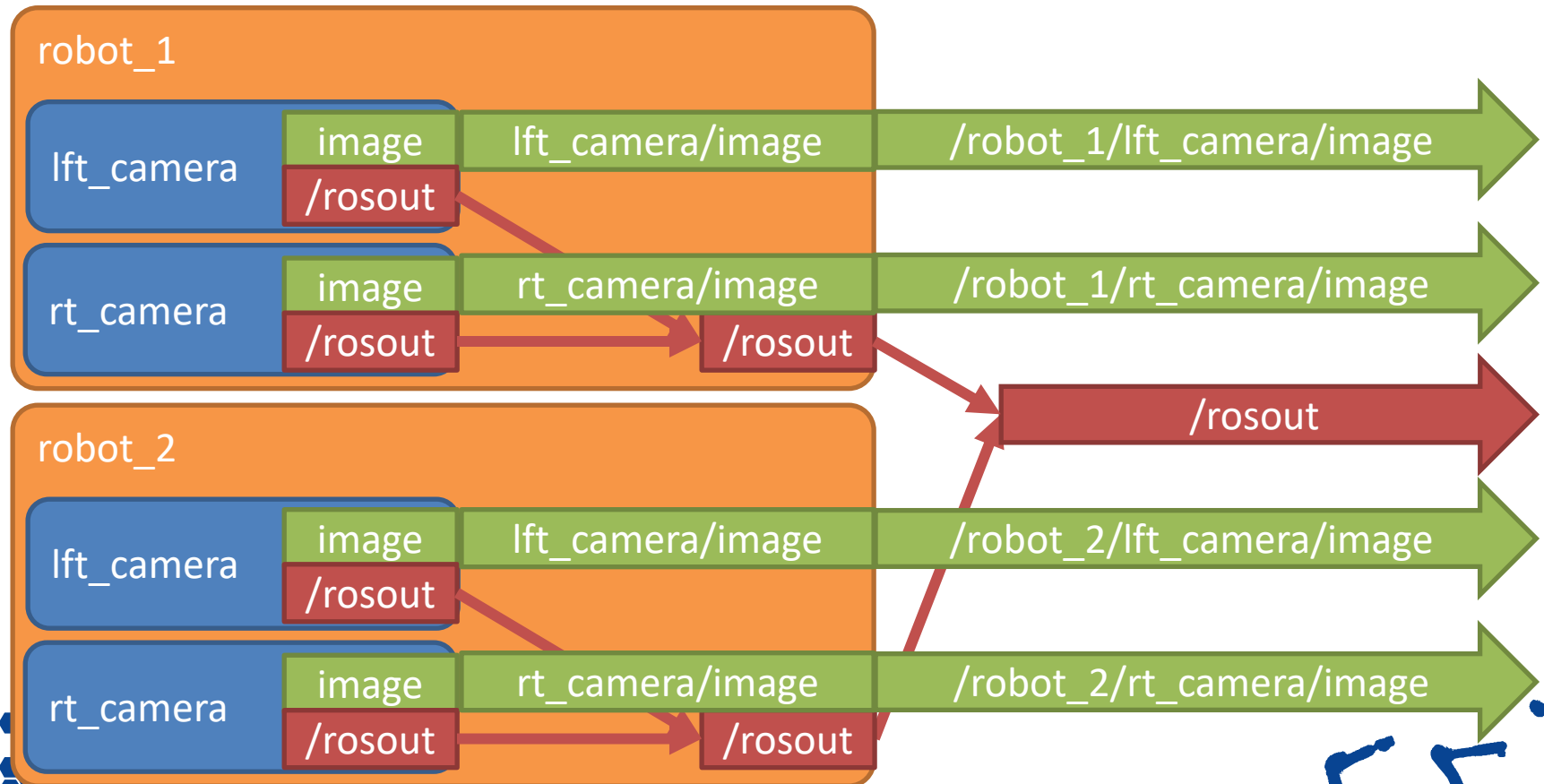




Namespaces



- ROS requires unique names for nodes/topics/etc.
- Namespaces allow separation:
 - *Similar nodes can co-exist, in different “namespaces”*
 - *relative vs. absolute name references*





Instead of text editor and building from terminal...

Use an IDE! ([detailed instructions here](#))



1. Launch QtCreator IDE from desktop shortcut
2. File -> New Project
3. Other Project -> ROS Workspace
4. Enter Project Properties:
 1. Name = "ROS2_Training" (or whatever)
 2. Distribution (should be auto-detected)
 3. Build System = Colcon
 4. Path = ~/ros2_ws
5. Build -> Build All
 1. you should see success in the "Compile" tab





Exercise 1.4

Exercise 1.4

Subscribe to fake_ar_publisher

