ROS-Industrial Basic Developer’s Training Class

October 2024

Southwest Research Institute

Session 1:

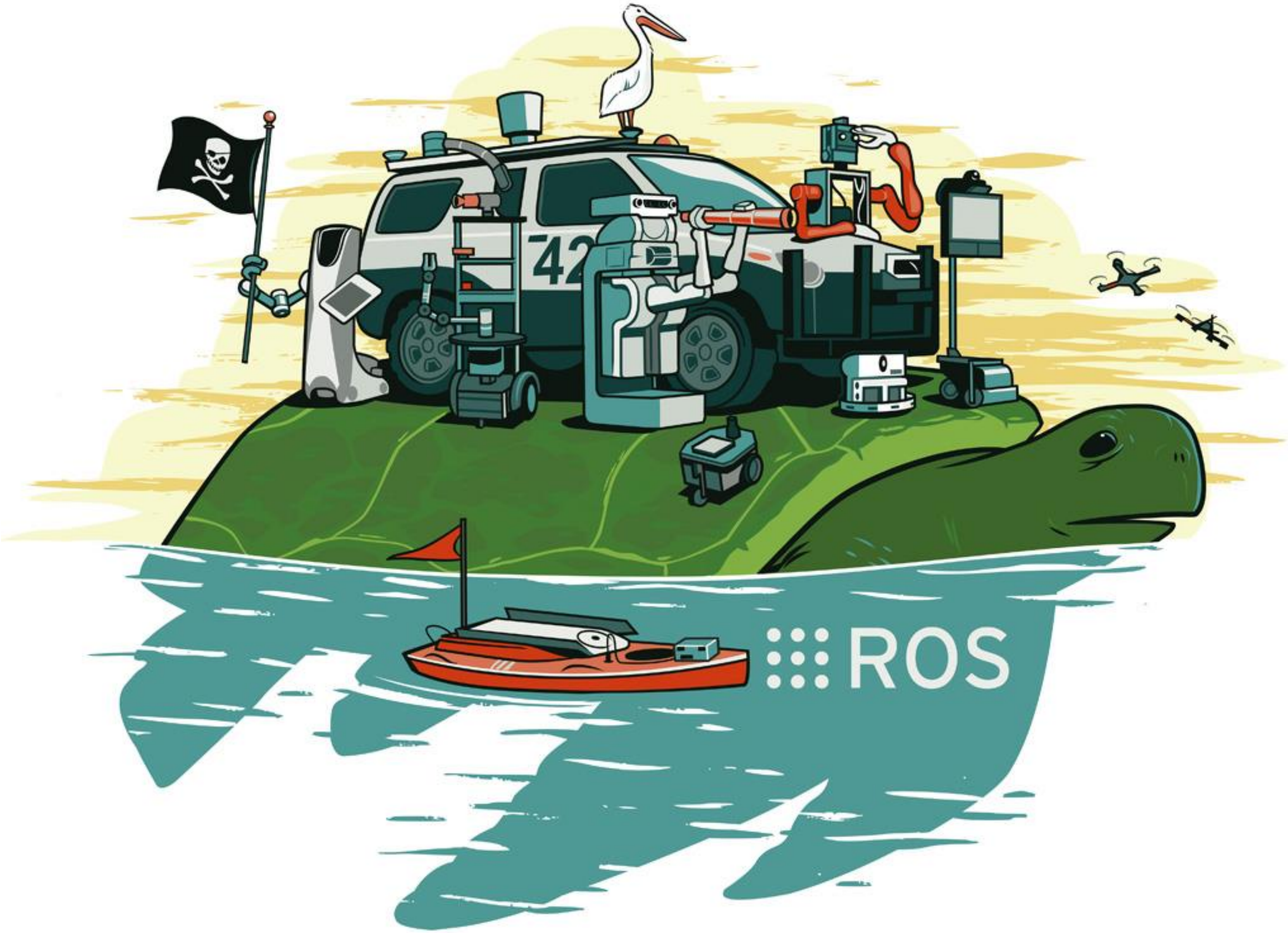
ROS Basics

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 reimagining of ROS
  - – Started in 2014
  - – Built on DDS, middleware proven in industry
  - – Now on 10th named release (Jazzy)

This class will focus on

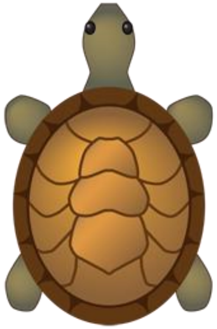
ROS2 Humble

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

…

…

Humble (LTS)

2022 - 2027

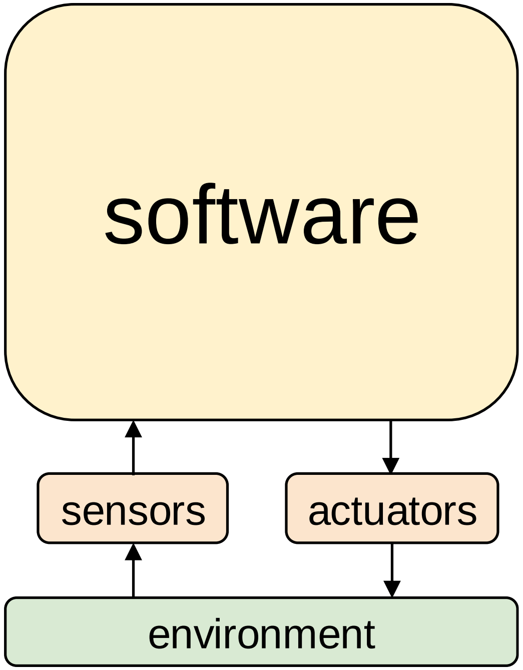
Iron

2023 - 2024

Jazzy (LTS)

2024-2029

ROS : The Big Picture

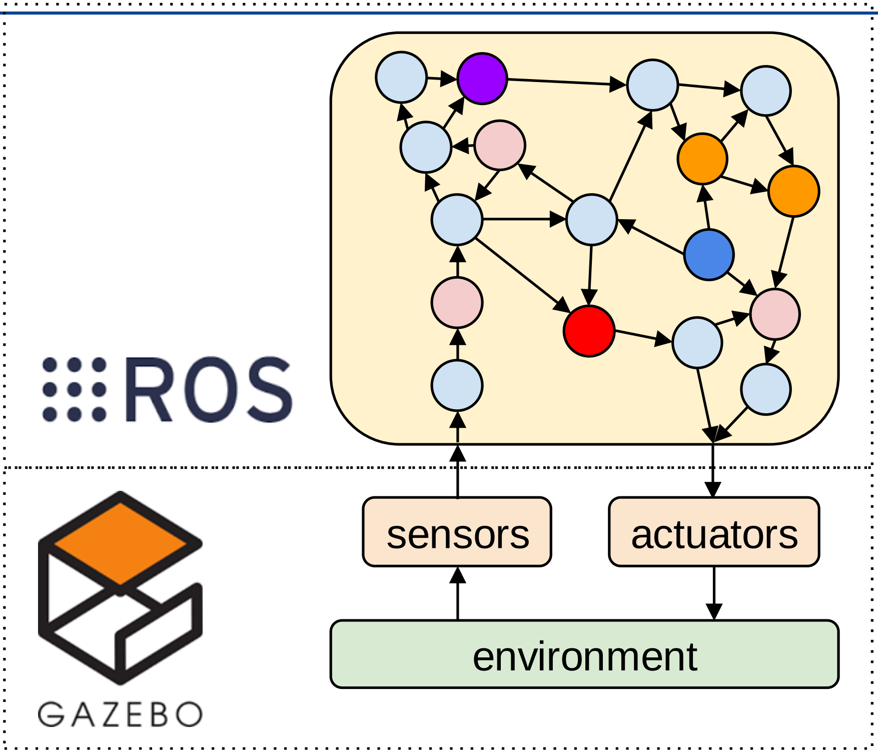


All robots are:

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

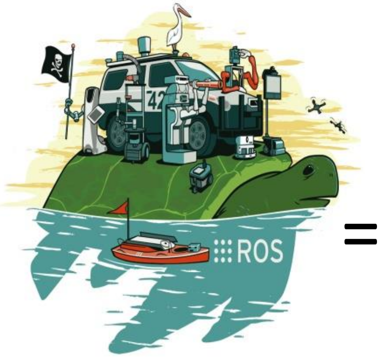


- Break Complex Software into Smaller Pieces
- Provide a framework, tools, and interfaces for distributed development
- Encourage re-use of software pieces
- Easy transition between simulation and hardware

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

What is ROS?

ROS is…



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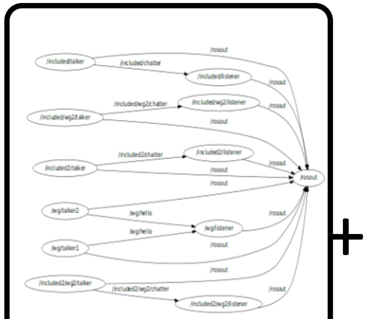
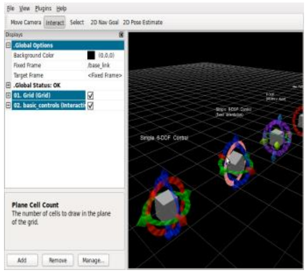


Plumbing

+

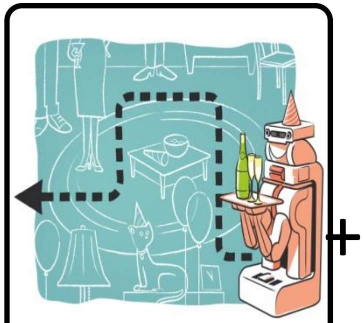


.Global Options
Background Color ■ (0,0,0)
Fixed Frame /base_link
Target Frame <Fixed Frame>
.Global Status: OK
01. Grid (Grid) ☑
02. basic_controls (Interacti ☑

Plane Cell Count
The number of cells to draw in the plane of the grid.

Tools

+



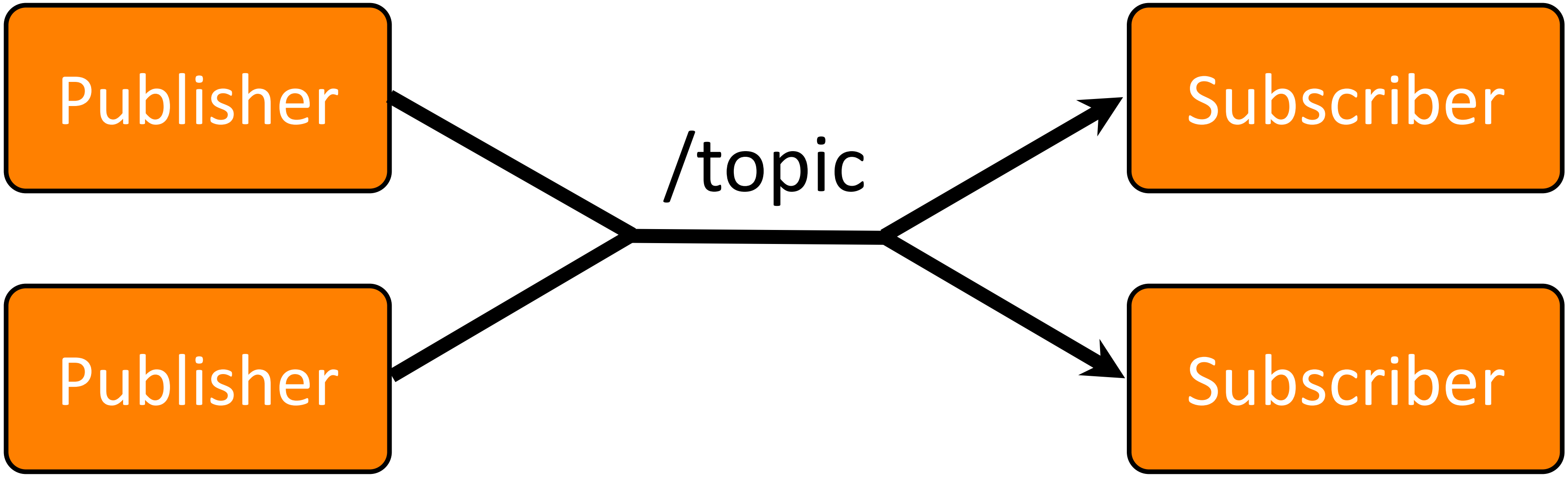
Capabilities

+

Ecosystem

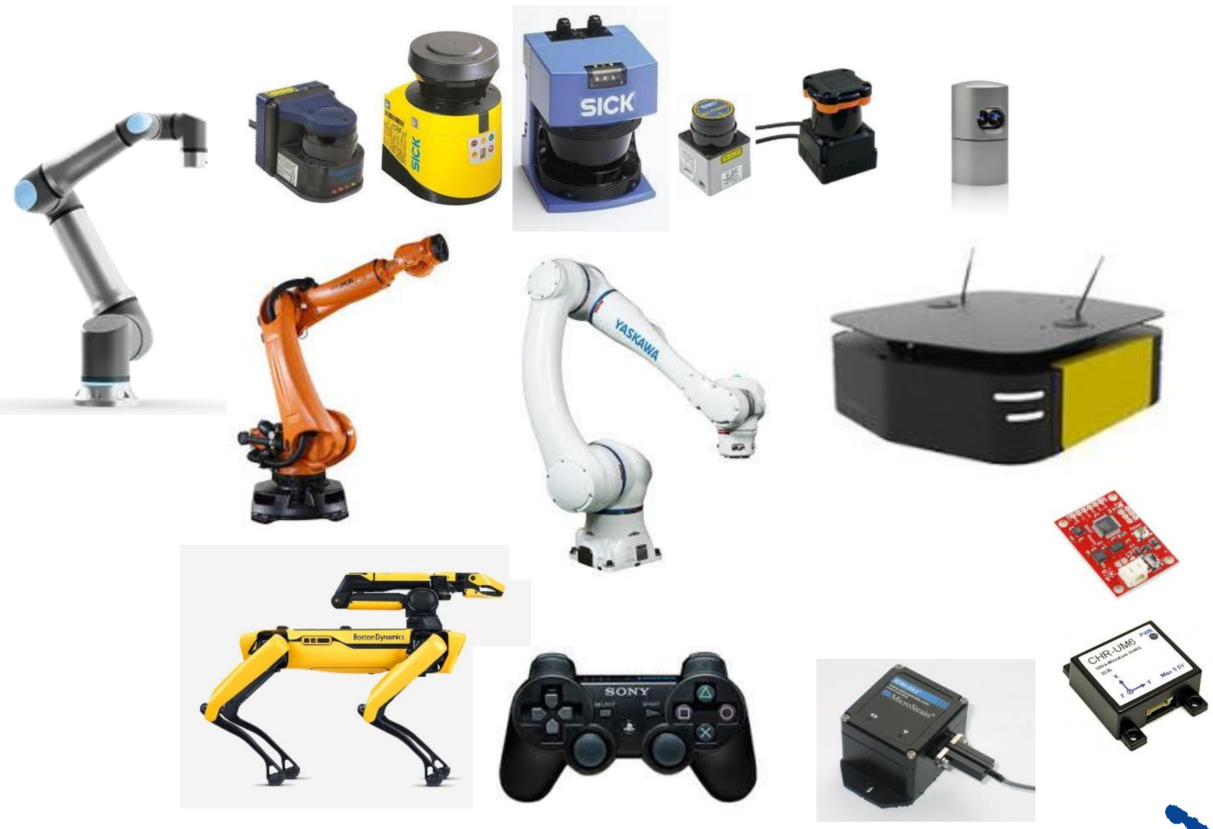
(Adapted from Willow Garage’s “What is ROS?” Presentation)

ROS is… plumbing



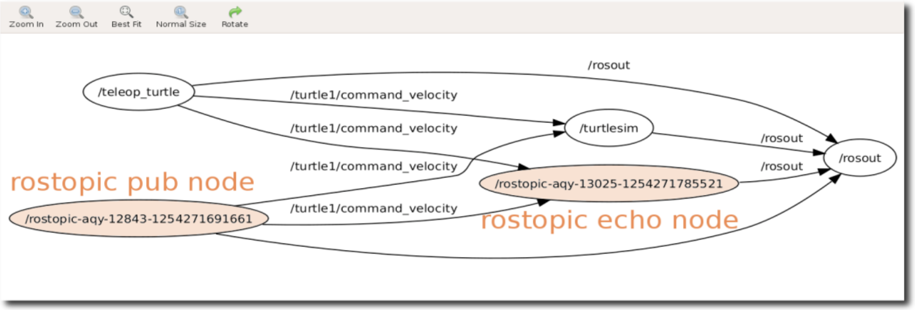
ROS Plumbing : Drivers

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

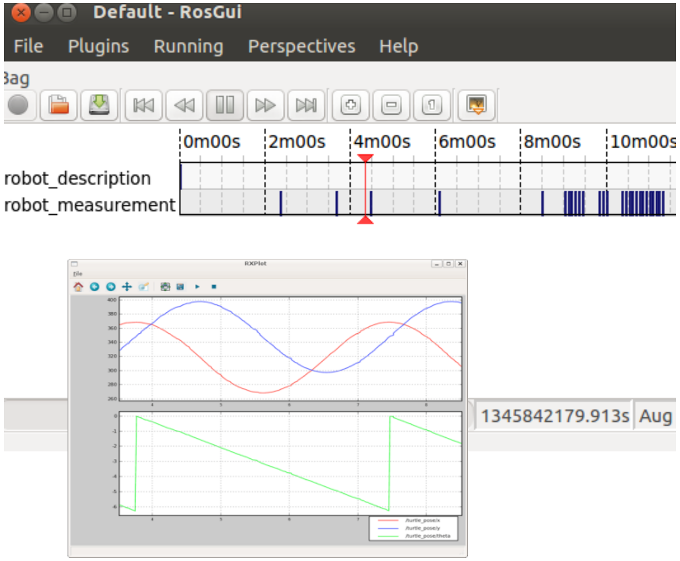


(Adapted from Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics" presentation)

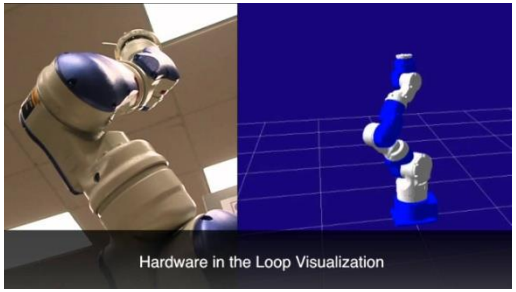
ROS is …Tools

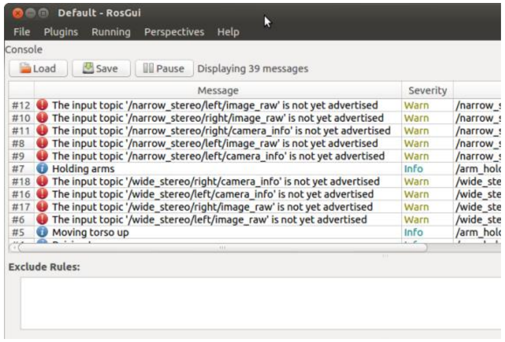


Zoom In
Zoom Out
Best Fit
Normal Size
Rotate
/teleop_turtle
/turtle1/command_velocity
/turtle1/command_velocity
/turtle1/command_velocity
/turtle1/command_velocity
/turtlesim
/rosout
/rosout
/rosout
/rosout
rostopic pub node
/rostopic-aqy-12843-1254271691661
/rostopic-aqy-13025-1254271785521
rostopic echo node



- logging/plotting
- graph visualization
- diagnostics
- visualization





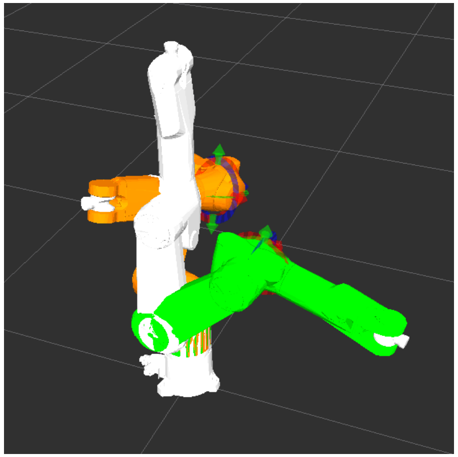
Displaying 39 messages

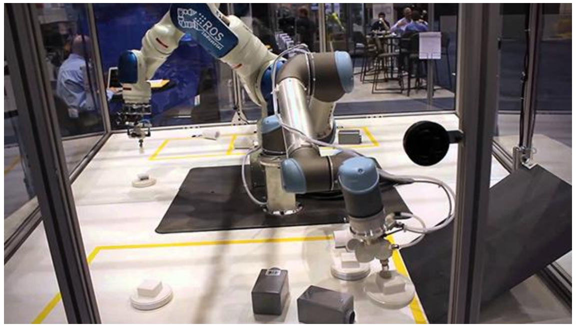
	Message	Severity	
#12	The input topic '/narrow_stereo/left/image_raw' is not yet advertised	Warn	/narrow_
#10	The input topic '/narrow_stereo/right/image_raw' is not yet advertised	Warn	/narrow_
#11	The input topic '/narrow_stereo/right/camera_info' is not yet advertised	Warn	/narrow_
#8	The input topic '/narrow_stereo/left/image_raw' is not yet advertised	Warn	/narrow_
#9	The input topic '/narrow_stereo/left/camera_info' is not yet advertised	Warn	/narrow_
#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

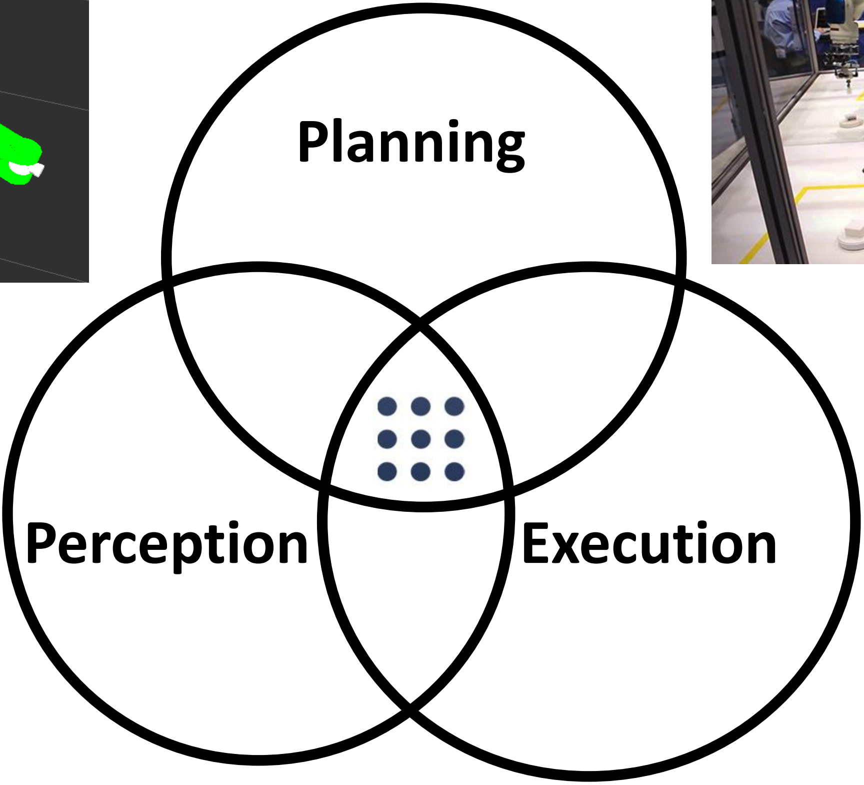
Exclude Rules:

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

ROS is…Capabilities

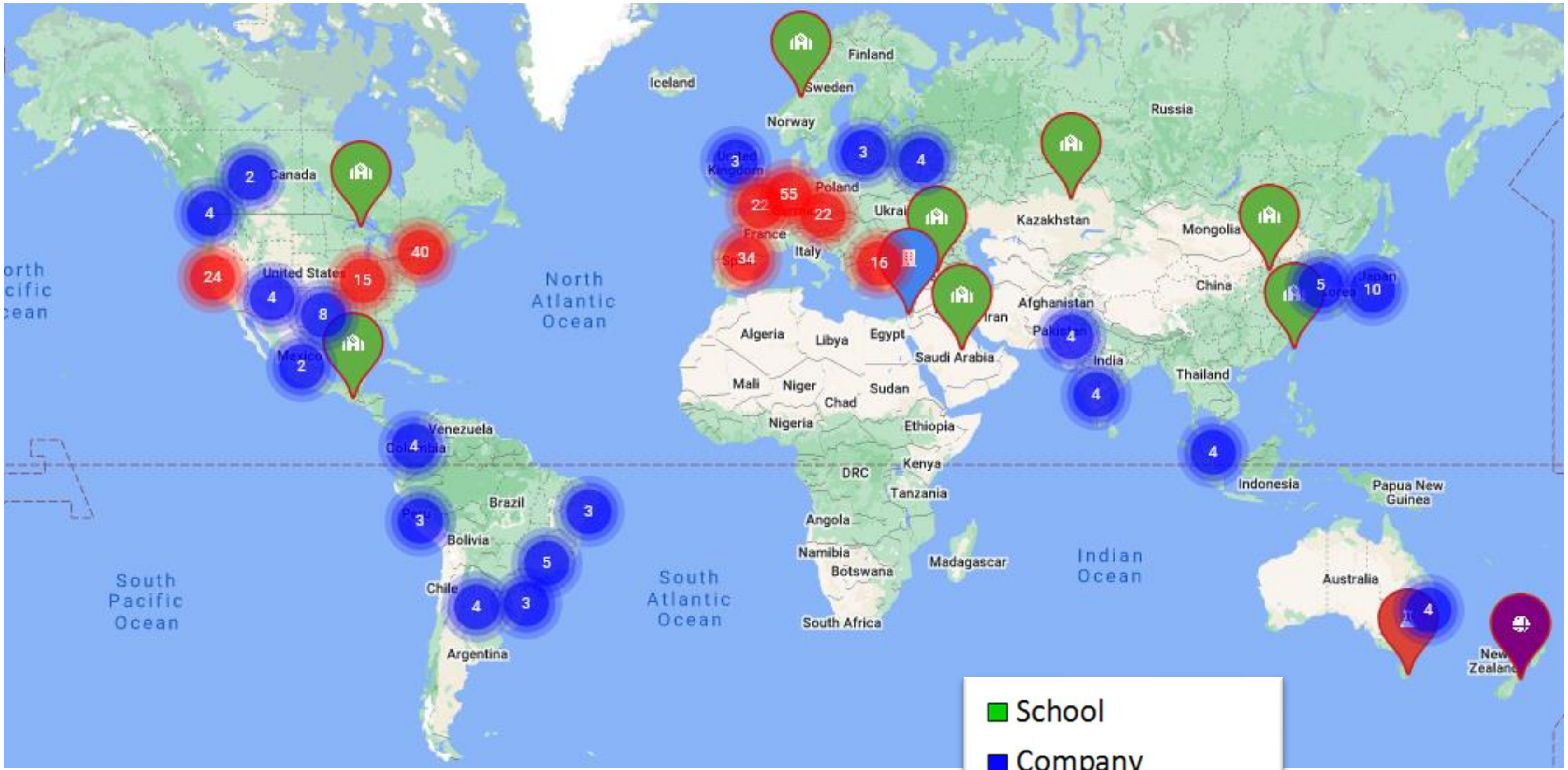






(Adapted from Willow Garage's "What is ROS?" Presentation)

ROS is… an Ecosystem



🟩 School

🟦 Company

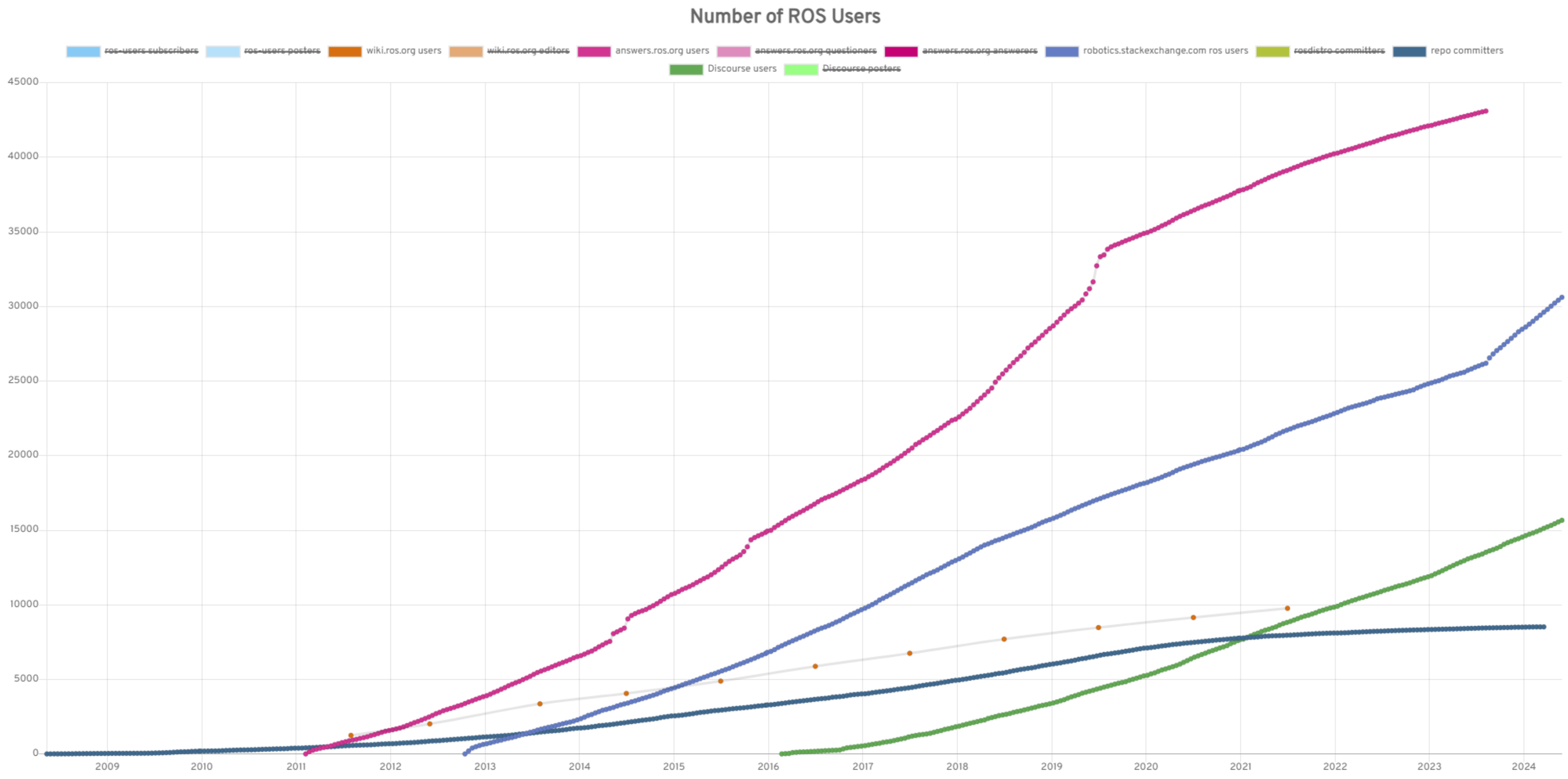
🟥 Research Institute

🟨 Other

□ Unknown

http://metrorobots.com/rosmap.html

ROS is a growing Ecosystem

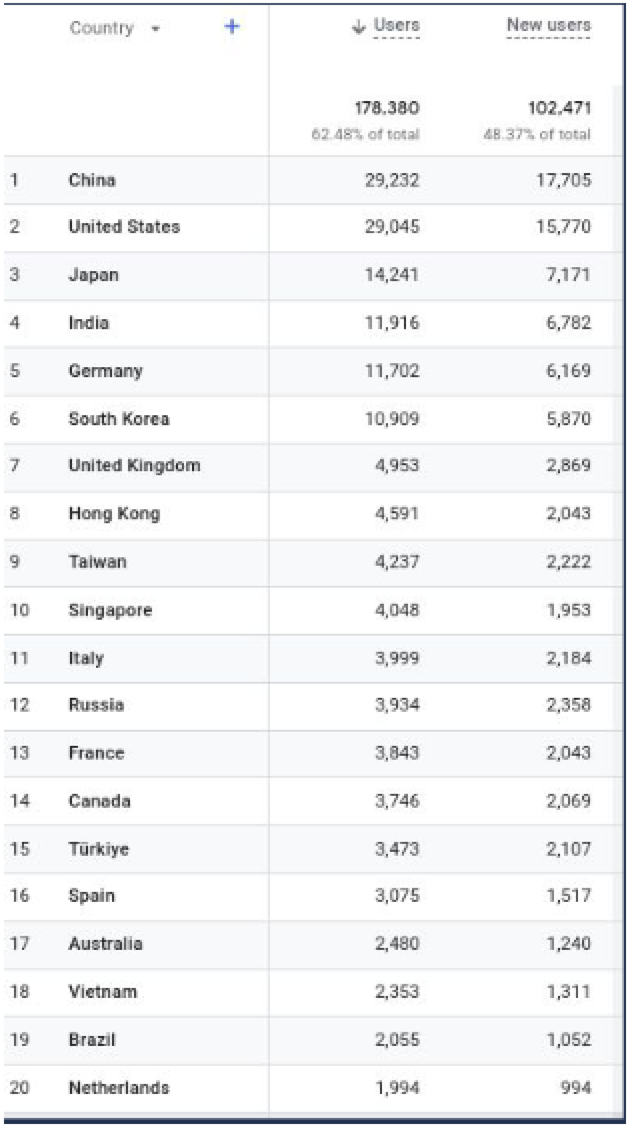


A collection of different metrics for measuring the number of users in the ROS community.

https://metrics.ros.org/

ROS is International

unique wiki visitors as of Oct 2023



	Country ▾ +	↓ Users	New users
		178,380 62.48% of total	102,471 48.37% of total
1	China	29,232	17,705
2	United States	29,045	15,770
3	Japan	14,241	7,171
4	India	11,916	6,782
5	Germany	11,702	6,169
6	South Korea	10,909	5,870
7	United Kingdom	4,953	2,869
8	Hong Kong	4,591	2,043
9	Taiwan	4,237	2,222
10	Singapore	4,048	1,953
11	Italy	3,999	2,184
12	Russia	3,934	2,358
13	France	3,843	2,043
14	Canada	3,746	2,069
15	Türkiye	3,473	2,107
16	Spain	3,075	1,517
17	Australia	2,480	1,240
18	Vietnam	2,353	1,311
19	Brazil	2,055	1,052
20	Netherlands	1,994	994

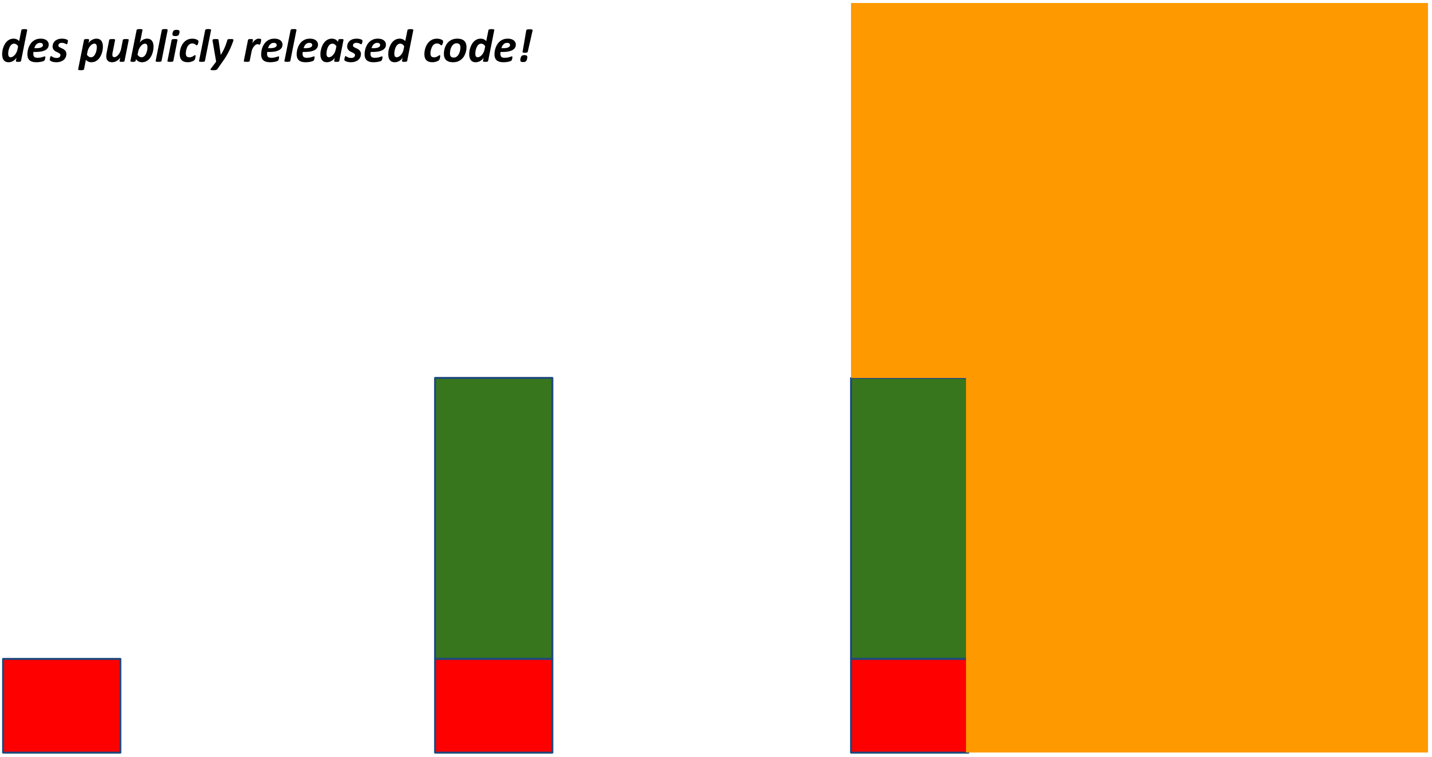
910+

Companies Using ROS

https://docs.ros.org/en/rolling/The-ROS2-Project/Metrics.html 2023

ROS is a Repository

only includes publicly released code!



ros_comm
("core")
100 KLOC

desktop-full
("core+tools")
400 KLOC

all buildfarm
("universe")
4000 KLOC

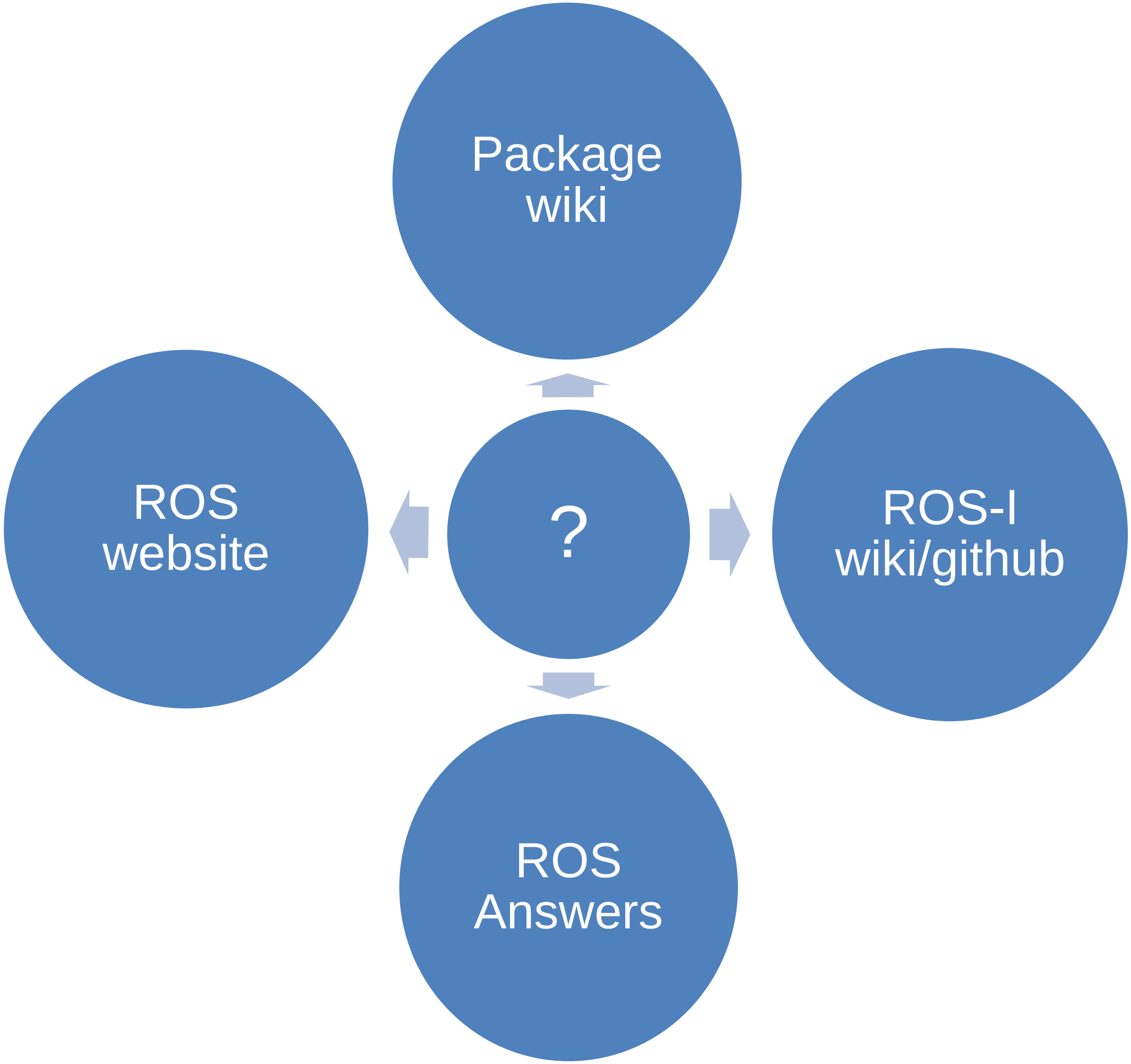
(From Morgan Quigley's "ROS: An Open-Source Framework for Modern Robotics")

ROS Programming

- ROS uses **platform-agnostic** methods for most communication
  - DDS, TCP/IP Sockets, XML, etc.

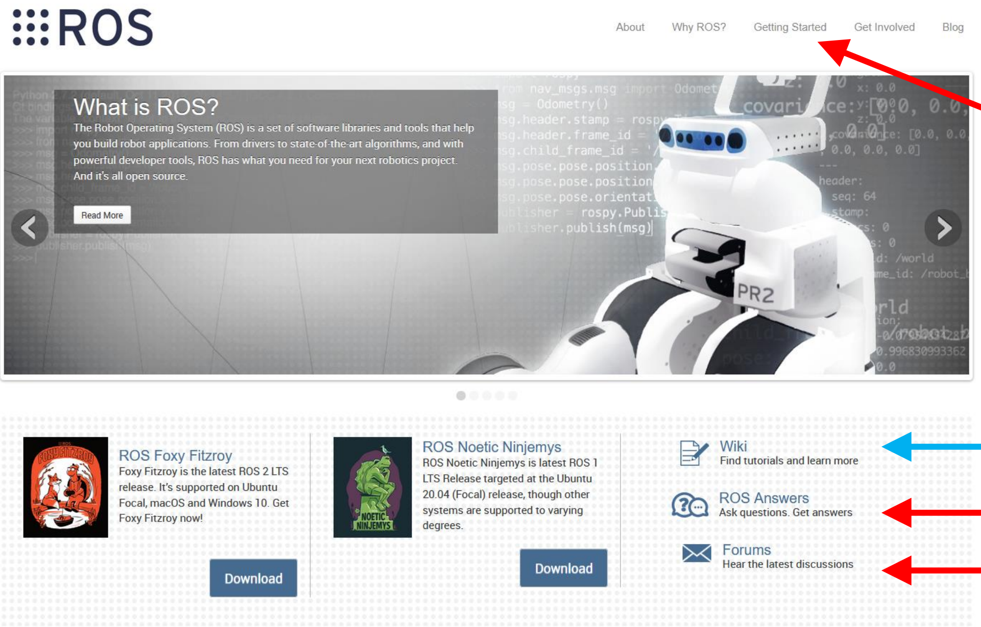
- Can intermix programming languages
  - Current 1st Tier support: C, C++, Python
  - We will be using C++ for our exercises

ROS Resources



ROS.org Website

http://ros.org



What is ROS?

The Robot Operating System (ROS) is a set of software libraries and tools that help you build 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.

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!

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.

Wiki
Find tutorials and learn more

ROS Answers
Ask questions. Get answers

Forums
Hear the latest discussions

ROS1

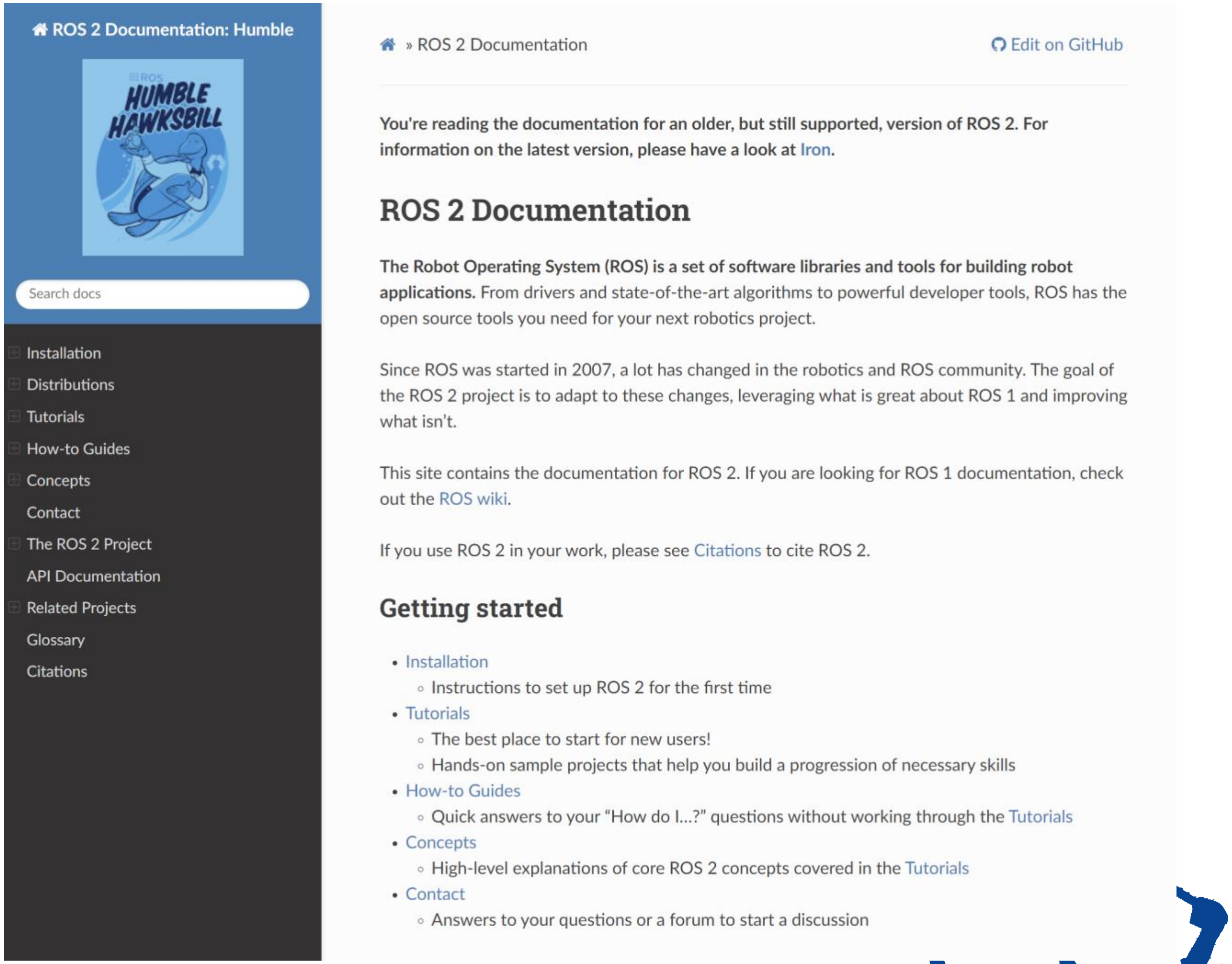
but still relevant

- Install Instructions
- ROS Answers
- Forums (Discourse)

ROS2 Documentation

http://docs.ros.org

- Install
- Tutorials
- Concepts
- APIs



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 Iron.

ROS 2 Documentation

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

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.

This site contains the documentation for ROS 2. If you are looking for ROS 1 documentation, check out the ROS wiki.

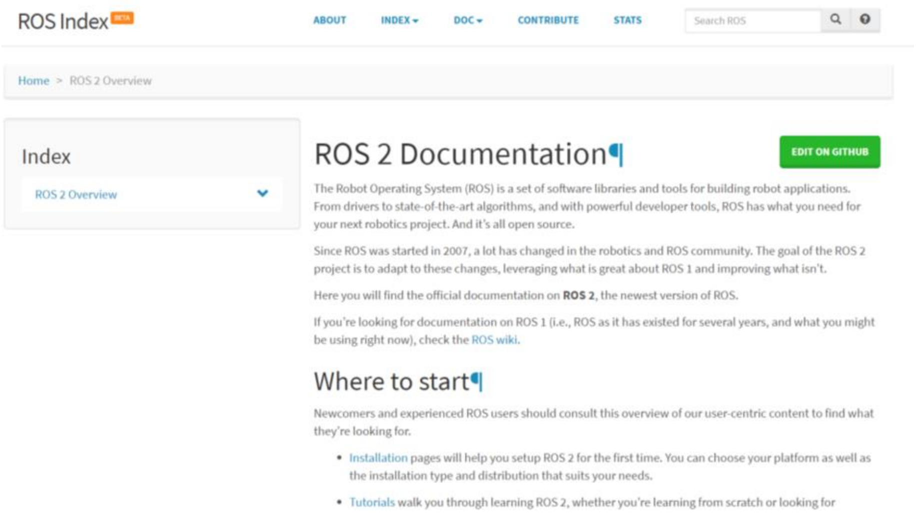
If you use ROS 2 in your work, please see Citations to cite ROS 2.

Getting started

- Installation
  - Instructions to set up ROS 2 for the first time
- Tutorials
  - The best place to start for new users!
  - Hands-on sample projects that help you build a progression of necessary skills
- How-to Guides
  - Quick answers to your "How do I...?" questions without working through the Tutorials
- Concepts
  - High-level explanations of core ROS 2 concepts covered in the Tutorials
- Contact
  - Answers to your questions or a forum to start a discussion

ROS Package Index

http://index.ros.org



ROS Index BETA

Home > ROS 2 Overview

Index

ROS 2 Overview

ROS 2 Documentation¶

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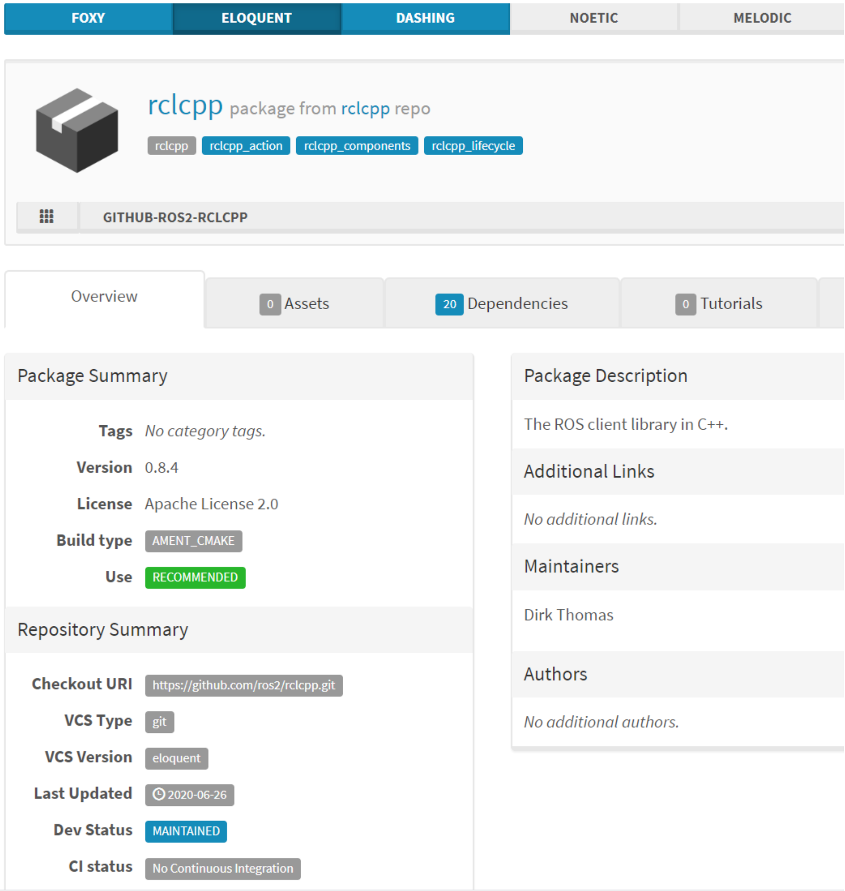
Here you will find the official documentation on **ROS 2**, the newest version of ROS.

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.
- Tutorials walk you through learning ROS 2, whether you're learning from scratch or looking for



rclcpp package from rclcpp repo

GITHUB-ROS2-RCLCPP

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.

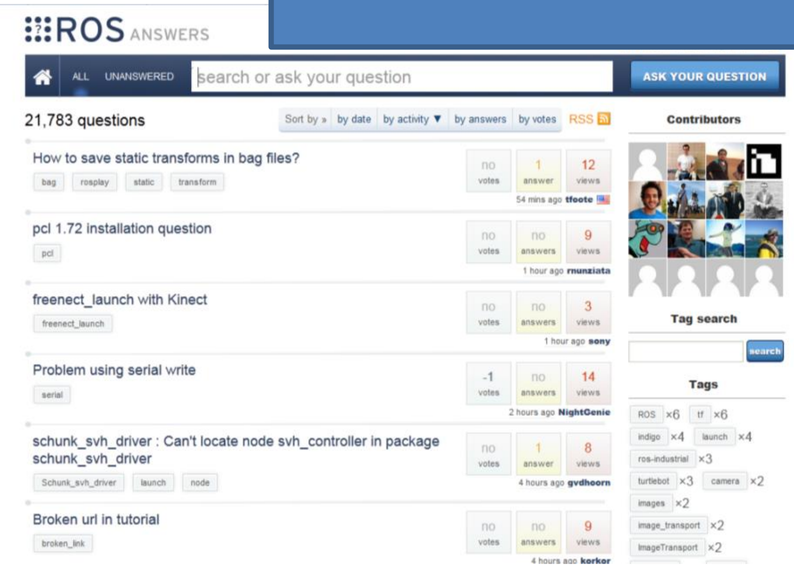
- Install Instructions
- Tutorials
- Package Info
- Still NEW – see ROS1 Wiki

ROS Answers

http://answers.ros.org

↓

https://robotics.stackexchange.com



ROS ANSWERS

ALL UNANSWERED search or ask your question ASK YOUR QUESTION

21,783 questions — Sort by » by date by activity ▼ by answers by votes RSS

How to save static transforms in bag files? — bag, rosplay, static, transform — no votes, 1 answer, 12 views — 54 mins ago tfoote

pcl 1.72 installation question — pcl — no votes, no answers, 9 views — 1 hour ago rnunziata

freenect_launch with Kinect — freenect_launch — no votes, no answers, 3 views — 1 hour ago sony

Problem using serial write — serial — -1 votes, no answers, 14 views — 2 hours ago NightGenie

schunk_svh_driver : Can't locate node svh_controller in package schunk_svh_driver — Schunk_svh_driver, launch, node — no votes, 1 answer, 8 views — 4 hours ago gvdhoorn

Broken url in tutorial — broken_link — no votes, no answers, 9 views — 4 hours ago korkor

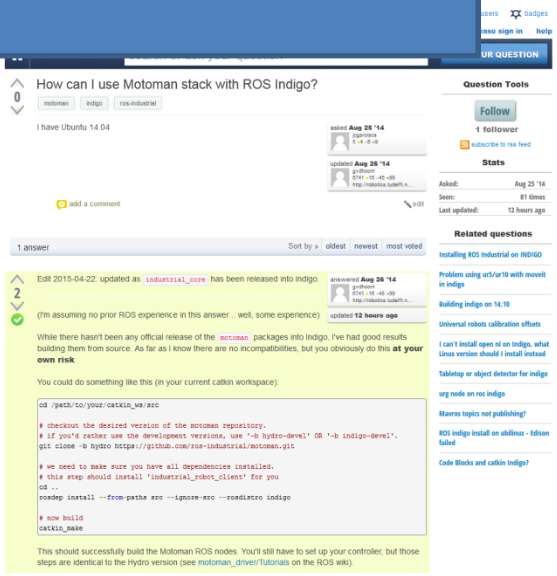
Contributors

Tag search

search

Tags

ROS ×6, tf ×6, indigo ×4, launch ×4, ros-industrial ×3, turtlebot ×3, camera ×2, images ×2, image_transport ×2, ImageTransport ×2



users badges

ase sign in help

UR QUESTION

How can I use Motoman stack with ROS Indigo?

0 — motoman, indigo, ros-industrial

I have Ubuntu 14.04

asked **Aug 25 '14** jogarciaca 5 •4 •6 •9

updated **Aug 26 '14** gvdhoorn 6741 •16 •45 •99 http://robotics.tudelft.n...

add a comment — edit

1 answer — Sort by » oldest newest most voted

2

Edit 2015-04-22: updated as `industrial_core` has been released into Indigo.

answered **Aug 26 '14** gvdhoorn 6741 •16 •45 •99 http://robotics.tudelft.n...

updated **12 hours ago**

(I'm assuming no prior ROS experience in this answer .. well, some experience)

While there hasn't been any official release of the `motoman` packages into Indigo, I've had good results building them from source. As far as I know there are no incompatibilities, but you obviously do this **at your own risk**.

You could do something like this (in your current catkin workspace):

```
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 ..
rosdep install --from-paths src --ignore-src --rosdistro indigo

# now build
catkin_make
```

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).

Question Tools

Follow

1 follower

subscribe to rss feed

Stats

Asked:	Aug 25 '14
Seen:	81 times
Last updated:	12 hours ago

Related questions

- Installing ROS Industrial on INDIGO
- Problem using ur5/ur10 with moveit in indigo
- Building indigo on 14.10
- Universal robots calibration offsets
- I can't install open ni on Indigo, what Linux version should I install instead
- Tabletop or object detector for indigo
- urg node on ros indigo
- Mavros topics not publishing?
- ROS indigo install on ubilinux - Edison failed
- Code Blocks and catkin Indigo?

- 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

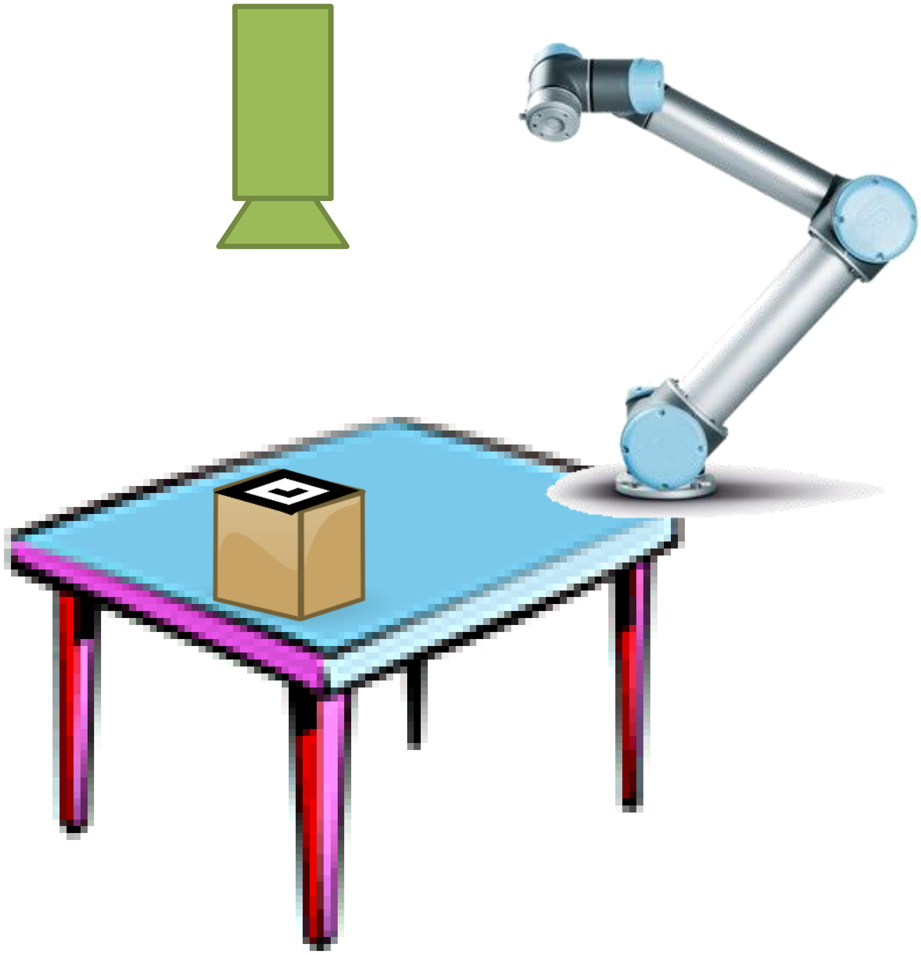
- Most ROS-code is open-source
  - can be reviewed / improved by everyone
  - we count on **YOU** to help ROS grow!

What is ROS to you?

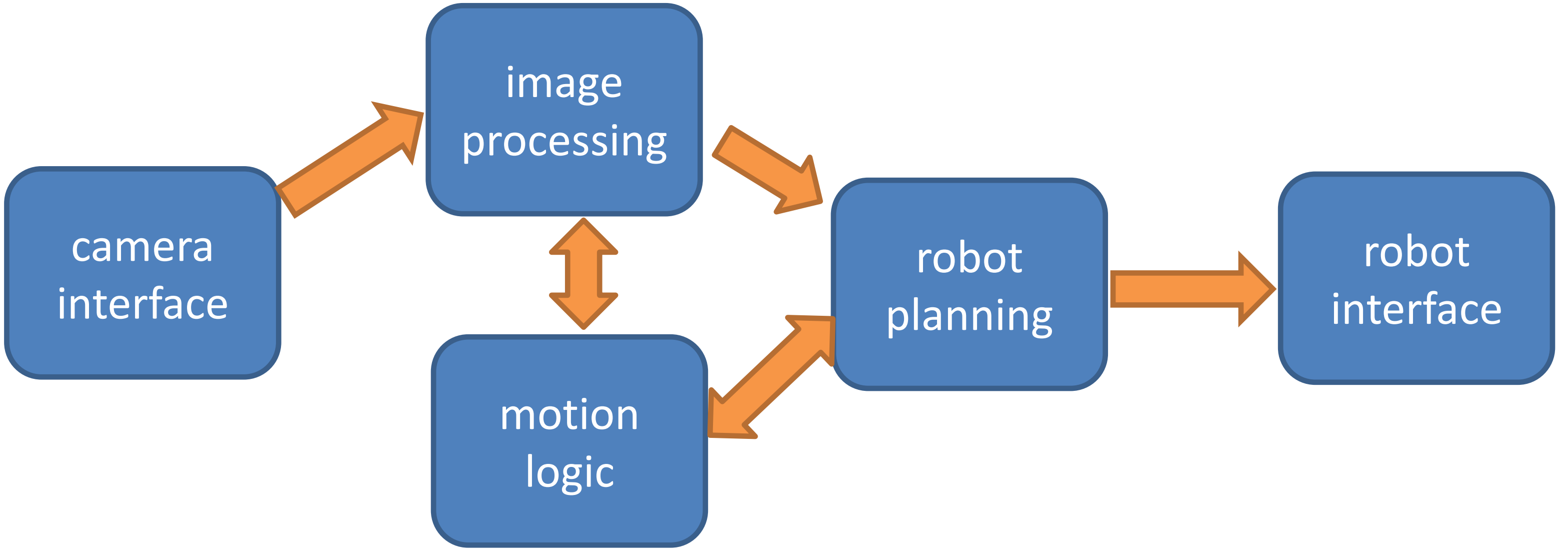
Training Goals:

- 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"

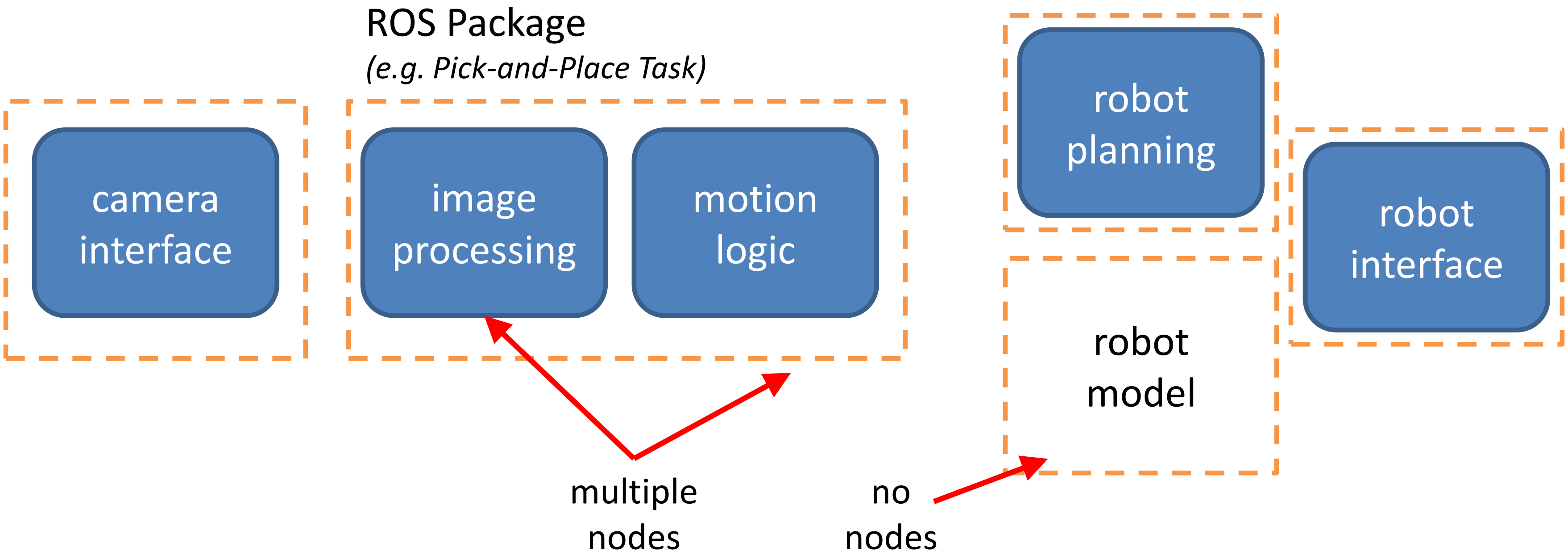


ROS Architecture: Nodes



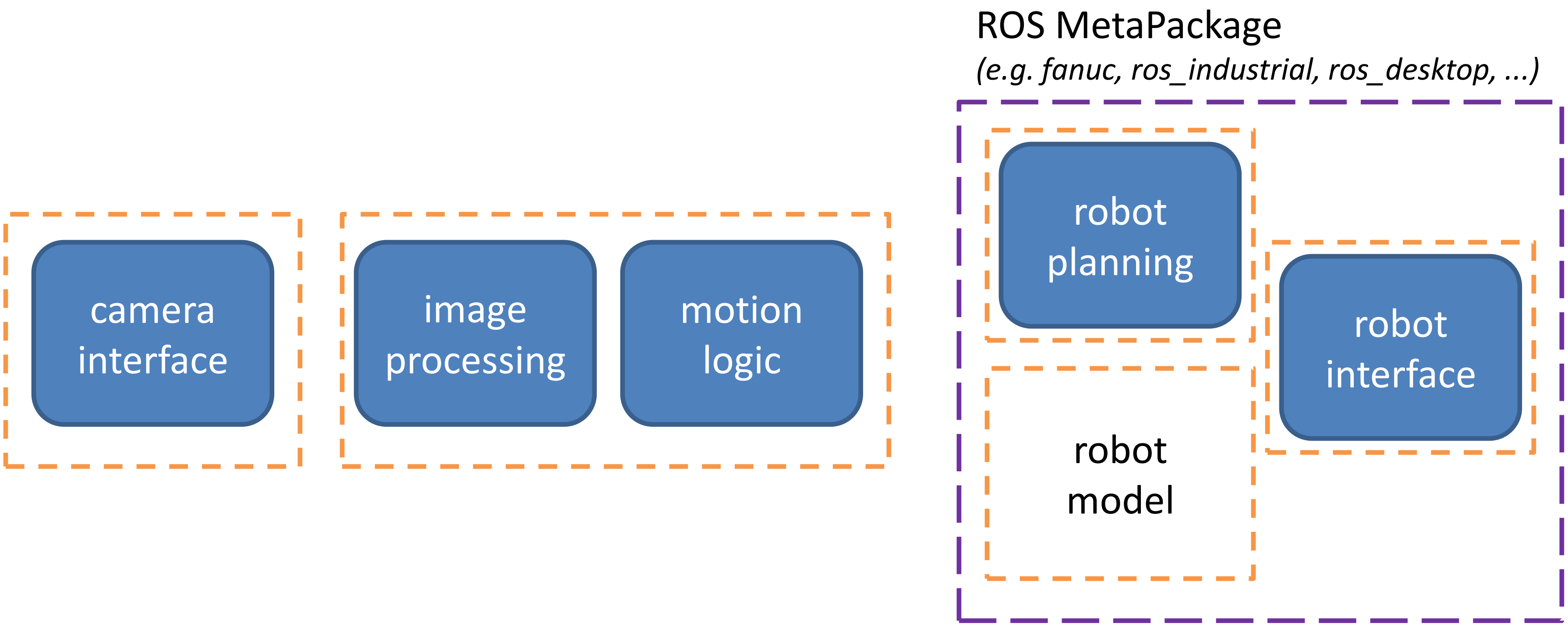
- A **Node** is a *standalone* piece of functionality
  - Most communication happens **between** nodes
  - Nodes can run on many different **devices**
  - Often one node per process, but not always

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**

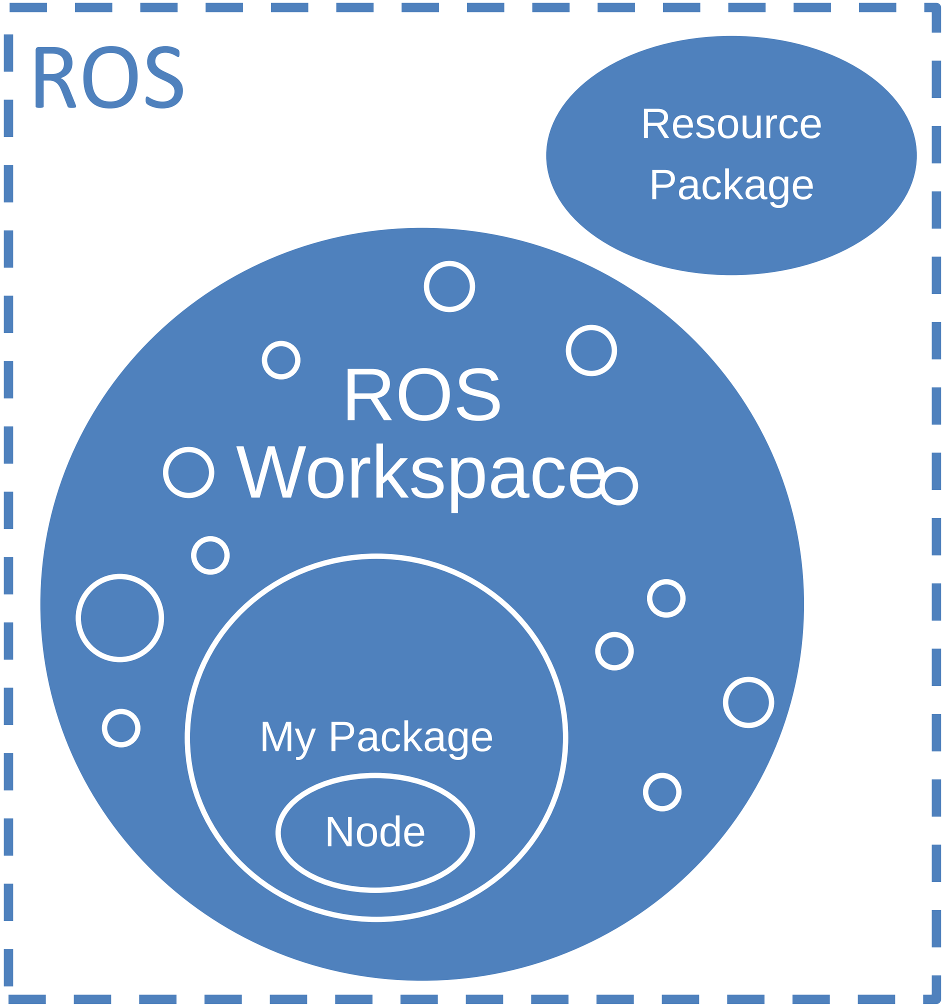
ROS Architecture: MetaPkg



- 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



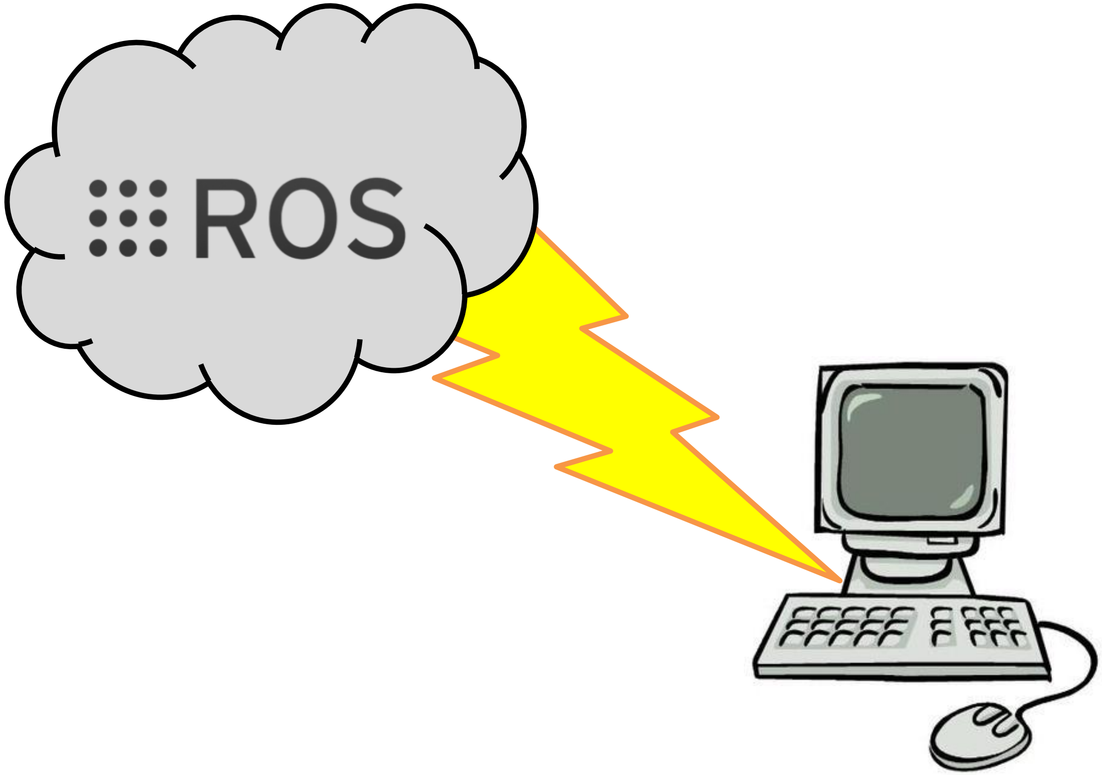
Installing ROS

Getting ROS2

[Installation — ROS 2 Documentation: Humble documentation](#)

Exercise 1.0

Basic ROS Install/Setup



Day 1 Progression

- ✓ Install ROS (check install)
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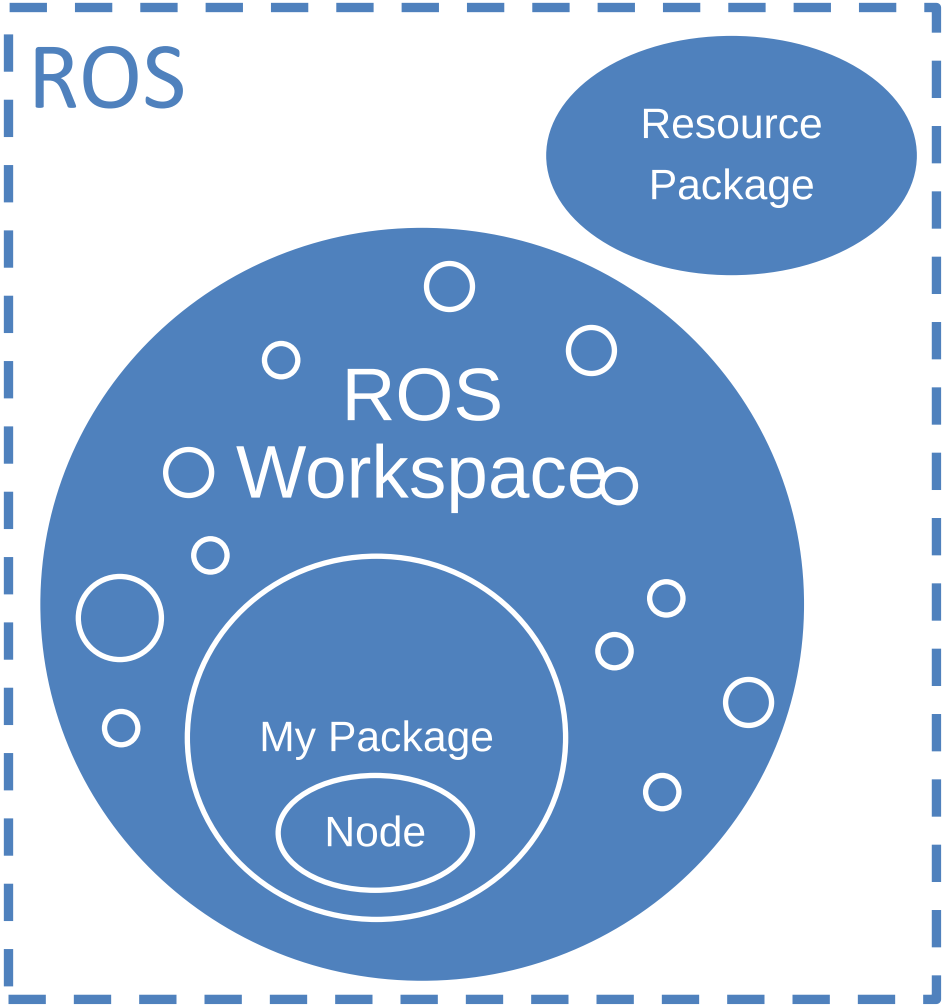
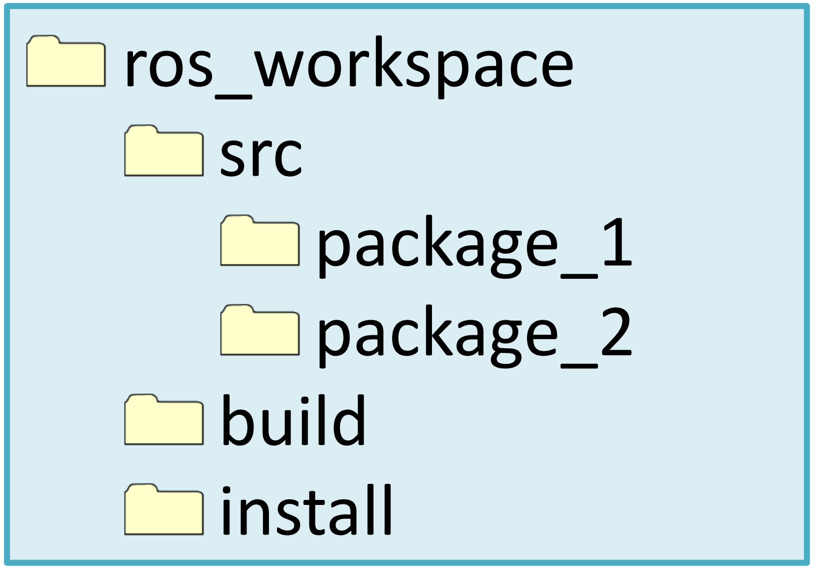
    - ❑ Messages
    - ❑ Services
- ❑ Run Node
  - ❑ ros2 run
  - ❑ ros2 launch



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**



```
ros_workspace
    src
        package_1
        package_2
    build
    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

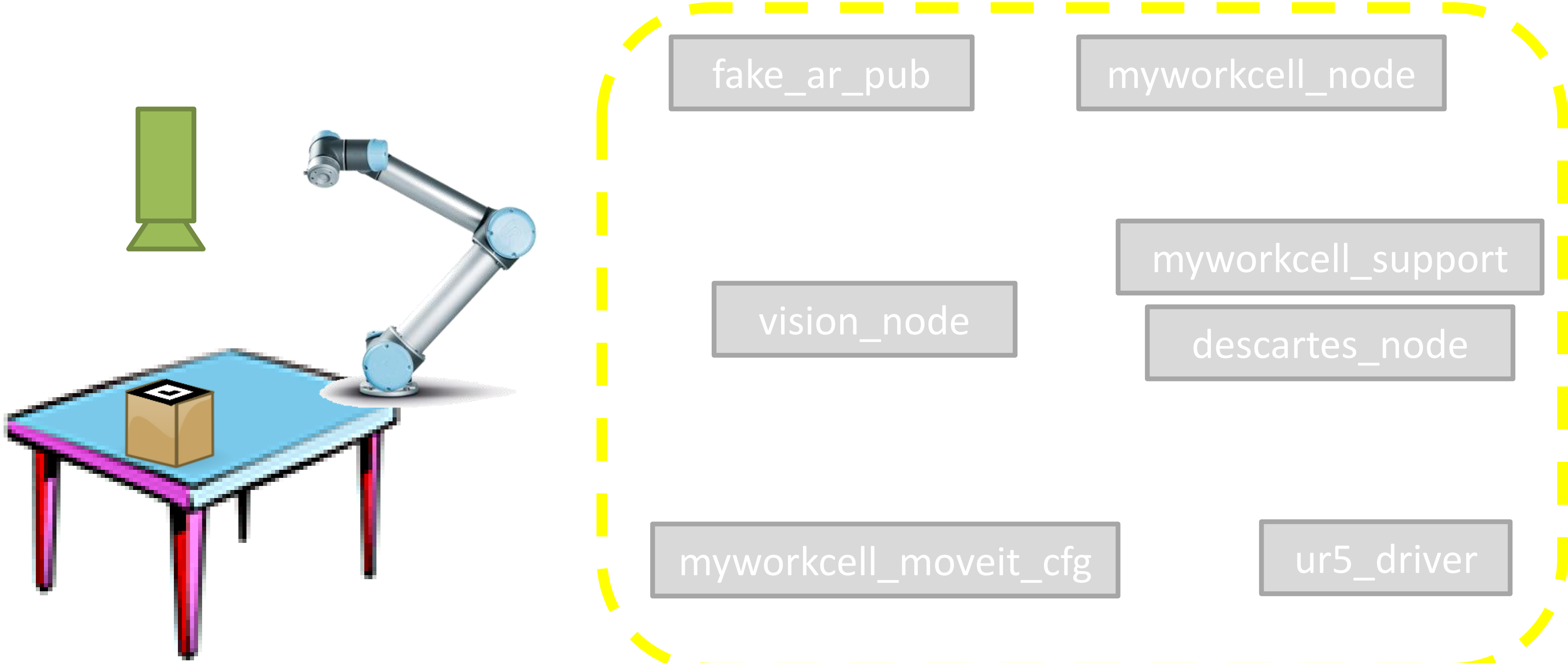
- Always run from the workspace root
- Source workspaces of any dependencies before running build.
  - e.g. source /opt/ros/humble/setup.bash
- Can chain multiple workspaces together:
  - base humble -> pcl_ws -> my_ws
- Don’t run from a terminal where you have “sourced” this workspace’s setup file (can 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

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
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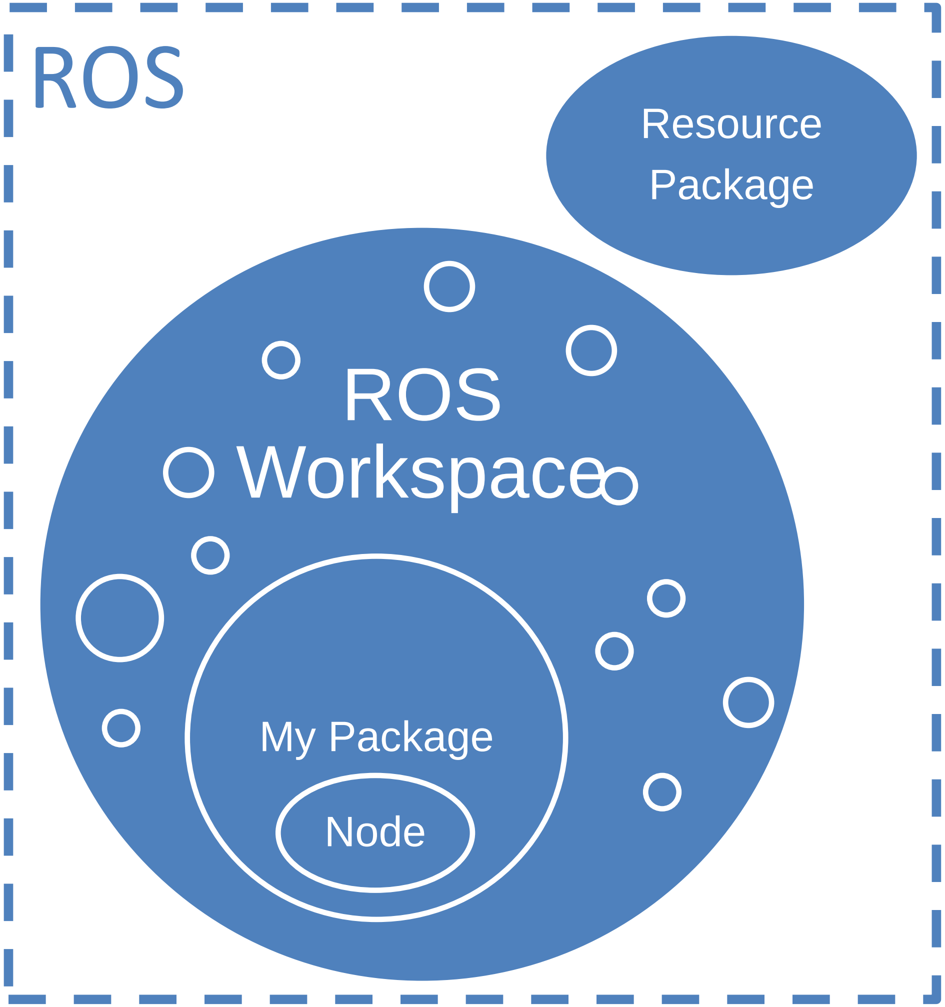


Add 3rd-Party Packages

(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*

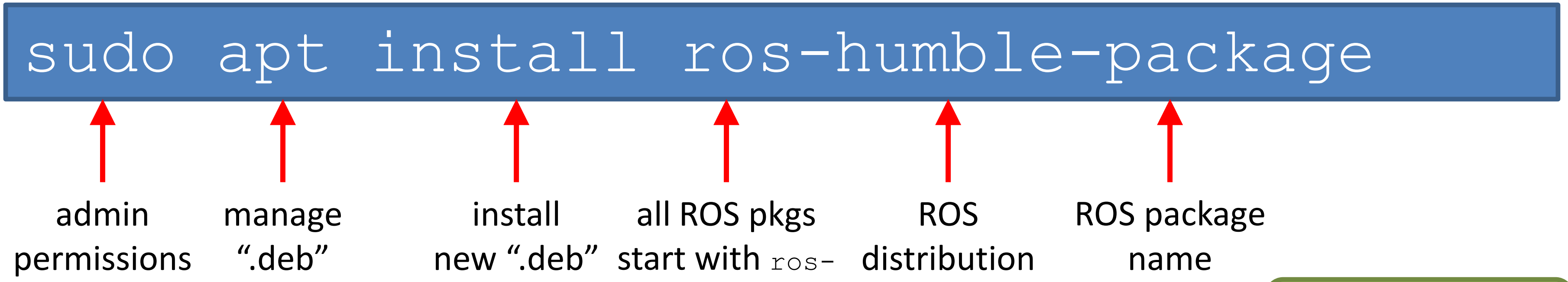
Can mix both options, as needed

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!
  - Migrating to https://robotics.stackexchange.com

Install using Debian Packages



```
sudo apt install ros-humble-package
```

admin permissions

manage ".deb"

install new ".deb"

all ROS pkgs start with `ros-`

ROS distribution

ROS package name

Use "-" not "_"

- Fully automatic install:
  - Download .deb package from central ROS repository
  - Copies files to standard locations (`/opt/ros/humble/...`)
  - ➢ 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 colcon workspace

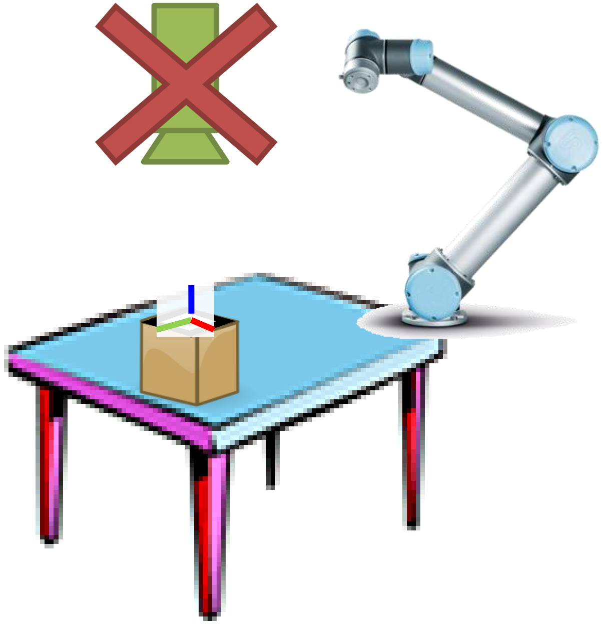
```
cd ros_ws
colcon build
```

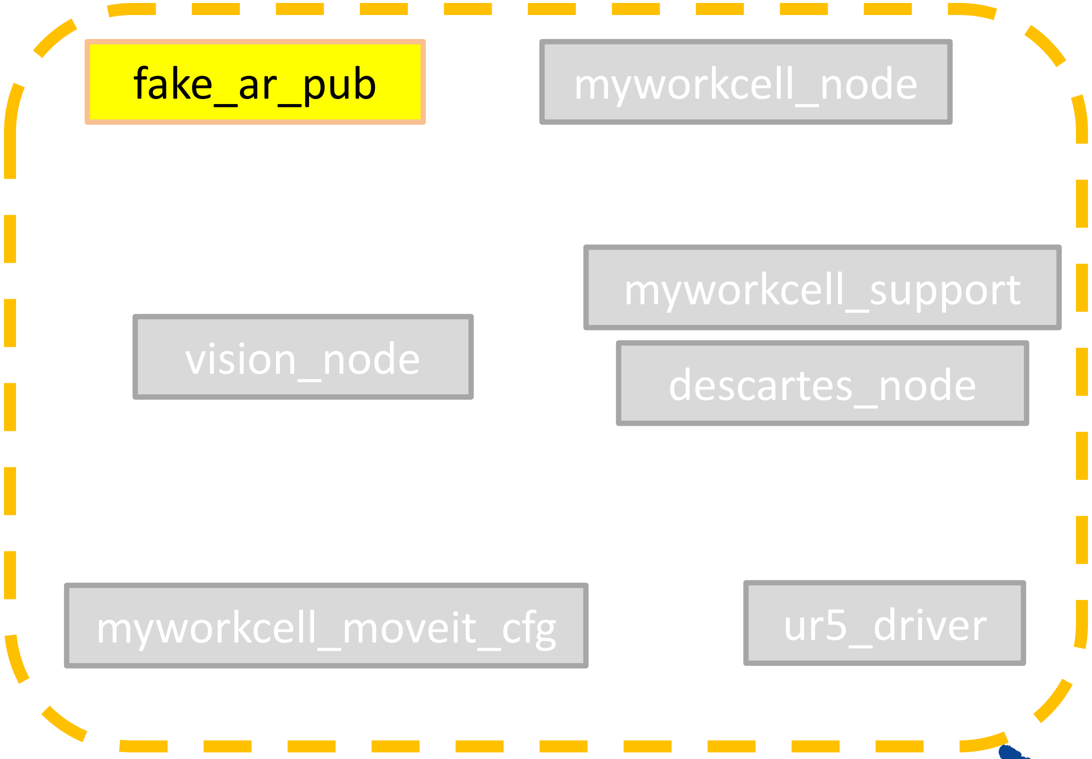
- Now the package and its resources are available to you

Exercise 1.2

Exercise 1.2

Install “resource” packages





fake_ar_pub

myworkcell_node

myworkcell_support

vision_node

descartes_node

myworkcell_moveit_cfg

ur5_driver

Day 1 Progression

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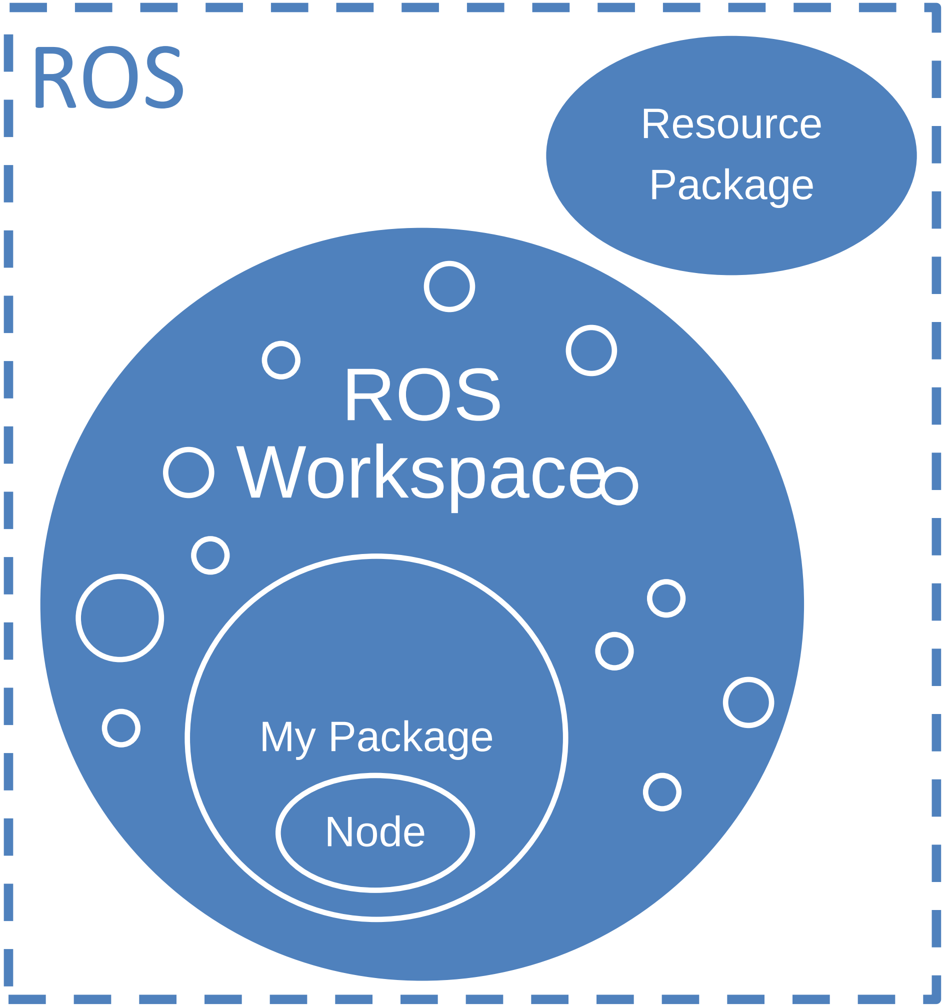
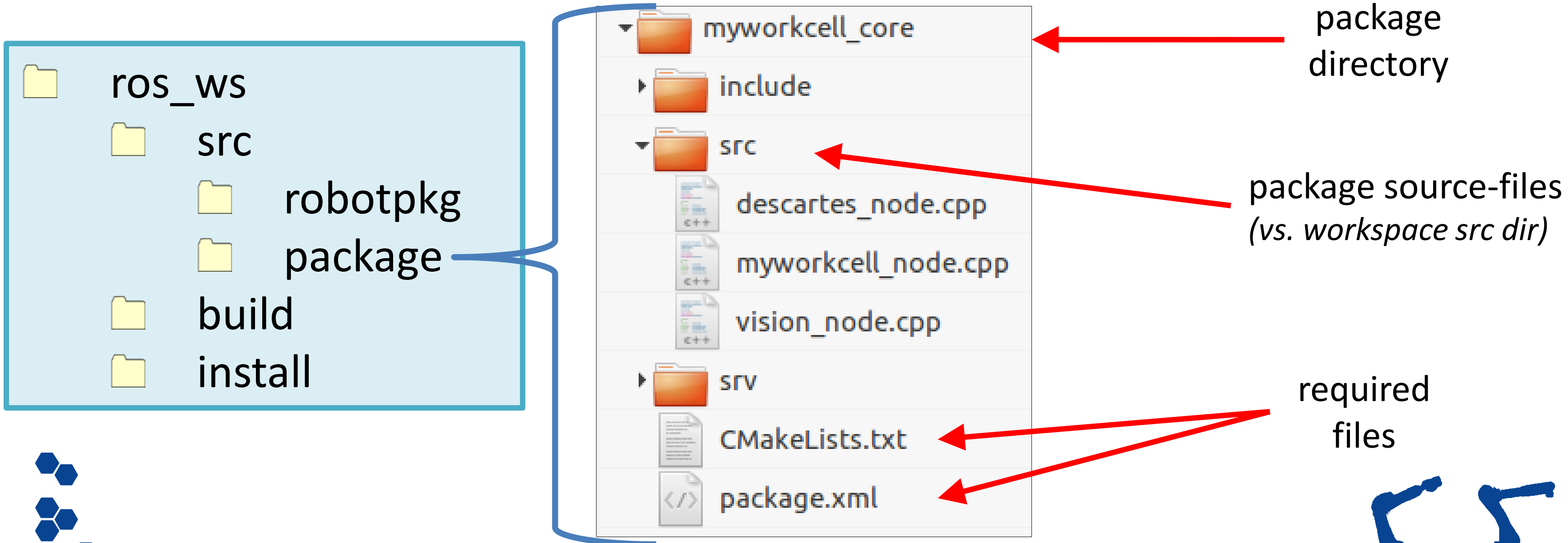


ROS Packages

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 ament



ros_ws
- src
  - robotpkg
  - package
- build
- install

myworkcell_core
- include
- src
  - descartes_node.cpp
  - myworkcell_node.cpp
  - vision_node.cpp
- srv
- CMakeLists.txt
- package.xml

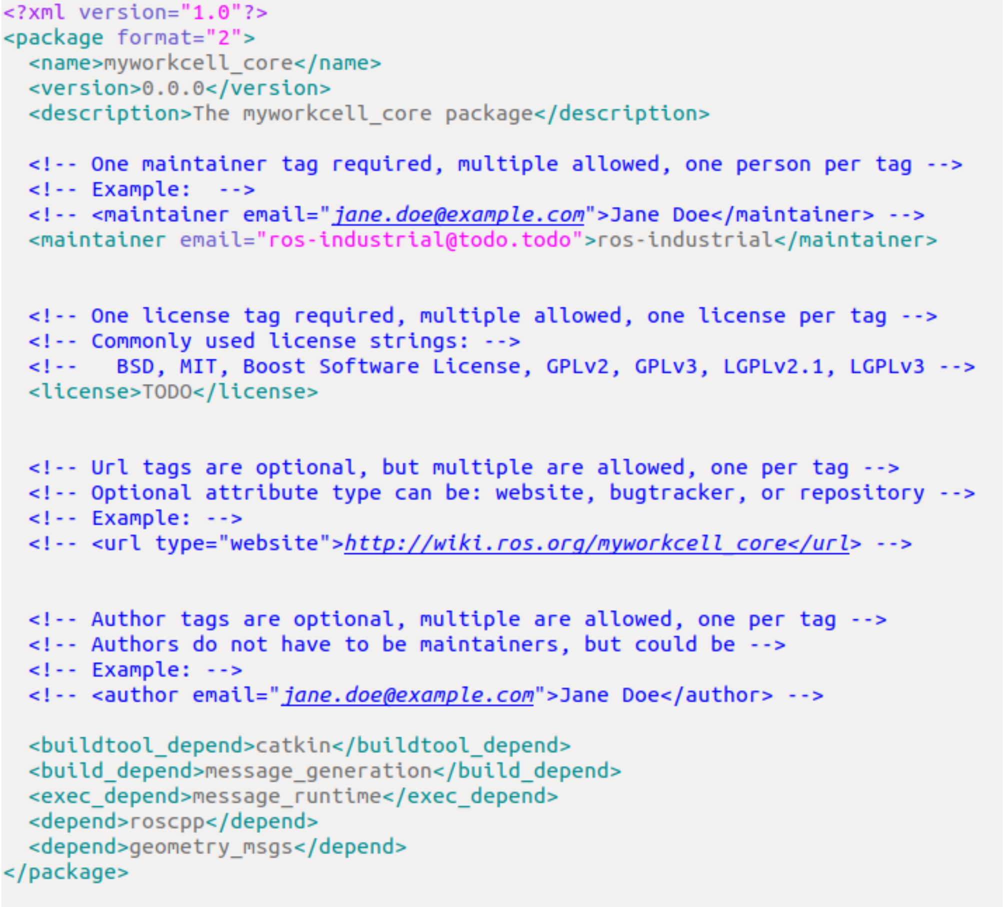
package directory

package source-files
(vs. workspace src dir)

required files

package.xml

- Metadata: name, description, author, license …



```xml
<?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>
```

package.xml

- 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.

CMakeLists.txt

- 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

ROS Package Commands

- **`ros2 pkg`**
  - `ros2 pkg create package_name`

    Create a new package, including template files

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

    ```
    --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

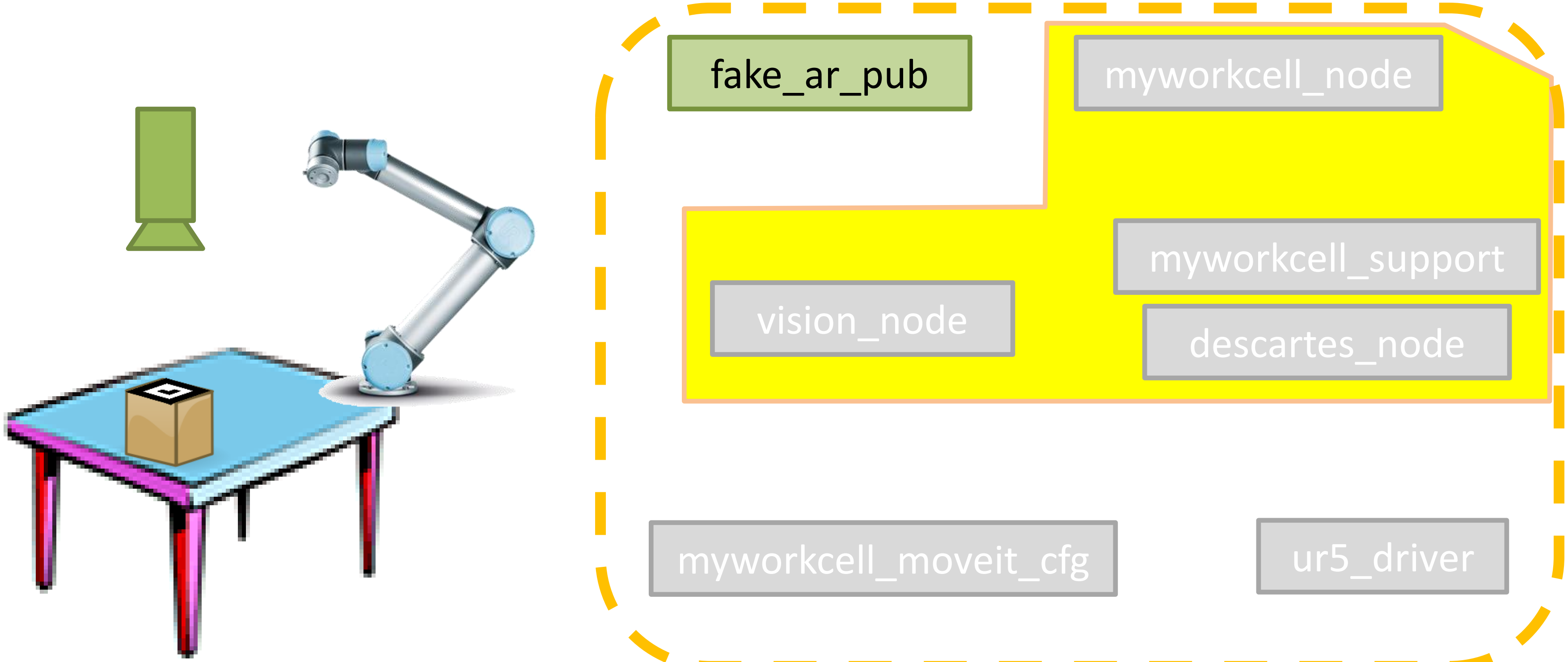
```
ros2 pkg create mypkg --node-name mynode
                      --dependencies dep1 dep2
```

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

Create Package



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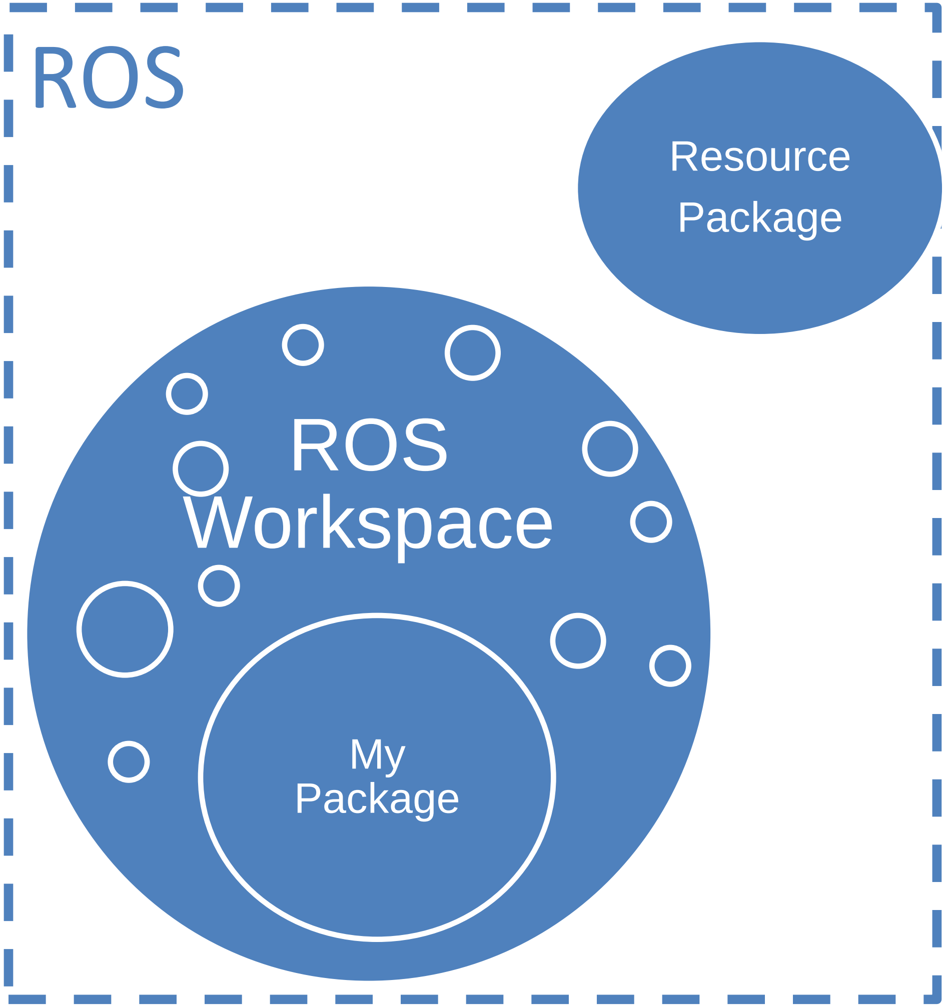


ROS Nodes

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.)

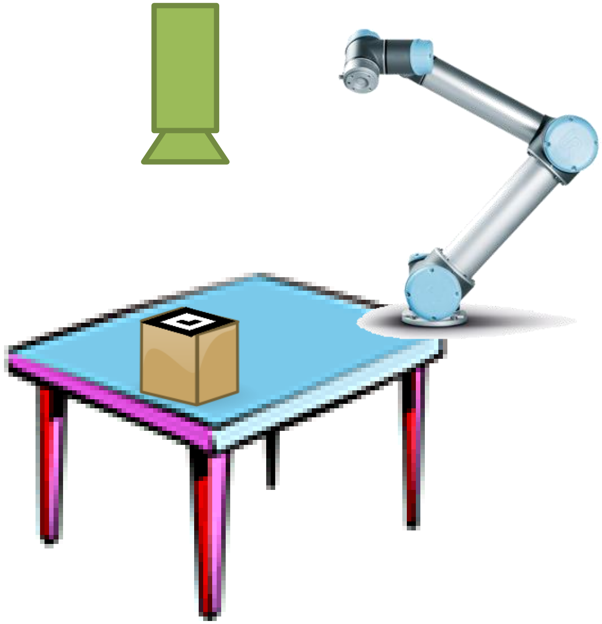
Exercise 1.3.2

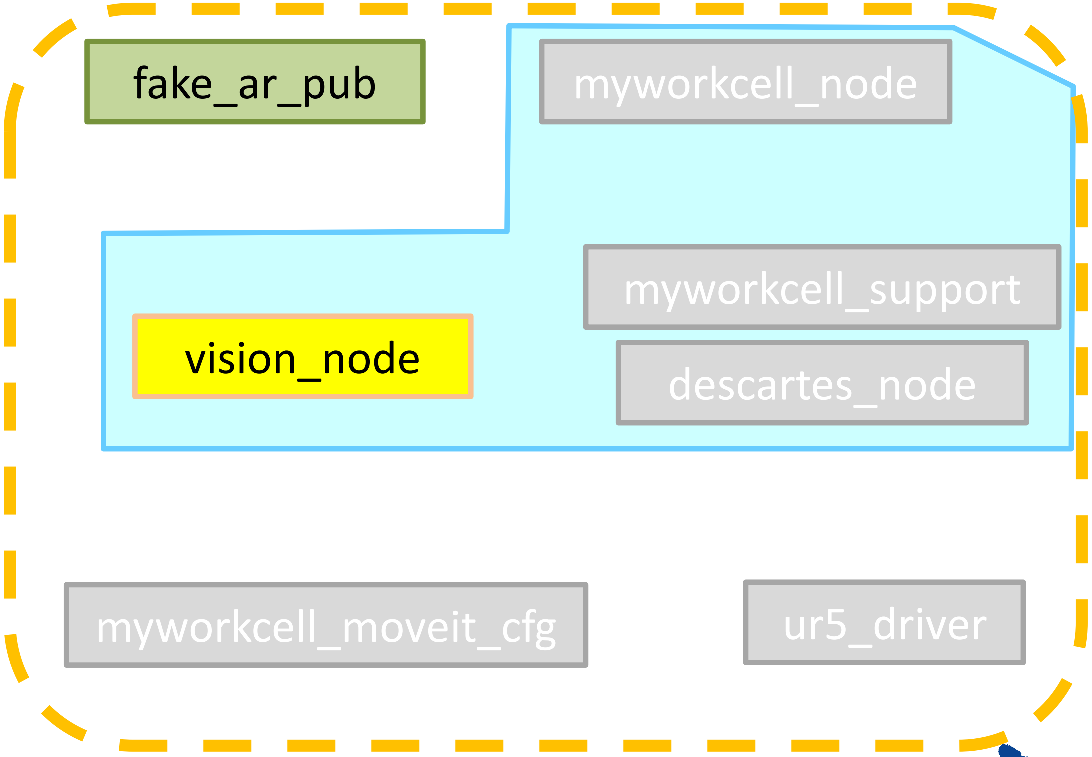
Exercise 1.3.2

Create a Node:

In myworkcell_core package

called vision_node





fake_ar_pub

myworkcell_node

vision_node

myworkcell_support

descartes_node

myworkcell_moveit_cfg

ur5_driver

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    - ❑ Services
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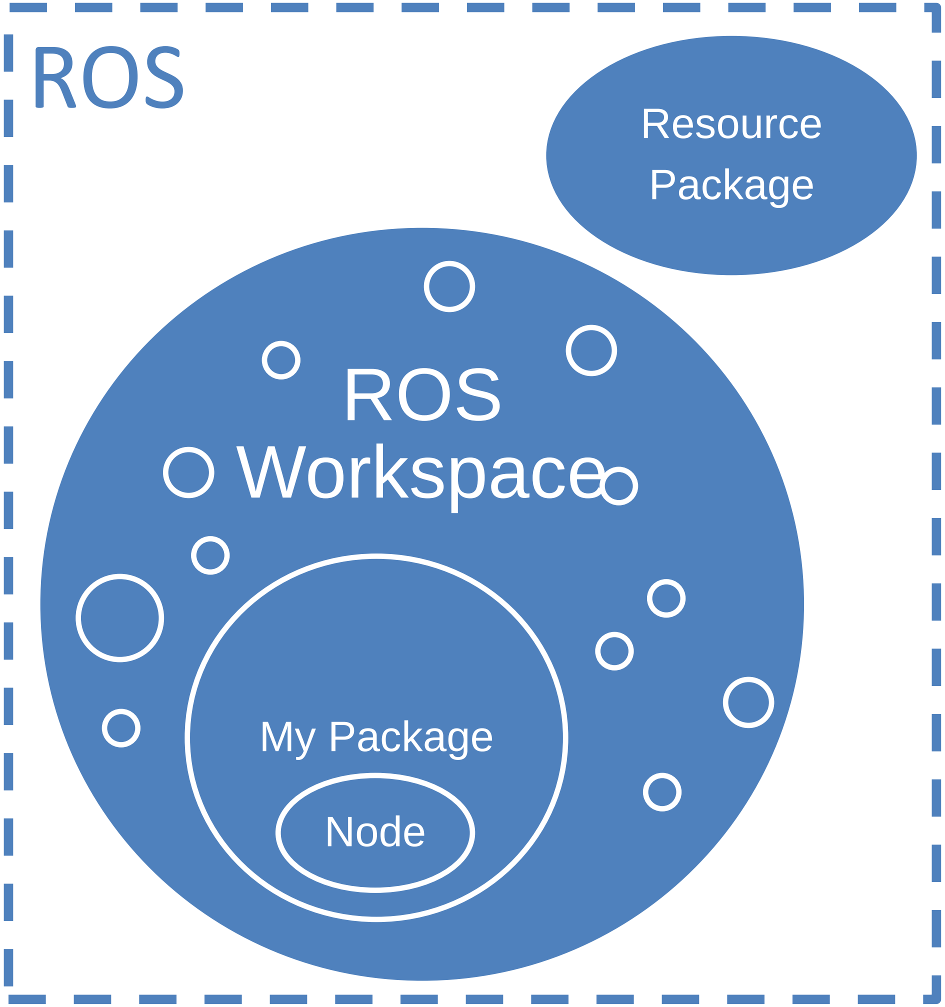
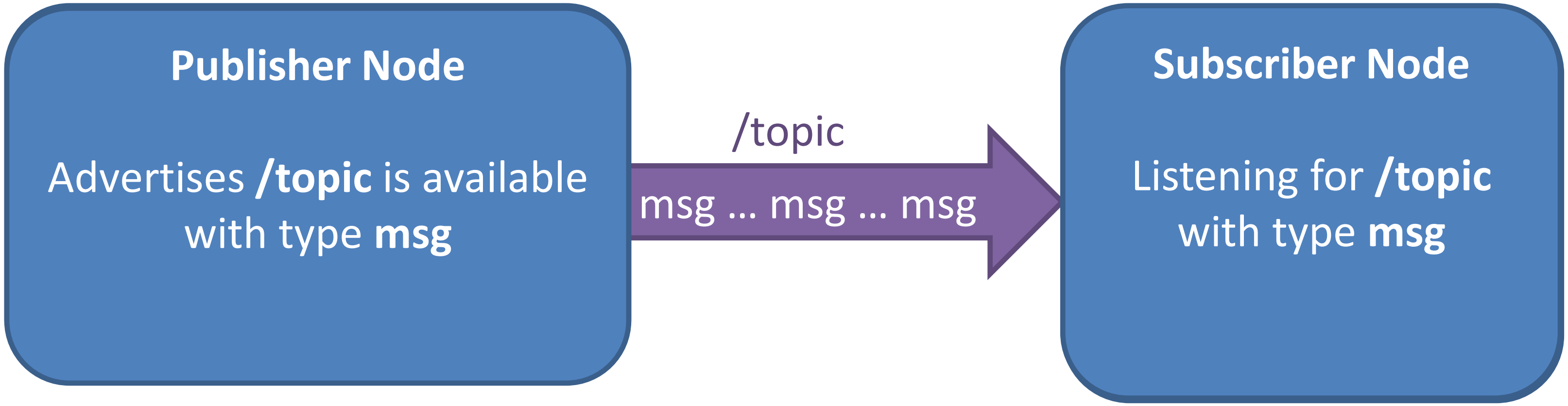
  - ✓ ros2 run
  - ❑ ros2 launch



Topics and Messages

ROS Topics/Messages

Topics are for **Streaming Data**



Publisher Node

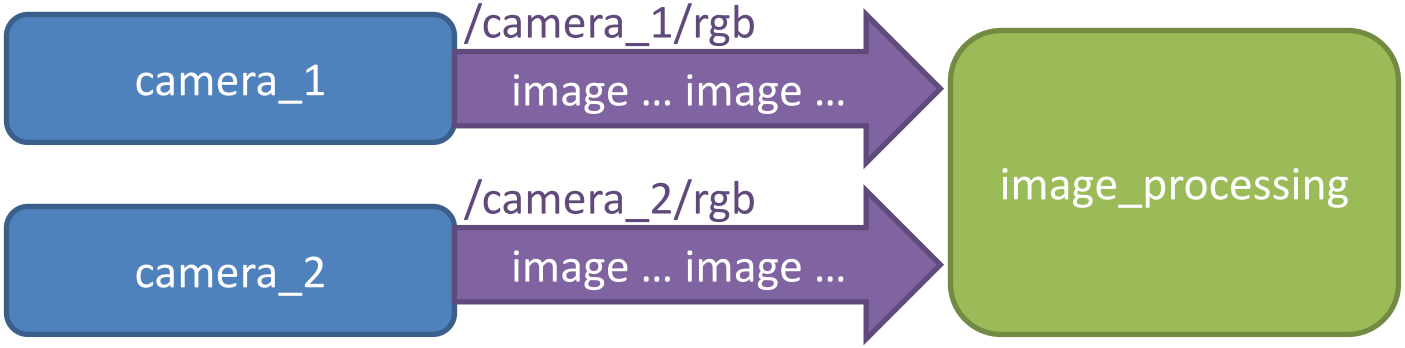
Advertises **/topic** is available with type **msg**

Subscriber Node

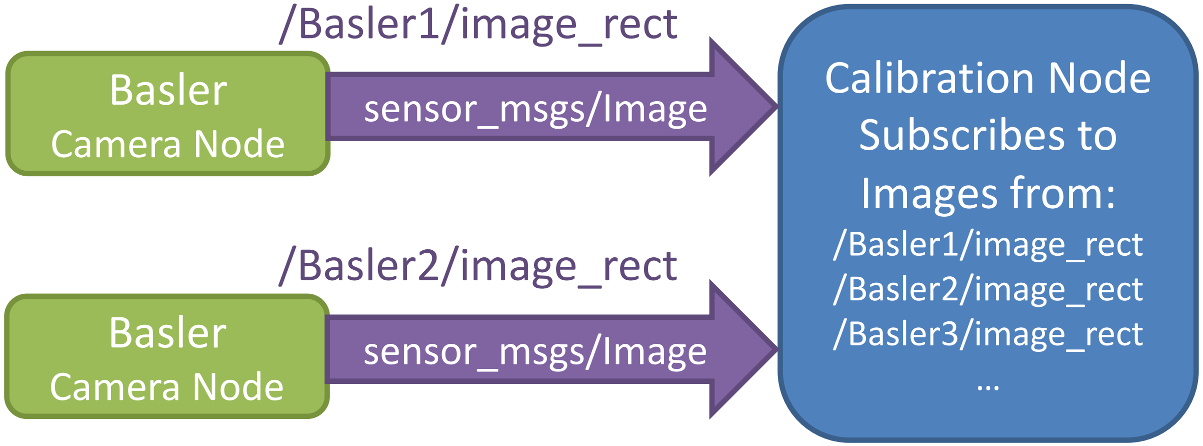
Listening for **/topic** with type **msg**

Topics vs. Messages

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



Practical Example



/Basler1/image_rect

Basler Camera Node

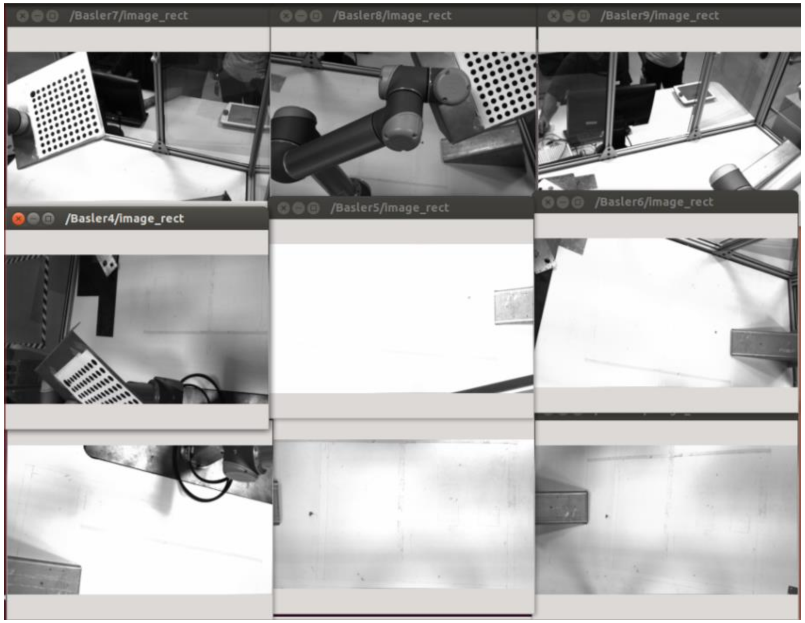
sensor_msgs/Image

/Basler2/image_rect

Basler Camera Node

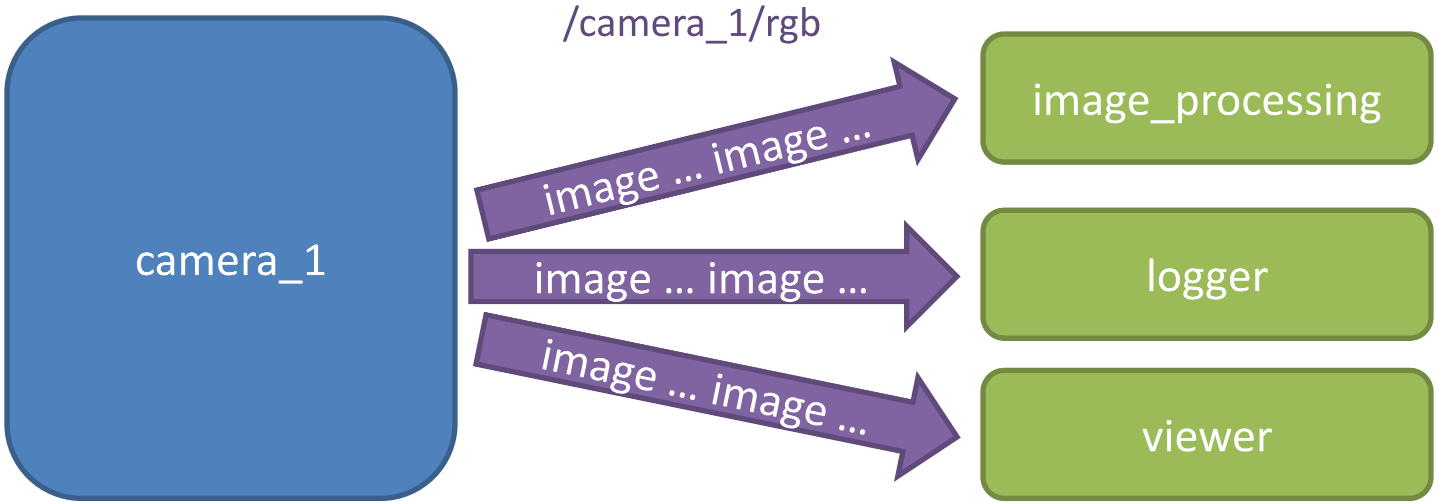
sensor_msgs/Image

Calibration Node Subscribes to Images from:
/Basler1/image_rect
/Basler2/image_rect
/Basler3/image_rect
…



Multiple Pub/Sub

- Many nodes can pub/sub to same topic
  - – communications 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 communication 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

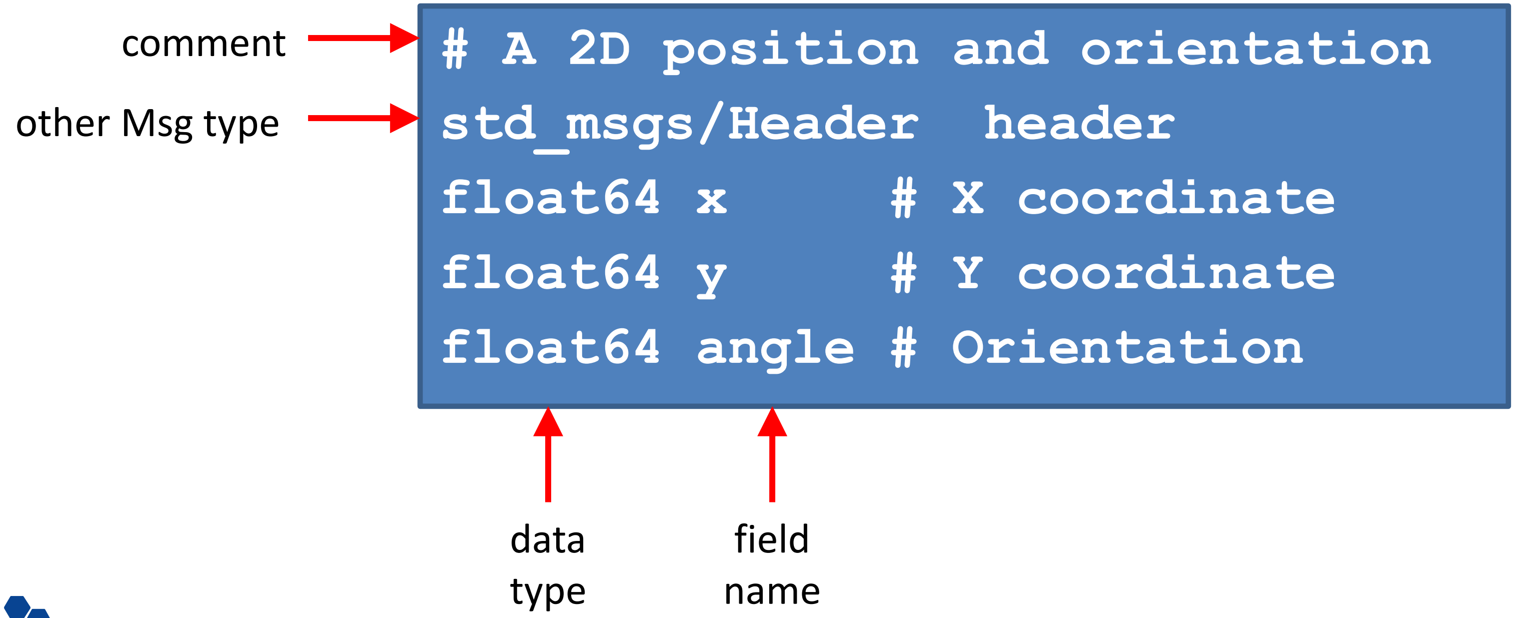
ROS Messages Types

- 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

Message Description File

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

PathPosition.msg



```
# A 2D position and orientation
std_msgs/Header  header
float64 x      # X coordinate
float64 y      # Y coordinate
float64 angle # Orientation
```

comment

other Msg type

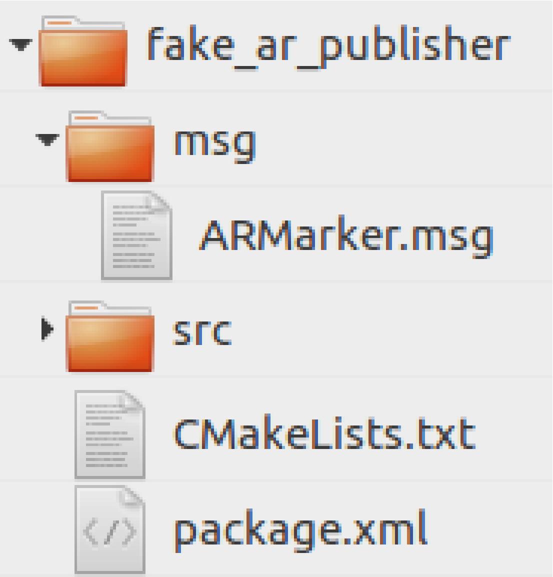
data type

field name

Custom ROS Messages

- Custom message types are defined in `msg` subfolder of packages

- Modify `CMakeLists.txt` to enable message generation.



```
fake_ar_publisher
  msg
    ARMarker.msg
  src
  CMakeLists.txt
  package.xml
```

CMakeLists.txt

- Lines needed to generate custom msg types

```
find_package(rosidl_default_generators
 REQUIRED)

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

package.xml

<build_depend> **rosidl_default_generators** </build_depend>

<exec_depend>**rosidl_default_runtime**</exec_depend>

<member_of_group>**rosidl_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

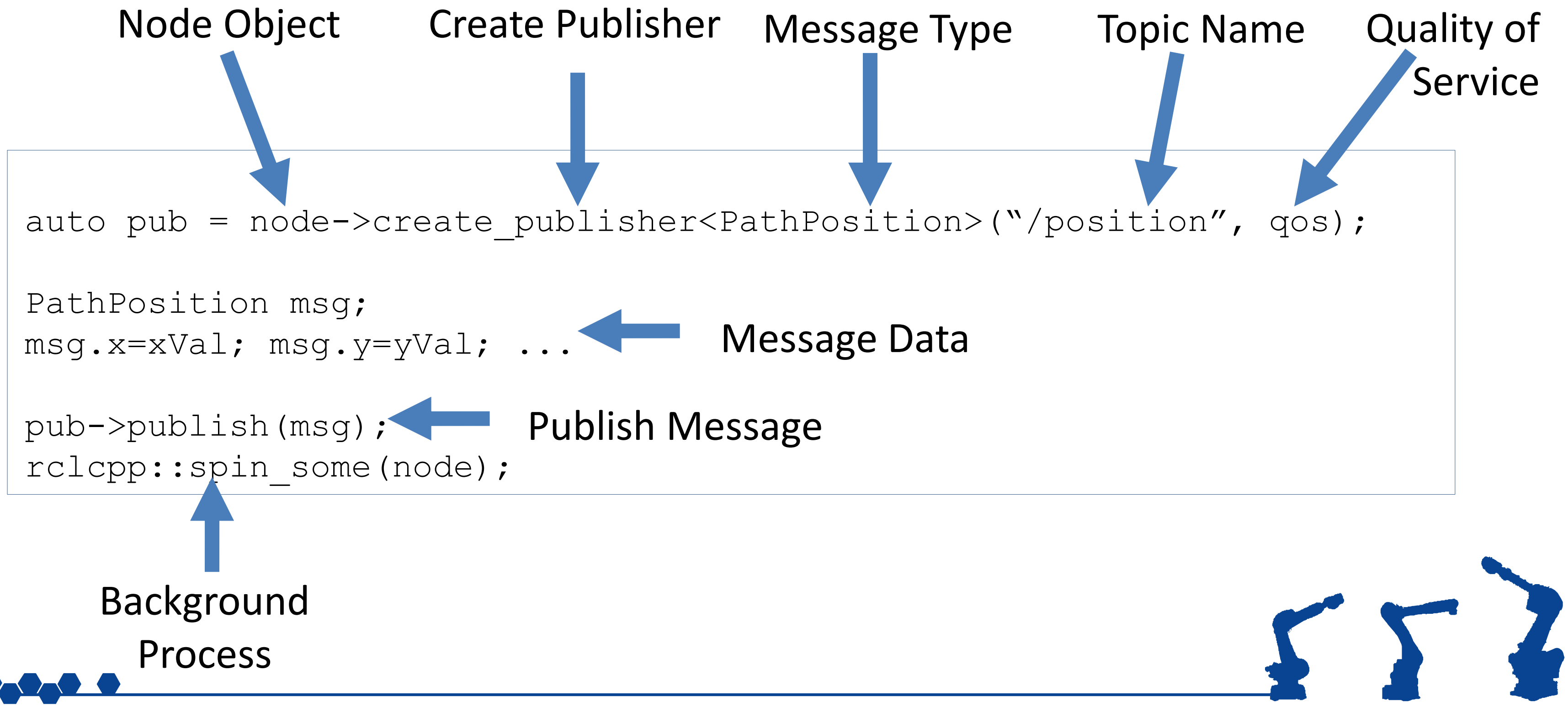
- `ros2 topic list`
  - List all topics currently subscribed to and/or publishing
- `ros2 topic type <topic>`
  - Show the message type of the topic
- `ros2 topic info <topic>`
  - Show topic message type, subscribers, publishers, etc.
- `ros2 topic echo <topic>`
  - Echo messages published to the topic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

Topics: Syntax

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



Node Object

Create Publisher

Message Type

Topic Name

Quality of Service

```
auto pub = node->create_publisher<PathPosition>(“/position”, qos);

PathPosition msg;
msg.x=xVal; msg.y=yVal; ...

pub->publish(msg);
rclcpp::spin_some(node);
```

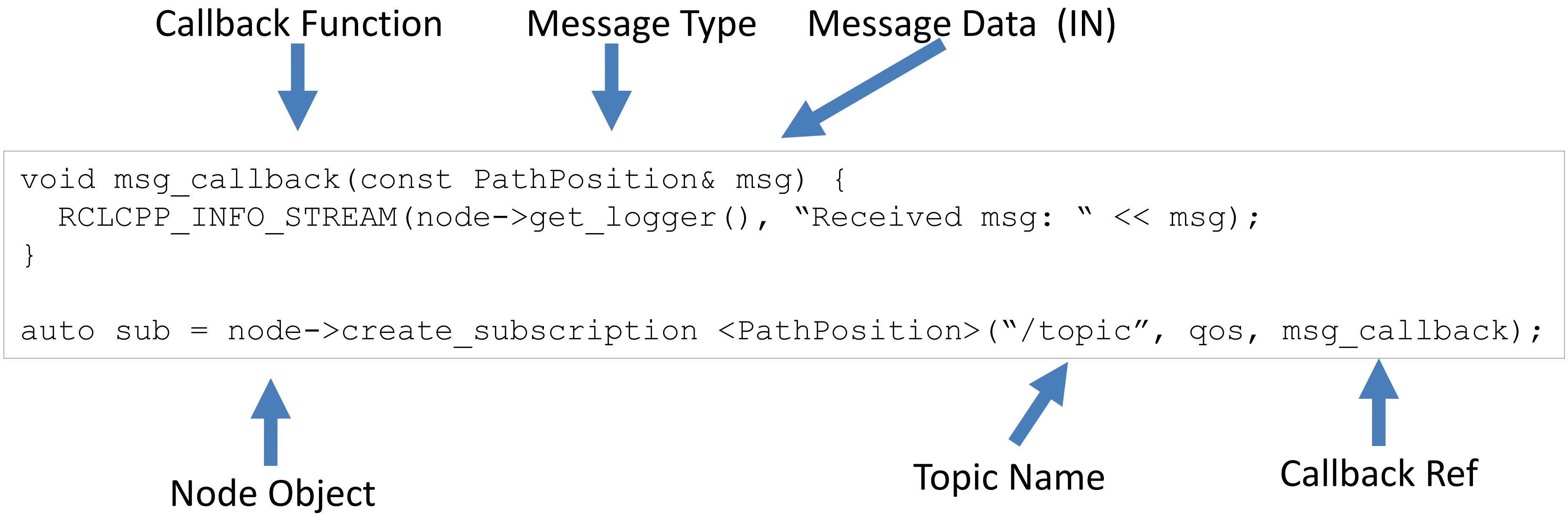
Message Data

Publish Message

Background Process

Topics: Syntax

- 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 <PathPosition>(“/topic”, qos, msg_callback);
```

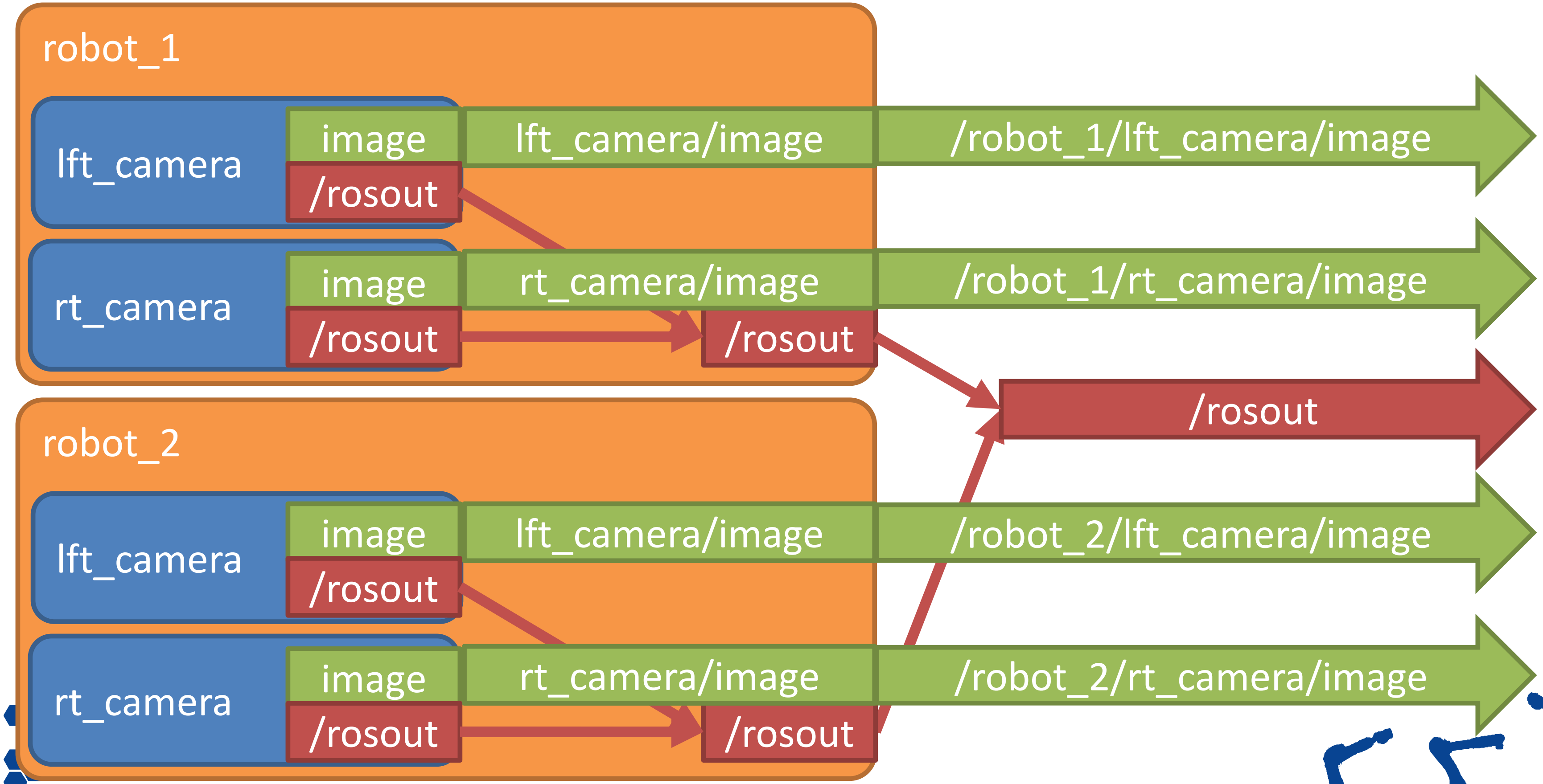
Node Object

Topic 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*



Qt

Instead of text editor and building from terminal…

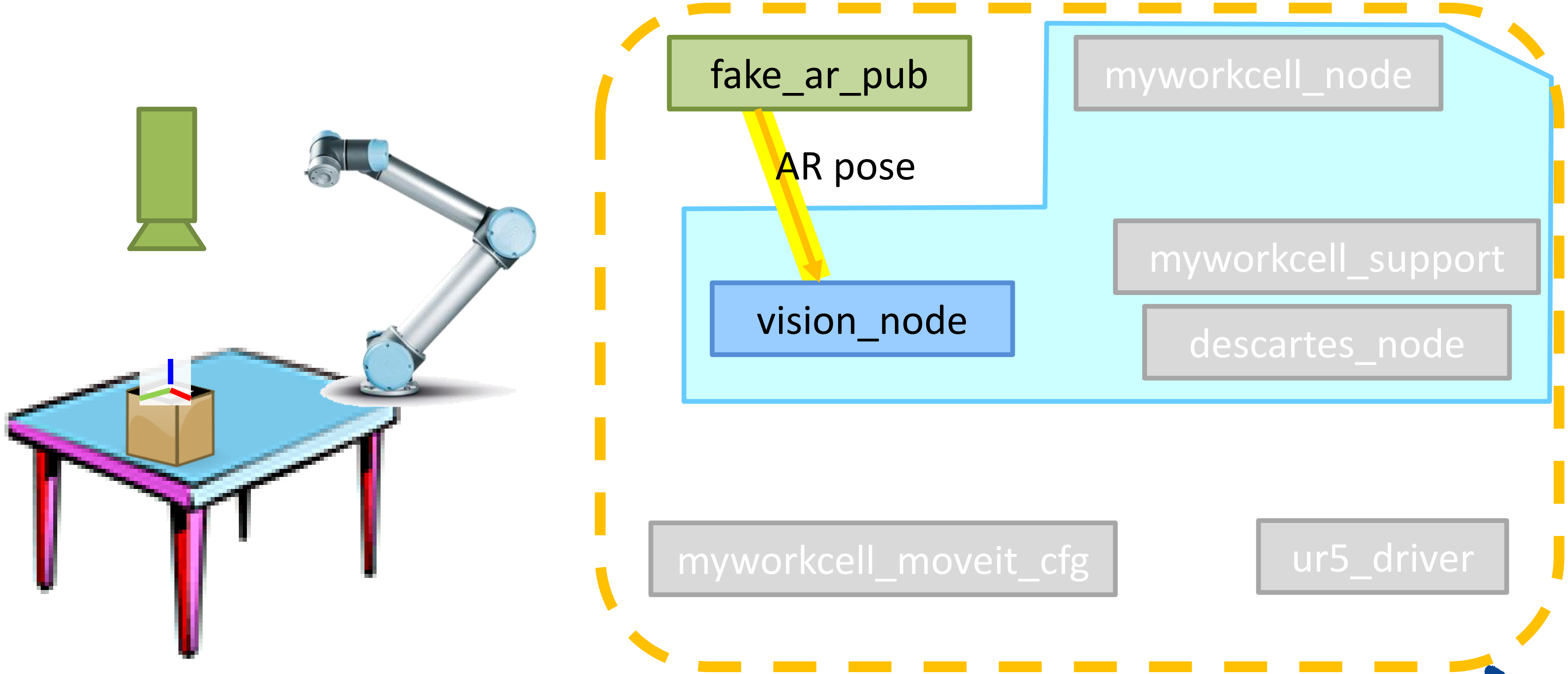
Use an IDE! (detailed instructions here)

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



fake_ar_pub

AR pose

vision_node

myworkcell_node

myworkcell_support

descartes_node

myworkcell_moveit_cfg

ur5_driver