ROS programming, testing, continuous integration

ROS Training for Industry: Day 3

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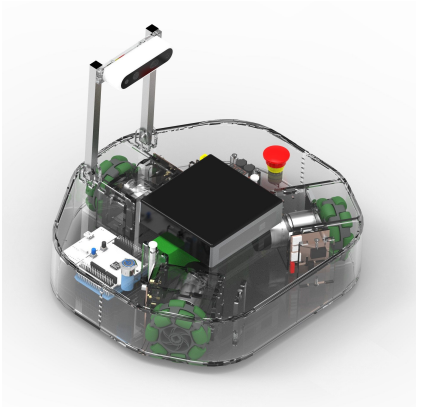
18.09.2019

Tartu, Estonia



Agenda: Day 3 (18.09)

- 09:15 Hardware & drivers
- 10:15 Coffee Break
- 10:30 Workshop: Implementing ROS driver for Custom Hardware
  - Write driver for Arduino Sonar
  - Publish sonar range, IMU orientation, and visualize in RViz
- 12:00 Lunch Break
- 13:00 ROS Testing Tools & Continuous Integration
- 14:30 Coffee Break
- 14:45 Workshop
  - write tests and documentation for the ongoing package
  - 17:00 End of Day 3

Hardware & drivers

Overview

- Defining the Problem
- Common ROS Tools
  - ROS Control
  - Nodelets
  - ROSSerial
- Third party libraries

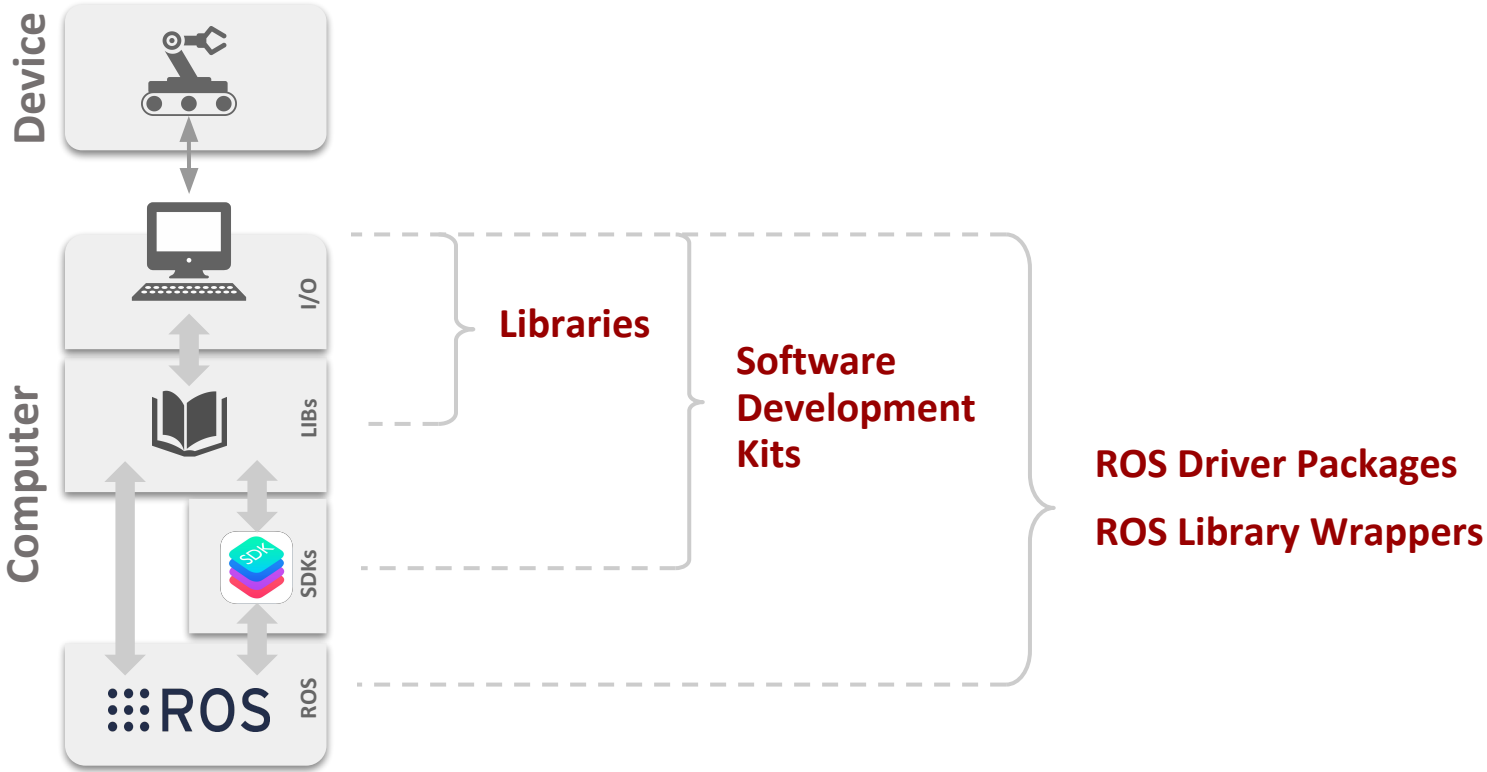
Defining the Problem

Defining the Problem

- **Type of device**
  - Sensor
  - Actuator
  - Combined
- **Type of data**
  - Protocol
  - Speed
  - Amount

- **Available tools**
  - Driver packages
  - Control packages
  - Peripheral libraries
  - Computation tools

Defining the Problem - don't reinvent the wheel



Defining the Problem - Architecture

- **Asynchrony**
  - Loops → *produce/process data*
  - Callbacks → receive/*handle data*
  - Interrupts
- **Threading**
  - Multi threaded → *efficiency*
  - Multi process → *modularity*

Common ROS Tools

Standard solutions for standard problems

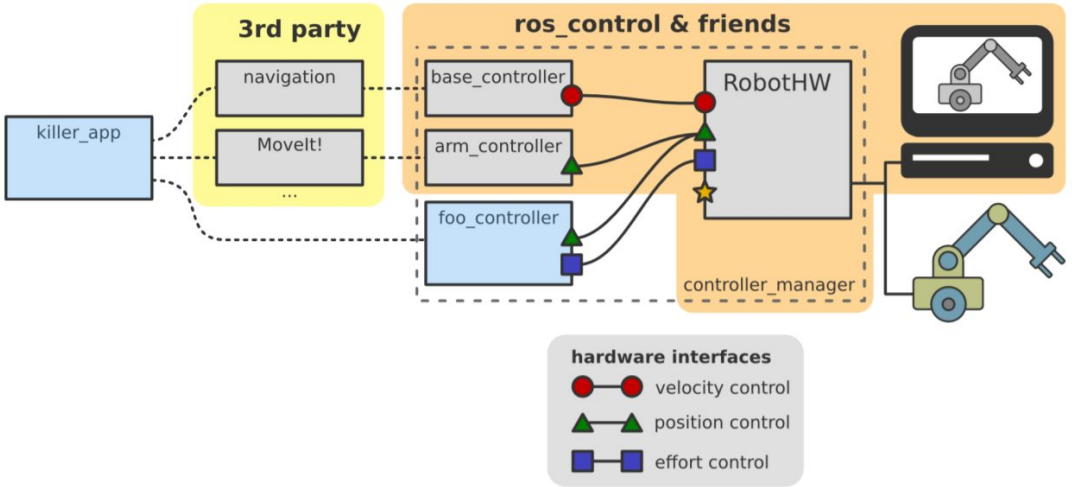
Common ROS Tools - ROS Control

- Standardizes controller infrastructure
- Offers base implementations for common controller types
  - joint _state_controller
  - diff_drive_controller

Adolfo Rodríguez: ROSCon 2014

Common ROS Tools - ROS Control

- Existing controllers
- Custom controllers
- Custom hardware backend
- Abstract interfaces



Adolfo Rodríguez: ROSCon 2014

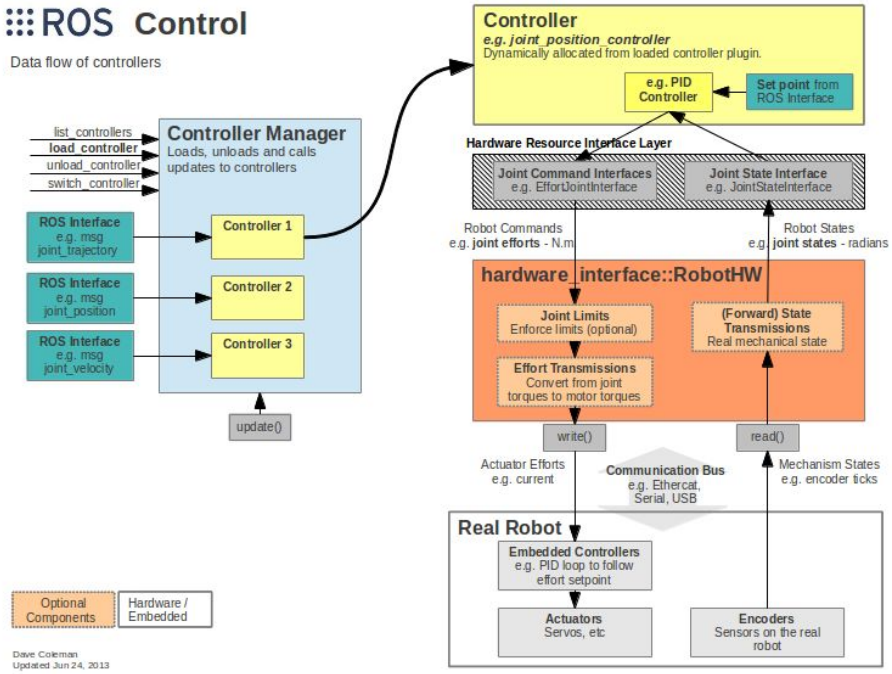
Common ROS Tools - ROS Control

ros_control handles two things from that process:

- receiving the goals (effort, position, velocity, trajectory, etc.)
- running the PID controllers

ros_control doesn't know or handle:

- implementing hardware control (sending current to motors)
- reading hardware state

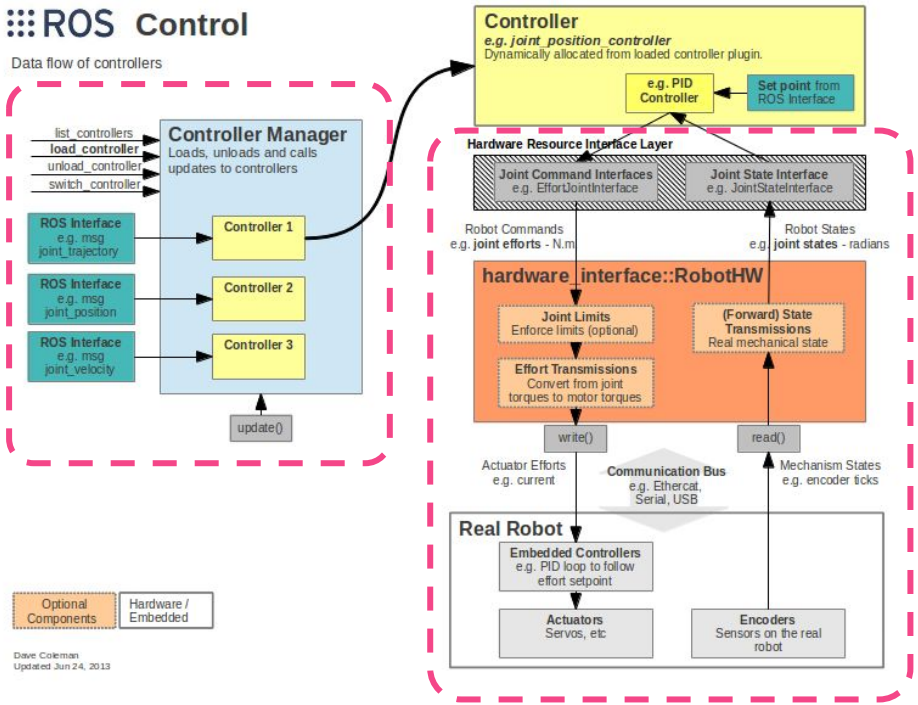


http://wiki.ros.org/ros_control

Common ROS Tools - ROS Control

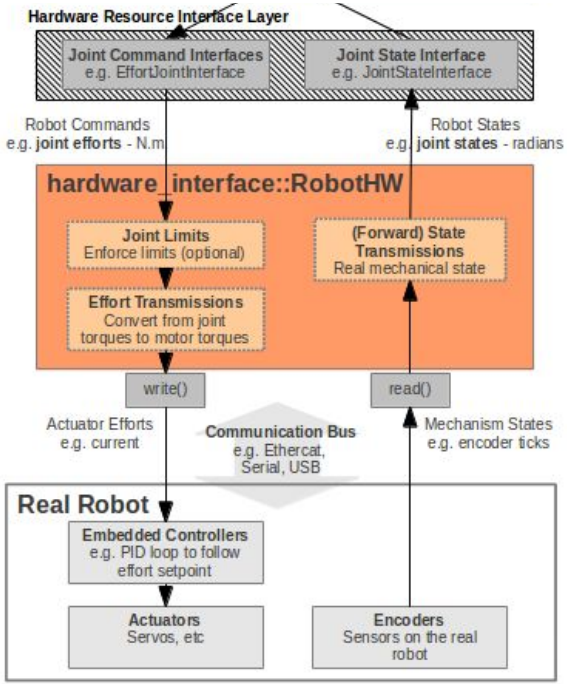
Configured

http://wiki.ros.org/ros_control



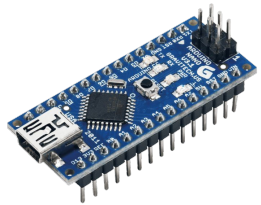
Implemented/ coded

Common ROS Tools - ROS Control

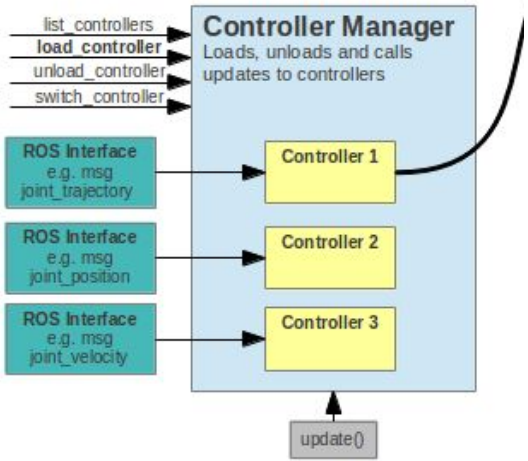


http://wiki.ros.org/ros_control

```
class ServoHardwareInterface: public hardware_interface::RobotHW
{
Public:
  JointStateInterface joint_state_interface_;
  PositionJointInterface joint_position_interface_;
  ServoHardwareInterface();
  void init();
  void update(const ros::TimerEvent& e);
  void read();
  void write(ros::Duration elapsed_time);
};
```



Common ROS Tools - ROS Control

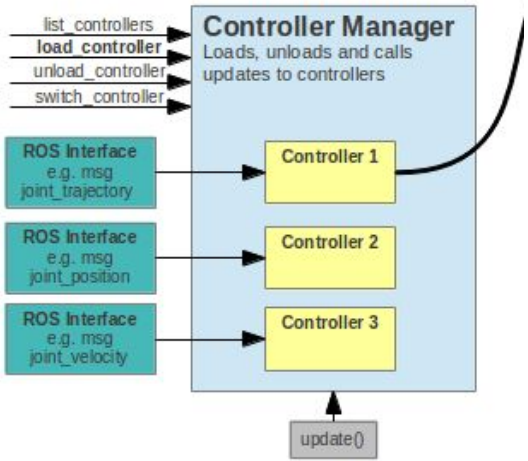


http://wiki.ros.org/ros_control

controllers YAML

```yaml
ROBOT:
  controller:
    state:
      type: joint_state_controller/JointStateController
      publish_rate: 50
    position:
      servo_joint_0:
        type: position_controllers/JointPositionController
        joint: servo_joint_0
        pid: {p: 10.0, i: 0.0, d: 1.0}
```

Common ROS Tools - ROS Control

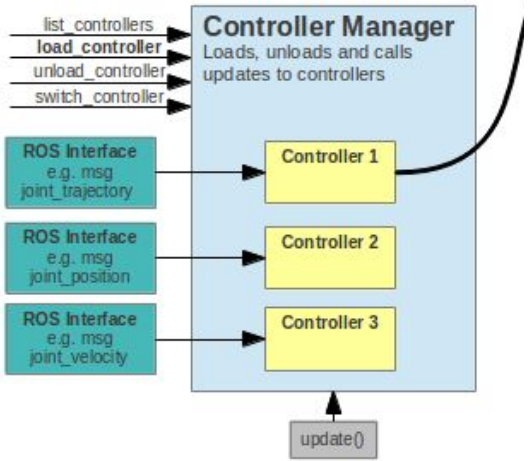


http://wiki.ros.org/ros_control

hardware YAML

```
ROBOT:
  hardware_interface:
     loop_hz: 50 # hz
     joints:
       - servo_joint_0
```

Common ROS Tools - ROS Control



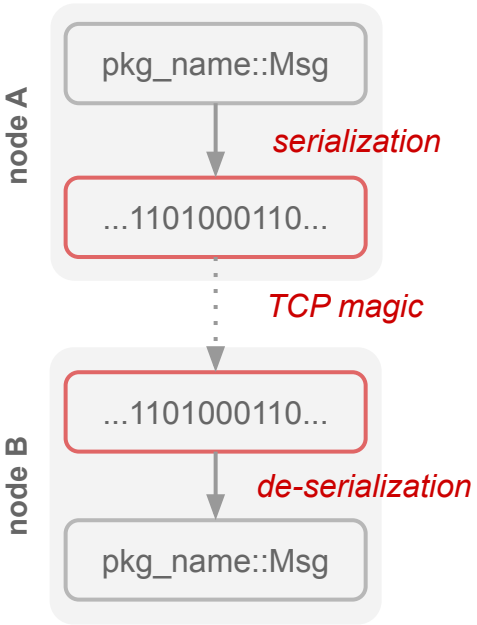
http://wiki.ros.org/ros_control

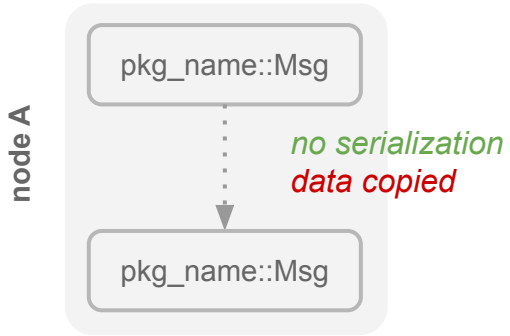
joint_limits YAML

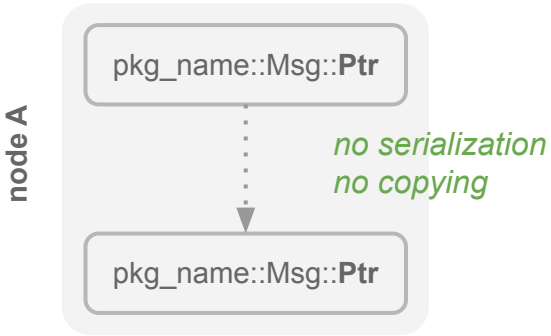
```
joint_limits:
  servo_joint_0:
    has_position_limits: true
    min_position: 0.02
    max_position: 3.14
    has_velocity_limits: true
    max_velocity: 2.0
    ...
```

Common ROS Tools - Nodelets

First … a bit about **sending messages in ROS**

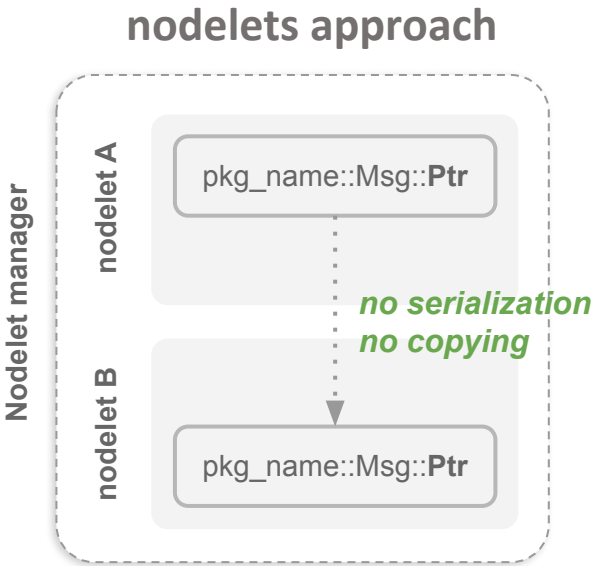


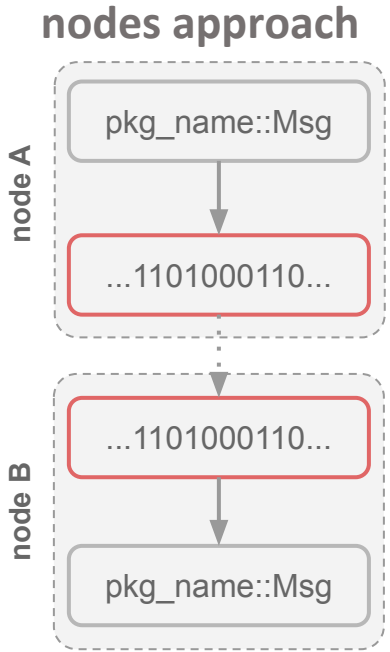




Common ROS Tools - Nodelets

Nodelets help to maintain **modularity without losing efficiency**





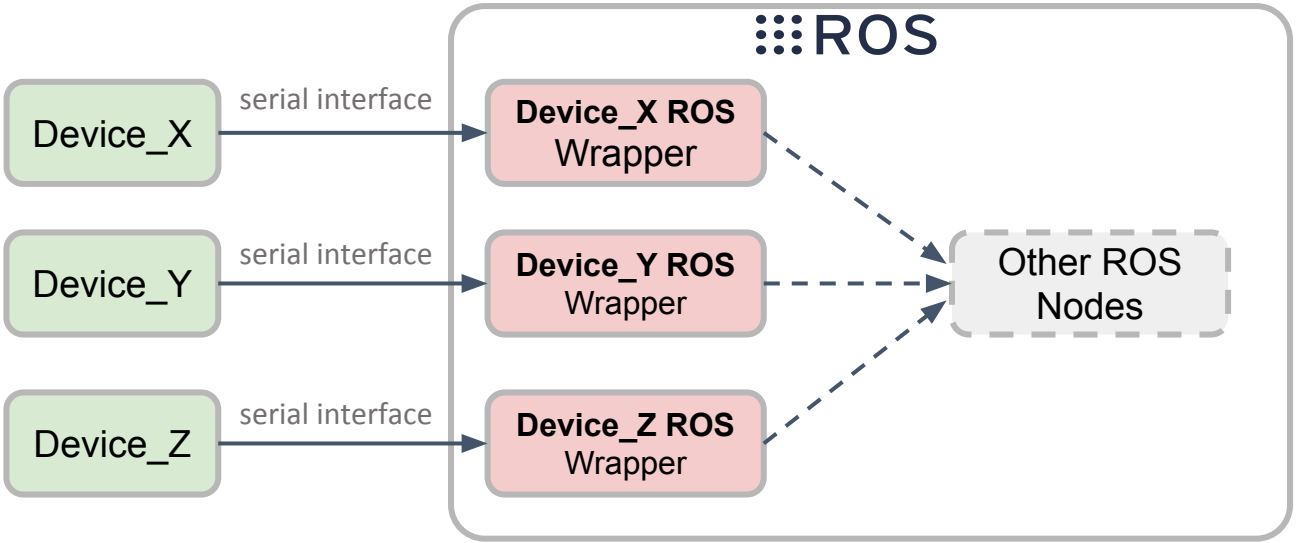
Common ROS Tools - Nodelets

What is it good for?

- Image processing pipelines
- Point cloud processing pipelines

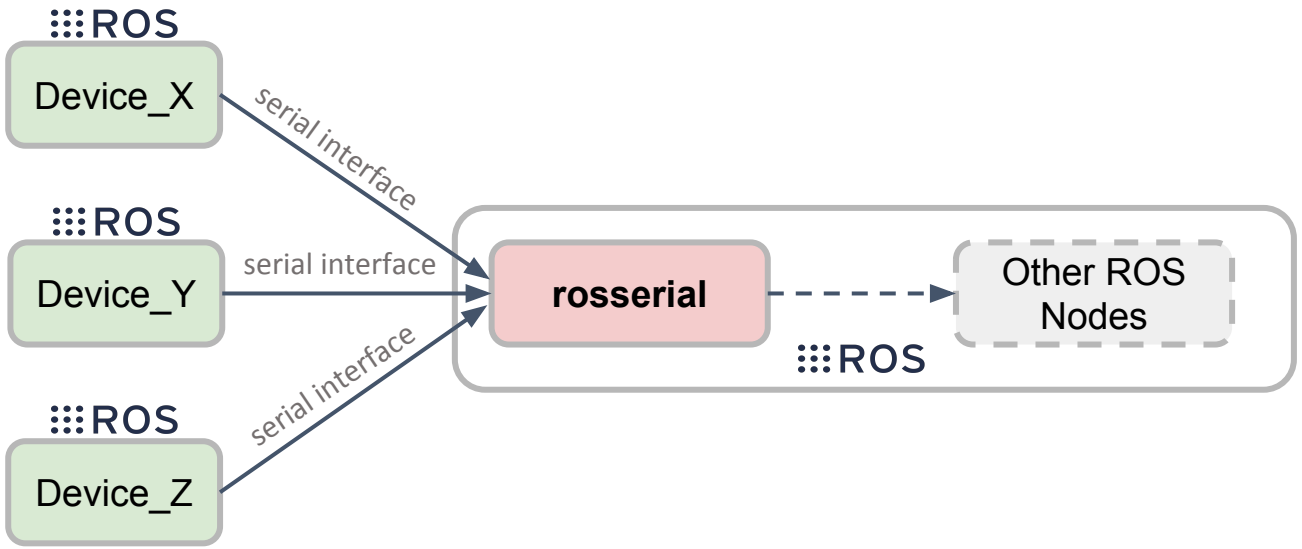
Rosserial - Concept

Regular approach for interfacing Device_X/Y/Z with ROS



Rosserial - Concept

Using rosserial on your Device_X/Y/Z + rosserial node on PC



Rosserial - Platforms

rosserial_arduino	support for Arduino compatible boards including UNO, Leonardo, MEGA, DUE, Teensy 3.x and LC, Spark, STM32F1, STM32Duino, ESP8266 and ESP32
rosserial_embeddedlinux	support for Embedded Linux (eg, routers)
rosserial_windows	support for communicating with Windows applications
rosserial_mbed	support for mbed platforms
rosserial_tivac	support for TI's Launchpad boards, TM4C123GXL and TM4C1294XL
rosserial_vex_v5	support for VEX V5 Robot Brain
rosserial_vex_cortex	support for VEX Cortex board
rosserial_stm32	support for STM32 MCUs, based on STM32CubeMX HAL
ros-teensy	support for teensy platforms

Third Party Libraries

How to decently integrate external libraries

Third Party Libraries

Library coming:

- … in its own **ROS package** (simplest case)
  - from package manager
  - from source
- … as a **non-ROS package**
- … **from non-ROS source** (trickier case)

Third Party Libraries - as bin ROS pkg

- sudo apt install ros-<distro>-**name-of-lib-package**
- In **CMakeLists.txt**
  - `find_package( catkin REQUIRED COMPONENTS <name_of_lib_package> …`
  - `CATKIN_DEPENDS <name_of_lib_package> …`
  - `include_directories( ${catkin_INCLUDE_DIRS} )`
  - `target_link_libraries( my_node ${catkin_LIBRARIES} )`
- In **package.xml**
  - `<build_depend>name_of_lib_package</build_depend>`
  - `<exec_depend>name_of_lib_package</exec_depend>`
- In **my_node.cpp**
  - `#include "name_of_lib_package/some_header_file.h"`

Third Party Libraries - as src ROS pkg

- git clone https://github.com/xyz/**name-of-lib-package.git**
- In **CMakeLists.txt**
  - `find_package( catkin REQUIRED COMPONENTS <name_of_lib_package> …`
  - `CATKIN_DEPENDS <name_of_lib_package> …`
  - `include_directories( ${catkin_INCLUDE_DIRS} )`
  - `target_link_libraries( my_node ${catkin_LIBRARIES} )`
- In **package.xml**
  - `<build_depend>name_of_lib_package</build_depend>`
  - `<exec_depend>name_of_lib_package</exec_depend>`
- In **my_node.cpp**
  - `#include "name_of_lib_package/some_header_file.h"`

Third Party Libraries - as non-ROS pkg

- sudo apt install **name-of-lib-package**
  - Pray that it has a **Config.cmake** file
- In **CMakeLists.txt**
  - `find_package( <name_of_lib_package> )`
  - `CATKIN_DEPENDS <name_of_lib_package> …`
  - `include_directories( ${catkin_INCLUDE_DIRS} )`
  - `target_link_libraries( my_node ${catkin_LIBRARIES} )`
- In **package.xml**
  - `<build_depend>name_of_lib_package</build_depend>`
  - `<exec_depend>name_of_lib_package</exec_depend>`
- In **my_node.cpp**
  - `#include "name_of_lib_package/some_header_file.h"`

Third Party Libraries - as non-ROS src

1. Either follow the instructions (if any)
   - `$ make && make install`
   - … and then continue as outlined in "**as non-ROS pkg**"
2. Or add as a **git submodule**
   - `$ git submodule add https://github.com/xyz/`**`name-of-lib-package`**`.git custom libs/`**`name-of-lib-package`**
   - `include_directories( ${catkin_INCLUDE_DIRS} custom_libs/name-of-lib-package/include)`
   - `target_link_libraries(my_node ${catkin_LIBRARIES}` **`custom_libs/name-of-lib-package/lib/libblah.so`**`)`

Workshop

Overview

- Documentation via **rosdoc**
  - Doxygen
  - Sphinx
- Unit & Integration tests via **rostest**
  - Googletest
  - rostest features
  - building tests
- Continuous Integration via **Travis CI**
  - Building packages
  - Running tests
  - Running custom build scripts

Documentation

Documentation - rosdoc

A convenience package that

- Combines common documentation tools such as
  - **doxygen**
  - **sphinx**
- Manages documentation build process via **rosdoc.yaml**

Documentation - doc generators

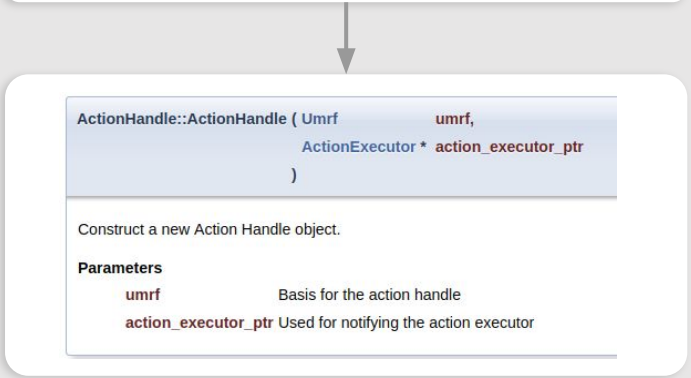
- Scan the workspace for source files
- Look for code comments in a **specific** format
- Extract as much info as indicated in the “**format-file”**
- Generate neat looking documents (html, pdf, latex, …)

Epydoc

Documentation - doc generators

C++

```
/**
 * @brief Construct a new Action Handle object
 *
 * @param umrf Basis for the action handle
 * @param action_executor_ptr Used for notifying the action executor
 */
ActionHandle(Umrf umrf, ActionExecutor* action_executor_ptr);
```



ActionHandle::ActionHandle (Umrf umrf,
ActionExecutor * action_executor_ptr
)

Construct a new Action Handle object.

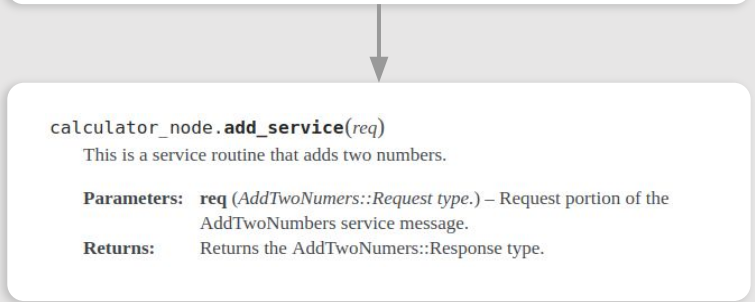
Parameters

umrf	Basis for the action handle
action_executor_ptr	Used for notifying the action executor

python

```
def add_service(req):
    """
    This is a service routine that adds two numbers.

    :param req: Request portion of the AddTwoNumbers service message.
    :type req: AddTwoNumers::Request type.
    :returns: Returns the AddTwoNumers::Response type.
    """
    print "Returning [%s + %s = %s]"%(req.num_a, req.num_b, (req.num_a + req.num_b))
    return AddTwoNumbersResponse(req.num_a + req.num_b)
```



calculator_node.**add_service**(*req*)

This is a service routine that adds two numbers.

Parameters: **req** (*AddTwoNumers::Request type.*) – Request portion of the AddTwoNumbers service message.

Returns: Returns the AddTwoNumers::Response type.

Documentation - doxygen

- Document the classes/functions/variables …
  - ```
    /**
     * @brief Adds two numbers
     * @param num_a first input number
     * @return double result of adding the two input numbers
     ...
    ```
- Specify the format in the **rosdoc.yaml**
  - ```
    - builder: doxygen
      output_dir: doc_cpp
      file_patterns: '*.c *.cpp *.h *.cc *.hh'
       ...
    ```
- Run
  - `$ cd <your_package> && rosdoc_lite .`
- Demo

Documentation - sphinx

- Document the classes/functions/variables …
  - """
  - This is a service routine that adds two numbers.
  - :**param** req: Request portion of the AddTwoNumbers service message.
  - :**type** req: AddTwoNumers::Request type.
  - :**returns**: Returns the AddTwoNumers::Response type.
  - …
- Specify the format in the **rosdoc.yaml**
  - `- builder: sphinx`
  - `sphinx_root_dir: ./pydoc`
  - …
- Run
  - `$ cd <your_package> && sphinx-quickstart`
  - `$ sphinx-apidoc -o ./pydoc ./scripts`
  - *Modify conf.py file to look for scripts*
  - `$ rosdoc_lite .`

http://wiki.ros.org/Sphinx

Testing

Testing - rostest

rostest allows you to do full integration testing across multiple nodes.

- **Test nodes**
  - **C++:** Gtest
  - **Python:** unittest
- **Reusable test nodes**
  - **hztest:** tests the publishing rate of a node
  - **paramtest:** tests if certain parameters are registered at the Parameter Server
  - **publishtest**: tests if specified topics are published at least once
- **Test launch files**
  - Compatible with *launch* file format
  - ".test" or ".launch" extension

```
<launch>
  <node pkg="mypkg" type="mynode" name="mynode" />
  <test test-name="test_mynode" pkg="mypkg" type="test_mynode" />
</launch>
```

Testing - rostest - gtest test.cpp

Declare the test via “TEST” macro

```
TEST(TestSuite, add_test)
{
  /*
   * Set up your test
   */

  /*
   * Use assertion macros to evaluate your results
   */
  EXPECT_EQ( ... ,  ... ); // Continues the test
  ASSERT_EQ( ... ,  ... ); // Terminates the test
  EXPECT_TRUE( ... );
  ASSERT_TRUE( ... );
}
```

Run the test from “main”

```
int main(int argc, char **argv)
{
  // Initialize the gtest
  testing::InitGoogleTest(&argc, argv);

  // Run the tests
  return RUN_ALL_TESTS();
}
```

Testing - rostest - gtest test.cpp

```
/*
 * Tests the adding functionality of the calculator node
 */
TEST(TestSuite, add_test)
{
  ros::NodeHandle nh;
  ros::ServiceClient scl = nh.serviceClient<robert_v_sandbox::AddTwoNumbers>(  "add_two_numbers");

  // Compose the service message
  robert v sandbox::AddTwoNumbers srv_msg;
  srv msg.request.num a =  34;
  srv_msg.request.num_b =  5;

  // The result we are expecting to receive from the service call
  double expected_result = srv_msg.request.num_a + srv_msg.request.num_b;

  // Invoke the service call
  if (scl.call(srv_msg))
  {
    // Check if the response is equal to the expected result
    EXPECT_EQ(srv_msg.response.result, expected_result ) << "Expected " << expected_result <<  " but got " << srv_msg.response.result;
  }
  else
  {
    // Assert false if the client was not able to reach the server
    ASSERT_TRUE(false) << "Could not reach the 'add_two_numbers' server" ;
  }
}
```

Testing - rostest - test launch

```
<?xml version="1.0"?>
<launch>
  <node name="calculator_node" pkg="robert_v_sandbox" type="calculator_node"/>
  <test test-name="calculator_test_node" pkg="robert_v_sandbox" type="calculator_test_node"/>
</launch>
```

Testing - rostest - CMakeLists.txt

gtest:

```
if(CATKIN_ENABLE_TESTING)
  find_package(rostest REQUIRED)
  add_rostest_gtest(tests_mynode test/mynode.test src/test/test_mynode.cpp [more cpp files])
  target_link_libraries(tests_mynode ${catkin_LIBRARIES})
endif()
```

python:

```
if(CATKIN_ENABLE_TESTING)
  find_package(rostest REQUIRED)
  add_rostest(test/mytest.test)
endif()
```

Testing - rostest - run

```
$ catkin run_tests
```

```
[ROSTEST]-----------------------------------------------------------------------

[robert_v_sandbox.rosunit-calculator_test_node/add_test][FAILURE]--------------
/home/robert/catkin_ws_3/src/robert_v_sandbox/src/test/calculator_test.cpp:25
Value of: expected_result
  Actual: 41
Expected: srv_msg.response.result
Which is: 39
Expected 41 but got 39
-----------------------------------------------------------------------


SUMMARY
 * RESULT: FAIL
 * TESTS: 1
 * ERRORS: 0
 * FAILURES: 1
```

Testing - rostest - test return code

```
$ cd catkin_ws
$ catkin_test_results build/<your_pkg>
```

```
Summary: 2 tests, 0 errors, 1 failures, 0 skipped
robert@robert-IMS:~/catkin_ws_3$ echo $?
1
```

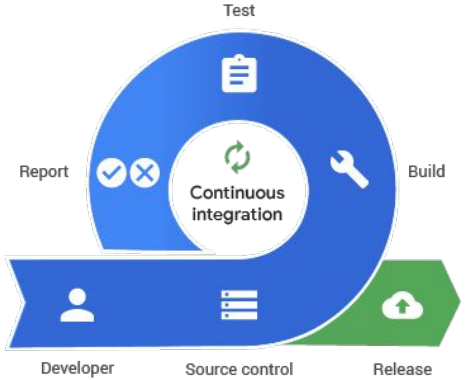
0 = success
1 = fail

Continuous Integration

Continuous Integration - overview

Automated routines that

- Are performed on pull request basis or periodically
- Validate the code
- Build the code
- Test the code
- Indicate the results via
  - Email
  - Status messages: build passing



MoveIt Package	Kinetic Source	Kinetic Debian	Melodic Source	Melodic Debian
moveit	build passing	build passing	build passing	build passing
moveit_chomp_optimizer_adapter	build passing	build failing	build passing	build passing
moveit_commander	build passing	build passing	build passing	build passing
moveit_core	build passing	build passing	build passing	build passing
moveit_experimental	build passing	build passing	build passing	build passing
moveit_fake_controller_manager	build passing	build passing	build passing	build passing
moveit_kinematics	build passing	build passing	build passing	build passing
moveit_msgs	build passing	build passing	build passing	build passing

https://cloud.google.com/solutions/continuous-integration/

Continuous Integration - options

- Cloud services

Travis CI

https://travis-ci.org/

GitLab

https://gitlab.com

- In-house/corporate servers

Jenkins

https://jenkins.io/

GitLab

https://gitlab.com

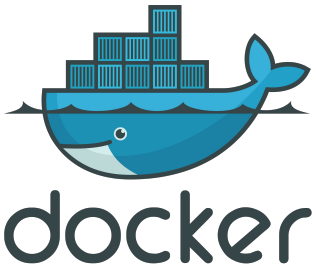
- CI jobs on ros build farm (hosted by OSRF)

http://build.ros.org/

http://wiki.ros.org/buildfarm

Continuous Integration - set-up via industrial_ci

- https://github.com/ros-industrial/industrial_ci
- Set of Docker based scripts for automating common tests:
  - ROS compilation and ROS testing scripts
  - catkin_lint
  - ABI compliance tests
- Supported platforms
  - Travis and Gitlab
  - Custom CI servers, e.g. Jenkins



Continuous Integration - Travis CI

- Add .travis.yml to your GitHub repository

```
services:
  - docker
language: generic
compiler:
  - gcc
notifications:
  email:
    recipients:
      - john.doe@gmail.com
env:
  - ROS_DISTRO="kinetic" NOT_TEST_BUILD=false NOT_TEST_INSTALL=true
  - ROS_DISTRO="melodic"  NOT_TEST_BUILD=false NOT_TEST_INSTALL=true
install:
  - git clone https://github.com/ros-industrial/industrial_ci.git .ci_config
script:
  - source .ci_config/travis.sh
```

- Enable CI for your repository
  https://docs.travis-ci.com/user/getting-started

Workshop