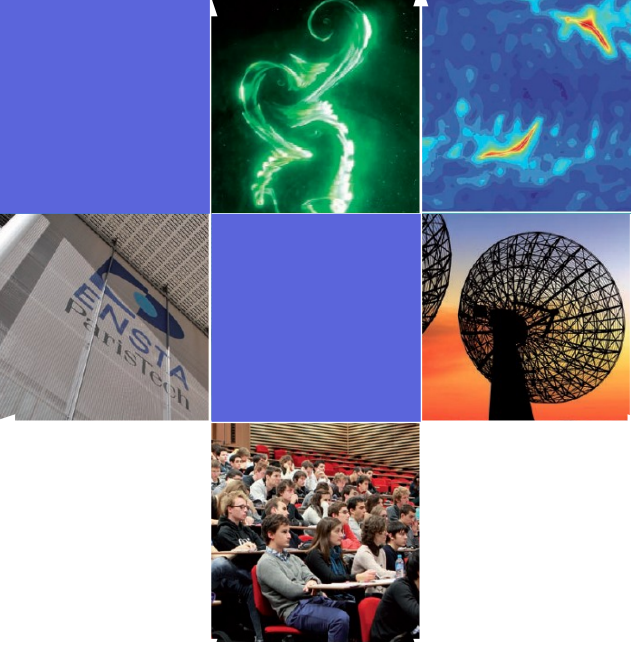


ENSTA | INSTITUT POLYTECHNIQUE DE PARIS

Introduction to ROS
CSC_5RO14_TA – Session 2

Emmanuel Battesti

Summary of the last session

- History and philosophy of ROS
- All the technical terms related to ROS : *package*, *node*, *master*, *topic*, *message*, etc.
- All the common ROS tools : *rosnode*, *rospackage*, *rostopic*, *roscd*, etc.
- Small exercises to use ROS tools
- Use of downloaded packages with catkin workspace
- Use of launch files
- Use Gazebo

Overview Course 2

- How to code a package :
  - Review the ROS package **structure**
  - Use of the ROS C++ client **library** (roscpp)
  - Create new ROS **subscribers** and **publishers**
  - Use of the ROS **parameter** server
  - **RViz** visualization

ROS Packages

- ROS software is organized into packages, which can contain
  - source code,
  - launch files (*.launch),
  - configuration files (*.yml),
  - message definitions (*.msg),
  - Data, documentation, etc.
- A package relies on other packages (for example, message definitions) and must declare them as dependencies.
- Help to create a new package, in your *~/catkin_ws/src*:

```
> catkin_create_pkg package_name {dependencies}
```

- For example, *catkin_create_pkg ensta_package std_msgs rospy roscpp*
- Sometimes, it can be easier to copy-paste from another package

ROS Package folder

package_name

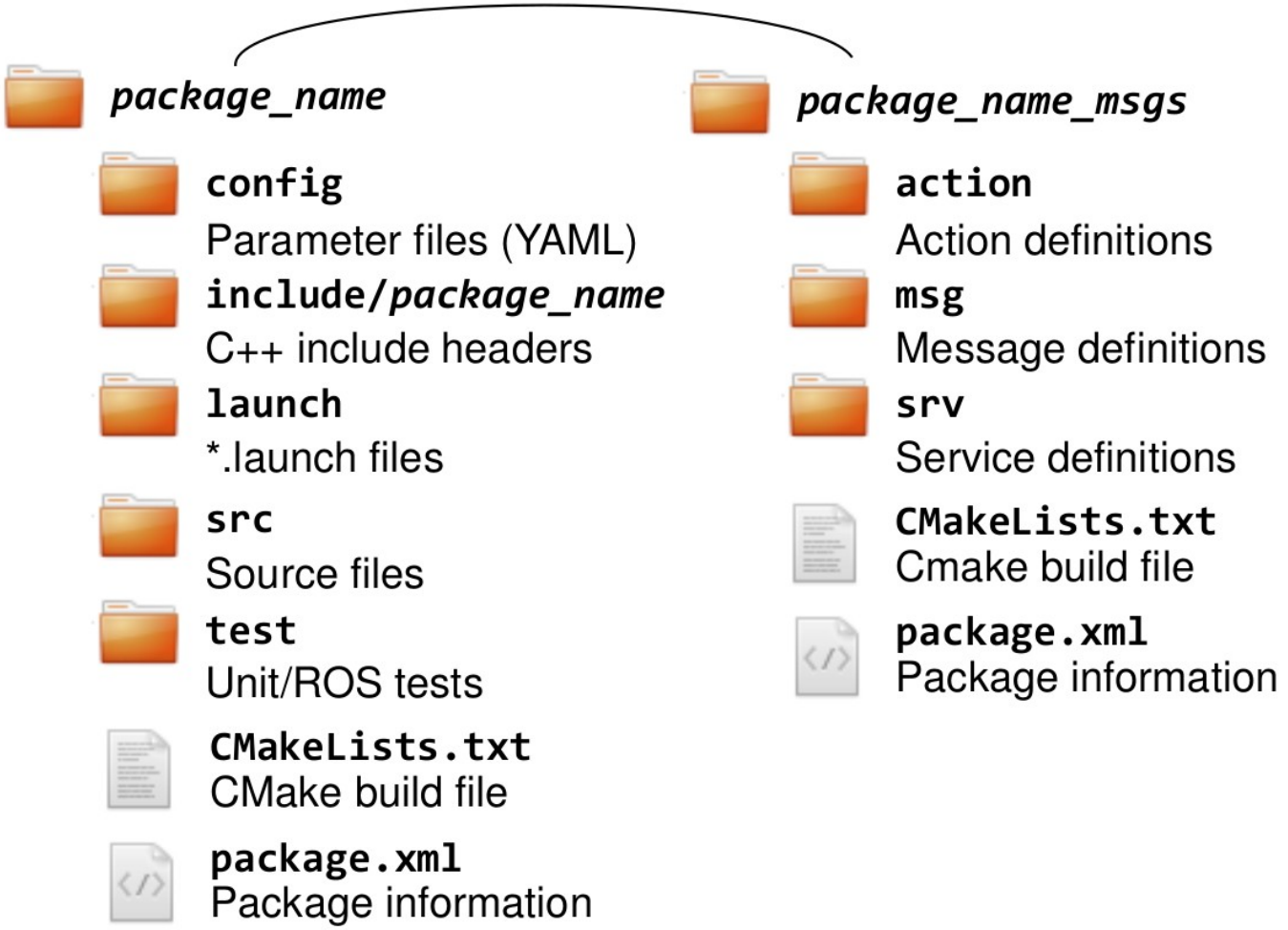
- **`config`**
  Parameter files (YAML)
- **`include/`*`package_name`***
  C++ include headers
- **`launch`**
  *.launch files
- **`src`**
  Source files
- **`test`**
  Unit/ROS tests
- **`action`**
  Action definitions
- **`msg`**
  Message definitions
- **`srv`**
  Service definitions
- **`CMakeLists.txt`**
  Cmake build file
- **`package.xml`**
  Package information

ROS Package folder

- Sometimes, in large projects, we may have a package only for messages, services and actions
- Why ?
  - It is not easy to tell which node owns a message.
  - It is easier when several people are working on the same project at different stages of progress.
  - The messages should change as little as possible so to not disturb the different developers. So this package can have stricter modification permissions. (Problem with ROS *bags*)

ROS Package folder

Separate message definition packages from other packages!



ROS: package.xml

- The ***package.xml*** file defines the **properties** of the package
  - Package name
  - Version number
  - Authors
  - **Dependencies on other packages**
  - …

```
<?xml version="1.0"?>
<package format="2">
  <name>ros_package_template</name>
  <version>0.1.0</version>
  <description>A ROS package</description>
  <maintainer email="pp@any...">Peter
Paul</maintainer>
  <license>BSD</license>
  <url>https://github.com/toprobot/ros_…</url>
  <author email="pp@anybotics.com">Peter
Paul</author>

  <buildtool_depend>catkin</buildtool_depend>

  <depend>roscpp</depend>
  <depend>sensor_msgs</depend>
</package>
```

ROS: CMakeLists.txt

- This file can be generated automatically by ***catkin_create_pkg***.
- CMakeLists.txt : related to **CMake**, a **ROS-independent** tool for easily creating C++ MakeFile.
- Necessary even in **Python**, to declare the package, manage dependencies and installation.
- In a ROS project, they provide **special macros** for ROS/Catkin in Cmake : *add_messages_files()*, *catkin_package(), etc.*
- A **#** is used for **comments.**
- In a file generated with *catkin_create_pkg*, simply **uncomment** the commands you wish **to use**.
- In general, this file is not often modified during the development of a package.

ROS: CMakeLists.txt

- The CMakeLists.txt is the input to the CMakebuild system
- 1. Required CMake Version ***`cmake_minimum_required`***
- 2. Package Name : ***`project`*** `()` → same as in *package.xml*
- 3. Find other CMake/Catkin packages needed for build : **`find_package()`** → `list of libs, same as in` *`package.xml`*
- 4. Message/Service/Action Generators to add your own stuff : **`add_message_files()`**, **`add_service_files()`**, **`add_action_files()`**
- 5. Invoke message/service/action generation : **`generate_messages`**`()` → `list of msg dependencies`
- 6. Allows the package to be used as a dependency in other projects : **`catkin_package`**`()`
- 7. Libraries/Executables to build : `add_library()/add_executable()/target_link_libraries()`
- 8. Tests to build : `catkin_add_gtest()`
- 9. Install rules : `install()`

Reference :
http://wiki.ros.org/catkin/CMakeLists.txt

```
cmake_minimum_required(VERSION 3.0.2)
project(ros_package_template)

## Use C++11
add_compile_options(-std=c++11)

## Find catkin macros and libraries
find_package(catkin REQUIRED COMPONENTS
  roscpp
  sensor_msgs
)

...
```

ROS: C++ CmakeLists.txt example

```
cmake_minimum_required(VERSION 3.0.2)
project(5ro14_husky_controller)
add_definitions(--std=c++11)

find_package(catkin REQUIRED
  COMPONENTS roscpp sensor_msgs
)

catkin_package(
  INCLUDE_DIRS include
  # LIBRARIES
  CATKIN_DEPENDS roscpp sensor_msgs
  # DEPENDS
)

include_directories(include ${catkin_INCLUDE_DIRS})

add_executable(${PROJECT_NAME}_node src/MyNode.cpp src/MyController.cpp)

target_link_libraries(${PROJECT_NAME}_node ${catkin_LIBRARIES})
```

- Use the same name as in the package.xml
- We use C++11 by default
- List the packages that your package requires to build (must be listed in package.xml)
- Specify build export information
  - INCLUDE_DIRS: Directories with exported header files
  - LIBRARIES: Exported libraries built in this project
  - CATKIN_DEPENDS: Other catkin projects that this project depends on
  - DEPENDS: Non-Catkin CMake projects that this project depends on (must be listed in package.xml)
- Specify locations of header files
- Declare a C++ executable
- Specify libraries to link the executable against

ROS: Python CmakeLists.txt example

```
cmake_minimum_required(VERSION 3.0.2)
project(5ro14_husky_controller_py)

find_package(catkin REQUIRED
  COMPONENTS rospy sensor_msgs
)

catkin_package()
```

- Use the same name as in the package.xml
- List the packages that your package requires to build (must be listed in package.xml)
- catkin_package() is required, but can be left empty as rospy does the rest.

Typical node : pseudo code v1

```
void callback_1(Msg1 msg) {... do stuff with msg from topic1...}

void callback_2(Msg2 msg) {... do stuff with msg from topic2...}

void main()
{
  ros::init("my_node");

  ros::Subscriber my_subscriber_1("topic1", callback_1);
  ros::Subscriber my_subscriber_2("topic2", callback_2);

  ros::Publisher my_publisher("topic3");

  while (ros::ok())
  {
    do_stuff();

    my_publisher.publish(my_msg);

    ros::spinOnce();
  }
}
```

Warning: pseudo code !!
Do not use as is !

Typical node : pseudo code v2

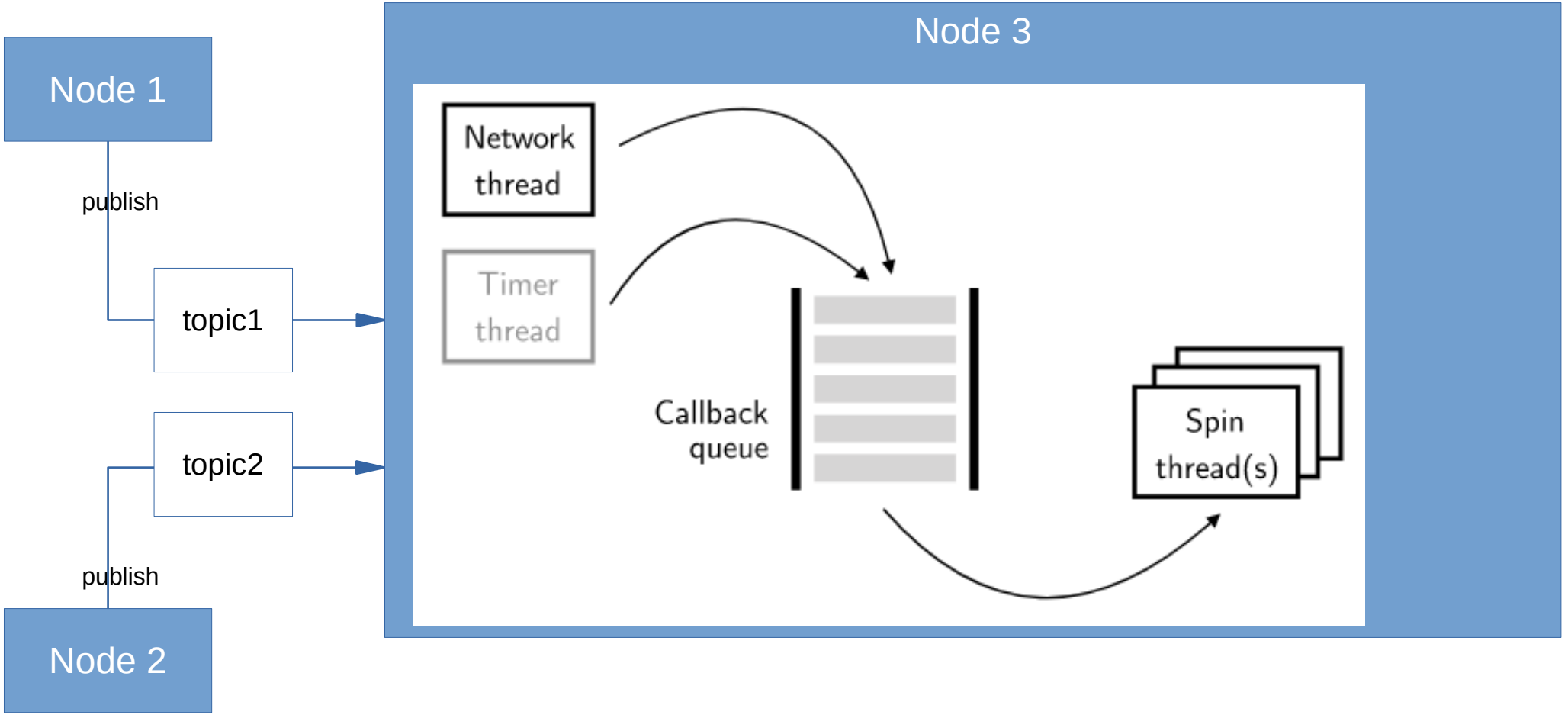
```
void callback_1(Msg1 msg) {... do stuff with msg from topic1 ...}

void callback_2(Msg2 msg) {... do stuff with msg from topic2
                               my_publisher.publish(other_msg);

                              ...}

void main()
{
  ros::init("my_node");

  ros::Subscriber my_subscriber_1("topic1", callback_1);
  ros::Subscriber my_subscriber_2("topic2", callback_2);

  ros::Publisher my_publisher("topic3");

  ros::spin();
}
```

Warning: pseudo code !!
Do not use as is !

Blocking function

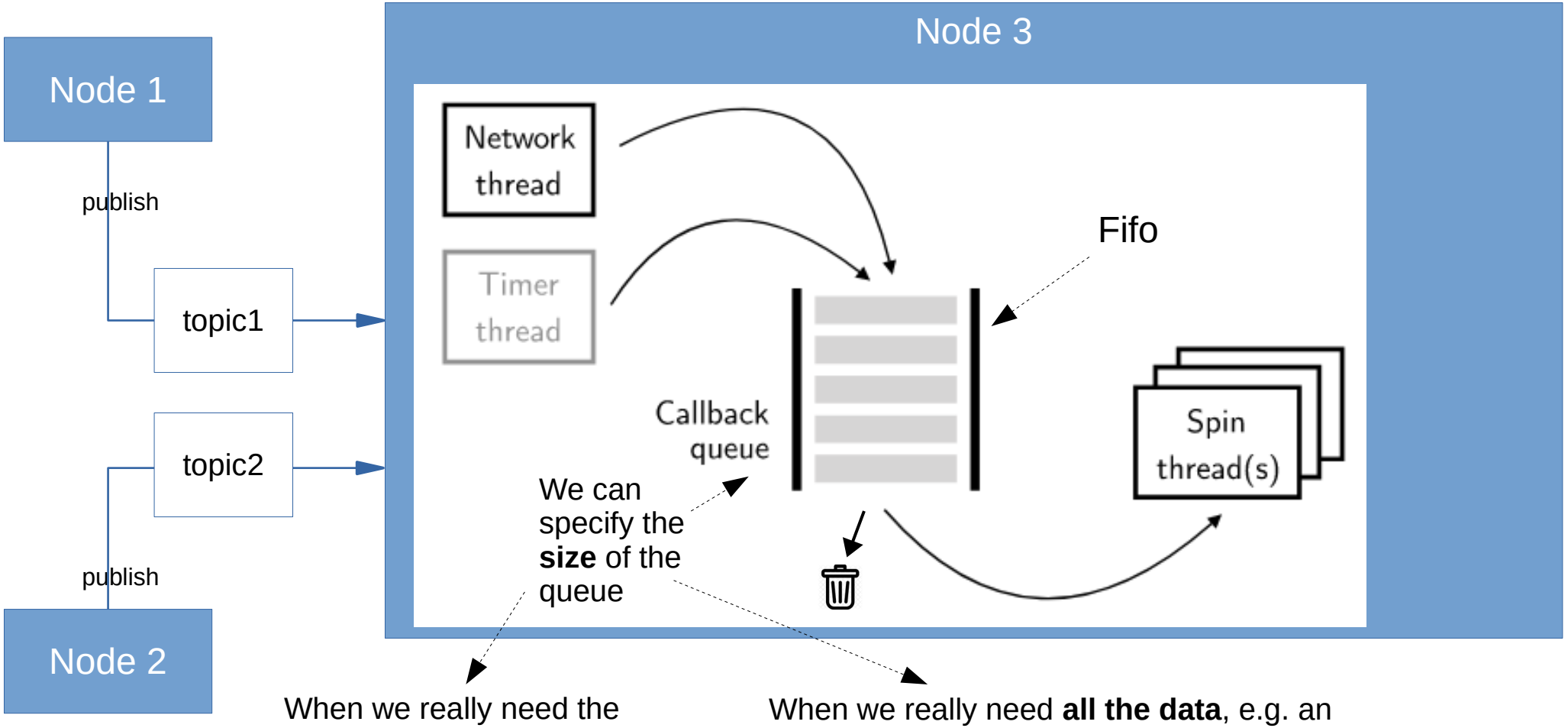
Callback queue

Callback : function to handle a message when it arrives



Callback queue

Callback : function to handle a message when it arrives



When we really need the **lastest** data, e.g. a position
→ **queue size = 1**

When we really need **all the data**, e.g. an object detection
→ **queue size = *big_value***

ROS Callback Handling

- Single-Threaded Spinner (**default**):
  - Each topic has its own callback queue.
  - Callbacks are processed sequentially in the order messages arrive for each topic.
  - Issue: A long callback can delay the processing of other topics.
- Multi-Threaded Spinner:
  - Allows parallel callback processing.
  - Multiple threads handle callbacks, preventing delays caused by long-running callbacks in other topics.

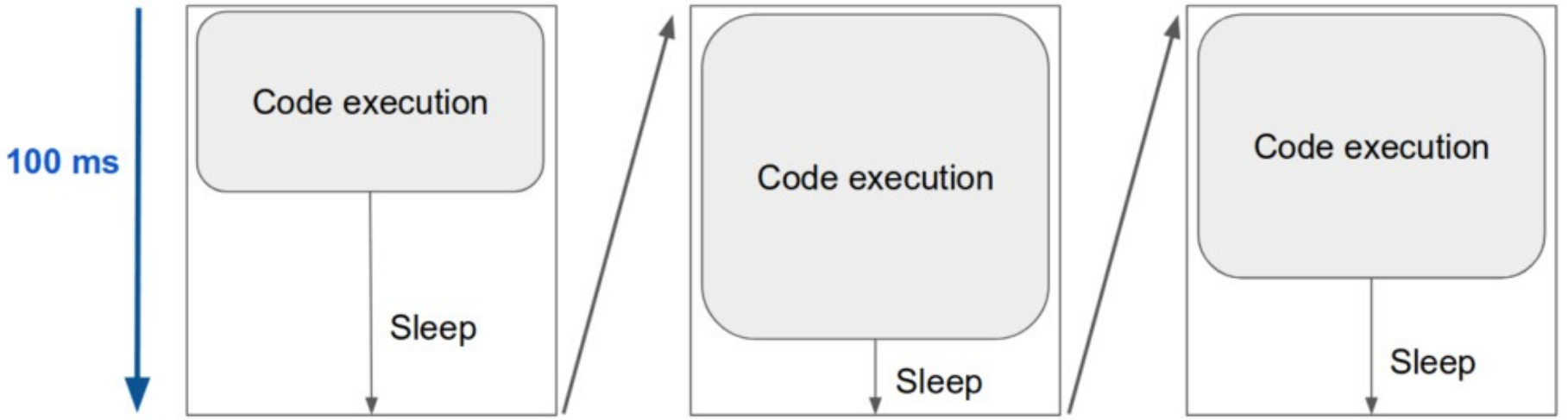
ROS C++ Client Library (roscpp) : code example

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

int main(int argc, char**
argv)
{
  ros::init(argc, argv,
"hello_world");
  ros::NodeHandle nodeHandle;
  ros::Rate loopRate(10);

  unsigned int count = 0;
  while (ros::ok()) {
    ROS_INFO_STREAM("Hello
World " << count);
    ros::spinOnce();
    loopRate.sleep();
    count++;
  }

  return 0;
}
```

- ROS main **header** file include
- ros::**init**(...) must be called before calling any other ROS functions.
- The node **handle** is the entry point for communication with the ROS system (topics, services, parameters),
- ros::**Rate** is a helper class to run loops at a desired frequency,
- ros::**ok**() checks if a node should continue running

  Returns false if SIGINT is received (Ctrl + C) or ros::shutdown() is called
- ROS_INFO() **logs** messages to the file system
- ros::**spinOnce**() processes incoming messages via callbacks

Roscpp - ros::Rate



Roscpp - ros::spin() vs ros::spinOnce()

- ***ros::spinOnce()*** calls the callbacks waiting to be called at that point in time.

- ***ros::spin()*** gives control over to ROS, which allows it to call user callbacks.
- It is a **blocking** function : it will not return until the node is shut down, by calling to ros::shutdown() or by pressing Ctrl-C.
- Internally, ***ros::spin()*** looks like :

```
ros::Rate loopRate(10);
while (ros::ok()) {
  ros::spinOnce();
  loopRate.sleep();
  count++;
}
```

Roscpp - Subscriber

- Start listening to a topic by calling the method *subscribe()* of the node handle

```
ros::Subscriber subscriber =
nodeHandle.subscribe(topic,
queue_size, callback_function);
```

- When a message is received, a callback function is called with the content of the message as an argument
- ros::spin() processes callbacks and will not return until the node has been shut down

listener.cpp

```
#include "ros/ros.h"
#include "std_msgs/String.h"

void chatterCallback(const std_msgs::String&
msg)
{
  ROS_INFO("I heard: [%s]", msg.data.c_str());
}

int main(int argc, char **argv)
{
  ros::init(argc, argv, "listener");
  ros::NodeHandle nodeHandle;

  ros::Subscriber subscriber =
nodeHandle.subscribe("chatter", 10,
chatterCallback);
  ros::spin();
  return 0;
}
```

Roscpp - Publisher

- Create a publisher using the node handle

```
ros::Publisher publisher =
nodeHandle.advertise<message_type>
(topic,queue_size);
```

- Create the message content

- Publish the content with

```
publisher.publish(message);
```

Reference :
https://github.com/ros/ros_tutorials/blob/melodic-devel/**roscpp_tutorials/talker**/talker.cpp

talker.cpp

```
#include <ros/ros.h>
#include <std_msgs/String.h>

int main(int argc, char **argv) {
  ros::init(argc, argv, "talker");
  ros::NodeHandle nh;
  ros::Publisher chatterPublisher =
nh.advertise<std_msgs::String>("chatter", 1);
  ros::Rate loopRate(10);

  unsigned int count = 0;
  while (ros::ok()) {
    std_msgs::String message;
    message.data = "hello world " +
std::to_string(count);
    ROS_INFO_STREAM(message.data);
    chatterPublisher.publish(message);
    ros::spinOnce();
    loopRate.sleep();
    count++;
  }
return 0;
}
```

ROS C++ Client Library : Object Oriented Programming

MyNode.cpp

```
#include <ros/ros.h>
#include "my_package/MyWork.hpp"

int main(int argc, char** argv)
{
  ros::init(argc, argv, "my_node_name");
  ros::NodeHandle nodeHandle("~");

  my_package::MyWork myWork(nodeHandle);

  ros::spin();
  return 0;
}
```

- We can have those files : MyNode.cpp, MyWork.cpp, MyWork.hpp, Algorithm.cpp, Algorithm.hpp
- class **MyWork** : Main node class providing the ROS interface (subscribers, parameters, timers etc.)
- class **Algorithm** : Class implementing the algorithmic part of the node. Note: The algorithmic part of the code could be separated in a (ROS-independent) library

Specify a function handler to a method from within the class (here **MyWork**) as:

```
subscriber_ = nodeHandle_.subscribe(topic, queue_size, &MyWork::one_callback, this);
```

Graph resource names 1/2

- Nodes, topics, services, and parameters = **graph resources**. Their name =**graph resource name**
- **Namespaces** are used to group related graph resources together. A **base name** describes the resource itself. e.g.
  /namespace1/namespace2/baseName
- **Global Names** : starting with a « / ».
  - For example :
    - */turtle1/cmd_vel*
    - */teleop_turtle*
- **Relative names** : **not** starting with a « / ». Not fully defined, the name should be resolved.
  - Relative names make it easier to build complicated systems by composing smaller parts.
  - Default namespace + relative name = global name
  - e.g. : */turtle1* + *cmd_vel* = */turtle1/*cmd_vel
  - e.g. : */turtle1* + *abc/cmd_vel* = */turtle1/abc/*cmd_vel

Graph resource names 2/2

- **Private names** : starting with a ~. Not fully defined, the name should be resolved.
  - Like *relative names* but use the **name of their node** as a namespace
  - Node name + ~private_name = global name
  - e.g. : /sim1/pubvel + ~max_vel = /sim1/pubvel/max_vel
  - *Private names* are often used **for parameters**

Roscpp - Node Handle

- Acts as the **interface between your program and the ROS** system.
- Communication:
  - Topic : Create publishers and subscribers.
  - Service : Advertise and handle services.
- Access Parameters from the Parameter Server.
- Usage Example:
  - Publisher: ros::Publisher pub = **nh**.advertise<std_msgs::String>("topic", 1000);
  - Subscriber: ros::Subscriber sub = **nh**.subscribe("topic", 1000, callback);

Roscpp - Node Handle

- Different types of node handles

  1. Default (public) node handle:

  `nh_ = ros::NodeHandle();`

  2. Private node handle:

  nh_private_ = ros::NodeHandle("~");

  3. Namespaced node handle:

  nh_foo_ = ros::NodeHandle("foo");

  4. Private node handle:

  nh_privfoo_ = ros::NodeHandle("~foo");

  5. Global node handle:

  nh_global_ = ros::NodeHandle("/");

- For a ***node*** in a namespace ***ns*** looking up ***topic***, these will resolve to:

⇒ `/ns/topic`

⇒ `/ns/node/topic`

⇒ `/ns/foo/topic`

⇒ `/ns/node/foo/topic`

⇒ `/topic`

Roscpp - Logging

- Mechanism for logging human readable text from nodes in the console and to log files
- Instead of std::cout, use e.g. ROS_INFO_STREAM
- Automatic logging to console, log file, and `/rosout` topic
- Different severity levels (Info, Warn, Error etc.)
- Supports both printf-style and stream-style formatting

```
ROS_INFO("Result: %d", result);

ROS_INFO_STREAM("Result: " << result);
```

- Other features like conditional, throttled, delayed logging etc.

ROS Parameter Server

- Nodes use the *parameter server* to **store** and **retrieve** parameters at runtime
- Best used for **static data** such as configuration parameters
- Parameters can be defined in **launch files** or separate ***YAML* files**
- Launch file can **load** YAML files

config.yaml

```
camera:
  left:
    name: left_camera
    exposure: 1.0
  right:
    name: right_camera
    exposure: 1.1
```

package.launch

```
<launch>
  <node name="name" pkg="package" type="node_type">
    <rosparam command="load" file="$(find package)/config/config.yaml" />
    <param name="camera/left/exposure" type="double" value="2.0" />
    <rosparam param="camera/left/exposure">3.0</rosparam>
    <rosparam>
      camera/left/exposure: 4.0
    </rosparam>
  </node>
</launch>
```

ROS Parameter Server

- List all parameters with

```
> rosparam list
```

- Get the value of a parameter with

```
> rosparam get parameter_name
```

- Set the value of a parameter with

```
> rosparam set parameter_name value
```

config.yaml

```
camera:
  left:
    name: left_camera
    exposure: 1.0
  right:
    name: right_camera
    exposure: 1.1
```

- For example, if *config.yaml* has been loaded, to get the exposure from the left camera:

```
> rosparam get camera/left/exposure
```

ROS Parameter Server : C++ API

- Get a parameter in C++ with

```
nodeHandle.getParam(parameter_name, variable)
```

- Method returns `true` if parameter was found, `false` otherwise
- Global and relative parameter access:
  - Global parameter name with preceding /

```
nodeHandle.getParam("/camera/left/exposure", variable)
```

  - Relative parameter name (relative to the node handle)

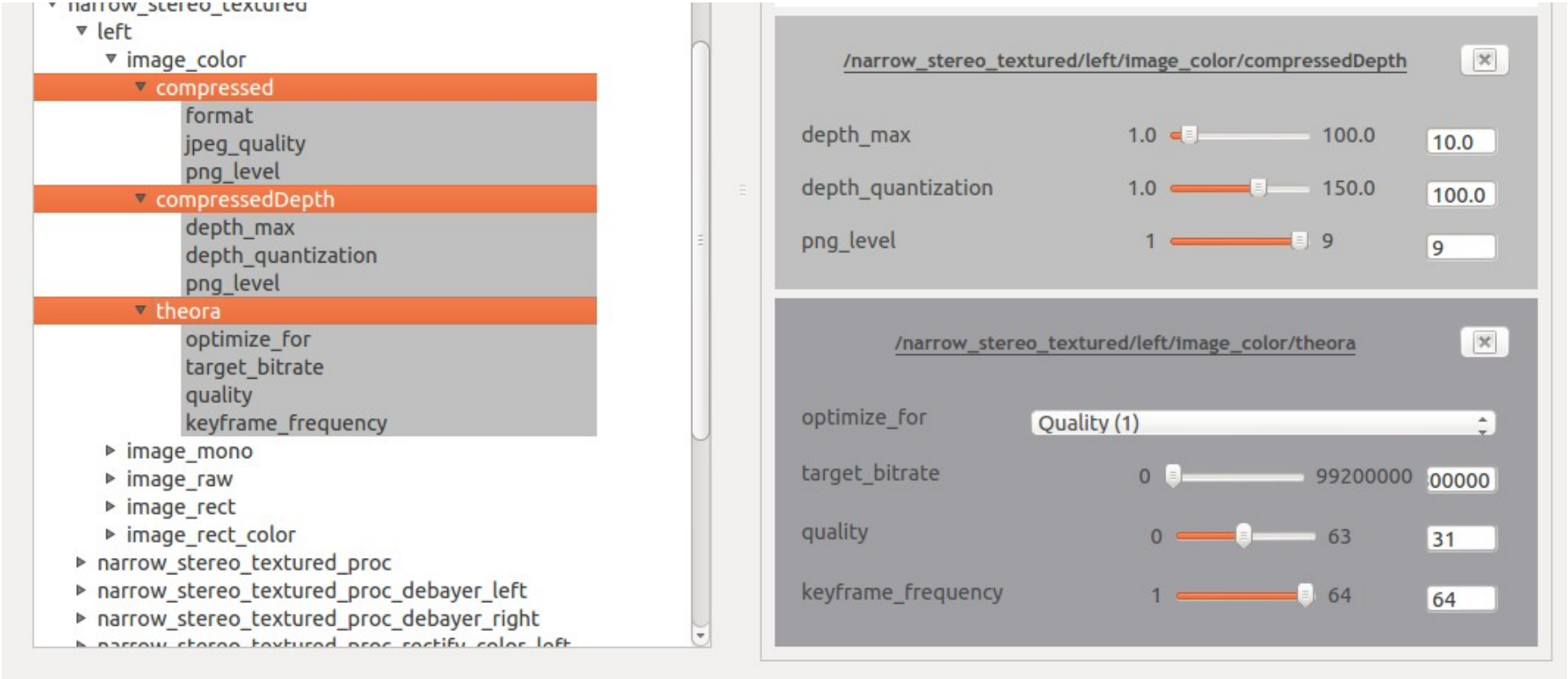
```
nodeHandle.getParam("camera/left/exposure", variable)
```

- For parameters, typically use the private node handle : ros::NodeHandle("~")

```
ros::NodeHandle nodeHandle("~");
std::string myParam;
If (!nodeHandle.getParam("myParam", myParam)) {
  ROS_ERROR("Could not find myParam parameter!");
}
```

ROS Parameter : dynamic reconfigure

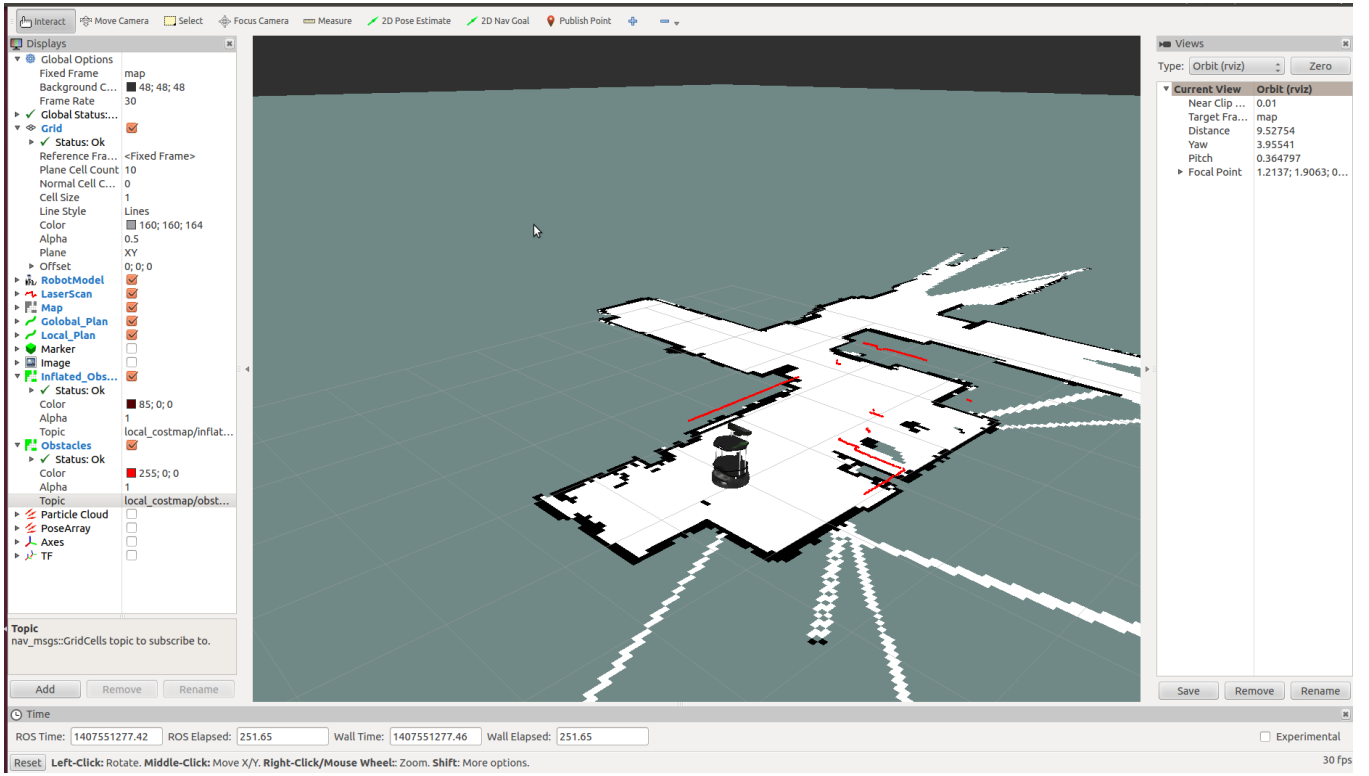
- The package `dynamic_reconfigure` permit to use parameter dynamically.



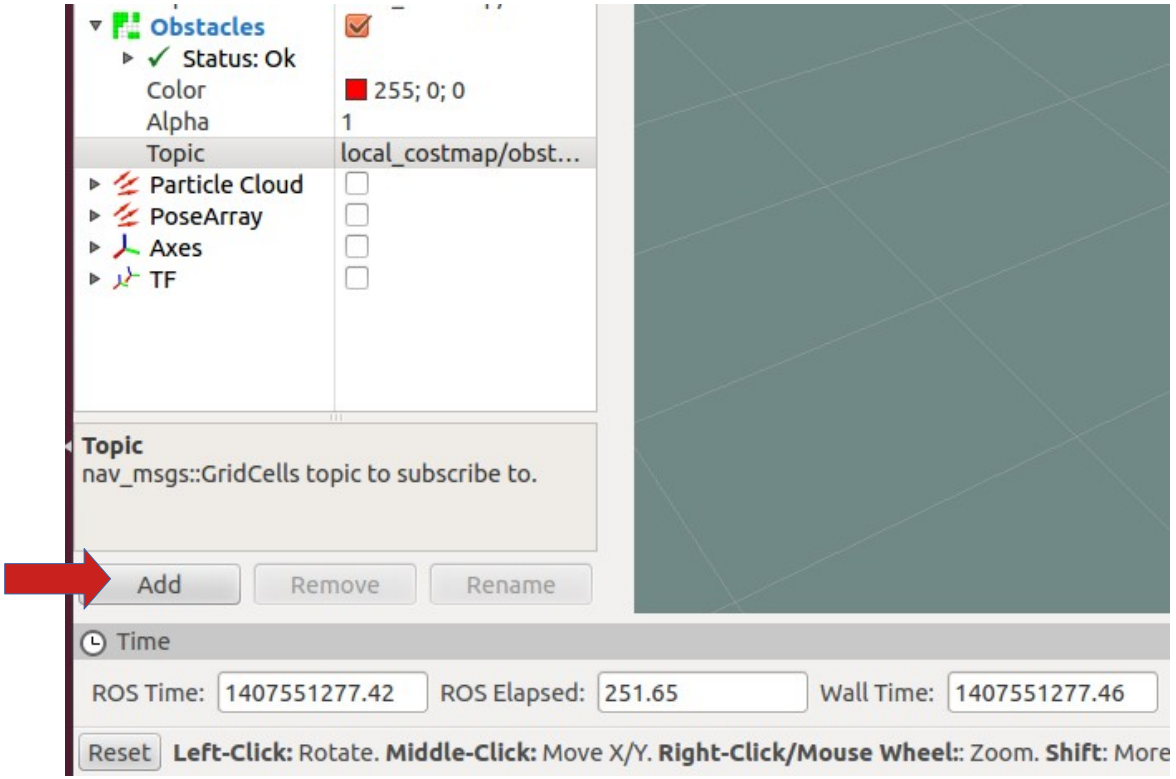
RViz

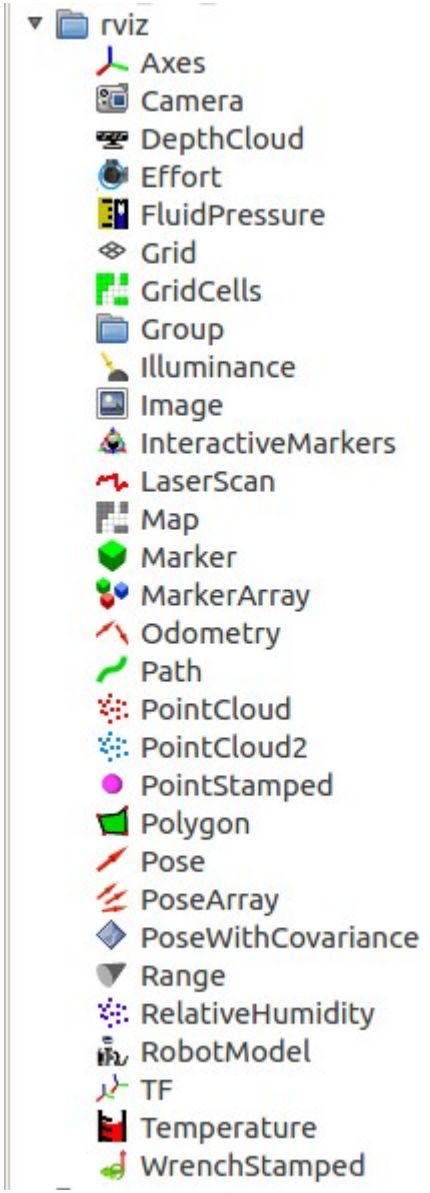
- 3D visualization tool for ROS
- Subscribes to topics and visualizes the message contents
- Different camera views (orthographic, topdown, etc.)
- Interactive tools to publish user information
- Save and load setup as RViz configuration
- Extensible with plugins
- Run RViz with

```
> rosrun rviz rviz
```



Rviz : Display Plugins



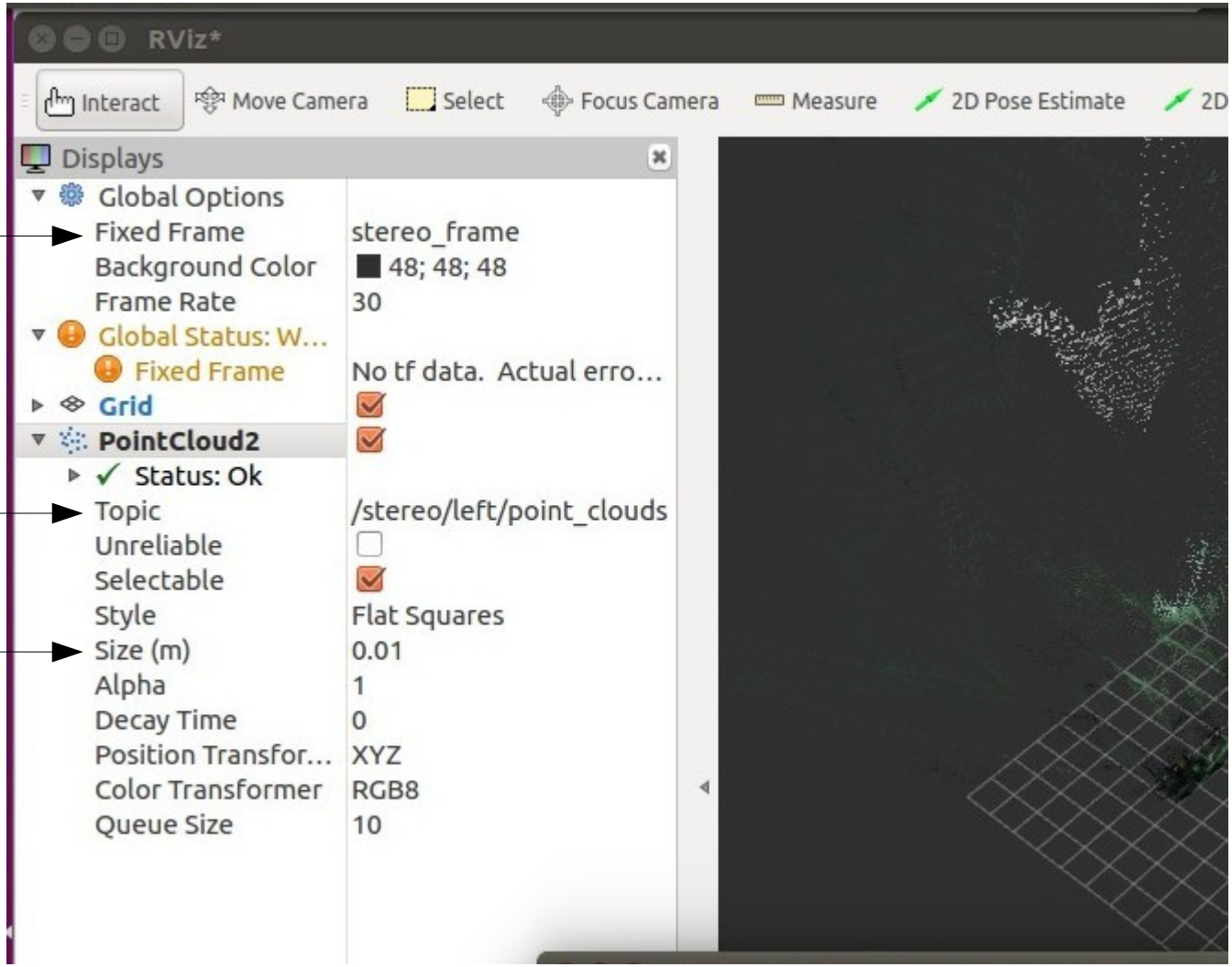


Rviz :Visualizing Point Clouds Example

Frame in which the data is displayed (has to exist!)

Choose the topic for the display

Change the display options (e.g. size)



Exercice 1 – Playing with husky (part 2)

- Topics covered :
  - ROS package structure
  - Integration and programming
  - ROS C++ client library (roscpp)
  - ROS subscribers and publishers
  - ROS parameter server
  - RViz visualization

Further References

- **ROS Wiki:**
  - http://wiki.ros.org/
- **Installation:**
  - http://wiki.ros.org/ROS/Installation
- **Tutorials:**
  - http://wiki.ros.org/ROS/Tutorials
- **Available packages:**
  - http://www.ros.org/browse/
- **ROS Cheat Sheet :**
  - https://www.clearpathrobotics.com/ros-robot-operating-system-cheat-sheet/
  - https://kapeli.com/cheat_sheets/ROS.docset/Contents/Resources/Documents/index
- **ROS Best Practices :**
  - https://github.com/leggedrobotics/ros_best_practices/wiki
- **ROS Package Template :**
  - https://github.com/leggedrobotics/ros_best_practices/tree/master/ros_package_template