Lesson 3: Starting with ROS programming (Part 1)

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OUTLINE

In this lesson we will develop ROS nodes to test the plumbing (and communication) capabilities of ROS:

- Publisher/Subscriber example
- ROS Service example

Installing ROS

ROS can be installed using APT tool:

- By default, ROS software is not present in the APT stack
- Configure APT to accept software from additional repositories

Installing ROS

ROS can be installed using APT tool:

- By default, ROS software is not present in the APT stack
- Configure APT to accept software from additional repositories
- Update your `sources.list.d` in the `/etc1/apt/` folder
- Update your APT repository
- Install one of the available ROS versions
- `http://wiki.ros.org/melodic/Installation/Ubuntu`

Environment Configuration

Load the setup file included in the installation directory of ROS.

```
$ source /opt/ros/melodic/setup.bash
```

For example you can use the `roscd` command to move in your ROS workspace

```
$ roscd
$ pwd
$ /opt/ros/melodic
```

Environment Configuration

Load the setup file included in the installation directory of ROS.

```
$ source /opt/ros/melodic/setup.bash
```

This directory is owned by the super user so you should create your own workspace in the user space:

```
$ cd ~
$ mkdir -p ros_ws/src
$ cd ros_ws/src
$ catkin_init_workspace
$ cd ..
$ catkin_make
```

Environment Configuration

- `catkin_make`: compilation command
  - Must be ran in the root of your ROS workspace
  - This command compile the whole workspace (all the packages contained into the ROS workspace)
- The workspace contains three directories:
  - `src` directory you must create or download new ROS packages. If a package is not placed there, it will not be compiled
  - `build` directory instead contains the compilation file
  - `devel` folder contains the compiled libraries

Environment Configuration

This workspace must be your default workspace!

- `roscd` command must bring you in the workspace just created
- If you type `roscd` command now, you will be moved in the `/opt/ros/VERSION/` directory (in the super user space)
- You need to source the `setup.bash` file contained in the `devel` folder.

  ```
  $ echo "source ~/ros_ws/devel/setup.bash" >>
   ~/.bashrc
  ```

- Open a new terminal or source the modified `bashrc` file load the new configuration. Test it with the `roscd` command.

ROS Package

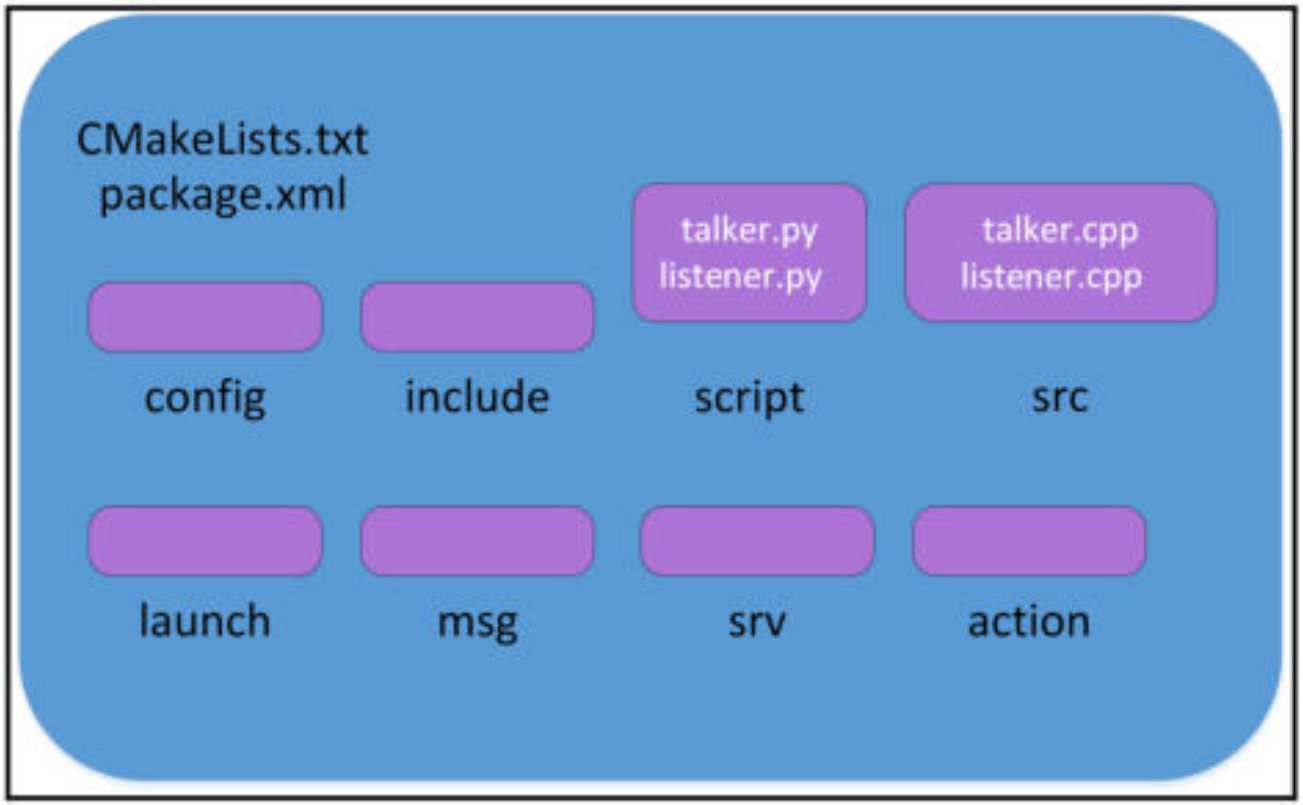
- Create a ROS package:
- A ROS package could contain different executable (ROS nodes)

  ```
  $ catkin_create_pkg package_name [dep1] ... [depN]
  ```

- Packages must be placed in the `src` directory of ROS workspace, otherwise they will not be compiled!!

ROS Package

The shape of a ROS package is a directory with the following sub-directories:



Example 1: pub/sub

- Create a ROS package with two nodes, a publisher and a subscriber:

  ```
  $ catkin_create_pkg ros_topic roscpp std_msgs
  ```

  - `roscpp`: C++ implementation of ROS. It provides APIs to C++ developers to make ROS nodes
  - `std_msgs`: standard ROS messages (int, string, array, ...)
- Navigate the new package:

  ```
  $ roscd ros_topic
  ```
- Create a new package:

  ```
  $ touch src/ros_publisher.cpp
  ```
- Goal: Publish an integer value on a topic called `/numbers`.

Example 1: pub/sub

```
1  #include "ros/ros.h"
2  #include "std_msgs/Int32.h"
3  #include <iostream>
```

Example 1: pub/sub

```
1   int main(int argc, char **argv) {
2     ros::init(argc, argv,"ros_topic_publisher");
3     ros::NodeHandle nh;
4     ros::Publisher topic_pub =
5     nh.advertise<std_msgs::Int32>("/numbers",10);
```

ROS messages

- ROS communication relies on a set of standard and custom data structures called ROS messages
- The types of data are described using a simplified message description language called ROS messages
- The message definition consists in a typical data structure composed by two main types: fields and constants

ROS messages

`geometry_msgs::PoseStamped` is used to share the pose of an object:

```
1  std_msgs/Header header
2    uint32 seq
3    time stamp
4    string frame_id
5  geometry_msgs/Pose pose
6    geometry_msgs/Point position
7      float64 x
8      float64 y
9      float64 z
10   geometry_msgs/Quaternion orientation
11     float64 x
12     float64 y
13     float64 z
14     float64 w
```

Example 1: pub/sub

The inbuilt tools called `rosmsg` is used to get information about ROS messages. Here are some parameters used along with `rosmsg`:

```
$ rosmsg show [message]
$ rosmsg list
$ rosmsg md5 [message]
$ rosmsg package [package_name]
```

Example 1: pub/sub

```
1       ros::Rate rate(10);
2       int count = 0;
3       while (ros::ok()) {
4         std_msgs::Int32 msg;
5         msg.data = count++;
```

Example 1: pub/sub

```
1         ROS_INFO("%d",msg.data);
2         topic_pub.publish(msg);
3         rate.sleep();
4       }
5       return 0;
6     }
```

Example 1: pub/sub

- To compile this package you must edit the `CMakeLists.txt` file
- You must specify the source files that must be compiled and its dependencies

```
1 add_executable(topic_publisher src/ros_publisher.cpp)
2 target_link_libraries(topic_publisher ${catkin_LIBRARIES})
```

- Build `ros_topic` package as follows:

```
$ cd ~/ros_ws
$ catkin_make
```

catkin_make

- `catkin_make` compiles all the package in your workspace.
- Compilation errors cause the failing of the compilation of all packages
- To compile only one package you can use the `DCATKIN_WHITELIST_PACKAGES` argument. With this option, it is possible to set one or more packages enabled to be compiled.

```
$ catkin_make -DCATKIN_WHITELIST_PACKAGES="pkg1,pkg2,..
```

- It is necessary to revert this configuration to compile other packages not specified in the `WHITELIST`.

```
$ catkin_make -DCATKIN_WHITELIST_PACKAGES=""
```

Run pub node

- Activate a `roscore` in your system

  ```
  $ roscore
  ```

- Run the publisher node

  ```
  $ rosrun ros_topic topic_publisher
  ```

The output on the linux shell shows the `INFO` about the integer that are going to be published on `/numbers` topic. We can use two additionally commands to debug and understand the working of the nodes: `rosnode` and `rostopic`.

rosnode command

```
$ rosnode info [node_name]
$ rosnode kill [node_name]
$ rosnode list
```

For example, `rosnode info /ros_topic_publisher` will provide information about the published and subscribed topics:

```
Node [/ros_topic_publisher]
Publications:
* /numbers [std_msgs/Int32]
* /rosout [rosgraph_msgs/Log]

Subscriptions: None
```

This is useful to understand the I/O of a node.

rostopic command

```
$ rostopic list
$ rostopic echo /topic
$ rostopic hz /topic
$ rostopic info /topic
$ rostopic pub /topic message_type args
$ rostopic type /topic
```

Using `rostopic` command you can check which kind of topics are published by the node:

```
$ rostopic list
Output:
/numbers
/rosout
/rosout_agg
```

rostopic command

And check its content:

```
$ rostopic echo /numbers
```

```
Output:
data: 609
---
data: 610
---
data: 611
```

Example 1: pub/sub

- Create a ROS package with two nodes, a publisher and a subscriber
- Goal: Subscribe to the `/numbers` topic and print out its contents

```
$ roscd ros_topic/src
$ touch ros_subscriber.cpp
```

- We will implement a new C++ class called `ROS_SUB`.
  - Multiple functions can easily share information get by topics

Example 1: pub/sub

```
1  #include "ros/ros.h"
2  #include "std_msgs/Int32.h"
3  #include <iostream>
```

Example 1: pub/sub

```
1  class ROS_SUB {
2    public:
3      ROS_SUB();
4      void topic_cb( std_msgs::Int32ConstPtr data);
5
6    private:
7      ros::NodeHandle _nh;
8      ros::Subscriber _topic_sub;
9  };
```

Example 1: pub/sub

```
1  ROS_SUB::ROS_SUB() {
2    _topic_sub = _nh.subscribe ("/numbers", 0, &ROS_SUB::topic_cb, this
         );
3
4  }
```

- `subscribe` function is part of the `ros::NodeHandle` class.
- No class function:

```
1  subscribe( string topic_name, int queue, void*
       function_callback)
```

- Class function:

```
1  subscribe( string topic_name, int queue,void(T::*)(M)
       callback function, T * obj)
```

  - inside a member function we can used the `this` pointer to refer to the invoking object.

Example 1: pub/sub

```
1  void ROS_SUB::topic_cb( std_msgs::Int32ConstPtr data) {
2    ROS_INFO("Listener: %d", data.data);
3  }
```

- What is a `Int32ConstPtr`??

```
1  melodic/include/std_msgs/Int32.h:
2    typedef boost::shared_ptr< ::std_msgs::Int32 const> Int32ConstPtr;
```

Example 1: pub/sub

```
1   int main( int argc, char** argv ) {
2     ros::init(argc, argv, "ros_subscriber");
3     ROS_SUB rs;
4     ros::spin();
5     return 0;
6   }
```

Example 1: pub/sub

- Modify the `CMakeLists.txt` file to add this new node (executable) and compile it with the `catkin_make` command

```
$ roscore
$ rosrun ros_topic topic_publisher
$ rosrun ros_topic topic_subsciber
```

Example 1: pub/sub

```
rostopic info /numbers

Output:
Type: std_msgs/Int32

Publishers:
* /ros_topic_publisher
(http://jcacace-Inspiron-7570:41703/)

Subscribers:
* /ros_subscriber
(http://jcacace-Inspiron-7570:34901/)
```

Example 1: pub/sub

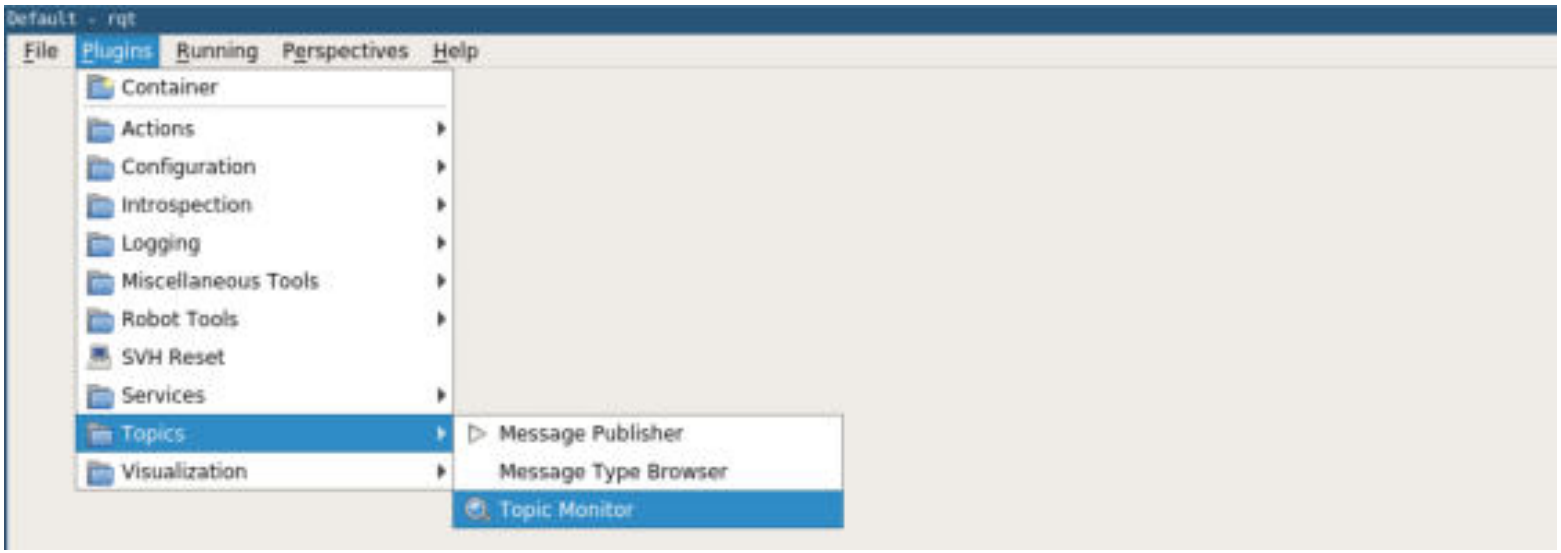
- Sometimes you just need to publish some data used to test a subscriber node
- Implement a ROS node from scratch could be a waste of time
- use `rostopic pub`

```
$ rostopic pub /numbers std_msgs::Int32
"data: 13" -r 10
```

This command publishes the number 13 on the topic `numbers` with a publishing rate of 10 Hz.

- `rqt` is a software framework that implements the various GUI tools as plugins
- To start `rqt` just type this command in your linux shell:

```
$ rqt
```

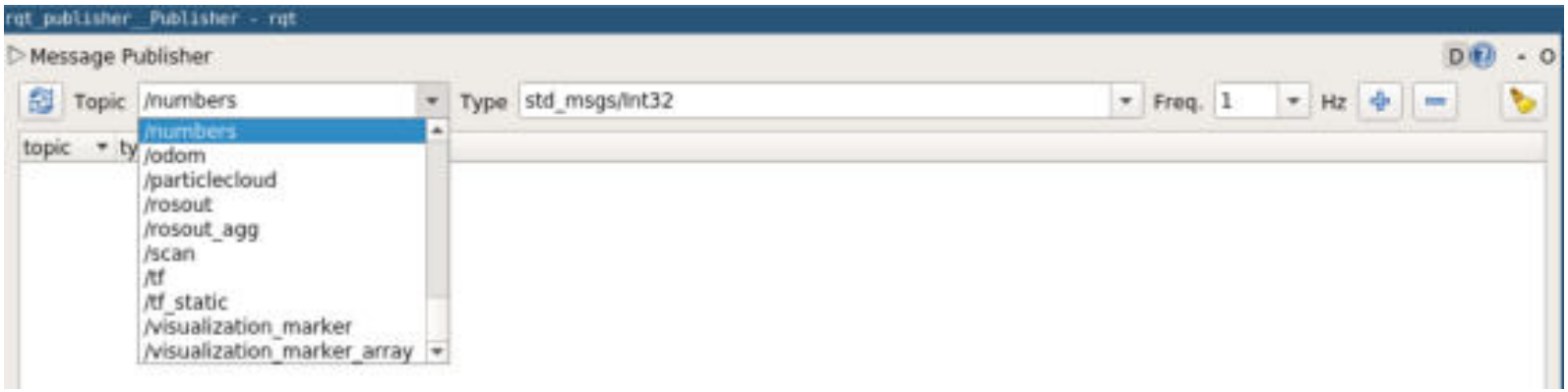


- In the `rqt` start window you can load any desired plugin present in your system.
- You can also add custom plugins.

Topic monitor:

- In the `rqt` start window you can load any desired plugin present in your system.
- You can also add custom plugins.

Topic publisher:



Notice that the same plugin can be launched directly from Linux shell:

```
$ rosrun rqt_publisher rqt_publisher
```

Example 2: ROS Service

- Create a ROS package with two nodes, a service server and a service client
- Goal: client node have to send a string to the server. The server must reply with a string
- ROS services doesn't rely on standard (already implemented) messages.
- We must implement our service message

```
$ roscd && cd ..
$ cd src
$ catkin_create_pkg ros_service roscpp std_msgs
message_generation message_runtime
```

- `message_generation` and `message_runtime` packages are used to handle the building and run-time usage of custom messages.

Example 2: ROS Service

- Create a new folder called `srv` in the package directory and add a `srv` file called `service.srv`

```
string in
---
string out
```

- Compile the message!

```
## Generate services in the 'srv' folder
add_service_files(
FILES
service.srv
)

generate_messages(
DEPENDENCIES
std_msgs
)
```

Example 2: ROS Service

- After compiled with `catkin_make` we can verify that everything works properly:

  ```
  $ rossrv show ros_service/service
  ```

  If we see the same content as we defined in the file, we can confirm it's working.

- Crate the source for client and server

  ```
  $ roscd ros_service/src
  $ touch service_server.cpp
  ```

Example 2: ROS Service

```
1  #include "ros/ros.h"
2  #include "ros_service/service.h"
3  #include <iostream>
4  #include <sstream>
5
6  using namespace std;
```

Example 2: ROS Service

```
1   bool service_callback
2   (ros_service::service::Request &req, ros_service::service::Response &
        res) {
3
4     std::stringstream ss;
5     ss << "Received Here";
6     res.out = ss.str();
7     ROS_INFO("From Client [%s], Server says
8     [%s]",req.in.c_str(),res.out.c_str());
9     return true;
10
11  }
```

Example 2: ROS Service

```
1  int main(int argc, char **argv) {
2    ros::init(argc, argv, "service_server");
3    ros::NodeHandle n;
4    ros::ServiceServer service = n.advertiseService("service",
         service_callback);
5    ROS_INFO("Ready to receive from client.");
6    ros::spin();
7    return 0;
8  }
```

Example 2: ROS Service

- Compile and run it!
- Check that the service instantiated in this node is active

```
$ rosservice list

Output:
/rosout/get_loggers
/rosout/set_logger_level
/service
/service_server/get_loggers
/service_server/set_logger_level
```

You can also call this service using the following command:

```
$ rosservice call /service "in_: 'Call'"

out: "Received Here"
```

Example 2: ROS Service

- Create the client node

```
$ roscd ros_service/src
$ touch service_client.cpp
```

```
1  #include "ros/ros.h"
2  #include <iostream>
3  #include "ros_service/service.h"
4  #include <iostream>
5  #include <sstream>
6
7  using namespace std;
```

Example 2: ROS Service

```
1  int main(int argc, char **argv) {
2  ros::init(argc, argv, "service_client");
3  ros::NodeHandle n;
4  ros::Rate loop_rate(10);
5  ros::ServiceClient client =
6  n.serviceClient<ros_service::service>("service");
```

Example 2: ROS Service

```
1       while (ros::ok()) {
2         ros_service::service srv;
3         std::stringstream ss;
4         ss << "Sending from Here";
5         srv.request.in = ss.str();
```

Example 2: ROS Service

```
1         if (client.call(srv)) {
2           cout << "From Client:
3           ["<<  srv.request.in << "],
4           Server says [" <<
5           srv.response.out << "]" << endl;
6         }
7         else {
8           ROS_ERROR("Failed to call service");
9           return 1;
10        }
11        ros::spinOnce();
12        loop_rate.sleep();
13      }
14      return 0;
15    }
```

Example 2: ROS Service

You can test the service connection running the server and later the client:

```
$ roscore
$ rosrun ros_service service_server
$ rosrun ros_service service_client
```

Additional commands to handle ROS service are reported in the following:

```
$ rosservice type /service: This will print the
message type of /service
$ rosservice info /service: This will print the
information of /service
```

Create custom messages

- ROS already provides a comprehensive set of messages for robotic programming
- In some situation could be useful to define your own ROS messages.
- ROS message definitions are stored in a `.msg` file in the `msg` folder of your package.

```
$ roscd ros_topic
$ mkdir msg && cd msg
$ touch demo.msg
```

```
1  string name
2  int32 data
```

Create custom messages

- When the package has been created custom messages were not considered
- Manually add the `message_generation` dependency in the `CMakeLists.txt`.

```
find_package(catkin REQUIRED COMPONENTS
  roscpp
  std_msgs
  message_generation

)
```

Create custom messages

- Uncomment the following line and add the custom message file:

```
1    add_message_files(
2      FILES
3      demo.msg
4    )
5    generate_messages(
6      DEPENDENCIES
7      std_msgs
8    )
```

- As usual, to use the added message, you have to compile the `ros_topic` package

Exercise 1

- Parrot package: develop a ROS package with a publisher and a subscriber. The publisher node accepts as input string or characters using the keyboard and publish such data on a ROS topic. The subscriber prints out the published data.
  - Test publisher and subscriber also using `rqt` and command line ROS commands.

Exercise 2

- Fibonacci Service: The Fibonacci Sequence is the series of numbers: `0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ...`. The next number is found by adding up the two numbers before it. Develop a ROS Service taking 2 numbers (**`index`**, **`length`**) as input and returning a portion of the fibonacci sequence:
  - The first argument of the service represents the index of an element along the fibonacci sequence:

    `f[0] = 0, f[1] = 1, f[2] = 1, f[3] = 2, ...`
  - The second argument represent the number of element to return

  Starting from the **`index`** element of the sequence, return the next **`length`** element of the sequence.

Exercise 2

- Fibonacci Service: The Fibonacci Sequence is the series of numbers: `0, 1, 1, 2, 3, 5, 8, 13, 21, 34, ....` The next number is found by adding up the two numbers before it. Develop a ROS Service taking 2 numbers (`index`, `length`) as input and returning a portion of the fibonacci sequence:

  `Example:`

  ```
  Input: ( 8, 3 ), Output: 21, 34, 55
  f[8] = 21, f[7] = 13 -> f[9] = 21+13 = 34
  ```

Exercise 3

- Adder package: develop a ROS package that adds and publishes two random numbers.
  - Node1: in an infinite loop generates two random float numbers and publishes them on a Topic using a custom message
  - Node2: subscribes to the topic of Node1, sums the two numbers and republishes the result on another topic using custom message with three field:
    - Field 1: first random number
    - Field 2: second random number
    - Field 3: result of the sum

Exercise

- Try to use Object oriented programming (classes) and modularity
- Share with me your solution on github
- We can discuss your solutions during next lesson
- This is not part of the evaluation (for better or worse)