

# F1/10 Autonomous Racing

## ROS - Filesystem/Workspaces/Publishing/Subscribing

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### Lab Session CS4501

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### Lab objective:

In this lab, several concepts are used to explain how ROS is internally formed, the folder structure, and the minimum number of files that it needs to work. We then see an example of ROS publishing and Subscribing.

- Section [A]: Managing a ROS Environment
  - Section [B]: Creating a ROS Workspace
  - Section [C]: ROS Filesystem Tools
  - Section [D]: Creating a ROS Package
  - Section [E]: rospy Publisher and Subscriber.
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## [A] Managing a ROS Environment

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If you are ever having problems finding or using your ROS packages make sure that you have your environment properly setup. A good way to check is to ensure that environment variables like `ROS_ROOT` and `ROS_PACKAGE_PATH` are set:

```
$ printenv | grep ROS
```

The output should look something like this (based on your ROS distribution)

```
madhur@ubuntu:~$ printenv | grep ROS
ROS_ROOT=/opt/ros/kinetic/share/ros
ROS_PACKAGE_PATH=/opt/ros/kinetic/share
ROS_MASTER_URI=http://localhost:11311
ROS_VERSION=1
ROSLISP_PACKAGE_DIRECTORIES=
ROS_DISTRO=kinetic
ROS_ETC_DIR=/opt/ros/kinetic/etc/ros
```

If they are not then you might need to 'source' some setup.\*sh files.

If you just installed ROS from apt on Ubuntu then you will have setup.\*sh files in '/opt/ros/', and you could source them like so:

```
$ source /opt/ros/<distro>/setup.bash
```

If you installed ROS Kinetic, that would be:

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

You will need to run this command on every new shell you open to have access to the ROS commands, unless you add this line to your .bashrc. [This process allows you to install several ROS distributions (e.g. indigo and kinetic) on the same computer and switch between them.]

To do so:

```
echo "source /opt/ros/<distro>/setup.bash" >> ~/.bashrc
source ~/.bashrc
```

You may recall doing so during the ROS installation. Now you know the reason - to let every shell instance know of the location where ROS is installed on your system and to set the `PATH` environment.

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## [B] Creating a ROS Workspace

In general terms, the workspace is a folder which contains packages, those packages contain our source files and the environment or workspace provides us with a way to compile those packages. It is useful when you want to compile various packages at the same time and it is a good way of centralizing all of our developments.

Lets create and build a catkin workspace - similar to what we discussed in the lectures.

You can create the workspace in any directory on your machine, **except inside an existing workspace!**. For this example we will just create it in the home directory.

Go ahead and type in these commands one at a time:

```
$ mkdir -p ~/catkin_ws/src
$ cd ~/catkin_ws/src
$ catkin_init_workspace
$ cd ..
$ catkin_make
$ echo "source ~/catkin_ws/devel/setup.bash" >> ~/.bashrc
$ source ~/.bashrc
```

The output will look something like:

```
madhur@ubuntu:~$ mkdir -p ~/catkin_ws/src
madhur@ubuntu:~$ cd ~/catkin_ws/src
madhur@ubuntu:~/catkin_ws/src$ catkin_init_workspace
Creating symlink "/home/madhur/catkin_ws/src/CMakeLists.txt" pointing to "/opt/ros/kinetic/share/catkin/cmake/CMakeLists.txt"
madhur@ubuntu:~/catkin_ws/src$
```

```

madhur@ubuntu:~/catkin_ws/src$ cd ..
madhur@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/madhur/catkin_ws
Source space: /home/madhur/catkin_ws/src
Build space: /home/madhur/catkin_ws/build
Devel space: /home/madhur/catkin_ws/devel
Install space: /home/madhur/catkin_ws/install
####
#### Running command: "cmake /home/madhur/catkin_ws/src -DCATKIN_DEVEL_PREFIX=/home/mad
####
-- The C compiler identification is GNU 5.4.0
-- The CXX compiler identification is GNU 5.4.0
.
.
.
-- Configuring done
-- Generating done
-- Build files have been written to: /home/madhur/catkin_ws/build
####
#### Running command: "make -j2 -l2" in "/home/madhur/catkin_ws/build"
####

```

The `catkin_make` command is a convenience tool for working with catkin workspaces. Running it the first time in your workspace, it will create a `CMakeLists.txt` link in your 'src' folder. Additionally, if you look in your current directory you should now have a 'build' and 'devel' folder. Inside the 'devel' folder you can see that there are now several `setup.*sh` files.

## [C] ROS Filesystem Tools

Code is spread across many ROS packages.

Navigating with command-line tools such as `ls` and `cd` can be very tedious which is why ROS provides tools to help you.

For this tutorial we will inspect a package in `ros-tutorials`, please install it using:

```
sudo apt-get install ros-<distro>-ros-tutorials
```

Example output:

```
madhur@ubuntu:~$ sudo apt-get install ros-kinetic-ros-tutorials
[sudo] password for madhur:
Reading package lists... Done
Building dependency tree
Reading state information... Done
ros-kinetic-ros-tutorials is already the newest version (0.7.1-0xenial-20181107-045510-
ros-kinetic-ros-tutorials set to manually installed.
0 upgraded, 0 newly installed, 0 to remove and 220 not upgraded.
```

## [C.1] rospack

rospack allows you to get information about packages. In this tutorial, we are only going to cover the find option, which returns the path to package.

Type in:

```
$ rospack find [package_name]
```

Example:

```
$ rospack find roscpp
```

would return:

```
madhur@ubuntu:~$ rospack find roscpp
/opt/ros/kinetic/share/roscpp
```

[Q.] Find and report where `turtlesim` is installed ?

[Q.] The package `turtlesim` depends on the `gennodejs` package. Is this statement true or false ?

Hint: Use `rospack help` to figure out which command to use to answer the true/false statement above.

## [C.2] roscd

roscd allows you to change directory (cd) directly to a package or a stack. [Recall what is a stack ?]

Usage:

```
$ roscd [locationname[/subdir]]
```

Example:

```
$ roscd roscpp
```

Now let's print the working directory using the Unix command `pwd` :

```
$ pwd
```

You should see:

```
YOUR_INSTALL_PATH/share/roscpp
```

Example:

```
madhur@ubuntu:~$ roscd roscpp
madhur@ubuntu:/opt/ros/kinetic/share/roscpp$ pwd
/opt/ros/kinetic/share/roscpp
```

**You can see that `YOUR_INSTALL_PATH/share/roscpp` is the same path that `rospack find` gave in the previous example.**

`roscd` can also move to a subdirectory of a package or stack.

**Wondering where does `turtlesim` store the images of all the turtles it renders in the ocean ?**

Type

```
$ roscd turtlesim/images/
```

`roscd log` will take you to the folder where ROS stores log files.

Note that if you have not run any ROS programs yet, this will yield an error saying that it does not yet exist.

## [C.3] `rosls`

`rosls` allows you to `ls` directly in a package by name rather than by absolute path.

Example:

```
$ rosls roscpp_tutorials
```

Output:

```
madhur@ubuntu:~/ros/log$ rosls roscpp_tutorials
cmake  launch  package.xml  srv
```

## Note

You may have noticed a pattern with the naming of the ROS tools:

`rospack` = `ros` + `pack`(age)

`roscd` = `ros` + `cd`

`rosls` = `ros` + `ls`

This naming pattern holds for many of the ROS tools.

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## [D] Creating a ROS Package

Similar to an operating system, an ROS program is divided into folders, and these folders have files that describe their functionalities.

- **Packages:** Packages form the atomic level of ROS. A package has the minimum structure and content to create a program within ROS. It may have ROS runtime processes (nodes), configuration files, and so on.
- **Package manifests:** Package manifests provide information about a package, licenses, dependencies, compilation flags, and so on. A package manifest is managed with a file called `package.xml`.
- **Message (msg) types:** A message is the information that a process sends to other processes. ROS has a lot of standard types of messages. Message descriptions are stored in `my_package/msg/MyMessageType.msg`
- **Service (srv) types:** Service descriptions, stored in `my_package/srv/MyServiceType.srv`, define the request and response data structures for services provided by each process in ROS.

## For a package to be considered a catkin package it must meet a few requirements:

1. The package must contain a catkin compliant `package.xml` file. That `package.xml` file provides meta information about the package.
2. The package must contain a `CMakeLists.txt` which uses `catkin`.
3. Each package must have its own folder. This means no nested packages nor multiple packages sharing the same directory.

The simplest possible package might have a structure which looks like this:

```
my_package/  
  CMakeLists.txt  
  package.xml
```

Packages usually reside inside ROS workspaces. A trivial workspace might look like this:

```
workspace_folder/      -- catkin ROS WORKSPACE  
  src/                  -- SOURCE SPACE  
    CMakeLists.txt      -- 'Toplevel' CMake file, provided by catkin  
    package_1/  
      CMakeLists.txt    -- CMakeLists.txt file for package_1  
      package.xml       -- Package manifest for package_1  
    ...  
    package_n/  
      CMakeLists.txt    -- CMakeLists.txt file for package_n  
      package.xml       -- Package manifest for package_n
```

### [D.1] Creating a `catkin` Package

Lets change to the source space directory of the catkin workspace you created earlier in Section [B].

```
# You should have created this in the Creating a Workspace Tutorial  
$ cd ~/catkin_ws/src
```

Now use the `catkincreatepkg` script to create a new package called 'beginner\_tutorials' which depends on `std_msgs`, `roscpp`, and `rospy`:



```
$ catkin_create_pkg beginner_tutorials std_msgs rospy roscpp
```

This will create a `beginner_tutorials` folder which contains a `package.xml` and a `CMakeLists.txt`, which have been partially filled out with the information you gave `catkin_create_pkg`.

`catkin_create_pkg` requires that you give it a `package_name` and optionally a list of dependencies on which that package depends:

```
$ catkin_create_pkg <package_name> [depend1] [depend2] [depend3]
```

The output will look something like this:

```
madhur@ubuntu:~/catkin_ws/src$ catkin_create_pkg beginner_tutorials std_msgs rospy roscpp
Created file beginner_tutorials/package.xml
Created file beginner_tutorials/CMakeLists.txt
Created folder beginner_tutorials/include/beginner_tutorials
Created folder beginner_tutorials/src
Successfully created files in /home/madhur/catkin_ws/src/beginner_tutorials.</br>
Please adjust the values in package.xml.
madhur@ubuntu:~/catkin_ws/src$
```

## [D.2] Building a catkin workspace and sourcing the setup file

Now you need to build the packages in the catkin workspace:

```
$ cd ~/catkin_ws
$ catkin_make
```

The output will look something like this:

```

madhur@ubuntu:~/catkin_ws$ catkin_make
Base path: /home/madhur/catkin_ws
Source space: /home/madhur/catkin_ws/src
Build space: /home/madhur/catkin_ws/build
Devel space: /home/madhur/catkin_ws/devel
Install space: /home/madhur/catkin_ws/install
####
#### Running command: "cmake /home/madhur/catkin_ws/src
.
.
.
-- +++ processing catkin package: 'beginner_tutorials'
-- ==> add_subdirectory(beginner_tutorials)
-- Configuring done
-- Generating done
-- Build files have been written to: /home/madhur/catkin_ws/build
####
#### Running command: "make -j2 -l2" in "/home/madhur/catkin_ws/build"
####

```

Add the workspace to your ROS environment you need to source the generated setup file:

```
$ source ~/catkin_ws/devel/setup.bash
```

### [D.3] package.xml: The package manifest

The generated package.xml should be in your new package. You can go through the new package.xml and touch up any elements that need your attention.

**[Q.] Use a ROS command from section C to list the directory and files (e.g. `package.xml` ) under the newly created `beginner_tutorial` package ?**

**[Q.] Change the current working directory to the directory which contains the `package.xml` manifest using a single ROS command.**

The `package.xml` would look like this:

```

1 <?xml version="1.0"?>
2 <package format="2">
3   <name>beginner_tutorials</name>
4   <version>0.1.0</version>
5   <description>The beginner_tutorials package</description>
6
7   <maintainer email="you@yourdomain.tld">Your Name</maintainer>
8   <license>BSD</license>
9   <url type="website">http://wiki.ros.org/beginner_tutorials</url>
10  <author email="you@yourdomain.tld">Jane Doe</author>
11
12  <buildtool_depend>catkin</buildtool_depend>
13
14  <build_depend>roscpp</build_depend>
15  <build_depend>rospy</build_depend>
16  <build_depend>std_msgs</build_depend>
17
18  <exec_depend>roscpp</exec_depend>
19  <exec_depend>rospy</exec_depend>
20  <exec_depend>std_msgs</exec_depend>
21
22 </package>

```

## [E] Python Publisher and Subscriber.

The following instructions assume that you created a `catkin_ws` folder on your machine, using the instructions discussed during the previous lab sessions and the `beginner_tutorials` package inside the `src` folder.

////////////////////////////////////

### Step 1)

Create a new directory in your home folder to clone the `f1tenth-course-labs` Github repository.

```

mkdir ~/github
cd ~/github
git clone https://github.com/linklab-uva/f1tenth-course-labs.git

```

This will create a `f1tenth-course-labs` folder inside the `github` directory you just created.

The git repository, will usually contain folders with source codes or templates for ROS nodes. For example, the

repository contains a folder `beginner_tutorials`, which we will use for illustrating the next step.

### Step 3)

Copy the contents of the `beginner_tutorials` directory in the github folder to the `beginner_tutorials` directory in the `src` folder of the catkin workspace.

After copying the contents of the github repo, you will find that a new folder called `scripts` has been added to the `beginner_tutorials` package. Make sure all the python scripts are executable: Run:

```
cp -a ~/github/fltenth-course-labs/beginner_tutorials/. ~/catkin_ws/src/beginner_tutorials
cd ~/catkin_ws
find . -name "*.py" -exec chmod +x {} \;
catkin_make
```

**Step 4)** Finally, as you may have already guessed, we need to source our new package that was just added to the ROS workspace.

```
sudo echo "source ~/catkin_ws/devel/setup.bash" >> ~/.bashrc
source ~/.bashrc
```

That's it!, you should now be able to run any ROS command that interacts with the `beginner_tutorials` package.

**Step 4)** Let's run the two nodes `talker` and `listener` we have just built with `catkin_make`

Run:

```
roscore
roslaunch beginner_tutorials talker.py
roslaunch beginner_tutorials listener.py
```

Talker should begin outputting text similar to:

```
[INFO] [WallTime: 1394915011.927728] hello world 1394915011.93
[INFO] [WallTime: 1394915012.027887] hello world 1394915012.03
[INFO] [WallTime: 1394915012.127884] hello world 1394915012.13
[INFO] [WallTime: 1394915012.227858] hello world 1394915012.23
...
```

And listener should begin outputting text similar to:

```
[INFO] [WallTime: 1394915043.555022] /listener_9056_1394915043253I heard hello world 13
[INFO] [WallTime: 1394915043.654982] /listener_9056_1394915043253I heard hello world 13
[INFO] [WallTime: 1394915043.754936] /listener_9056_1394915043253I heard hello world 13
[INFO] [WallTime: 1394915043.854918] /listener_9056_1394915043253I heard hello world 13
...
```

Now run

```
rostopic echo chatter
```

`chatter` is the name of the topic on which the messages are being published, and subscribed. You should see an output similar to what is shown below:

```
data: hello world 1394915083.35
---
data: hello world 1394915083.45
---
data: hello world 1394915083.55
---
data: hello world 1394915083.65
---
data: hello world 1394915083.75
---
...
```

**Step 5)** For you reference, the talker.py and listener.py code is shown below:

*talker.py*

```
1 #!/usr/bin/env python
2 # license removed for brevity
3 import rospy
4 from std_msgs.msg import String
5
6 def talker():
7     pub = rospy.Publisher('chatter', String, queue_size=10)
8     rospy.init_node('talker', anonymous=True)
9     rate = rospy.Rate(10) # 10hz
10    while not rospy.is_shutdown():
11        hello_str = "hello world %s" % rospy.get_time()
12        rospy.loginfo(hello_str)
13        pub.publish(hello_str)
14        rate.sleep()
15
16 if __name__ == '__main__':
17     try:
18         talker()
19     except rospy.ROSInterruptException:
20         pass
```

*listener.py*

```

1 #!/usr/bin/env python
2 import rospy
3 from std_msgs.msg import String
4
5 def callback(data):
6     rospy.loginfo(rospy.get_caller_id() + "I heard %s", data.data)
7
8 def listener():
9
10     # In ROS, nodes are uniquely named. If two nodes with the same
11     # name are launched, the previous one is kicked off. The
12     # anonymous=True flag means that rospy will choose a unique
13     # name for our 'listener' node so that multiple listeners can
14     # run simultaneously.
15     rospy.init_node('listener', anonymous=True)
16
17     rospy.Subscriber("chatter", String, callback)
18
19     # spin() simply keeps python from exiting until this node is stopped
20     rospy.spin()
21
22 if __name__ == '__main__': catkin package as we just changed some code
23     listener()

```

## Exercise:

---

We know that ROS does not allow two nodes to have the same name, but let us verify this with the `talker.py` and `listener.py` nodes that we just installed and executed.

1. Open a new terminal instance.
2. type `roscd beginner_tutorials/scripts` and hit enter
3. Next, we will edit the `rospy.init_node` command in `talker.py` and change the argument `anonymous=True` on line 8 to `anonymous=False`.
4. You can use your favorite file editor to do this. Just be sure, to save your changes.
5. Lets rebuild the catkin package as we just changed some code.
6. You know the drill: