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ROS Nodes, Topics, and Messages

Foundation Course

September 5, 2019

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Recap

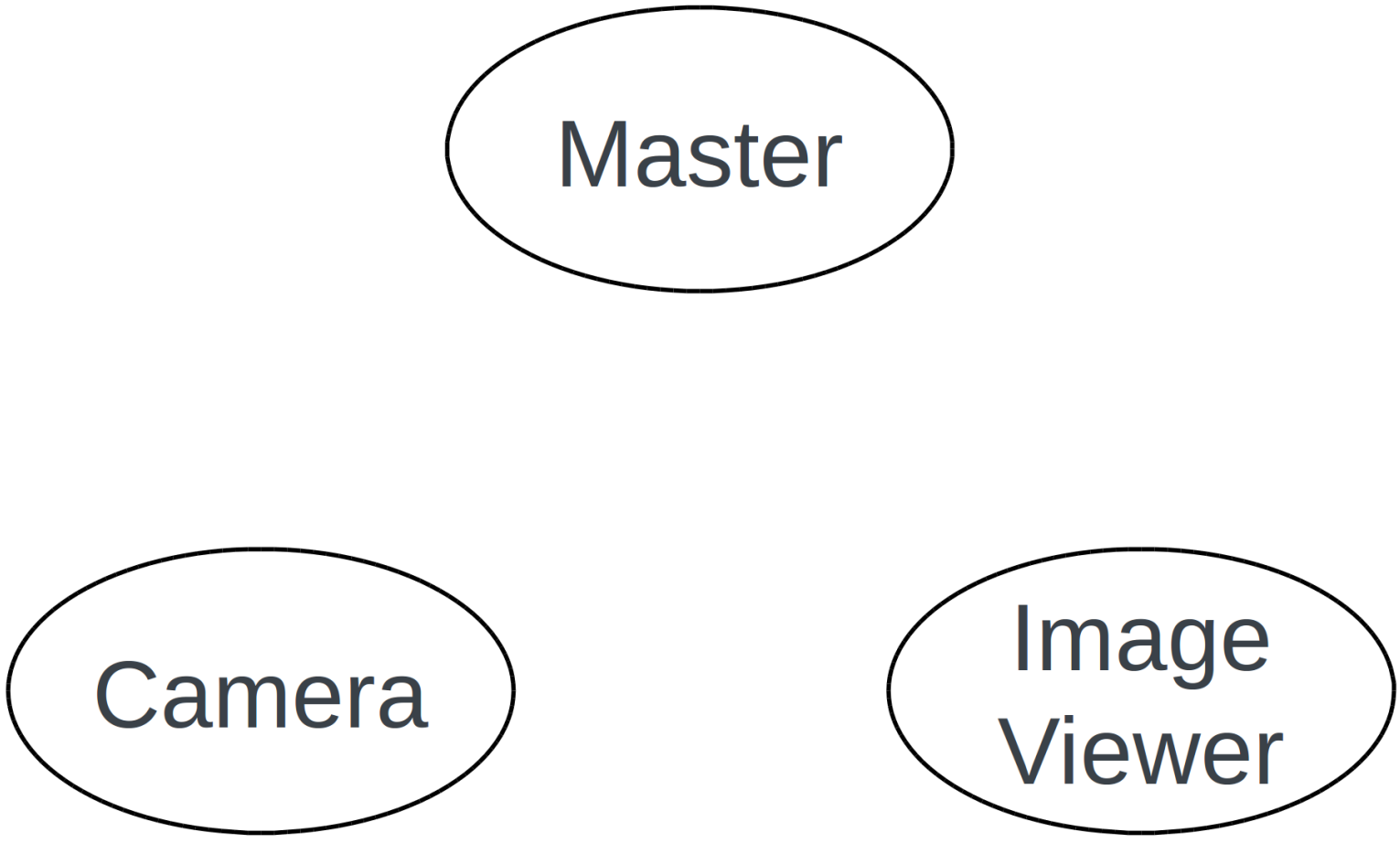
Summary of yesterday's session

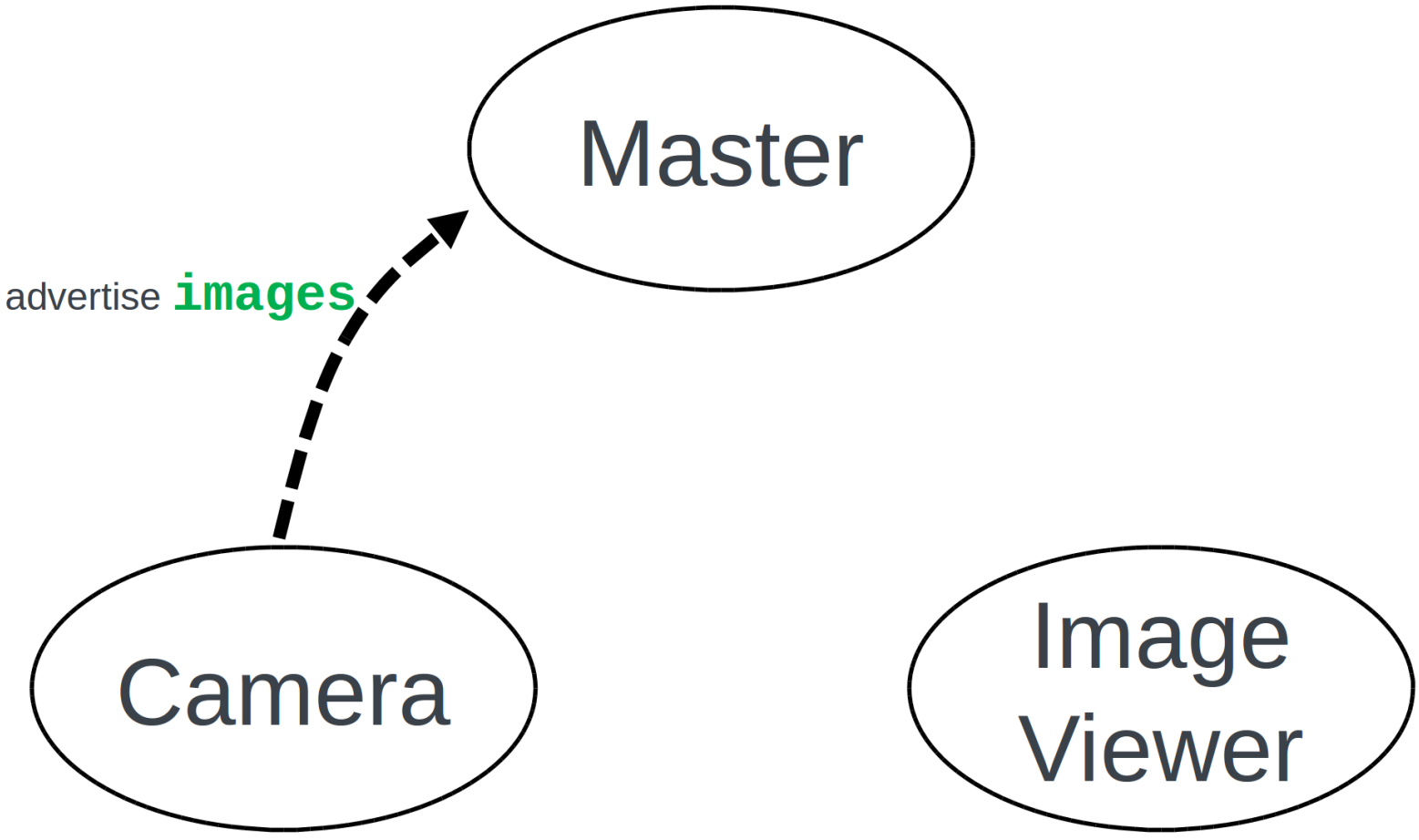
- ROS is a collection of libraries and tools that helps you when you develop software for robots.
- ROS provides several ways to transfer data between nodes:
  1. ROS topics and messages (**publish/subscribe**).
  2. ROS services (**request/reply**).
  3. ROS actions (**request/reply**).
  4. Parameter server.

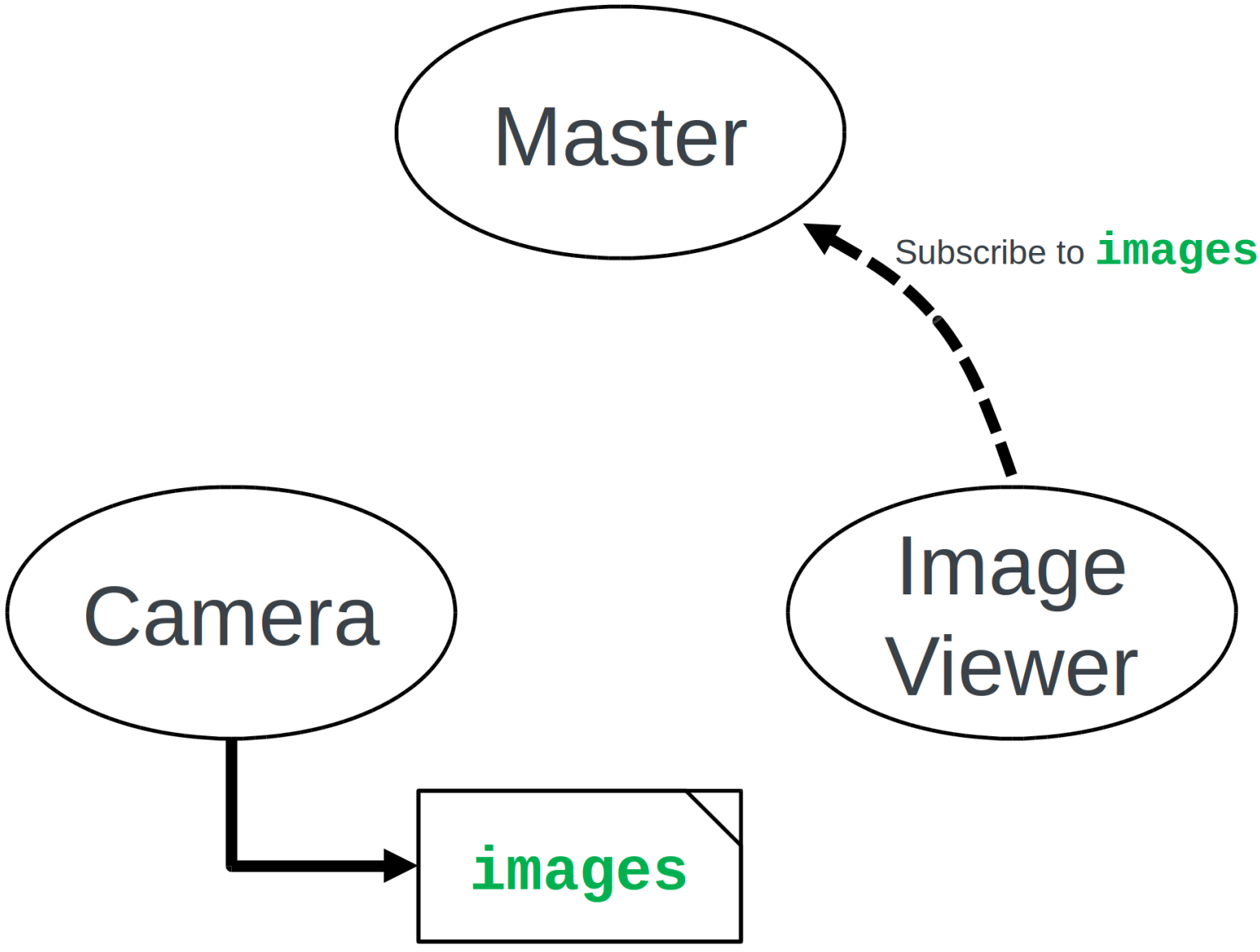
Recap

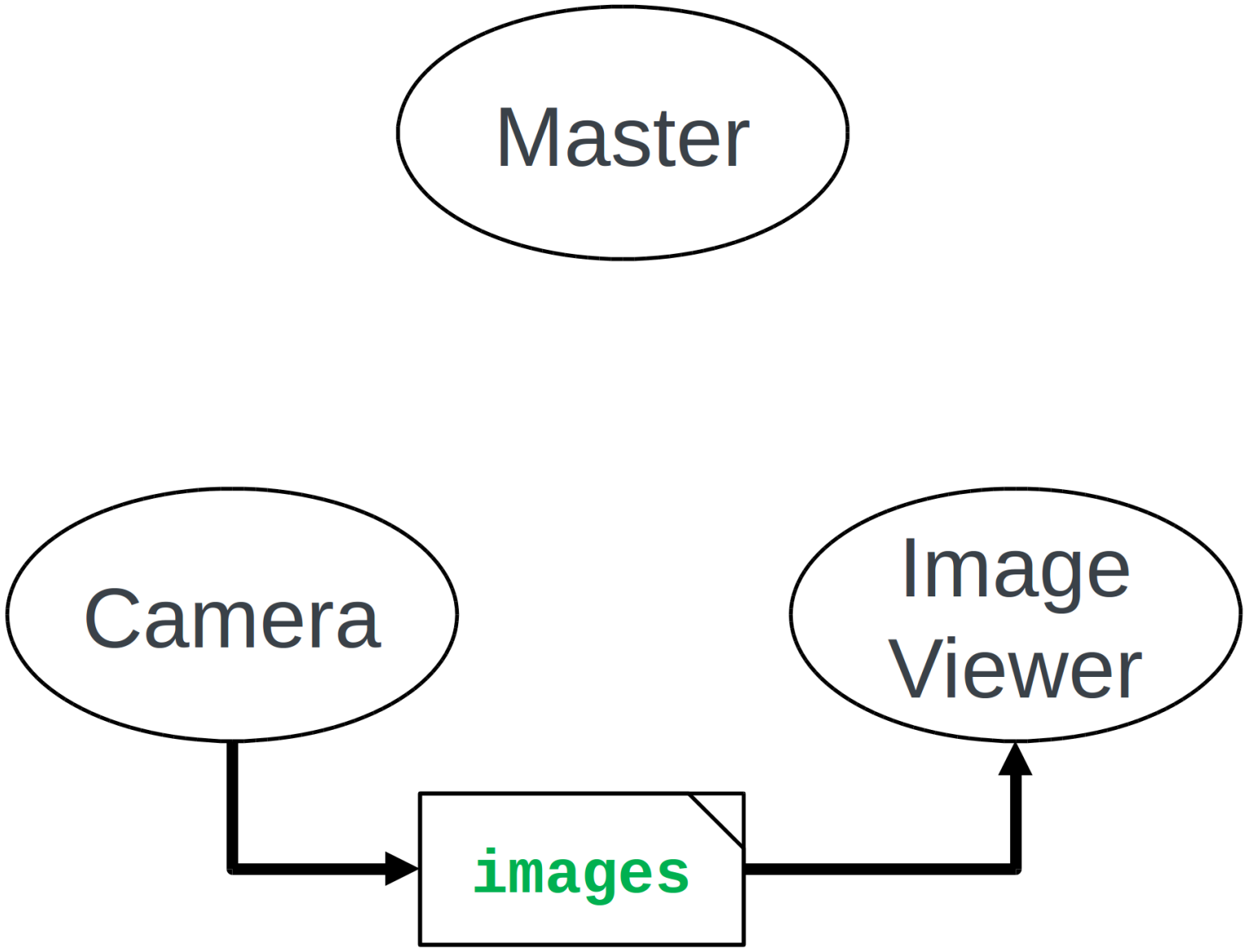
Summary of yesterday's session

- We will focus today on ROS topics and messages..


Master
Camera
Image
Viewer


Master
advertise images
Camera
Image
Viewer


Master
Subscribe to images
Camera
Image Viewer
images


Master
Camera
Image
Viewer
images

A simple ROS node

../scripts/00_simple_node.py

```
#!/usr/bin/env python


import rospy
from time import sleep

rospy.init_node("print_text")


while True:
    print "Hello world!"
    sleep(1)
```

A simple ROS node

../scripts/01_simple_node.py

```
#!/usr/bin/env python

import rospy


rospy.init_node("print_text")
rate = rospy.Rate(1)

while not rospy.is_shutdown():
    print "Hello world!"
    rate.sleep()
```

Writing a publisher node in Python

../scripts/02_simple_publisher.py

```
rospy.init_node('node name')
```

- nodes name must be unique. If you want to make sure the name of the node is unique:

```
rospy.init_node('node name', anonymous= True)
```

- node name will look like this:
  `/print_text_19637_1567065017476`

Three ways to run a node

ROS Nodes

There are 3 ways to run a node:

1. Like you normally do (not recommended). Example (in case of python node):

```
python <file name>
```

2. using rosrun command:

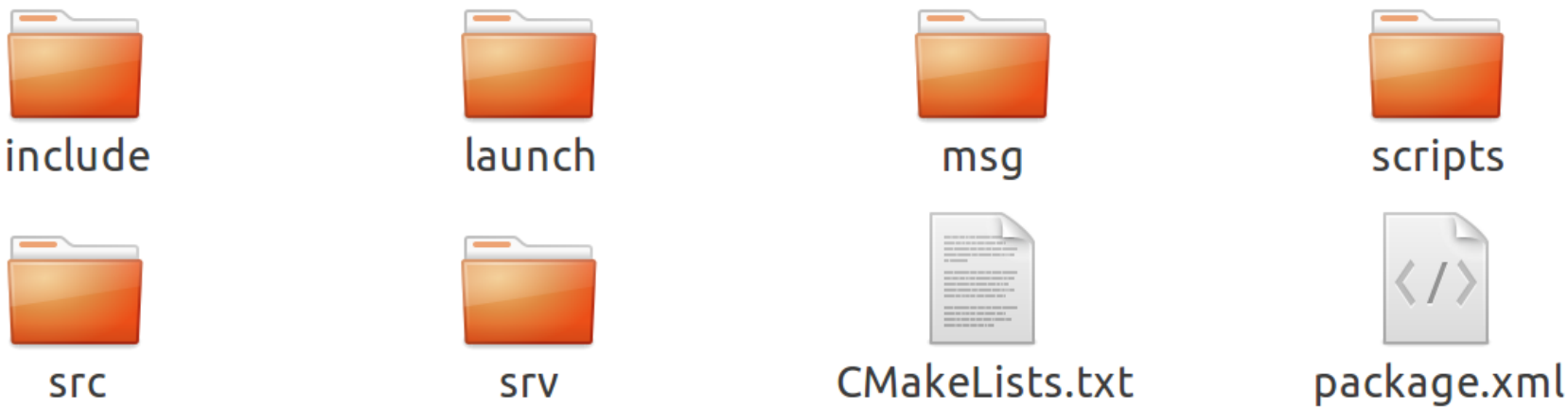
```
rosrun <package name> <node name>
```

3. Using launch files. (we'll see it later)

Let's create a package first!

ROS Nodes

- ROS commands find your files (python scripts, cpp files, launch files, message definitions) if they are located in a package inside the workspace.
- Normally, a package looks like this:



Let's create a package first!

ROS Nodes

- go to the README and do the steps for **creating a package**.

ROS commands

ROS Nodes

- Navigate to a ROS package directly:

```
roscd <package name>
```

- run a node without navigating to it's directory:

```
rosrun <package name> <executable>
```

Let's create a package first!

ROS Nodes

- go to the README and do the steps for **running a node**.

More ROS commands

ROS Nodes, Topics, and Messages

- List all the running nodes:

```
rosnode list
```

- Get more info. about a certain node:

```
rosnode info <node name>
```

Writing a publisher node in Python

ROS Nodes, Topics, and Messages

- Let's extend our previous node and make it publish a String ROS message.

Writing a publisher node in Python

../scripts/02_simple_publisher.py

```
#!/usr/bin/env python

import rospy

from std_msgs.msg import String

rospy.init_node('talker')

pub = rospy.Publisher('myFirstTopic', String, queue_size=10)

rate = rospy.Rate(1)

my_message = String()
my_message.data = "Hello there! How are you?"

while not rospy.is_shutdown():
    pub.publish(my_message)
    rate.sleep()
```

Writing a publisher node in Python

../scripts/02_simple_publisher.py

```
rospy.Publisher(name, data_class, queue_size)
```

- `name`: Name of the topic to publish on.
- `data_class`: The type of message. It is a ROS message class.
- `queue_size`: The size of the outgoing message queue.

Writing a publisher node in Python

../scripts/02_simple_publisher.py

```
rospy.Publisher(
name,
data_class,
subscriber_listener=None,
tcp_nodelay=False,
latch=False,
headers=None,
queue_size=None
)
```

Writing a publisher node in Python

Things to note..

- ROS messages are implemented as classes.
- To publish a message you also need to define a **Publisher** class.
- Most of ROS concepts and functionalities are implemented as classes. This is why understanding OOP helps you understand ROS better.

Writing a publisher node in Python

ROS Nodes, Topics, and Messages

- Go to the README file and do the instructions of section: **some of ROS commands**.

More ROS commands

ROS Nodes, Topics, and Messages

- Get the current list of topics:

```
rostopic list
```

- Print published messages:

```
rostopic echo <topic name>
```

More ROS commands

ROS Nodes, Topics, and Messages

- Publish a message from terminal:

```
rostopic pub <topic name> <msg type> <msg>
```

- Get message type of a topic:

```
rostopic type <topic name>
```

How to use ROS messages

ROS Nodes, Topics, and Messages

- ROS messages are just classes with attributes you can fill.
- ROS messages are defined in separate files and have to be placed in a package. (will be covered today).
- The following command can be used to see the class attributes, or the description, of a ROS message:

```
rosmsg show <package/msg>
```

How to use ROS messages

Example

```
rosmsg show std_msgs/String
```

The output is:

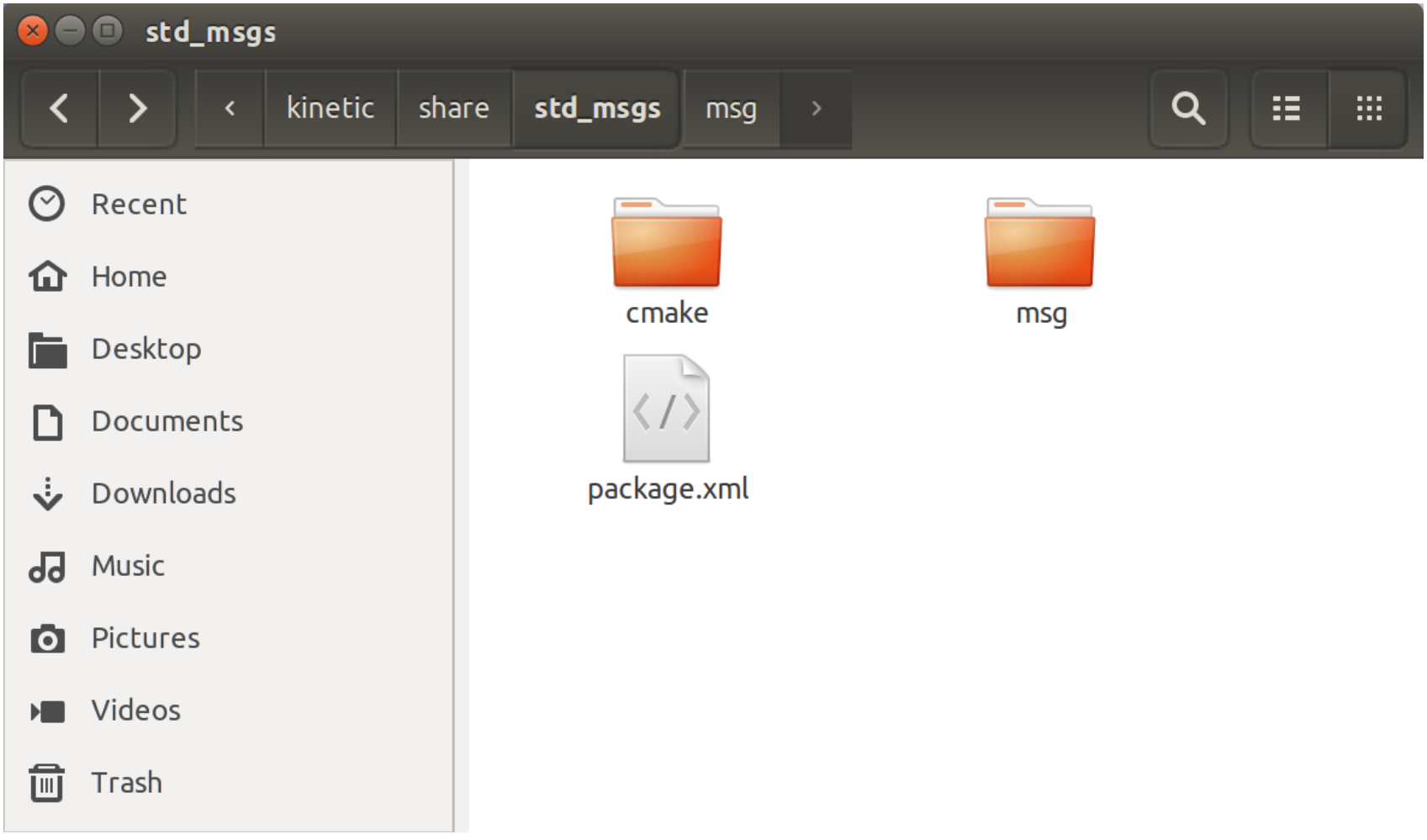
```
string data
```

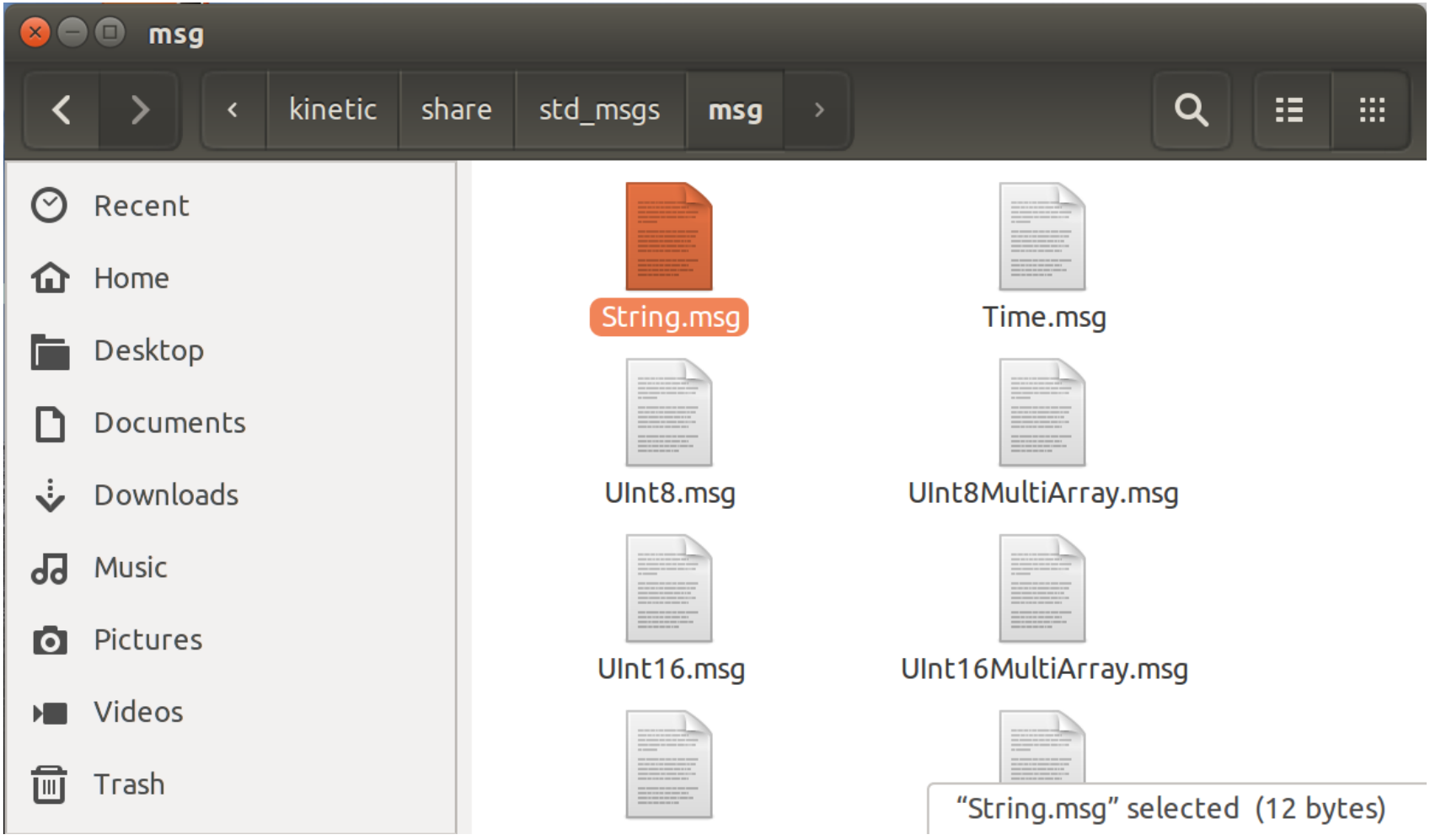
- It means ROS `String` message is a class with an attribute named `data` of type string (Python string).

How to use ROS messages

Importing a ROS message

- `String` message is located in the `std_msgs` package.


std_msgs
kinetic
share
std_msgs
msg
Recent
Home
Desktop
Documents
Downloads
Music
Pictures
Videos
Trash
cmake
msg
package.xml



Note: this is not the file that is imported in our script though! this file is not even Python nor C++. We will see later what this file is.

How to use ROS messages

Importing a ROS message

Python

```python
from std_msgs.msg import String
```

C++

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

Exercise 1

Writing a subscriber node in Python

../scripts/03_simple_subscriber.py

```
#!/usr/bin/env python

import rospy
from std_msgs.msg import String

def my_callback_function(msg):
    print msg

rospy.init_node('listener')
rate = rospy.Rate(100)
sub = rospy.Subscriber('myFirstTopic', String,
                       callback=my_callback_function)

while not rospy.is_shutdown():
    pass
```

Writing a subscriber node in Python

../scripts/04_simple_subscriber.py

```
#!/usr/bin/env python

import rospy
from std_msgs.msg import String


def my_callback_function(msg):
    print msg

rospy.init_node('listener')
rate = rospy.Rate(100)

rospy.Subscriber('myFirstTopic', String, callback=my_callback_function)

rospy.spin()
```

Writing a subscriber node in Python

Subscriber class

- go to the README, and let's do section:
  Simple subscriber

Writing a subscriber node in Python

Subscriber class

```
rospy.Subscriber(
name,
data_class,
callback=None,
callback_args=None,
queue_size=None,
buff_size=65536,
tcp_nodelay=False
)
```

Writing a subscriber node in Python

Subscriber class

- go to the README, and let's do section:
  Simple subscriber

General notes

more on ROS nodes

- You can define multiple publishers and subscribers in a node.
- You can call `init_node` function once only!
- To make your code look neat, you can wrap ROS stuff in a class and hide them!

Let's see an example with multiple publishers/subscribers and let's define them in a class...

Let’s see script
05_node_example.py

ROS Launch Files

- If you are working on a project that is comprised of multiple nodes, it's not practical to run each node manually everytime!
- ROS Launch files provide a way to run/launch multiple nodes at once.

ROS Launch Files

../launch/00_simple.launch

```
<!-- Example launch file to run the turtlesim node-->

<launch>

    <node pkg="turtlesim" type="turtlesim_node" name="turtle"/>

</launch>
```

ROS Launch Files

- To run a launch file:

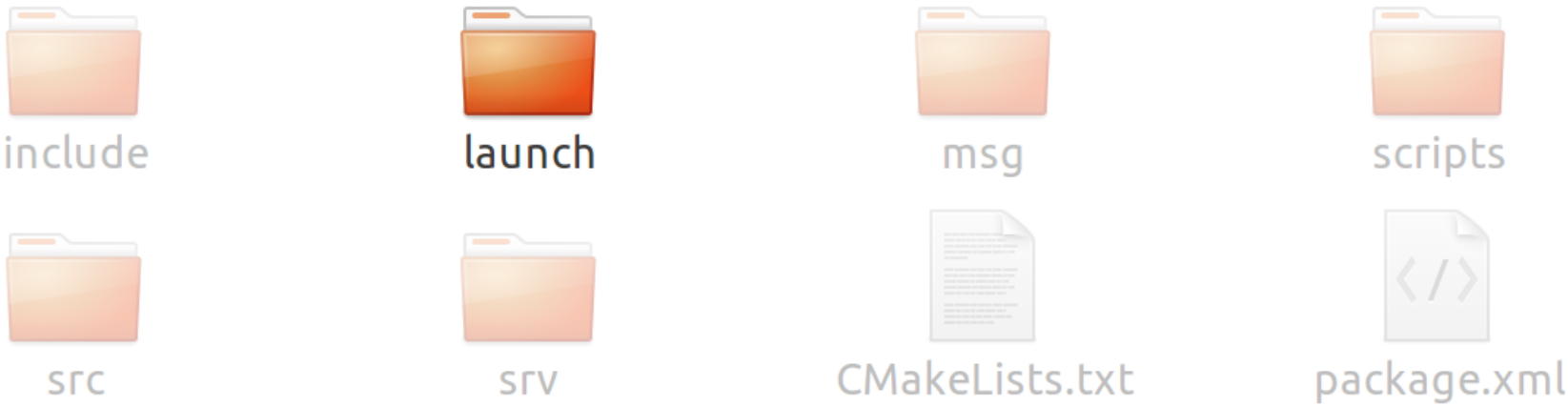
```
roslaunch <package name> <launch file>
```

- Example

```
roslaunch my_first_package 00_simple.launch
```

ROS Launch Files

- Ros launch files are XML files that consists for tags.
- They have `.launch` file extension.
- You would ideally place them inside a `launch` folder inside your package.



ROS Launch Files

- With launch files, you can do the following:
  - Define nodes to be run.
  - Set ROS parameters on the parameter server.
  - Name remapping (will be covered later).
  - Define arguments for the launch file itself.
  - Include other launch files, and pass arguments to them.
  - Bring up the master (no need to call `roscore`).
  - Push a group of nodes into a separate namespace (will be covered later).
  - The list goes on..

ROS Launch Files

../launch/01_simple.launch

```
<!-- Example launch file to run
the turtlesim node and our script 06-->

<launch>

    <node pkg="turtlesim" type="turtlesim_node" name="turtle"/>

    <node pkg="my_first_package" type="06_parameters_example.py"
     name="commander"/>

</launch>
```

ROS Launch Files

- Go to the README, and do section
  Using launch files

Exercise 2

Names in ROS

- Resources in ROS computation graph (nodes, topics, parameters, etc..) must all have unique names.

Names in ROS

- Suppose we have a `camera` node that publishes on a topic named `image`
- what if you added a camera to your robot, and want to run two `camera` nodes?
- You will get name collision if you run the node twice!

Names in ROS

- ROS provides two mechanisms to avoid such situation:
  - Namespaces.
  - Remappings.

Namespaces

Names in ROS

- A node can be run under a namespace. For example, if we have two cameras, left camera, and right camera, the two `camera` nodes can have different namespaces:
- Node names:

```
/left/camera
/right/camera
```

- Topic names:

```
/left/image
/right/image
```

Namespaces

How to? Using rosrun

- From the terminal using `rosrun` command:

```
rosrun <package name> <node name> __ns:=<namespace>
```

Example:

```
rosrun turtlesim turtlesim_node __ns:=first
```

Node name becomes:

```
/first/turtlesim
```

- Notice the forward slash (/) is used as a separator.

Namespaces

How to? from a launch file

- Using the `group` tag, you can push down resource names under a chosen namespace.

Namespaces

How to? from a launch file

../launch/02_group_tag.launch

```
<!-- Example launch file using the group tag-->

<launch>

    <group ns="/first">
        <node pkg="turtlesim" type="turtlesim_node" name="turtle"/>
    </group>

</launch>
```

Name Remappings

- The second way ROS provides to change resource names is **remapping**.
- With name remapping, you can rename any resource. Examples:
  - rename a node.
  - Change the name of the topic a node publishes/subscribes to.
- Again, this is done without having to edit source code of the node. (node is reusable without altering it).

Name Remappings

How to? Using rosrun

- Example, from the terminal using `rosrun` command:

```
rosrun turtlesim turtlesim_node /turtle1/cmd_vel:=/vel
```

Changes topic name to:

/vel

- Example, from the terminal changing node name:

```
rosrun turtlesim turtlesim_node /turtlesim:=/second_turtle
```

Changes node name to:

/second_turtle

Name Remappings

How to? from a launch file

../launch/03_remap_tag.launch

```
<!-- Example launch file using remap tag-->

<launch>
    <node pkg="turtlesim" type="turtlesim_node" name="turtle">
    <remap from="/turtle1/cmd_vel" to="/vel"/>
    </node>
</launch>
```

Name resolution

- When you define a resource name (ex: node name, topic name, etc..), you can specify how names should be resolved.

Name resolution

- Example, suppose the snippet below is for a node named `talker` and has a namespace of `group1` (so the resolved node name is `/group1/talker`):

```
rospy.Publisher(myTopic, String, queue_size=10)
```

- The resolved topic name (what appears when you do `rostopic list`) will be:

```
/group1/myTopic
```

Name resolution

- The previous example shows **relative** name resolution, which is the default way names are resolved in ROS.
- The following table shows all types of name resolutions

Figures

Tables, graphs, and images

node name	syntax	type	resolved name
/group1/talker	`myTopic`	relative	/group1/myTopic
/group1/talker	`/myTopic`	global	/myTopic
/group1/talker	`~myTopic`	private	/group1/talker/myTopic

Parameter Server

- A network-shared dictionary accessible to all nodes.
- All nodes can access and modify those values.
- Parameter server is a part of ROS Master.

Parameter Server

Command line tools

- The `rosparam` command can do the following:
  - Get a list of parameter names currently held by the master.

```
rosparam list
```

  - Set/change the value of a parameter:

```
rosparam set <parameter name>
```

  - Get/fetch the value of a parameter:

```
rosparam get <parameter name>
```

Parameter Server

rospy interface to the parameter server

- A node can fetch/retrieve a parameter as follows:

```
rospy.get_param(param_name)
```

- It can optionally define a default value in case the parameter is not set in the parameter server:

```
rospy.get_param(param_name,default=value)
```

- A node can set a parameter on the parameter server:

```
rospy.set_param(param_name,param_value)
```

Let’s see script

06_parameters_example.py

Parameter Server

Using launch files

../launch/04_param_tag.launch

```
<!-- Example launch file using param tag-->

<launch>
<param name="rate" value="100"/>
<param name="radius" value="0.5"/>
<param name="angular_speed" value="1"/>

<node pkg="my_first_package" type="06_parameters_example.py" name="command
<node pkg="turtlesim" type="turtlesim_node" name="turtle"/>
</launch>
```

Parameter Server

Name resolution

- Name resolution applies also to parameter names (as we discussed earlier).
- The examples that follows, assume the node name is `move` and has a namespace of `/robot1`, so the resolved node name is `/robot1/move`.

Parameter Server

- Global naming:

```
var = rospy.get_param("/speed")
resolves to ⇒ /speed
```

- Relative naming:

```
var = rospy.get_param("speed")
resolves to ⇒ /robot1/speed
```

- Private naming:

```
var = rospy.get_param("~speed")
resolves to ⇒ /robot1/move/speed
```

Let’s use private parameter names instead of relative

07_parameters_example.py

Parameter Server

Using launch files

../launch/05_private_params.launch

```
<!-- Example launch file, setting private parameters-->

<launch>
<node pkg="my_first_package" type="07_parameters_example.py" name="command
<param name="rate" value="100"/>
<param name="radius" value="0.5"/>
<param name="angular_speed" value="1"/>
</node>
<node pkg="turtlesim" type="turtlesim_node" name="turtle"/>
</launch>
```

Exercise 3

Catkin

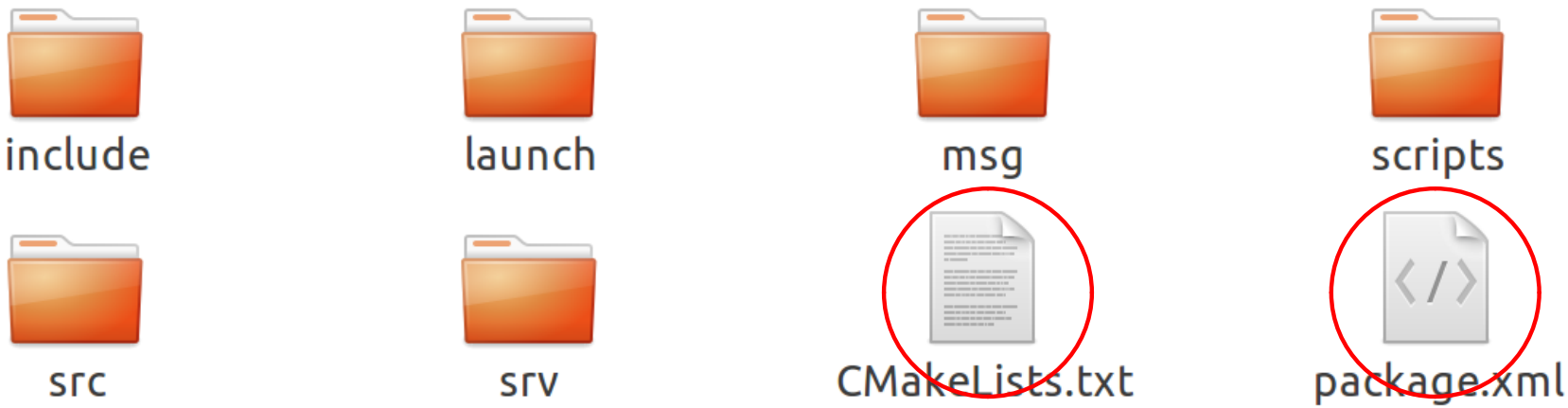
- In ROS, packages are compiled and built using Catkin.
- The build process is not only to compile C++ nodes, it's also used to generate source files (ex. Python and C++ files that define ROS messages as classes which you can import/include).
- Today, we will look at ROS message generation, and how to define custom ROS messages.

Catkin

- Catkin is not a compiler. It is a tool that handles the compilation process starting from source files up to generating executables.
- It invokes system's compiler (ex. g++, gcc, etc..) and handles your package dependencies.
- to do that, Catkin needs information on what to compile, where to find, etc...

A ROS package

- The `CMakeList.txt` file is what tells Catkin these things.
- `package.xml` file is where you add information about the package (author, maintainer, dependencies, etc..).



Catkin

- These files are auto-generated by `catkin_create_pkg` command.

Package Manifest

package.xml file

- Go to the package we have created earlier (`my_first_package`) and open the `package.xml` file there.

Package Manifest

package.xml file

- It's an XML file that consists of tags you need to fill.
- It defines properties of the package which include:
  - Name of the package: <name>.
  - Version number: <version>.
  - Description: <description>.
  - Package maintainer: <maintainer>.
  - License: <license>.
  - Package URL: <url>.
  - Author of package <author>.

Package Manifest

package.xml file

- It also defines package dependencies:
  - Build Dependencies: <build_depend>.
  - Build Export Dependencies: <build_export_depend>.
  - Execution Dependencies: <exec_depend>.
  - Test Dependencies: <test_depend>.
  - Build Tool Dependencies: <buildtool_depend>. (catkin)
  - Documentation Tool Dependencies: <doc_depend>
  - All of the above: <depend>.

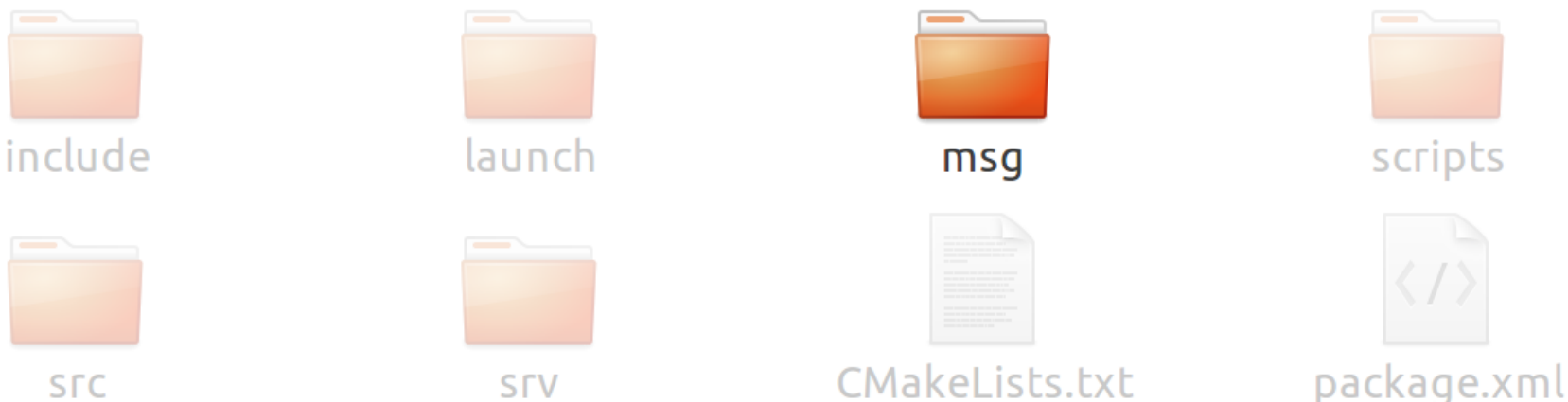
CMakeLists.txt

- The second file is (`CMakeLists.txt`). This defines how to build the package, what to compile, etc..
- Go to the package we have created earlier (`my_first_package`) and open the(`CMakeLists.txt`).

Custom ROS message

How to define them

- Custom messages are defined in separate text files.
- These files have `.msg` extension and have to be placed in `msg` folder inside the package.



Custom ROS message

msg file format

- The format is as follows:

```
fieldtype1    fieldname1
fieldtype2    fieldname2
fieldtype3    fieldname3
```

Custom ROS message

Examples

- `String.msg`:

```
string data
```

- The `String` message has one field of built-in type `string`.

Custom ROS message

Built-in types

- Some of the built-in field types:

Built-in type	C++	Python
bool	uint8_t	bool
int8	int8_t	int
int32	int32_t	int
string	std::string	string (str)
float32	float	float

Custom ROS message

Examples

- `Twist.msg`:

```
Vector3 linear
Vector3 angular
```

- It's possible to embed other message descriptions. In this example `Vector3` is another message.

Custom ROS message

Examples

- `Twist.msg`:

```
Vector3 linear
Vector3 angular
```

- `Vector3.msg`:

```
float64 x
float64 y
float64 z
```

Custom ROS message

- Let's define a custom message and see how to build the package!

- Go to the README and see section **Custom ROS messages**.

Custom ROS message

Behind the scenes

- Catkin uses these message description files to generate Python and C++ source files.
- The generated source files actually define the messages as classes, with public attributes matching the fields defined in the message description file.
- The generated source files are what you actually import or include in your nodes.

Custom ROS message

Behind the scenes

- This is why you need to build your package after writing a new `.msg` file. Otherwise you won't be able to import it.
- You need to explicitly tell Catkin about your `.msg` files and the dependencies needed to generate message classes.
- You do that in both the `CMakeLists.txt` and `package.xml` files.

References

- rospy full documentation (all the classes, all the functions ..etc):

  `http://docs.ros.org/kinetic/api/rospy/html/`
- ROS wiki
- On ROS names: “Programming Robots with ROS: a practical introduction to the Robot Operating System" Book, 2015, by Quigley and others.
- More on ROS names: `https://wiki.ros.org/Remapping%20Arguments`

Thank you

Any questions?