ROS STRUCTURE

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Today schedule

- ROS Core components and structure
- How to start ROS on your device (you should have docker running)
- ROS core components
- Debugging visualization tools
- First simple ros node creation

Note: we received many applications for the challenges, we had to perform some selection, first meetings next week

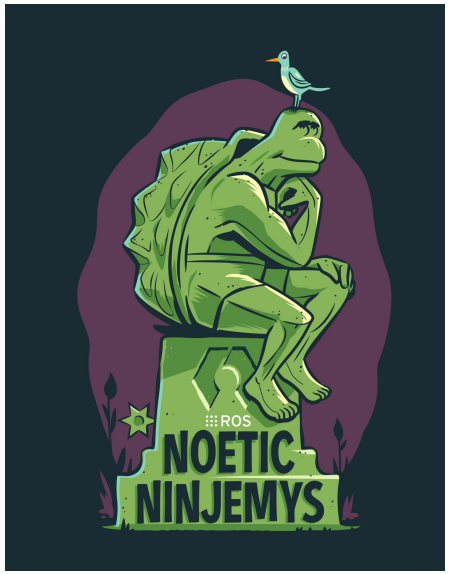
ROS: ROBOT OPERATING SYSTEM

ROS main features:

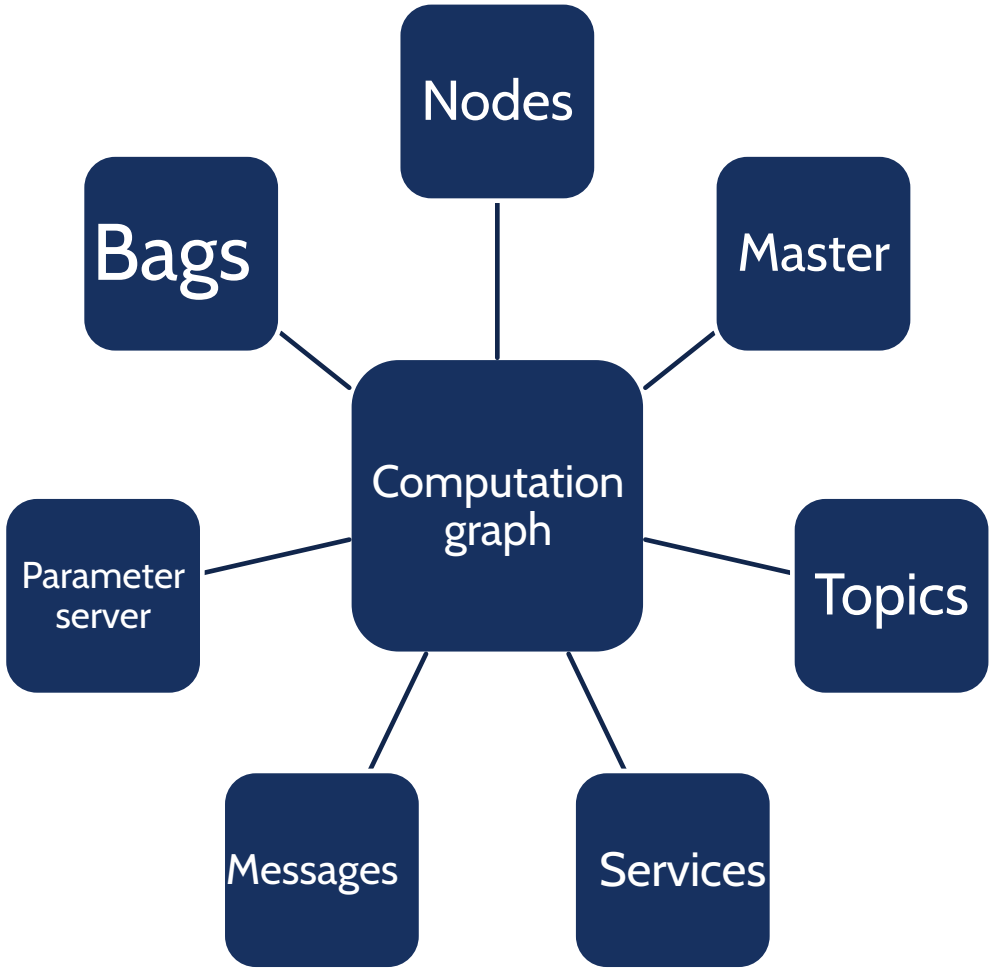
- Distributed framework
- Reuse code
- Language independent
- Easy testing on Real Robot & Simulation
- Scaling

ROS Components

- File system tools
- Building tools
- Packages
- Monitoring and GUIs
- Data Logging



ROS STRUCTURE: COMPUTATIONAL GRAPH



The *Computation Graph* is the peer-to-peer network of ROS processes that are processing data together.

NODES

Executable unit of ROS:

- Scripts for Python
- Compiled source code for C++

Process that performs computation

Nodes exchange information via the graph

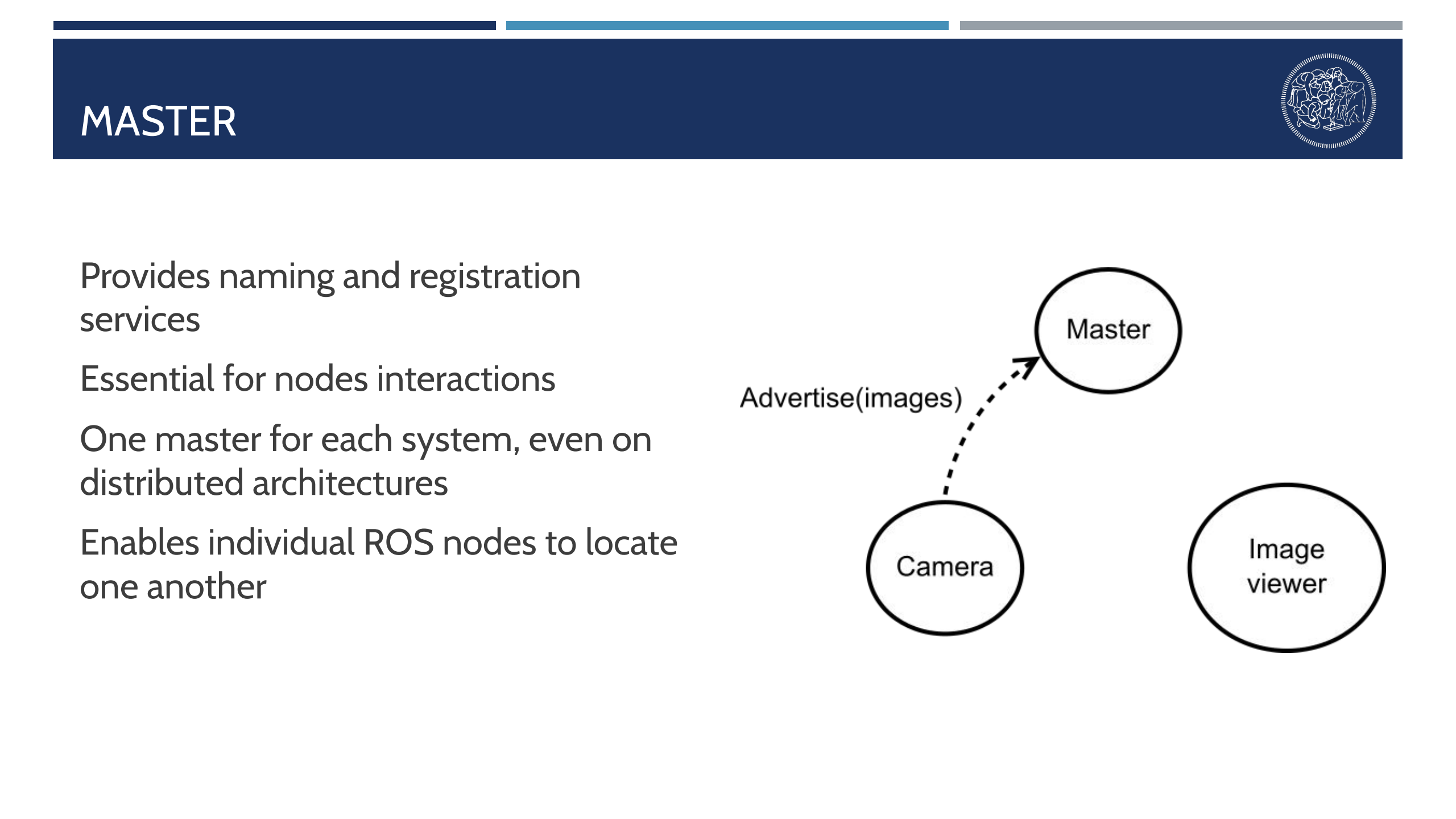
Meant to operate at fine-grained scale

A robot system is composed by various nodes

```
rosrun package_name node_name
```

```
rosrun turtlesim turtlesim_node
```

MASTER



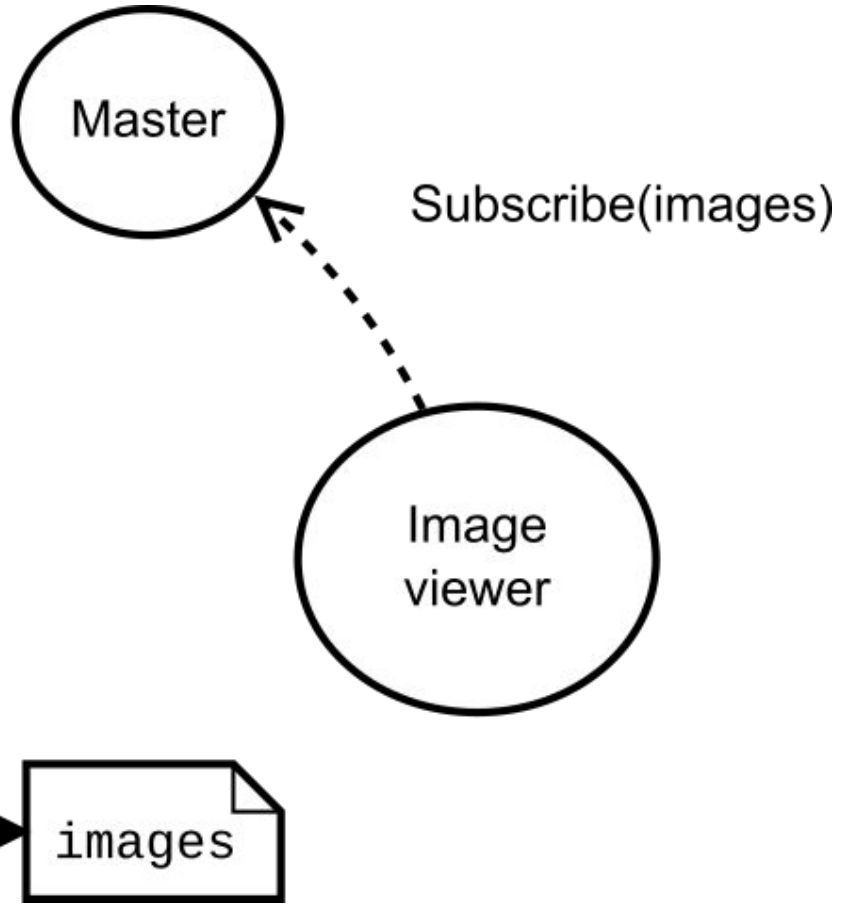
Provides naming and registration services

Essential for nodes interactions

One master for each system, even on distributed architectures

Enables individual ROS nodes to locate one another

MASTER



- Provides naming and registration services
- Essential for nodes interactions
- One master for each system, even on distributed architectures
- Enables individual ROS nodes to locate one another

MASTER

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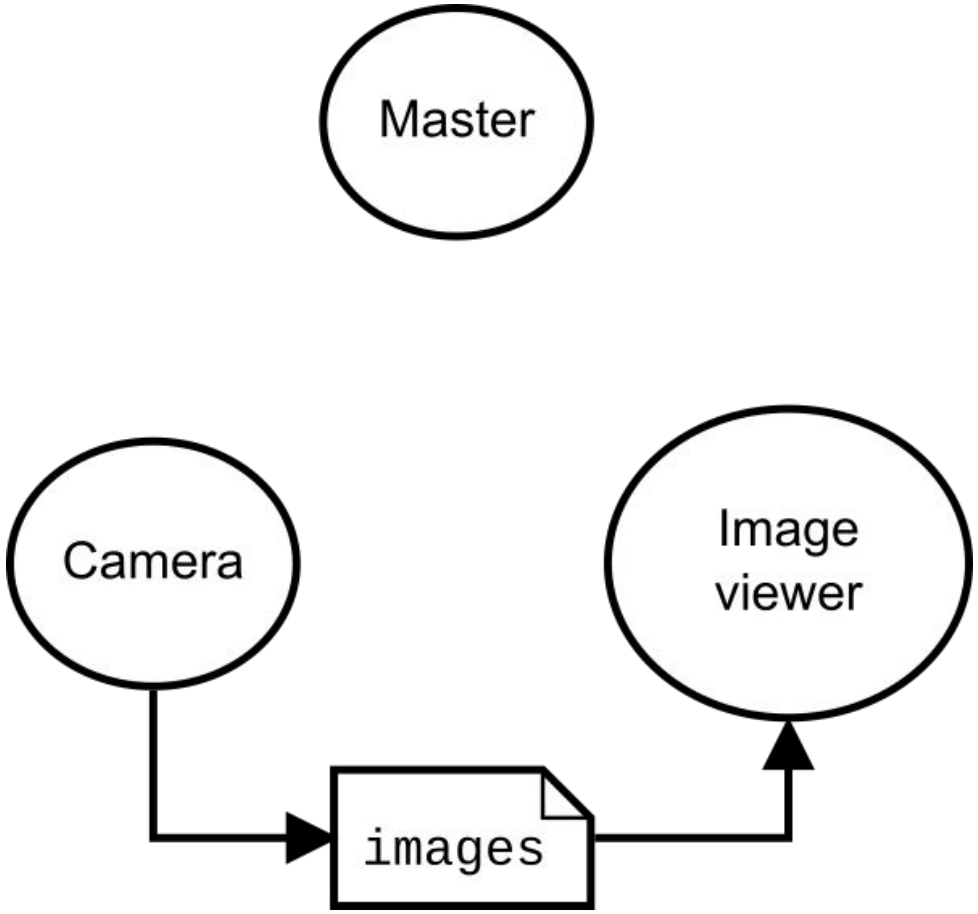
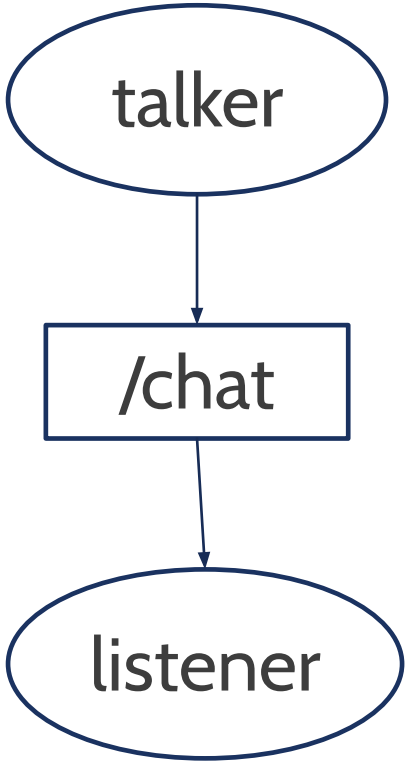


TOPICS

- Named channels for communication
- Implement the publish/subscribe paradigm
- No guarantee of delivery
- Have a specific message type
- Multiple nodes can publish messages on a topic
- Multiple nodes can read messages from a topic



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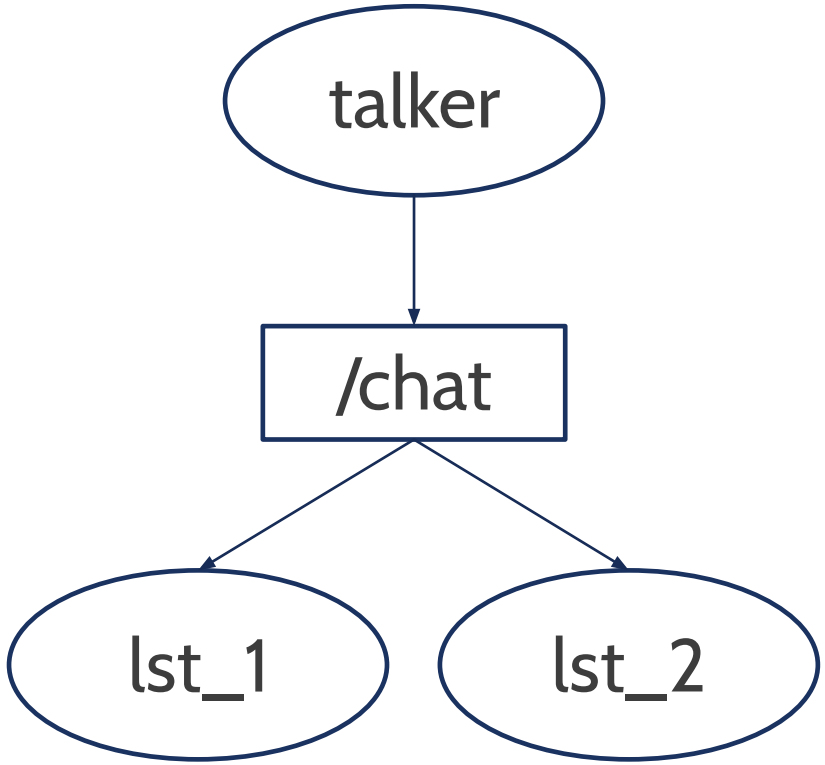

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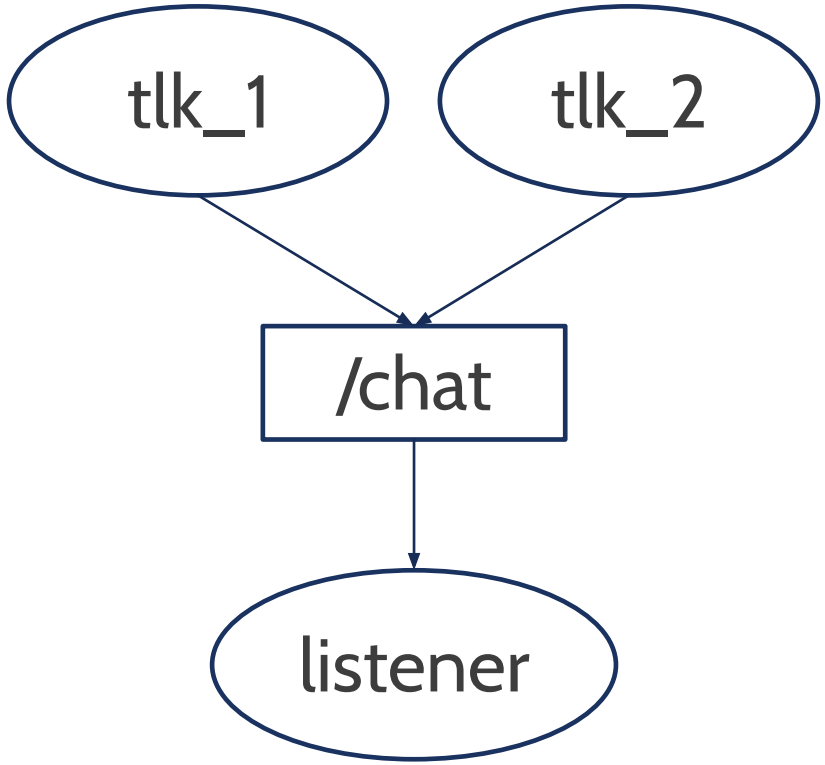

MESSAGES

Messages are exchanged on topics

They define the type of the topic

Various already available messages

It is possible to define new messages using a simple language

Existing message types can be used in new messages together with base types

std_msgs/Header.mgs

```
uint32 seq
time stamp
string frame_id
```

std_msgs/String.msg

```
string data
```

sensor_msgs/Joy.msg

```
std_msgs/Header header
float32[] axes
int32[] buttons
```

MESSAGES

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Existing message types can be used in new messages together with base types

Quick recap:

14 base types

32 std_msgs

29 geometry_msgs

26 sensor_msgs

...and more

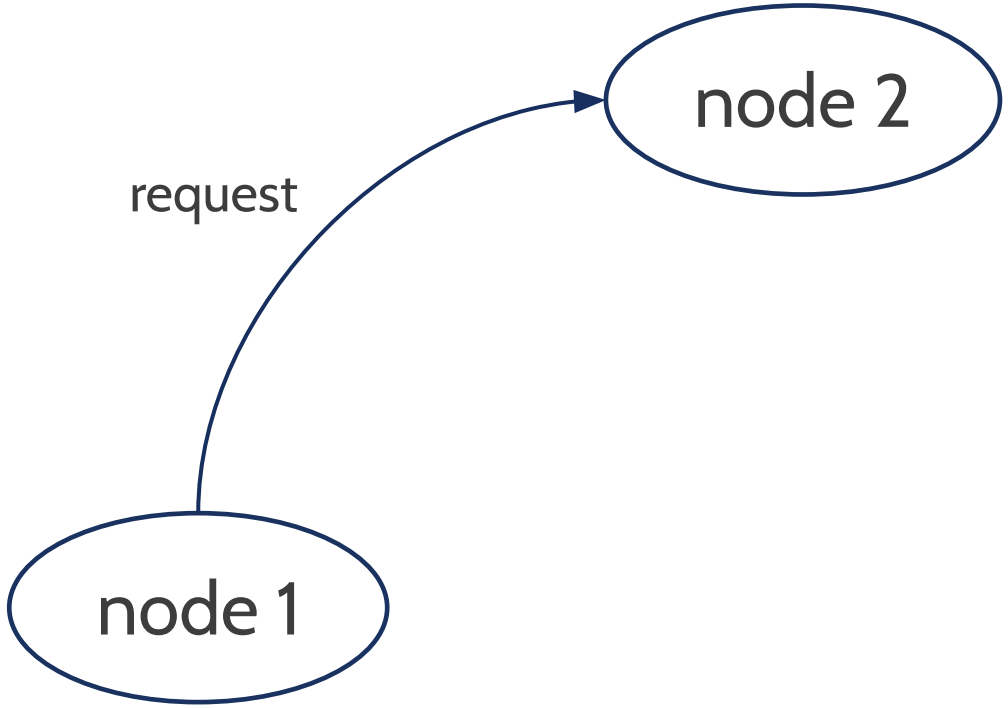
SERVICES

Work like remote function calls

Implement the client/server paradigm

Code waits for service call to complete

Guarantee of execution



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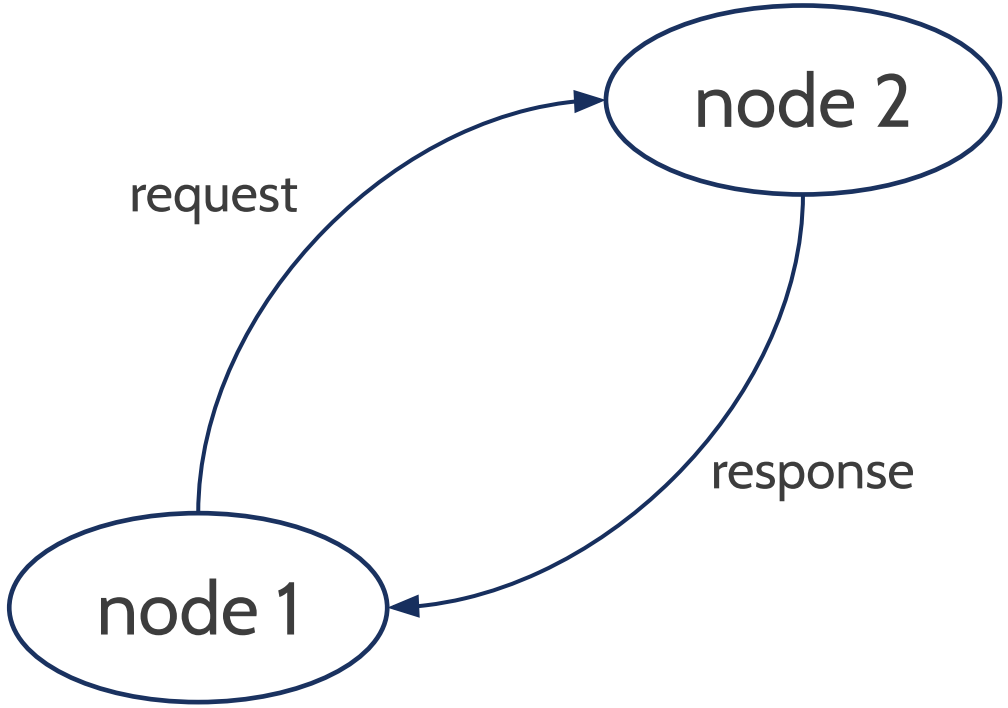

SERVICES

Work like remote function calls

Implement the client/server paradigm

Code waits for service call to complete

Guarantee of execution

Use of message structures

example/AddTwoInt.srv

```
int64 A
int64 B
---
int64 Sum
```

request

response

PARAMETER SERVER

Shared, multivariable dictionary that is accessible via network

Nodes use this server to store and retrieve parameters at runtime

Not designed for performance, not for data exchange

Connected to the master, one of the functionalities provided by roscore

name	value
/gains/P	10.0
/gains/I	1.0
/gains/D	0.1
use_sim_time	True

rosparam [set|get] name value

rosparm set use_sim_time True

rosparam get use_sim_time

> True

PARAMETER SERVER

Shared, multivariable dictionary that is accessible via network

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Connected to the master, one of the functionalities provided by roscore

Available types:

- 32-bit integers
- Booleans
- Strings
- Doubles
- ISO8601 dates
- Lists
- Base64-encoded binary data

BAGS

File format (**.bag*) for storing and playing back messages

Primary mechanism for data logging

Can record anything exchanged on the ROS graph (messages, services, parameters, actions)

Important tool for analyzing, storing, visualizing data and testing algorithms.

```
rosbag record –a
```

```
rosbag record /topic1 /topic2
```

```
rosbag play ~/bags/fancy_log.bag
```

```
rqt_bag ~/bags/fancy_log.bag
```

ROSCORE

roscore is a collection of nodes and programs that are pre-requisites of a ROS-based system

Must be running in order for ROS nodes to communicate

Launched using the roscore command.

Elements of roscore:

- a ROS Master
- a ROS Parameter Server
- a rosout logging node

ROS FILESYSTEM

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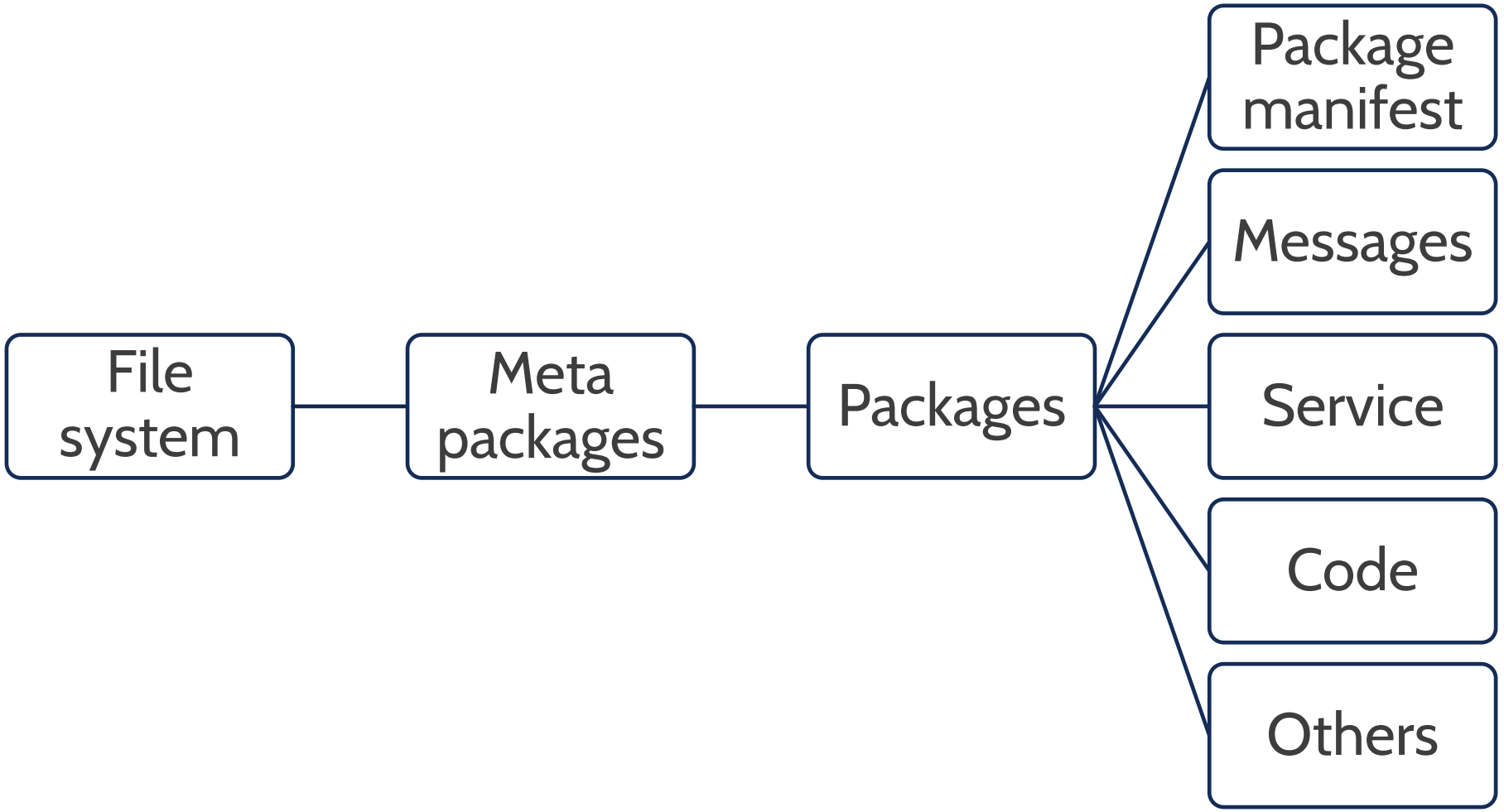
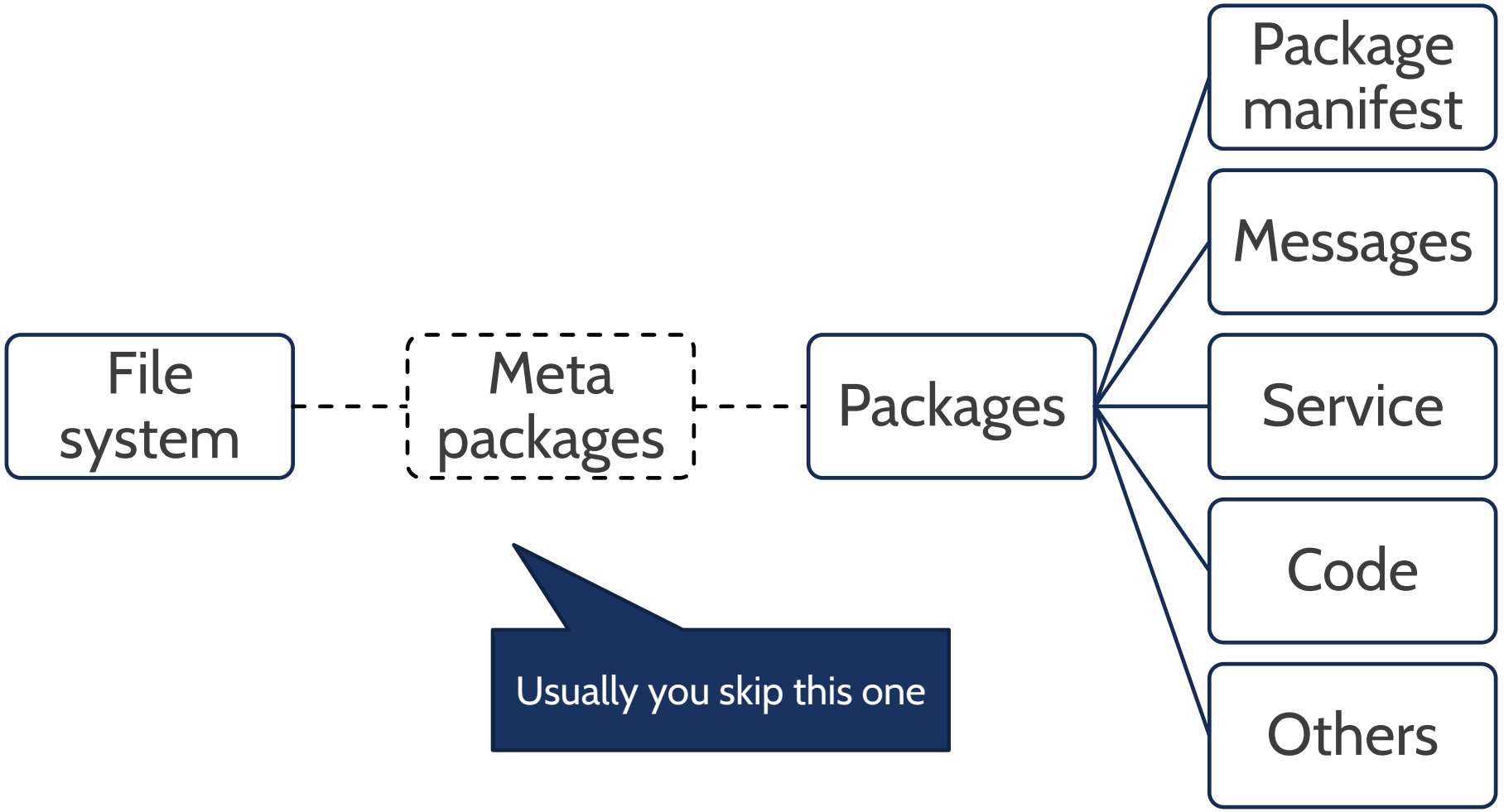
ROS FILE SYSTEM



ROS FILE SYSTEM



PACKAGES AND METAPACKAGES

PACKAGES

- Atomic element of ROS file system
- Used as a reference for most ROS commands
- Contains nodes, messages and services
- package.xml used to describe the package
- Mandatory container

METAPACKAGES

- Aggregation of logical related elements
- Not used when navigating the ROS file system
- Contains other packages
- package.xml used to describe the package
- Not required

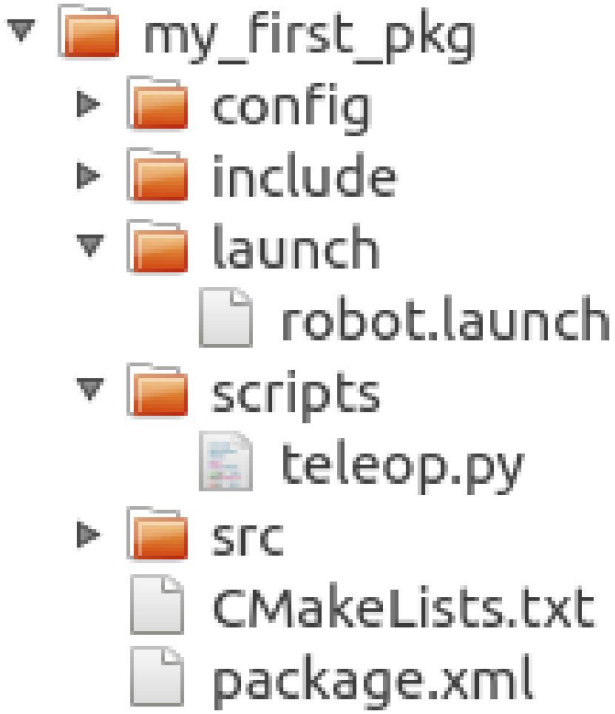
STRUCTURE OF A PACKAGE

Folder structure:

- /src, /include, /scripts (coding)
- /launch (launch files)
- /config (configuration files)

Required files:

- CMakeList.txt: Build rules for catkin
- package.xml: Metadata for ROS



ROS COMMANDS

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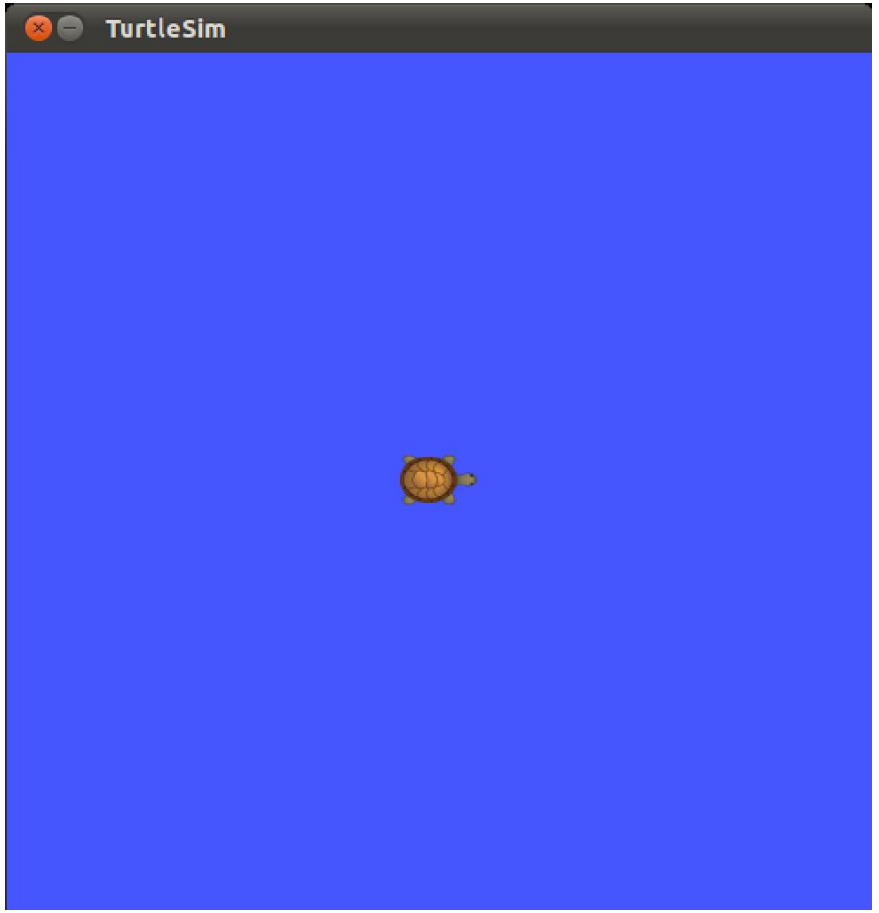
FILE SYSTEM TOOLS

Ros Desktop-full come with lots of tutorials and tools

Before creating our own package and start writing some code we will learn how to navigate the ROS file system and use the turtlesim package to test some of the most useful tools



FILE SYSTEM TOOLS

Change directory in the ROS file system

roscd [package_name[/subdir]]

roscd roscpp && pwd /opt/ros/kinetic/share/roscpp

roscd roscpp/srv /opt/ros/kinetic/share/roscpp/srv

roscd robby_roboto ~/catkin_ws/src/robby_roboto

FILE SYSTEM TOOLS

Getting information about installed packages

rospack <subcommand> [options] [package]

subcommands (among the others)

depends [package]	package dependencies
find [package]	find package directory
list	list available packages
profile	scan all workspace and index packages

rospack find roscpp	/opt/ros/kinetic/share/roscpp
rospack list	<several packages>

STARTING THE MIDDLEWARE

To start the ROS middleware just type in a terminal

roscore

Now it is possible to display information about the elements currently running

rosnode list

rostopic list

rostopic echo /rosout

rosservice list

rqt_graph

DEALING WITH NODES

Getting information about running nodes

rosnode <command> [other_commands]

subcommands (among the others)

ping	test connectivity to node
info	print information about node
kill	kill a running node
cleanup	purge registration information of unreachable nodes

rosnode list

rosnode info /rosout

STARTING ROS NODES

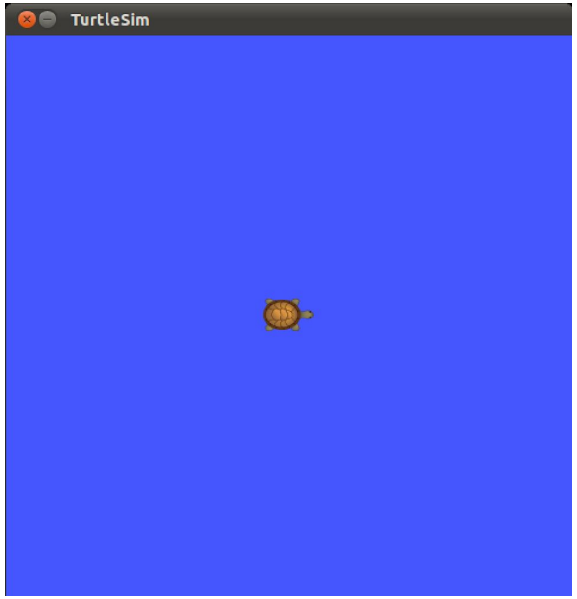
To start a ROS node type in a terminal

rosrun [package_name] [node_name]

rosrun turtlesim turtlesim_node

rosnode ping /turtlesim

rosnode info /turtlesim



STARTING ROS NODES

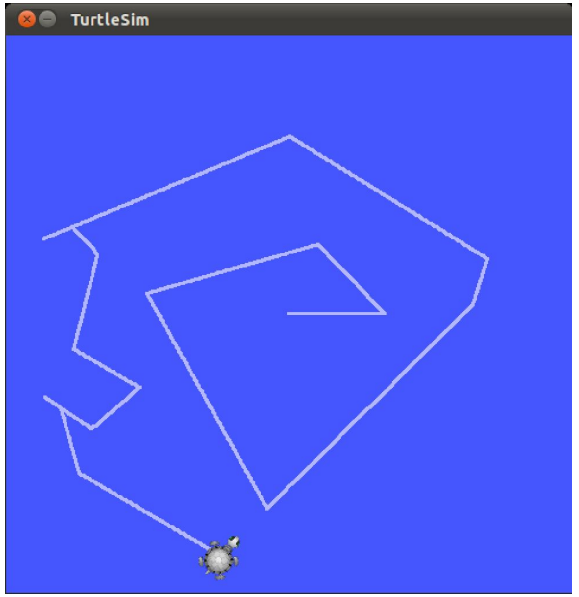
In a new terminal

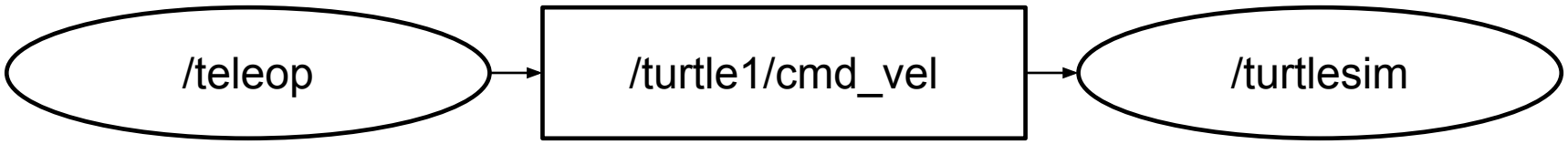
rosrun turtlesim turtle_teleop_key

Notes:

turtle_teleop_key is publishing the key strokes on a topic

turtlesim subscribes to the same topic to receive the key strokes





DEALING WITH TOPICS

To show the running node type in a terminal

rqt_graph

To plot published data on a topic

rqt_plot /turtle1/pose/x /turtle1/pose/y

rqt_plot /turtle1/pose/x:y

To monitor a topic on a terminal type

rostopic echo /turtle1/cmd_vel

DEALING WITH TOPICS CONT.

Getting information about ROS topics

rostopic <command> [topic_name]

subcommands (among the others)

echo	print messages to screen
find	find topics by type
hz	display publishing rate of topic
info	print information about active topic
list	list active topics
pub	publish data to topic
type	print topic type

DEALING WITH TOPICS CONT.

Getting information about ROS topics

rostopic type [topic_name]

rostopic type /turtle1/cmd_vel

Publishing ROS topics

rostopic pub [topic] [msg type] [args]

$ rostopic pub my_topic std_msgs/String "hello there"

$ rostopic pub -r 10 /cmd_vel geometry_msgs/Twist '{linear: {x: 2.0, y: 0.0, z: 0.0},
angular: {x: 0.0,y: 0.0,z: 0.0}}'

DEALING WITH TOPICS CONT.

```
$ rostopic pub -1 /turtle1/cmd_vel geometry_msgs/Twist -- '[2.0, 0.0, 0.0]' '[0.0, 0.0, 1.8]'
```

The -1 option force rostopic to publish the message only once, if you want to publish the message at a specific frequency you will use:

```
$ rostopic pub /turtle1/cmd_vel geometry_msgs/Twist -r 1 -- '[2.0, 0.0, 0.0]' '[0.0, 0.0, 1.8]'
```

Where the -r 1 option specify that the message will be published at 1hz frequency

MESSAGES (ALSO SERVICES)

Getting information about msg/srv files

rosmsg <command> [msg/srv_file]

subcommands (among the others)

show	Display the fields in the msg/srv.
list	Display names of all msg/srv.
package	List all the msg/srv in a package.
packages	List all packages containing the msg/srv.

rosmsg show Pose

rosmsg package nav_msgs

DEALING WITH SERVICES

Calling services from command line and getting information:

rosservice <command> [other_commands]

subcommand (among the others)

list	Print information about active services.
node	Print name of node providing a service.
call	Call the service with the given args.
args	List the arguments of a service.
type	Print the service type.
find	Find services by service type

rosservice call /reset

rosservice type /reset

BAGS

bag: file format to store messages data

Used to test different algorithm with the exact same input and to debug a system when it's not monitorable at runtime

To record a bag use:

rosbag record

to record all the topics use:

$ rosbag record -a

to record only a subset of the topic use:

$ rosbag record topic1 topic2 etc

BAGS

To get info regarding a beg use the command:

$ rosbag info bag_name

To play a bag run:

$ rosbag play bag_name

remember that to run rosbag you need an active ros session (roscore should be on)

Always monitor your bag size, sometimes logging all the topics (if you are working with cameras) is not the best idea because you will produce more data/sec than your max disk writing speed.

CREATE THE ROS WORKSPACE

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CREATING THE WORKSPACE

ROS uses a custom compiling environment called **Catkin**

cmake/make with specific flags

Requires a workspace with a specific structure

Easy to setup and “easy” to use

You should already have a catkin_ws/src folder where all your code should go

WORKSPACE STRUCTURE

Source space (/src):

All your stuff goes here!

contains the source code of catkin packages.

Subfolder of this are the ROS packages you want to add to your system

Build space (/build):

Not where catkin_make is invoked!

space where cmake is invoked to build the catkin packages

cmake and catkin keep their cache information and other intermediate files here

Devel space (/devel):

Space where built targets are placed prior to being installed

PACKAGE CREATION

Command to create a new package

catkin_create_pkg [package_name] [depend1] [depend2] [depend3]

Before running the script cd to your src directory, then:

catkin_create_pkg pub_sub std_msgs rospy roscpp

Important Notes

roscpp and rospy are client libraries to use C++ and Python

this command has to be run inside the src folder, otherwise you will not be able to compile the node

PACKAGE CREATION

cd to the new package, the script should have created:

- **CMakeLists.txt**
- **package.xml**
- **include** folder
- **src** folder

cd to your catkin workspace root to compile the new package, simply using **catkin_make**

EDITORS/ IDEs

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ROSED

rosed is part of the rosbash suite

Allow the user to edit files using directly the package name, rather than typing the entire path

rosed [package_name] [filename]

rosed roscpp Logger.msg

The default editor is vim

You can edit the .bashrc file setting a more user friendly editor

IDEs

No official IDE by ROS

C++ editor with ROS specific plugins

On ROS wiki you can guides on how to properly configure the plugins

http://wiki.ros.org/IDEs

Simply add some features like easier compiling and some debug tools

Should have Docker integration to edit and compile inside running container

ROS DEVELOPMENT

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EVERYTHING HAPPENS IN NODES

Nodes are the main and atomic element of ROS. Each node is an independent process.

How do we create a node?

Write code in C++ or Python

INSIDE THE NODE

INITIALIZATION

Any node has to be registered to the ROS master using an unique identifier

The actual node is initialized using an handler

Each executable has an **unique name**

Each executable may have multiple handlers

```
void ros::init(argv, argc, std::string node_name, uint32_t options);
ros::init(argc, argv, "my_node_name");
ros::init(argc, argv, "my_node_name", ros::init_options::AnonymousName);

ros::NodeHandle nh;
```

MAIN LOOP

Each ROS node loops waiting for something to do

At each loop checks:

- is there a message waiting to be received?
- is there a completed timer?
- is there a parameter to be reconfigured?

Two ways to implement the main loop:

- Automatically, no developer intervention
- Manual, specific sleep time and execution at each loop

```
ros::spin();
```

```
ros::Rate r(10); //10 hz
while (ros::ok()) {
  /* some execution */
  ros::spinOnce();
  r.sleep();
}
```

PARAMETERS

Stored in the parameter server and retrieved at the beginning of the execution

Adjustable at runtime using dynamic reconfigure

Global parameters and relative parameters (in the node namespace)

```
if(!nh.getParam("/global_name", global_name)) { /* :( */ }
if(!nh.getParam("relative_name", relative_name)) { /* :( */ }
nh.param<std::string>("param_name", default_param, "default_value");
```

PUBLISHER

Used to publish messages on a ROS topic

On declaration connect the publisher to a topic and define the type of the message

Can be called from everywhere

The frequency of the messages are not set

```
ros::Publisher pub = nh.advertise<std_msgs::String>("topic_name", 5);
std_msgs::String str;
str.data = "hello world";
pub.publish(str);
```

SUBSCRIBER

Used to read messages from a ROS topic

On declaration connect the subscriber to a topic and define the type of the message

Call a specific function when receive a message

Operate at a given frequency

```
ros::Subscriber sub = nh.subscribe("topic_name", 10, callback);
```

```
void [class::]callback(const pack_name::msg_type::ConstPtr& msg)
```

TIMER

Used to execute something after a specific time (repeatable)

When the timer ends a callback function get called

Tied to ROS internal clock

```
ros::Timer timer = nh.createTimer(ros::Duration(0.5), callback);

void [class::]callback(const ros::TimerEvent& t)
```

SERVICE PROVIDER (SERVER)

Answer to a service call and execute some logic associated with the content of the call

On declaration connect to the callback with the implemented logic

The answer of the service is already in the callback

```
ros::ServiceServer s = nh.advertiseService("service", callback);
```

```
bool [class::]callback(pack::srv_type::Request& req, pack::srv_type::Response& res);
```

SERVICE PROVIDER (SERVER)

Generates the call for a specific service

On declaration is connected to the a service identified by a name

Can be called everywhere in the code

May result in a bad call

```
ros::ServiceClient cl = nh.serviceClient<pack::srv_type>("service");
pack::srv_type srv;
/* fill the service */
if (cl.call(srv)) { /* :) */ } else { /* :( */ }
```

BUILDING YOUR CODE

```
cmake_minimum_required(VERSION 2.8.3)
project(package_name)
find_package(catkin REQUIRED COMPONENTS roscpp std_msgs genmsg)
add_message_files(FILES custom_message.msg)
add_service_files(FILES custom_service.srv)
generate_messages(DEPENDENCIES std_msgs)
catkin_package()

include_directories(include ${catkin_INCLUDE_DIRS})
add_executable(executable_name src/source_code.cpp)
target_link_libraries(executable_name ${catkin_LIBRARIES})
add_dependencies(executable_name package_name_generate_messages_cpp)
```

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```

This is what you have to change depending on your code!

BUILDING YOUR CODE

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```

Only if you have custom messages!