

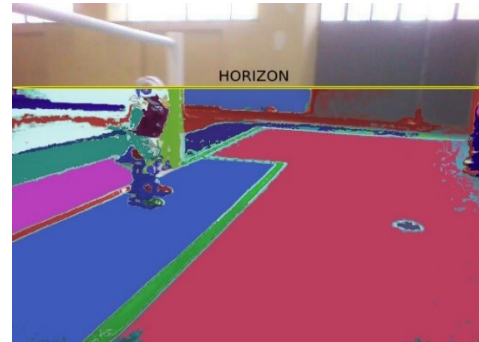
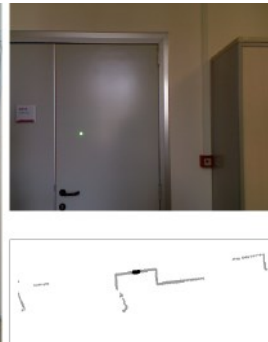
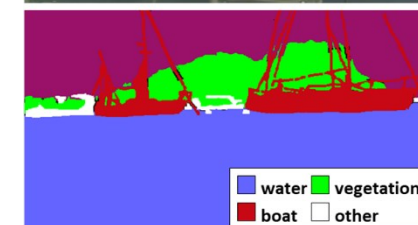
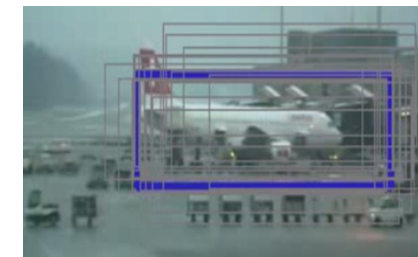


**UNIVERSITÀ DEGLI STUDI  
DELLA BASILICATA**

*Corso di Sistemi Informativi*  
*A.A. 2018/19*

Docente  
**Domenico Daniele Bloisi**

# ROS intro



Aprile 2019

# ROS

---

**ROS** (Robot Operating System) is an open-source, flexible framework for writing robot software

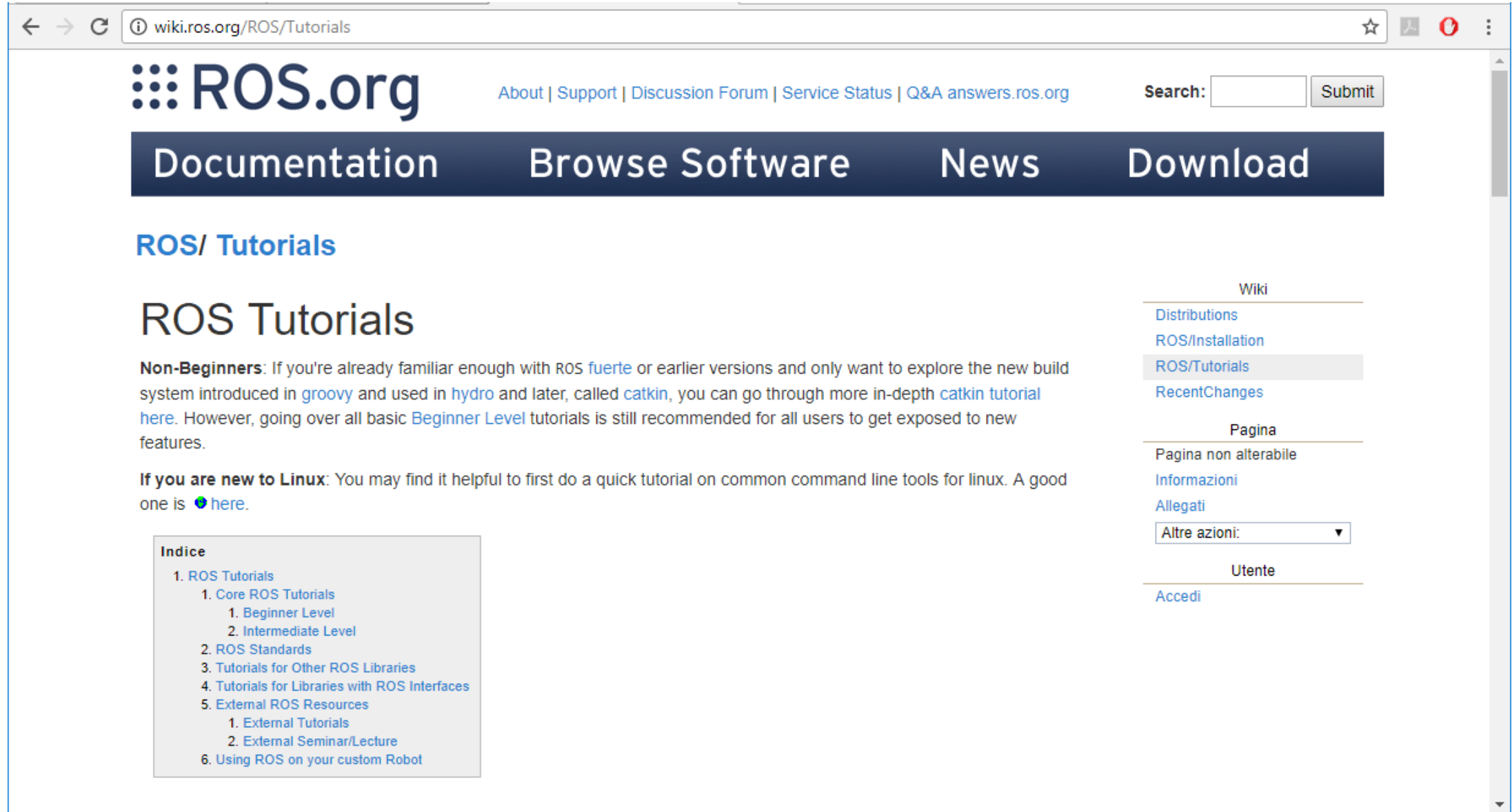
Site: <http://www.ros.org/>

Blog: <http://www.ros.org/news/>

Documentation: <http://wiki.ros.org/>



# ROS Tutorials



The screenshot shows the ROS.org website. The browser address bar displays 'wiki.ros.org/ROS/Tutorials'. The page header includes the ROS.org logo, navigation links (About, Support, Discussion Forum, Service Status, Q&A answers.ros.org), a search bar, and a dark blue navigation bar with links to Documentation, Browse Software, News, and Download. The main content area is titled 'ROS/ Tutorials' and 'ROS Tutorials'. It contains two paragraphs: one for 'Non-Beginners' and one for 'If you are new to Linux'. A sidebar on the left titled 'Indice' lists a hierarchy of tutorial topics. A right sidebar contains sections for 'Wiki' (with links to Distributions, ROS/Installation, ROS/Tutorials, and RecentChanges), 'Pagina' (with links to Pagina non alterabile, Informazioni, and Allegati), and 'Utente' (with a link to Accedi).

← → ↻ ⓘ wiki.ros.org/ROS/Tutorials ☆ ⌵ 🔴 ⋮

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**ROS/ Tutorials**

## ROS Tutorials

**Non-Beginners:** If you're already familiar enough with ROS [fuerte](#) or earlier versions and only want to explore the new build system introduced in [groovy](#) and used in [hydro](#) and later, called [catkin](#), you can go through more in-depth [catkin tutorial here](#). However, going over all basic [Beginner Level](#) tutorials is still recommended for all users to get exposed to new features.

**If you are new to Linux:** You may find it helpful to first do a quick tutorial on common command line tools for linux. A good one is [here](#).

**Indice**

- 1. ROS Tutorials
  - 1. Core ROS Tutorials
    - 1. Beginner Level
    - 2. Intermediate Level
  - 2. ROS Standards
  - 3. Tutorials for Other ROS Libraries
  - 4. Tutorials for Libraries with ROS Interfaces
  - 5. External ROS Resources
    - 1. External Tutorials
    - 2. External Seminar/Lecture
  - 6. Using ROS on your custom Robot

**Wiki**

- [Distributions](#)
- [ROS/Installation](#)
- [ROS/Tutorials](#)
- [RecentChanges](#)

**Pagina**

- Pagina non alterabile
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- Altre azioni:

**Utente**

- [Accedi](#)

# Idea

---

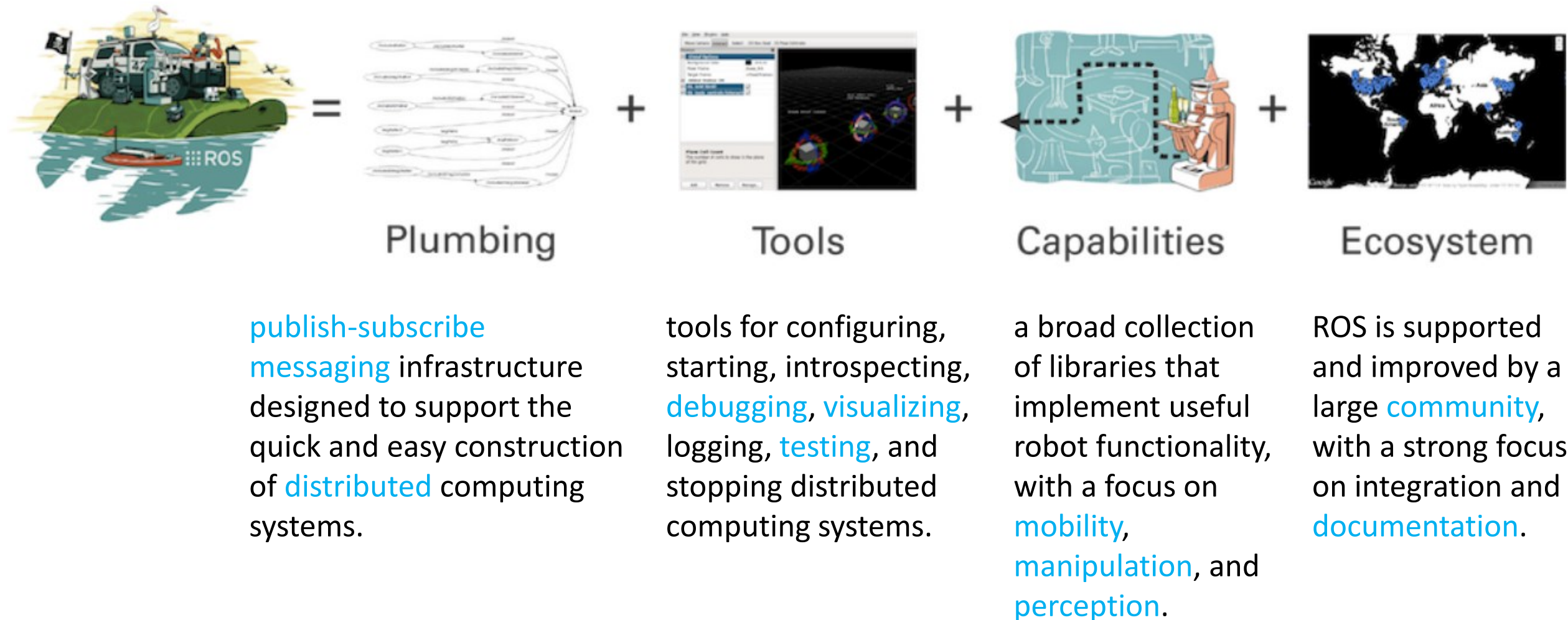
- Use **processes** to isolate functionalities of the system
- Processes communicate through **messages** (less efficient than using shared memory, but safer)
- Benefits
  - If a process crashes, it can be restarted
  - A functionality can be exchanged by replacing a process that provides it
  - Decoupling of modules through inter-process communication

# ROS features

---

- Code reuse (exec. nodes, grouped in packages)
- Distributed, modular design (scalable)
- Language independent (C++, Python, Java, ...)
- ROS-agnostic libraries (code is ROS indep.)
- Easy testing (ready-to-use)
- Vibrant community & collaborative environment

# ROS = plumbing + tools + capabilities + ecosystem



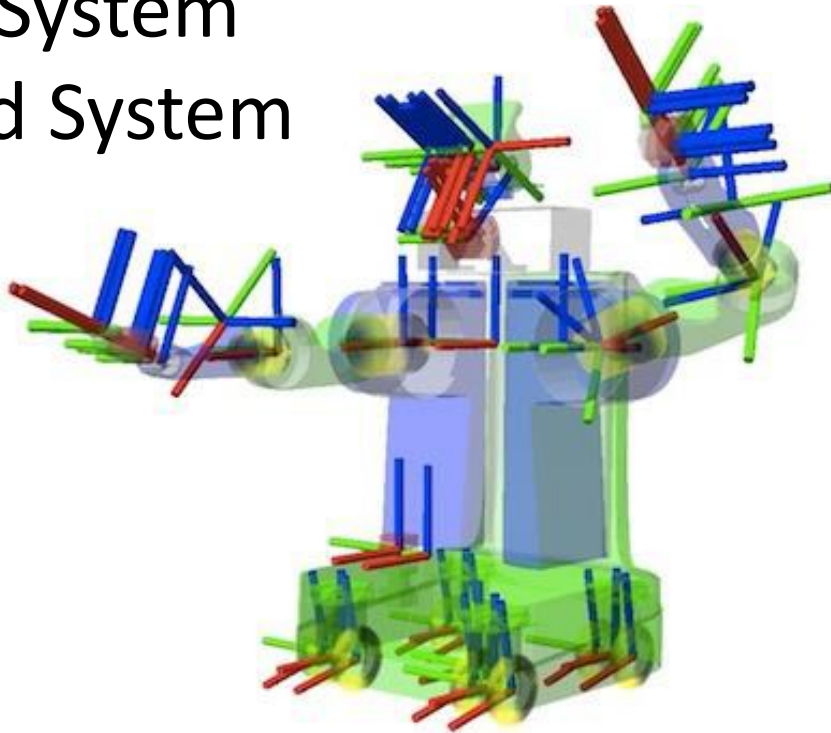


# Robot specific features

---

Provides tools for

- Message Definition
- Process Control
- File System
- Build System



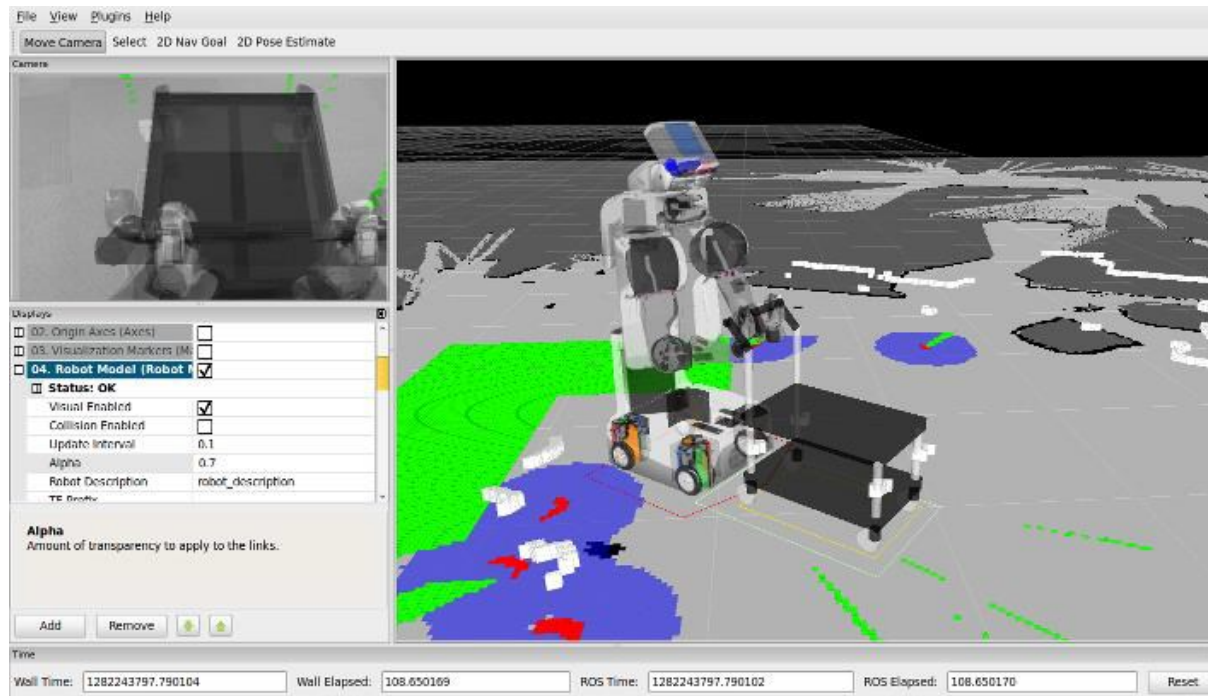
Provides basic functionalities like:

- Device Support
- Navigation
- Control of Manipulator
- Object Recognition



# ROS tools

- Command-line tools
- Rviz
- rqt (e.g., rqt\_plot, rqt\_graph)

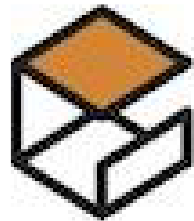




# Integration with external libraries

---

ROS provides seamless integration of external libraries and popular open-source projects



GAZEBO



pcl

and many others

# ROS installation

---

**Suggested OS:** Ubuntu 16.04.3 LTS (Xenial Xerus)

**Suggested release:** Kinetic Kame

- Install ROS from source (not recommended),  
<http://wiki.ros.org/kinetic/Installation/Source>
- Install ROS from Debian packages:  
<http://wiki.ros.org/kinetic/Installation/Ubuntu>



# Post installation

---

Initialize rosdep in your system:

<http://wiki.ros.org/rosdep>

```
sudo rosdep init  
rosdep update
```

rosdep is a tool for checking and installing package dependencies in an OS-independent way

**Note: do not use sudo for rosdep update.** It is not required and will result in permission errors later on.

# ROS definitions

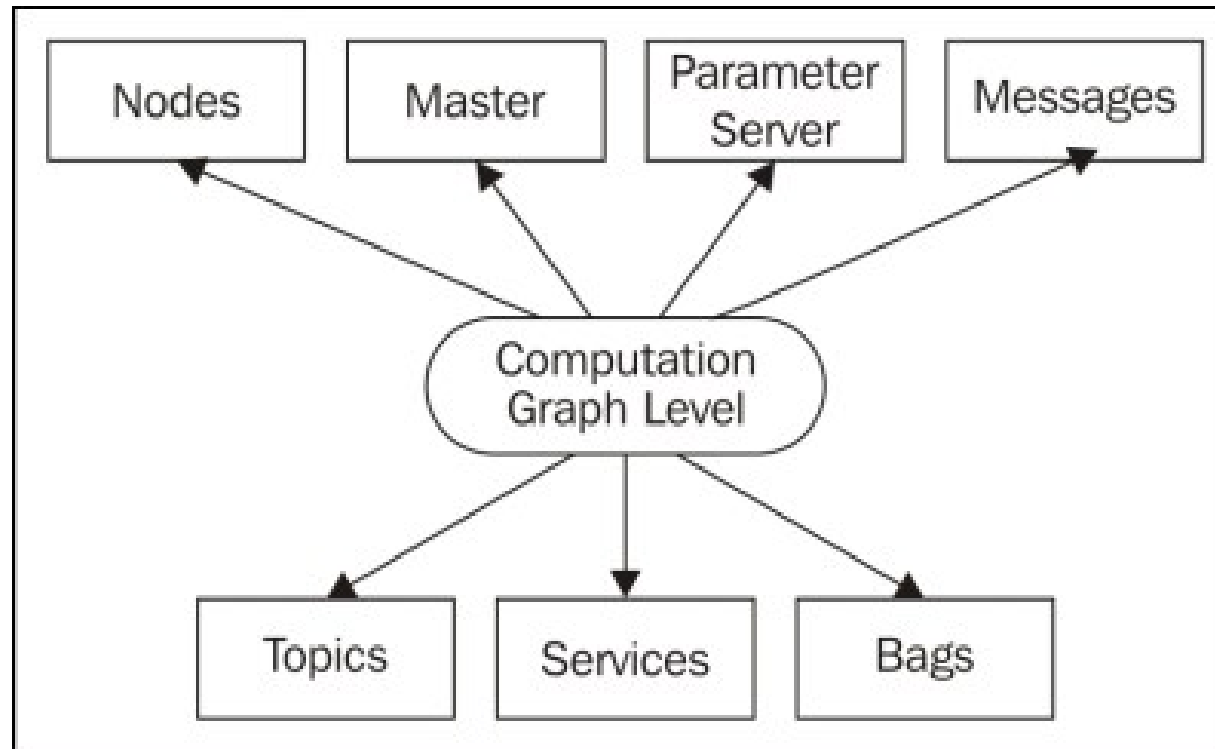
---

- **Node:** process
- **Message:** Type of a data structure used to communicate between processes
- **Topic:** stream of message instance of the same type used to communicate the evolution of a quantity  
e.g., a CameraNode will publish a stream of images. Each image is of type ImageMessage (a matrix of pixels)
- **Publishing:** the action taken by a node when it wants to broadcast a message
- **Subscribing:** requesting messages of a certain topic

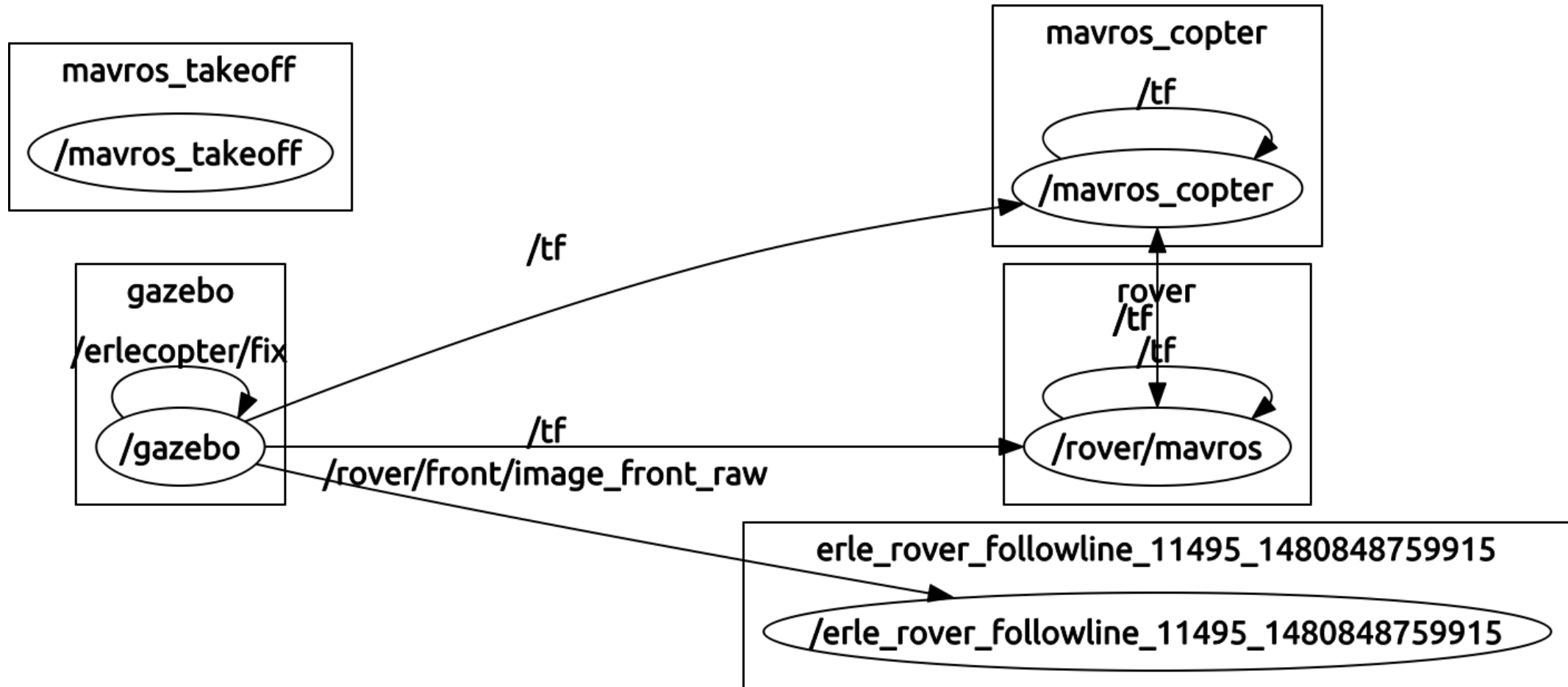
# ROS Computation Graph level

---

ROS creates a network where all the processes are connected.



# ROS Graph





# ROS master

---

- One of the goals of ROS is to enable the use of small and mostly independent programs (**nodes**), all running at the same time
- The ROS master provides naming and registration services to enable the nodes to locate each other and, therefore, to communicate
- Every node registers at startup with the master

# roscore

---

- Start the ROS master on a terminal with  
`roscore`
- It provides bookkeeping of which nodes are active, which topics are requested by whom, and other facilities
- Nodes need to communicate with the master only at the beginning to know their peers, and which topics are offered
- After that the communication among nodes is peer-to-peer

# Nodes

---

- Running instance of a ROS program

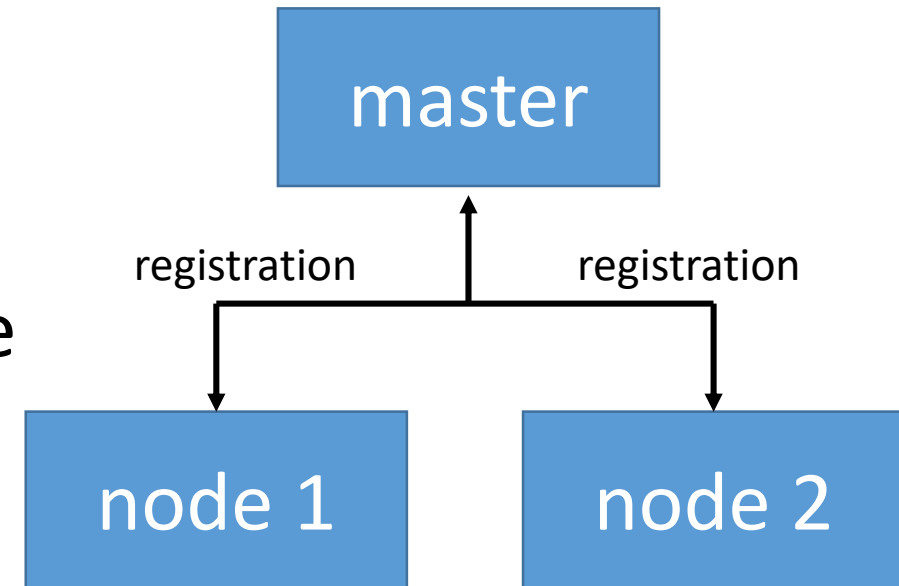
- Starting a node:

```
roslaunch <package-name> <node-name>
```

- Listing running nodes:

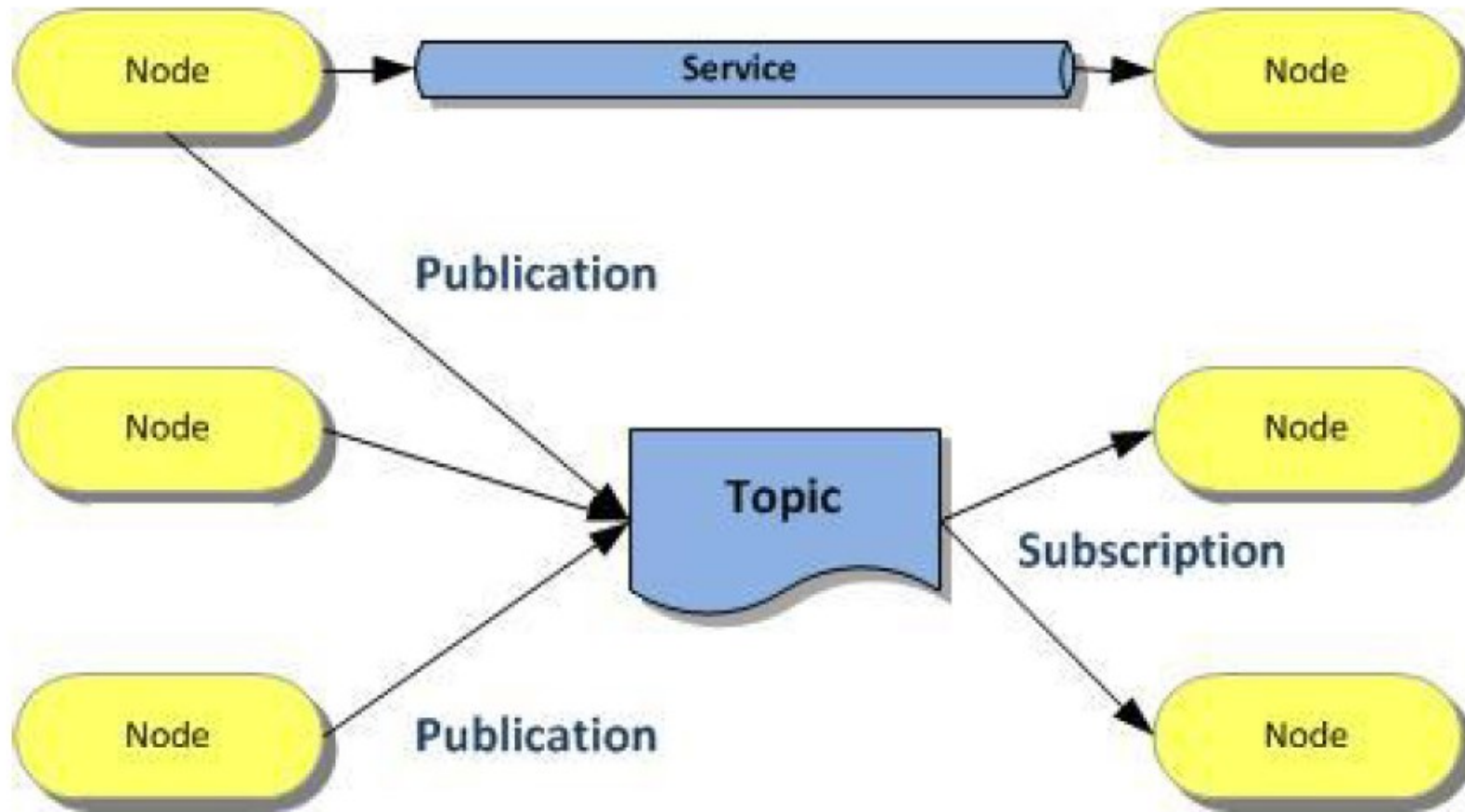
```
roslaunch list
```

- `/roslaunch` is a node started by roscore (similar to `stdout`)
- `/` indicates the global namespace



# ROS definitions

---



<http://wiki.ros.org/ROS/Concepts>

# Nodes

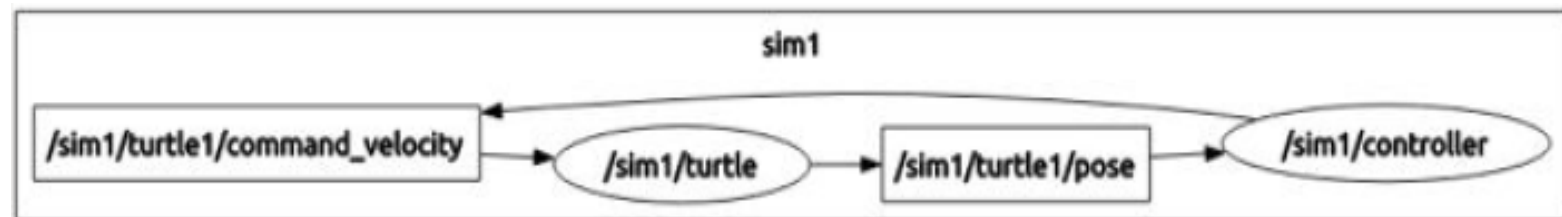
---

- Inspecting a node (list of topics published and subscribed, services, PID and summary of connections with other nodes):  
`roscallinfo node-name`
- Kill a node (also CTRL+C, but unregistration may not happen)  
`roscallkill node-name`
- Remove dead nodes:  
`rosclean`

# Topics and Messages

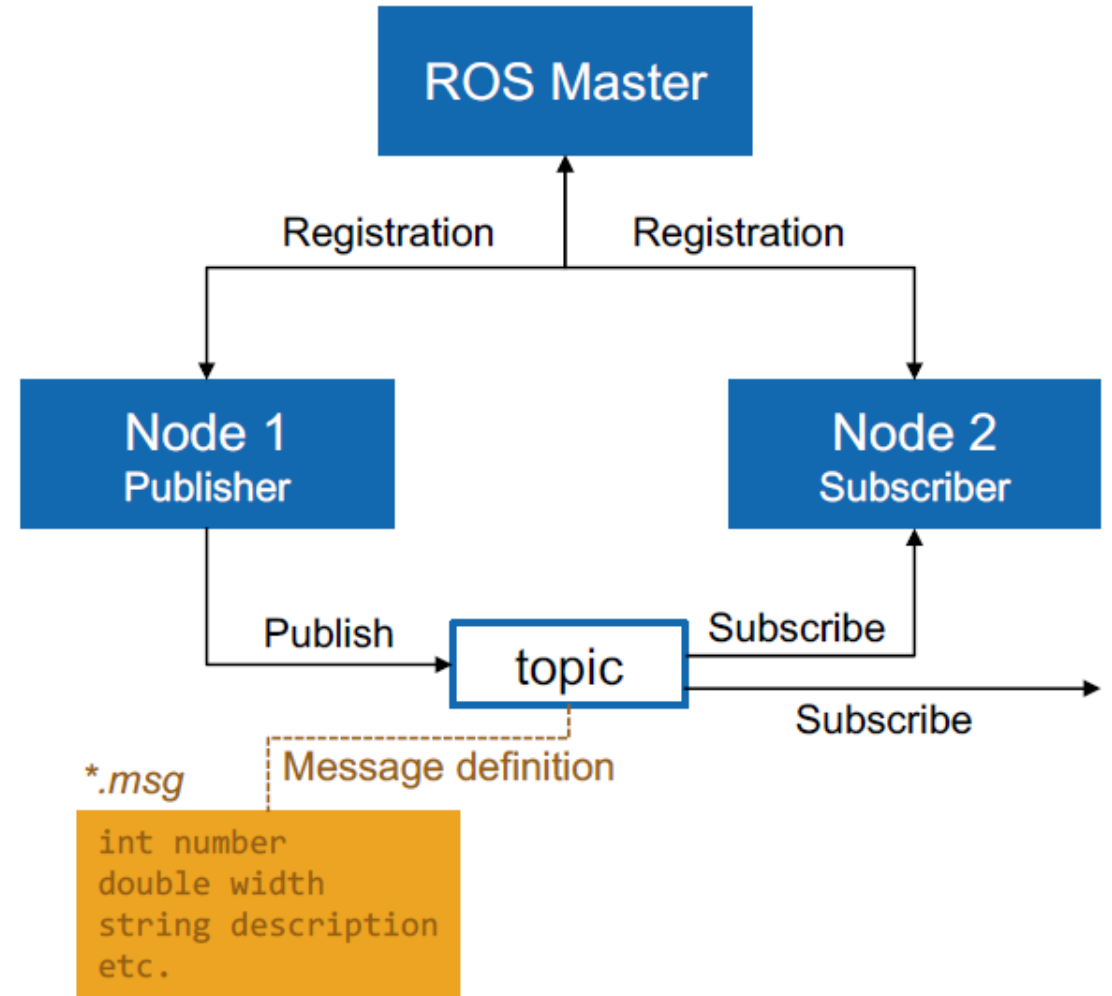
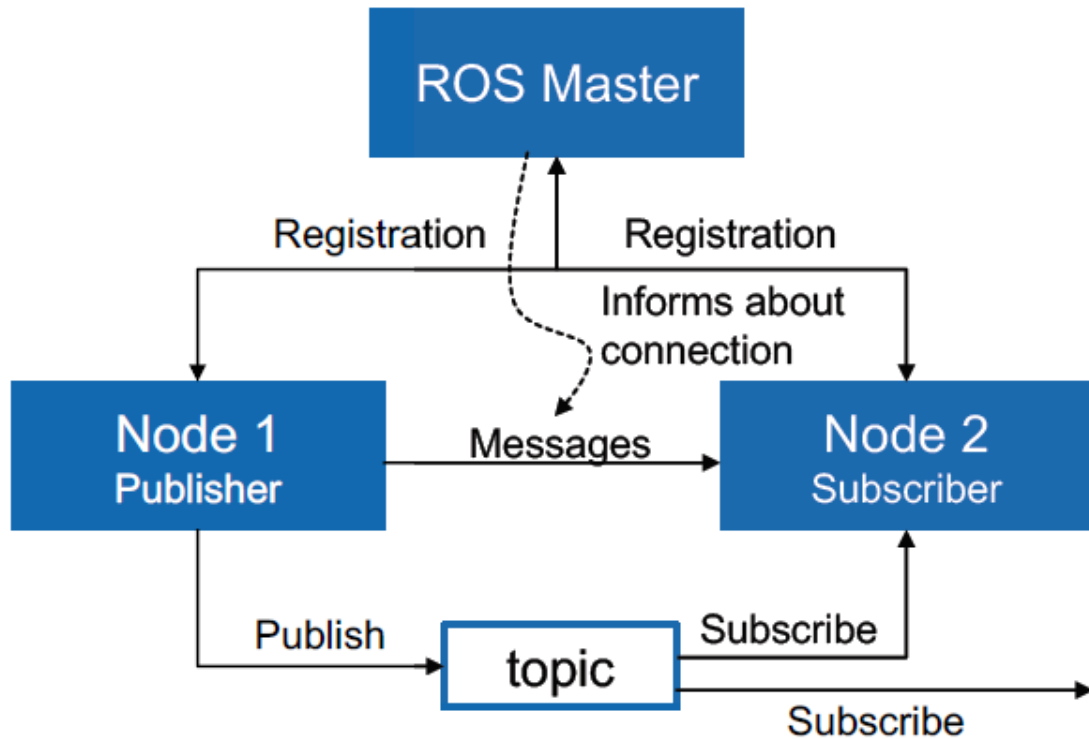
---

- Communication in ROS exploits *messages*
- Messages are organized in *topics*
- A node that wants to share information will *publish* messages on a topic(s)
- A node that wants to receive information will *subscribe* to the topic(s)
- ROS master takes care of ensuring that publishers and subscribers can find each other
- Use of *namespaces*





# Topics and Messages



# Example

---

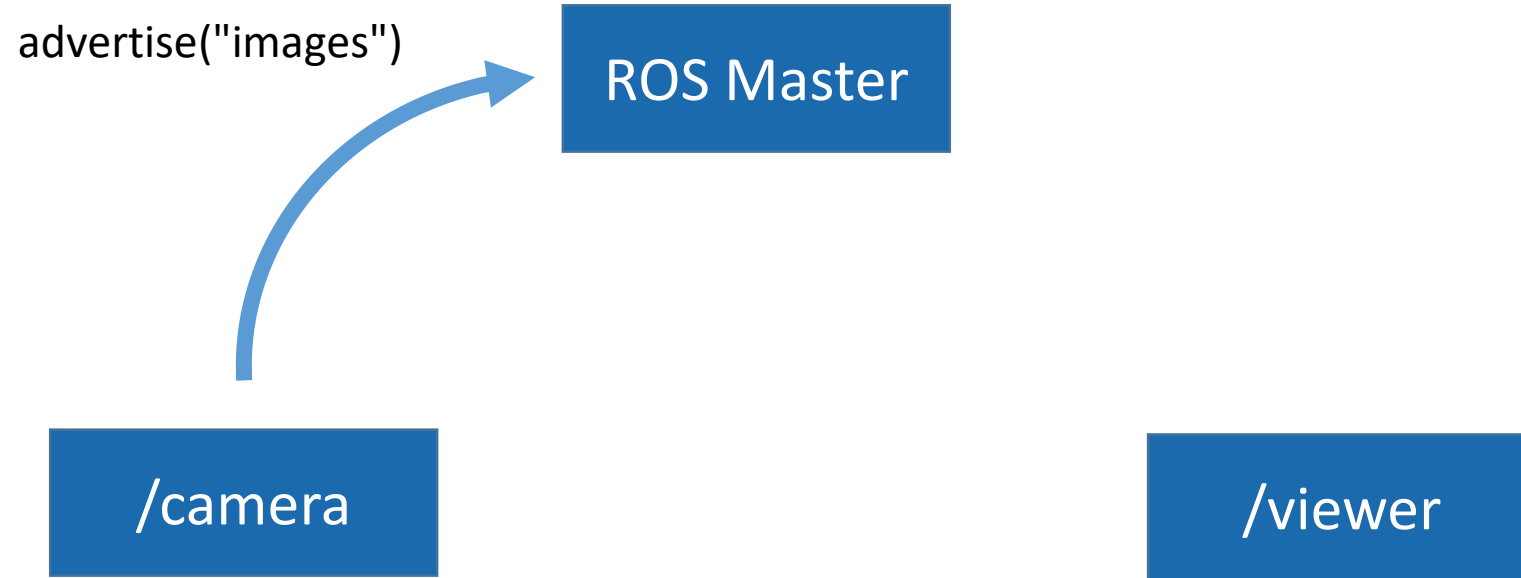
ROS Master

/camera

/viewer

# Example

---



# Example

---

ROS Master

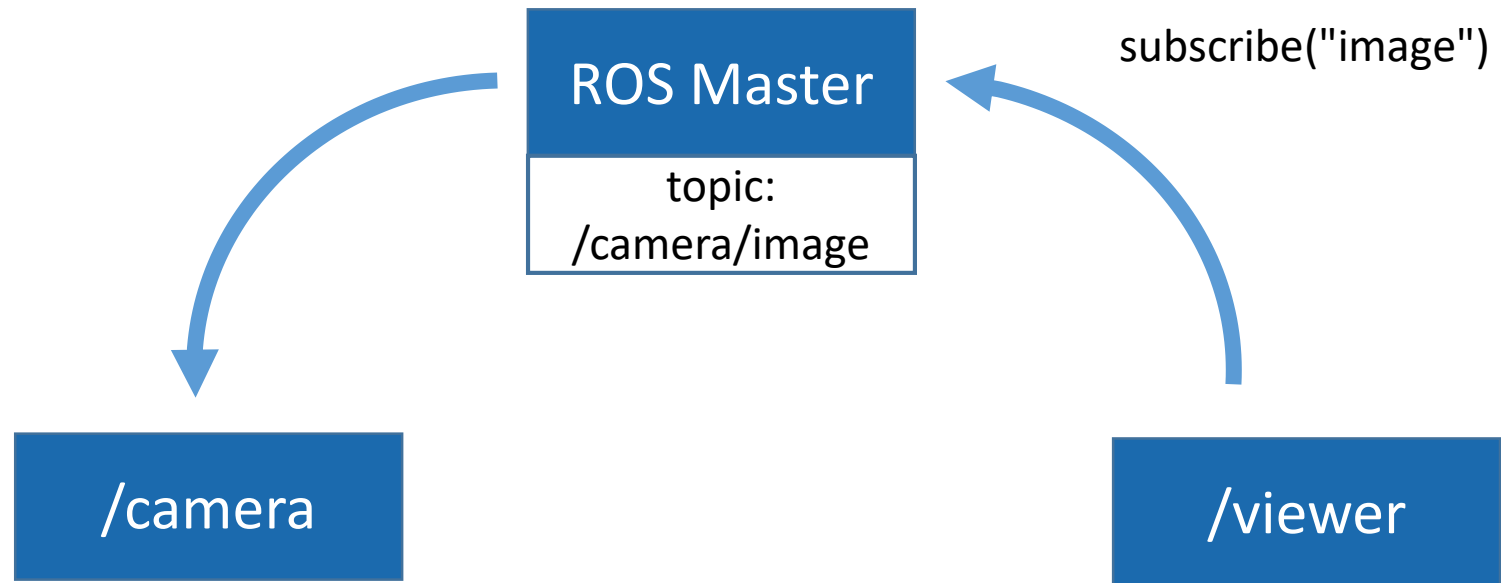
topic:  
/camera/image

/camera

/viewer

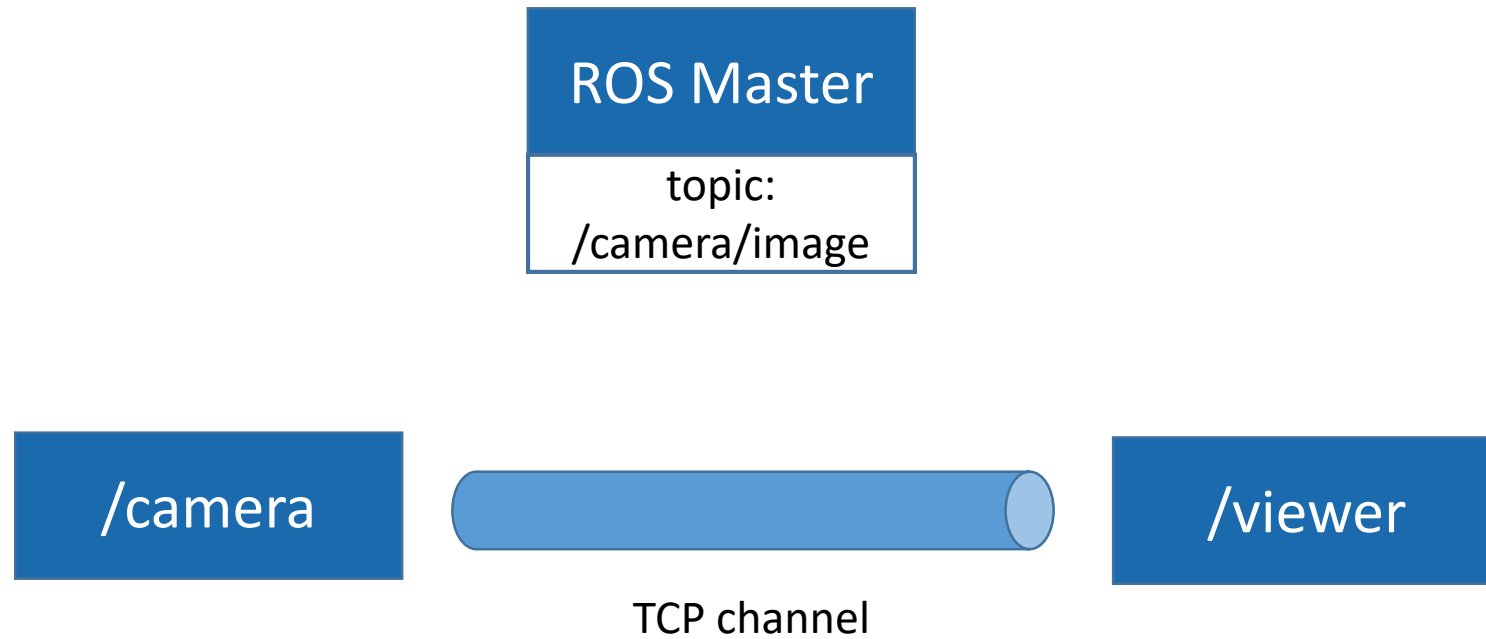
# Example

---



# Example

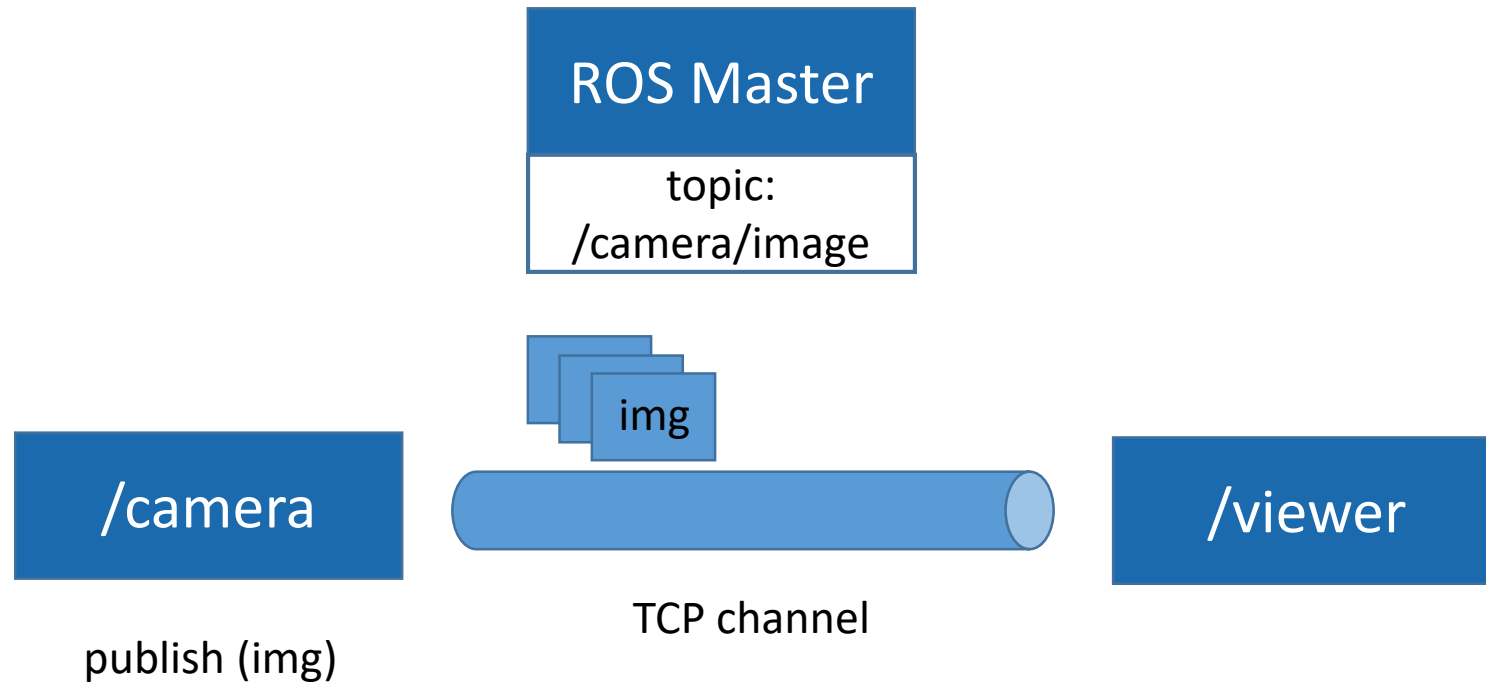
---





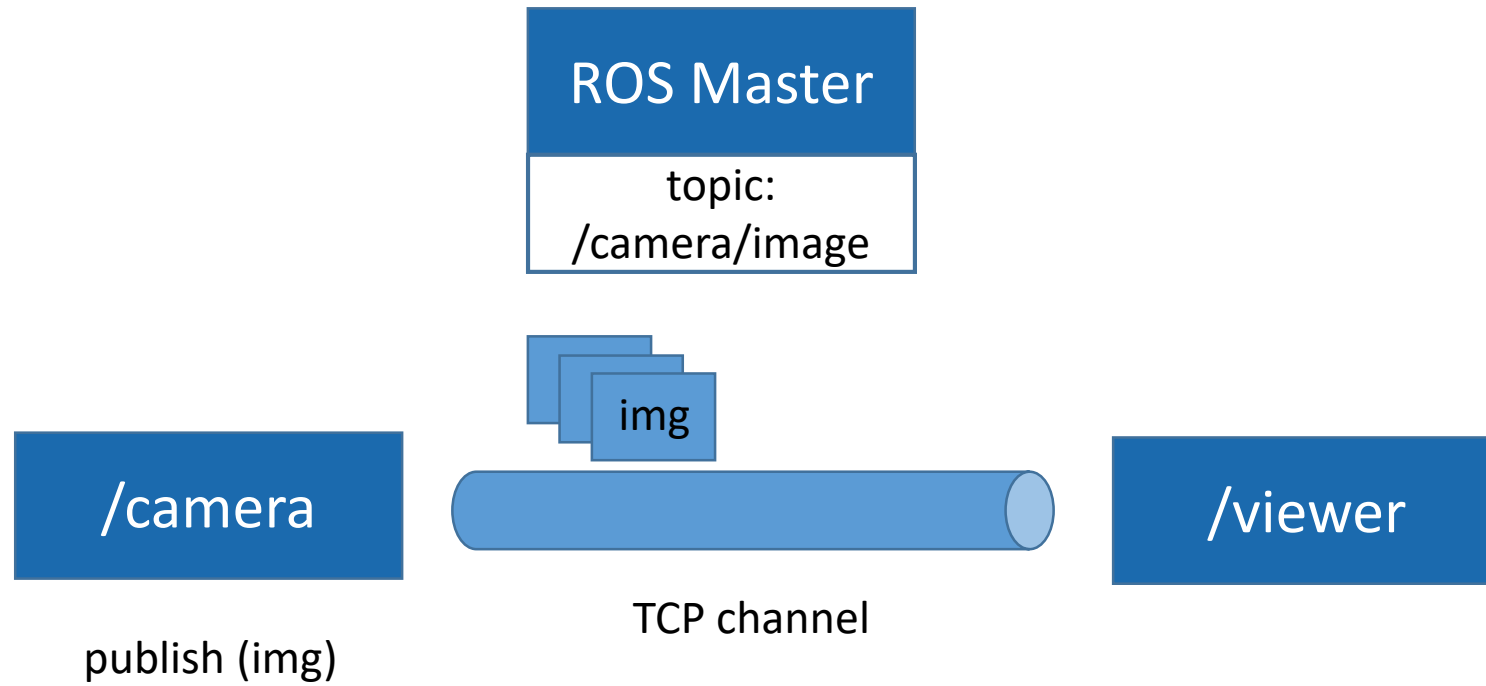
# Example

---



# Example

---



# Inspecting topics


---

- Listing active topics:  
`rostopic list`
- Seeing all messages published on topic:  
`rostopic echo topic-name`
- Checking publishing rate:  
`rostopic hz topic-name`
- Inspecting a topic (message type, subscribers, etc...):  
`rostopic info topic-name`
- Publishing messages through terminal line:  
`rostopic pub -r rate-in-hz topic-name message-type message-content`

<http://wiki.ros.org/ROS/Tutorials/UnderstandingTopics/>

# TurtleSim

[wiki.ros.org/turtlesim](#)

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turtlesim

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[ros\\_tutorials](#): [roscpp\\_tutorials](#) | [rospy\\_tutorials](#) | [turtlesim](#)

Package Summary

✓ Released ✓ Continuous integration ✓ Documented

turtlesim is a tool made for teaching ROS and ROS packages.

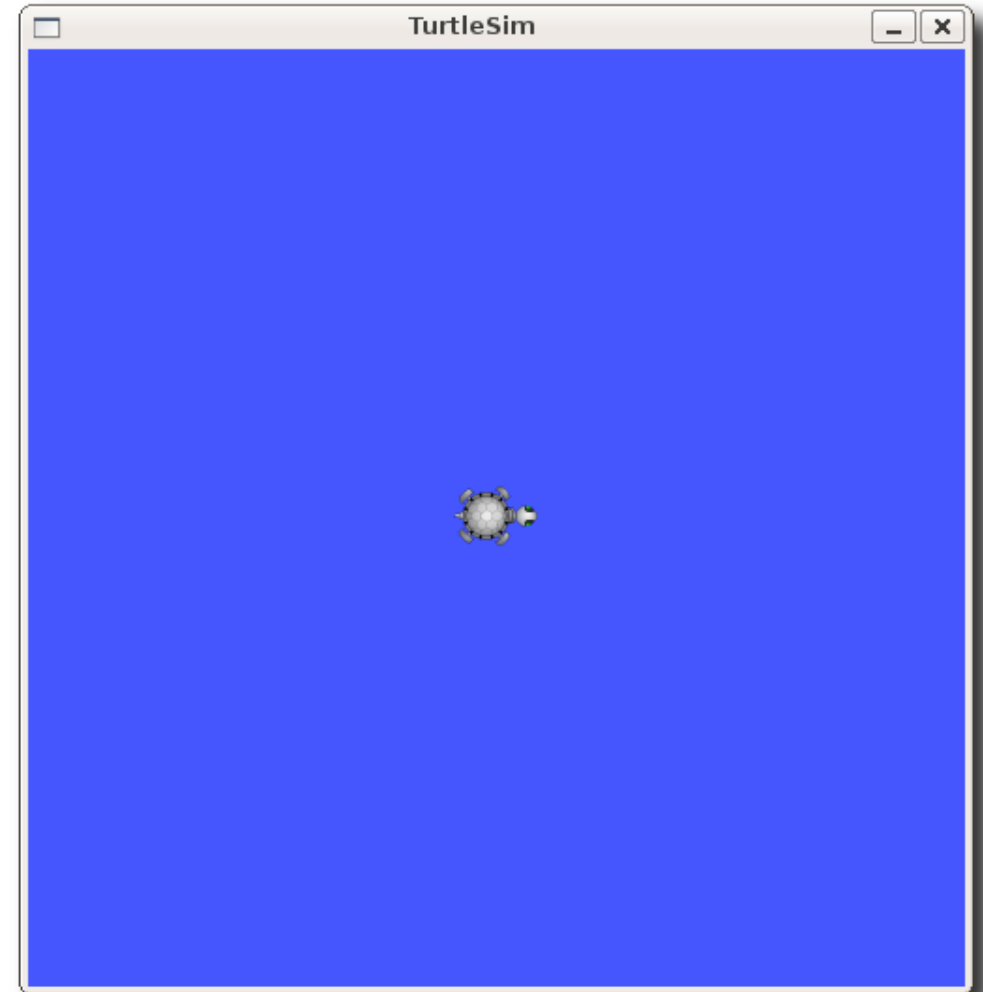
- Maintainer status: maintained
- Maintainer: Dirk Thomas <dthomas AT osrfoundation DOT org>
- Author: Josh Faust
- License: BSD
- Bug / feature tracker: [https://github.com/ros/ros\\_tutorials/issues](https://github.com/ros/ros_tutorials/issues)
- Source: git [https://github.com/ros/ros\\_tutorials.git](https://github.com/ros/ros_tutorials.git) (branch: lunar-devel)

**Indice**

- 1. [Getting Started with Turtlesim](#)
- 2. [Nodes](#)
  - 1. [turtlesim\\_node](#)
    - 1. [Subscribed Topics](#)
    - 2. [Published Topics](#)
    - 3. [Services](#)
    - 4. [Parameters](#)
  - 2. [mimic](#)
    - 1. [Subscribed Topics](#)

**Package Links**

- [Code API](#)
- [Msg/Srv API](#)
- [Tutorials](#)
- [FAQ](#)
- [Changelog](#)
- [Change List](#)
- [Reviews](#)
- [Dependencies](#) (11)**
- [Used by](#) (4)**
- [Jenkins jobs](#) (13)**



# Demo TurtleSim



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## ROS/ Tutorials/ UnderstandingTopics

**Note:** This tutorial assumes that you have completed the previous tutorials: [understanding ROS nodes](#).

💡 Please ask about problems and questions regarding this tutorial on [answers.ros.org](#). Don't forget to include in your question the link to this page, the versions of your OS & ROS, and also add appropriate tags.

## Understanding ROS Topics

**Description:** This tutorial introduces ROS topics as well as using the [rostopic](#) and [rqt\\_plot](#) commandline tools.

**Tutorial Level:** BEGINNER

**Next Tutorial:** [Understanding ROS services and parameters](#)

### Indice

1. Setup
  1. [roscore](#)
  2. [turtlesim](#)
  3. [turtle keyboard teleoperation](#)
2. ROS Topics
  1. [Using rqt\\_graph](#)
  2. [Introducing rostopic](#)
  3. [Using rostopic echo](#)
  4. [Using rostopic list](#)
3. ROS Messages
  1. [Using rostopic type](#)

### Wiki

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[ROS/Installation](#)  
[ROS/Tutorials](#)  
[RecentChanges](#)  
[UnderstandingTopics](#)

### Pagina

Pagina non alterabile  
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Altre azioni:

### Utente

[Accedi](#)

# roscore

```
roscore http://localhost:11311/
nvidia@tegra-ubuntu:~$ roscore
... logging to /home/nvidia/.ros/log/d98a064e-26dc-11e8-9cf9-00044b66f63a/roslau
nch-tegra-ubuntu-3829.log
Checking log directory for disk usage. This may take awhile.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

started roslaunch server http://localhost:44412/
ros_comm version 1.12.12

SUMMARY
=====

PARAMETERS
* /rostdistro: kinetic
* /rosversion: 1.12.12

NODES

auto-starting new master
process[master]: started with pid [3949]
ROS_MASTER_URI=http://localhost:11311/

setting /run_id to d98a064e-26dc-11e8-9cf9-00044b66f63a
process[rosout-1]: started with pid [3985]
started core service [/rosout]
```



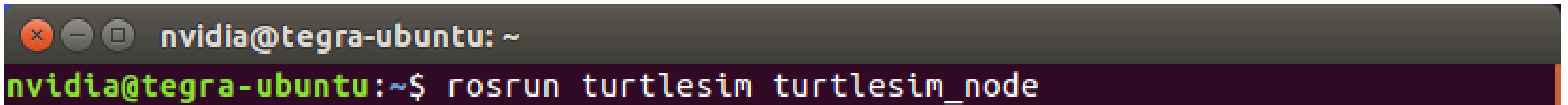
# Run turtlesim\_node

---

1. Open a **new terminal**

2. run:

```
$ rosrun turtlesim turtlesim_node
```

A screenshot of a terminal window. The title bar shows standard Ubuntu window controls (close, minimize, maximize) and the text 'nvidia@tegra-ubuntu: ~'. The terminal content shows the command 'nvidia@tegra-ubuntu:~\$ rosrun turtlesim turtlesim\_node' being entered. The prompt 'nvidia@tegra-ubuntu:~\$' is in green, and the command is in white. A vertical orange cursor is at the end of the command line.

```
nvidia@tegra-ubuntu: ~  
nvidia@tegra-ubuntu:~$ rosrun turtlesim turtlesim_node
```

# Installing a new package

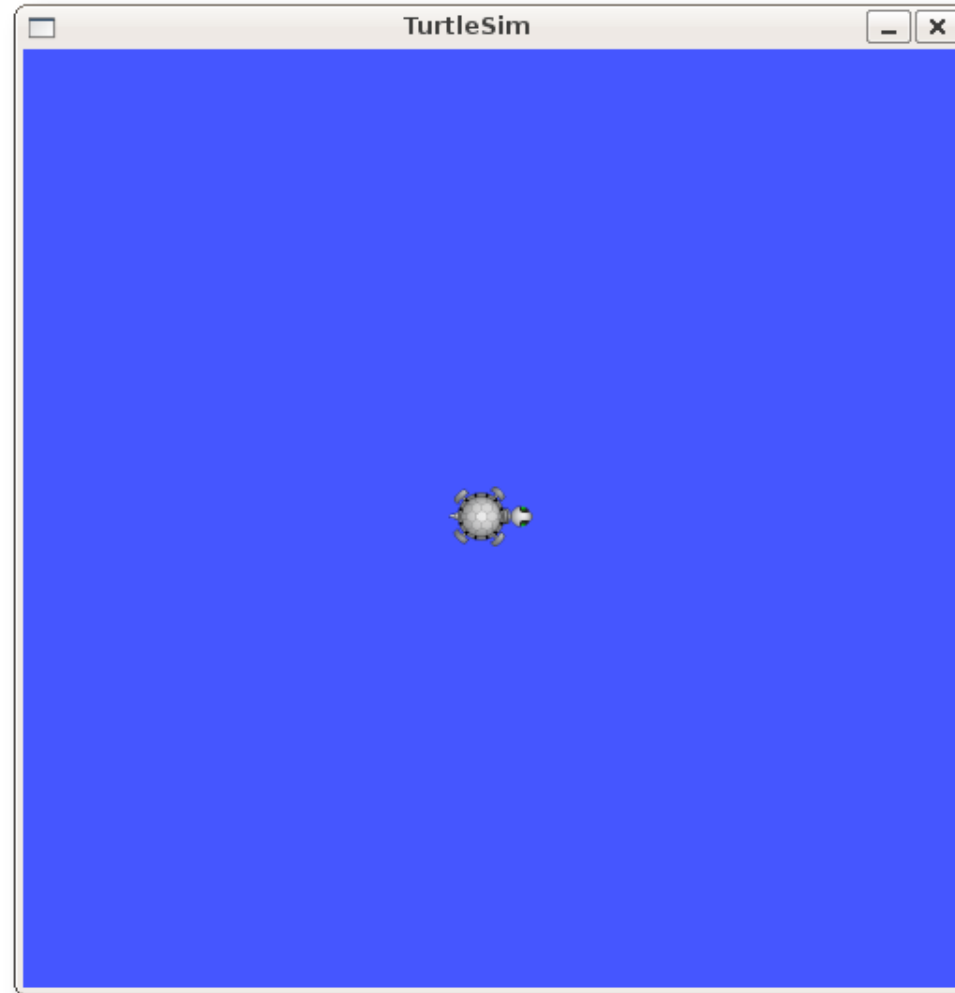
---

If package turtlesim is not found, we can install it

```
nvidia@tegra-ubuntu: ~  
nvidia@tegra-ubuntu:~$ rosrunc turtlesim turtlesim_node  
[rospack] Error: package 'turtlesim' not found  
nvidia@tegra-ubuntu:~$ sudo apt-get install ros-kinetic-turtlesim  
[sudo] password for nvidia:  
Reading package lists... Done  
Building dependency tree  
Reading state information... Done  
The following package was automatically installed and is no longer required:  
  libqmi-glib1  
Use 'sudo apt autoremove' to remove it.  
The following NEW packages will be installed:  
  ros-kinetic-turtlesim  
0 upgraded, 1 newly installed, 0 to remove and 39 not upgraded.  
Need to get 203 kB of archives.  
After this operation, 1,000 kB of additional disk space will be used.  
Get:1 http://packages.ros.org/ros/ubuntu xenial/main arm64 ros-kinetic-turtlesim  
  arm64 0.7.1-0xenial-20171117-145052-0800 [203 kB]  
Fetched 203 kB in 0s (391 kB/s)  
Selecting previously unselected package ros-kinetic-turtlesim.  
(Reading database ... 283137 files and directories currently installed.)  
Preparing to unpack .../ros-kinetic-turtlesim_0.7.1-0xenial-20171117-145052-0800  
_arm64.deb ...  
Unpacking ros-kinetic-turtlesim (0.7.1-0xenial-20171117-145052-0800) ...  
Setting up ros-kinetic-turtlesim (0.7.1-0xenial-20171117-145052-0800) ...
```

# turtlesim\_node running

---



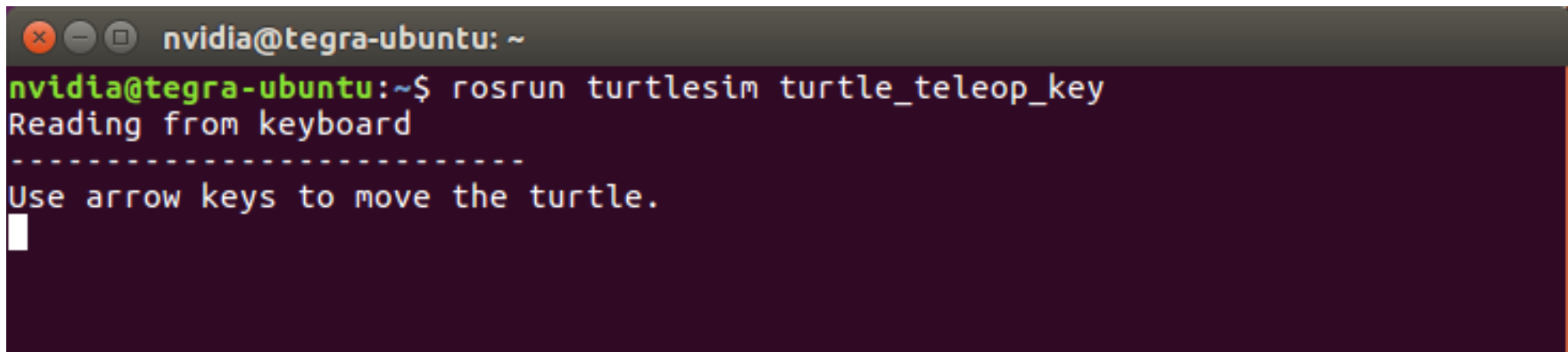
# turtle\_teleop\_key node

---

1. Open a **new terminal**

2. run:

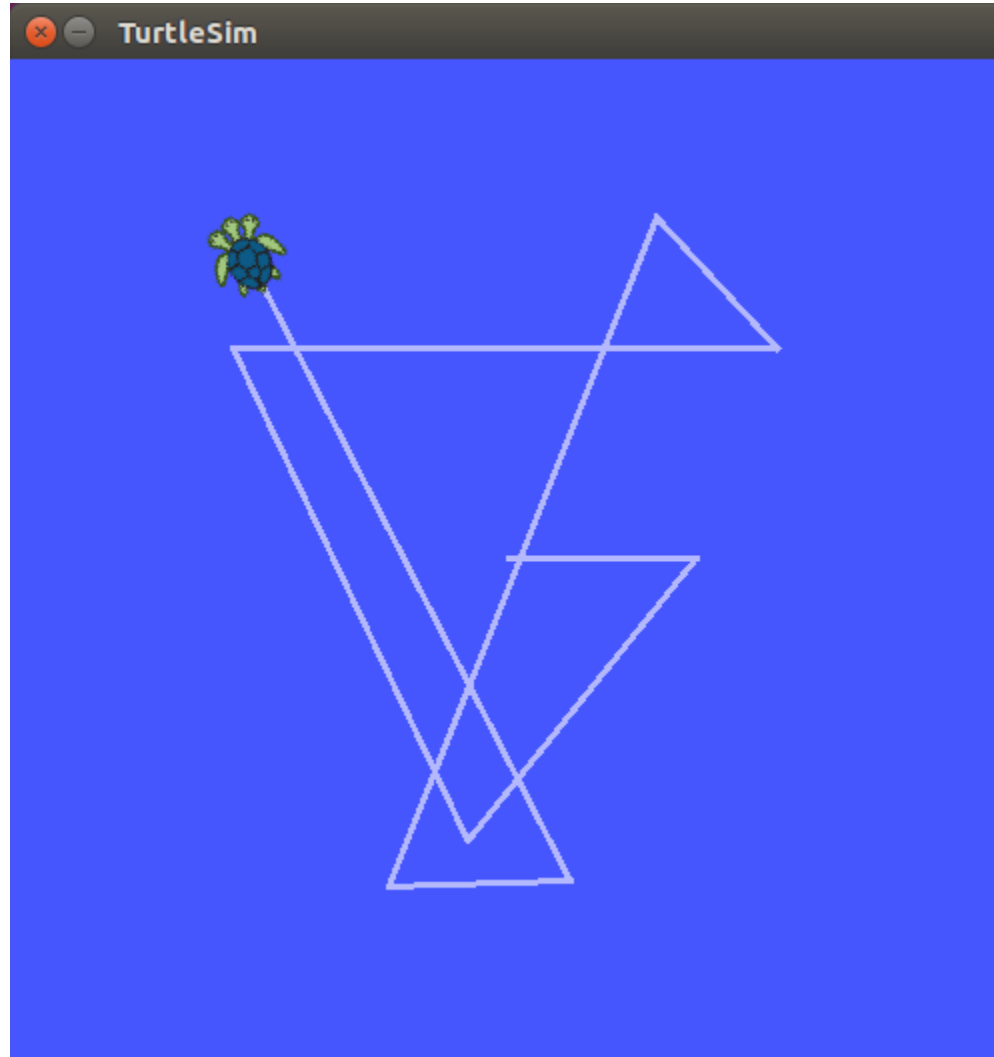
```
$ rosrun turtlesim turtle_teleop_key
```

A terminal window with a dark background and light text. The window title bar shows 'nvidia@tegra-ubuntu: ~'. The terminal content shows the command 'nvidia@tegra-ubuntu:~\$ rosrun turtlesim turtle\_teleop\_key' being executed. Below the command, the text 'Reading from keyboard' is displayed, followed by a dashed line and the instruction 'Use arrow keys to move the turtle.' A white cursor is visible on the line following the instruction.

```
nvidia@tegra-ubuntu: ~  
nvidia@tegra-ubuntu:~$ rosrun turtlesim turtle_teleop_key  
Reading from keyboard  
-----  
Use arrow keys to move the turtle.  
█
```

# Playing with the turtle

---



# ROS filesystem

---

- **Package**  
unit for organizing software in ROS. Each package can contain libraries, executables, scripts, or other artifacts
- **Manifest** ([package.xml](#))  
meta-information about a package (e.g., version, maintainer, license, etc.) and description of its dependencies (other ROS packages, messages, services, etc.)

<http://wiki.ros.org/catkin/package.xml>

# package.xml

---

```
<?xml version="1.0"?>
<package>
<name>my_package</name>
<version>1.0</version>
<description>My package description</description>
<!-- One maintainer tag required, multiple allowed, one
person per tag -->
<maintainer email="my@mail.com">Your Name</maintainer>
<!-- One license tag required, multiple allowed, one
license per tag. Commonly used license strings: BSD,
MIT, Boost Software License, GPLv2, GPLv3, LGPLv2.1,
LGPLv3 -->
<license>LGPLv3</license>
```

# Url tags and Author tags

---

```
<!-- Url tags are optional, but mutiple are allowed, one per tag.  
Optional attribute type can be: website, bugtracker, or repository -  
->  
<url type="website">http://wiki.ros.org/my_package</url>
```

```
<!-- Author tags are optional, mutiple are allowed, one per tag.  
Authors do not have to be maintianers, but could be -->  
<author email="my@mail.com">Your Name</author>
```

```
<!-- The *_depend tags are used to specify dependencies.  
Dependencies can be catkin packages or system dependencies. Use  
build_depend for packages you need at compile time. Use  
buildtool_depend for build tool packages. Use run_depend for  
packages you need at runtime. Use test_depend for packages you need  
only for testing. -->
```



# Dependencies

---

```
<buildtool_depend>catkin</buildtool_depend>
```

```
<build_depend>message_generation</build_depend>
```

```
<build_depend>roscpp</build_depend>
```

```
<build_depend>roslib</build_depend>
```

```
<run_depend>message_runtime</run_depend>
```

```
<run_depend>roscpp</run_depend>
```

```
<run_depend>roslib</run_depend>
```

```
<!-- The export tag contains other, unspecified, tags --> <export>
```

```
<!-- You can specify that this package is a metapackage here: -->
```

```
<!-- <metapackage/> -->
```

```
<!-- Other tools can request additional information be placed here -->
```

```
</export>
```

```
</package>
```

# Catkin workspace configuration

---

```
$ source /opt/ros/kinetic/setup.bash
$ mkdir -p ~/catkin_ws/src
$ cd ~/catkin_ws/src
$ catkin_init_workspace
$ cd ~/catkin_ws/
$ catkin_make
```

load default workspace



Open ~/.bashrc and add the following lines:

```
#ROS
source ~/catkin_ws/devel/setup.bash
```

overlay your catkin workspace



# Catkin workspace

---

```
catkin_ws/
  src/
    CMakeLists.txt
    package_1/
      CMakeLists.txt
      package.xml
      ...
    package_n/
      CMakeLists.txt
      package.xml
      ...
  devel/
  build/
```

-- WORKSPACE  
-- SOURCE SPACE  
-- The 'toplevel' cmake file  
  
-- DEVELOPMENT SPACE  
-- BUILD SPACE

# catkin\_make

---

- `catkin_make` is a convenience tool for building code in a catkin workspace
- Execute `catkin_make` in the root of your catkin workspace
- Running the command is equivalent to:  
\$ `mkdir build`  
\$ `cd build`  
\$ `cmake ../src -DCMAKE_INSTALL_PREFIX=../install`  
\$ `cmake --build . -DCATKIN_DEVEL_PREFIX=../devel`  
\$ `make`

# Anatomy of a ROS Node

---

```
ros::Publisher pub;

// function called whenever a message is received
void my_callback(MsgType* m) {
    OtherMessageType m2;
    ... // do something with m and valorize m2
    pub.publish(m2);
}

int main(int argc, char** argv){
    // initializes the ros ecosystem
    ros::init(argc, argv);

    // object to access the namespace facilities
    ros::NodeHandle n;

    // tell the world that you will provide a topic named "published_topic"
    pub.advertise<OtherMessageType>("published_topic");

    // tell the world that you will provide a topic named "published_topic"
    Subscriber s = n.subscribe<MessageType*>("my_topic", my_callback);
    ros::spin();
}
```

# Parameters

---

- Setting values to nodes
- Actively queried by the nodes, they are most suitable for configuration information that will not change (much) over time

```
double max_tv;  
private_nh.param("max_tv", max_tv, 2.0);  
double max_rv;  
private_nh.param("max_rv", max_rv, 2.0);  
planner->setMaxVelocity(max_tv, max_rv);
```

<http://wiki.ros.org/ROS/Tutorials/UnderstandingServicesParams>

# roslaunch

---

The ROS master and the nodes can be activated all at once, using a launch file

See details at:

<http://wiki.ros.org/roslaunch/XML>

```
<launch>

  <group ns="turtlesim1">
    <node pkg="turtlesim" name="sim" type="turtlesim_node"/>
  </group>

  <group ns="turtlesim2">
    <node pkg="turtlesim" name="sim" type="turtlesim_node"/>
  </group>

  <node pkg="turtlesim" name="mimic" type="mimic">
    <remap from="input" to="turtlesim1/turtle1"/>
    <remap from="output" to="turtlesim2/turtle1"/>
  </node>

</launch>
```

```
roslaunch package-name launch-file-name
```

# rosvbag

---

- A bag is a serialized message data in a file
- rosvbag for recording or playing data
  - `rosvbag record -a` Record all the topics
  - `rosvbag info bag-name` Info on the recorded bag
  - `rosvbag play --pause bag-name` Play the recorded bag, starting paused
  - `rosvbag play -r #number bag-name` Play the recorded bag at rate *#number*



# Creating messages

---

- Messages in ROS are .msg files stored in the corresponding package folder, within the msg dir
- Supported field types are:
  - int8, int16, int32, int64 (plus uint\*)
  - float32, float64
  - string
  - time, duration
  - other msg files
  - variable length array [] and fixed length array [C]
  - Header: timestamp and coordinate frame information

# Example: creating messages

---

```
Header header
```

```
string child_frame_id
```

```
geometry_msgs/PoseWithCovariance pose
```

```
geometry_msgs/TwistWithCovariance twist
```

## Exercise

Create a message Num.msg with a field  
num of type int64

# Exercise

---

- Follow the ROS beginner tutorials:
  - Build and run the “Simple Publisher and Subscriber”
  - Build and run the “Simple Service and Client”
- Modify the talker node and the listener node
  1. Publish the message Num (created earlier) on the topic oddNums:
    - the message Num should be sent if the variable count is odd
    - Num should contain the value of count
  2. Additionally subscribe to topic oddNums
  3. Create a callback function oddNumsCallback to print the content of the received message

# Exercise

---

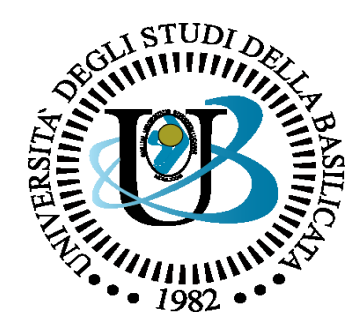
Create a package with a client and a server:

- The server should take in input a service with an integer and an array of strings and return an array of strings, that are substrings of the corresponding input strings
- The client should input a sequence of strings and request a service

# References and Credits

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- Introduction to ROS  
Roberto Capobianco, Daniele Nardi
- Robot Programming - Robotic Middlewares  
Giorgio Grisetti, Cristiano Gennari

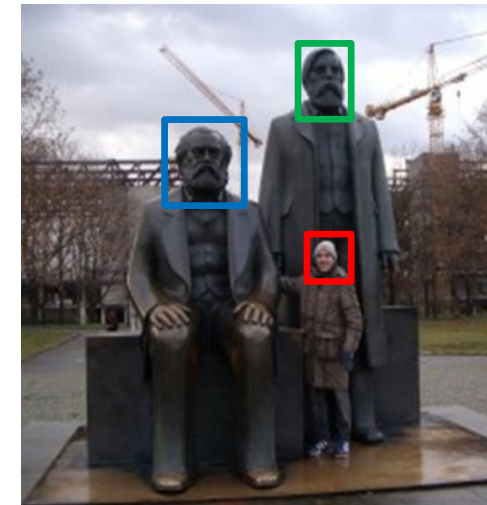
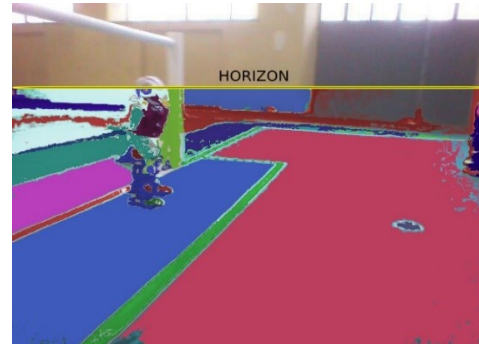
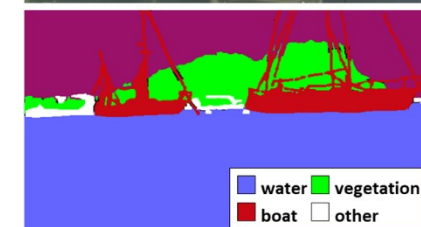
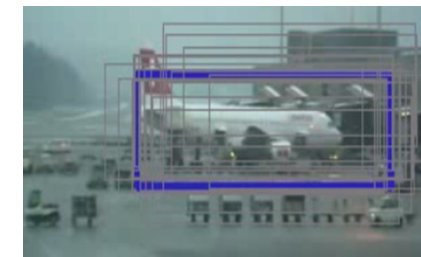


**UNIVERSITÀ DEGLI STUDI  
DELLA BASILICATA**

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# ROS intro



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