UNIVERSITÀ di VERONA | Dipartimento di INFORMATICA

*Corso di Laboratorio Ciberfisico*
*Modulo di Robot Programming with ROS*

# ROS intro

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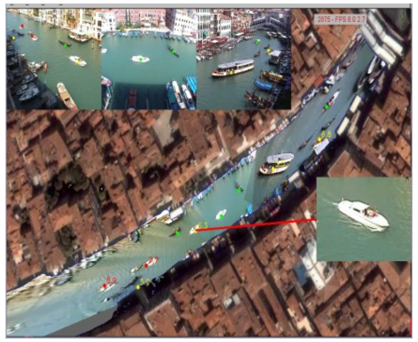
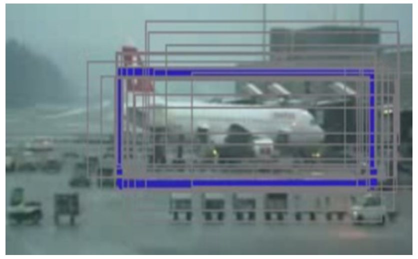
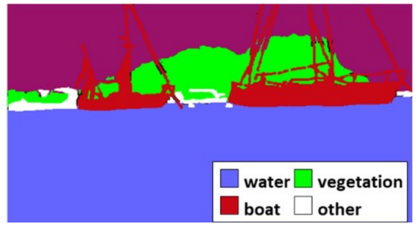
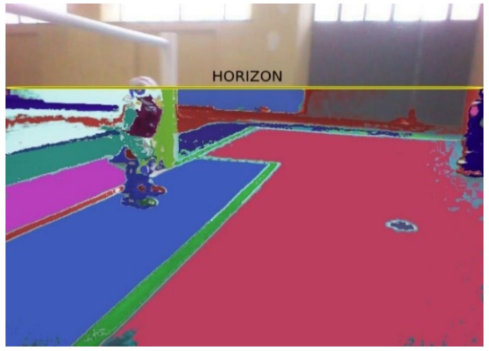
*Marzo 2018*





## ROS

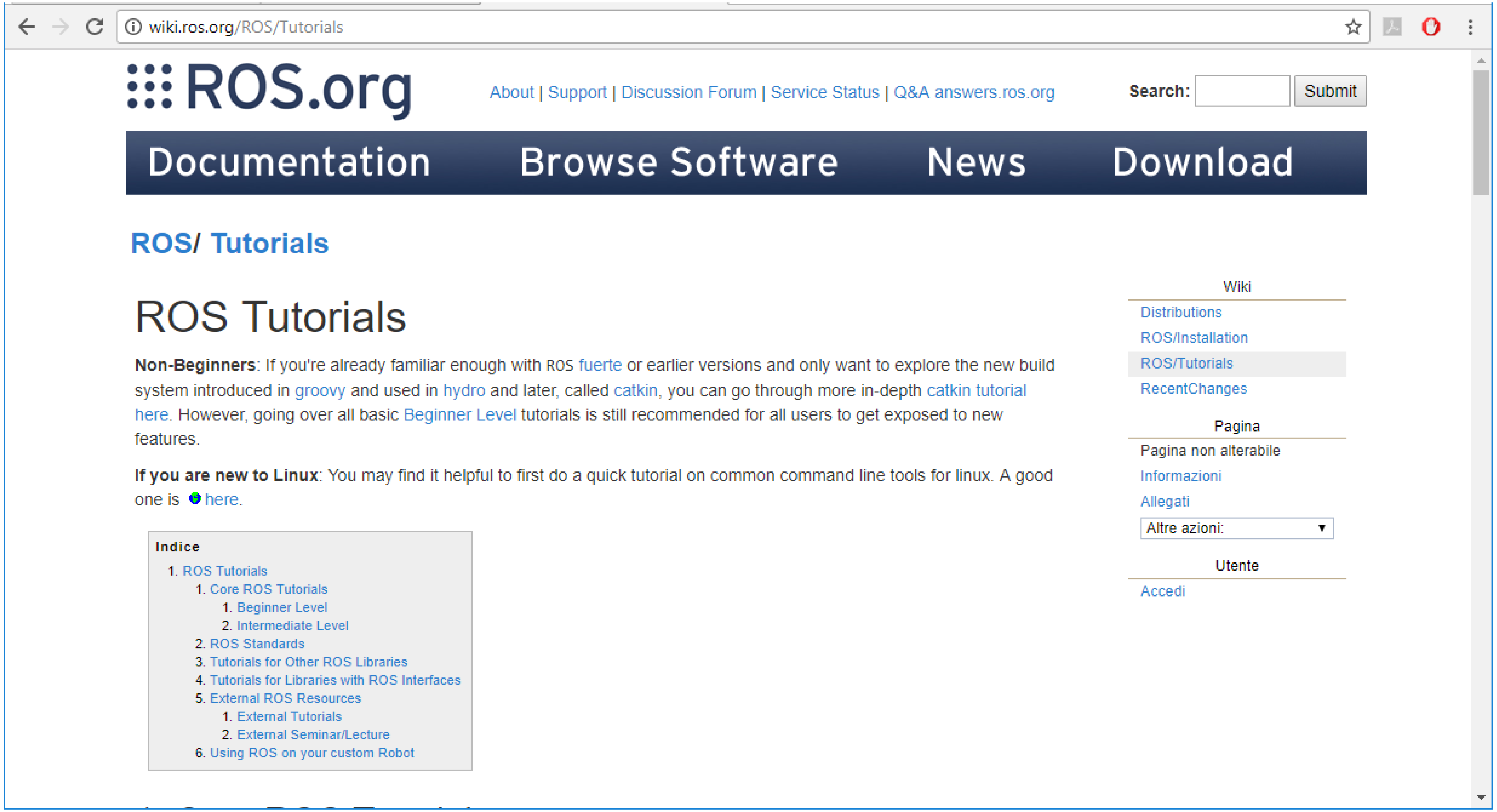
**ROS** (Robot Operating System) is an open-source, flexible framework for writing robot software

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

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

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

# ROS Tutorials



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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**

## Idea

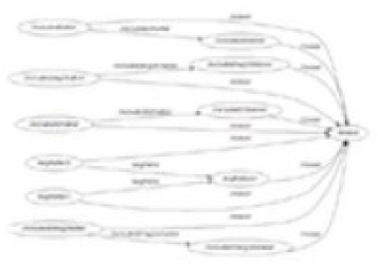
- Use processes to isolate functionalities of the system
- Processes communicate through messages (less efficient than using shared memory, but safer)
- Benefits
  - If a process crashes, it can be restarted
  - A functionality can be exchanged by replacing a process that provides it
  - Decoupling of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

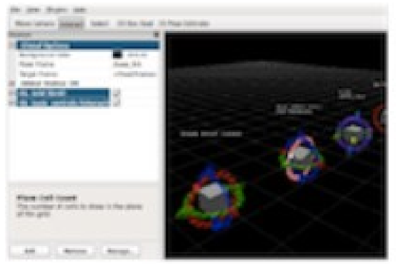
=



Plumbing

publish-subscribe messaging infrastructure designed to support the quick and easy construction of distributed computing systems.

+



Tools

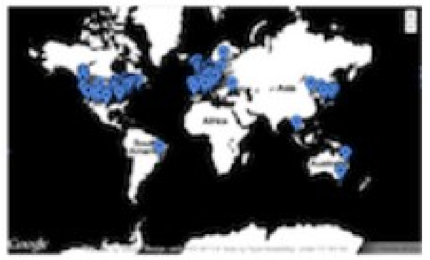
tools for configuring, starting, introspecting, debugging, visualizing, logging, testing, and stopping distributed computing systems.

+

Capabilities

a broad collection of libraries that implement useful robot functionality, with a focus on mobility, manipulation, and perception.

+



Ecosystem

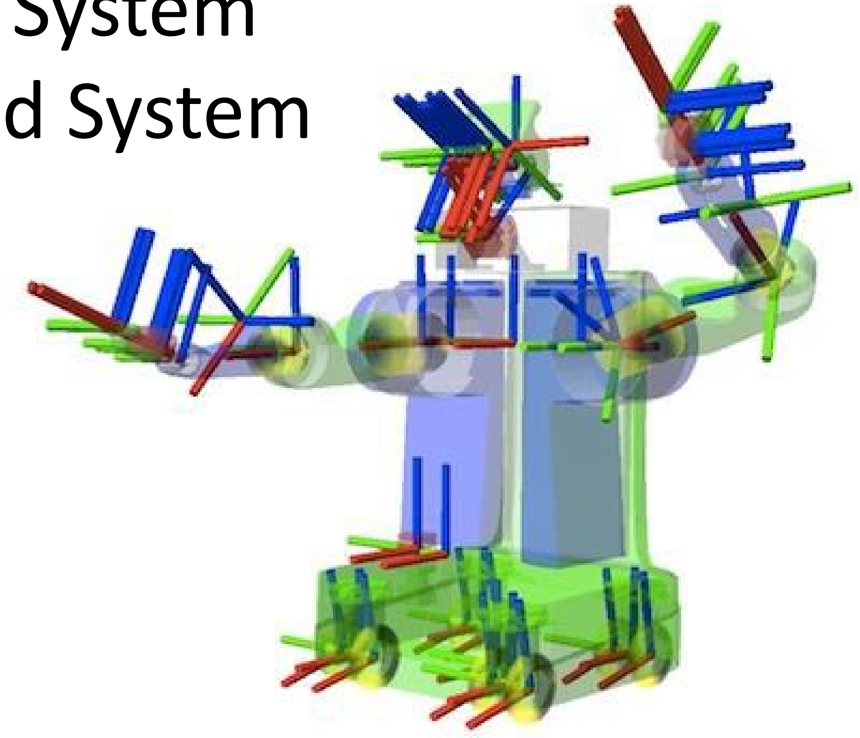
ROS is supported and improved by a large community, with a strong focus on integration and documentation.

https://answers.ros.org/question/12230/what-is-ros-exactly-middleware-framework-operating-system/

# Robot specific features

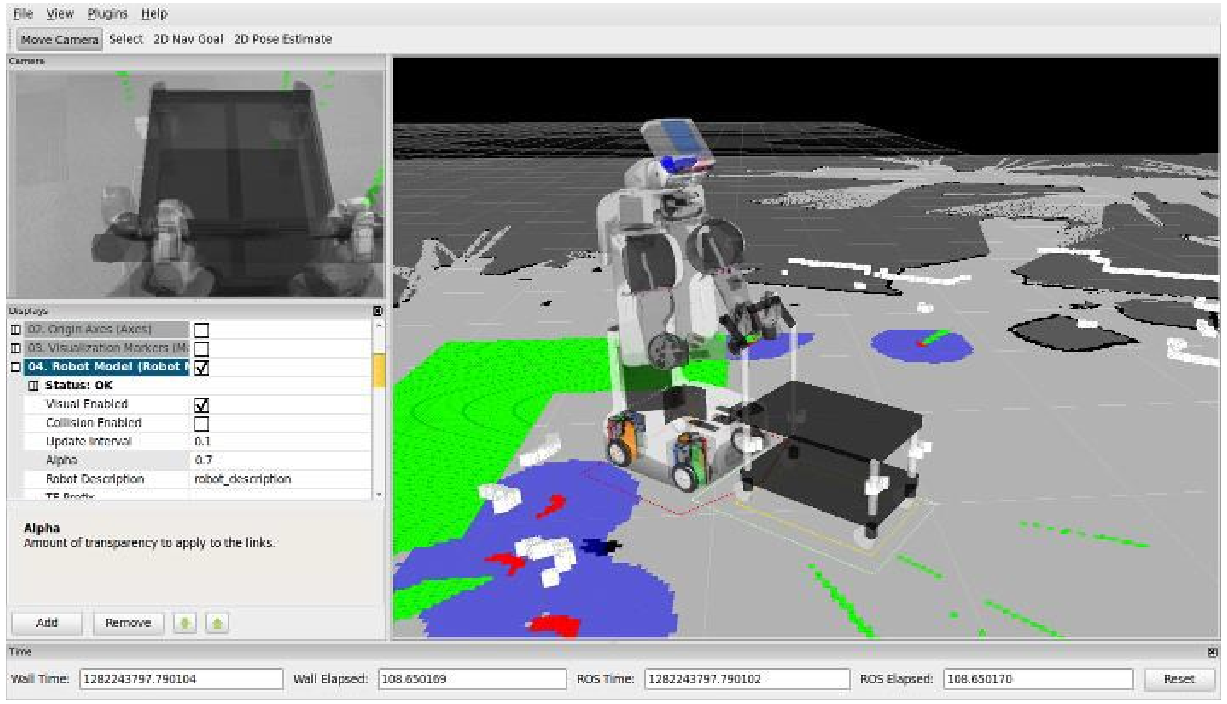
Provides tools for
- Message Definition
- Process Control
- File System
- Build System

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)



| | |
|---|---|
| 02. Origin Axes (Axes) | ☐ |
| 03. Visualization Markers (M | ☐ |
| 04. Robot Model (Robot M | ✓ |
| Status: OK | |
| Visual Enabled | ✓ |
| Collision Enabled | ☐ |
| Update Interval | 0.1 |
| Alpha | 0.7 |
| Robot Description | robot_description |
| TF Prefix | |

**Alpha**
Amount of transparency to apply to the links.

Wall Time: 1282243797.790104 Wall Elapsed: 108.650169 ROS Time: 1282243797.790102 ROS Elapsed: 108.650170

# Integration with external libraries

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

OpenCV

GAZEBO

pcl

and many others

# ROS installation

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

**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 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/                 -- WORKSPACE
  src/                     -- SOURCE SPACE
    CMakeLists.txt         -- The 'toplevel' cmake file
    package_1/
      CMakeLists.txt
      package.xml
      ...
    package_n/
      CMakeLists.txt
      package.xml
      ...
  devel/                   -- DEVELOPMENT SPACE
  build/                   -- 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
-DCATKIN_DEVEL_PREFIX=../devel
$ make
```

# 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 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

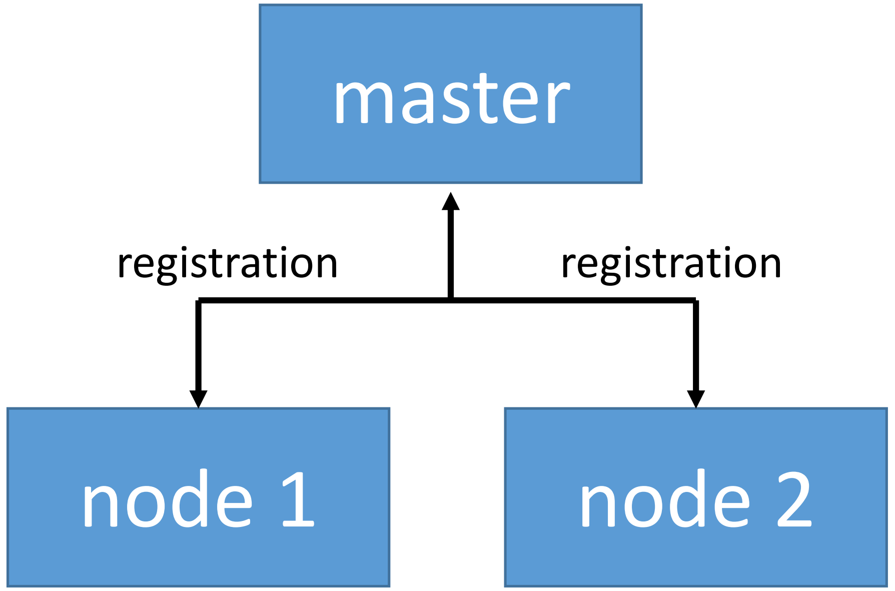
- Start the ROS master on a terminal with
  `roscore`
- It provides bookkeeping of which nodes are active, which topics are requested by whom, and other facilities
- Nodes need to communicate with the master only at the beginning to know their peers, and which topics are offered
- After that the communication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

# Nodes

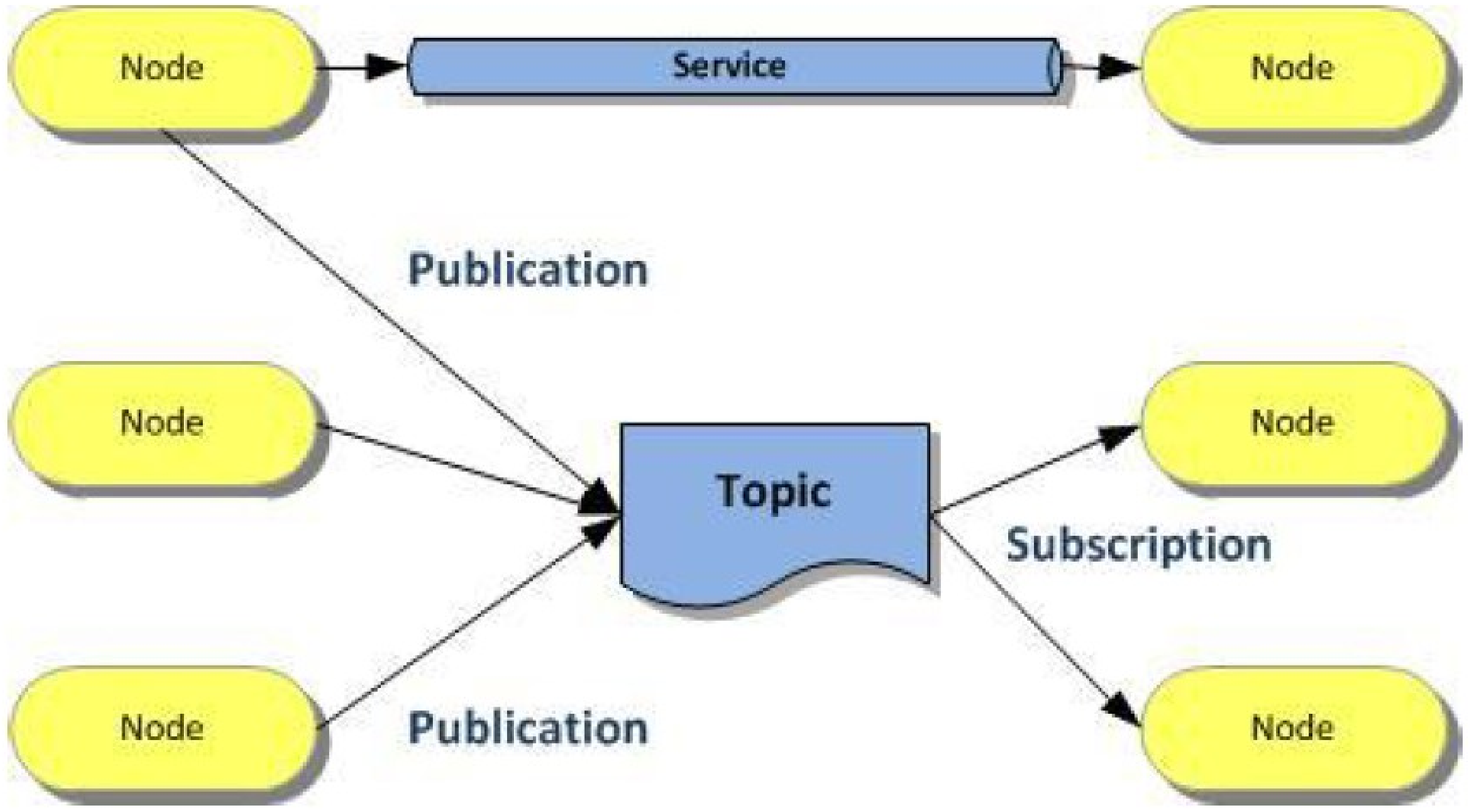
- Running instance of a ROS program

- Starting a node:
  `rosrun <package-name> <node-name>`

- Listing running nodes:
  `rosnode list`
  - `/rosout` is a node started by roscore (similar to `stdout`)
  - / indicates the global namespace



# ROS definitions



[http://wiki.ros.org/ROS/Concepts](http://wiki.ros.org/ROS/Concepts)

## Nodes

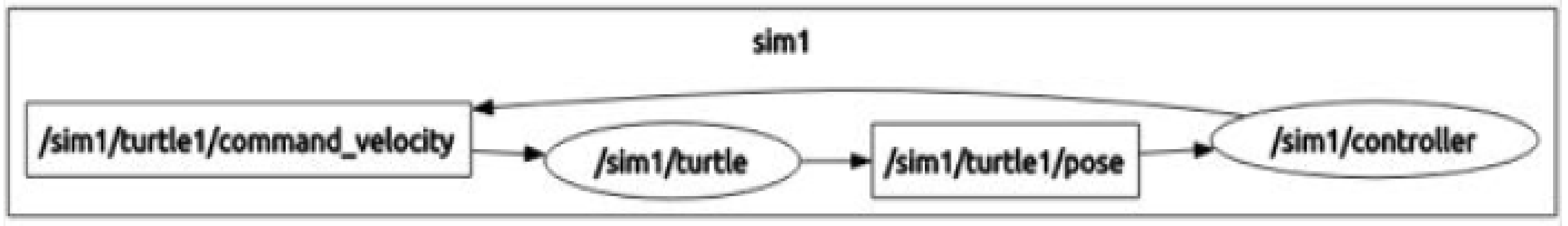
- Inspecting a node (list of topics published and subscribed, services, PID and summary of connections with other nodes):
  ```
  rosnode info node-name
  ```

- Kill a node (also CTRL+C, but unregistration may not happen)
  ```
  rosnode kill node-name
  ```

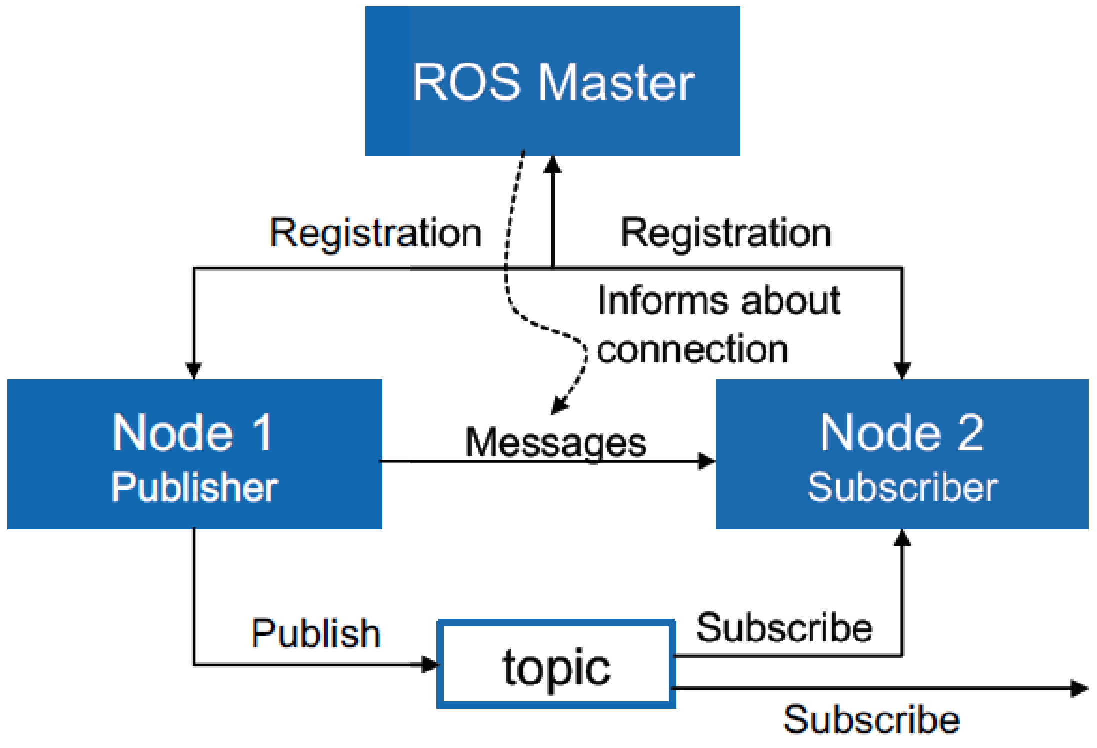
- Remove dead nodes:
  ```
  rosnode cleanup
  ```

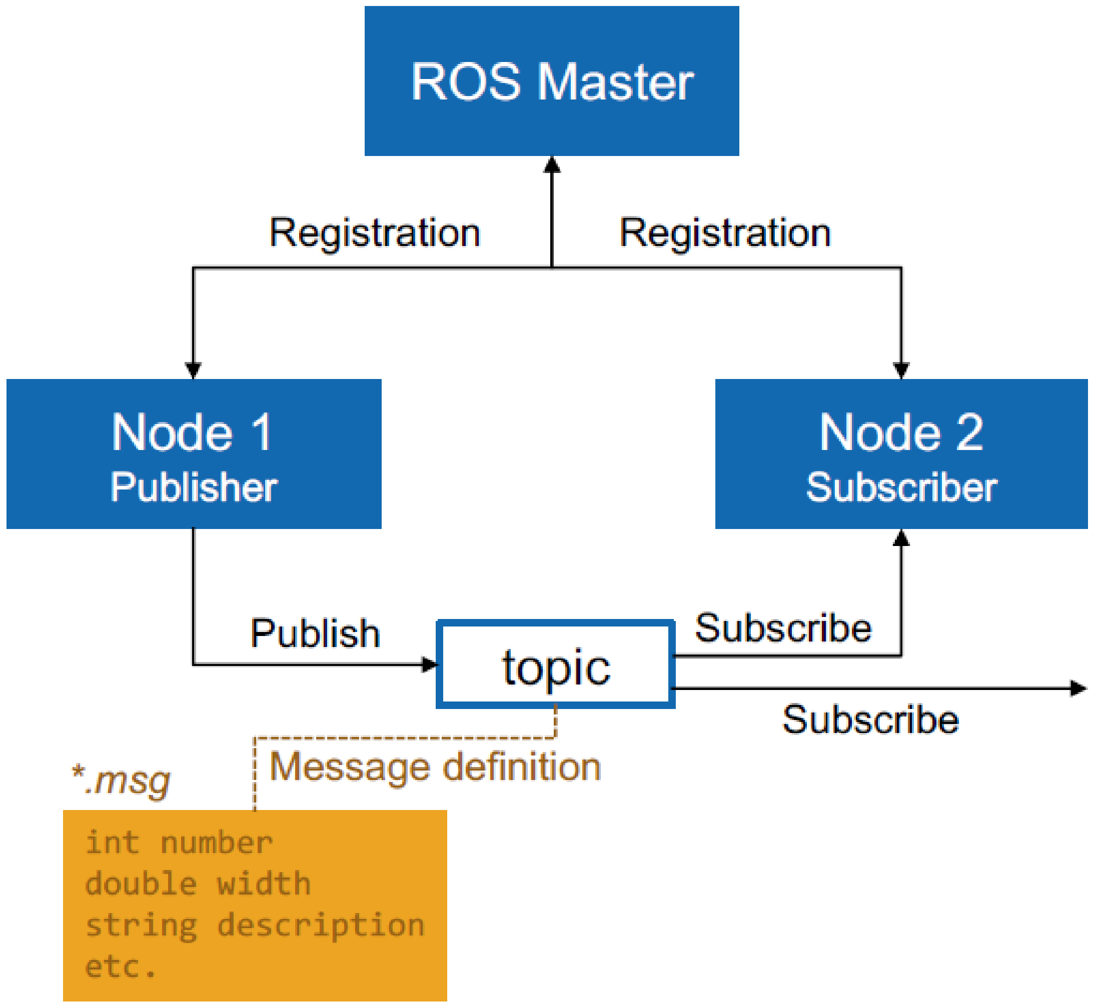
# Topics and Messages

- 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





```
int number
double width
string description
etc.
```

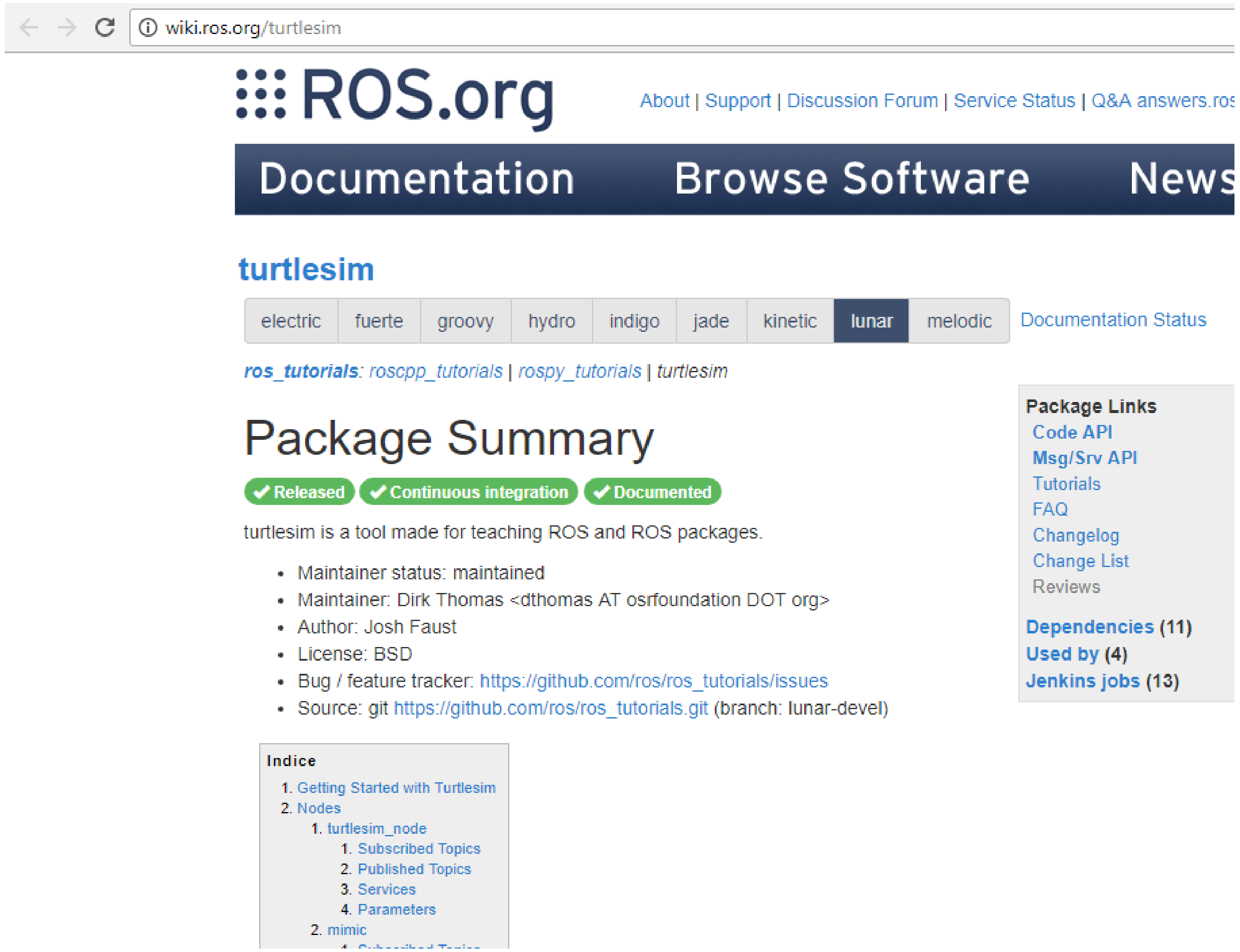
Images taken from
*Programming for Robotics*
Péter Fankhauser, Dominic Jud, Martin Wermelinger, Prof. Dr. Marco Hutter

# 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 trough 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**

electric | fuerte | groovy | hydro | indigo | jade | kinetic | lunar | melodic — Documentation Status

***ros_tutorials***: *roscpp_tutorials* | *rospy_tutorials* | *turtlesim*

## Package Summary

✓ Released ✓ Continuous integration ✓ Documented

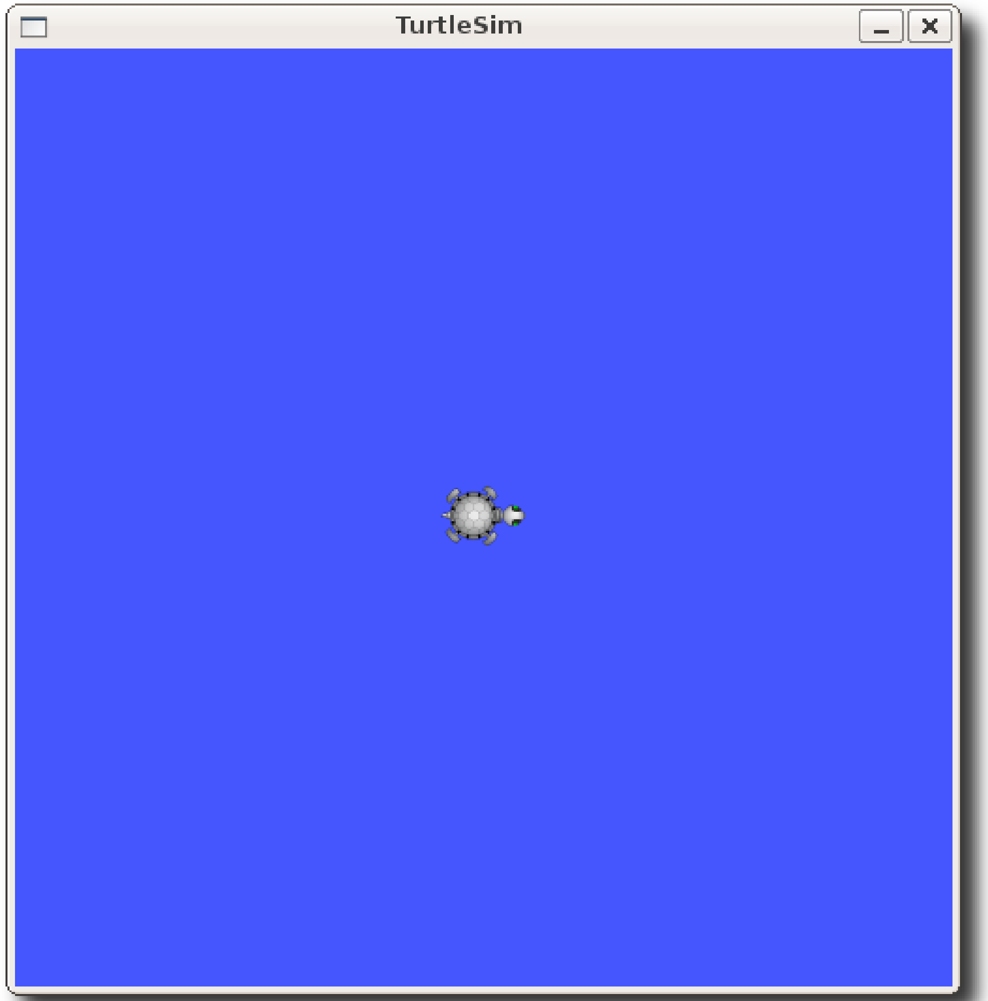
turtlesim is a tool made for teaching ROS and ROS packages.

- 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
- Source: git https://github.com/ros/ros_tutorials.git (branch: lunar-devel)

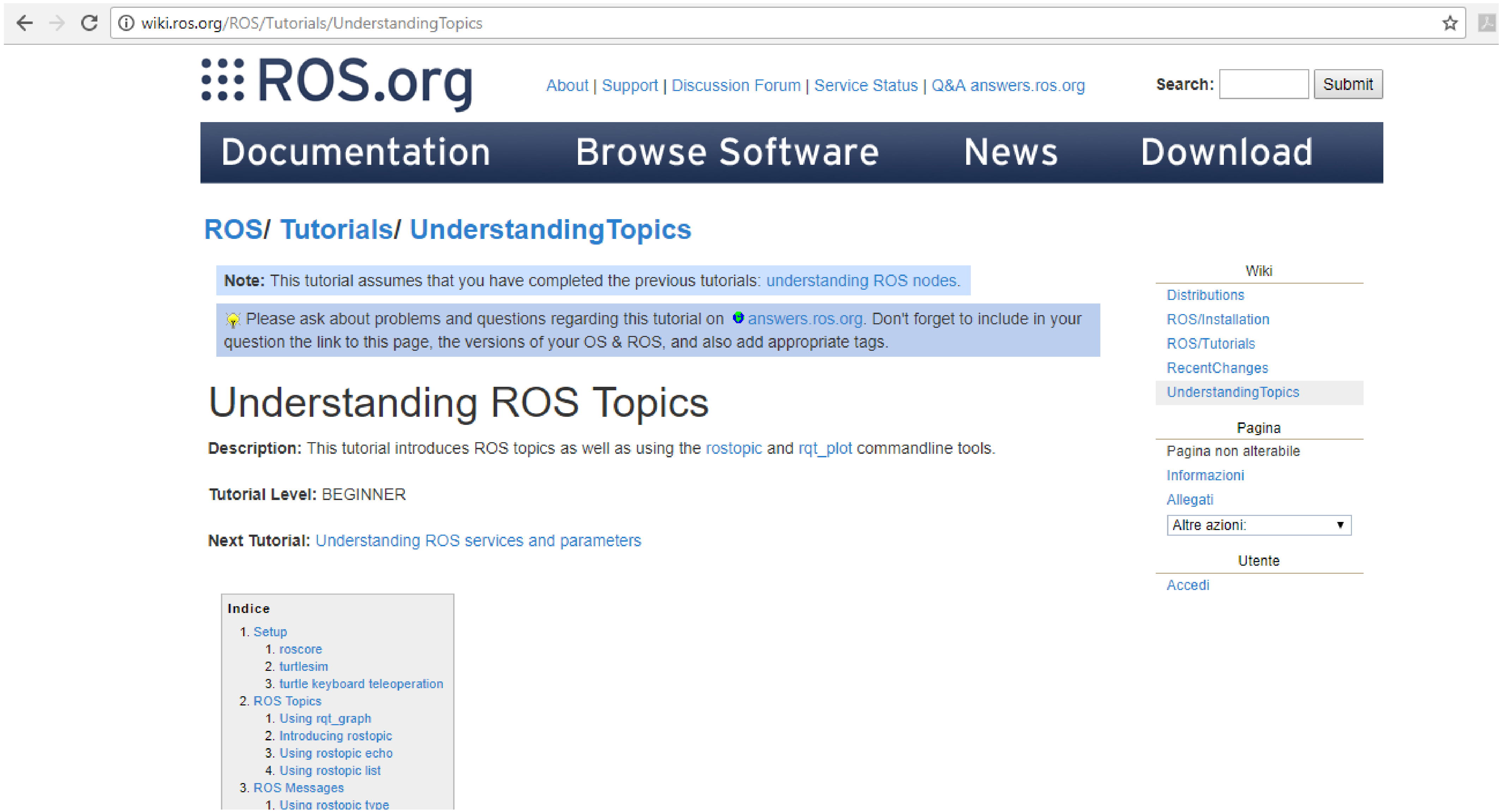
**Package Links**
- Code API
- Msg/Srv API
- Tutorials
- FAQ
- Changelog
- Change List
- Reviews

**Dependencies** (11)
**Used by** (4)
**Jenkins jobs** (13)

**Indice**



# 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

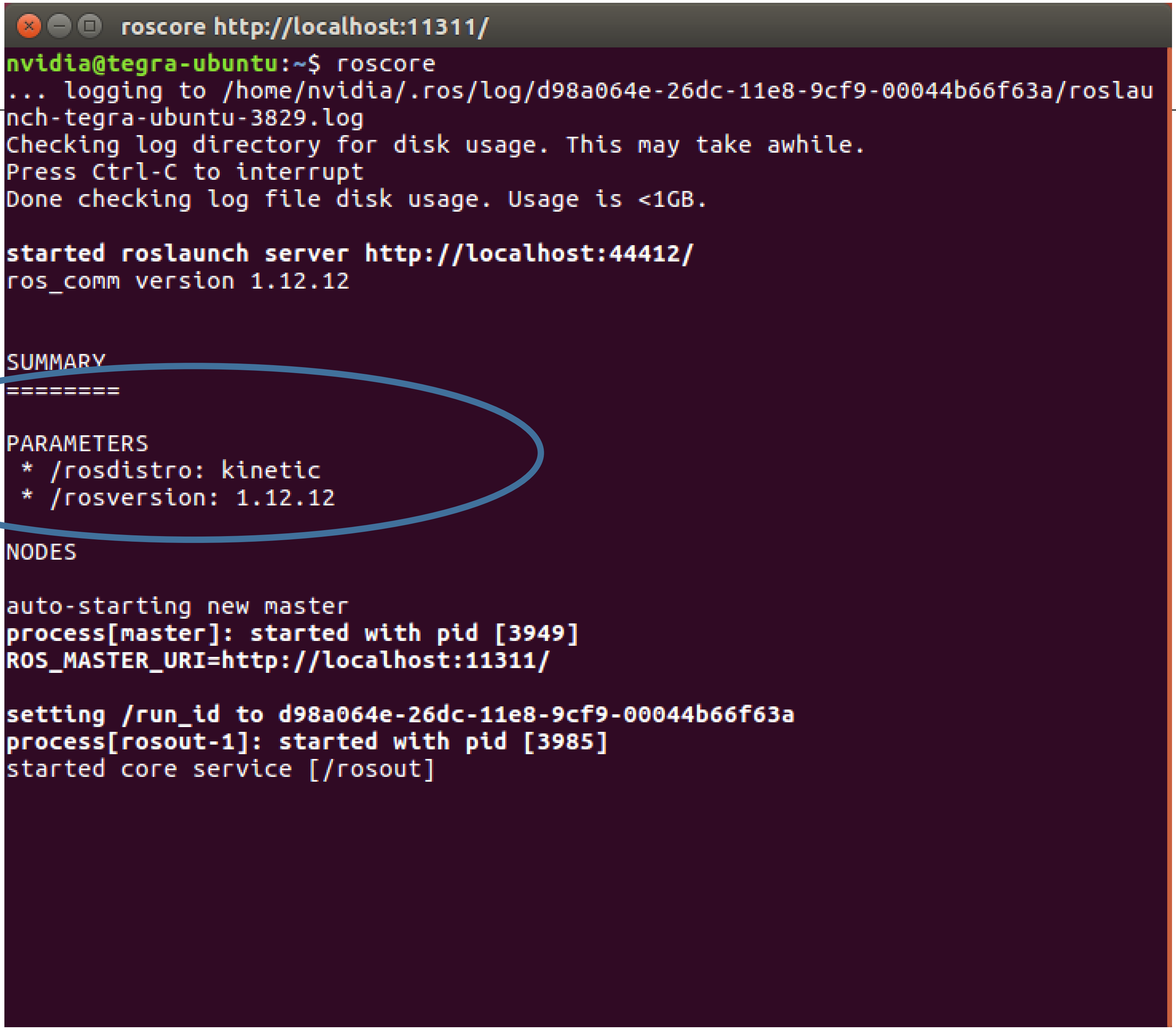
**Indice**

Wiki
- Distributions
- ROS/Installation
- ROS/Tutorials
- RecentChanges
- UnderstandingTopics

Pagina
- Pagina non alterabile
- Informazioni
- Allegati
- Altre azioni:

Utente
- Accedi

## roscore



roscore http://localhost:11311/

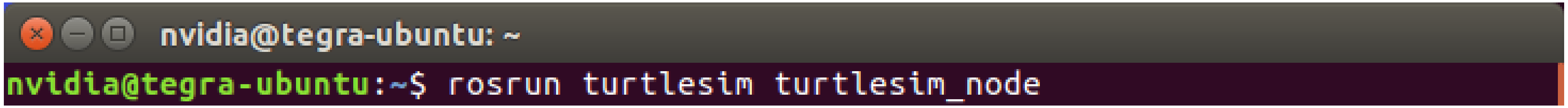
```
nvidia@tegra-ubuntu:~$ roscore
... logging to /home/nvidia/.ros/log/d98a064e-26dc-11e8-9cf9-00044b66f63a/roslau
nch-tegra-ubuntu-3829.log
Checking log directory for disk usage. This may take awhile.
Press Ctrl-C to interrupt
Done checking log file disk usage. Usage is <1GB.

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


SUMMARY
========

PARAMETERS
 * /rosdistro: 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
```

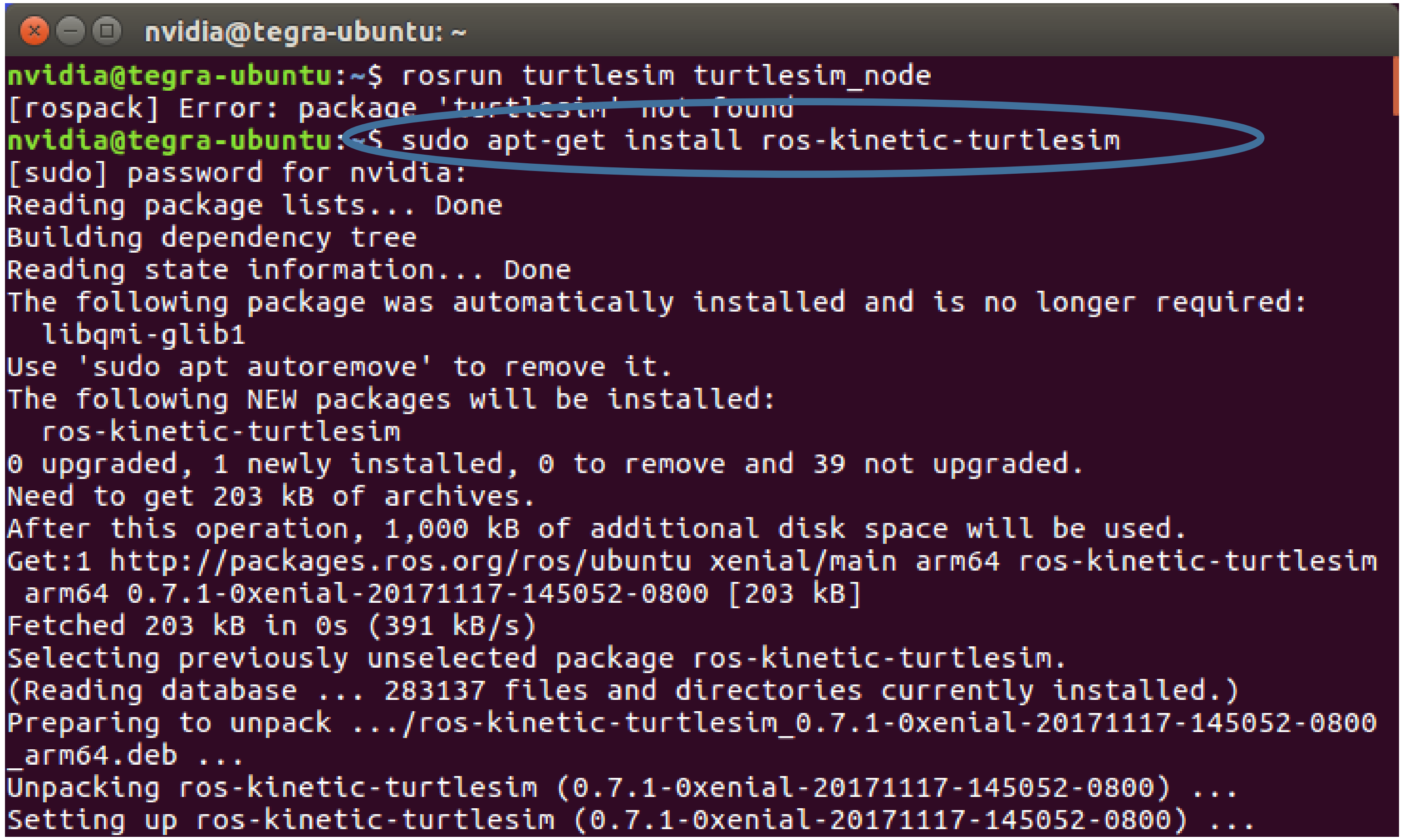


nvidia@tegra-ubuntu: ~

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

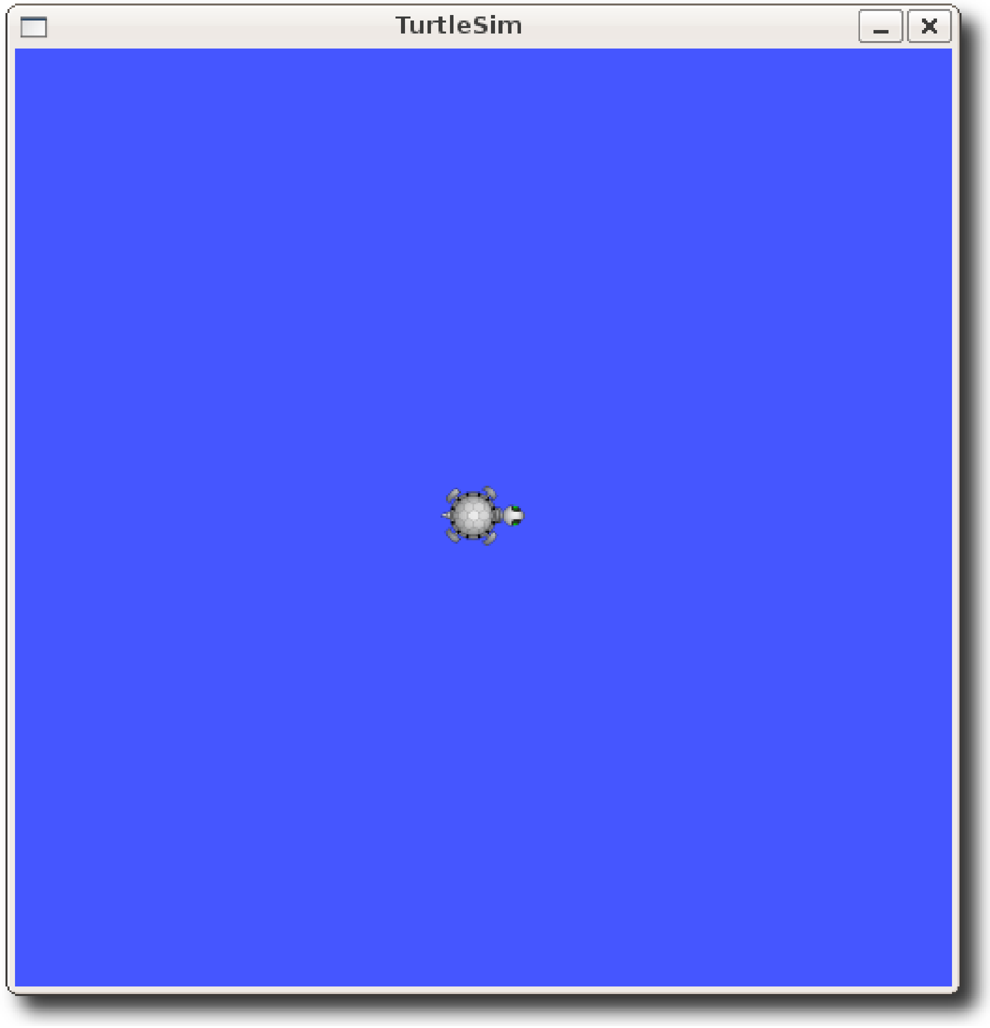
# Installing a new package

If package turtlesim is not found, we can install it



```
nvidia@tegra-ubuntu:~$ rosrun 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) ...
```

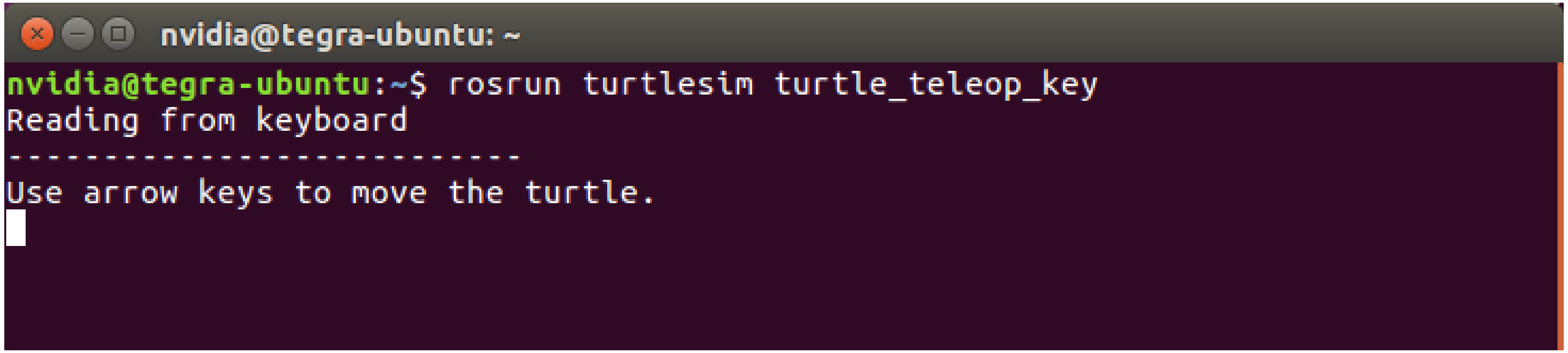
# turtlesim_node running



## turtle_teleop_key node

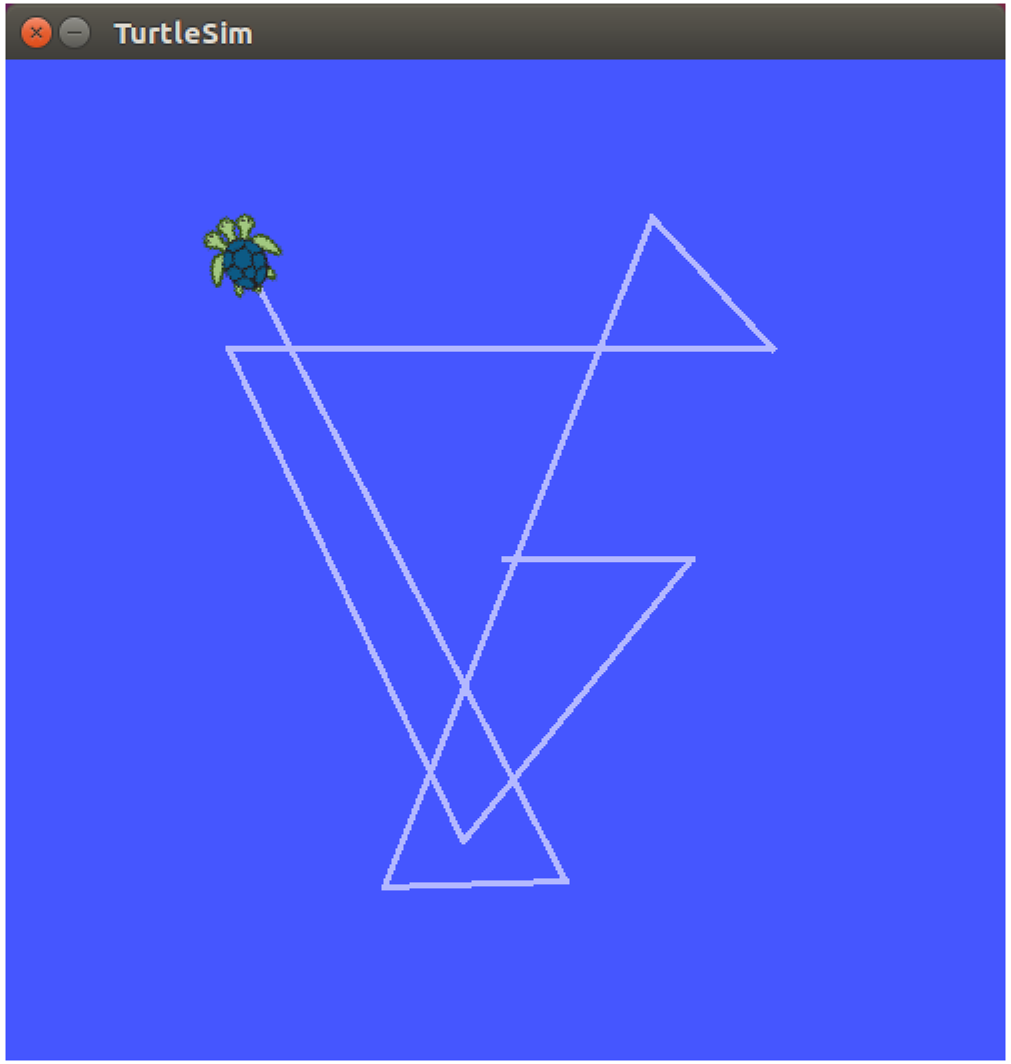
1. Open a **new terminal**

2. run:
   ```
   $ rosrun turtlesim turtle_teleop_key
   ```



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

## Playing with the turtle



# 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](http://wiki.ros.org/roslaunch/XML)

```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
```

## rosbag

- A bag is a serialized message data in a file

- rosbag for recording or playing data
  `rosbag record –a` Record all the topics
  `rosbag info` *`bag-name`* Info on the recorded bag
  `rospag play --pause` *`bag-name`* Play the recorded bag, starting paused
  `rospag 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

- Introduction to ROS
  Roberto Capobianco, Daniele Nardi

- Robot Programming - Robotic Middlewares
  Giorgio Grisetti, Cristiano Gennari

UNIVERSITÀ di VERONA

Dipartimento di INFORMATICA

*Corso di Laboratorio Ciberfisico*
*Modulo di Robot Programming with ROS*

# ROS intro

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