ROS

Module V
Introduction to Robot Operating System

Continuing Education Program
October 26-28, 2018

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References

- Morgan Quigley, Brian Gerkey, and William D. Smart, **Programming Robots with ROS.** O'Reilly Media, First edition.
- Lentin Joseph, Jonathan Cacace , **Mastering ROS for Robotics Programming,** Packt Publishing, Second Revised edition.
- Lentin Joseph, **Learning Robotics Using Python.** Packt Publishing, Second edition.

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References

- Jason M. O'Kane, **A Gentle Introduction to ROS.** CreateSpace Independent Publishing Platform.
- Wyatt Newman**, A Systematic Approach to Learning Robot Programming with ROS,** Chapman and Hall/CRC, First edition.
- Lentin Joseph , **ROS Robotics Projects,** Packt Publishing, First edition

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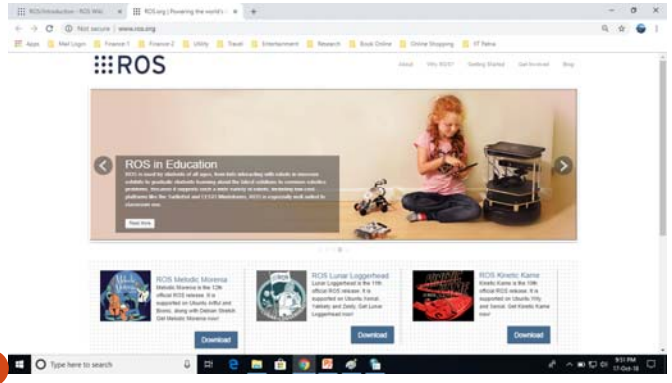
Official Website

http://www.ros.org **"Powering the world's robots"**



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Official Website

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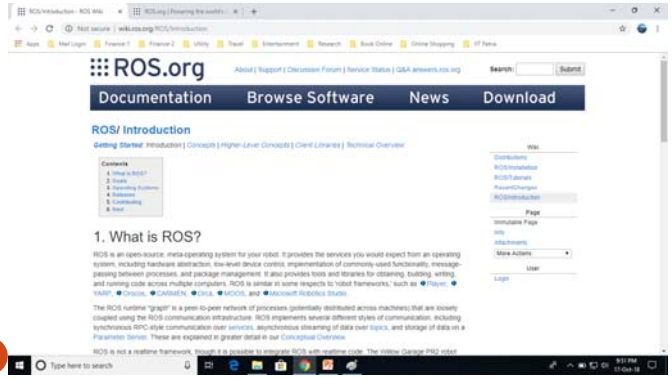

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Robots using ROS

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http://wiki.ros.org/Robots

ROS

- ROS: **Robot Operating System**
- It is not exactly same as existing operating systems, like Windows, Linux, etc.
- Flexible framework for writing robot software: Collection of libraries and tools supporting robotic software development.

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ROS

- A suite of user contributed packages that implement common robot functionality such as SLAM, planning, perception, vision, manipulation, etc.
- OS-like functionality: Provides hardware abstraction, device drivers, libraries, visualizers, message-passing, package management, etc.

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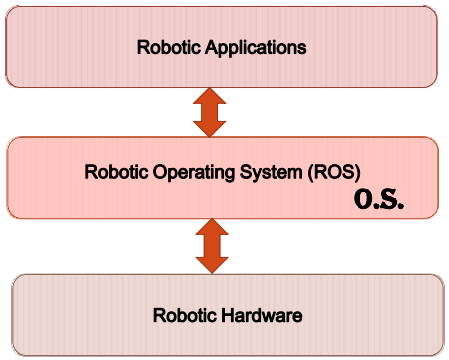
ROS



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ROS

"ROS is an open-source, meta-operating system for your robot. It provides the services you would expect from an operating system, including hardware abstraction, low-level device control, implementation of commonly-used functionality, message-passing between processes, and package management. It also provides tools and libraries for obtaining, building, writing, and running code across multiple computers."

Source: "http://wiki.ros.org/ROS/Introduction"

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History

- Developed at the Stanford Artificial Intelligence Laboratory in 2007.
- Since 2013, ROS is managed by Open Source Robotics Foundation (OSRF).
- De facto standard for robot programming.
- Already used by many robots, popular in both academia and industry.

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Why ROS

- Code reuse in robotics research and development
- Ready-to-use development environment
- Comprehensive tools and client API libraries (C++, Python, Lisp, Java, …)
- Scalable (distributed network of processes loosely coupled)
- Big community and continuous support: Many device drivers and algorithms are available.

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Supporting libraries

- openCV: computer vision
- Eigen: Matrix Algebra
- Gazebo: Robot Simulator
- KDL: Kinematics and Dynamics
- TREX: High Level Planning
- PCL: Point Cloud Library
- Many others …

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ROS Philosophy

- Peer to peer: Individual programs communicate over defined API (ROS messages, services, etc.).
- Distributed: Programs can be run on multiple computers and communicate over the network.
- Multi-lingual: ROS modules can be written in any language for which a client library exists (C++, Python, MATLAB, Java, etc.).
- Light-weight: Stand-alone libraries are wrapped around with a thin ROS layer.
- Free and open-source: Most ROS software is open-source and free to use.

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ROS =

Plumbing	**Process Management** **Inter-process Communication** **Device Drivers**
Tools	**Simulation** **Visualization** **Graphical User Interface**
Capability	**Control, Planning, Perception** **Mapping, Manipulation**
Ecosystems	**Package Organization** **Software Distribution** **Documentation, Distribution**

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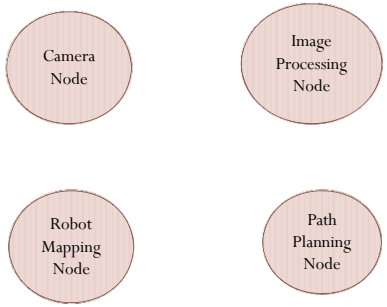
Nodes

- A node is a process that performs computation.



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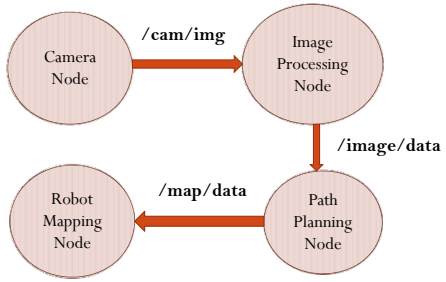
Topics

- Topics are streams of data with publish / subscribe semantics.
- Nodes can publish and subscribe to topic in order to transfer data.



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Messages

- A message is simply a data structure, comprising typed fields.
- Language agnostic data representation. C++ can talk to Python.
- Messages are sent on defined topics.

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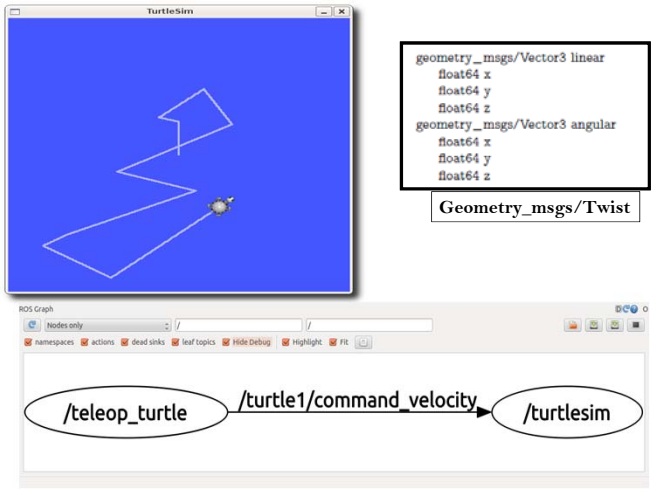

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Source: http://wiki.ros.org/ROS/Tutorials/CreatingMsgAndSrv

Built-in field types of ROS messages

Primitive type	Serialization	C++	Python
bool(1)	unsigned 8-bit int	uint8_t(2)	bool
int8	signed 8-bit int	int8_t	int
uint8	unsigned 8-bit int	uint8_t	int (3)
int16	signed 16-bit int	int16_t	int
uint16	unsigned 16-bit int	uint16_t	int
int32	signed 32-bit int	int32_t	int
uint32	unsigned 32-bit int	uint32_t	int
int64	signed 64-bit int	int64_t	long
uint64	unsigned 64-bit int	uint64_t	long
float32	32-bit IEEE float	float	float
float64	64-bit IEEE float	double	float
string	ascii string(4)	std::string	string
time	secs/nsecs unsigned 32-bit ints	ros::Time	rospy.Time
duration	secs/nsecs signed 32-bit ints	ros::Duration	rospy.Duration

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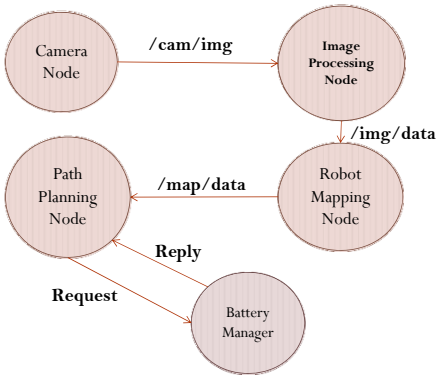
Source: Mastering ROS for Robotics Programming by Lentin Joseph

Services

- Request / reply is done via services, which are defined by a pair of message structures: one for the request and one for the reply.



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ROS Master

- The ROS Master provides name registration and lookup to nodes. Without the Master, nodes would not be able to find each other, exchange messages, or invoke services.

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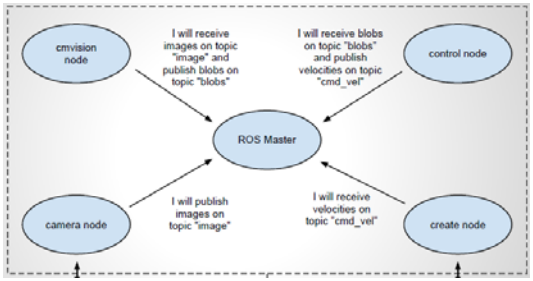
ROS Master



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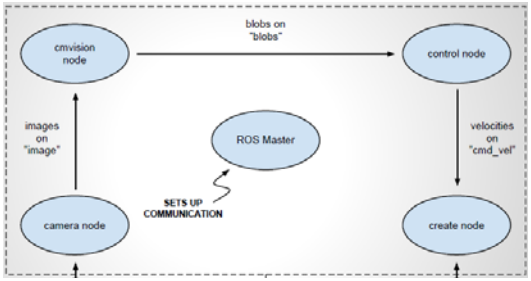
ROS Master



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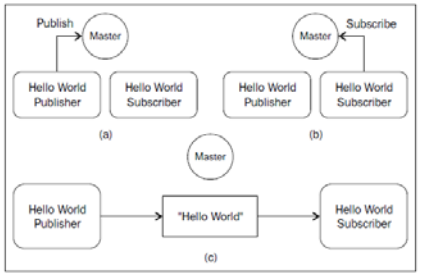
ROS Master



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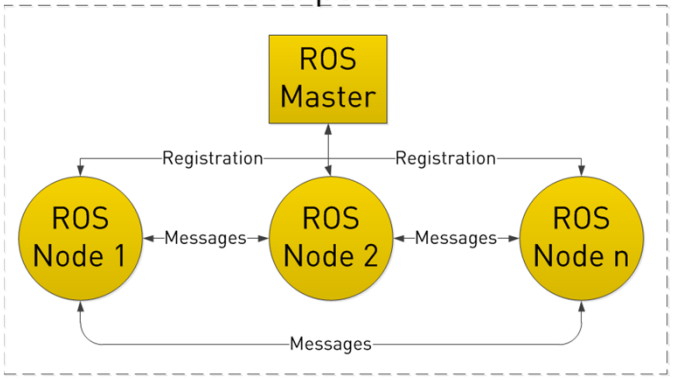
Computer 1



Source: http://www.clearpathrobotics.com

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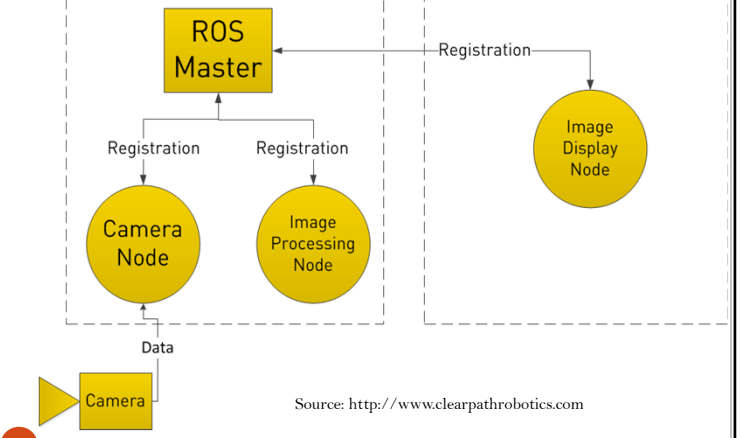
Computer on the Robot

Laptop



Source: http://www.clearpathrobotics.com

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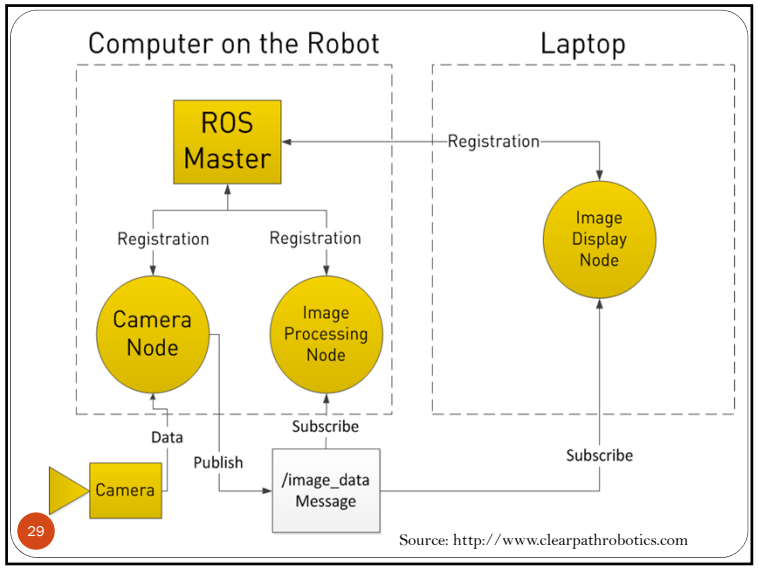

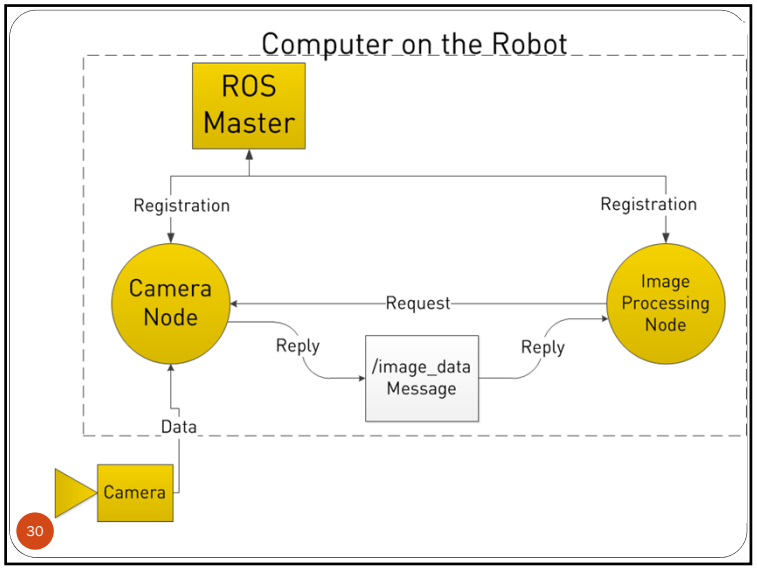

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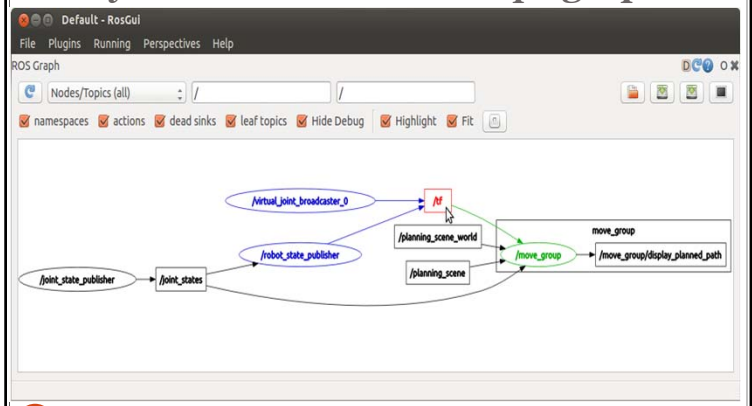
System Visualisation: rqt_graph



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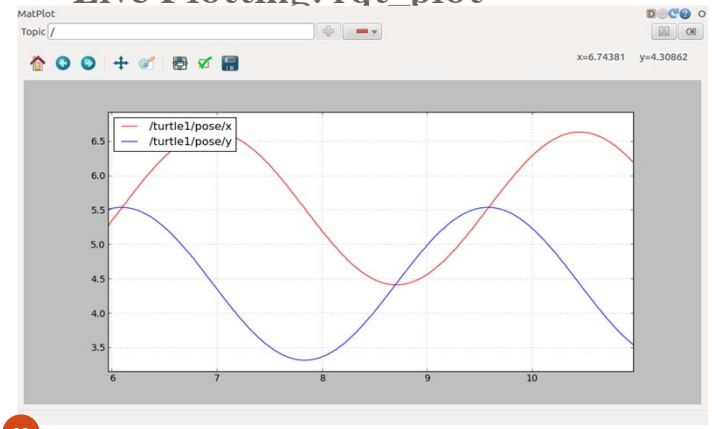
http://wiki.ros.org/rqt_graph

Live Plotting: rqt_plot



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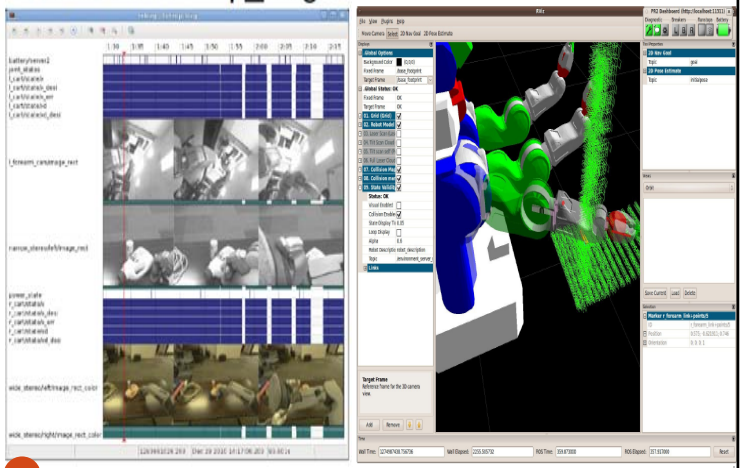
http://wiki.ros.org/rqt_plot

ROS tools - rqt_bag

ROS tools - rviz



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http://wiki.ros.org/Tools

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ROS Statistics July 2016 - July 2017

- **Total traffic on packages.ros.org:**
  - 232,577 Unique Visitors (105 % increase)
  - 4714.22 GB (54% increase)
- **Total downloads of .deb packages:**
  - 13,441,711 (59% increase)
- **Unique package names downloaded as .deb files:**
  - 9395 (24% increase)
- **Number of unique versions of .deb packages downloaded:**
  - 53,382 (16 % decrease)

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Worldwide User Base

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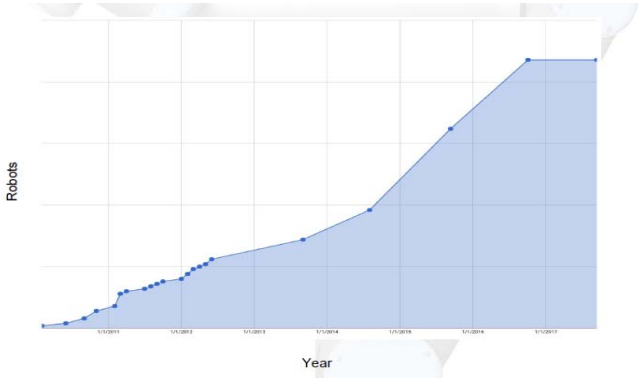
No. of Robots Supporting ROS



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ROS Packages

- Packages are the main unit for organizing large complex software in ROS.
- Packages are the most atomic build item and release item in ROS.
- A package may contain ROS source code, launch files, configuration files, message definitions, datasets, or anything else that is usefully organized together

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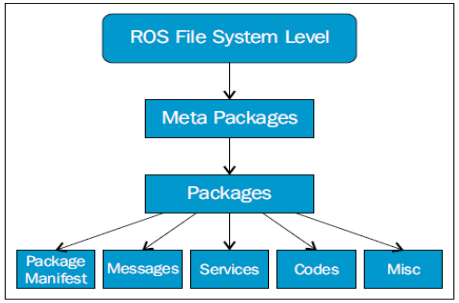
ROS file system level



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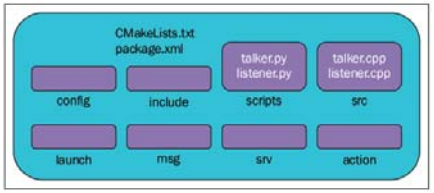
ROS Packages



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ROS Packages

- **config:** Consists of all configuration files.
- **include/package_name:** This folder consists of headers and libraries required in the package.
- **scripts:** This folder keeps executable Python scripts.
- **src:** This folder stores the C++ source codes.
- **launch:** This folder keeps the launch files that are used to launch one or more ROS nodes.
- **msg:** This folder contains custom message definitions.
- **srv:** This folder contains the service definitions.
- **action:** This folder contains the action definition.
- **package.xml:** This is the package manifest file of this package.
- **CMakeLists.txt:** This is the CMake build file of this package.

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ROS Packages: A Sample Package

```
mastering_ros_demo_pkg/
|-- action
|   `-- Demo_action.action
|-- CMakeLists.txt
|-- include
|-- msg
|   `-- demo_msg.msg
|-- package.xml
|-- src
|   |-- demo_action_client.cpp
|   |-- demo_action_server.cpp
|   |-- demo_msg_publisher.cpp
|   |-- demo_msg_subscriber.cpp
|   |-- demo_service_client.cpp
|   |-- demo_service_server.cpp
|   |-- demo_topic_publisher.cpp
|   `-- demo_topic_subscriber.cpp
`-- srv
    `-- demo_srv.srv
```

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Source: Mastering ROS for Robotics Programming by Lentin Joseph

ROS Packages: package.xml

```xml
<?xml version="1.0"?>
<package>
  <name>hello_world</name>
  <version>0.0.0</version>
  <description>The hello_world package</description>

  <maintainer email="qboticslabs@gmail.com">Lentin Joseph</maintainer>
  <license>BSD</license>
  <url type="website">http://wiki.ros.org/hello_world</url>
 <author email="qboticslabs@gmail.com">Lentin Joseph</author>

  <buildtool_depend>catkin</buildtool_depend>
  <build_depend>roscpp</build_depend>
  <build_depend>rospy</build_depend>
  <build_depend>std_msgs</build_depend>

  <run_depend>roscpp</run_depend>
  <run_depend>rospy</run_depend>
  <run_depend>std_msgs</run_depend>

  <export>
  </export>
</package>
```

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Source: Mastering ROS for Robotics Programming by Lentin Joseph

ROS Packages: CMakeLists.txt

Required CMake Version (cmake_minimum_required)

Package Name (project())

Find other CMake/Catkin packages needed for build (find_package())

Enable Python module support (catkin_python_setup())

Message/Service/Action Generators (add_message_files(), add_service_files(), add_action_files())

Invoke message/service/action generation (generate_messages())

Specify package build info export (catkin_package())

Libraries/Executables to build (add_library()/add_executable()/target_link_libraries())

Tests to build (catkin_add_gtest())

Install rules (install())

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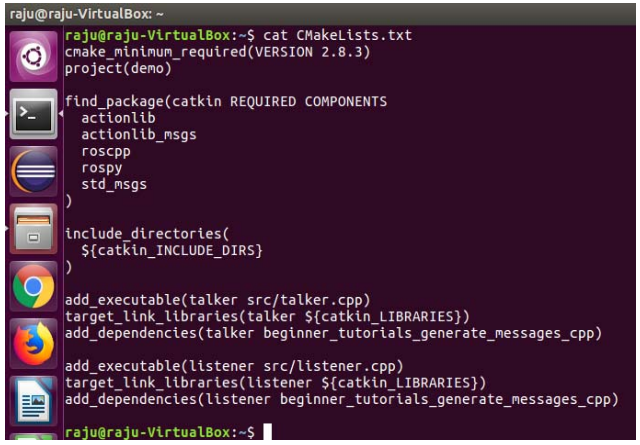
Source: http://wiki.ros.org/catkin/CMakeLists.txt

ROS Packages: CMakeLists.txt



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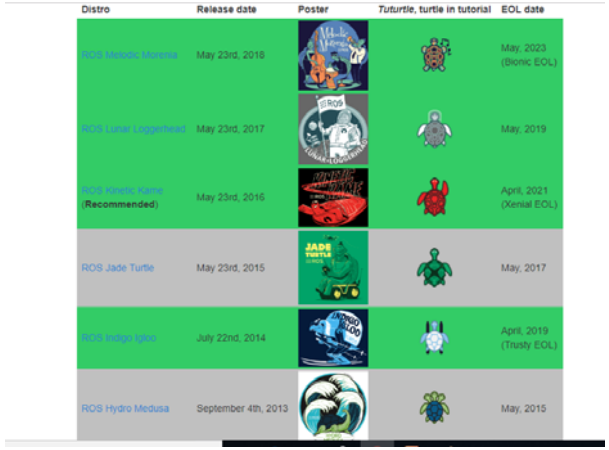
ROS Distribution Releases



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ROS Supported Platforms

- ROS is currently supported only on Ubuntu
  - Other variants (Windows and Mac OS X) are considered experimental
- ROS Kinetic supports the following Ubuntu versions:
  - Wily (Ubuntu 15.10),
  - Xenial (Ubuntu 16.04),
  - Jessie (Debian 8)

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Basic Unix Command

- **ls:** Lists files and folders in the working directory
- **cd <folder>:** Change the working directory to **<folder>**
- **pwd:** Prints the current working directory
- **mkdir <directory>:** Creates a directory in your working directory named **<directory>**
- **mv <src> <dest>:** Move files from **<src>** to **<dest>**
- **cp <src> <dest>:** Copies files from **<src>** to **<dest>**
- **gedit or nano <file>:** Opens a text editor to edit **<file>**
- **sudo apt-get install ros-kinetic-desktop:** Install as a root users using Advanced Package Tool.

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ROS Installation

- If you already have Ubuntu installed, follow the instructions at:
  http://wiki.ros.org/Kinetic/Installation/Ubuntu
- Also you can use Oracle VM VirtualBox
  https://www.virtualbox.org
- You can also download a VM with ROS Pre-installed from here:
  http://nootrix.com/downloads/#RosVM

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Installing ROS

- Set up your system to accept ROS packages from packages.ros.org.

```
$ sudo sh -c 'echo "deb http://packages.ros.org/ros/ubuntu $(lsb_release -sc) main" > /etc/apt/sources.list.d/ros-latest.list'
```

- Add apt-keys. The apt-key is used to manage the list of keys used by apt to authenticate the packages.

```
$ sudo apt-key adv --keyserver hkp://ha.pool.sks-keyservers.net:80 --recv-key 421C365BD9FF1F717815A3895523BAEEB01FA116
```

- Update the Ubuntu package index.

```
$ sudo apt-get update
```

- Install the packages.

```
$ sudo apt-get install ros-kinetic-desktop-full
```

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Installing ROS (Cont…)

- Initializing ROSDEP

```
$ sudo rosdep init
$ rosdep update
```

- Add ROS environmental variables to the .bashrc file.

```
$ echo "source /opt/ros/kinetic/setup.bash" >> ~/.bashrc
$ source ~/.bashrc
```

- Add…

```
$ sudo apt-get install python-rosinstall python-rosinstall-generator python-wstool build-essential
```

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Setting ROS Workspace

- Every new project should be organized in packages
- We need to work in a very specific ROS workspace, which is known as the catkin workspace. (catkin_ws)
- CREATING ROS WORKSPACE (Only one time)
  - The default directory for ROS packages is the path: /opt/ros/kinetic/share/
  - Verify it with the command: printenv| grep ROS
  - Directory path for new ROS projects: ~/catkin_ws/src

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Setting ROS Workspace

- **Create an empty workspace and a folder 'src' in it to store packages:**
  - mkdir -p ~/catkin_ws/src
- **GO to 'src' and initialize a catkin workspace**
  - cd ~/catkin_ws/src
  - catkin_init_workspace
- **Go into your empty workspace and build packages**
  - cd ~/catkin_ws/
  - catkin_make
- **Before continuing make sure you source your new setup.*sh file**
  - source devel/setup.bash
  - echo $ROS_PACKAGE_PATH
- **Test your path:** /home/youruser/catkin_ws/src:/opt/ros/kinetic/share

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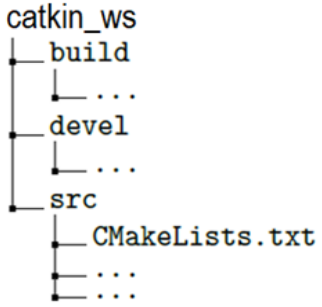
Setting ROS Workspace: An Example



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Integrate Eclipse with ROS: Install Eclipse

- sudo apt-get install default-jre
- Download Eclipse C/C++ IDE from: https://www.eclipse.org/downloads/packages/
- tar -xfvz <downloadedfile>
- sudo mv eclipse /opt
- cd /opt
- sudo chmod -R 777 eclipse
- sudo ln -s /opt/eclipse/eclipse /usr/bin/eclipse

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Install Eclipse

- $sudo gedit /usr/share/applications/eclipse.desktop

```
[Desktop Entry]
Name=Eclipse
Type=Application
Exec=bash -i -c "/opt/eclipse/eclipse"
Terminal=false
Icon=/opt/eclipse/icon.xpm
Comment=Integrated Development Environment
NoDisplay=false
Categories=Development;IDE
Name[en]=eclipse.desktop
```

The bash –i - c command will cause your IDE's launcher icon to load your ROS-sourced shell environment before launching eclipse

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Install Eclipse

- Alternate Option:

$ sudo apt-get install eclipse eclipse-cdt g++

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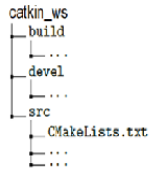
Make Eclipse Project Files

- Go to workspace directory and run catkin_make with options to generate eclipse project files:

```
$ cd ~/catkin_ws
$ catkin_make --force-cmake -G"Eclipse CDT4 - Unix Makefiles"
```

- The project files will be generated in ~/catkin_ws/build.



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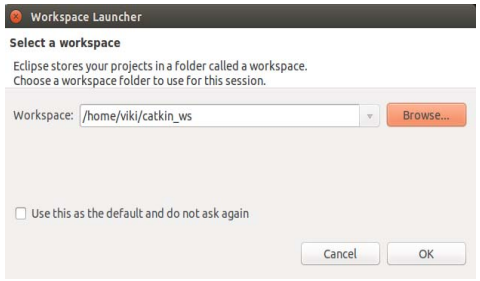
Import the Project into Eclipse

- Now start Eclipse
- Choose catkin_ws folder as the workspace folder



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Import the Project into Eclipse

- Choose File --> Import --> General --> Existing Projects into Workspace

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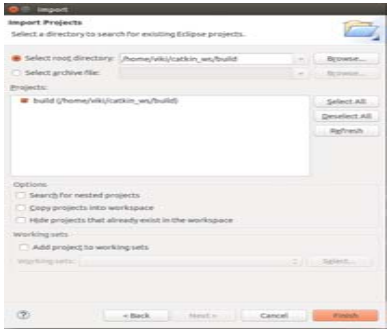
Import the Project into Eclipse

- Now import the project from the ~/catkin_ws/build folder



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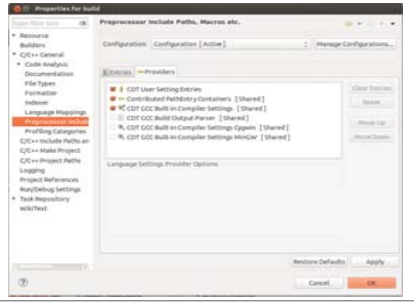
Fix Preprocessor Include Paths

- By default, the intelligence in Eclipse won't recognize the system header files (like <string>). To fix that:
  - Go to Project → Properties --> C/C++ General --> Preprocessor Include Paths, Macros, etc. --> Providers tab
  - Check CDT GCC Built-in Compiler Settings [Shared]



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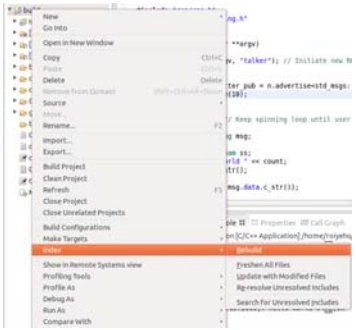
Fix Preprocessor Include Paths

- After that rebuild the C/C++ index by Right click on project -> Index -> Rebuild



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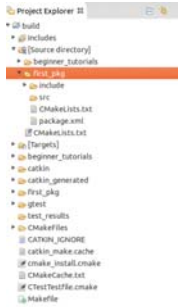
Project Structure

- Eclipse provides a link "Source directory" within the project so that you can edit the source code



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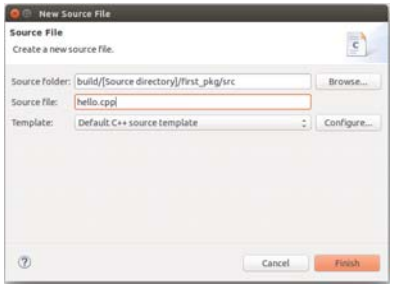
Add New Source File

- Right click on src and select New –> Source File, and create a file named hello.cpp



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Code Completion

- Use Eclipse standard shortcuts to get code completion (i.e., Ctrl+Space)

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Running the Node Inside Eclipse

- Click on: Project → build project
- Create a new launch configuration, by clicking on Run → Run configurations… → C/C++ Application (double click or click on New).
- Select the correct binary on the main tab (use the Browse… button)

  ~/catkin_ws/devel/lib/first_pkg/hello
- Make sure roscore is running in a terminal
- Click Run

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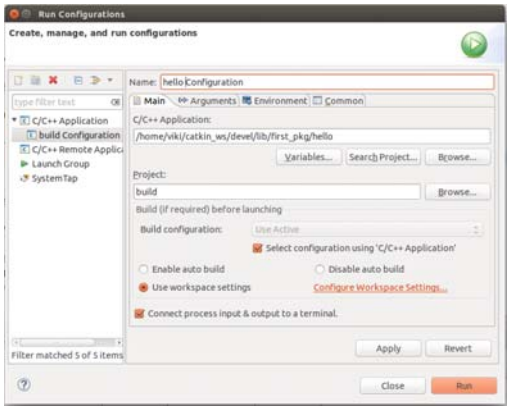
Running the Node Inside Eclipse



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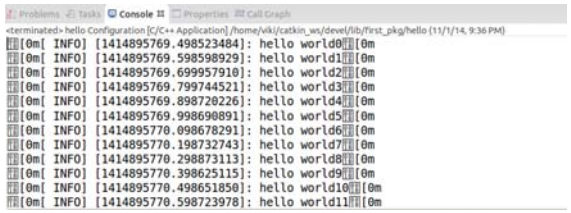
Running the Node Inside Eclipse



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Debugging

- To enable debugging, you should first execute the following command in catkin_ws/build:

```
$ cmake ../src -DCMAKE_BUILD_TYPE=Debug
```

- Restart Eclipse
- Then you will be able to use the standard debugging tools in Eclipse

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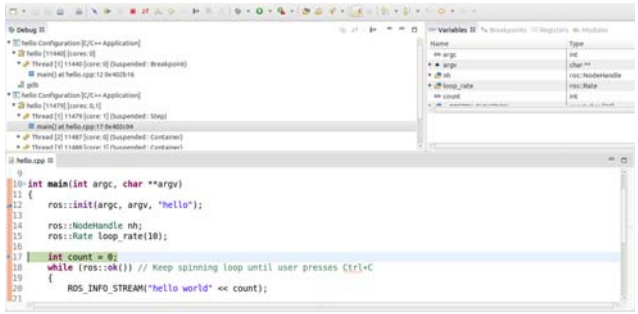
Debugging



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