Introduction to the Robot Operating System (ROS)

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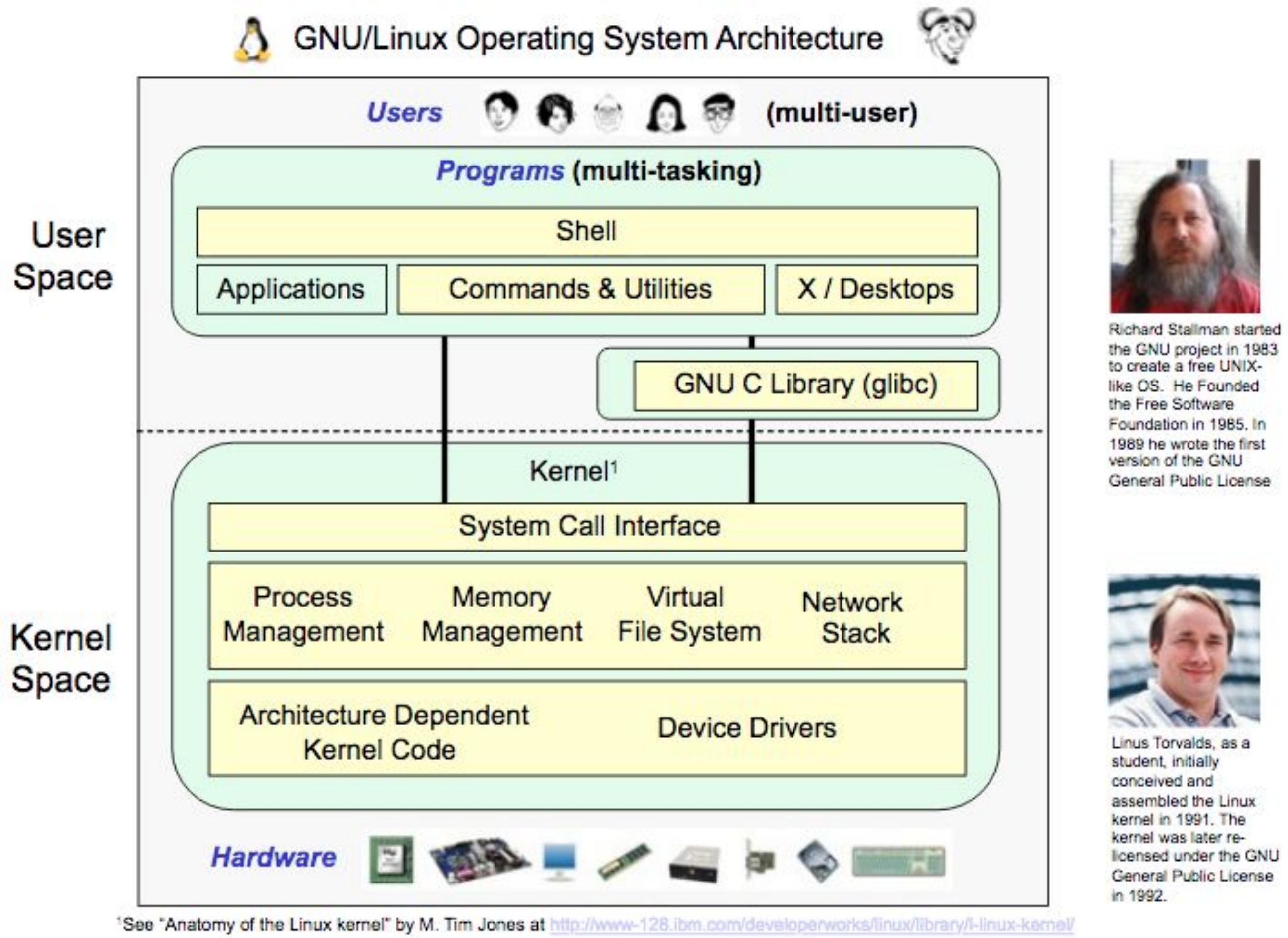
What is ROS?

- **ROS = Robot Operating System**
- Framework for robot software development providing operating system-like functionality
- Originated at Stanford Artificial Intelligence Lab, then further developed at Willow Garage
- Works quite well in Linux Ubuntu, but there are bindings to Java, C#, and can be tunneled via websockets
- Large user base; getting widespread use
- ROS users forum: http://answers.ros.org



GNU/Linux Operating System Architecture

User Space

Kernel Space

Users (multi-user)

Programs (multi-tasking)

Shell

Applications

Commands & Utilities

X / Desktops

GNU C Library (glibc)

Kernel[1]

System Call Interface

Process Management

Memory Management

Virtual File System

Network Stack

Architecture Dependent Kernel Code

Device Drivers

Hardware

Richard Stallman started the GNU project in 1983 to create a free UNIX-like OS. He Founded the Free Software Foundation in 1985. In 1989 he wrote the first version of the GNU General Public License

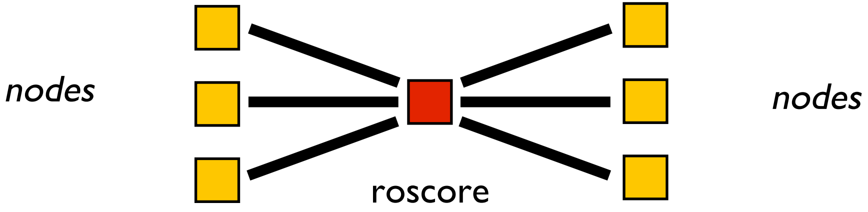
Linus Torvalds, as a student, initially conceived and assembled the Linux kernel in 1991. The kernel was later re-licensed under the GNU General Public License in 1992.

[1] See "Anatomy of the Linux kernel" by M. Tim Jones at http://www-128.ibm.com/developerworks/linux/library/l-linux-kernel/

[source: https://slideplayer.com/slide/7335359/]

Basic concept #1: Node

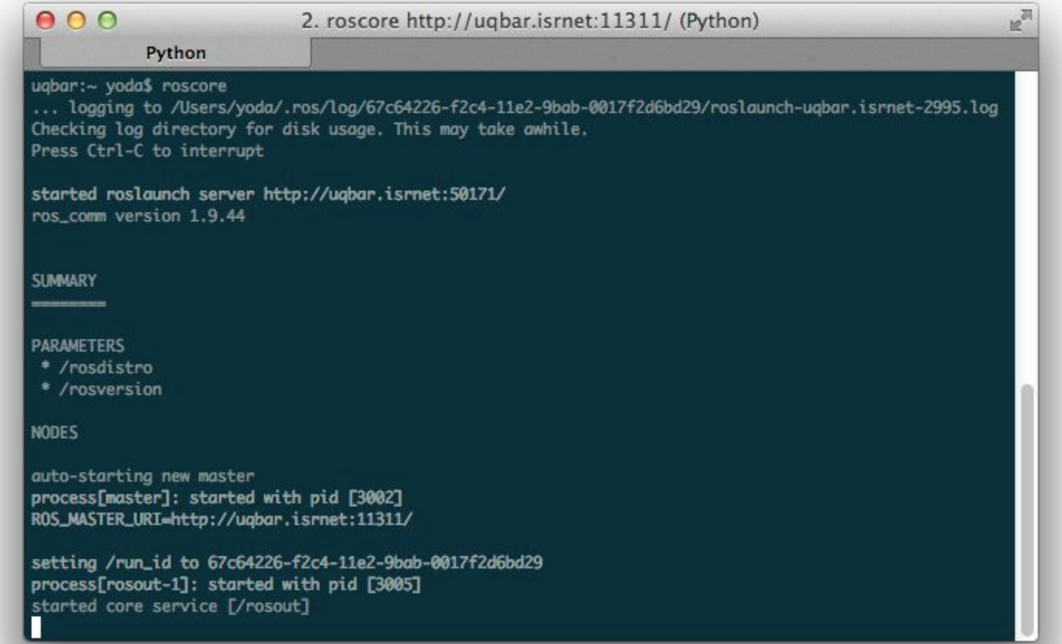
- Modularization in ROS is achieved by operating system processes
- **Node** = a process that uses ROS framework
- Nodes may reside in different machines transparently
- Nodes get to know one another via roscore



- roscore acts primarily as a “name server”, i.e., maps names to nodes
- Nodes use the roscore running in localhost by default overridden by the environment variable ROS_MASTER_URI

Basic concept #1: Node

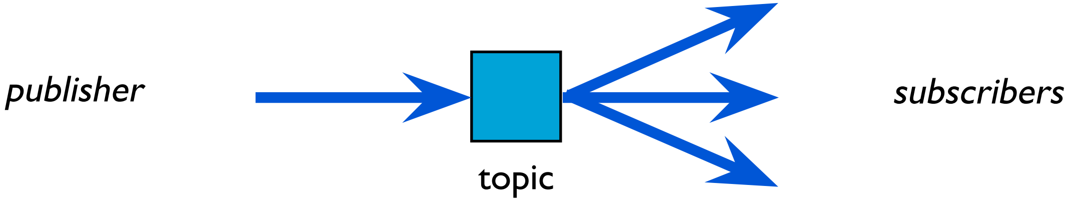
Demo: launching roscore



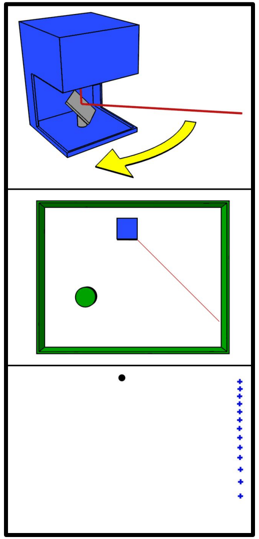
```
uqbar:~ yoda$ roscore
... logging to /Users/yoda/.ros/log/67c64226-f2c4-11e2-9bab-0017f2d6bd29/roslaunch-uqbar.isrnet-2995.log
Checking log directory for disk usage. This may take awhile.
Press Ctrl-C to interrupt

started roslaunch server http://uqbar.isrnet:50171/
ros_comm version 1.9.44


SUMMARY
========

PARAMETERS
 * /rosdistro
 * /rosversion

NODES

auto-starting new master
process[master]: started with pid [3002]
ROS_MASTER_URI=http://uqbar.isrnet:11311/

setting /run_id to 67c64226-f2c4-11e2-9bab-0017f2d6bd29
process[rosout-1]: started with pid [3005]
started core service [/rosout]
```

Basic concept #2: Topic

- **Topic** = mechanism to send messages among nodes
- Follows a publisher-subscriber design pattern

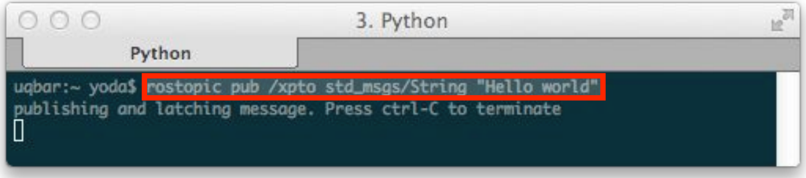


- **Publish** = to send a message to a topic
- **Subscribe** = get called whenever a message is published
- Published messages are broadcast to all Subscribers
- Example: LIDAR publishing scan data

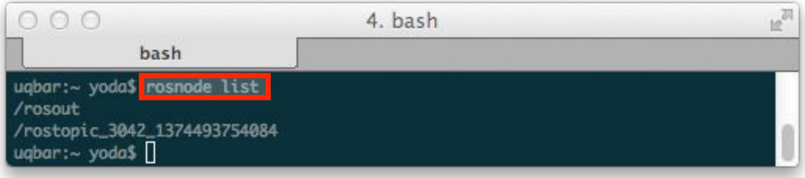


Basic concept #2: Topic

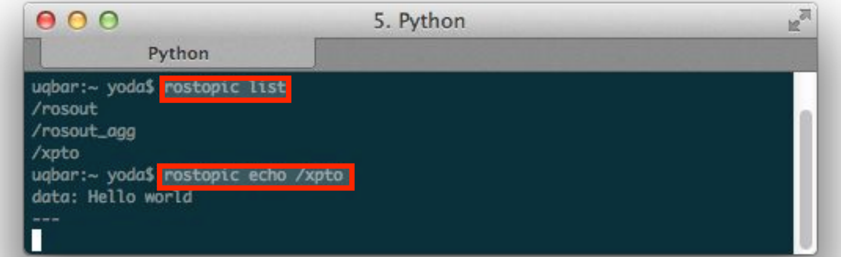
Demo: publishing an “Hello world” String to topic /xpto



```
uqbar:~ yoda$ rostopic pub /xpto std_msgs/String "Hello world"
publishing and latching message. Press ctrl-C to terminate
```



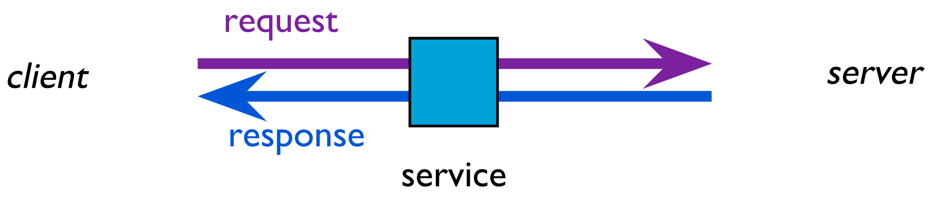
```
uqbar:~ yoda$ rosnode list
/rosout
/rostopic_3042_1374493754084
uqbar:~ yoda$
```



```
uqbar:~ yoda$ rostopic list
/rosout
/rosout_agg
/xpto
uqbar:~ yoda$ rostopic echo /xpto
data: Hello world
---
```

Basic concept #3: Service

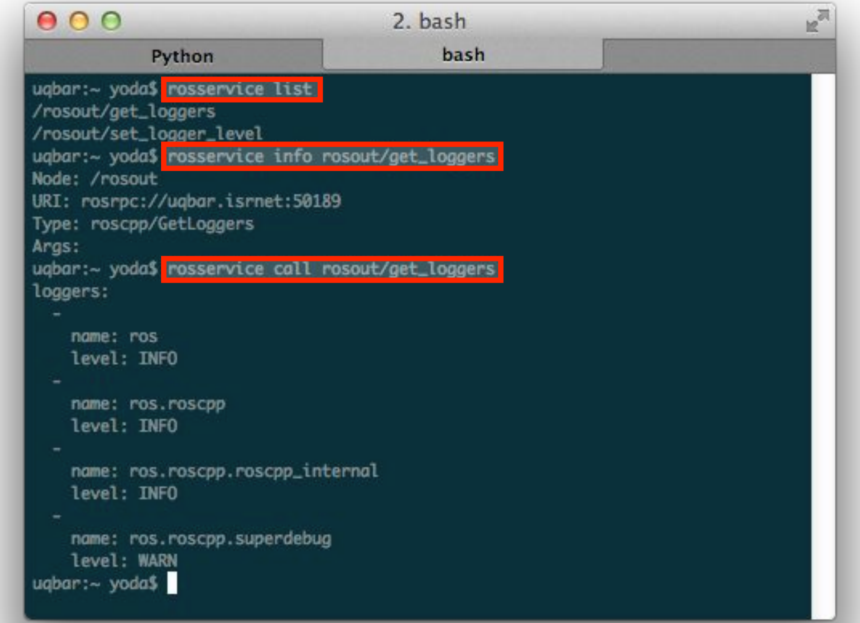
- **Service** = mechanism for a node to send a request to another node and receive a response from it in return
- Follows a request-response design pattern



- A service is called with a request structure, and in return, a response structure is returned
- Similar to a Remote Procedure Call (RPC)
- Example: reset location algorithm

Basic concept #3: Service

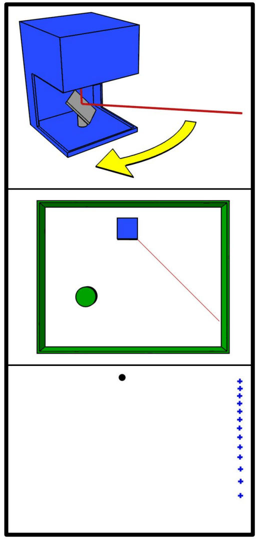
Demo: querying and calling a service



```
uqbar:~ yoda$ rosservice list
/rosout/get_loggers
/rosout/set_logger_level
uqbar:~ yoda$ rosservice info rosout/get_loggers
Node: /rosout
URI: rosrpc://uqbar.isrnet:50189
Type: roscpp/GetLoggers
Args:
uqbar:~ yoda$ rosservice call rosout/get_loggers
loggers:
  -
    name: ros
    level: INFO
  -
    name: ros.roscpp
    level: INFO
  -
    name: ros.roscpp.roscpp_internal
    level: INFO
  -
    name: ros.roscpp.superdebug
    level: WARN
uqbar:~ yoda$
```

Message types

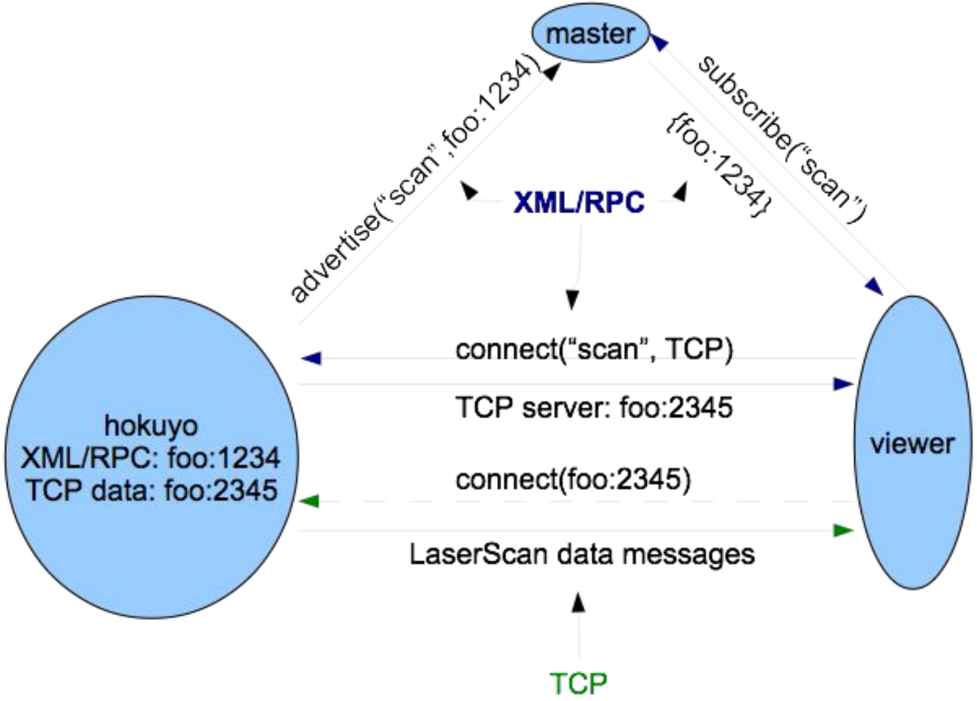
All messages (including service requests/responses) are defined in text files



Contents of sensor_msgs/msg/LaserScan.msg:

```
Header header           # timestamp in the header is the acquisition time of
                        # the first ray in the scan.
                        #
                        # in frame frame_id, angles are measured around
                        # the positive Z axis (counterclockwise, if Z is up)
                        # with zero angle being forward along the x axis

float32 angle_min       # start angle of the scan [rad]
float32 angle_max       # end angle of the scan [rad]
float32 angle_increment # angular distance between measurements [rad]

float32 time_increment  # time between measurements [seconds] - if your scanner
                        # is moving, this will be used in interpolating position
                        # of 3d points
float32 scan_time       # time between scans [seconds]

float32 range_min       # minimum range value [m]
float32 range_max       # maximum range value [m]

float32[] ranges        # range data [m] (Note: values < range_min or > range_max should be discarded)
float32[] intensities   # intensity data [device-specific units].  If your
                        # device does not provide intensities, please leave
                        # the array empty.
```

Topic internals



Development

- Two major languages are supported:
  - C++
  - Python
- ROS provides a portable build system (catkin, replacing rosbuild)
- **Package** = encapsulation of sources, data files, and building files
- The code reuse units in ROS are packages
- A large variety of packages can be found on the web
- examples: sensor drivers, simulators, SLAM, image processing, etc.

Command line tools

rosnode is a command-line tool for printing information about ROS Nodes.

```
Commands:
     rosnode ping    test connectivity to node
     rosnode list    list active nodes
     rosnode info    print information about node
     rosnode machine list nodes running on a particular machine  or list machines
     rosnode kill    kill a running node
     rosnode cleanup purge registration information of unreachable nodes
```

Command line tools

rostopic is a command-line tool for printing information about ROS Topics.

```
Commands:

        rostopic bw     display bandwidth used by topic

        rostopic echo   print messages to screen

        rostopic find   find topics by type

        rostopic hz     display publishing rate of topic

        rostopic info   print information about active topic

        rostopic list   list active topics

        rostopic pub    publish data to topic

        rostopic type   print topic type
```

Command line tools

rosservice is a command-line tool for printing information about ROS Services.

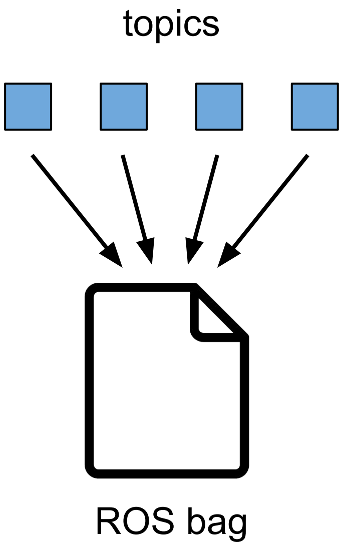
```
Commands:
        rosservice args print service arguments
        rosservice call call the service with the provided args
        rosservice find find services by service type
        rosservice info print information about service
        rosservice list list active services
        rosservice type print service type
        rosservice uri  print service ROSRPC uri
```

Command line tools

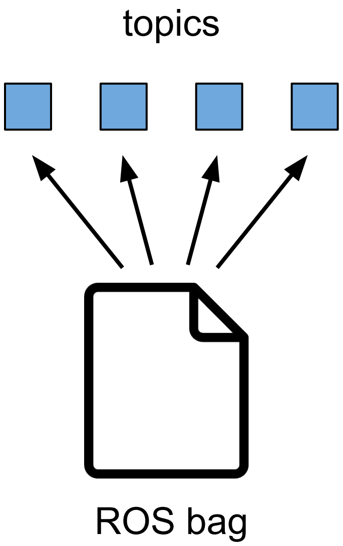
rosbag is a command-line tool for manipulating log files (a.k.a. bags)

```
Available subcommands:
   check
   compress
   decompress
   filter
   fix
   help
   info
   play
   record
   reindex
```

rosbag record ...



rosbag play ...



Useful ROS facilities

- **Parameters**: repository of parameters (stored in the roscore)
  - Loading from files (formatted in YAML)
  - Dynamic update
  - Command-line utility: rosparam

params.yaml

```
course_name: “SAut”

robot1:
  name: "Calvin"
  height: 0.5

robot2:
  name: "Hobbes"
  height: 1.0
```

```
$ rosparam load params.yaml
$ rosparam list
/course_name
/robot1/height
/robot1/name
/robot2/height
/robot2/name
[...]
$ rosparam get course_name
SAut
$ rosparam get /robot2/name
Hobbes
```

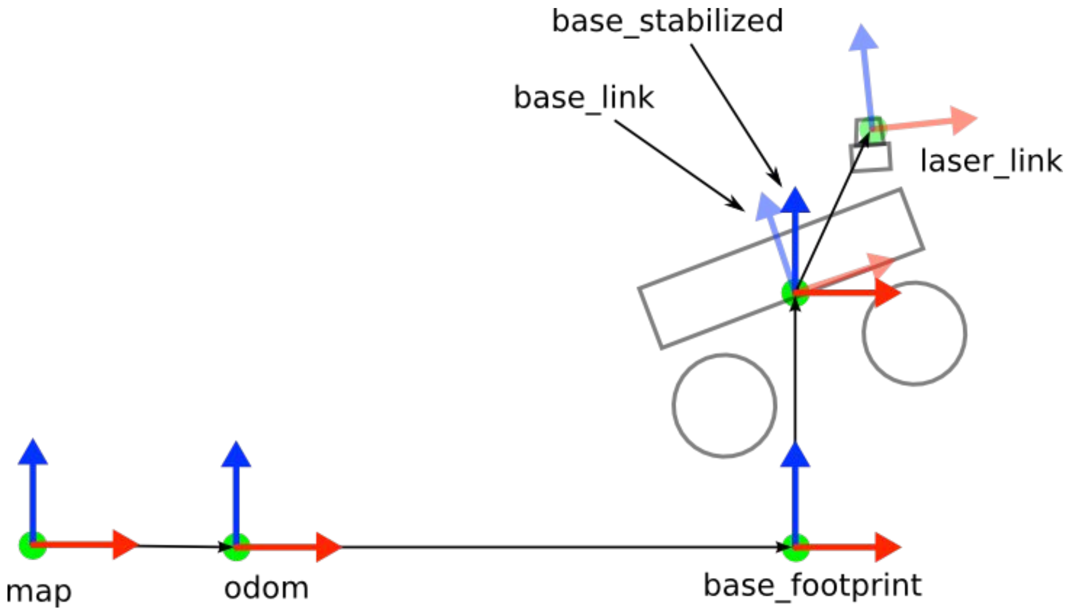
Useful ROS facilities

- **Launch files:** XML file specifying the launch of multiple nodes
  - Loading of parameters
  - Remapping topic names, parameters, etc.
  - Multiple machine support
  - Command-line utility: roslaunch

```
<?xml version="1.0"?>
<launch>
      <arg name="map" default="$(find scout_maps)/isr8-v05cr.yaml"/>
      <param name="map" type="string" value="$(arg map)"/>
      <rosparam file="$(find scout_config)/mbot.yaml"/>
      <include file="amcl.launch"/>
      <node name="navigation" pkg="scout_navigation" type="navigator">
            <param name="~guidance_method" type="string" value="fmm"/>
            <param name="~platform_mode" type="string" value="omni"/>
      </node>
</launch>
```

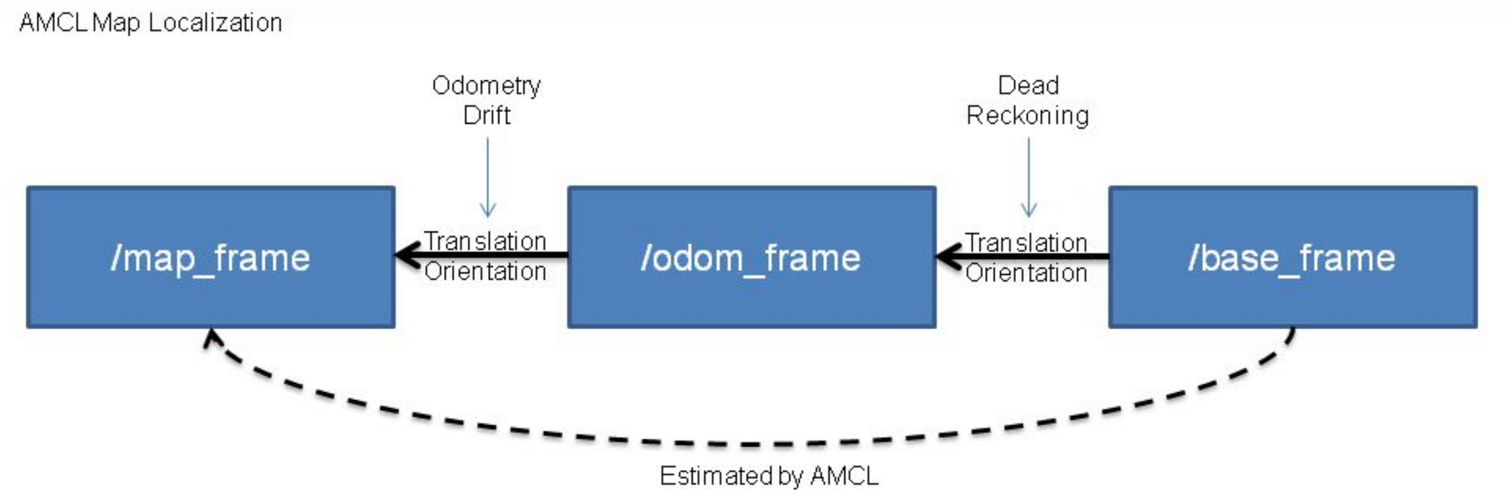
Useful ROS facilities

- **TF** framework: represents geometric transformations in 3D, position and orientation (6-DoF)



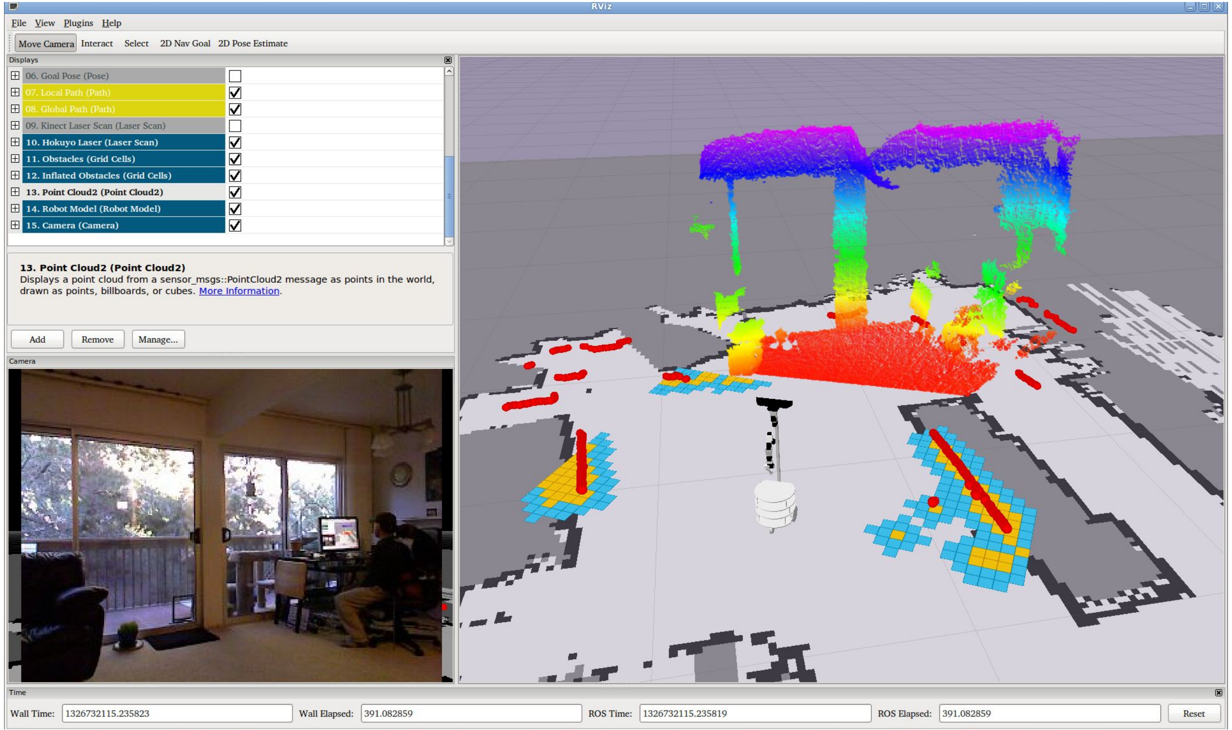
Useful ROS facilities

- **TF** framework: *de facto* standard frame assignment:



Useful ROS facilities

- **RVIZ:** visualisation framework



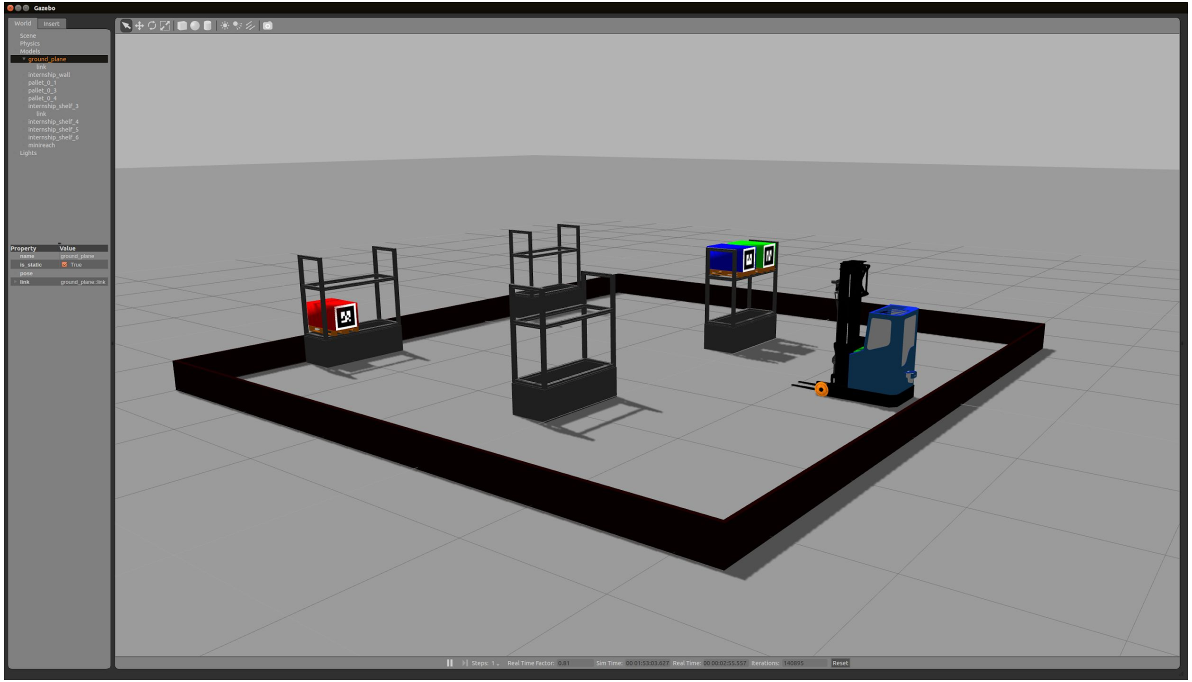
- ⊞ 06. Goal Pose (Pose) □
- ⊞ 07. Local Path (Path) ☑
- ⊞ 08. Global Path (Path) ☑
- ⊞ 09. Kinect Laser Scan (Laser Scan) □
- ⊞ 10. Hokuyo Laser (Laser Scan) ☑
- ⊞ 11. Obstacles (Grid Cells) ☑
- ⊞ 12. Inflated Obstacles (Grid Cells) ☑
- ⊞ 13. Point Cloud2 (Point Cloud2) ☑
- ⊞ 14. Robot Model (Robot Model) ☑
- ⊞ 15. Camera (Camera) ☑

13. Point Cloud2 (Point Cloud2)
Displays a point cloud from a sensor_msgs::PointCloud2 message as points in the world, drawn as points, billboards, or cubes. More Information.

Wall Time: 1326732115.235823 Wall Elapsed: 391.082859 ROS Time: 1326732115.235819 ROS Elapsed: 391.082859

Useful ROS facilities

- **Gazebo:** physics simulation framework

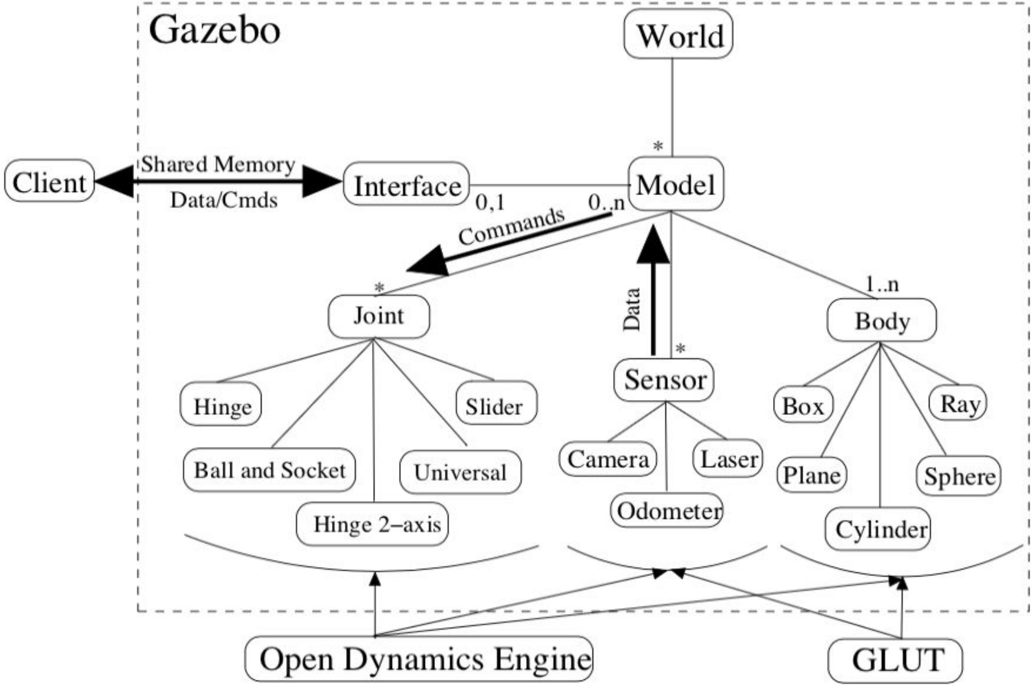


Property	Value
name	ground_plane
is_static	☑ True
pose	
link	ground_plane::link

Steps: 1 Real Time Factor: 0.81 Sim Time: 00 01:53:03.627 Real Time: 00 00:02:55.557 Iterations: 140895

Useful ROS facilities

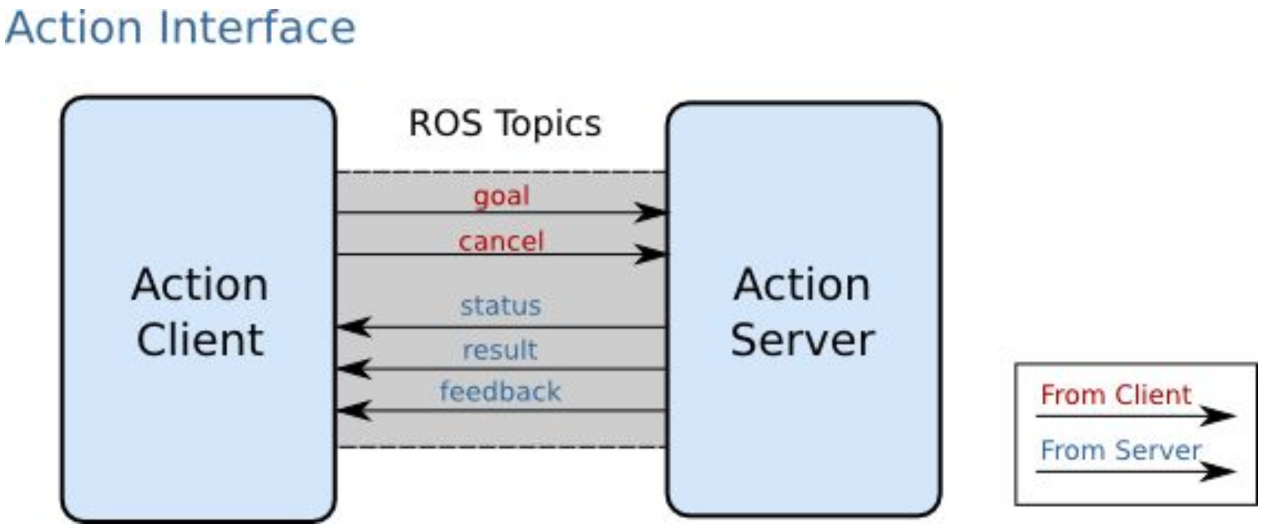
- **Gazebo**: physics simulation framework



Koenig, N., & Howard, A. (2004). Design and use paradigms for gazebo, an open-source multi-robot simulator. IROS 2004. IEEE.

Useful ROS facilities

- **Actionlib** framework: state-full scheme to manage action execution

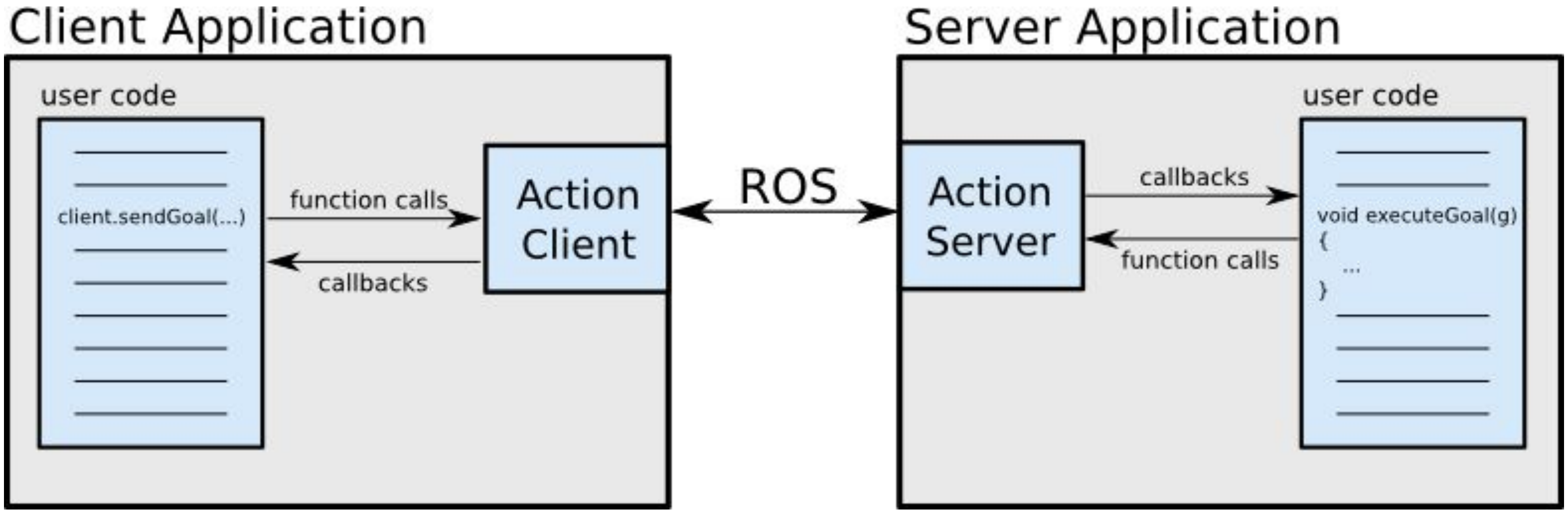


Calls for start/stop action

Performs the action

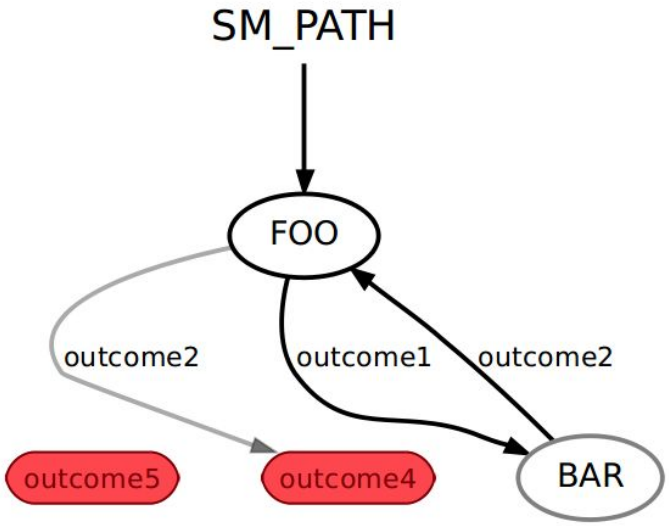
Useful ROS facilities

- **Actionlib** framework: state-full scheme to manage action execution



Useful ROS facilities

- **SMACH** framework: FSM executor fully integrated into ROS
  Ingredients: states, transitions, and outcomes



Useful ROS facilities

- **SMACH** framework:
  - Types of states:
    `MonitorState` -- subscribes to topic, waits while condition True
    `ConditionState` -- polls a callback function, waits until True
    `SimpleActionState` -- calls actionlib action
    and can be a container
  - Types of containers:
    `StateMachine` -- finite state machine
    `Concurrence` -- all states run in parallel (split/join logic)
    `Sequence` -- StateMachine with linear sequence of states

Useful ROS facilities

- Other off-the-shelf packages:
  - **Gmapping**: creates occgrid maps from laser data
  - **AMCL**: localizes on occgrid maps using laser data
  - **Move_base**: path planning and guidance with obstacle avoidance using laser data
  - **MoveIt**: trajectory planner for robotic arms
  - **Octomap**: creates 3D occupancy maps using RGB-D
  - **ROSPlan**: integrates classical planner into ROS