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EUROPEAN ROBOTICS WEEK
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Short Course on ROS Programming 2020
Part 1

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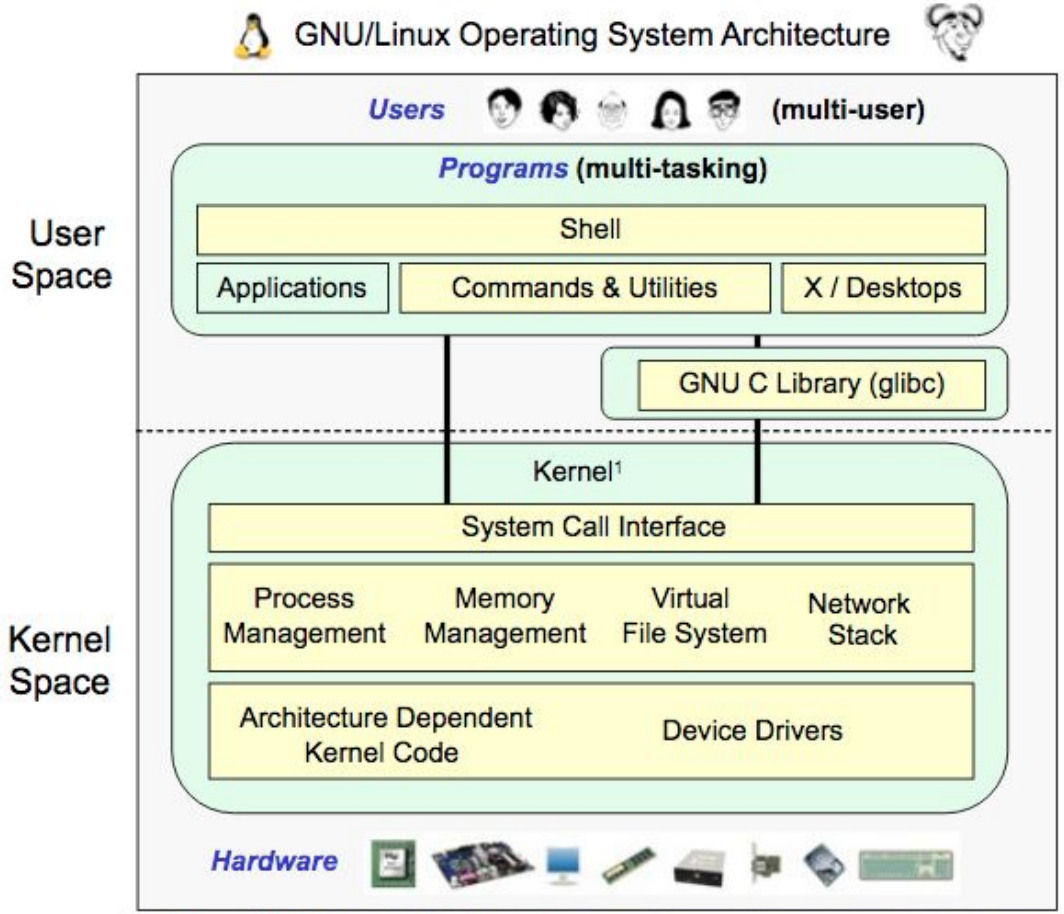
What is ROS?

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



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

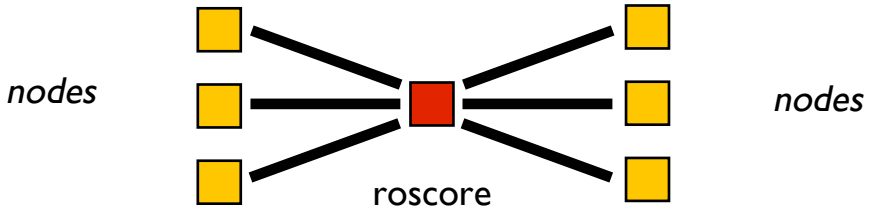
Richard Stallman started the GNU project in 1983 to create a free UNIX-like OS. He Founded the Free Software Foundation in 1985. In 1989 he wrote the first version of the GNU General Public License

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.

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

Basic concept #1: Node

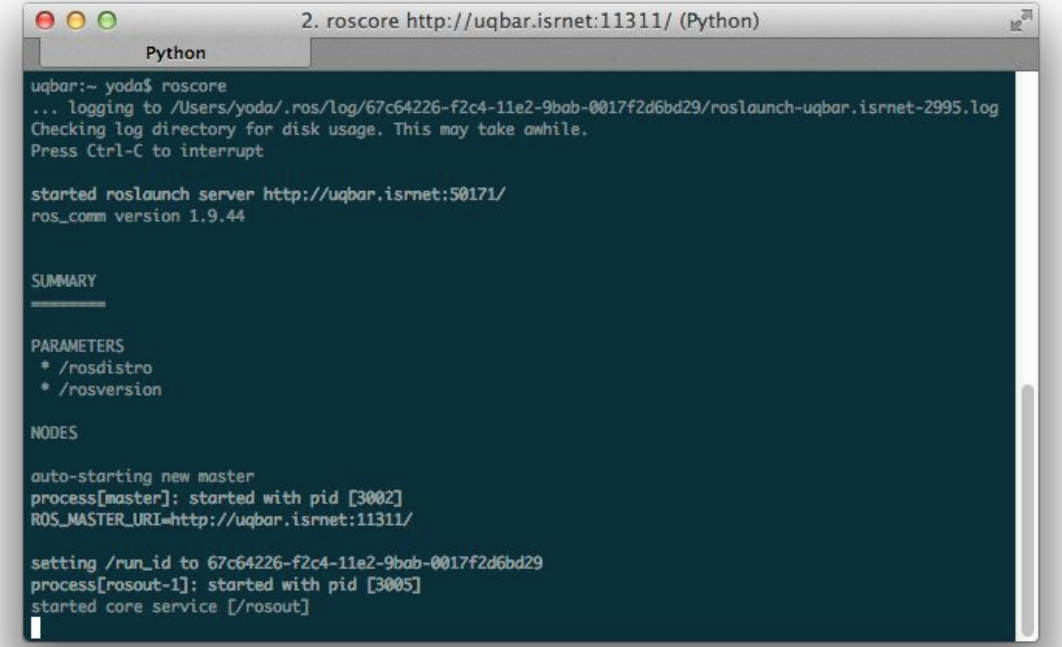
- Modularization in ROS is achieved by operating system processes
- **Node** = a process that uses ROS framework
- Nodes may reside in different machines transparently
- Nodes get to know one another via roscore



- 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

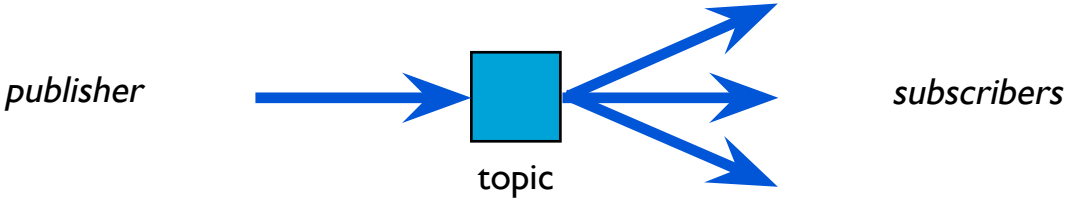
Basic concept #1: Node

Demo: launching roscore

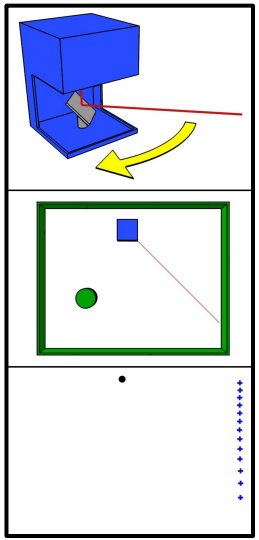


Basic concept #2: Topic

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

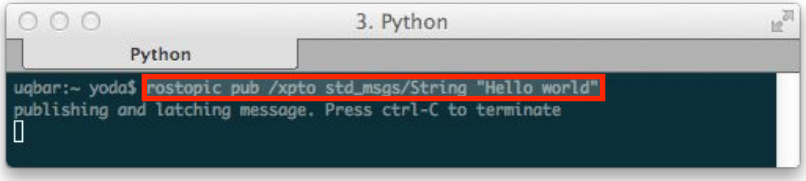


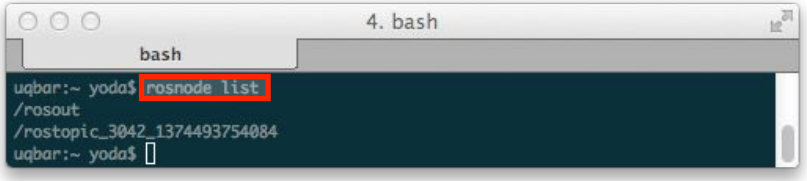
- **Publish** = to send a message to a topic
- **Subscribe** = get called whenever a message is published
- Published messages are broadcast to all Subscribers
- Example: LIDAR publishing scan data

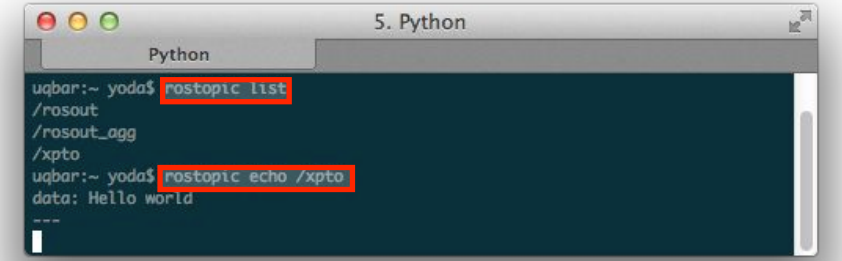


Basic concept #2: Topic

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

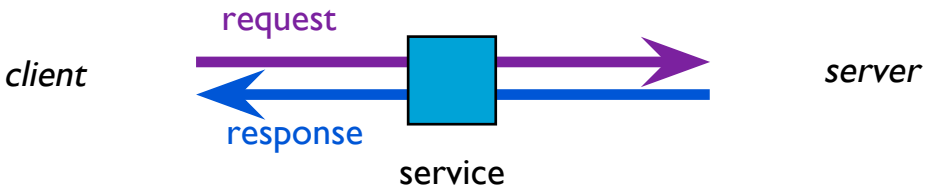






Basic concept #3: Service

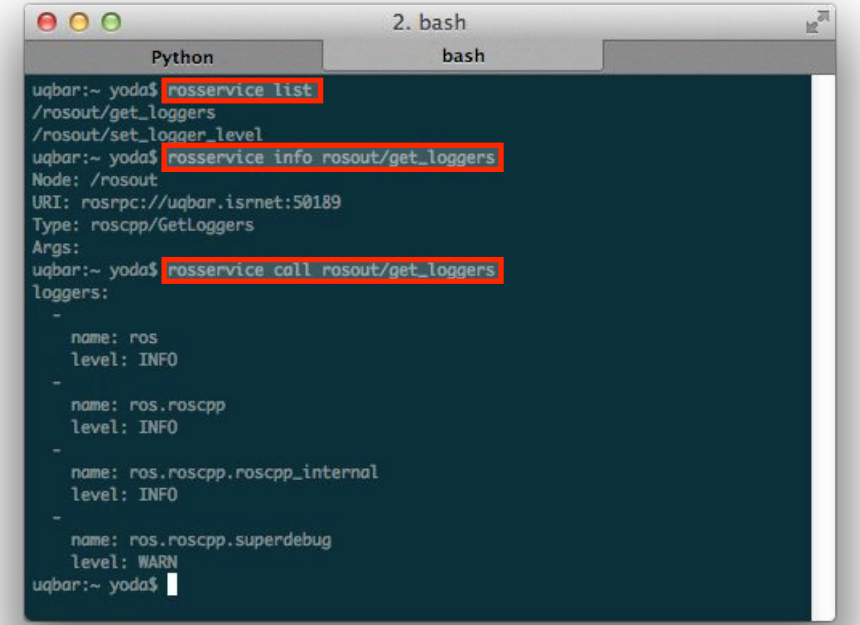
- **Service** = mechanism for a node to send a request to another node and receive a response from it in return
- Follows a request-response design pattern



- 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

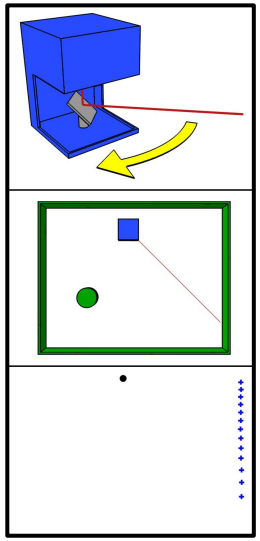
Basic concept #3: Service

Demo: querying and calling a service



Message types

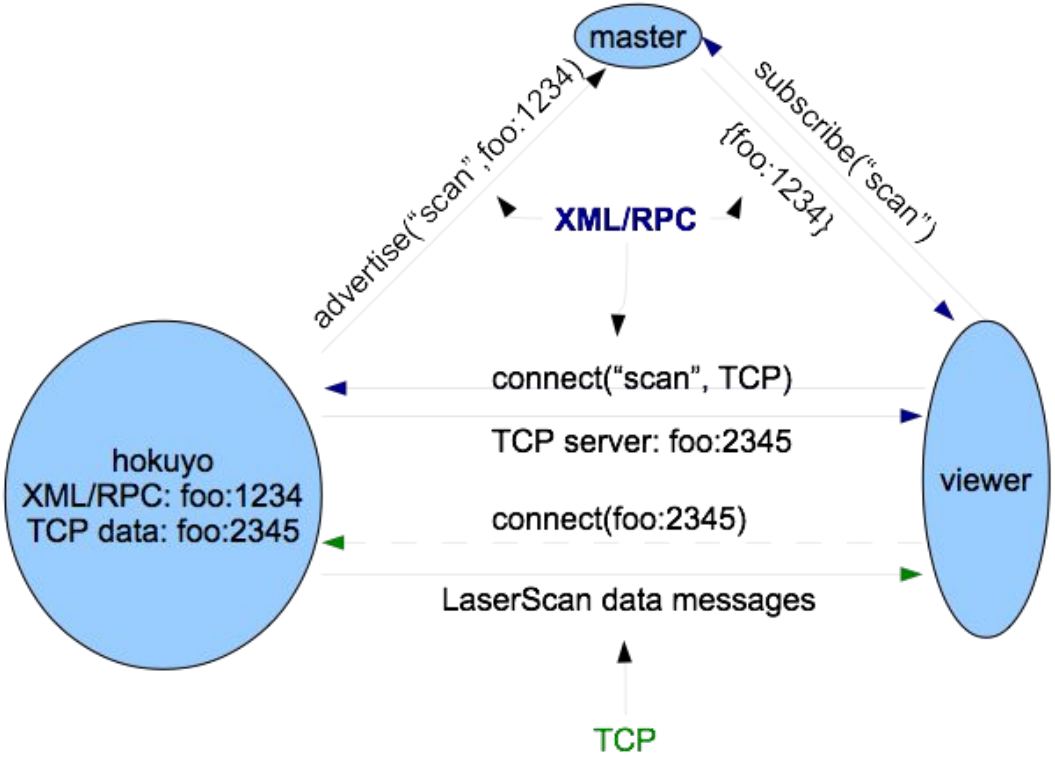
All messages (including service requests/responses) are defined in text files



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



Note: UDP transport is also supported.

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.

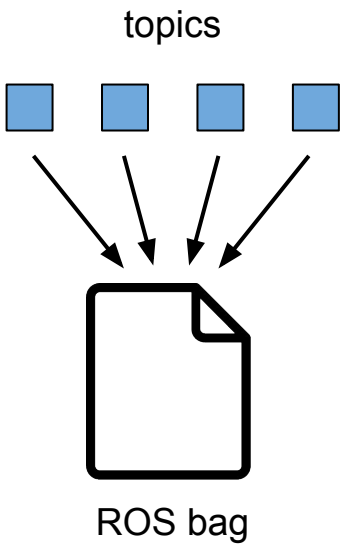
```
Commands:
        rosservice args print service arguments
        rosservice call call the service with the provided args
        rosservice find find services by service type
        rosservice info print information about service
        rosservice list list active services
        rosservice type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

Command line tools

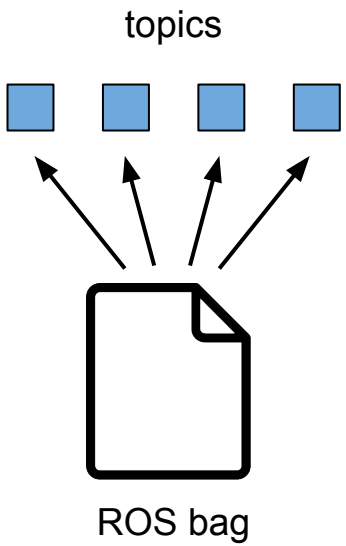
rosbag is a command-line tool for manipulating log files (a.k.a. bags)

```
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
```

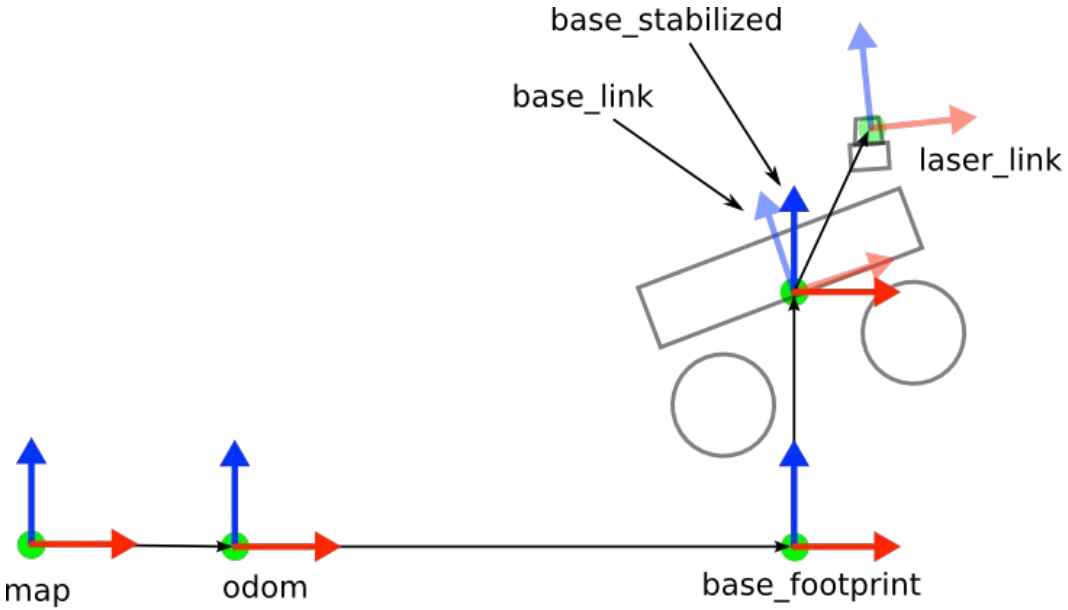
Useful ROS facilities

- **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>
```

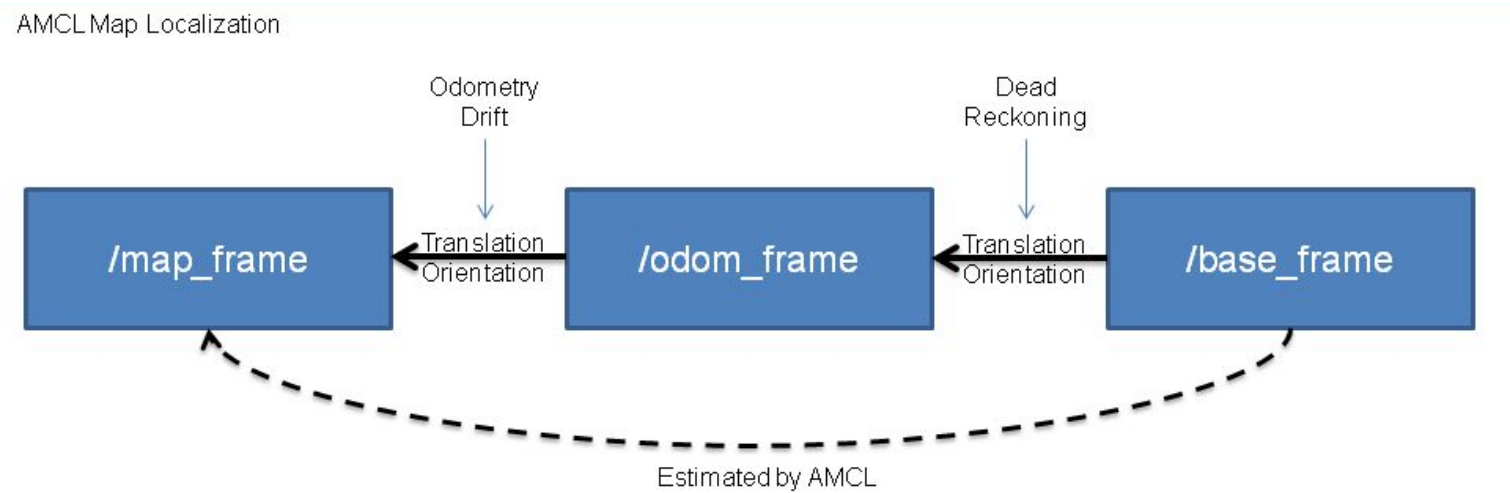
Useful ROS facilities

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



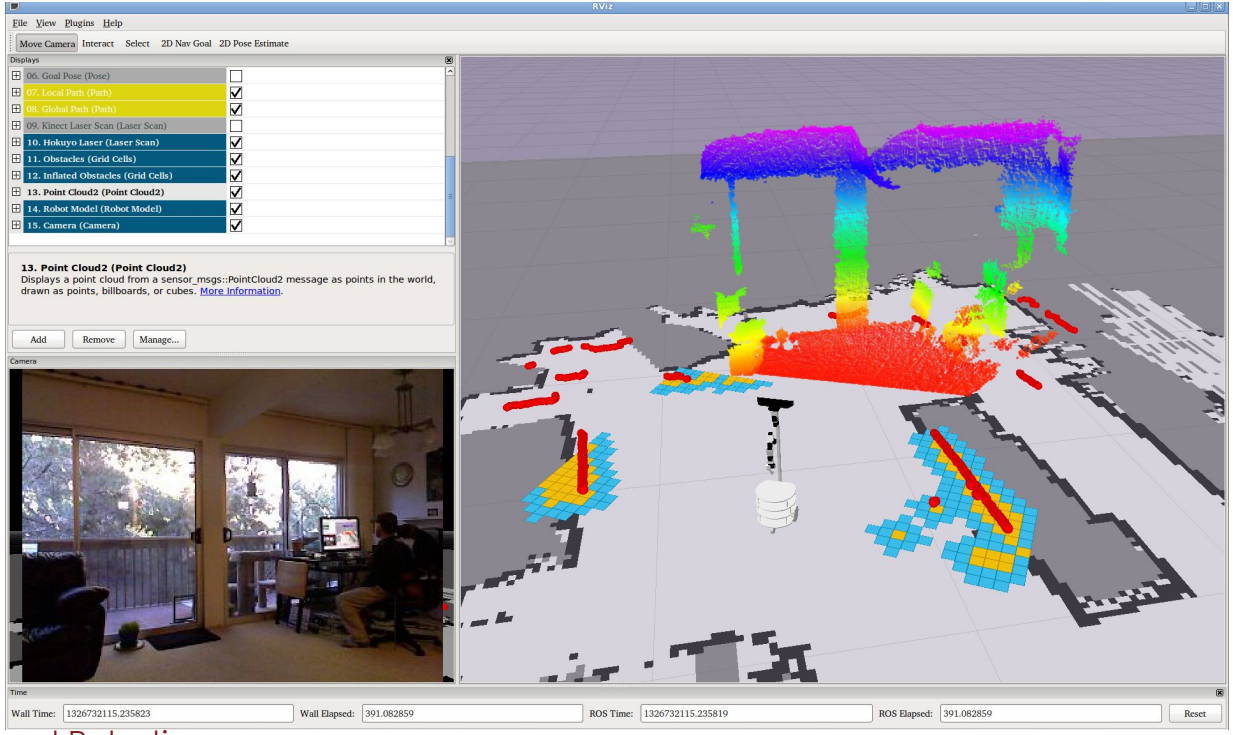
Useful ROS facilities

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



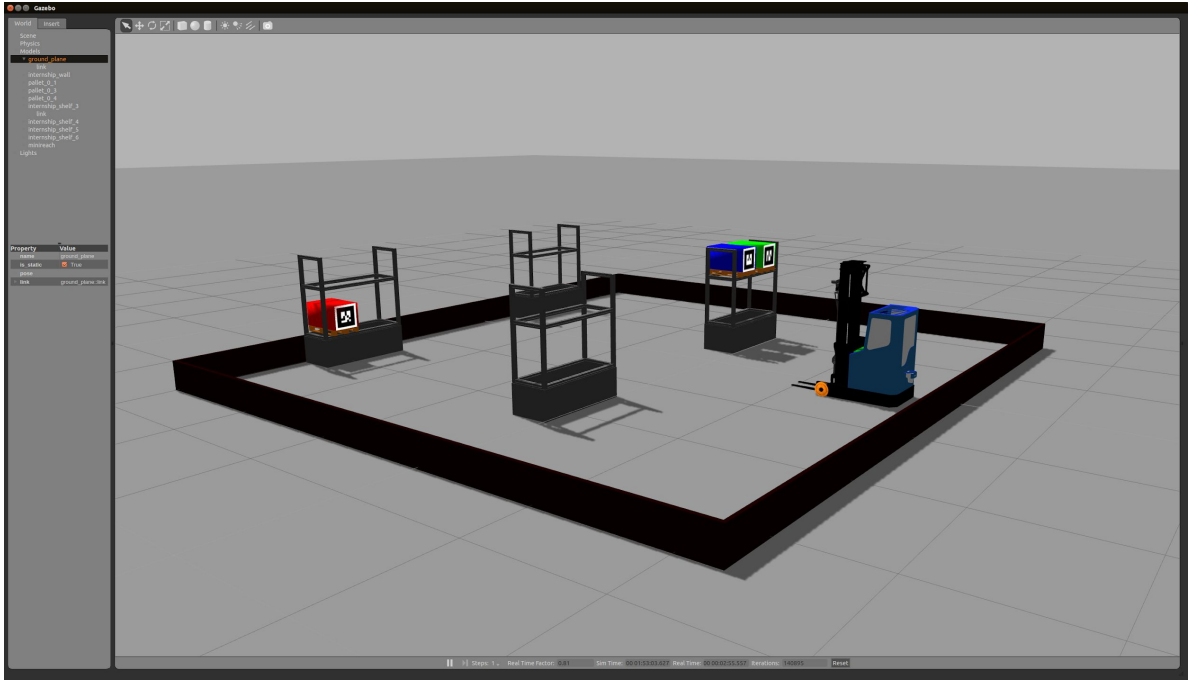
Useful ROS facilities

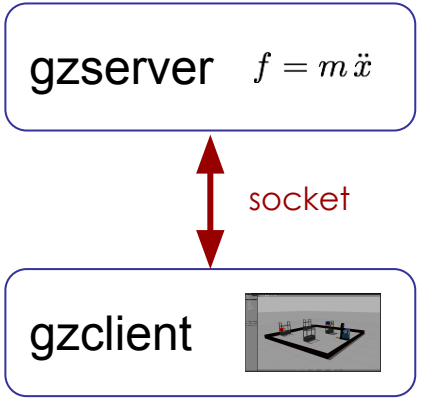
- **RVIZ**: visualisation framework



Useful ROS facilities

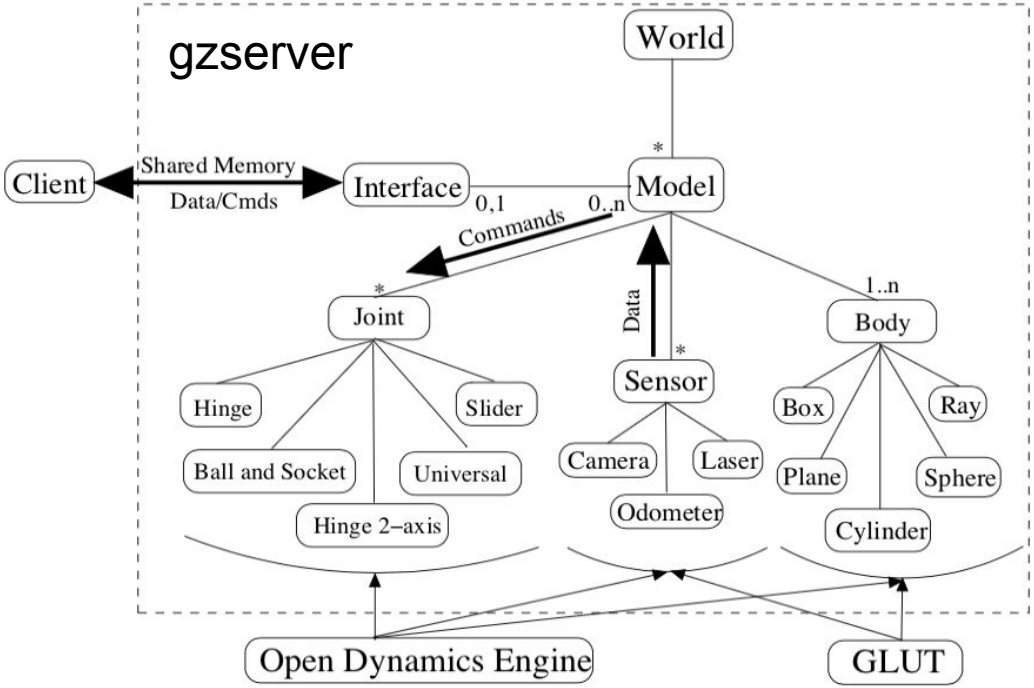
- **Gazebo**: physics simulation framework





Useful ROS facilities

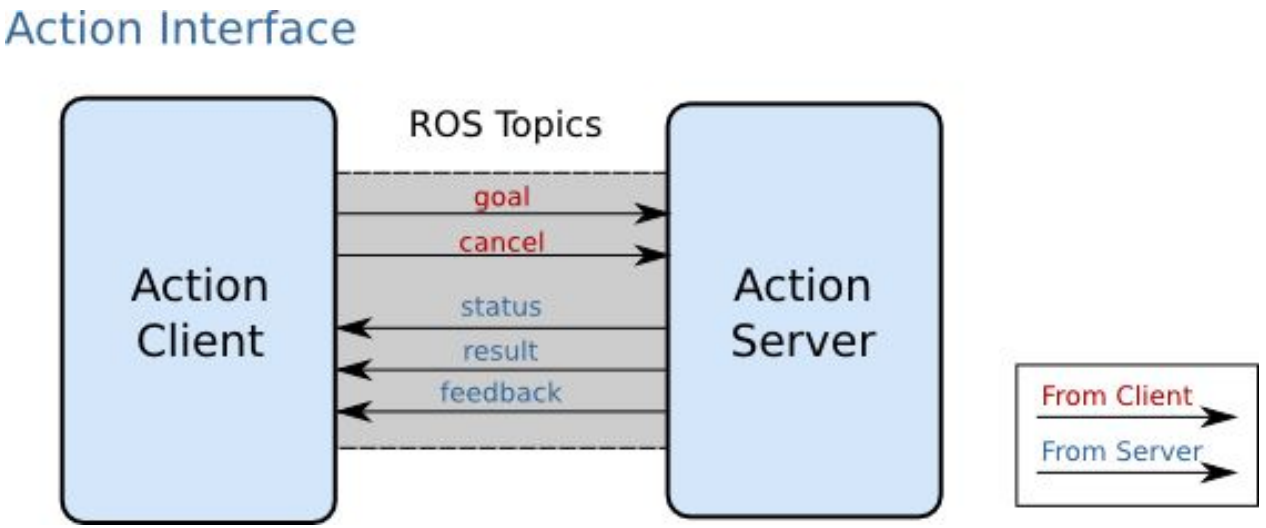
- **Gazebo**: physics simulation framework



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

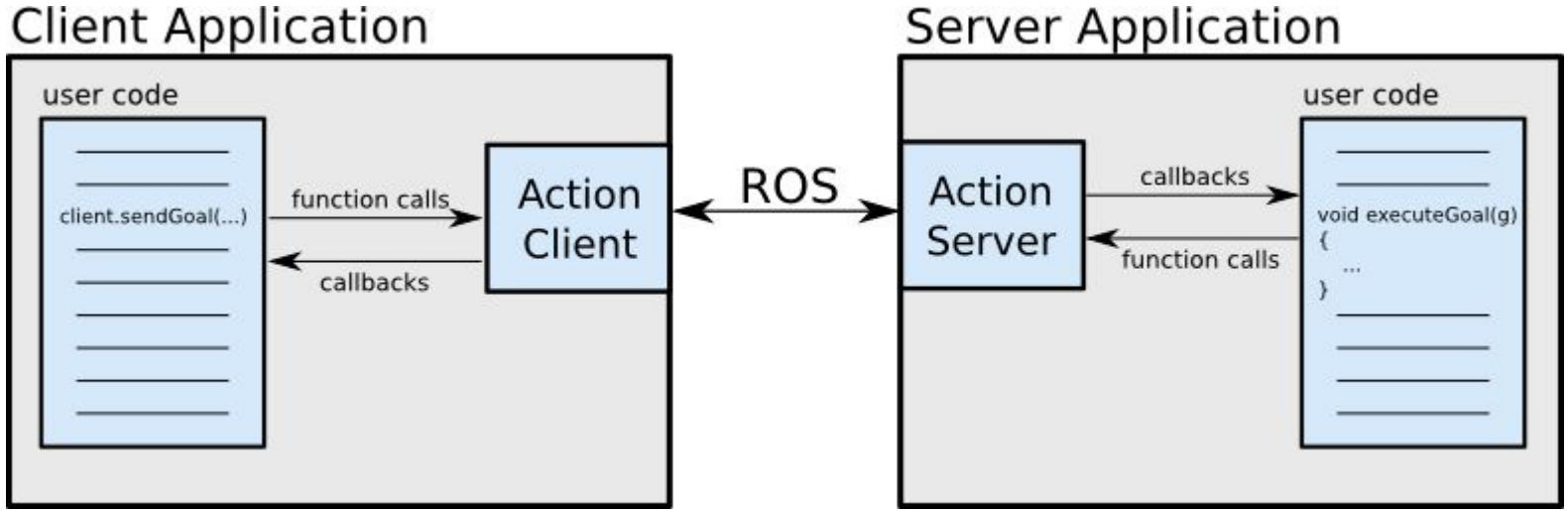
Useful ROS facilities

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



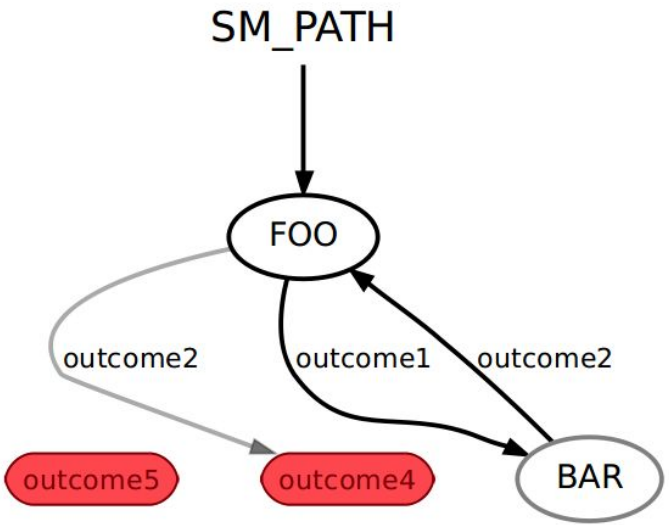
Useful ROS facilities

- **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

- More off-the-shelf packages:
  - **Gmapping**: creates occgrid maps from laser data
  - **Cartographer**: creates maps in 2D or 3D
  - **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
  - ...