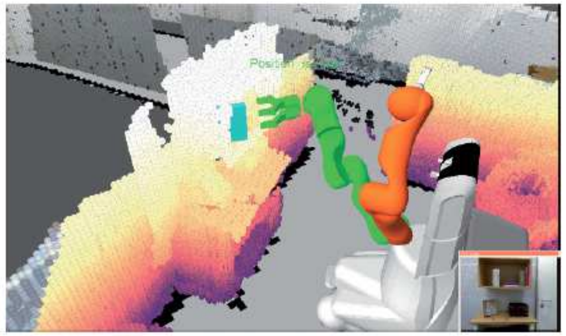
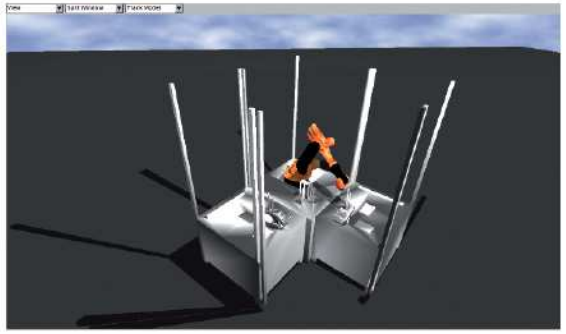
ROS INTRODUCTION

Dipl.-Ing. Florian Weißhardt, Fraunhofer IPA

Technology Seminar – ROS in Industrial Applications

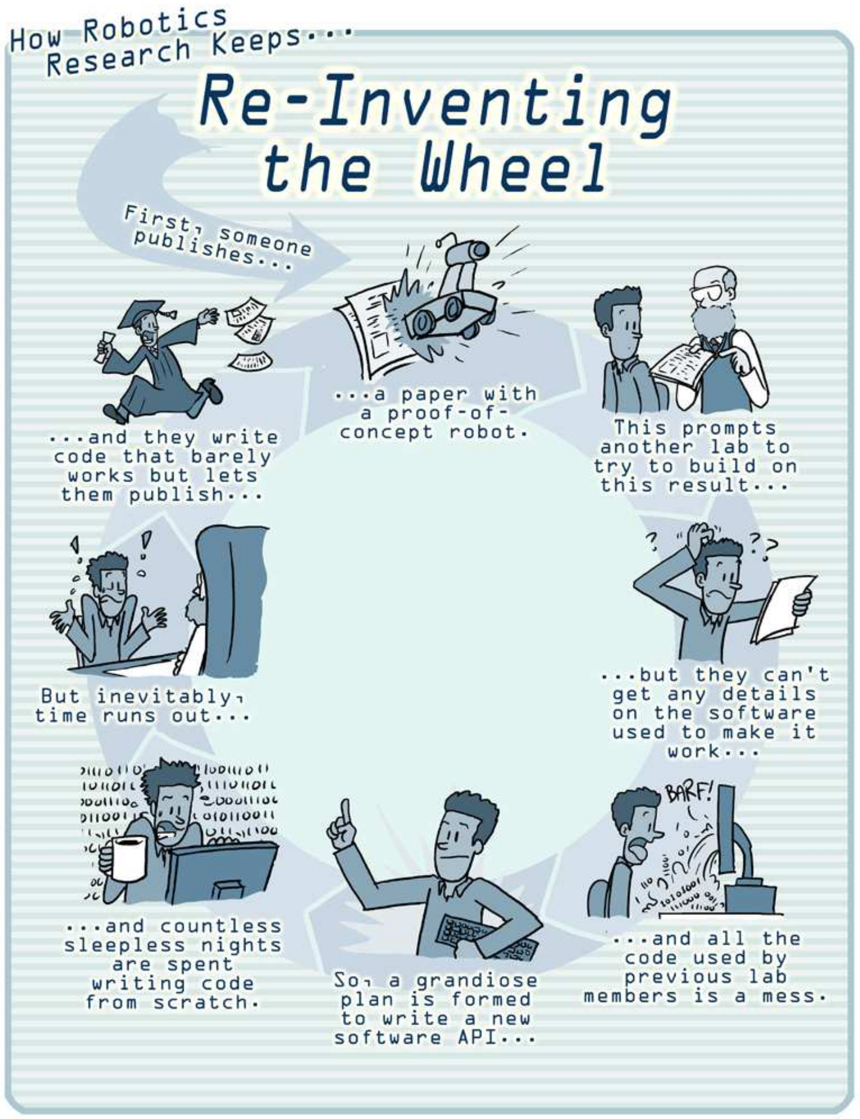




Research in robotics

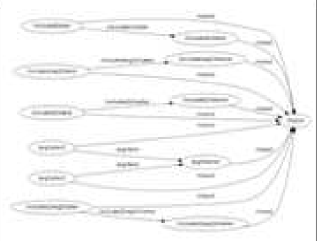
- Reinvention of the Wheel
- Little Commonality
- Short Lifespan
- Inability to Compare Results

→ ROS addresses these

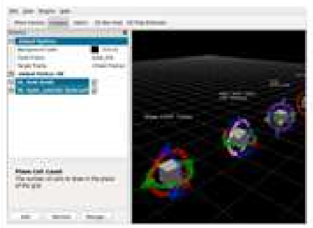

How Robotics Research Keeps...
Re-Inventing the Wheel
First, someone publishes...
...a paper with a proof-of-concept robot.
This prompts another lab to try to build on this result...
...but they can't get any details on the software used to make it work...
BARF!
...and all the code used by previous lab members is a mess.
So, a grandiose plan is formed to write a new software API...
...and countless sleepless nights are spent writing code from scratch.
But inevitably, time runs out...
...and they write code that barely works but lets them publish...

ROS – Robot Operating System

- ROS = **R**obot **O**perating **S**ystem
- „ROS is an open-source, meta-operating system for your robot." [ROS-wiki]
- ROS is a "robot framework" [ROS-wiki]


Plumbing

+


Tools

+

Capabilities

+

Ecosystem

www.ros.org/wiki/ROS/Introduction

ROS – Video

- 5 years of ROS

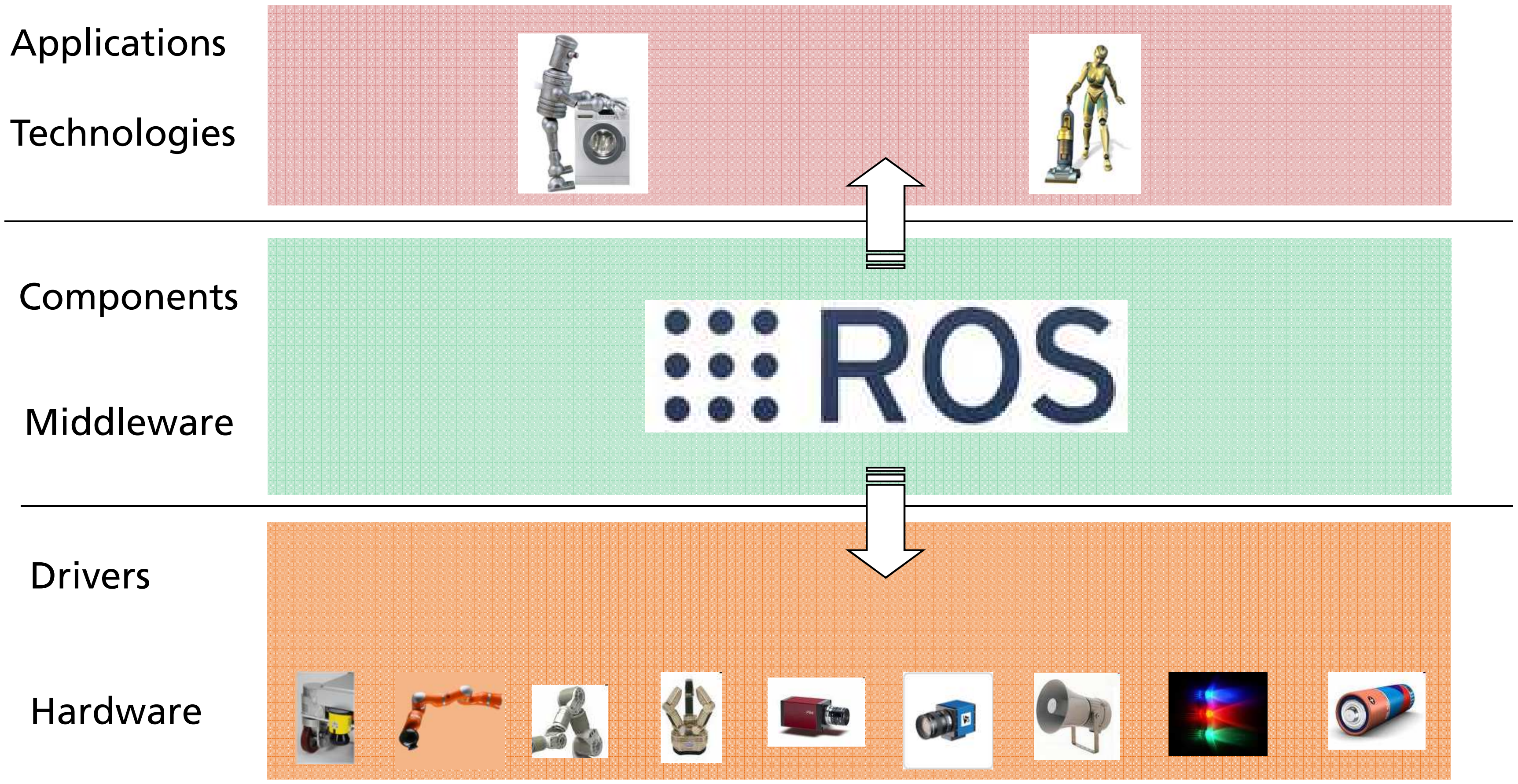
ROS

http://youtu.be/PGaXiLZD2KQ

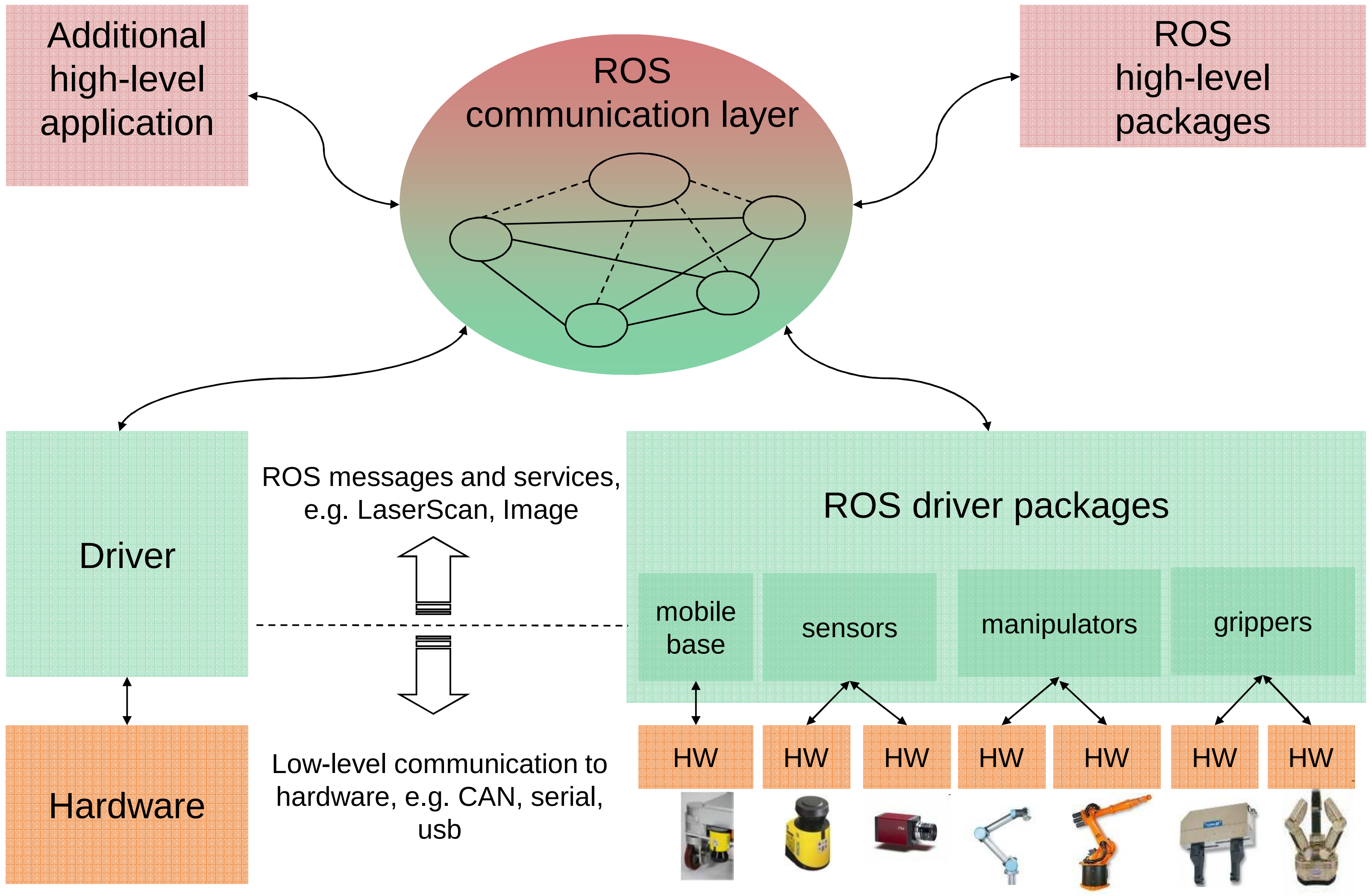
ROS – Robot Operating System

- What is ROS?
- Provides
  - Hardware abstraction
  - Low-level device control
  - Communication layer with message-passing between processes
  - Recursive package management and build system
  - Runs primarily on Linux but is intended to be cross-platform compatible to MAC OS X and Windows
- Content
  - ROS core build and runtime system
  - ROS packages, a collection of robotic algorithms

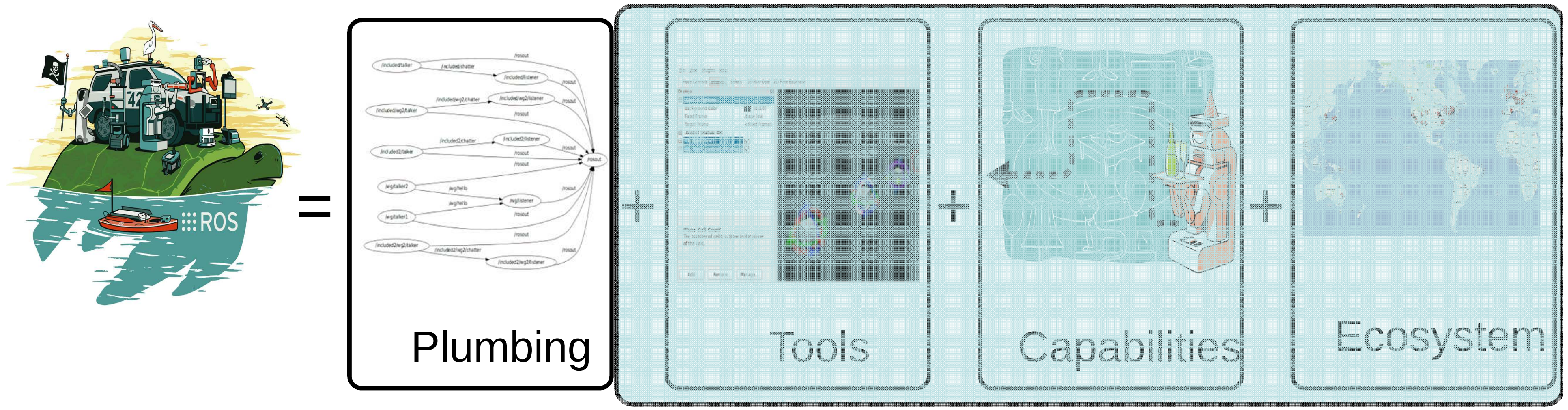
Layered architecture



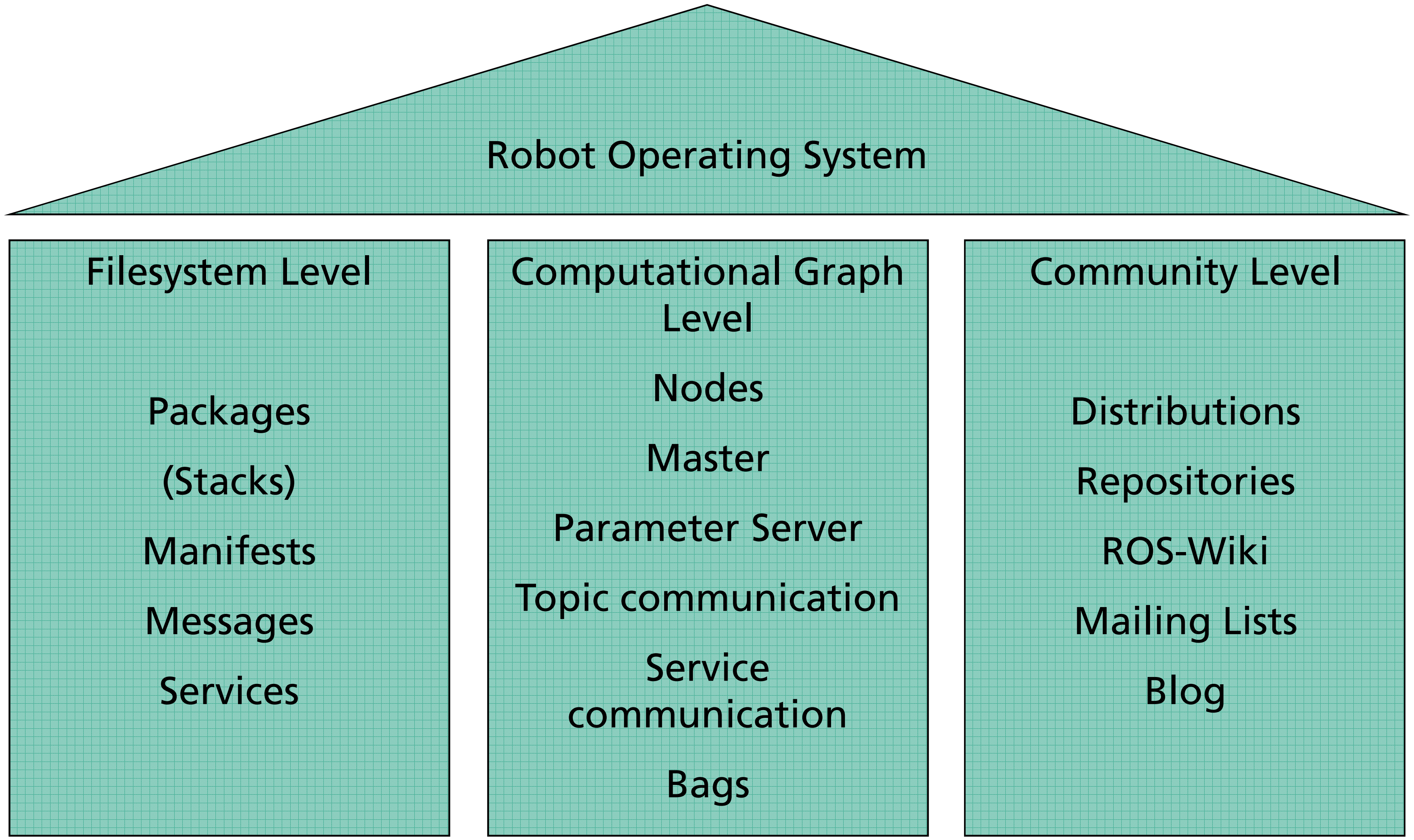
Control Structure


Additional high-level application
ROS communication layer
ROS high-level packages
Driver
ROS messages and services, e.g. LaserScan, Image
ROS driver packages
mobile base
sensors
manipulators
grippers
Hardware
Low-level communication to hardware, e.g. CAN, serial, usb
HW
HW
HW
HW
HW
HW
HW

Computational Graph/Plumbing



Three levels of ROS concepts



→ http://ros.org/wiki/ROS/Concepts

Filesystem Level

- Packages
  - Main unit for organizing software
  - Typically one functionality, e.g. localisation or path planning
  - Contains: runtime processes (nodes), libraries, datasets, configuration files, …
- Meta-packages (former stacks)
  - Collection of packages
  - Aggregate functionality, e.g. navigation stack
  - Releases and versioning
- Package- Manifests (*.xml)
  - Provide Metadata about a package/meta-package, e.g. license information and dependencies to other packages/meta-packages

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

Filesystem Level

- Messages types (*.msg)
  - Message descriptions, define data structures used for message communication
  - Language independent

TargetPoses.msg

```
Header header
Std_msgs/String name
Geometry_msgs/Pose2D[] poses
```

Pose2D.msg

```
Float64 x
Float64 y
Float64 theta
```

- Services types (*.srv)
  - Service descriptions, define request and response data structures used for service communication
  - Language independent

GetPose.srv

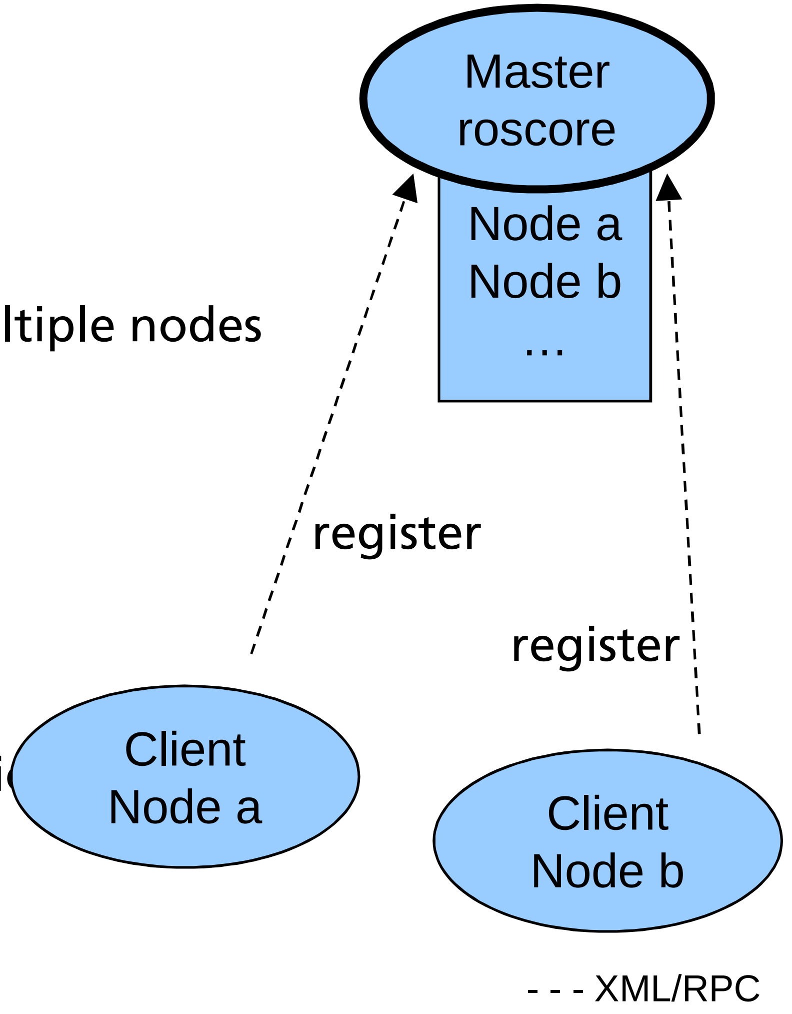
```
std_msgs/String name
--
Geometry_msgs/Pose2D pose
```

➡ http://ros.org/wiki/msg, http://ros.org/wiki/srv

Computational Graph Level

- Nodes
  - Processes to perform computation
  - A robot control system consists of multiple nodes
  - Nodes can be inserted, changed and

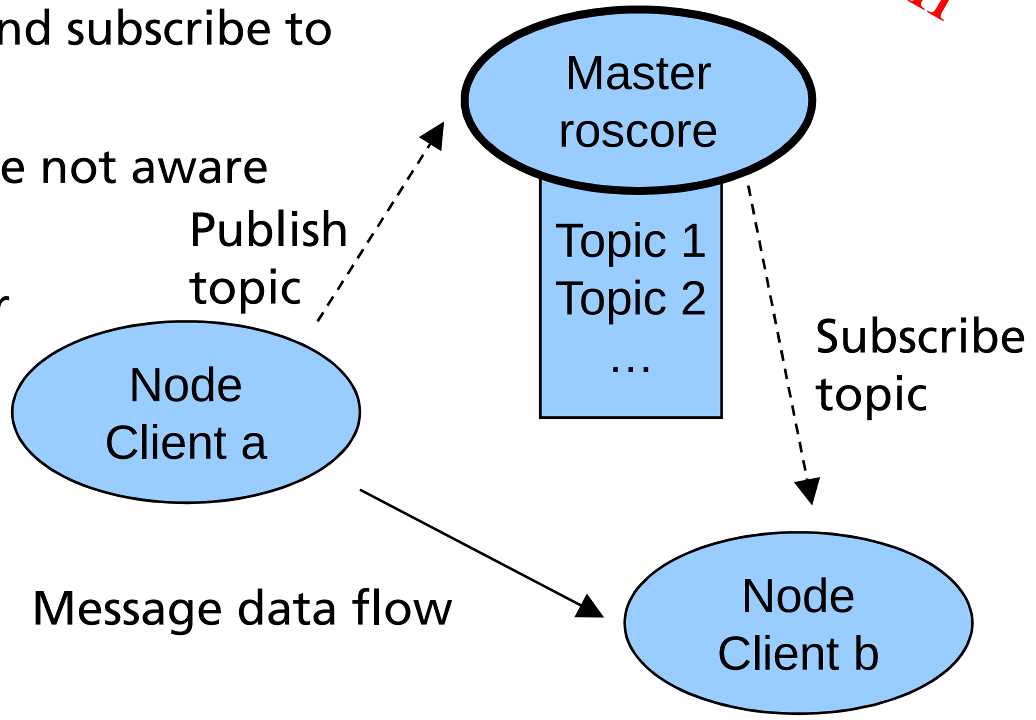
    removed at runtime
  - Written by a ROS client library,
    e.g. roscpp, rospy, …
- Master
  - Coordinating processes and communi
  - Name registration and lockup
- Parameter Server
  - Central location for storing data



➡ http://www.ros.org/wiki/ROS/Technical%20Overview

Communication concepts – topics

- Topics (asynchronous streaming)
- Multiple concurrent publishers and subscribers for one topic
- A single node can publish and subscribe to multiple topics
- Publisher and subscribers are not aware of each others' existence
- Decoupling between sender and receiver
- Works like a "chat room"

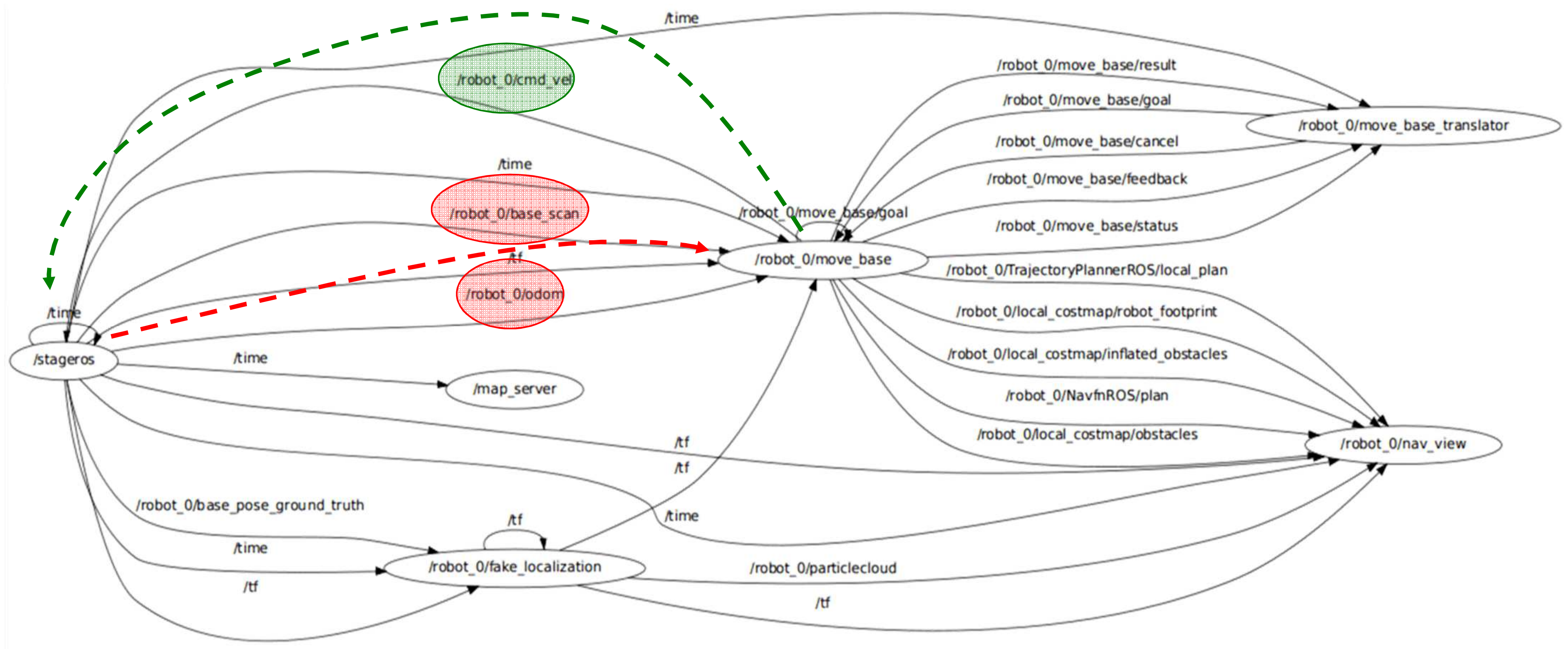


- - - XML/RPC

----- TCP/IP or UDP

→ http://www.ros.org/wiki/Topics

Computation Graph Level – Example


/time
/robot_0/cmd_vel
/robot_0/move_base/result
/robot_0/move_base/goal
/robot_0/move_base_translator
/robot_0/move_base/cancel
/time
/robot_0/move_base/feedback
/robot_0/base_scan
/robot_0/move_base/goal
/robot_0/move_base/status
/tf
/robot_0/move_base
/robot_0/TrajectoryPlannerROS/local_plan
/robot_0/odom
/time
/robot_0/local_costmap/robot_footprint
/stageros
/time
/robot_0/local_costmap/inflated_obstacles
/map_server
/robot_0/NavfnROS/plan
/robot_0/local_costmap/obstacles
/tf
/robot_0/nav_view
/tf
/robot_0/base_pose_ground_truth
/time
/tf
/time
/robot_0/fake_localization
/robot_0/particlecloud
/tf
/tf

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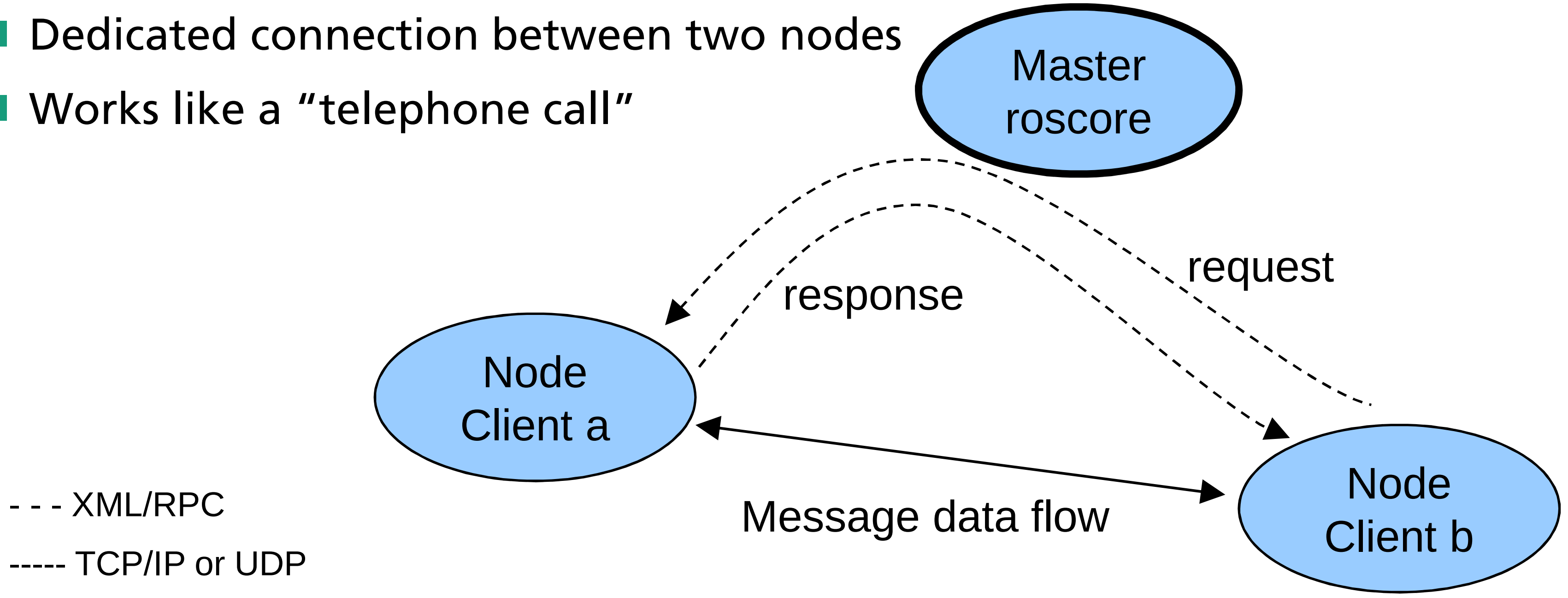
Communication concepts – services

One-to-one, two-way communication

- Services (synchronous communication)
- Request and reply interaction
- Defined by a pair of message structures: request and reply
- Dedicated connection between two nodes
- Works like a “telephone call”



http://www.ros.org/wiki/Services

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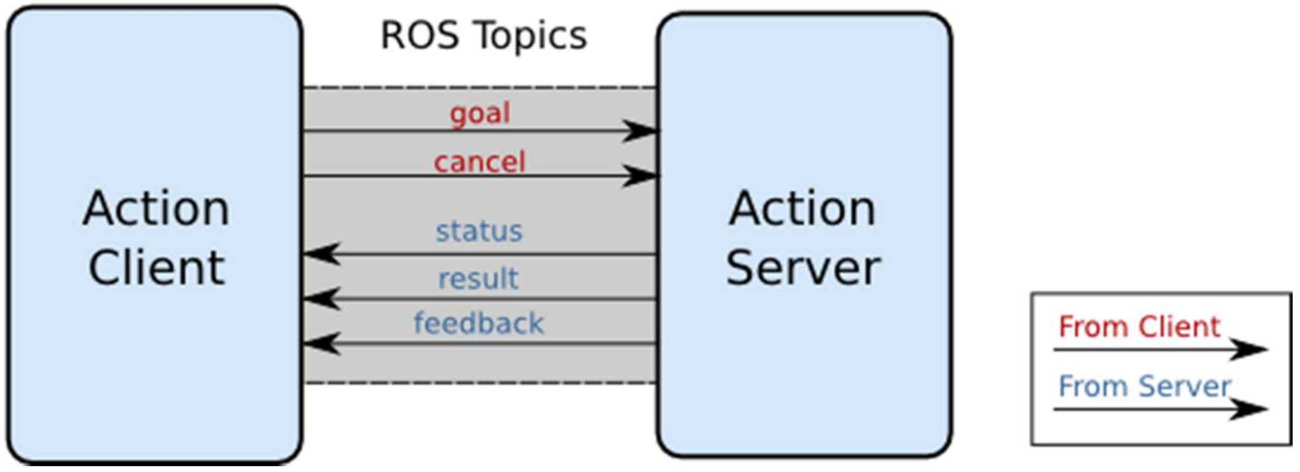
Computation Graph Level

- Actionlib
  - Goal description similar to message and service definitions
  - State-machine running on server and client

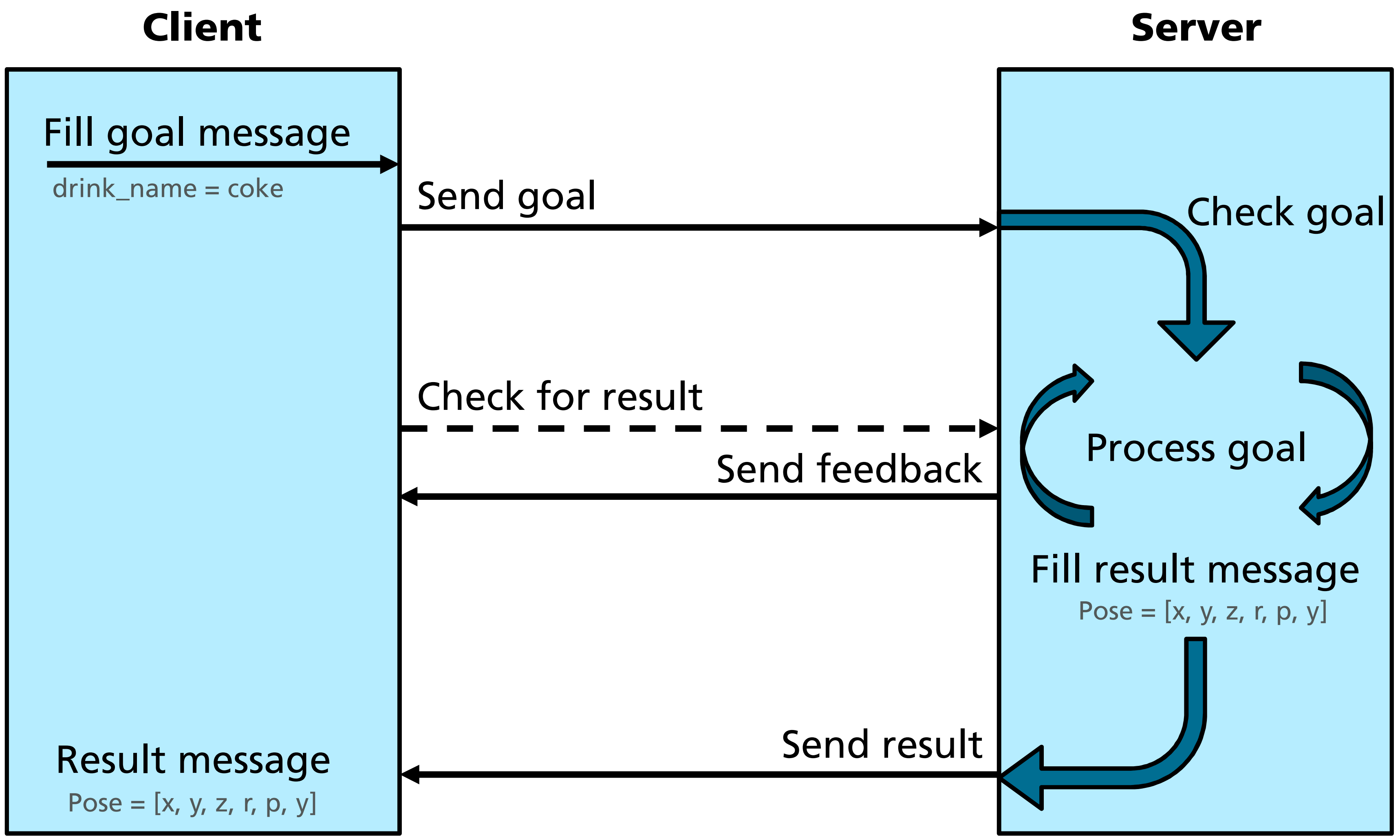
DetectBottle.action

```
#goal
std_msgs/String drink_name
---
#result
Geometry_msgs/Pose3D pose
---
#feedback
Int16 status
```

Action Interface



Actionlib workflow example: detect bottle



ROS environment settings

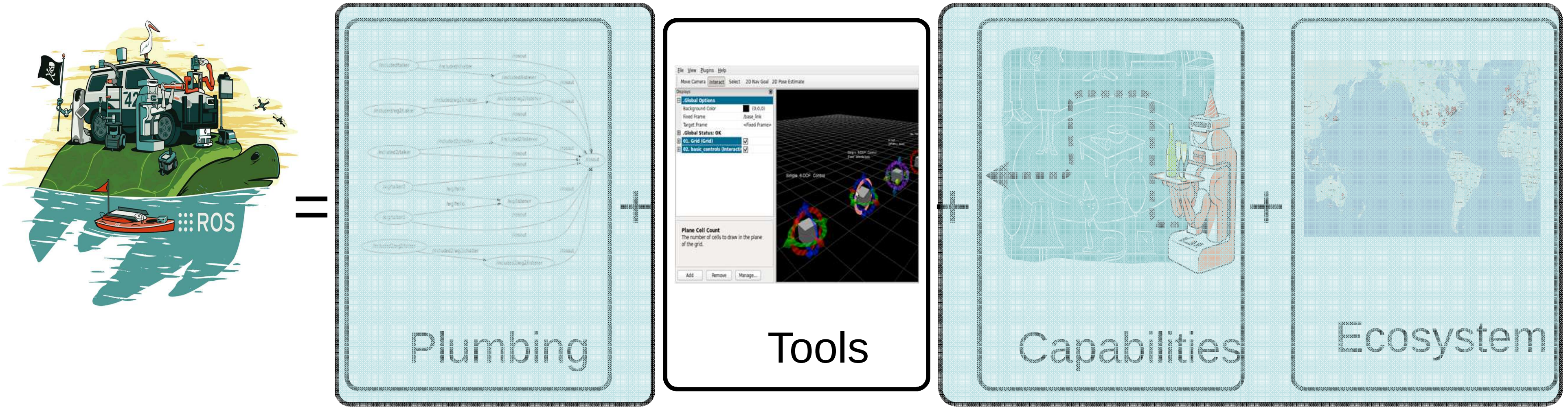
- ROS_PACKAGE_PATH
  - Search path to find packages
  - E.g.
    ROS_PACKAGE_PATH=<Path_to_your_overlays>:/opt/ros/groovy/stacks:/opt/ros/groovy/share
- ROS_MASTER_URI
  - Defines host and port where the roscore is running
  - All ROS nodes need to be able to connect to this URL
  - E.g.
    http://localhost:11311
- ROS cheat sheet
  - Lists lot of useful terminal commands
  - http://download.ros.org/downloads/ROScheatsheet.pdf

ROS deployment

- Starting a single node with rosrun
  - rosrun <package_name> <executable_name> [arguments]

- Starting multiple nodes with roslaunch
  - roslaunch <package_name> <launchfile_name> [arguments]
  - Can be grouped and hierarchically included
  - Support use of arguments and renaming of topics
  - Support uploading of parameters through yaml-files

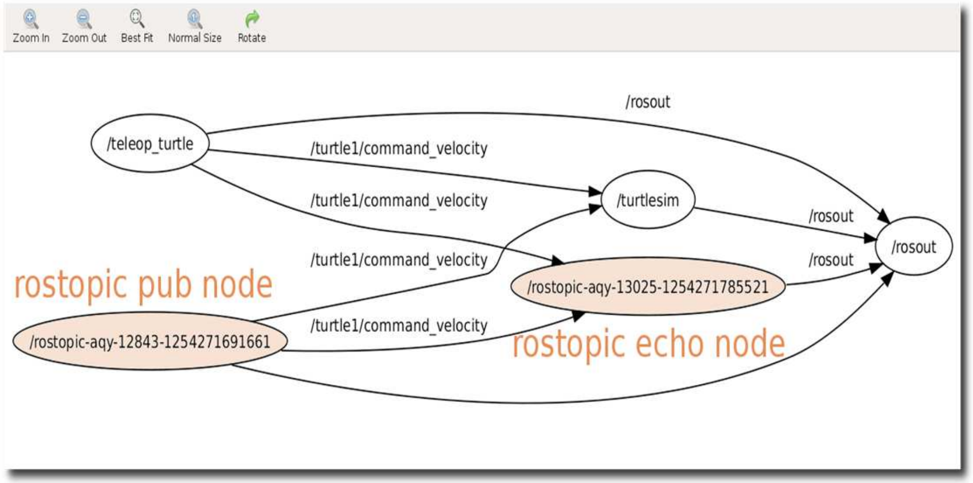
Tools

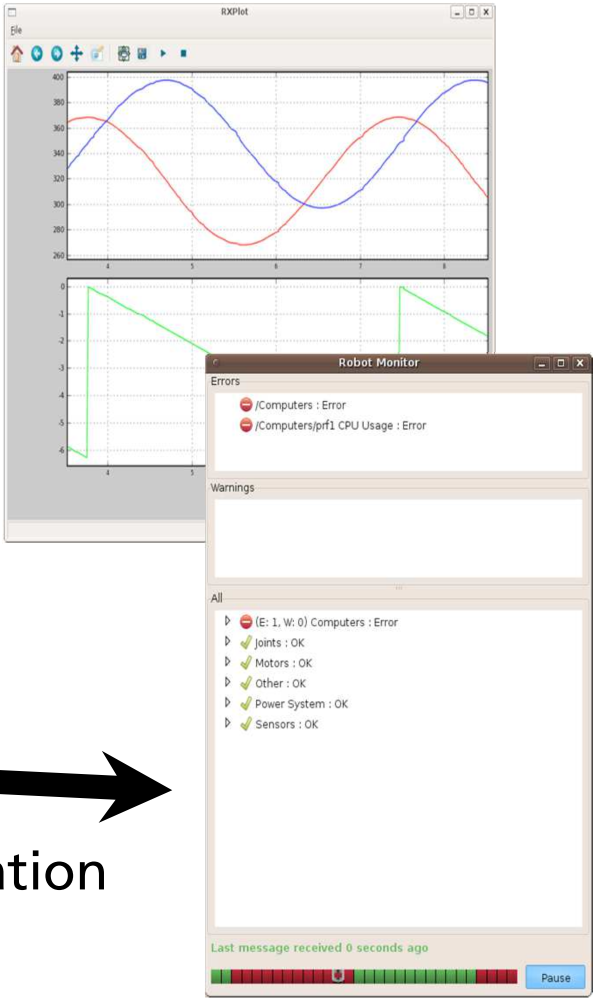


Tools

- Standard Linux tools
  - Compilers, Debuggers, Loggers, IDEs
- Multiple language support
  - C/C++, Java, Python, Lisp
- Standard libraries
  - Boost, MySQL, XML (whatever you can imagine)
- Modern GUI tools

Tools

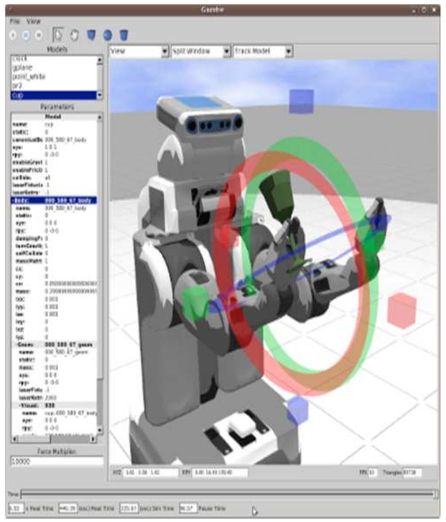




/Computers : Error
/Computers/prf1 CPU Usage : Error

(E: 1, W: 0) Computers : Error
Joints : OK
Motors : OK
Other : OK
Power System : OK
Sensors : OK

Last message received 0 seconds ago



plotting

graph visualization

diagnostics

Simulation/visualization

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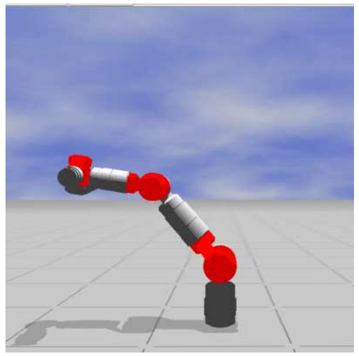
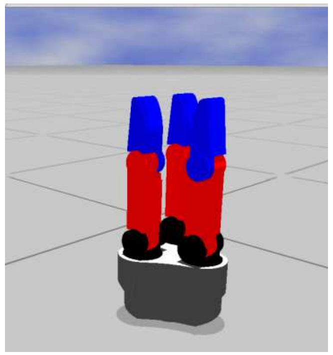
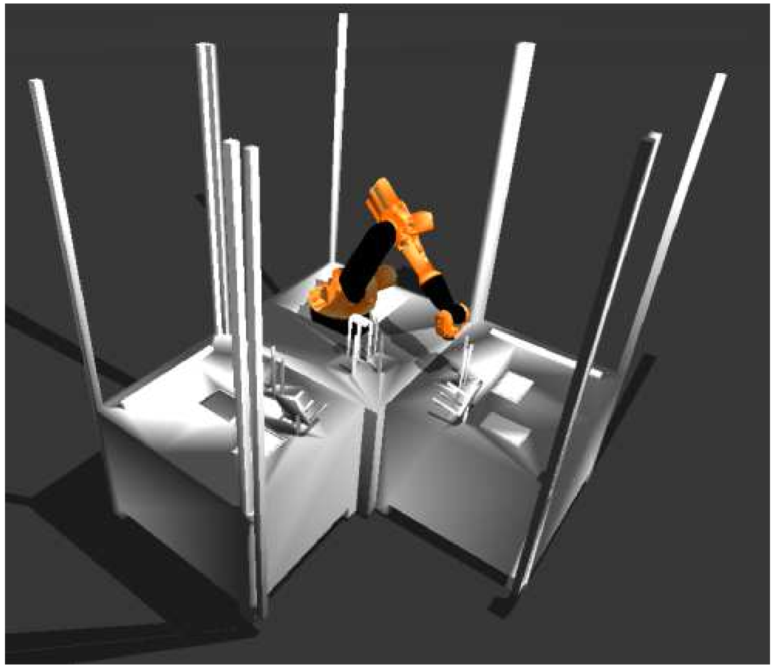
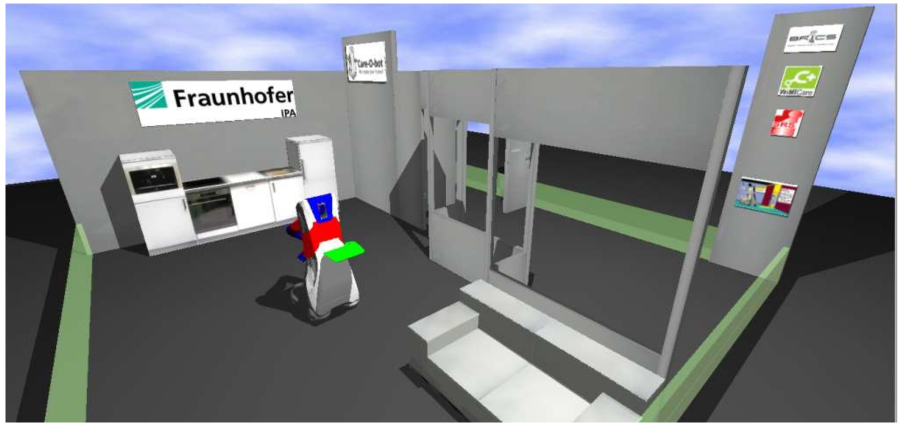
Tools: Simulation – Gazebo







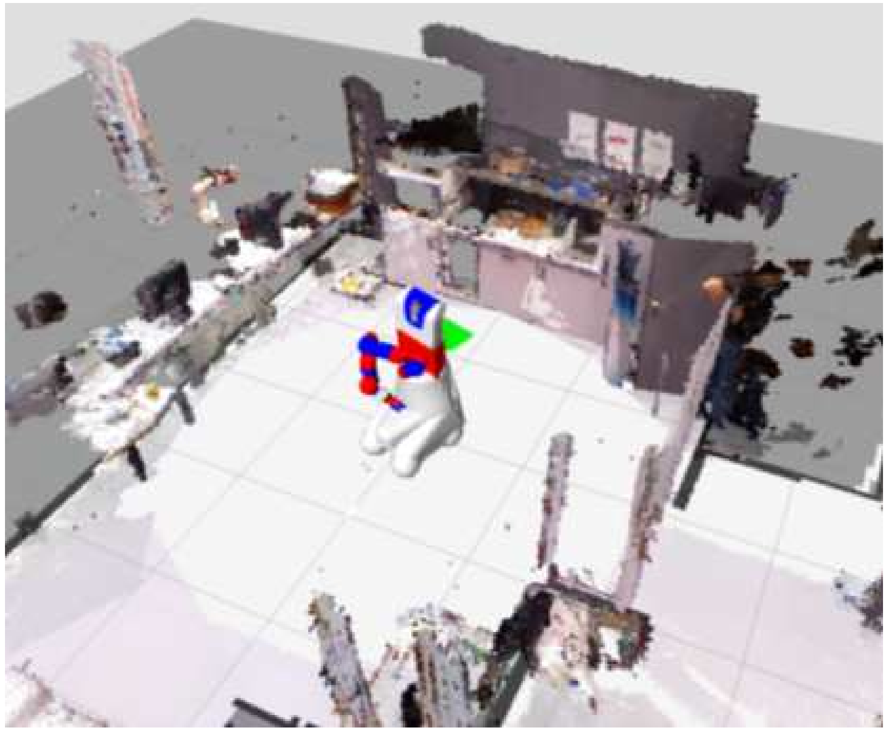
- Single simulated components
- Simulated sensors and actors, e.g.
  - Arm joints, hand
  - Cameras, laser scanners
- Model of the whole robot
- Kinematic and dynamic models of hardware components
- Environment model

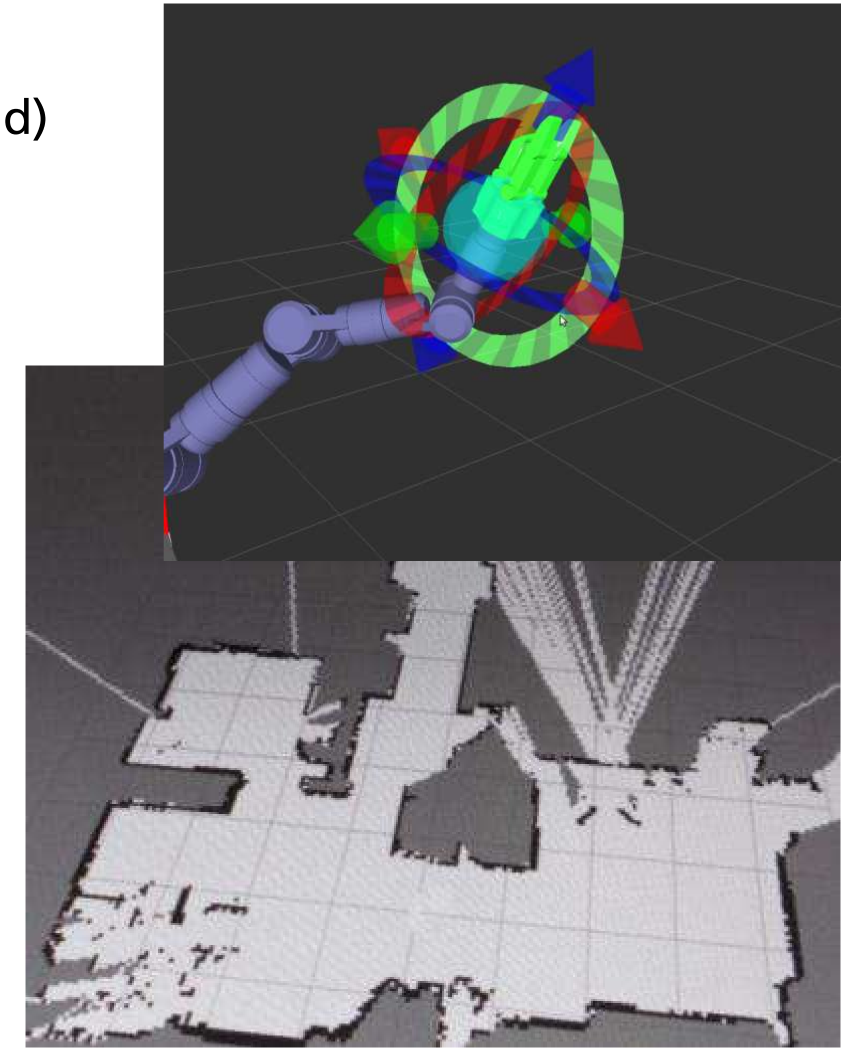


http://www.ros.org/wiki/simulator_gazebo

Tools: Visualization – RVIZ

- Robot Model
- Sensor data (laser scanner, point cloud)
- 2D and 3D maps
- (Interactive-) markers

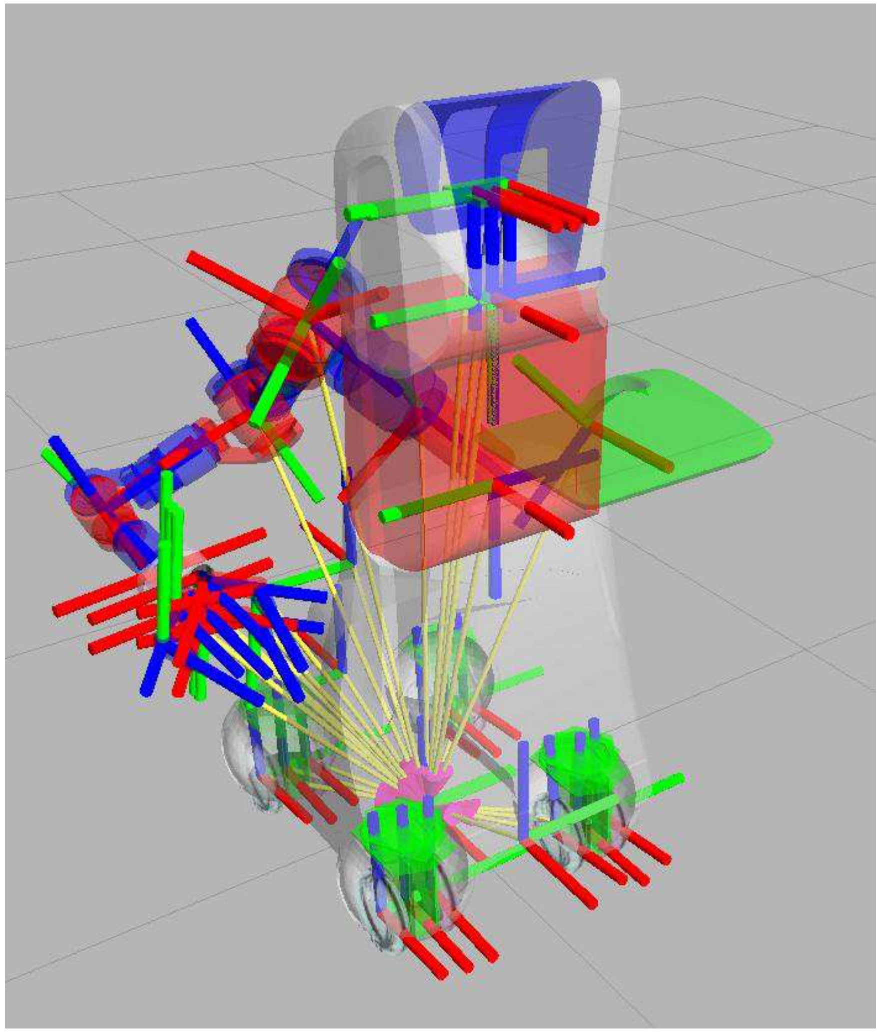




→ http://www.ros.org/wiki/rviz

Tools: transformations library (tf)

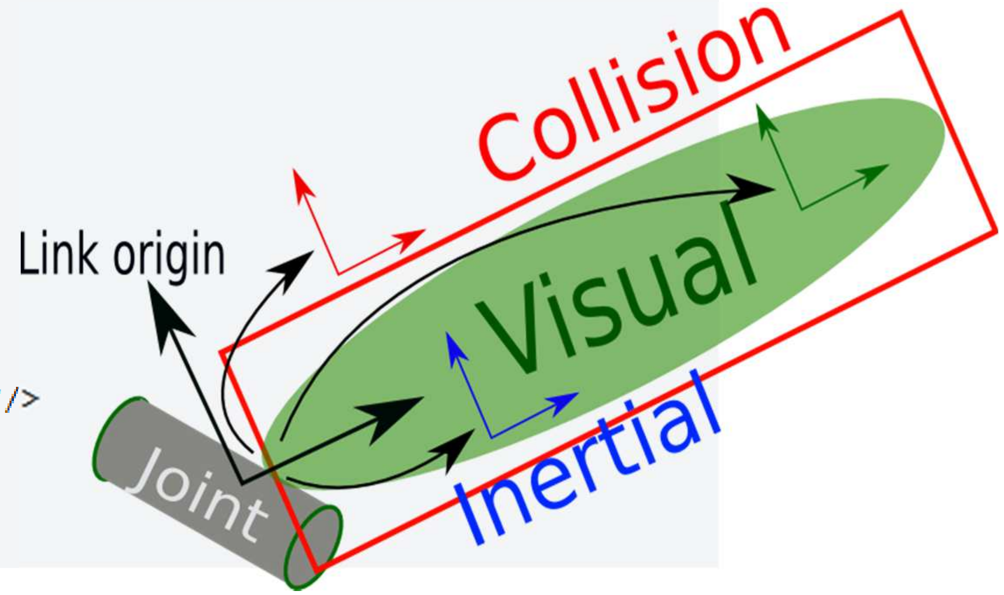
- Tree of coordinate systems
- Defined by urdf (Robot Description Language)
- Generated automatically out of /joint_states topic
- Transformations between all coordinate systems available
- API for geometic transformations and convertion (C++ and Python)



→ http://www.ros.org/wiki/tf

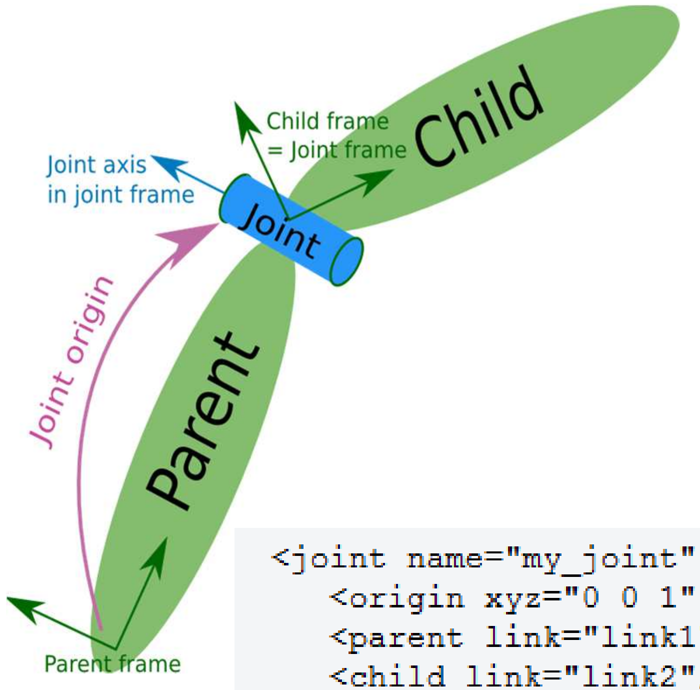
Tools URDF (link)

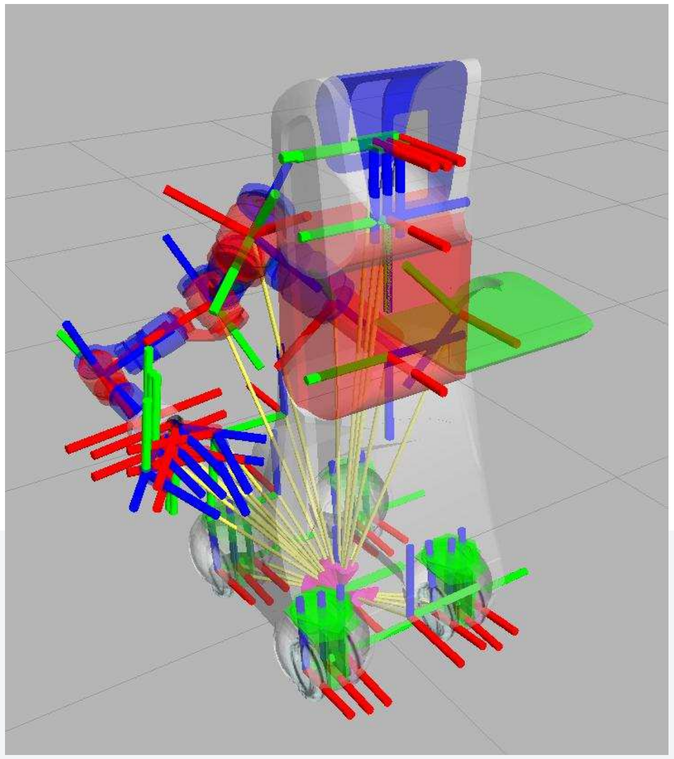
```
<link name="my_link">
  <inertial>
    <origin xyz="0 0 0.5" rpy="0 0 0"/>
    <mass value="1"/>
    <inertia ixx="100"  ixy="0"  ixz="0" iyy="100" iyz="0" izz="100" />
  </inertial>

  <visual>
    <origin xyz="0 0 0" rpy="0 0 0" />
    <geometry>
      <box size="1 1 1" />
    </geometry>
    <material name="Cyan">
      <color rgba="0 255 255 1.0"/>
    </material>
  </visual>

  <collision>
    <origin xyz="0 0 0" rpy="0 0 0"/>
    <geometry>
      <cylinder radius="1" length="0.5"/>
    </geometry>
  </collision>
</link>
```



- http://www.ros.org/wiki/urdf

Tools URDF (joint)

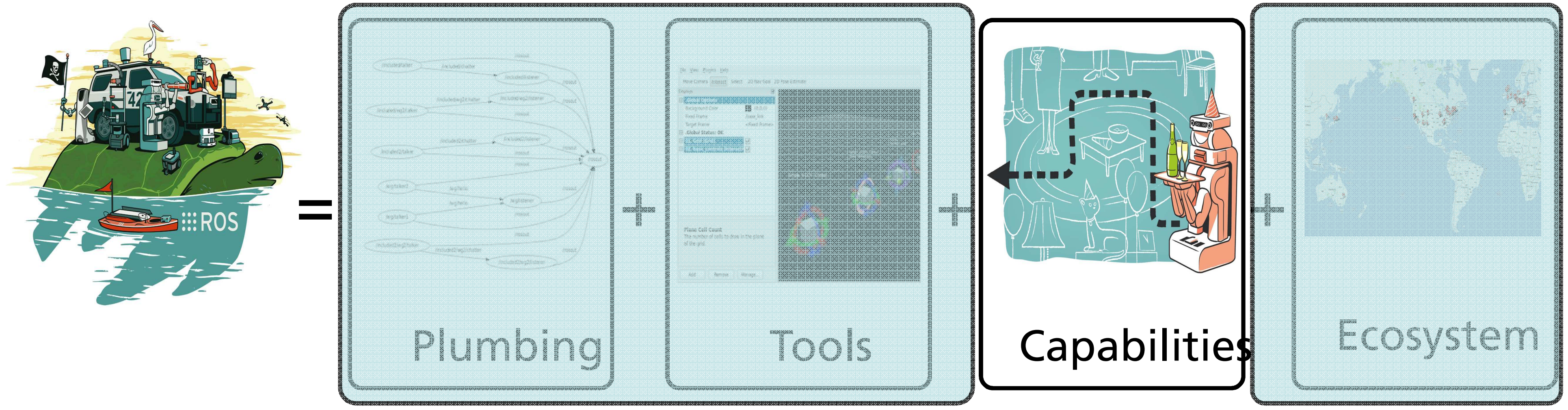




```
 <joint name="my_joint" type="floating">
    <origin xyz="0 0 1" rpy="0 0 3.1416"/>
    <parent link="link1"/>
    <child link="link2"/>

    <calibration rising="0.0"/>
    <dynamics damping="0.0" friction="0.0"/>
    <limit effort="30" velocity="1.0" lower="-2.2" upper="0.7" />
    <safety_controller k_velocity="10" k_position="15" soft_lower_limit="-2.0" 
soft_upper_limit="0.5" />
 </joint>
```

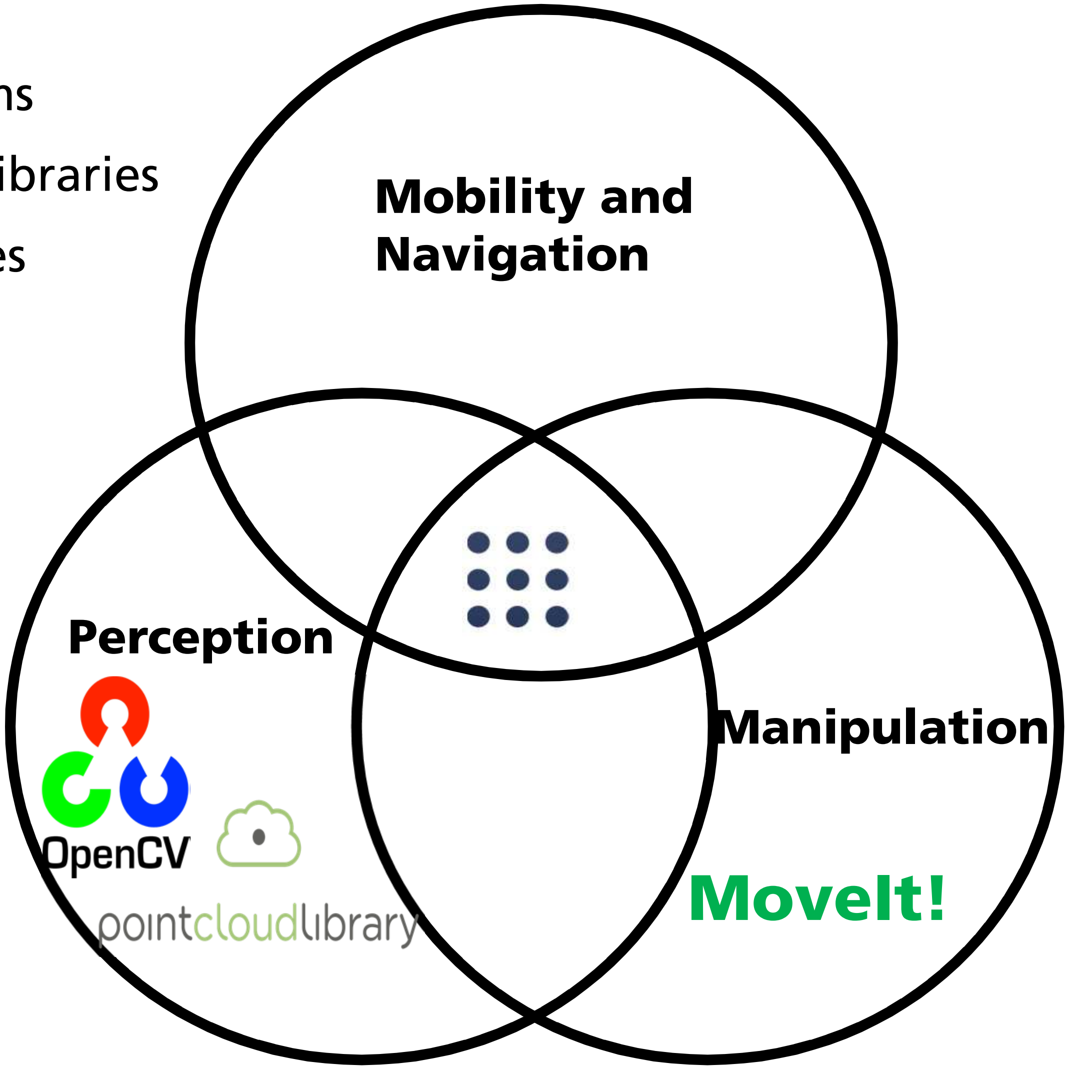
- http://www.ros.org/wiki/urdf

Capabilities



Capabilities

- State of the art algorithms
- Integration of available libraries
- Wide range of capabilities
  - Navigation
  - Perception
  - manipulation



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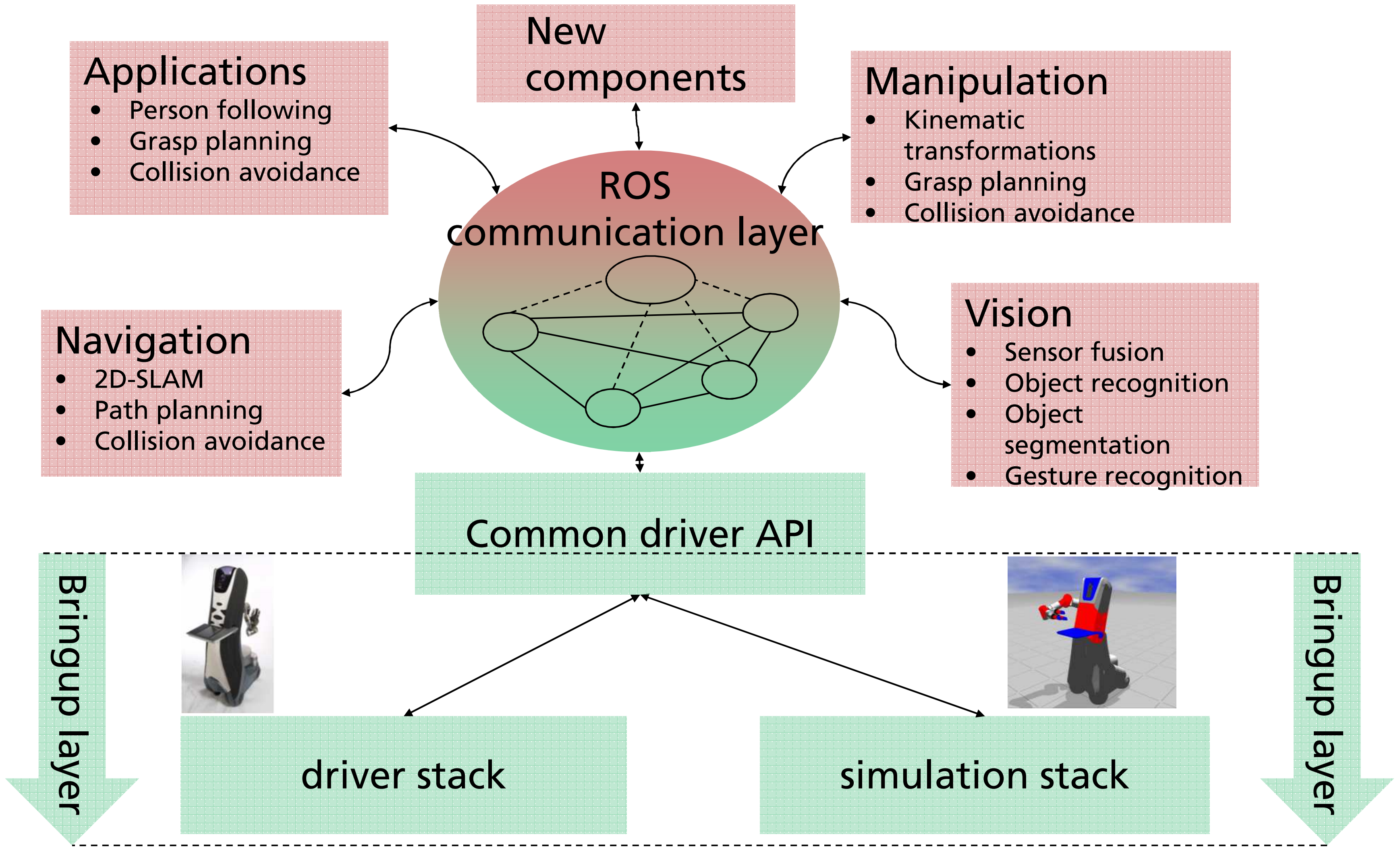
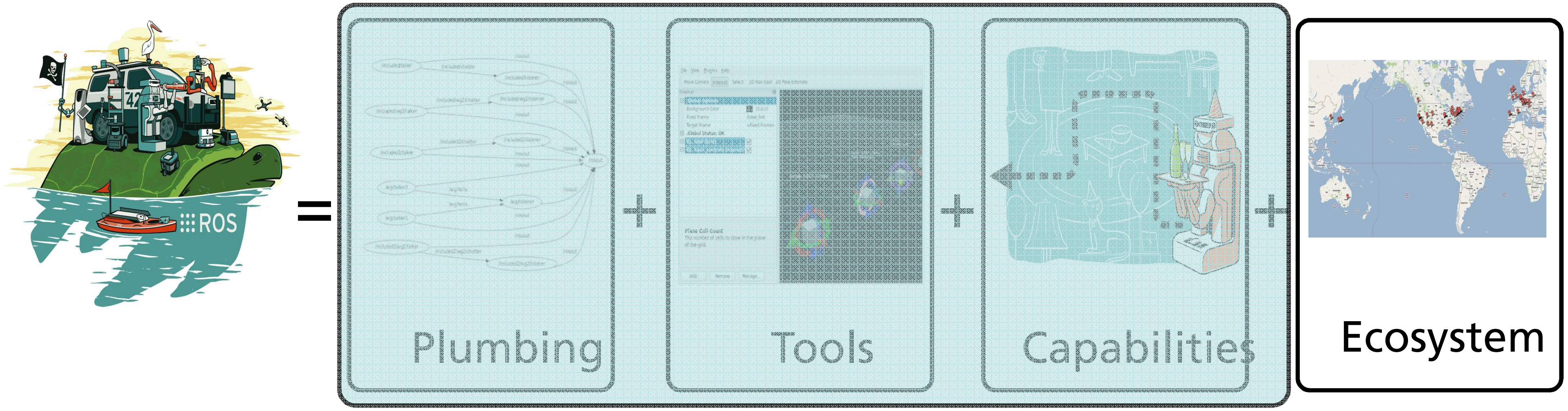
Capabilities



Community/Ecosystem

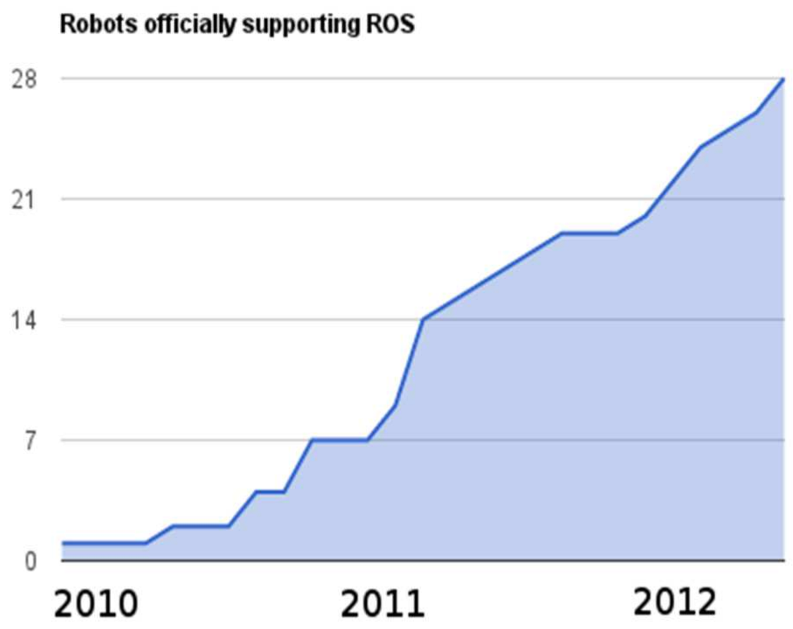


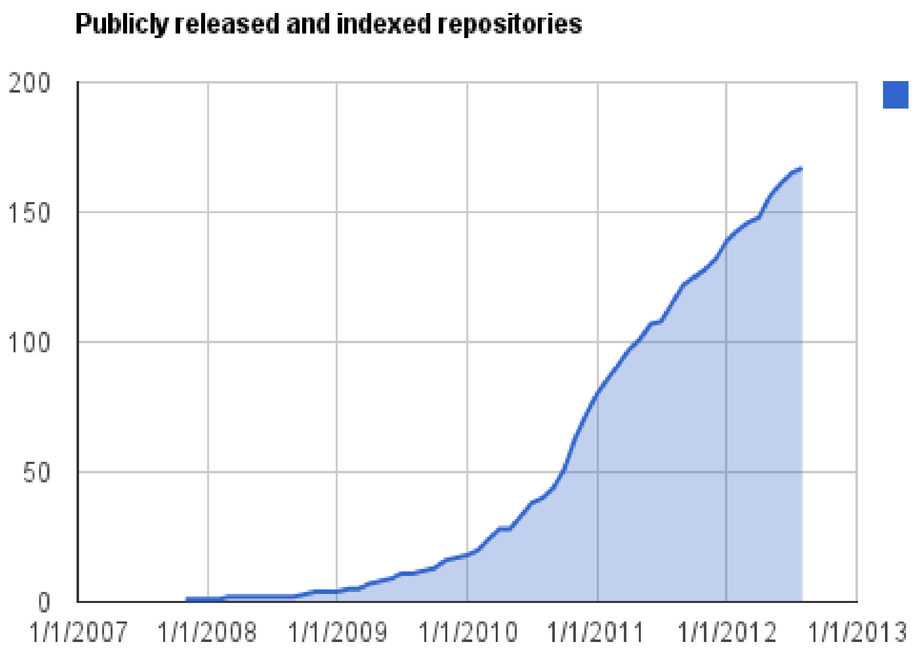
Community/Ecosystem

- Repositories
  - Federated network of code repositories
  - Different institutions can develop and release robot software components
- ROS Wiki (www.ros.org)
  - Main forum for information and documentation
  - Tutorials
- Bug Ticket System "trac" (https://code.ros.org/trac/ros) and github issues
  - Bugs can be reported and processed
- Mailing Lists
  - Review information and discussion about packages and interfaces
  - Information about new packages
- OSRF consultant network
  - http://osrfoundation.org/consultants-network/

Community/Ecosystem

- Fast growing community
- De facto standard for service robotics





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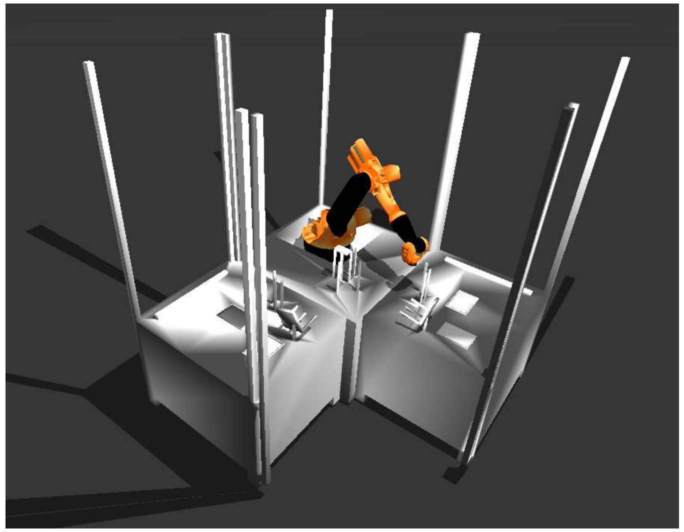
Next step: from ROS to ROS Industrial



How can the power of ROS be used in the industrial domain?

www.rosindustrial.org
www.ros.org/wiki/Industrial

HANDS-ON SESSIONS

Station 1:
Perception

Georg Arbeiter

Station 2:
Navigation

Alexander Bubeck

- Please form groups of max 4 persons
- After 1.5h switch to next station
- At each station
  - You will get an introduction to the topic
  - You will find tutorial information

Station 3:
Manipulation

Felix Meßmer

Station 4:
Application

Florian Weißhardt

Session 1: 10:00 – 11:30
Session 2: 11:30 – 13:00
Session 3: 13:45 – 15:15
Session 4: 15:15 – 16:45