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Middleware

Introduction from the robotics point of view

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Middleware in computer science

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- Middleware is software providing services to applications beyond those available from the operating system.
- Middleware makes it easier for software developers to perform communication and input/output.
- Most commonly used in the context of distributed applications.
- More specifically: dash in “client-server”.
- Also used in a sense of: a software driver, an abstraction layer hiding details of hardware and software from an application.

Middleware taxonomy

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1. Message oriented middleware: asynchronous store and forward application messaging.
2. Object middleware: object request brokers, manages communication between objects.
3. RPC middleware: synchronous interaction, usually within an application.
4. Database middleware: direct access to data structures allowing interaction with DB directly.
5. Transaction middleware: transaction processing as well as web application servers.
6. Portals: enterprise portal servers allowing access from user's desktop to back end systems and services.

CORBA, my first middleware

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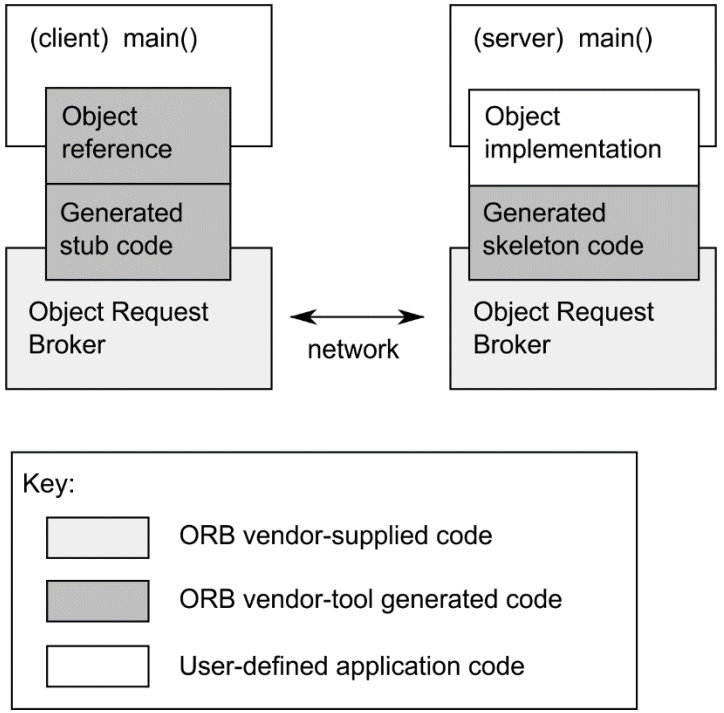
- Common Object Request Broker Architecture (CORBA) is a standard enabling software components written in multiple computer languages and running on multiple computers to work together.
- Used in our ActIPret project (2001-2004) to control a robot with various vision sensors.
- It was to heavy and slow.



- There was a need to write a lightweight middleware allowing real-time interaction.

Middleware in robotics

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- Glue software to connect software and hardware components together.
- Often, communication between components is considered to be middleware.
- The look is from the software developer perspective.
- In addition, all application-independent helping composition of subsystems into larger systems are often included too.
- Middleware should be invisible.

Four minimal primitive concepts

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- Communication: components must exchange information (data, events, commands,…), and how this exchange is done is an important property of the composite system.
- Computation: each component performs certain computations that are necessary to provide the functionality that is expected from the system.
- Configuration: components should be usable in more than one possible configuration (i.e., concrete settings for each of their variable parameters).
- Coordination: at the system level. Involves: decision making, scheduling, (de)activating subsystems and/or their interconnections, etc.

Robotic middleware examples

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- OpenRDK http://openrdk.sourceforge.net/
- Urbi – for complex organization of components, French company GOSTAI
- MIRO, based on CORBA,
- http://miro-middleware.berlios.de/
- OpenNI – middleware for 3D sensing, http://www.openni.org/

Middleware V. Hlaváč has some experience with

- RSB - U of Bielefeld
- ROS

Three issues to be tackled

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when developing robot software:

1. Sequential programming ill-suited to asynchronous world.
2. Must manage significant complexity.
3. Details of a specific robot hardware have to be abstracted.

Ad 1. Avoiding seq. programming

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Callback:

- Function that's called whenever data is available for processing.
- Asynchronous: callback can happen anytime.

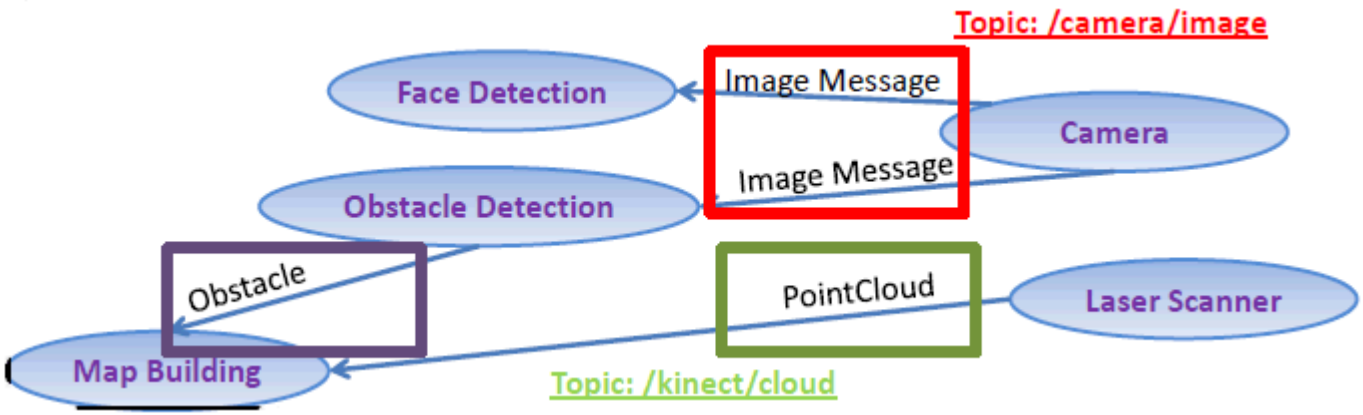
Examples:

- An image is read from the camera.
- A bumper tells that the robot hit something.

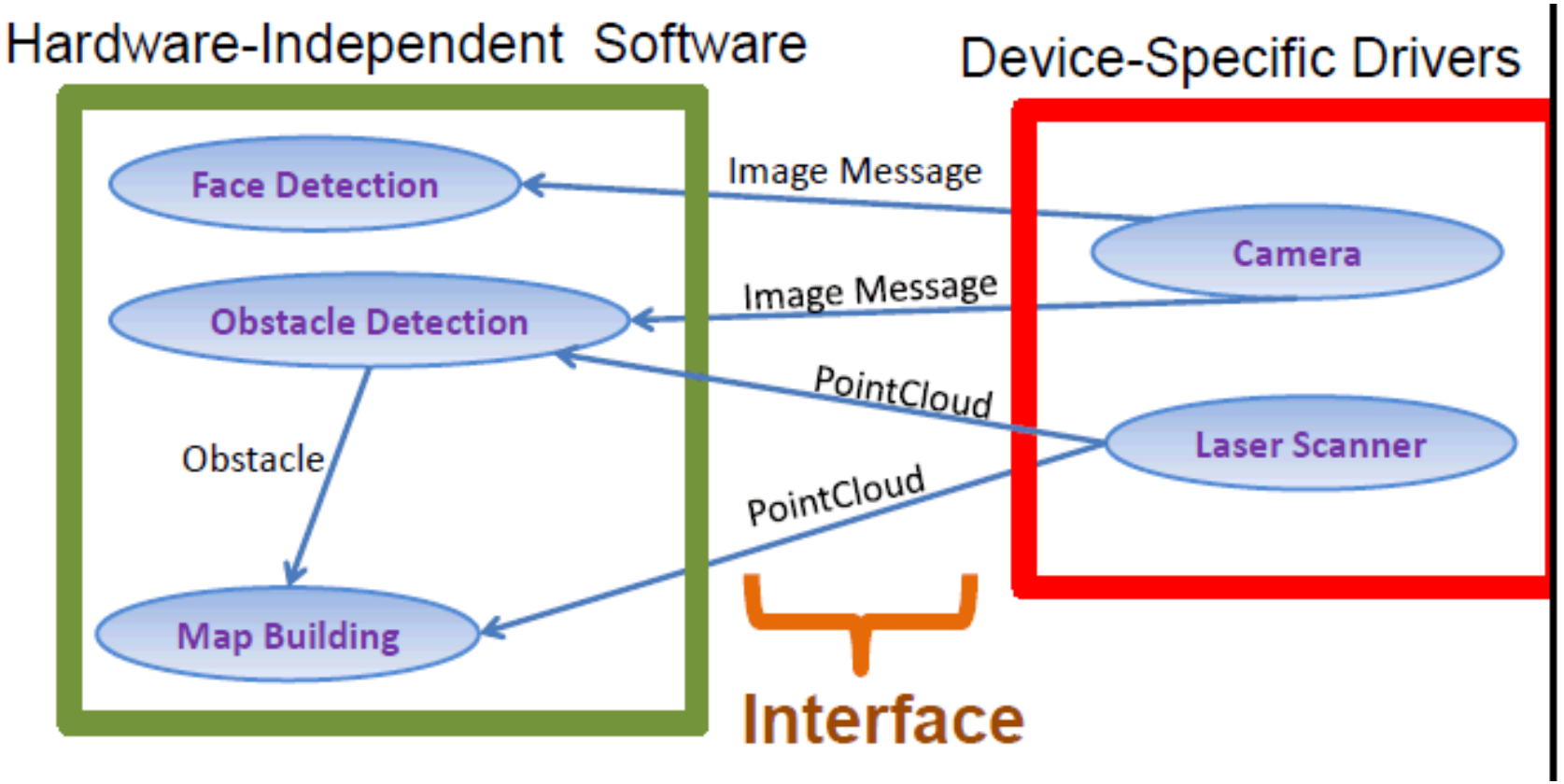
Ad 2. Tackling complexity

Code organization

- Separate processes: cameras, odometry, map creation …
  Can be separated out and interact through an interface.
- Interfaces: SW processes; in ROS “nodes” communicate about shared “topics”.
- Publish/subscribe: each piece of sw receives only messages it requests.



Ad 3. Hardware abstraction



ROS Robot Operating System

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Solves all three above discussed issues (callbacks, interface, hardware).

- Initiated by Willow Garage.
- Meta-operating system.
- Message passing.
- Debugging tools.
- Visualization tools.
- Software Management (compiling, packaging).
- Libraries.
- Hardware agnostic.
- Free + open source.
- Suitable for large scale research.
- Emphasis on distributed computing.
- Ubuntu Linux is the only supported platform.
- Support for other platforms, including Windows, is experimental.

ROS design goals

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- Peer-to-peer: ROS components, potentially on different hosts, are connected in peer-to-peer topology.
- Tool-based: Microkernel design, with large number of small tools, used to build, run and analyze ROS components.
- Multi-lingual: ROS components can be written in various languages. Commonly: Python, C++, Lisp.
- Thin: Drivers and algorithms are encouraged to be written in separated libraries.
- Open-Source: ROS is distributed under terms of the BSD license.

ROS concepts

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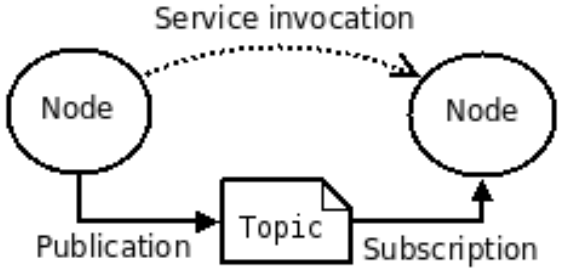
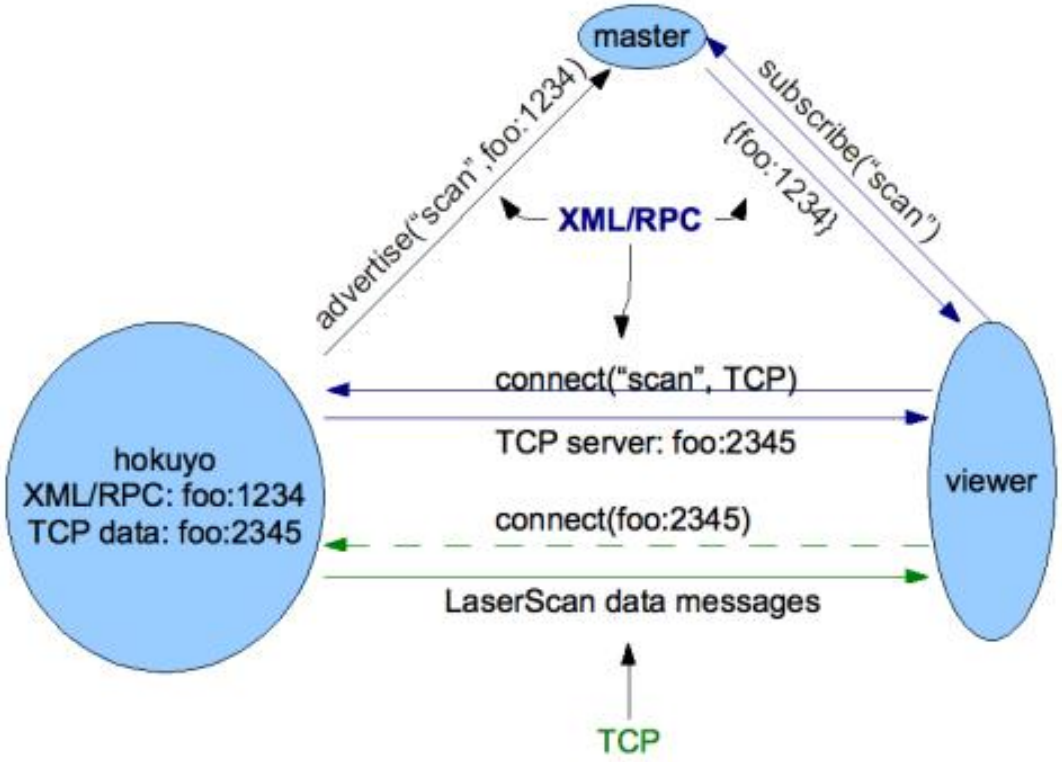
- **Node:**
  A single computation unit (component).
- **Message:**
  Data structure used by nodes to communicate.
- **Topic:**
  Broadcast communication between nodes (publisher-subscriber architecture).
- **Service:**
  Synchronous communication between nodes (client-server architecture).
- **Package:**
  A software unit solving a specific task, e.g. navigation.

Node

- A single process that performs a particular computation.
- ROS supported application is often composed of a large number of nodes.
- Nodes communicate with each other by passing messages through topic or service.
- Connection between two nodes is accomplished through roscore, which acts as a name server. There is only one roscore that secures the communication.



Example: initiating topic communication



ROS tools and packages

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- rviz: visualisation tool.
- rosbag: allows recording all communication between nodes and play it back later.
- rqt_graph: visualizes the graph of ROS application.
- rosparam: can manipulate data on the ROS parameter server.

ActionLib

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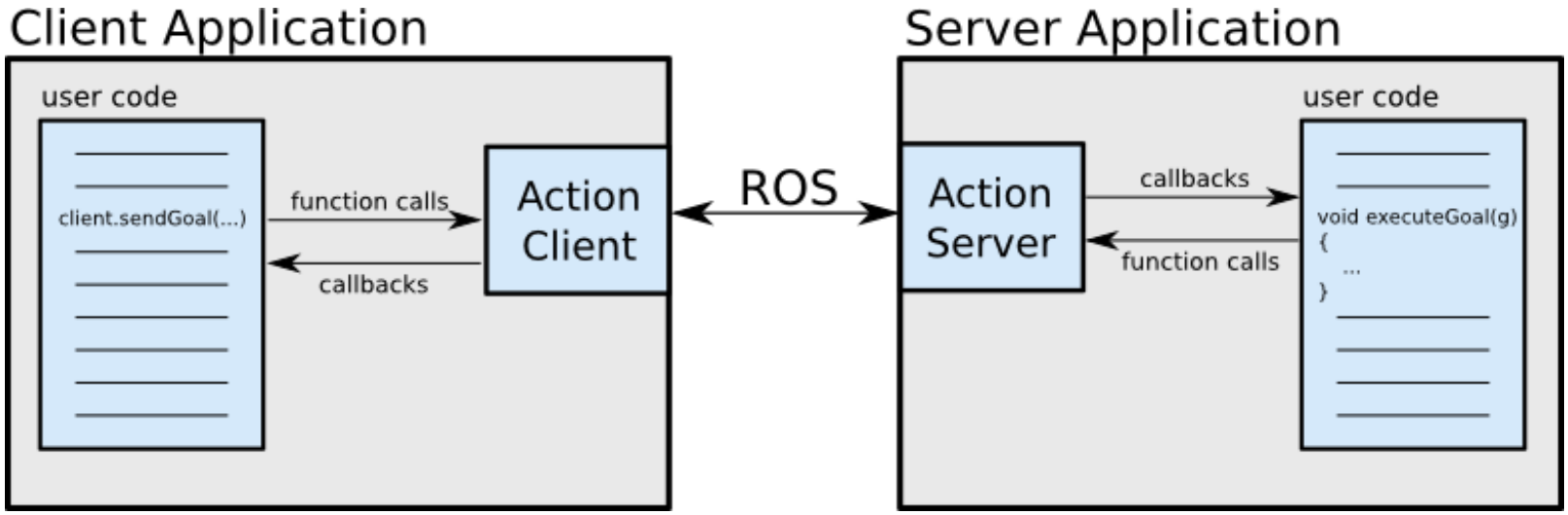
- For preemptable tasks / Longtime running tasks.
- Communication build on top of ROS messages.
- Action is specied by three messages: goal, feedback and result.
- For example Goto: Planning, Filtering, Trajectory execution (can be interrupted).



Transformation (tf)

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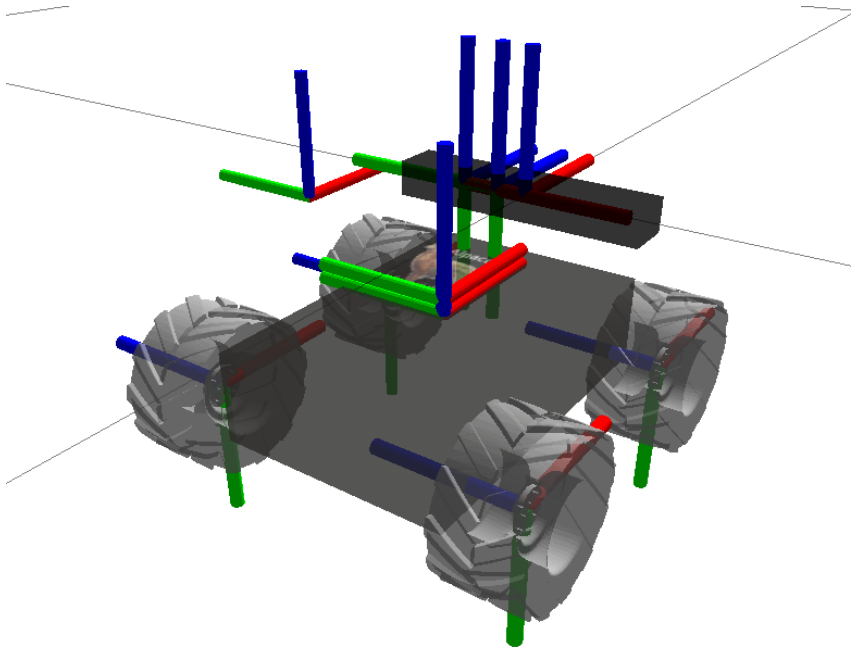
- Transformations in a tree structure.
- Any transformation is relative to any coordinate frame.
- Buffered in time, i.e. it can be asked what was the transformation in the past instant.



URDF, Xacro

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Unified Robot Description Format

- XML format
- links (origin, visual and collision model, color)
- joints (origin, type)

Xacro

- XML macro language
- more readable XML
- macros, parameters, maths

URDF, Xacro (2)

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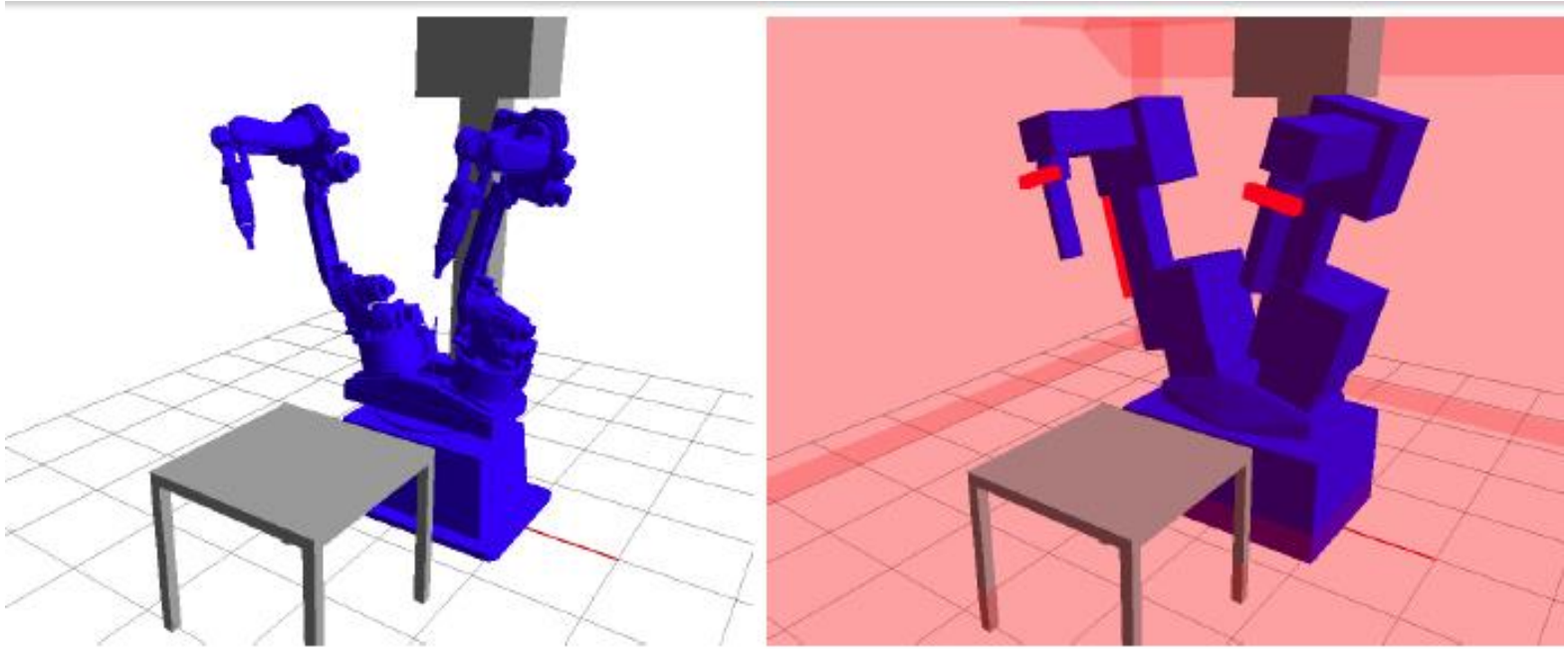
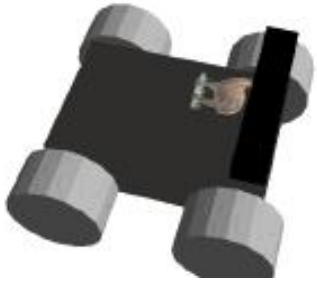
```
1  <xacro:macro name="table_leg" params="*origin parent suffix color height">
2      <link name="${suffix}">
3          <xacro:default_inertial/>
4          <visual>
5              <geometry>
6                  <box size="0.05 0.05 ${height-0.050}" />
7              </geometry>
8              <material name="${color}" />
9              <origin xyz="0 0 -${(height+0.05)/2}"/>
10         </visual>
11     </link>
12     <joint name="${suffix}joint_ftable_leg" type="fixed">
13         <insert_block name="origin" />
14         <parent link="${parent}"/>
15         <child link="${suffix}"/>
16     </joint>
17 </xacro:macro>
```

URDF, rviz vizualization





SMACH – State MACHine

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- Implements higher-Level behaviors via finite automata.
- Hierarchical (every state machine can be the state in another state machine).
- Concurrence containers (parallel).

Gazebo

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- Multi-robot dynamic simulator for outdoor environments.
- Started in 2002, independent of ROS.
- There is an interface to ROS.
- Plenty of sensors (laser, camera, Kinect, GPS).