Robot Programming with Lisp

7. Lisp Packaging and Introduction to ROS

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Outline

Lisp Packages and ASDF Systems
- Lisp Packages
- ASDF Systems

Robot Operating System
- What is a Robot?
- ROS Overview
- ROS Communication Layer
- ROS Build System
- Programming with ROS

Organizational
- Info

Lisp Packages

Lisp packages define namespaces.
They are used to avoid naming clashes and control access permissions.

Lisp Packages

```
CL-USER> (defun lambda () #\L)
Lock on package COMMON-LISP violated when proclaiming LAMBDA as ...
CL-USER> (defpackage :i-want-my-own-lambda)
CL-USER> (in-package :i-want-my-own-lambda)
#<COMMON-LISP:PACKAGE "I-WANT-MY-OWN-LAMBDA">
I-WANT-MY-OWN-LAMBDA> (common-lisp:defun lambda () #\L)
LAMBDA
I-WANT-MY-OWN-LAMBDA> (common-lisp:in-package :cl-user)
#<PACKAGE "COMMON-LISP-USER">
CL-USER> (describe *)
#<PACKAGE "COMMON-LISP-USER">
Documentation:
  public: the default package for user code and data
Nicknames: CL-USER
Use-list: COMMON-LISP, SB-ALIEN, SB-DEBUG, SB-EXT, SB-GRAY, SB-PROFILE
```

Lisp Packages [2]
Defining a Package

defpackage *defined-package-name [[option]] => package*

```
option::= (:nicknames nickname*)* |
          (:documentation string) |
          (:use package-name*)* |
          (:shadow symbol-name*)* |
          (:shadowing-import-from package-name symbol-name*)* |
          (:import-from package-name symbol-name*)* |
          (:export symbol-name*)* |
          (:intern symbol-name*)* |
          (:size integer)
```

Lisp Packages [3]

Example Package Definition

```
CL-USER> (defpackage :homework
           (:nicknames :hw)
           (:documentation "A namespace for my homework assignments")
           (:use :common-lisp))
#<PACKAGE "HOMEWORK">
CL-USER> (in-package :homework)
#<PACKAGE "HOMEWORK">
HW> (defun say-hello () (print "hello"))
HW> (say-hello)
"hello"
HW> (in-package :common-lisp-user)
#<PACKAGE "COMMON-LISP-USER">
CL-USER> (say-hello)
The function COMMON-LISP-USER::SAY-HELLO is undefined.
CL-USER> (hw:say-hello)
The symbol "SAY-HELLO" is not external in the HOMEWORK package.
CL-USER> (hw::say-hello)
"hello"
```

Symbol Namespaces

symbol-package

```
CL-USER> (in-package "HOMEWORK")
#<PACKAGE "HOMEWORK">
HW> (describe 'say-hello)
HOMEWORK::SAY-HELLO
HW> (describe 'defun)
COMMON-LISP:DEFUN
HW> (describe :hello)
:HELLO
HW> (symbol-package 'say-hello)
#<PACKAGE "HOMEWORK">
HW> (symbol-package :hello)
#<PACKAGE "KEYWORD">
HW> (eql ':hello :hello)
T
HW> keyword:hello
:HELLO
HW> (eql :hello keyword:hello)
T
```

Symbol Namespaces [2]

Uninterned symbols, find-package, intern

```
HW> '#:hello
#:HELLO
HW> (symbol-package '#:hello)
NIL
HW> (eql '#:hello '#:hello)
NIL
HW> (gensym)
#:G1008
HW> (find-package :homework)
#<PACKAGE "HOMEWORK">
HW> (intern "HELLO" (find-package :homework))
HELLO
NIL
HW> (describe 'hello)
HOMEWORK::HELLO
HW> (loop for i from 1 to 5
          collect (intern (format nil "NAME-~a" i)))
(NAME-1 NAME-2 NAME-3 NAME-4 NAME-5)
```

Outline

ASDF Systems

ASDF is Another System Definition Facility:

- It takes care of compiling and “linking” files together in correct order.
- It is also responsible for finding Lisp files across the file system.

ASDF System Definition

```
(in-package :cl-user)
(asdf:defsystem my-system
  :name "My Super-Duper System"
  :description "My Super-Duper System is for doing cool stuff."
  :long-description "Here's how it does cool stuff: ..."
  :version "0.1"
  :author "First Last <email@bla.bla>"
  :licence "BSD"
  :depends-on (alexandria and-another-system)
  :components ((:file "package")))
```

ASDF Systems [2]

ASDF keeps a *registry* of all the paths where it expects to find `.asd` files. A registry is a list of paths.

There are different types of registries: for users, for administrators, etc. But the simplest is to work with the `*central-registry*`.

Managing the Registry

```
CL-USER> asdf:*central-registry*
(#P"/some/path/"
 #P"/some/other/path/")
CL-USER> (push "~/path/to/dir/of/my-system/" asdf:*central-registry*)
("~/path/to/dir/of/my-system/"
 #P"/some/path/"
 #P"/some/other/path/")
CL-USER> (asdf:load-system :my-system)
T
```

The trailing slash is important ("/some/path/")!

Outline

Industrial Robots

Logistics

Image courtesy: BIBA

Automotive

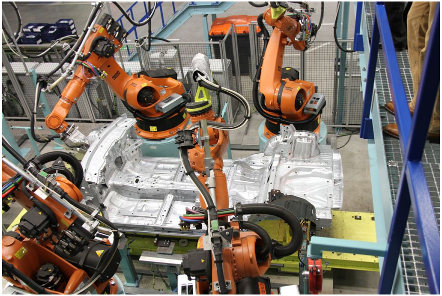


Image courtesy: Mercedes Benz Bremen

- Extremely heavy, precise and dangerous, not really smart
- Mostly no sensors, only high-precision motor encoders
- Programmable through PLCs (using block diagrams or Pascal / Basic like languages)

Industrial Light-weight Robots

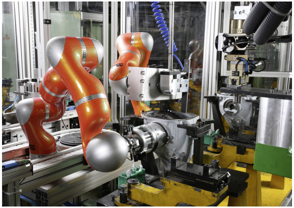
Production:

Copyright: Universal Robots

Medicine:

Copyright: Intuitive Surgical

Automotive:



Copyright: KUKA Roboter GmbH

- Very precise, moderately dangerous, somewhat smart
- High-precision motor encoders, sometimes force sensors, cameras
- Native programming and simulation tools (C++, Java, Python, GUIs)

Service Robots

Autonomous aircrafts

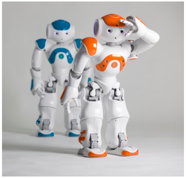
Courtesy DJI

Mobile platforms

Courtesy NASA/JPL-Caltech

Manipulation platforms

Humanoids



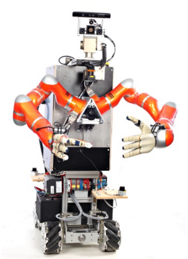
- Usually not very precise
- Not really dangerous
- Usually cognition-enabled
- Equipped with lots of sensors
- Usually running a Linux

Service Robots with Light-weight Arms

DLR Justin

Courtesy of DLR

Rosie / Boxy



- Moderately precise and dangerous
- Cognition-enabled
- Equipped with lots of sensors
- Usually running a combination of a real-time and non real-time OS.

Outline

Motivation

- Numerous different robotics labs, each with their own robot platforms, different operating systems and programming languages but similar software and hardware modules for most of them.

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  - Different operating systems

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  - Different operating systems
  - Distributed processing over multiple computers / robots

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  - Different operating systems
  - Distributed processing over multiple computers / robots
  - Easy software sharing mechanisms

Robot Operating System

At 2007 Willow Garage, a company founded by an early Google employee Scott Hassan at 2006 in the Silicon Valley, starts working on their Personal Robotics project and ROS.

=

Plumbing

+

Tools

+

Capabilities

+

Ecosystem

Robot Operating System [2]

ROS core components:

- Meta-Operating System for programming robotics software (configuring, starting / stopping, logging etc. software components)
- Middleware for communication of the components of a robotic system (distributed inter-process / inter-machine communication)
- A collection of packaging / build system tools with a strong focus on integration and documentation
- Language-independent architecture (C++, Python, Lisp, Java, JavaScript, ...)

ROS core software developed and maintained by OSRF and some externals.

Robot Operating System [3]

In addition, developed by the ROS community:

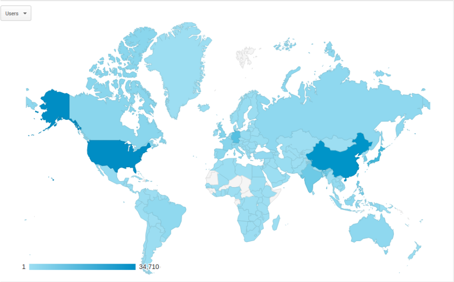
- hardware drivers
- libraries (PCL, OpenCV, TF, ...)
- capabilities (navigation, manipulation, control, ...)
- applications (fetching beer, making popcorn, ...)

ROS Community

From the community report:

1.	United States	34,710	(19.08%)
2.	China	31,946	(17.56%)
3.	Japan	15,518	(8.53%)
4.	Germany	12,711	(6.99%)
5.	India	8,400	(4.62%)
6.	Philippines	7,235	(3.98%)
7.	South Korea	6,790	(3.73%)
8.	United Kingdom	4,325	(2.38%)
9.	Taiwan	4,233	(2.33%)
10.	France	3,725	(2.05%)
11.	Canada	3,354	(1.84%)
12.	Spain	2,955	(1.62%)
13.	Singapore	2,842	(1.56%)
14.	Italy	2,744	(1.51%)
15.	Russia	2,465	(1.35%)
16.	Indonesia	2,461	(1.35%)
17.	Australia	2,436	(1.34%)
18.	Brazil	2,231	(1.23%)
19.	Hong Kong	2,147	(1.18%)
20.	Turkey	1,928	(1.06%)
21.	Netherlands	1,511	(0.83%)
22.	Thailand	1,437	(0.79%)
23.	Poland	1,335	(0.73%)
24.	Switzerland	1,242	(0.68%)
25.	Vietnam	1,125	(0.62%)

wiki.ros.org visitor locations:



Source: Google Analytics
Site: wiki.ros.org in July 2018

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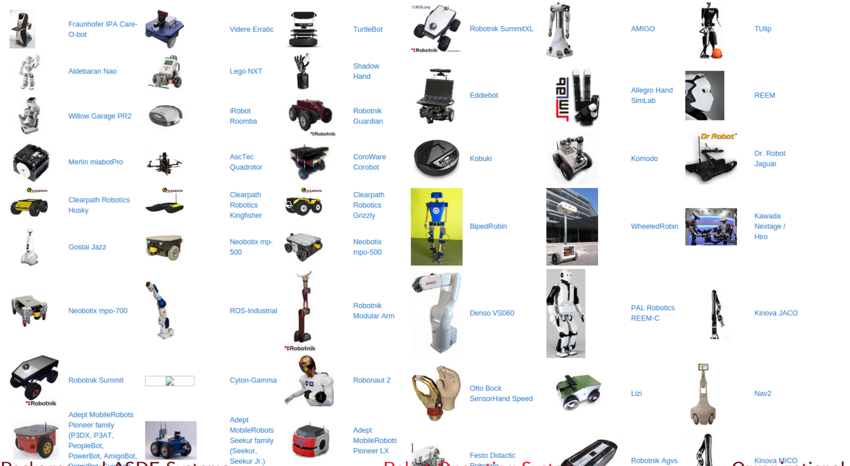
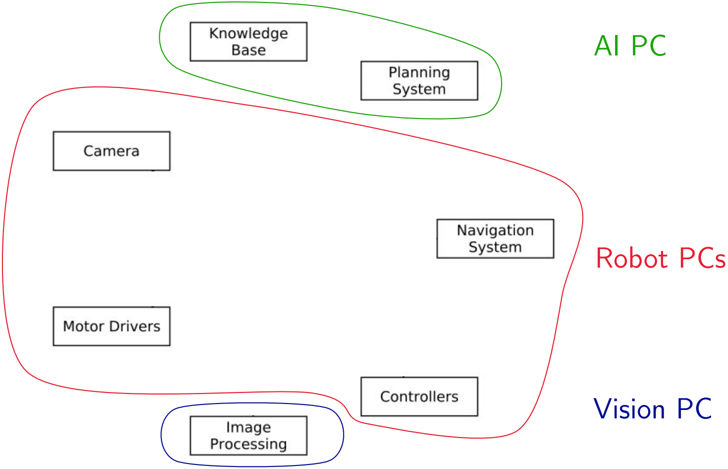
ROS Community [2]

Some robots supporting ROS (data from November 2014):

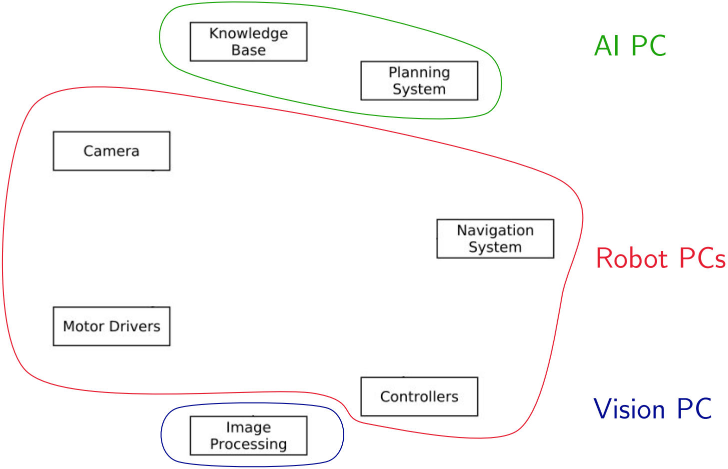


Outline

Robotic software components

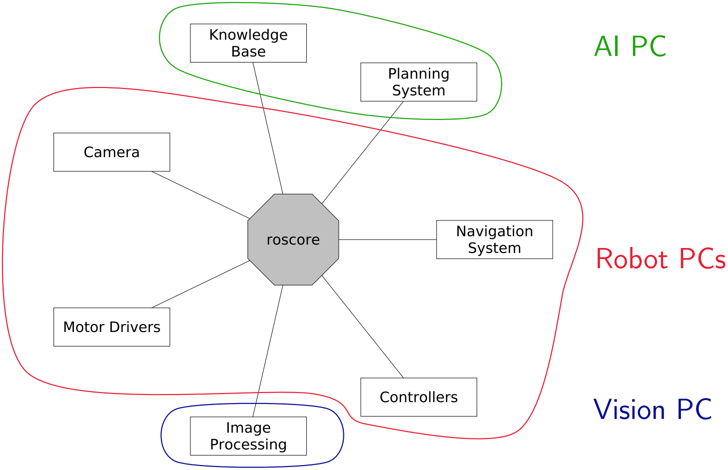


Robotic software components

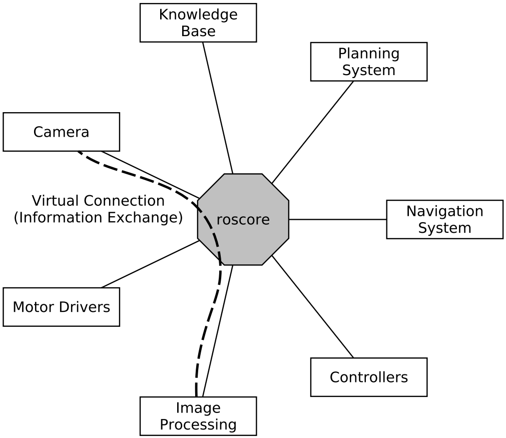


→ Processes distributed all over the place.

Connecting Pieces Together



Connecting Pieces Together [2]



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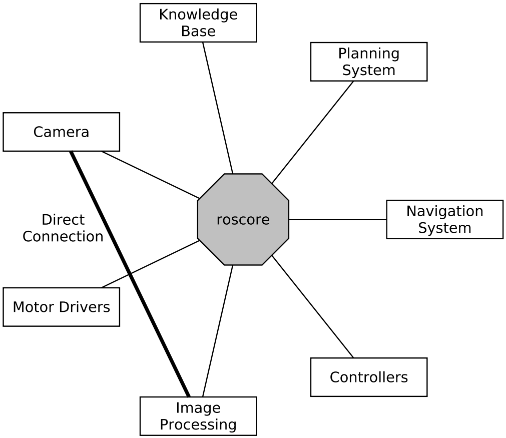

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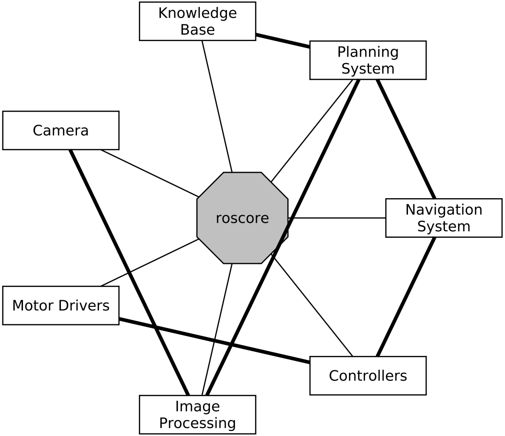
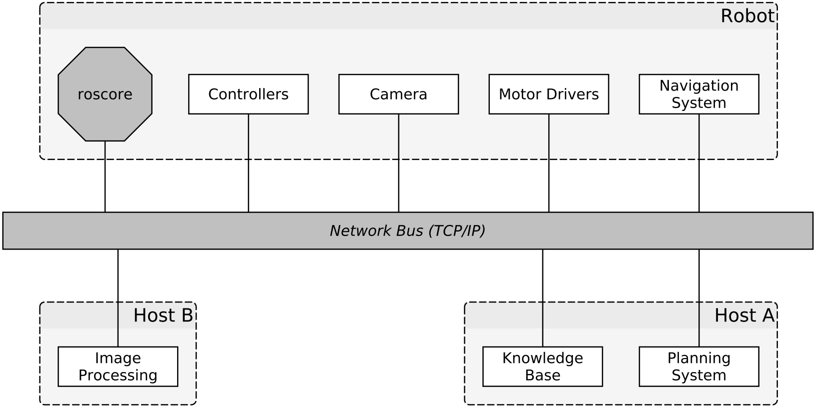


Distributed Hosts



roscore

- ROS master
  - A centralized XML-RPC server
  - Negotiates communication connections
  - Registers and looks up names of participant components
- Parameter Server
  - Stores persistent configuration parameters and other arbitrary data
- rosout
  - Distributed stdout

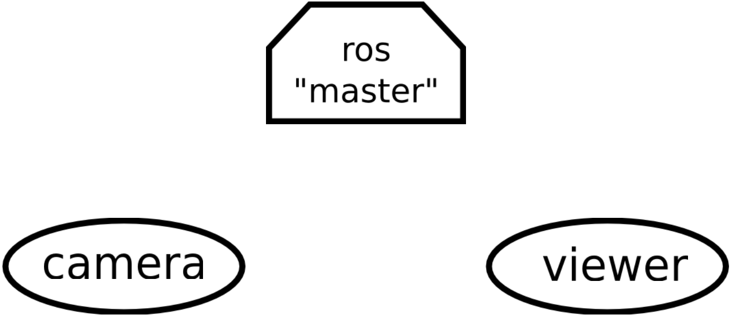
Terminology

- **Nodes** are processes that produce and consume data
- **Parameters** are persistent data stored on parameter server, e.g. configuration and initialization settings

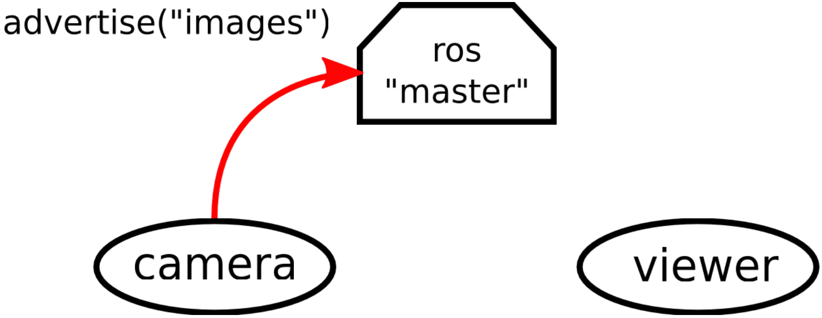
Node communication means:

- **Topics**: asynchronous many-to-many “streams-like”
  - Strongly-typed (ROS .msg spec)
  - Can have one or more *publishers*
  - Can have one or more *subscribers*
- **Services**: synchronous blocking one-to-many “function-call-like”
  - Strongly-typed (ROS .srv spec)
  - Can have only one *server*
  - Can have one or more *clients*
- **Actions**: asynchronous non-blocking one-to-many “function-call-like”
  - Built on top of topics but can be canceled

Establishing Communication



Establishing Communication



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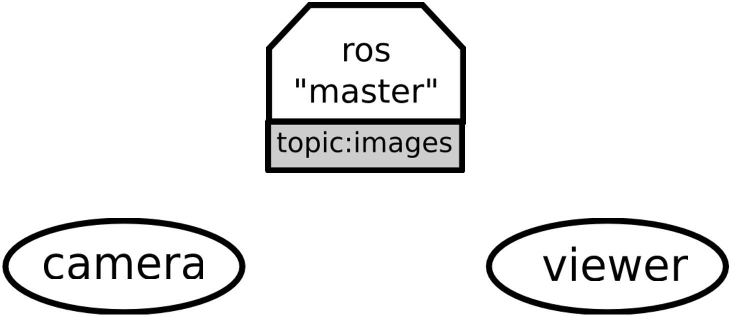

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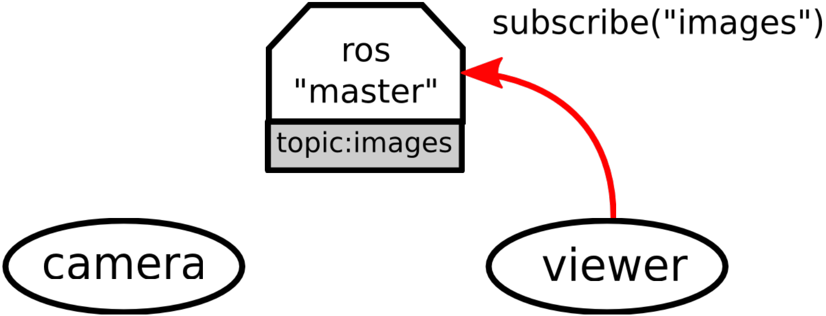

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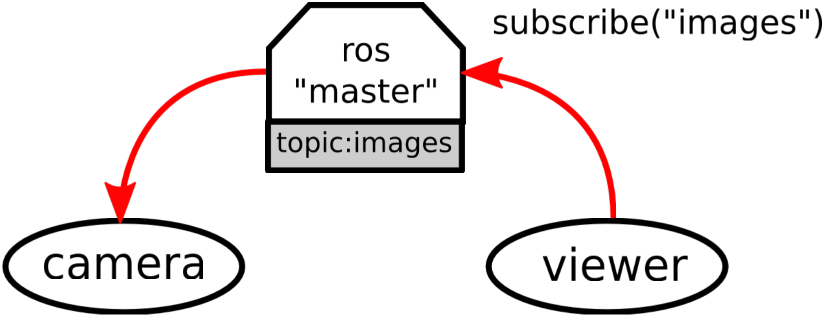

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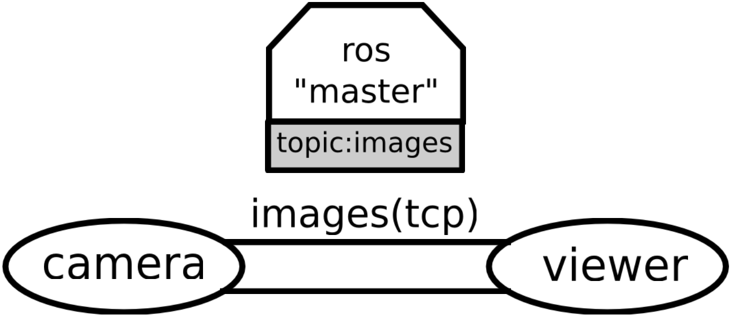

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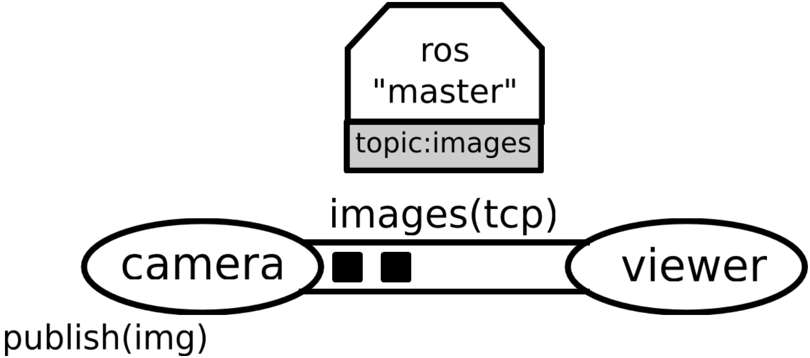

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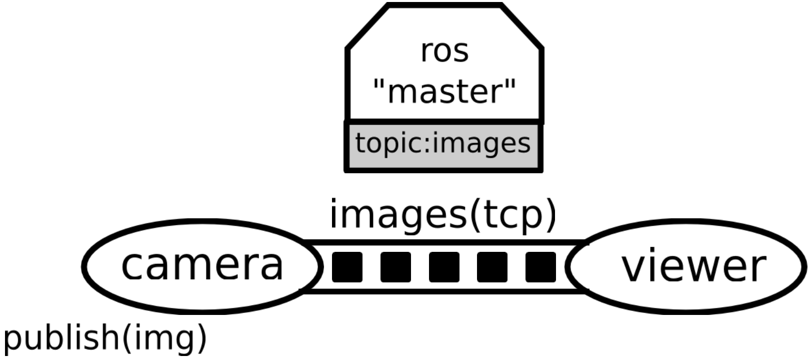

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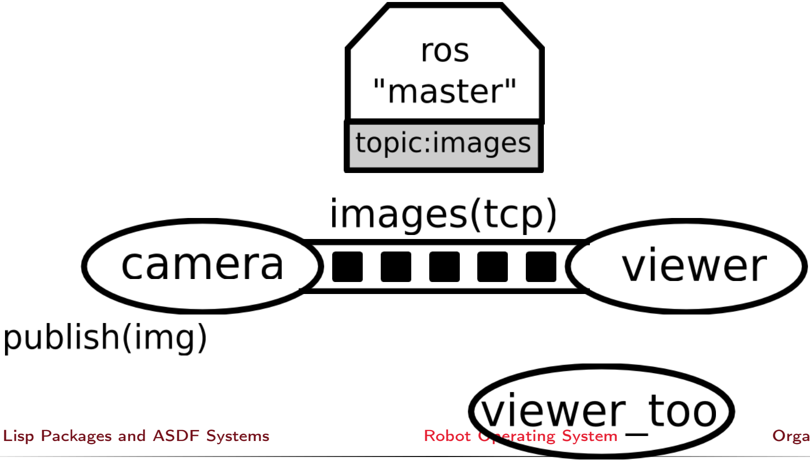

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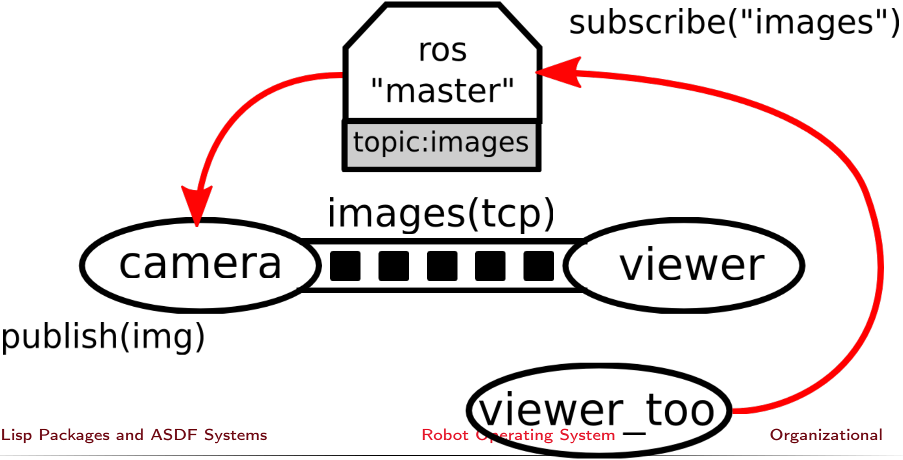

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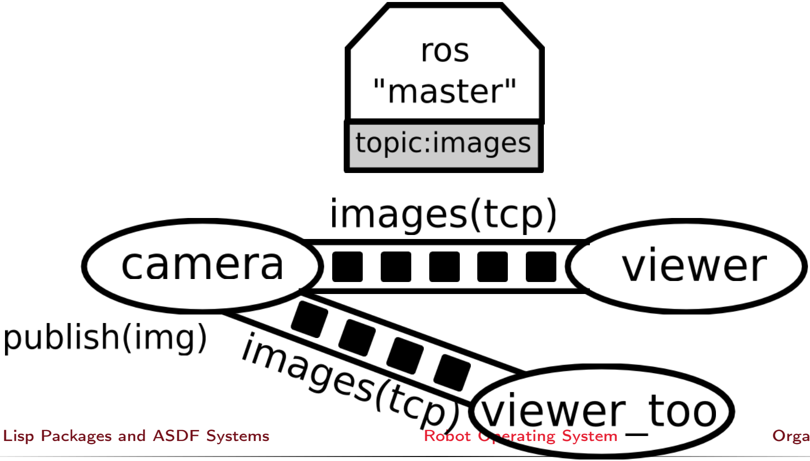


ROS Graph

- Starting the core:

```
$ roscore
```

- Starting a node:

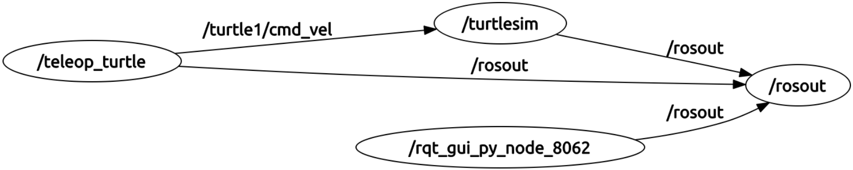
```
$ rosrun turtlesim turtlesim_node
```

- Starting another node:

```
$ rosrun turtlesim turtle_teleop_key
```

- Examining the ROS Graph:

```
$ rqt_graph
```



Tools

- `rosnode`: gives the user information about a node

  ```
  $ rosnode -h
  ```

  ```
  cleanup, info, kill, list, machine, ping
  ```

- `rostopic`: gives publishers, subscribes to the topic, datarate, the actual data

  ```
  bw, echo, find, hz, info, list, pub, type
  ```

- `rosservice`: enables a user to call a ROS Service from the command line

  ```
  call, find, list, type, uri
  ```

- `rosmsg`: gives information about message types

  ```
  list, md5, package, packages, show
  ```

- `rossrv`: same as above for service types

  ```
  list, md5, package, packages, show
  ```

- `roswtf`: diagnoses problems with a ROS network

Outline

Packages and Metapackages

- *Packages* are a named collection of software that is built and treated as an atomic dependency in the ROS build system.
- *Metapackages* are dummy "virtual" packages that reference one ofr more related packages which are loosely grouped together

Similar to Debian packages.
Actually released through the Debian packaging system.

ROS Workspace

Packages are stored in ROS workspaces:

```
$ roscd
```

Workspaces have a specific structure

```
├── build
├── devel
├── install
└── src
    ├── CMakeLists.txt
    ├── ros_package_1
    └── metapack_repo_1
        ├── metapackage_1
        ├── ros_package_2
        └── ros_package_3
            ├── CMakeLists.txt
            ├── package.xml
            ├── asdf-system.asd
            └── src
```

Managing Packages

- Creating a package:

```
$ roscd && cd src/lisp_course_material
$ catkin_create_pkg assignment_6 roslisp turtlesim geometry_msgs
```

- Compiling a package:

```
$ roscd && catkin_make
```

- Moving through ROS workspaces:

```
$ roscd assignment_6
```

Naming convention: underscores (no CamelCase, no-dashes)!

All the packages in your workspace are one huge CMake project.

→ Multiple workspaces chained together.

Package.xml

assignment_6/package.xml

```
<?xml version="1.0"?>
<package>
  <name>assignment_6</name>
  <version>0.0.0</version>
  <description>The assignment_6 package</description>
  <maintainer email="kazhoyan@cs.uni-bremen.de">Gaya</maintainer>
  <license>Public domain</license>
  <buildtool_depend>catkin</buildtool_depend>
  <build_depend>geometry_msgs</build_depend>
  <build_depend>roslisp</build_depend>
  <build_depend>turtlesim</build_depend>
  <run_depend>geometry_msgs</run_depend>
  <run_depend>roslisp</run_depend>
  <run_depend>turtlesim</run_depend>
</package>
```

CMakeLists

assignment_6/CMakeLists.txt

```
cmake_minimum_required(VERSION 2.8.3)
project(assignment_6)
find_package(catkin REQUIRED COMPONENTS
  roslisp
  geometry_msgs
)
catkin_package(
  CATKIN_DEPENDS roslisp geometry_msgs
)
```

Launch Files

Automated Starting, Stopping and Configuring the Nodes

XML files for launching nodes:

- automatically set parameters and start nodes with a single file
- hierarchically compose collections of launch files
- automatically re-spawn nodes if they crash
- change node names, namespaces, topics, and other resource names
- without recompiling
- easily distribute nodes across multiple machines

Launch Files [2]

Automated Starting, Stopping and Configuring the Nodes

Example

```
<launch>
  <!-- Starting nodes-->
  <node pkg="turtlesim" type="turtlesim_node" name="sim"/>
  <node pkg="turtlesim" type="turtle_teleop_key" name="teleop"
        output="screen"/>

  <!-- Setting parameters -->
  <param name="some_value" type="double" value="2.0"/>
</launch>
```

Using the launch file:

```
$ roslaunch package_name launch_file_name
```

Outline

ROS API

ROS API provides the programmer with means to

- start ROS node processes
- generate messages
- publish and subscribe to topics
- start service servers
- send service requests
- provide and query action services
- find ROS packages
- ...

ROS APIs: `roscpp`, `rospy`, `rosjava`, `rosjs`, **`roslisp`**

Links

- ROS documentation
  `http://wiki.ros.org/`
- ROS community support
  `http://answers.ros.org/questions/`

Outline

Organizational Info

- Tutorial link:

  `http://wiki.ros.org/roslisp/Tutorials/OverviewVersion`
- Grades: 5 points for this assignment
- Due: 05.12, 23:59 AM German time
- Next class: 06.12, 14:15

Q & A

Thanks for your attention!

Special thanks to Lorenz Mösenlechner and Jan Winkler for providing illustrations!