ROS Crash-Course, Part I

Introduction to ROS distribution, build system and infrastructure

Jonathan Bohren

With some information and figures adapted from `http://www.ros.org` and the COTESYS-ROS School 2010 presentation given by Radu Rusu

LABORATORY FOR
Computational Sensing + Robotics
THE JOHNS HOPKINS UNIVERSITY

Outline

Outline (revisted)

What is ROS?

More than just middleware

- A "meta" operating system for robots
- A collection of packaging, software building tools
- An architecture for distributed* inter-process/inter-machine communication and configuration
- Development tools for system runtime and data analysis
- Open-source under permissive BSD licenses (*ros core libraries*)
- A language-independent architecture (c++, python, lisp, java, *and more*)
- A *scalable* platform (ARM CPUS to Xeon Clusters)

With the intent to enable researchers to rapidly develop new robotic systems without having to "reinvent the wheel" through use of standard tools and interfaces.

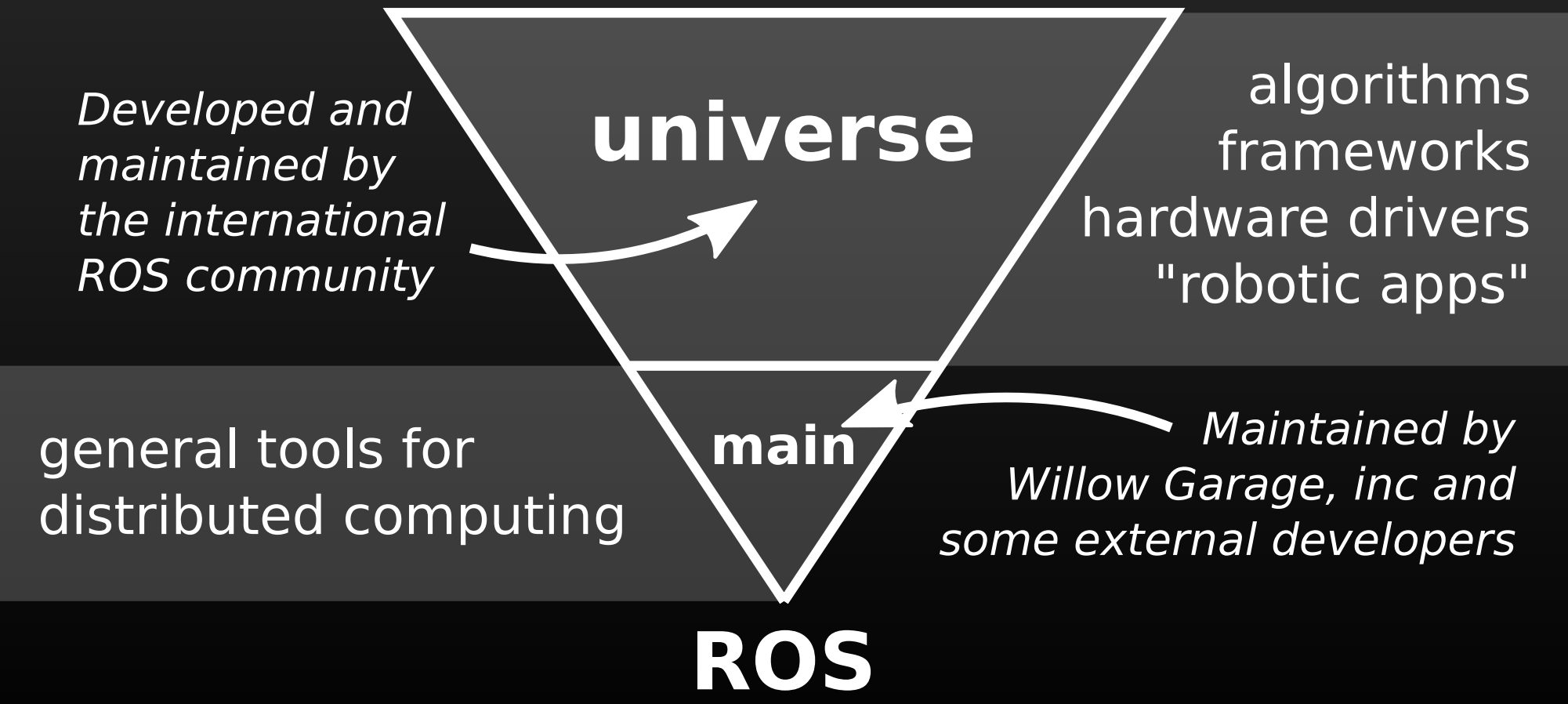
What is ROS *not*?

No confusion

- An *actual* operating system
- A programming language
- A programming environment / IDE
- A hard real-time architecture*

What does ROS get you?

All levels of development



What does ROS get you?

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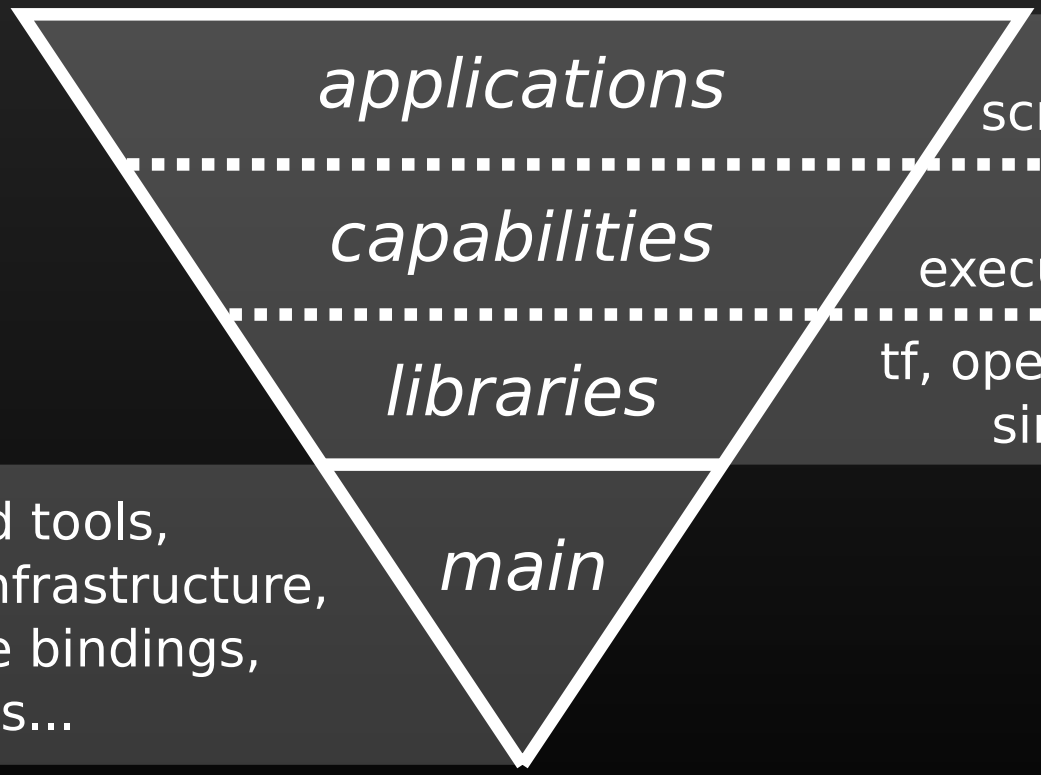


fetching beer, scraping the seafloor

grasping, control, execution, navigation...

tf, opencv, pcl, kdl, cisst, simulation, drivers...

packaging & build tools, communication infrastructure, ROS API language bindings, introspection tools...

Outline (revisted)

ROS Core

Where it all comes together

Thr ROS core is a set of the only three programs that are necessary for the ROS runtime. They include:

- ROS Master
  - A centralized XML-RPC server
  - Negotiates communication connections
  - Registers and looks up names for ROS graph resources
- Parameter Server
  Stores persistent configuration parameters and other arbitrary data
- rosout
  Essentially a network-based `stdout` for human-readable messages

ROS "Graph" Abstraction

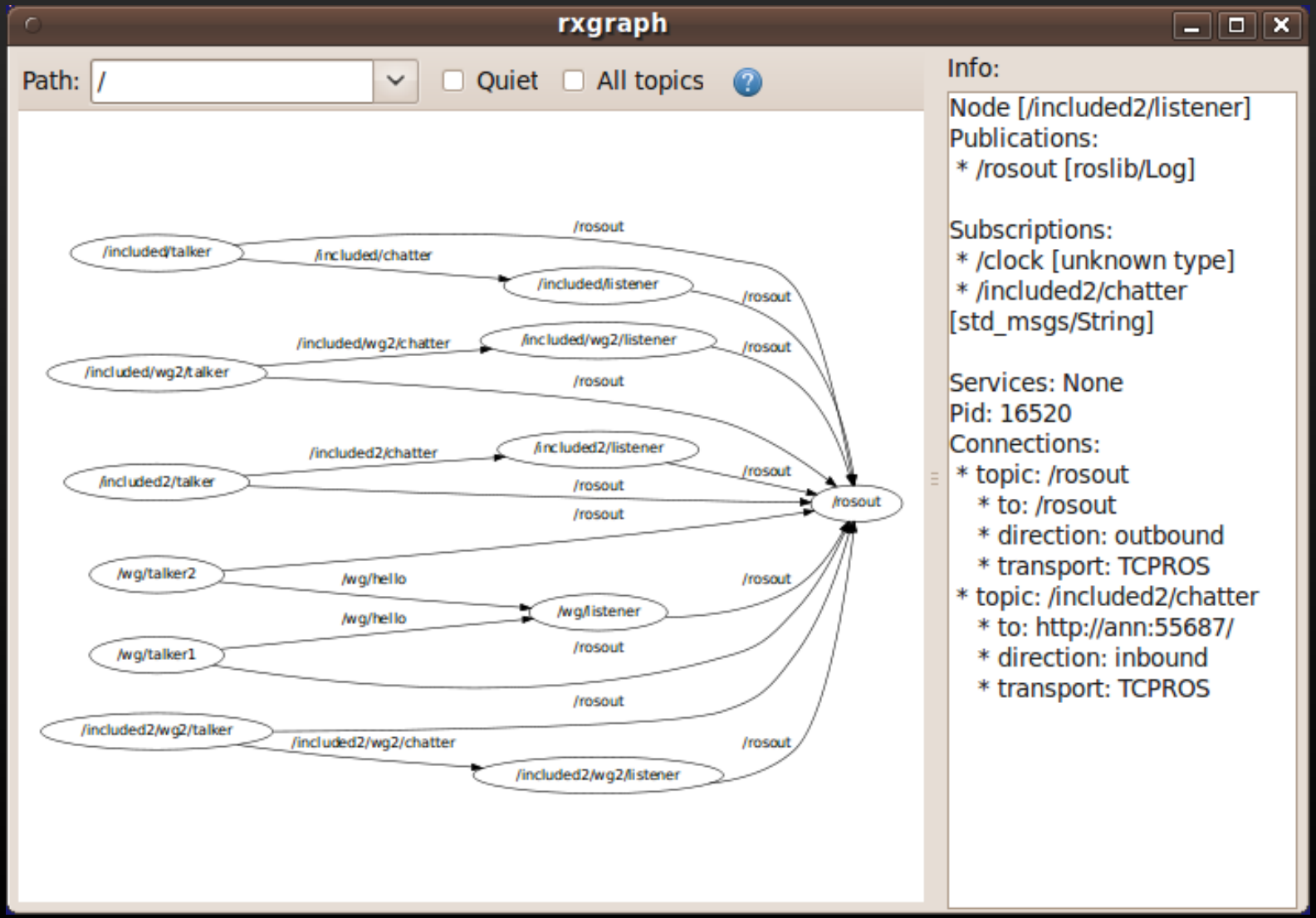
Named network resources

The ROS runtime designates several classes of named ROS *graph resources*. These resources can exist in namespaces to reduce naming collisions, and fall into the following categories:

- nodes
  Represent processes distributed across the ROS network. A ROS node is a source and sink for data that is sent over the ROS network.
- parameters
  Persistent (while the core is running) data such as configuration & initialization settings, stored on the parameter server.
- topics
  Asynchronous many-to-many communication streams.
- services
  Synchronous one-to-many network-based functions.

ROS "Graph"

rxgraph: communication network visualization



Creating and Running ROS Nodes

Distributing computation with ROS

ROS provides a mechanism for simultaneously configuring and *launching* collections of ROS nodes. This is done with lightweight xml files and the `roslaunch` program.

Launch files enable users to:

- Associate a set of parameters and nodes with a single file
- Hierarchically compose collections of other 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
- Attach `gdb` to a series of nodes

ROS Communication Protocols

Connecting nodes over the network

ROS supports a growing number of communication capabilities that enable distributing computation in a robotic system. These capabilities are currently built entirely on two high-level communication APIs:

- ROS Topics
  - Asynchronous "stream-like" communication
  - TCP/IP or UDP Transport
  - Strongly-typed (ROS .msg spec)
  - Can have one or more *publishers*
  - Can have one or more *subscribers*

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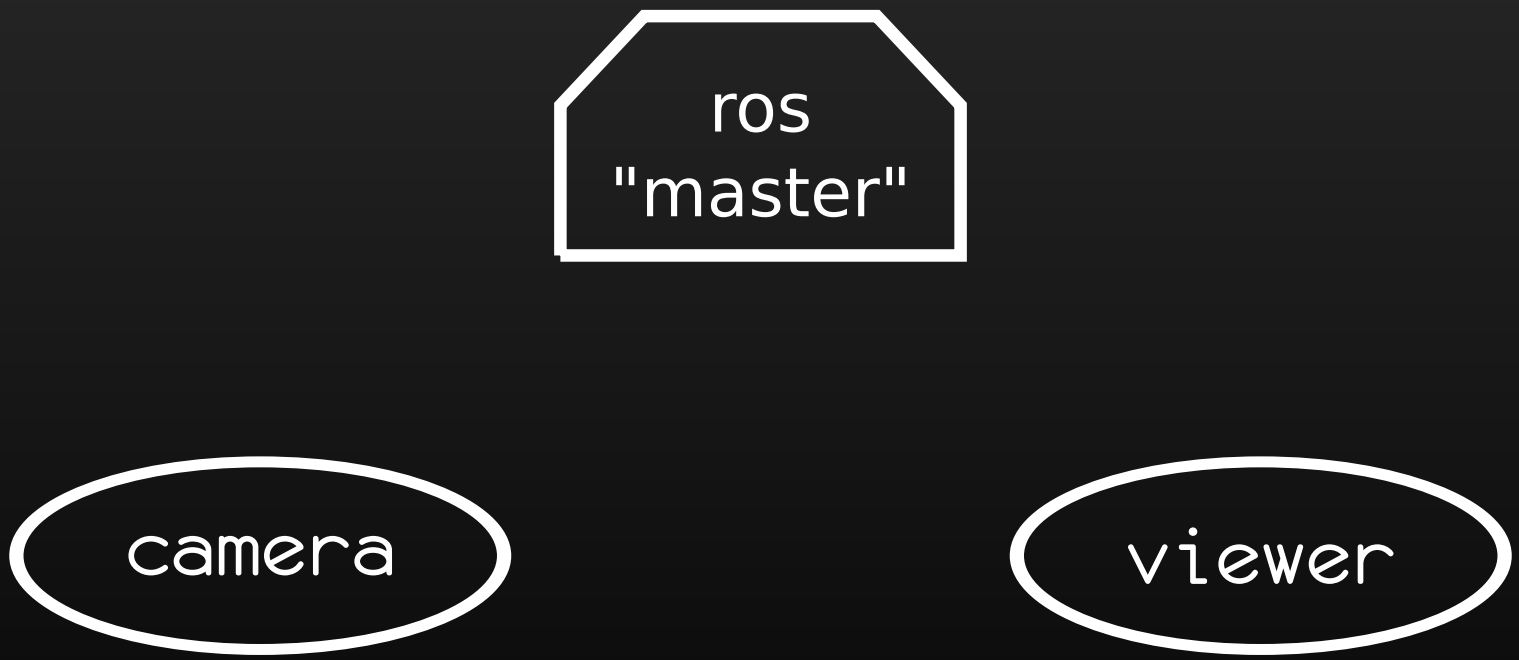
- ROS Services
  - Synchronous "function-call-like" communication
  - TCP/IP or UDP Transport
  - Strongly-typed (ROS .srv spec)
  - Can have only one *server*
  - Can have one or more *clients*

Asynchronous Distributed* Communication

ROS TCP Topics



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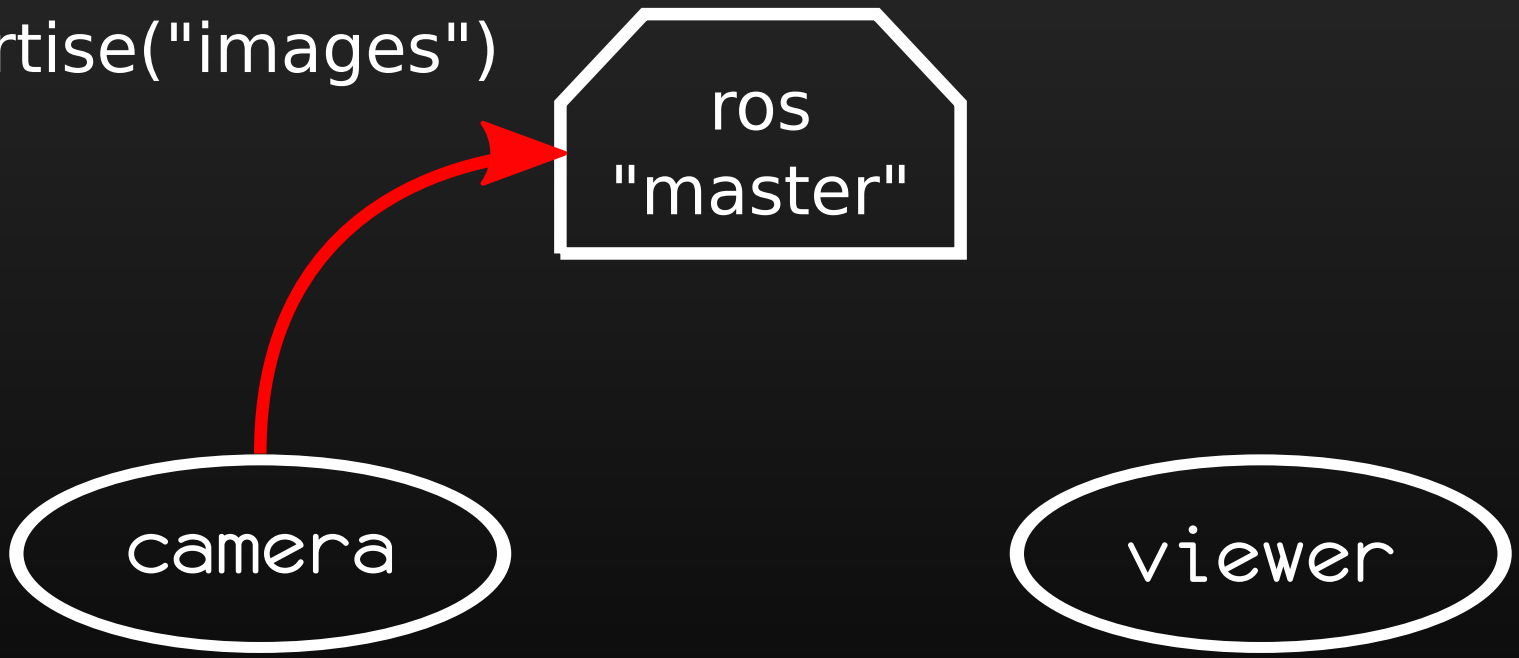

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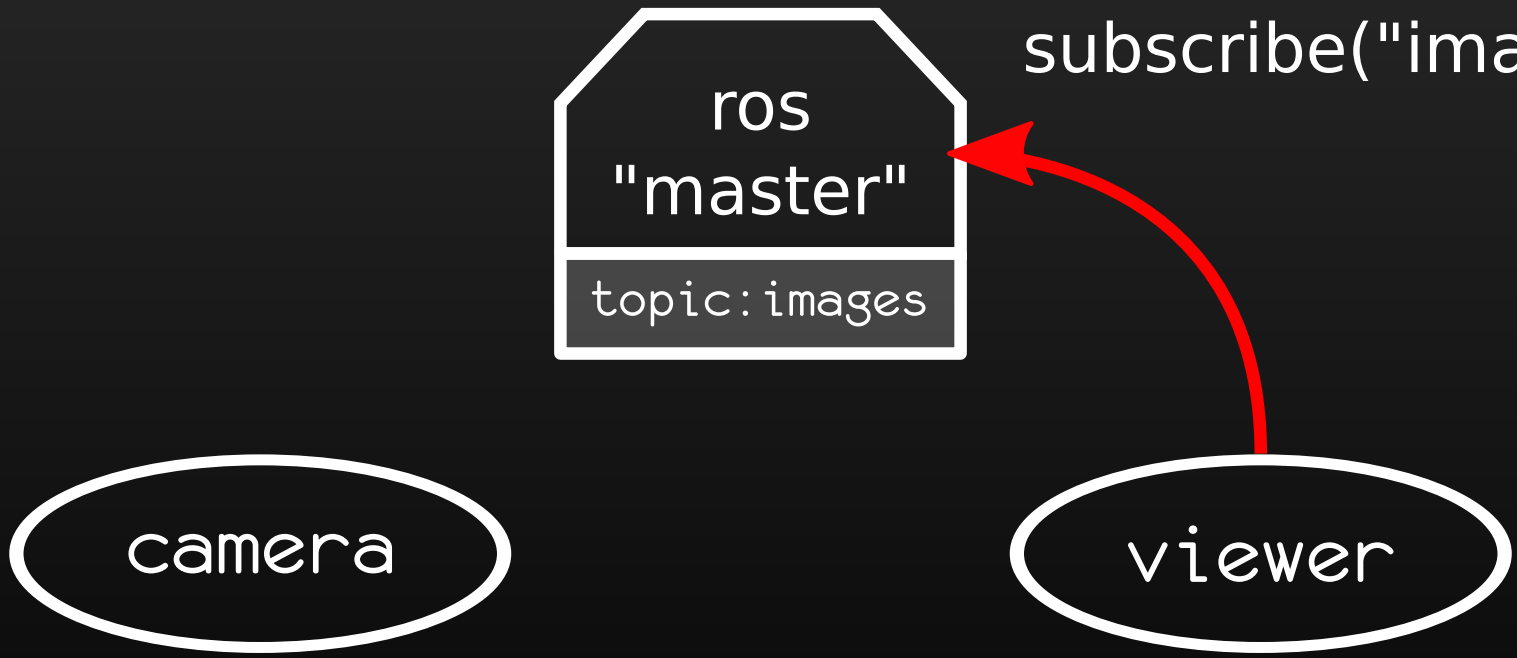

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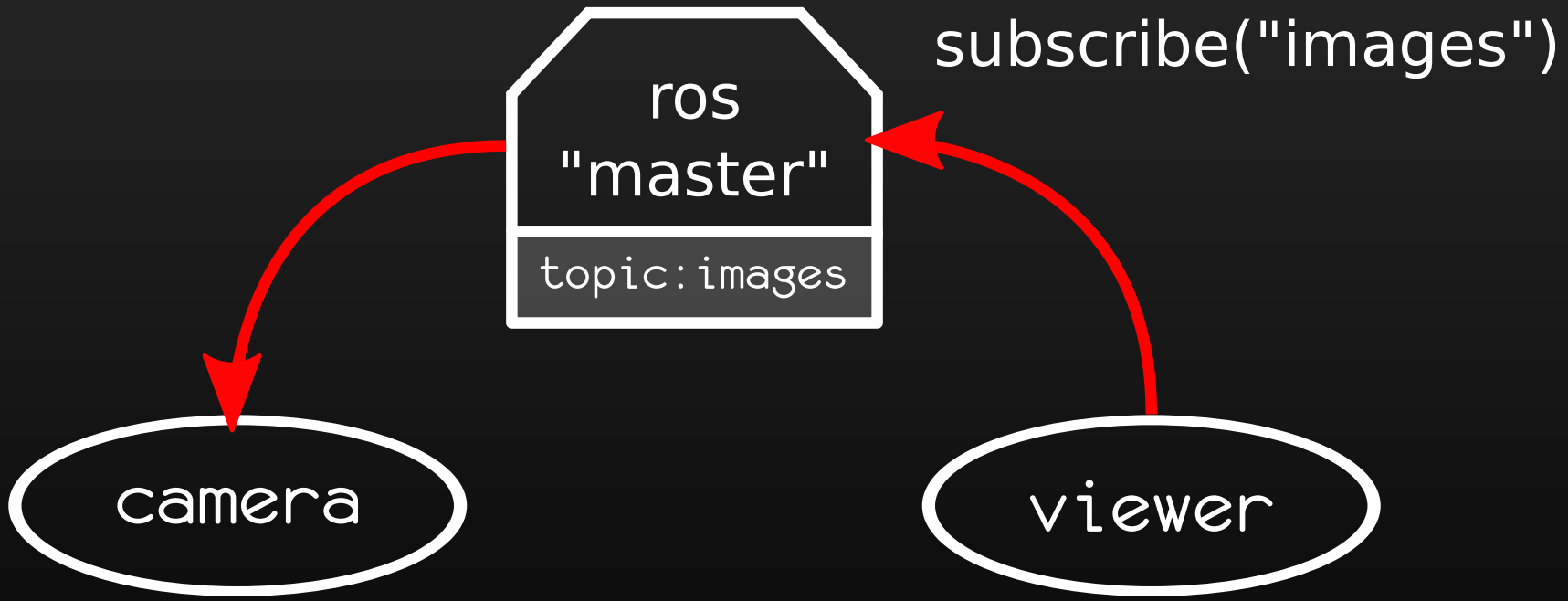

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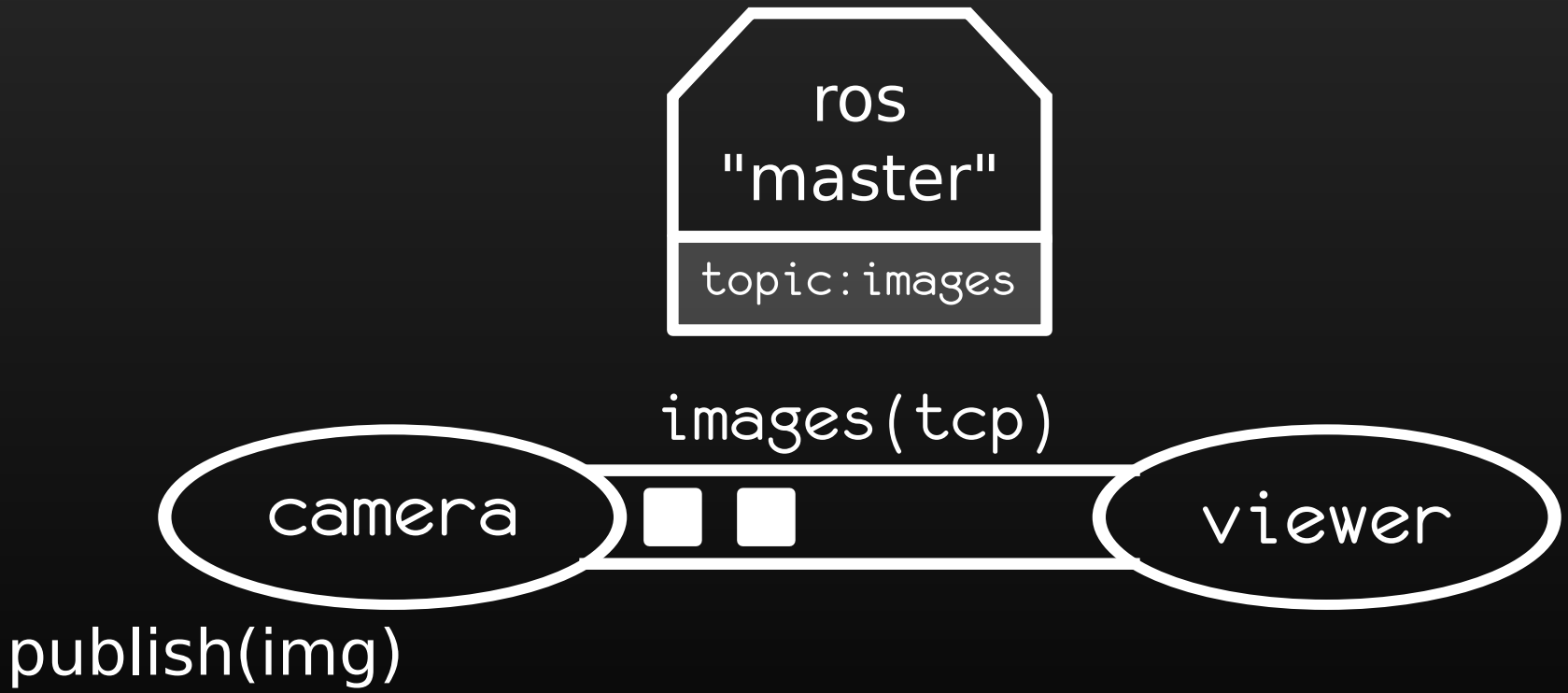

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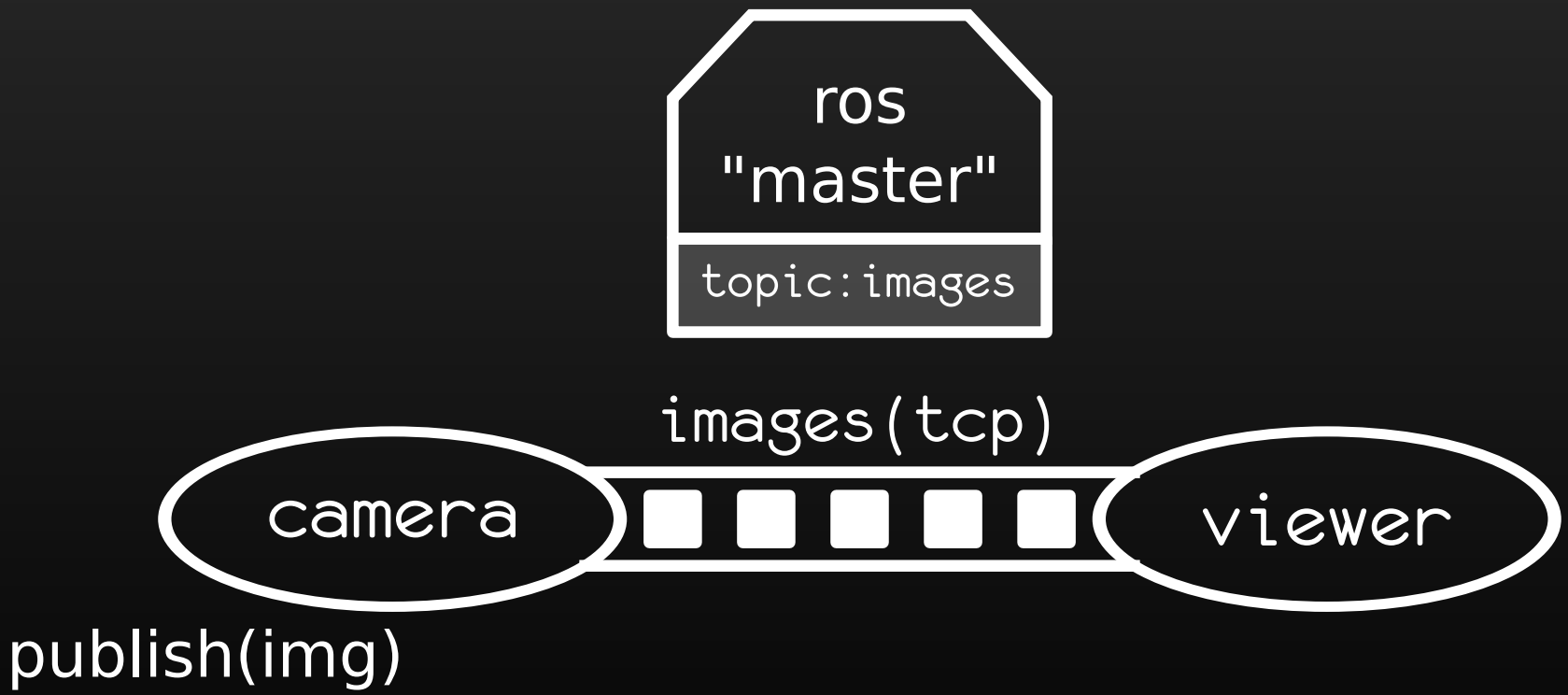

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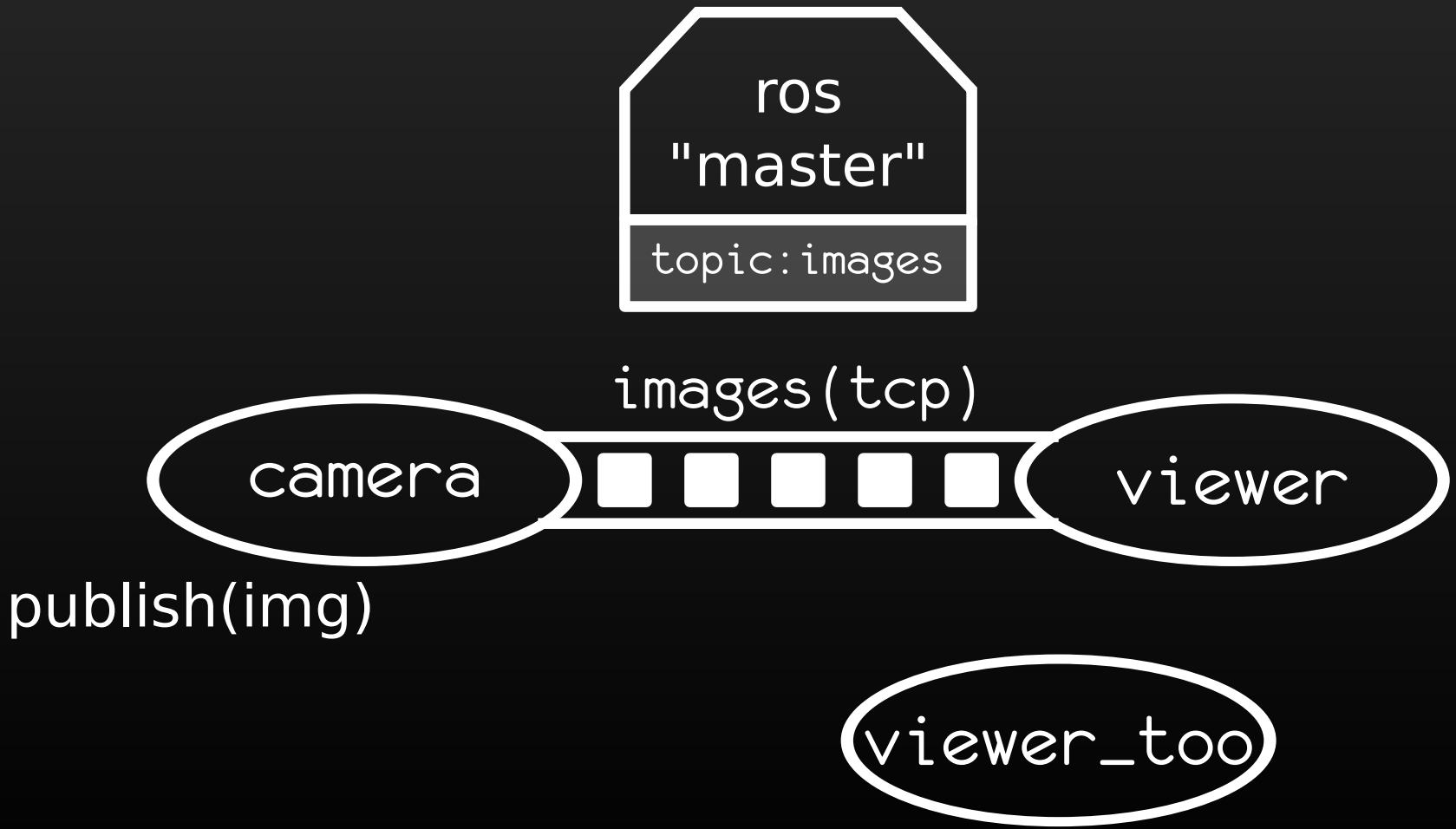

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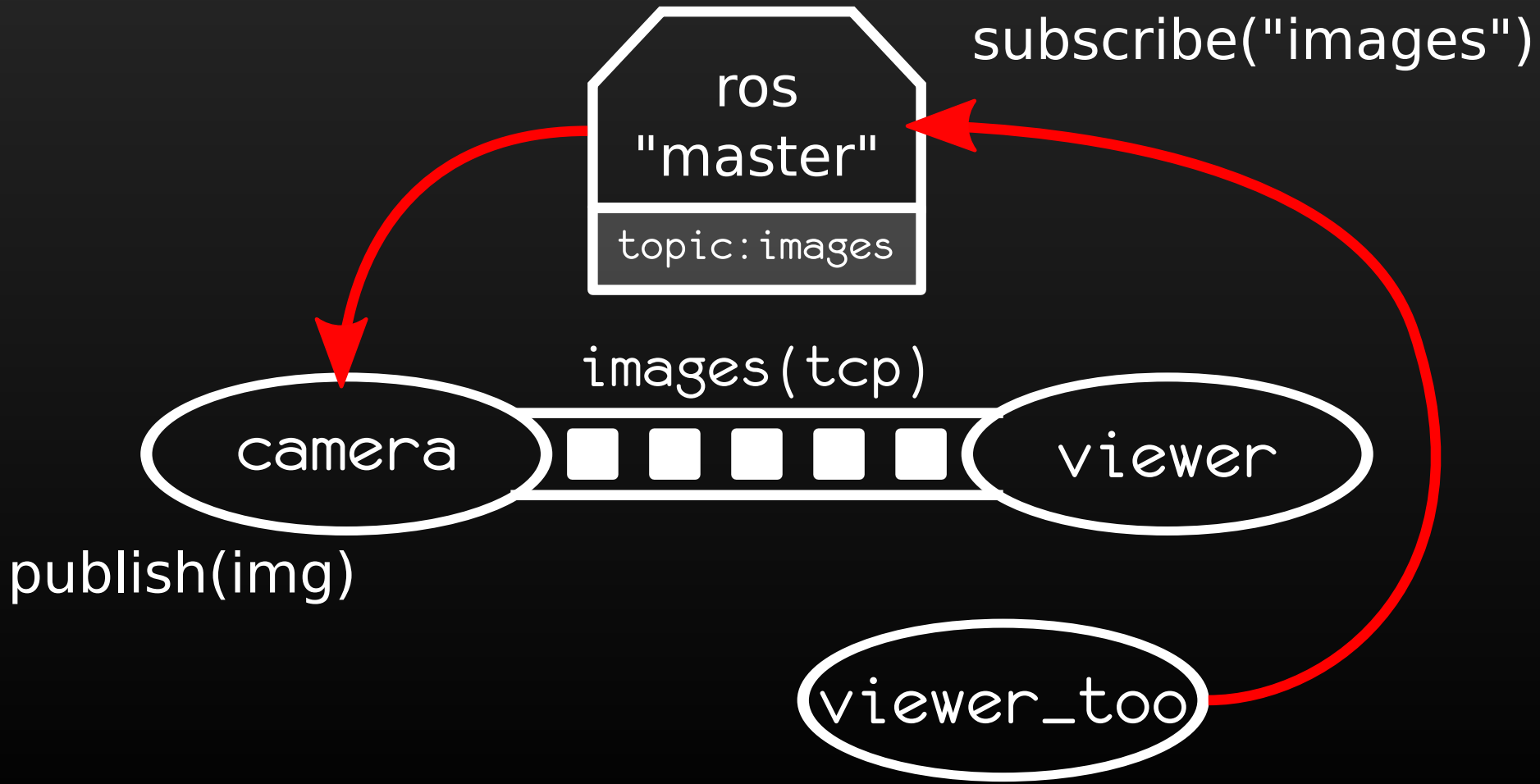

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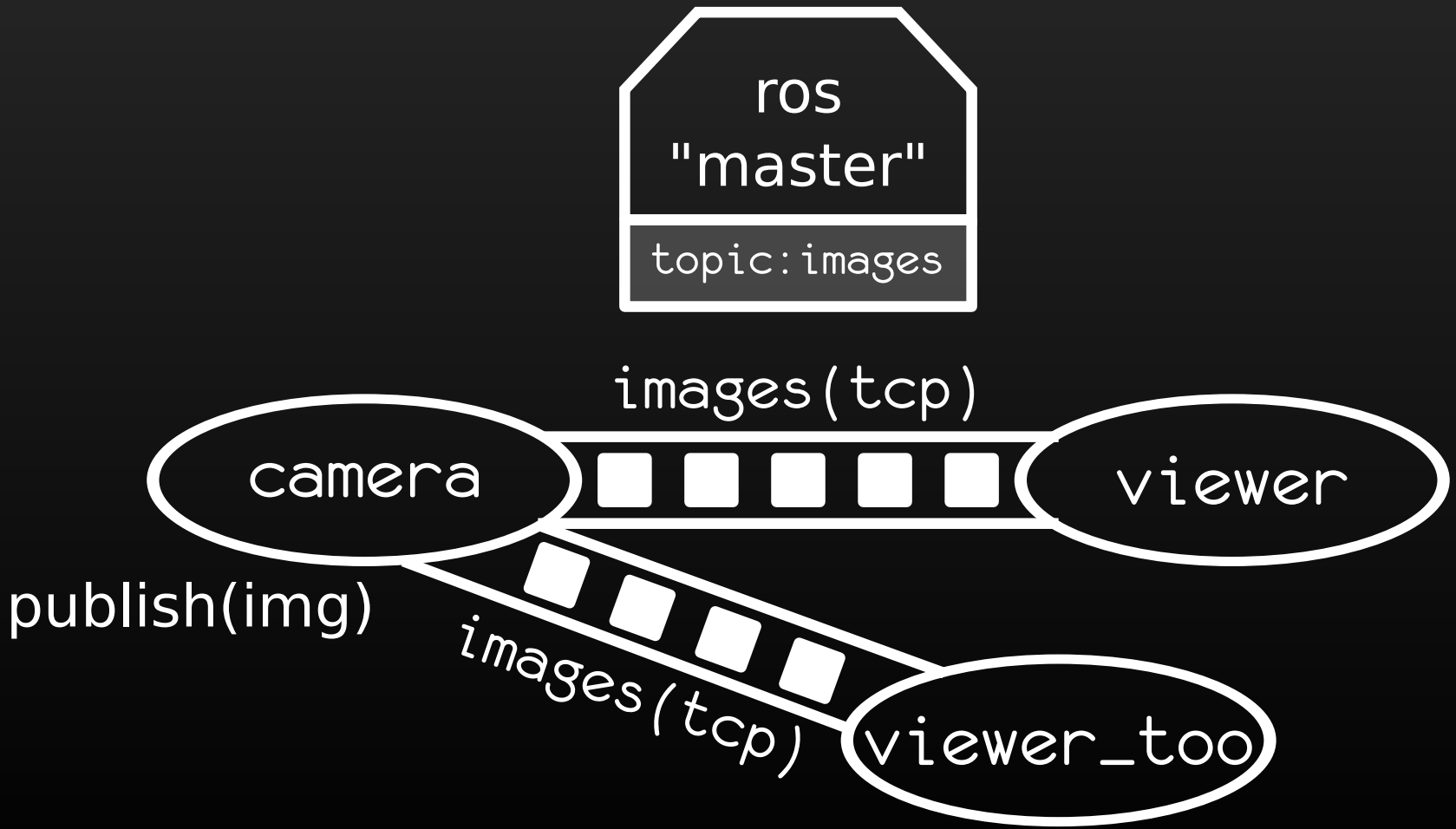


rosout Messaging

stdout on steroids

ROS provides mechanisms in all languages for specifying different *levels* of human-readable log messages. The five default levels are:

- fatal
- error
- warn
- info
- debug

These enable a user to "add printf's" to their code for debugging, and selectively enable and disable them *at runtime* without a large performance hit. For example, useful debug messages that might be necessary to diagnose a problem could be left in the code and re-enabled at a critical time.

ROS Graph Introspection

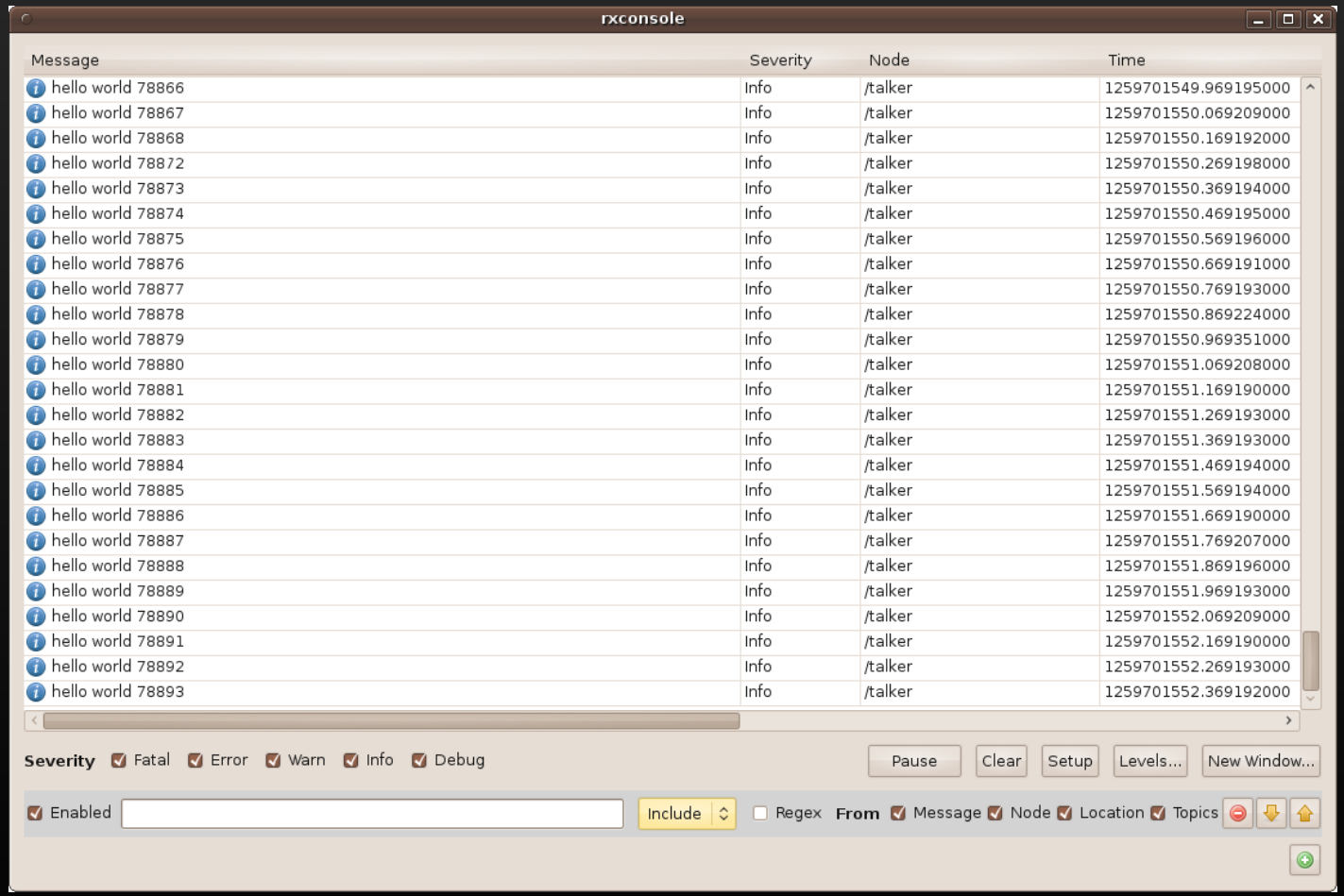
No more wireshark

ROS provides several tools for analyzing the data flowing over ROS communcation resources:

- `rosnode`
  Gives a user infomation about a node: publications, subscriptions, etc
- `rostopic`
  Gives datarate, actual data, publishers, subscribes
- `rosservice`
  Enables a user to call a ROS Service from the command line
- `roswtf` (wire trouble finder)
  Diagnoses problems with a ROS network

ROS GUI Tools

There are lots. . .



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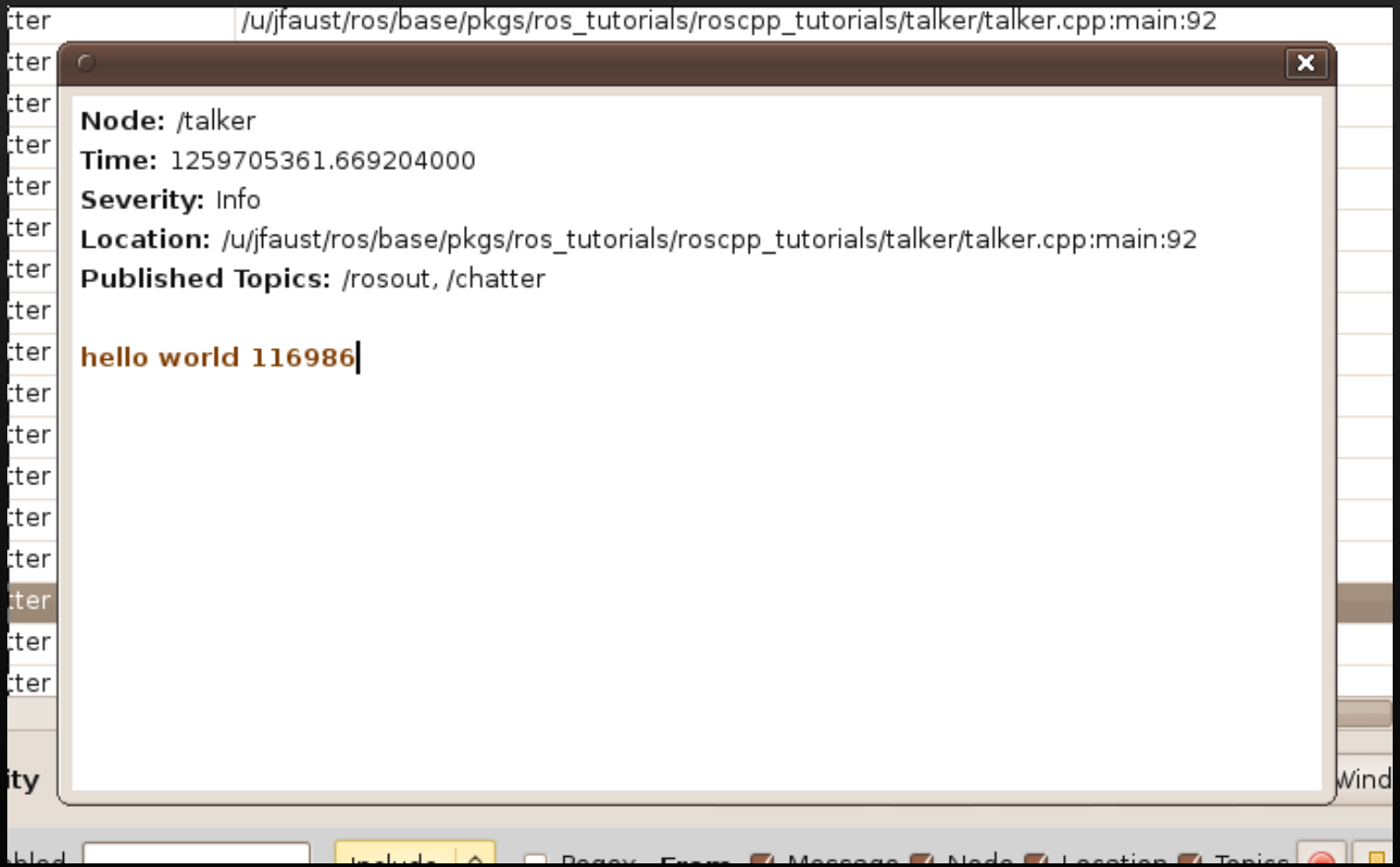

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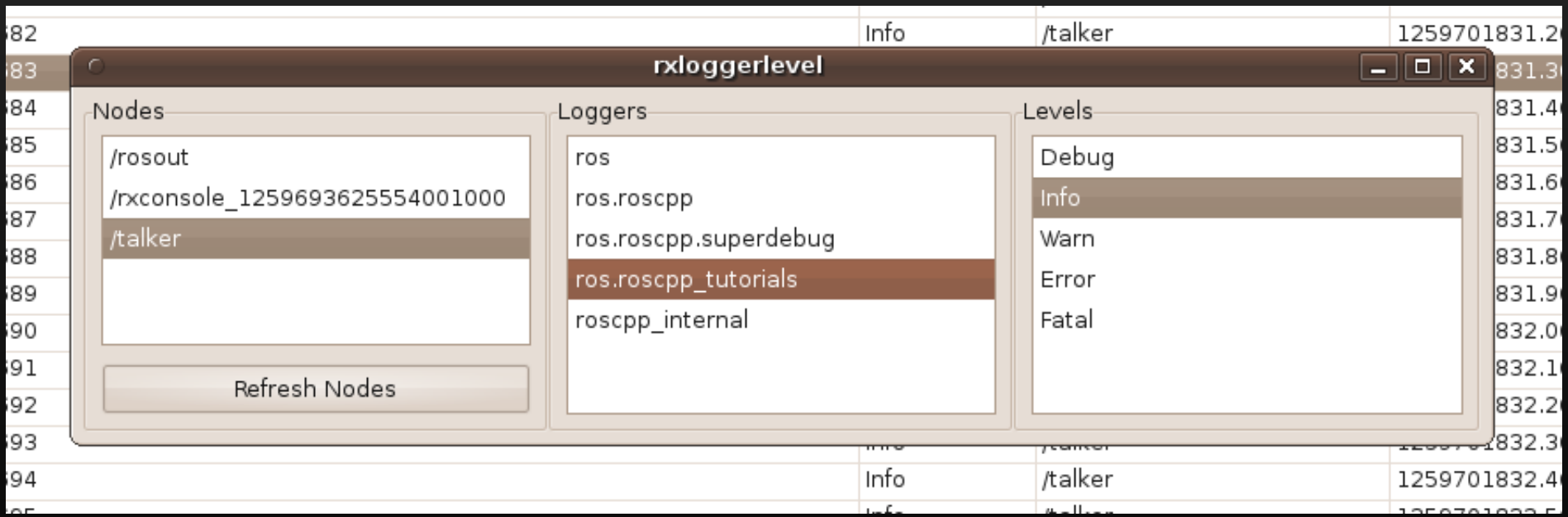

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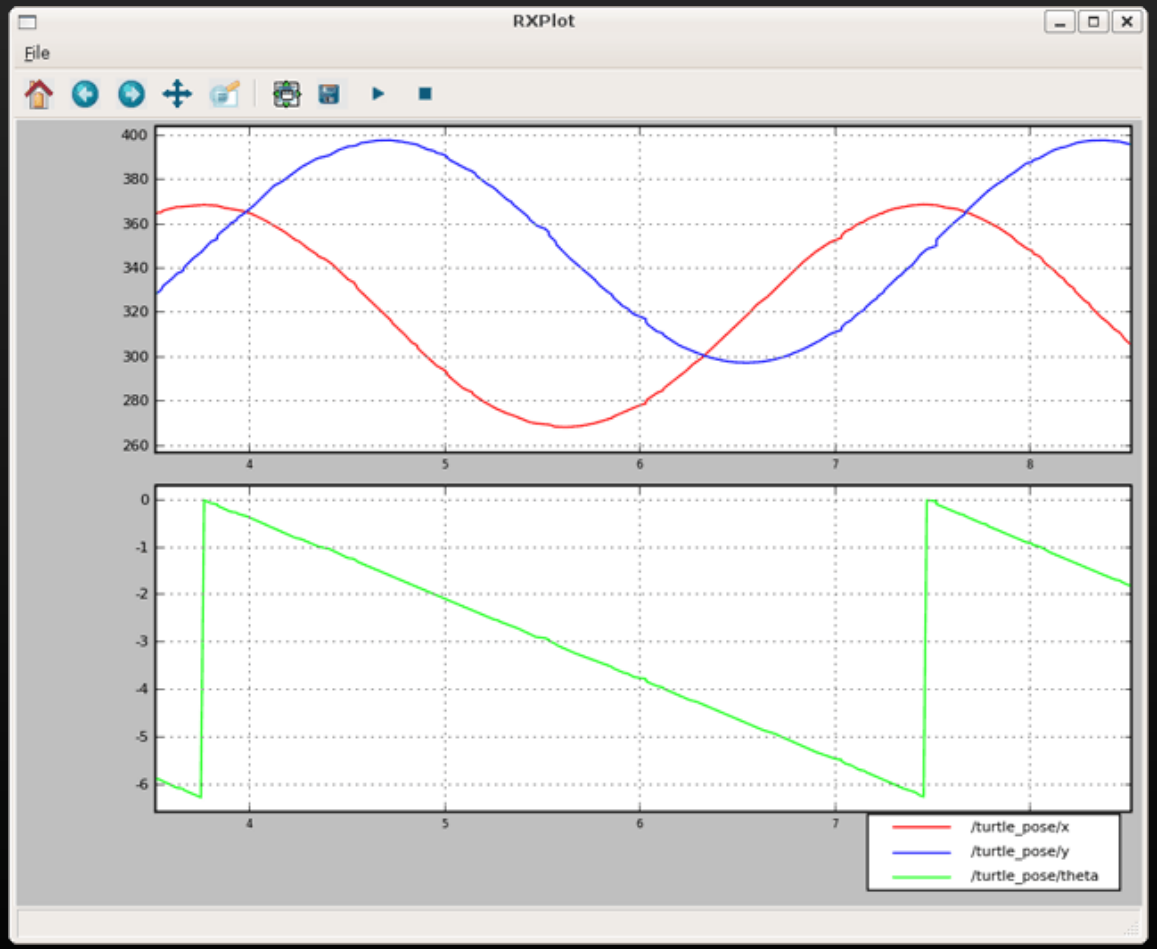

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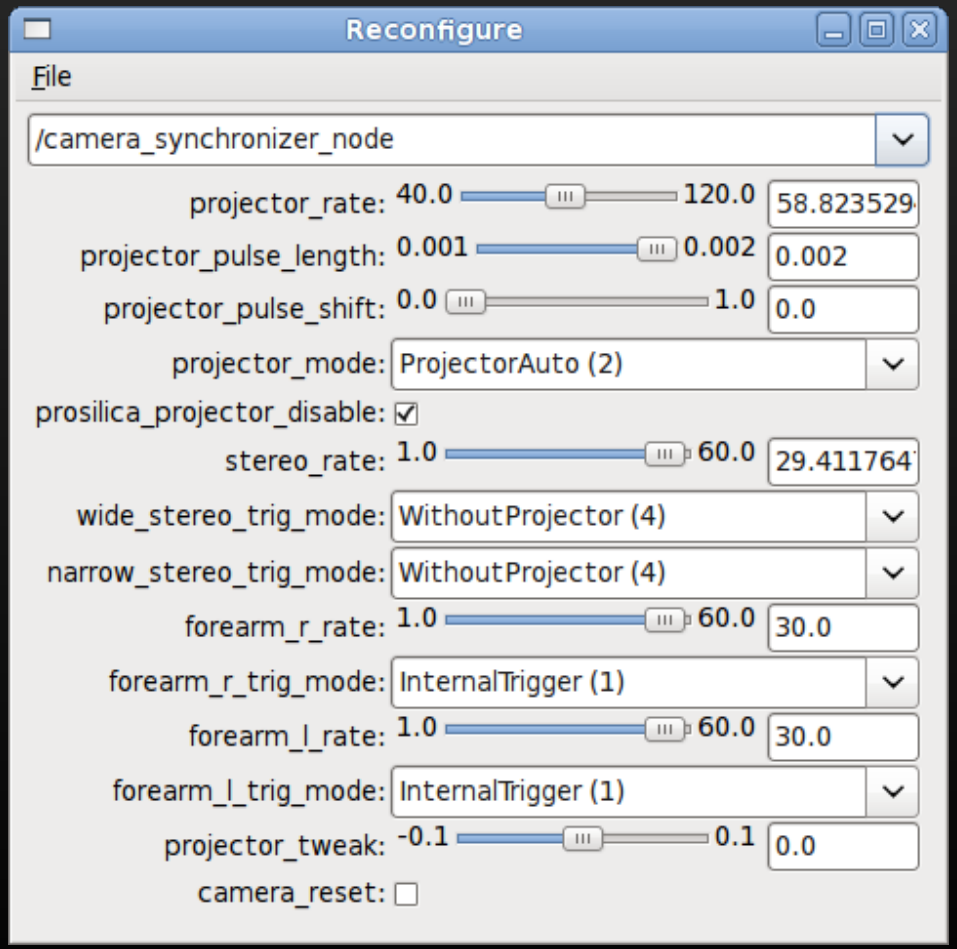

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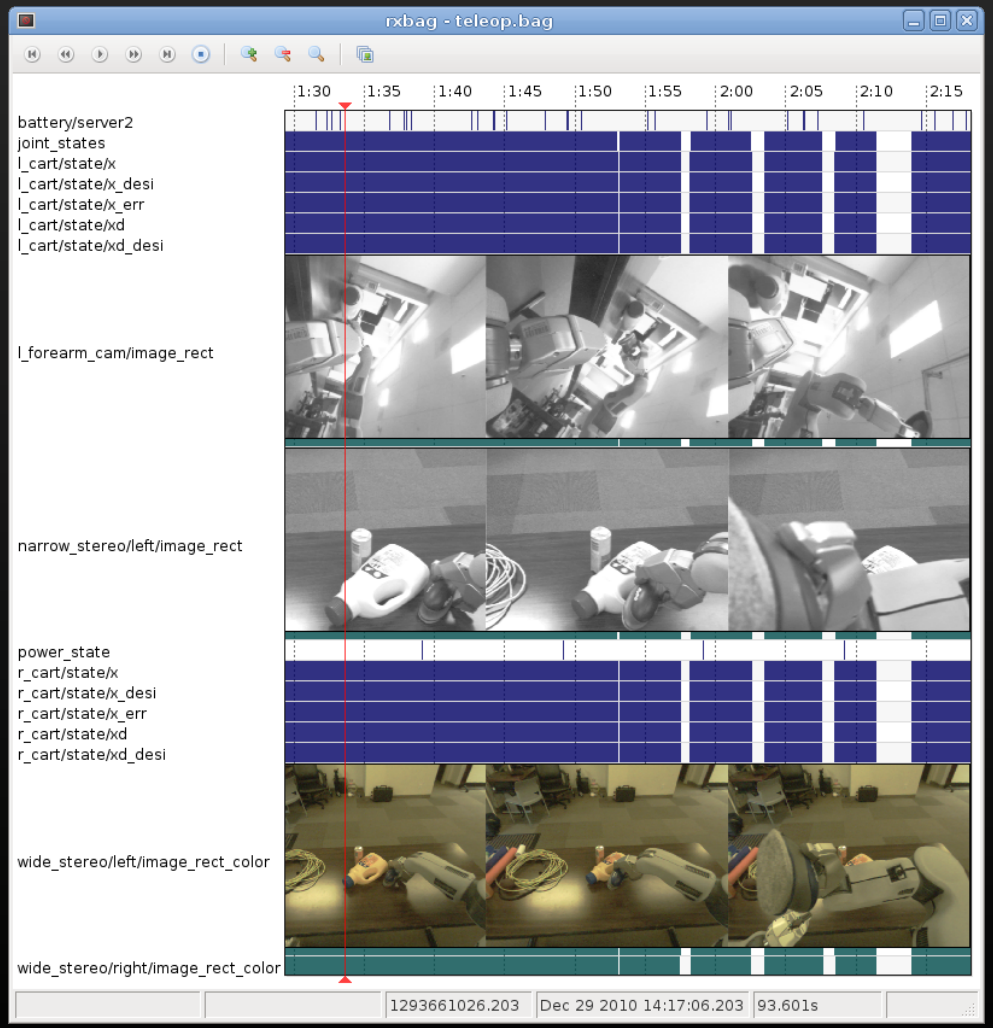
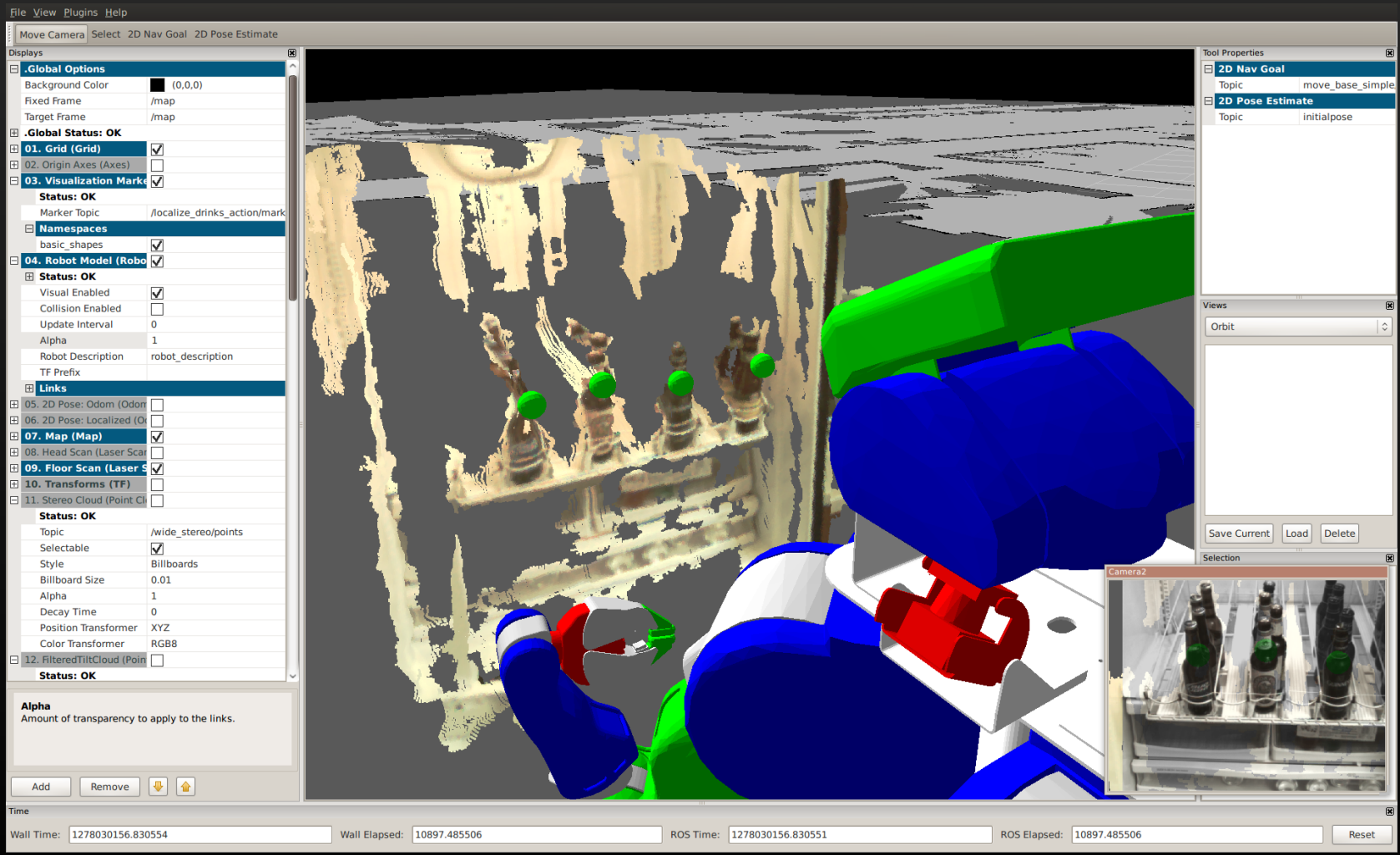


rviz - 3D Visualization

Modular state and sensor visualization



Outline (revisted)

ROS Stacks & Packages

How to organize code in a ROS ecosystem

ROS code is grouped at two different levels:

- Packages
  A named collection of software that is built and treated as an atomic dependency in the ROS build system.
- Stacks
  A named collection of packages for distribution.

ROS Distributions

Delivering ROS packages to the masses

source code
header declarations
scripts
message definitions
service definitions
configuration files
launch files
metadata
...

ROS Distributions

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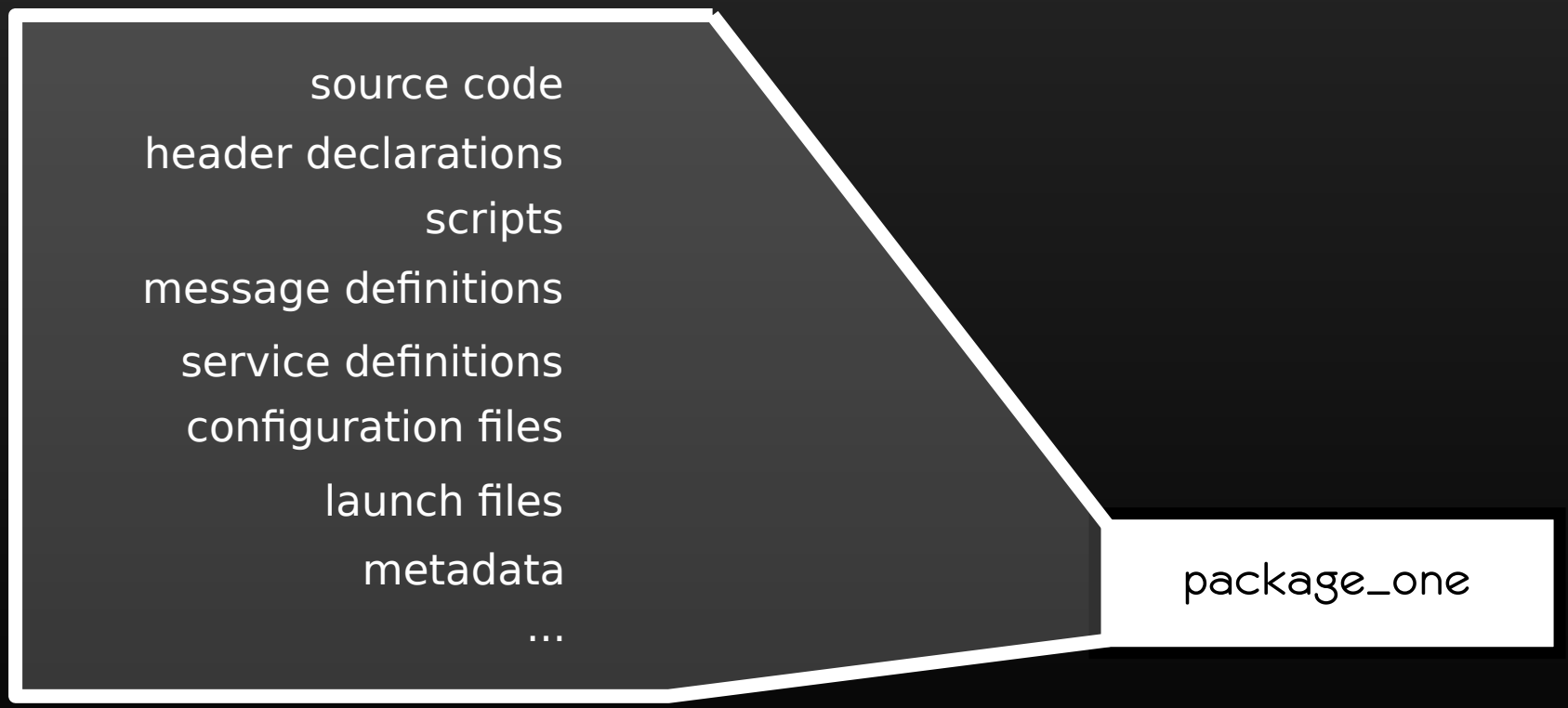

"package"

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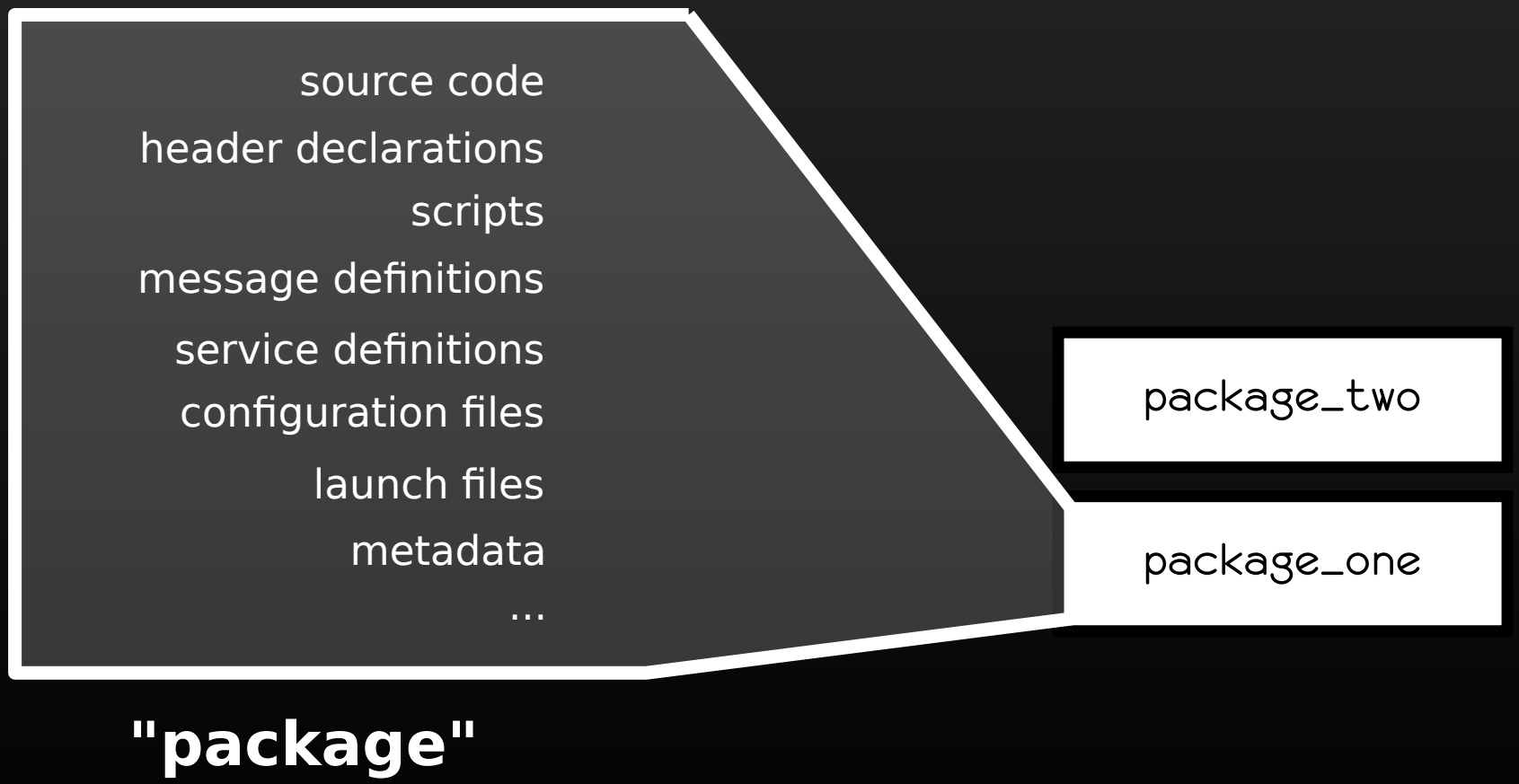

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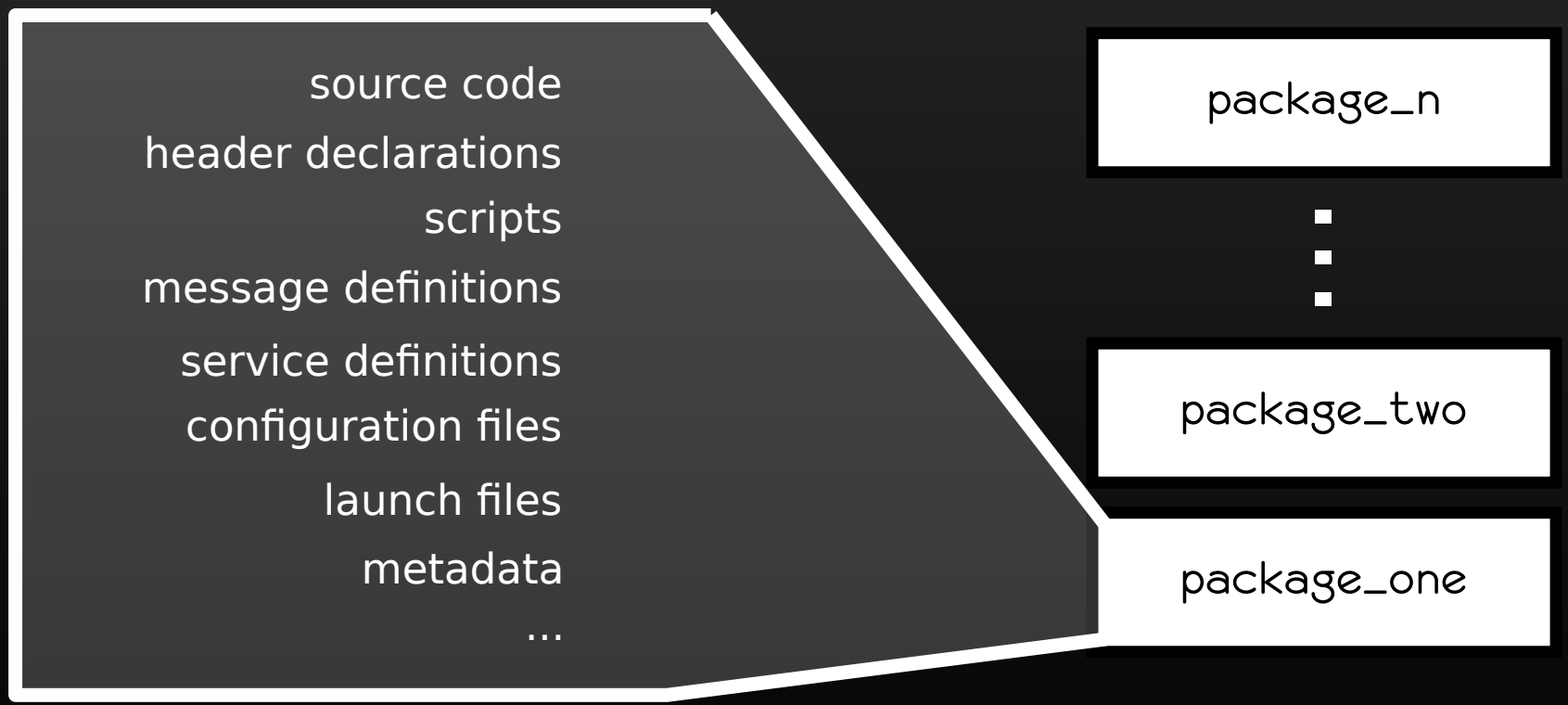

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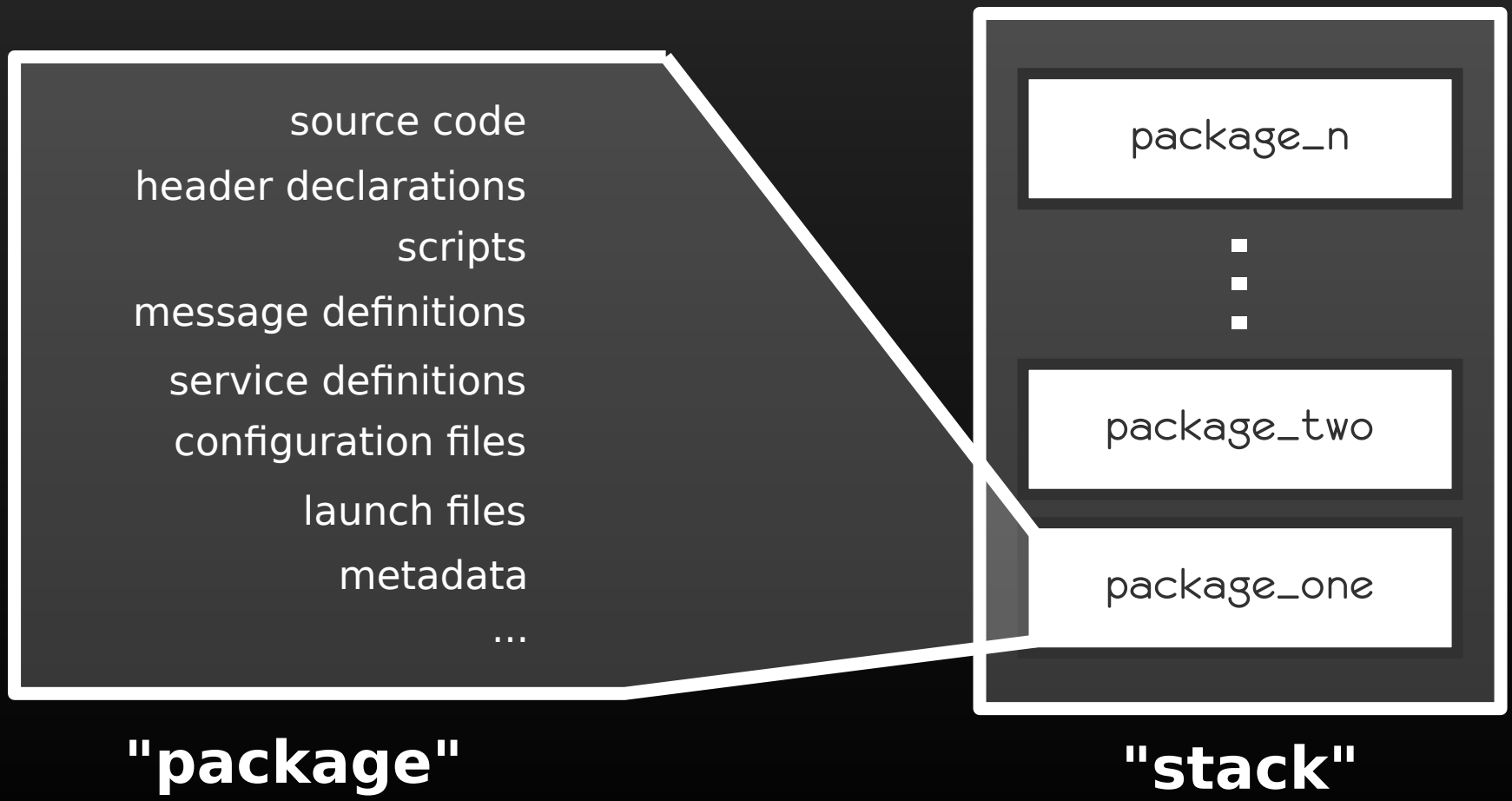

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stack_a-0.4.0

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stack_a-0.4.0 stack_b-1.0.2

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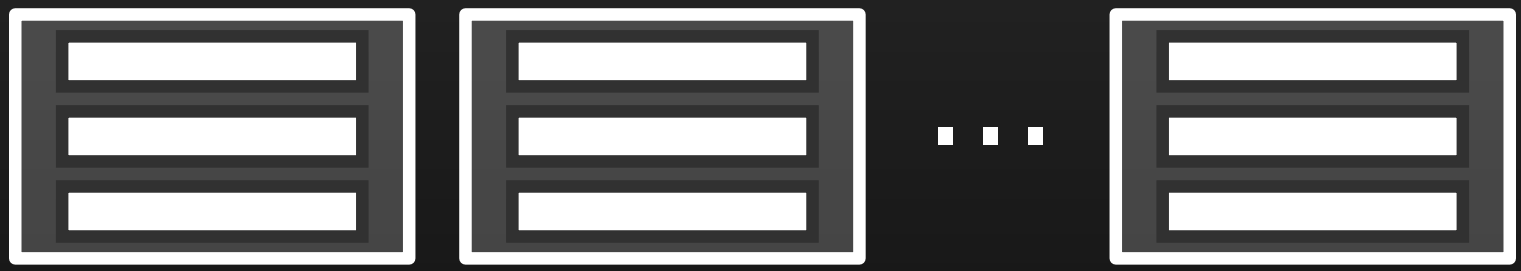

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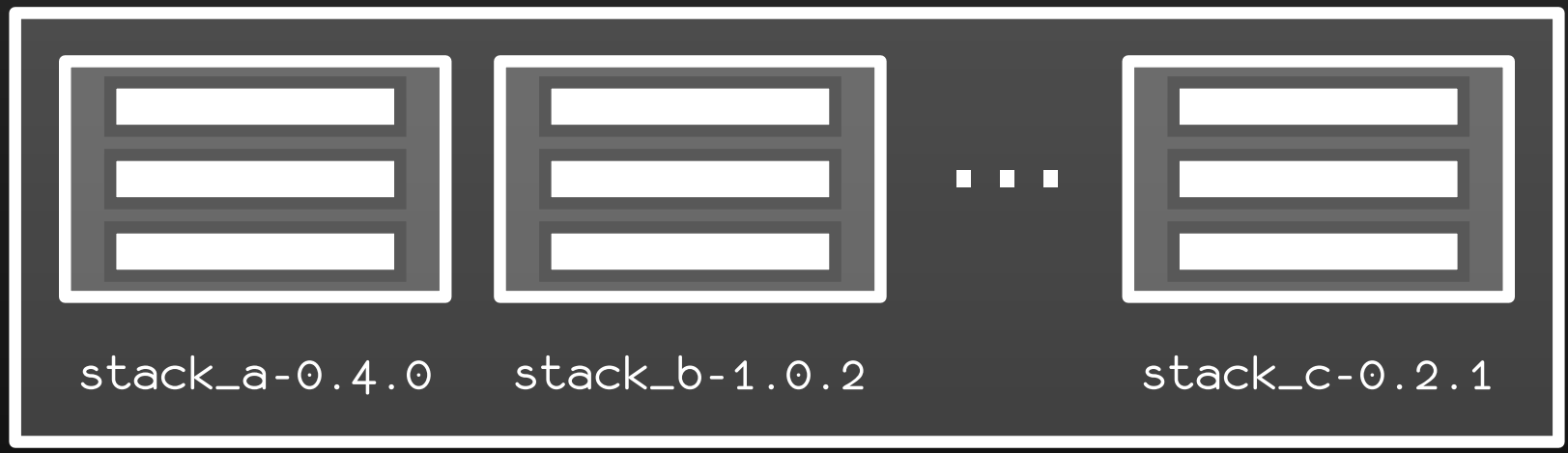

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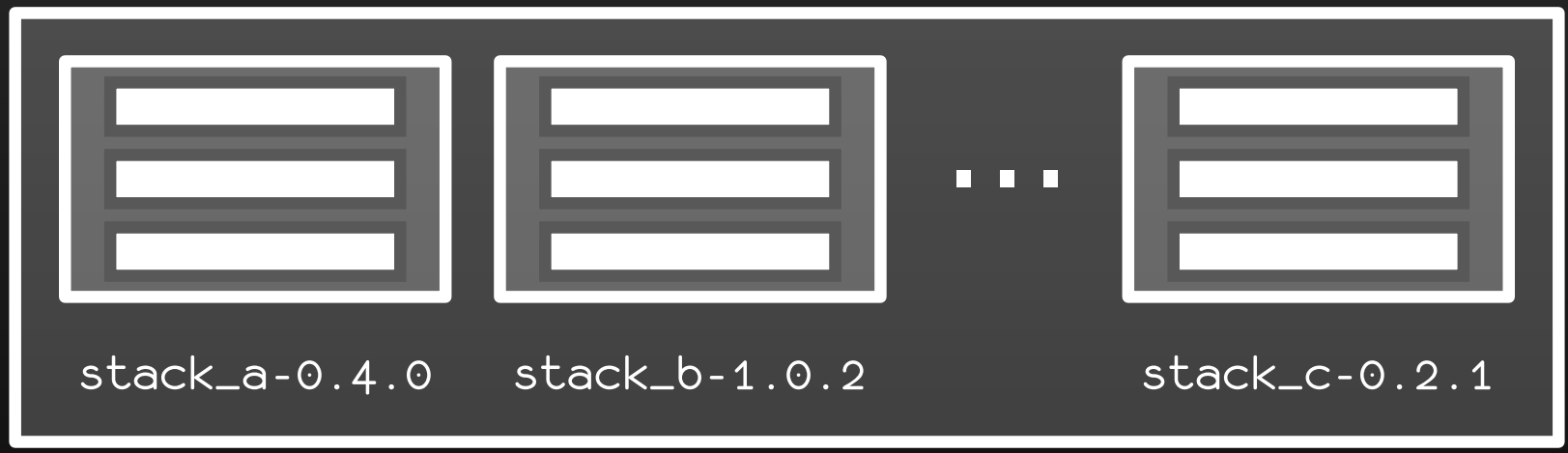

"distribution"

ROS "Box Turtle"
March 2, 2010

ROS "C-Turtle"
August 2, 2010

ROS "Diamondback"
March 2, 2011

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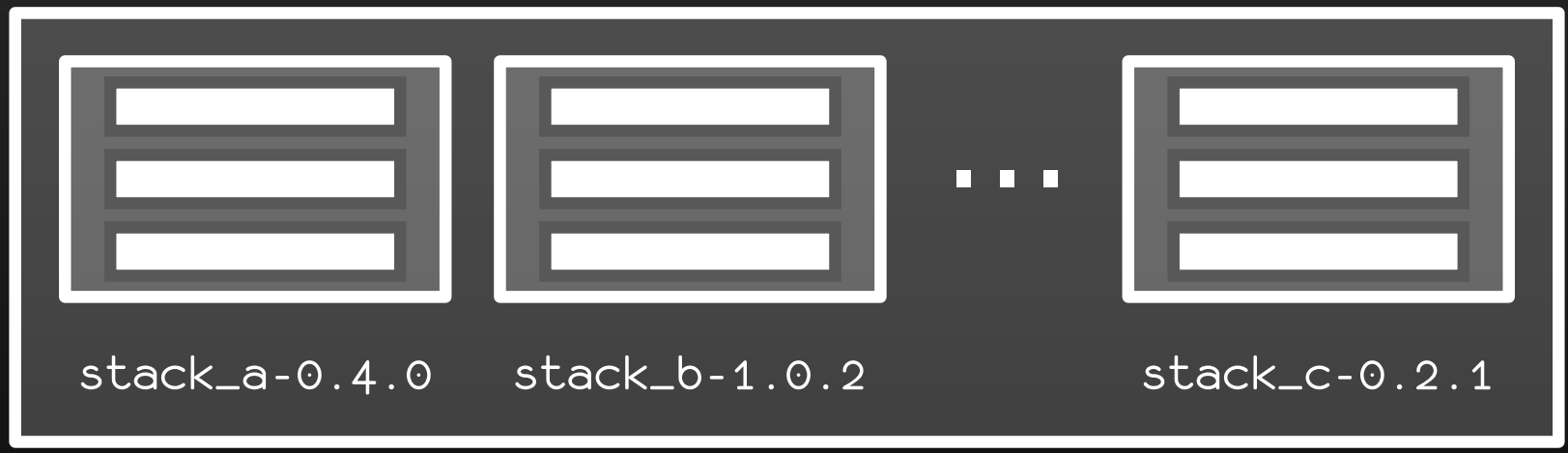

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Future: *ROS "Elecrtic Emys"*
August, 2011

ROS Meta-Filesystem

Increasing codebase flexibility

The minimal representation of a ROS package is a directory in the `$ROS_PACKAGE_PATH` which contains a single file:

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  - Specifies language-specific *export* flags
- `CMakeLists.txt`
  Contains ROS build rules (executables, libraries, custom build flags, etc)
- `Makefile`
  Just a proxy to build *this* package

ROS Meta-Filesystem

This meta-filesystem allows ROS (`rospack`, specifically) to locate *any* package in the designated path, be it at compile time or runtime.

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Since ROS can find any package at any time, it enables packages to be moved aoround in the actual filesystem and greater codebase flexibility.

Building Code with ROS

Easier CMake

While ROS uses CMake (`www.cmake.org`) internally to compile and link code, the ROS build system it adds several useful features that make it easier to build ROS code.

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- ROS CMake macros enable rapid building of executables, libaries, and automated regression tests

Thank you!

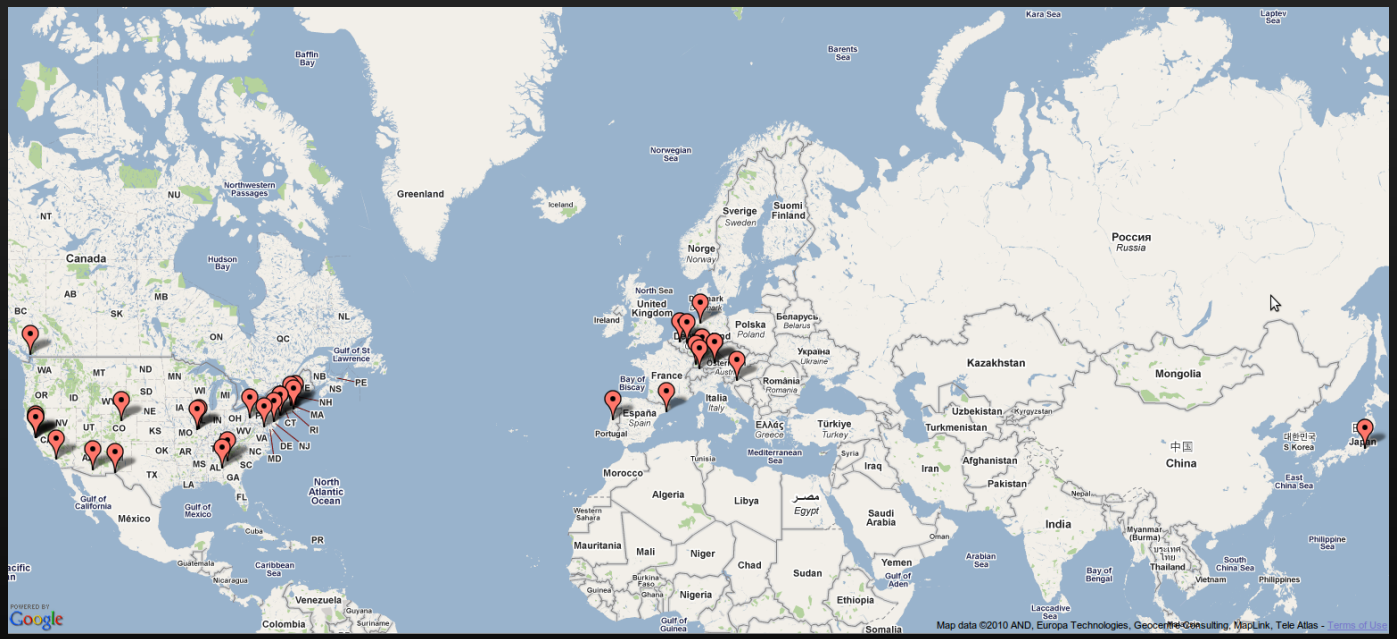
Thank you!

Now proceed to the ROS Beginner Tutorials!

`http://www.ros.org/wiki/ROS/Tutorials`

The ROS Community

Researchers using common tools to enable collaboration

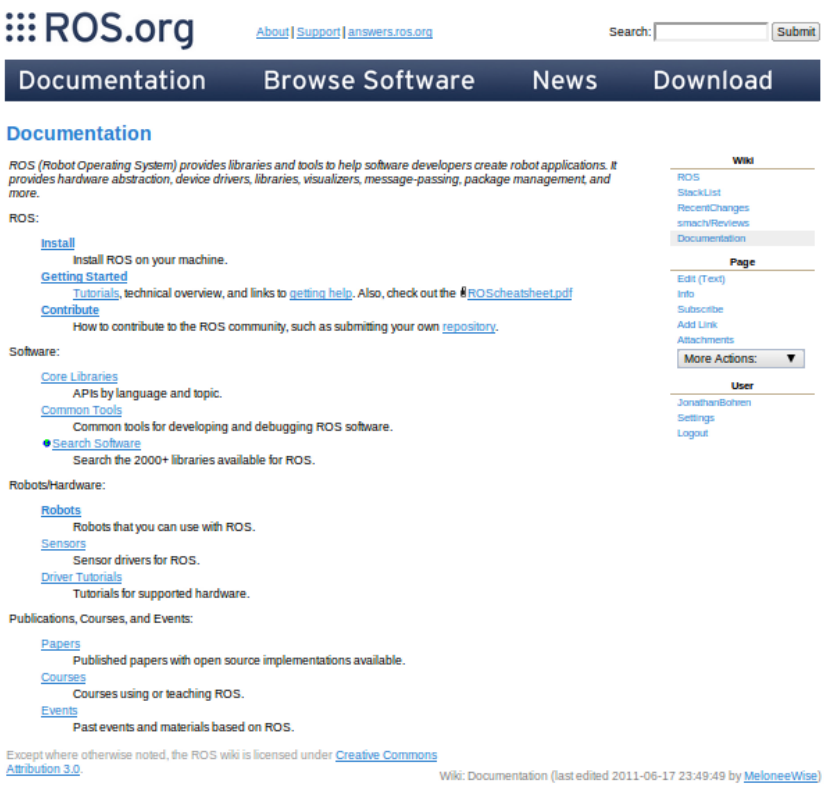


79 Institutional ROS Repositories, all over the world (July, 2011)

(jhu-lcsr-ros-pkg would make 80)

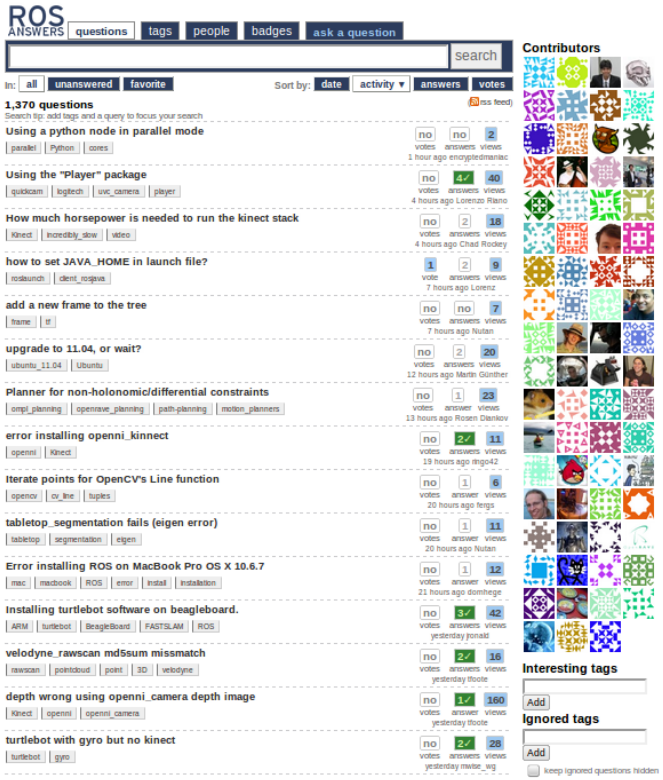
www.ros.org - The ROS Hub

A centralized location for ROS users and developers



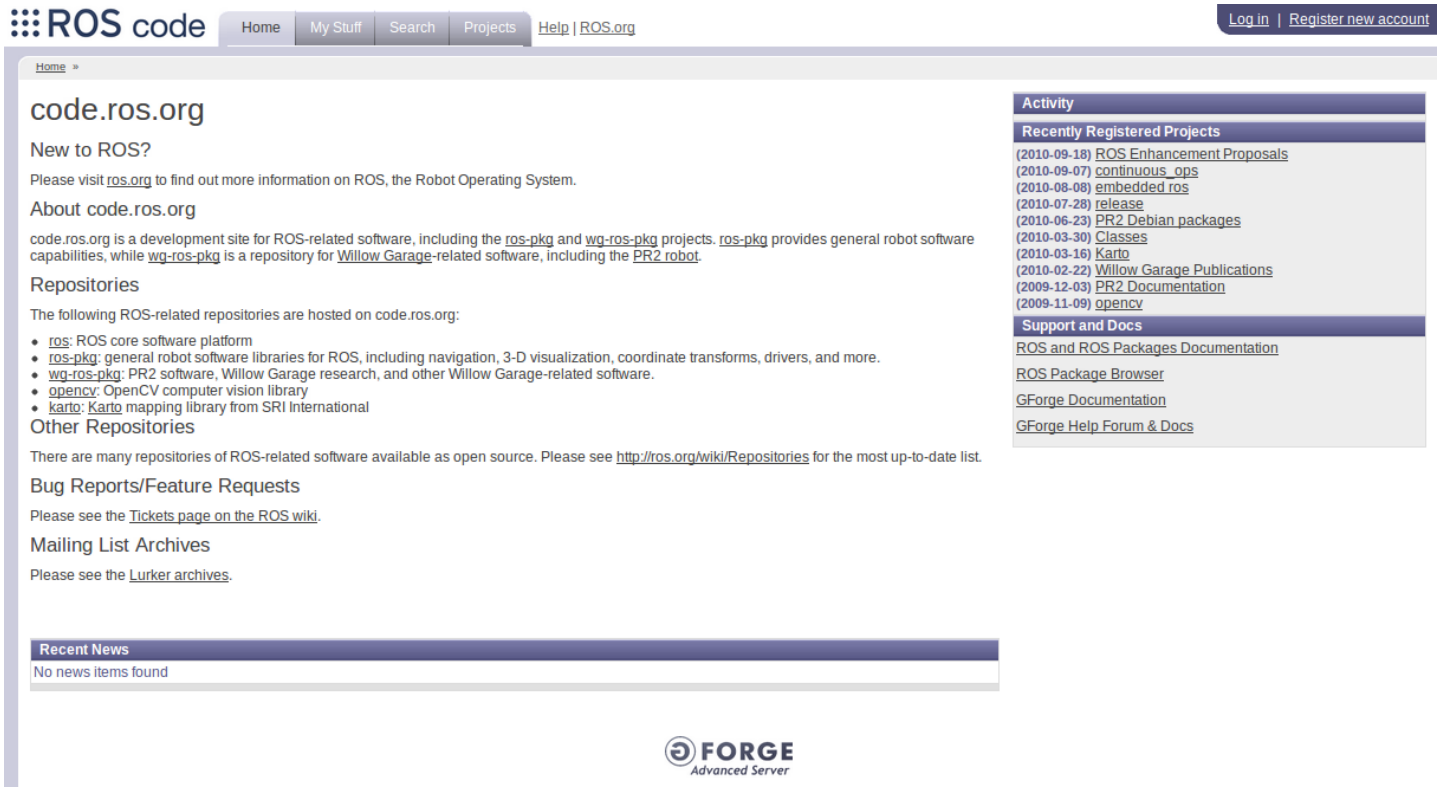
answers.ros.org - ROS Questions & Answers

Community-supported help for ROS users



code.ros.org - Willow Garage, Inc Code

Hosting and project management for "official" packages



ros mailing lists

Getting in touch with the developer community

- ROS Users - *for general ROS-related discussions*
  https://code.ros.org/mailman/listinfo/ros-users
- ROS Developers - *for ROS core development*
  https://code.ros.org/mailman/listinfo/ros-developers
- Other Lists & List Archives
  http://code.ros.org/lurker