RAINBOW group

Sensor-based and interactive robotics

Bringing Intervals into **ROS**, the Robot Operating System

Vincent Drevelle, Téva Demangeot

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Univ Rennes, Inria, CNRS, IRISA
Rennes, France
vincent.drevelle@irisa.fr

The *interval* ROS package is still a work in progress...

This talk is about motivation and current development.

Outline

Intervals and Robotics

ROS, the Robot Operating System

The *interval* ROS package

- Messages
- Visualization
- Bridge with Ibex

Live demo

Intervals and robotics

Representation of uncertainty

- Epistemic uncertainty
- Stochastic uncertainty: noise

Representation of domains / sets

- Maps
- Bounded error estimation

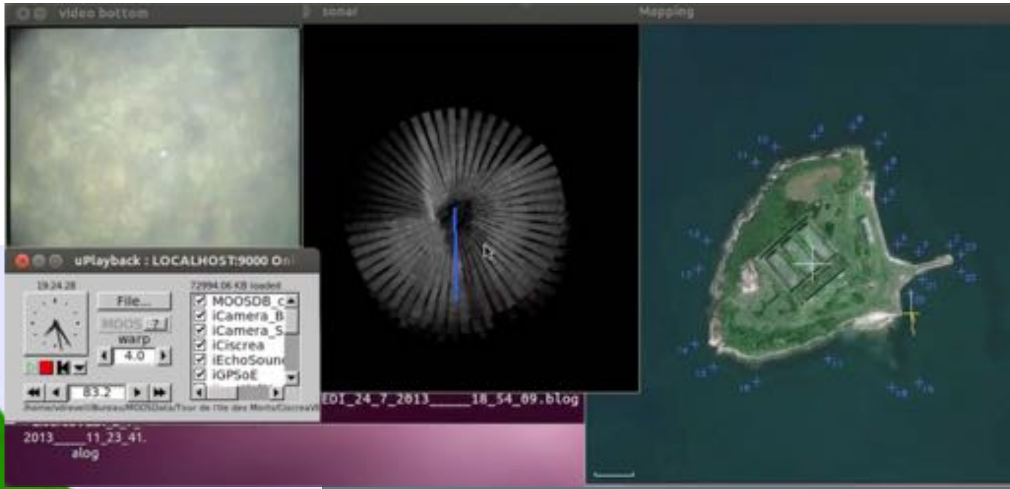
Applications

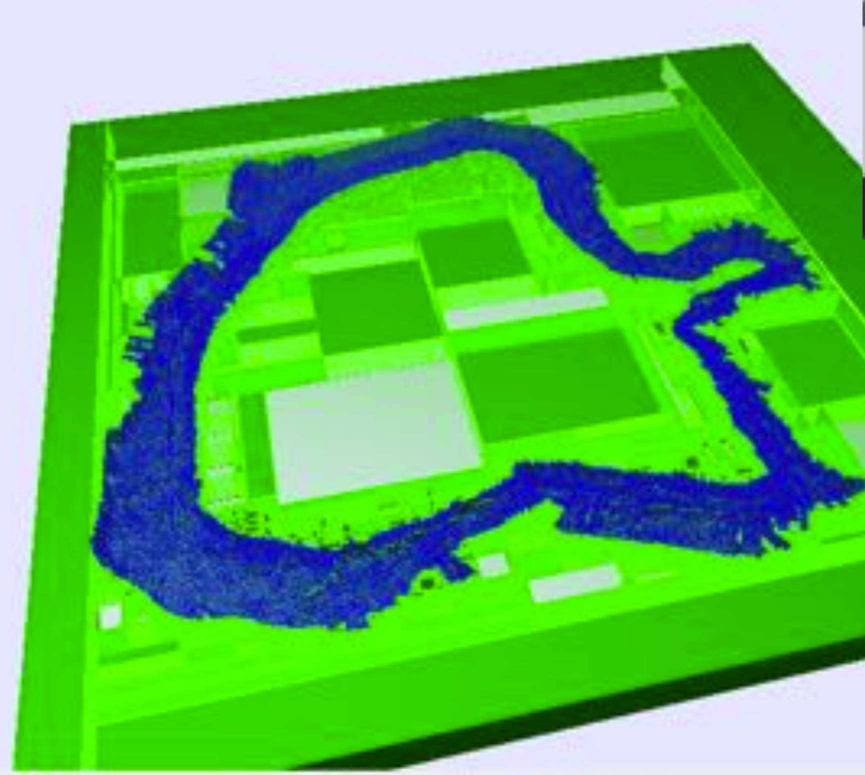
- Control under uncertainty
- Bounded-error state estimation
- Fault detection and isolation
- Mapping, SLAM (data association)
- Design (under constraints and uncertainty)
- ...

Intervals in field robotics: Underwater mapping

Île des Morts (near Brest, France, 2014)

- > V. Drevelle, with L. Jaulin and S. Rohou



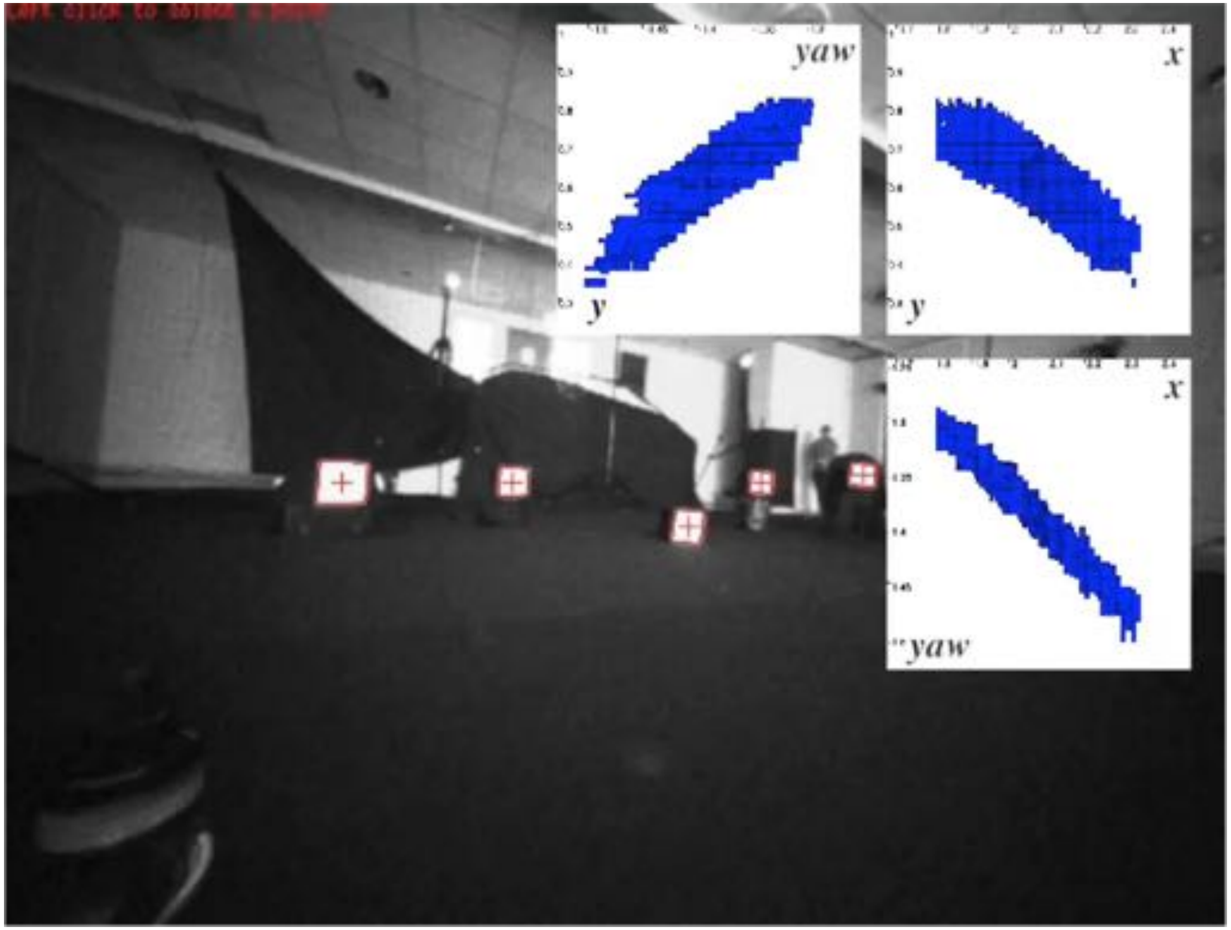


Intervals in field robotics: Drone localization

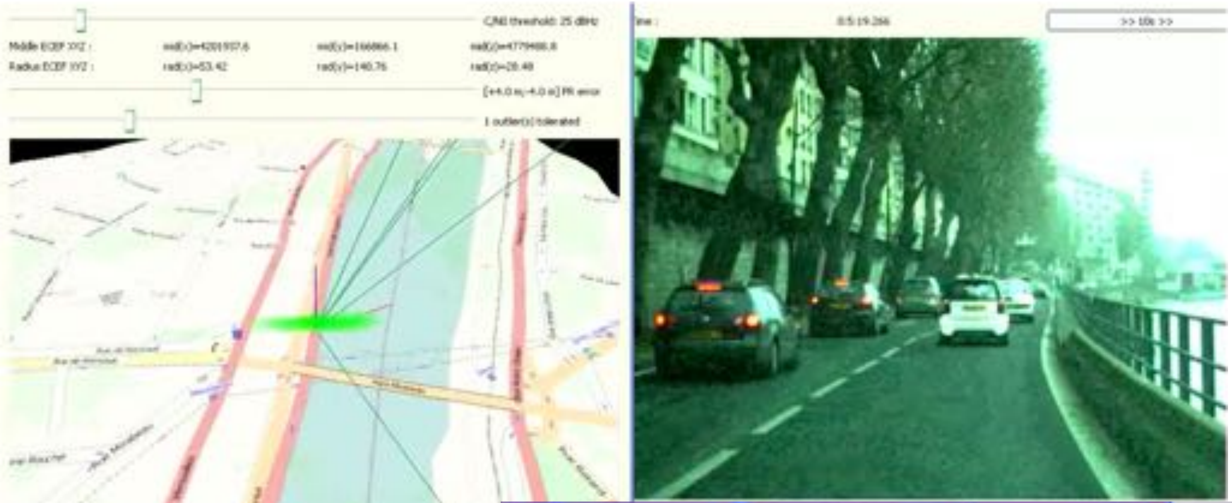
Camera-based localization

IRISA
(Rennes, France, 2017)

I.F. Kenmogne



Intervals in field robotics: Vehicle positioning


C/N0 threshold: 25 dBHz

Middle ECEF XYZ : mid(x)=4201937.6 mid(y)=166866.1 mid(z)=4779488.8

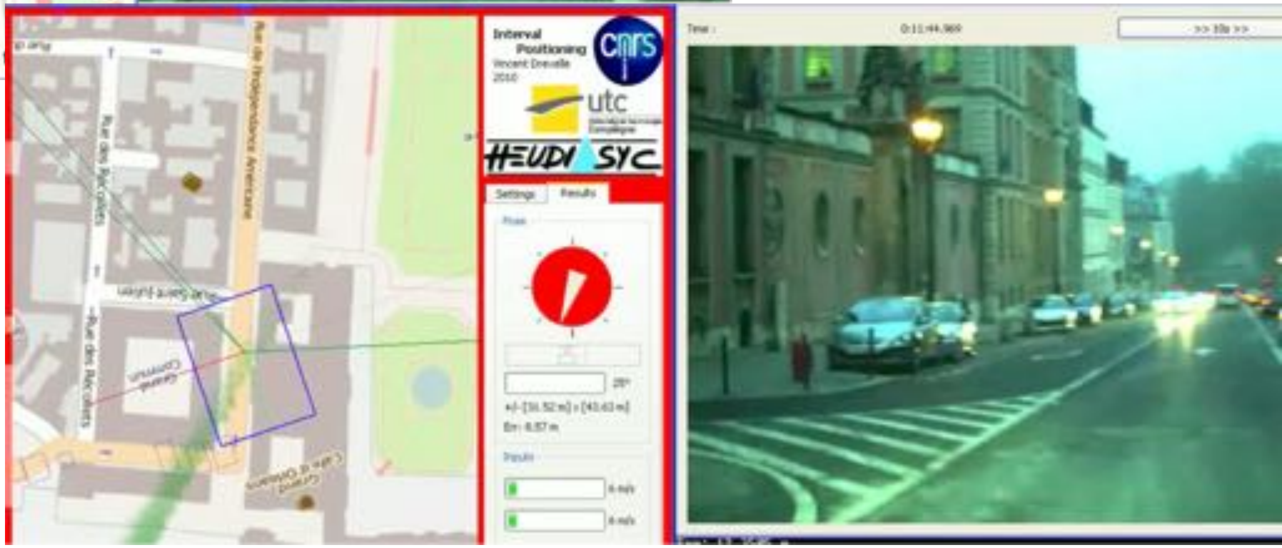
Radius ECEF XYZ : rad(x)=53.42 rad(y)=140.76 rad(z)=28.48

[+4.0 m;-4.0 m] PR error

1 outlier(s) tolerated

HeuDiaSyC [vincent.drevelle@hds.utc.fr] -- 5 sat. used /

GPS with FDI
(Paris, France, 2010)
V. Drevelle & Ph. Bonnifait



GPS with FDI and
onboard sensors fusion
(Versailles, France, 2010)
V. Drevelle & Ph. Bonnifait

Intervals in field robotics

Use intervals in real robots / systems

- Sensors
- Estimation algorithms
- Control algorithms
- Actuators

Interval data

- Data logging
- Monitoring and visualization
- Data exchange

Interval data

ROS, the Robot Operating System

History

- Started in 2007 in Stanford, development continued by Willow Garage since 2008
- 2010: ROS 1.0
- 2013: Open Source Robotics Foundation (OSRF), now Open Robotics
- 2018: *Melodic Morenia* version, see ros.org

What is ROS?

ROS stands for “the robot operating system”…

…but ROS is not an operating system!

ROS is robotics middleware

A collection of software frameworks for robot software development.

Main features

A ROS application is a network of **nodes** (sensor/actuator interfaces, processing, display) interconnected with a message passing infrastructure

- > Nodes are distributed, and can be written in different programming languages
- > Packages and dependencies management
- > Collection of software components, targeted to robotics applications needs

ROS communication main features

Master node: rosmaster

Coordination node, name server

Topics

Publish / subscribe **message** passing

Services

Remote procedure call

Parameter server

Share and update parameters for all nodes connected to the ROS network

Supported languages for nodes

> Main client libraries: C++, Python, Lisp
> JSON-RPC interface with ROSBridge
> Contributed client libraries for Java, Matlab, Javascript, etc

Introspection (messages, topics, graph)

ROS tools and libraries

Command line tools

Examine the graph, data flow, display live data, node and message type information, deployment…

Visualization tools

Rviz: 3D **rqt**: 2D plot, ROS network graph, image viewer, …

Data recording and playback

".bag" dataset file format. rosbag,(console) and rqt_bag (graphical) utilities.

Transform library (tf2)

Transform coordinates between coordinates frames (e.g. world, base, head, arm, gripper).
Keeps track of a transform database over time.

Drivers

For sensors (cameras, lasers…) and actuators (servomotors, …)

Robotics algorithms

Localization, EKF, SLAM, planning…

Messages

Standard and custom datatypes defined in a *.msg* text file

Compiled to C++, Python and Lisp classes

A message is a data structure made of:

- Basic types (int32, float64, ...)
- Other messages types
- Arrays of basic types/messages

Standard sensor and geometry messages already available (Point, Vector3, Pose, Path, Image, LaserScan...)

```
rosmsg show geometry_msgs/Pose

geometry_msgs/Point position
  float64 x
  float64 y
  float64 z
geometry_msgs/Quaternion orientation
  float64 x
  float64 y
  float64 z
  float64 w
```

Topics

Data channel on which nodes exchange data related to a particular information (e.g. the speed reading of the front-left wheel of the robot, or, the map of the free space, etc...)

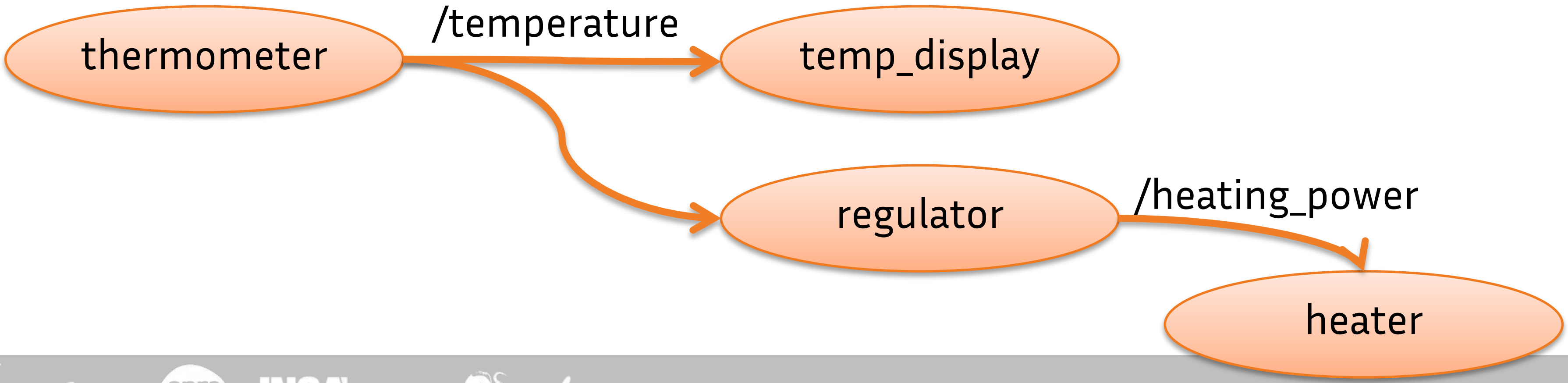
> Unidirectionnal communication

> Strongly typed by message type

> Accessed by its name (e.g /car/wheel_speed_fl)

- Nodes that generate data **publish** messages to the relevant topic(s)
- Nodes that consume data **subscribe** to the relevant topic(s)

There can be multiple publishers and subscribers to a topic



Bringing **intervals** into ROS

ROS

De-facto « 1st choice » middleware for roboticians

Lots of debugging tools (visualization, graph introspection, etc)

Large user community, packages browser, documentation and tutorials available

Used in robotics classes

Intervals

Available methods for state estimation, mapping, SLAM, FDI

Specific visualization needs (boxes, pavings...)

Alternative to the classical probabilistic methods (most of the time Gaussian)

Intervals in ROS

- Ease the use of interval methods with real robots / data
- Increase the visibility of interval methods

The *interval* ROS Package

Messages

- Intervals ✓
- Pavings ✓

Visualisation

- 3D with Rviz ✓
- 2D with RQT
- Vibes connector

Computation

- Link with Ibex ✓
- Tutorials (SIVIA, ...) ✓
- Basic interval estimator
- Basic paver

Interval Messages

Standardize data exchange between interval computation nodes

- Enable log and replay of interval results
- Basic interval types, as a foundation for application specific interval data
- Conversion to/from interval libraries types

interval_msgs/Interval

- float64 lb
- float64 ub

interval_msgs/IntervalVector

- interval_msgs/Interval[] box

interval_msgs/SubPaving

- interval_msgs/IntervalVector domain
- interval_msgs/IntervalVector[] subpaving

Interval Messages

Geometrical and time messages

PointInterval (for position), PoseInterval, Vector3Interval (e.g for speed)

TimeInterval, DurationInterval

Stamped versions of messages

Messages with an additional standard header

- Sequence number
- Timestamp
- Coordinate frame name

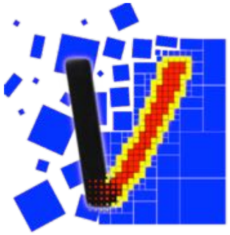
ROS intervals: Visualization

Display interval quantities (boxes) and subpavings published as ROS messages

2D display (Work in progress)

- 2D view in **rqt**
  - Qt-based graphical user interface developpement framework in ROS

- Bridge with **Vibes**
  - Easy to use interval display system
  - enstabretagnerobotics.github.io/VIBES



3D display

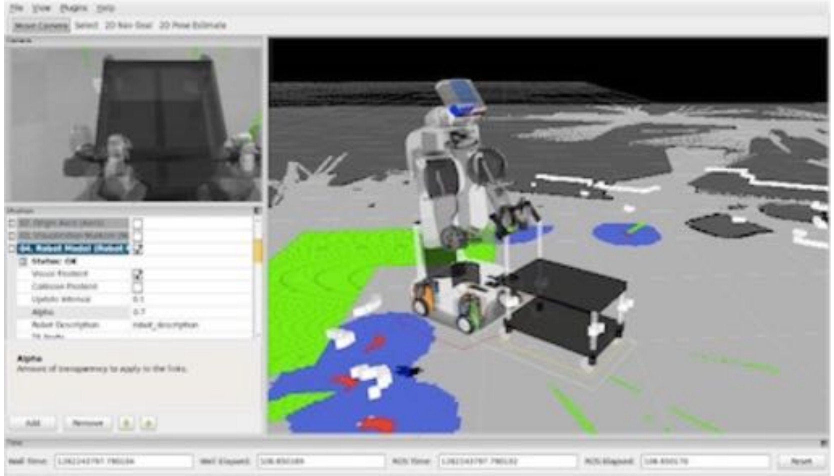
- 3D view in **RViz**

RViz interval display plugins

RViz

ROS 3-D visualization tool

Off-the-shelf display of standard robotics quantities: points, poses, maps, paths...



Uses **stamped** message datatypes

- All geometry is transformed to a common frame before display
- Allows mixed display of global frame objects (e.g map) with robot/sensor body frame data (e.g measurements)

Interval RViz Plugins

interval_rviz_plugin package

Rviz plugins to display Interval messages in 3D

- interval Points (position box), Poses, Vector3 (speed box)
- SubPavings and Pavings (position)

ROS intervals: link with Ibex lib

Ibex library

ibex-lib.org (Chabert et al.)

C++ library for constraint processing over real numbers

> Interval arithmetics

> Contractors / Separators

> Solvers

ROS Interval Ibex

Conversion between Ibex types and ROS interval messages

Display of Set solutions

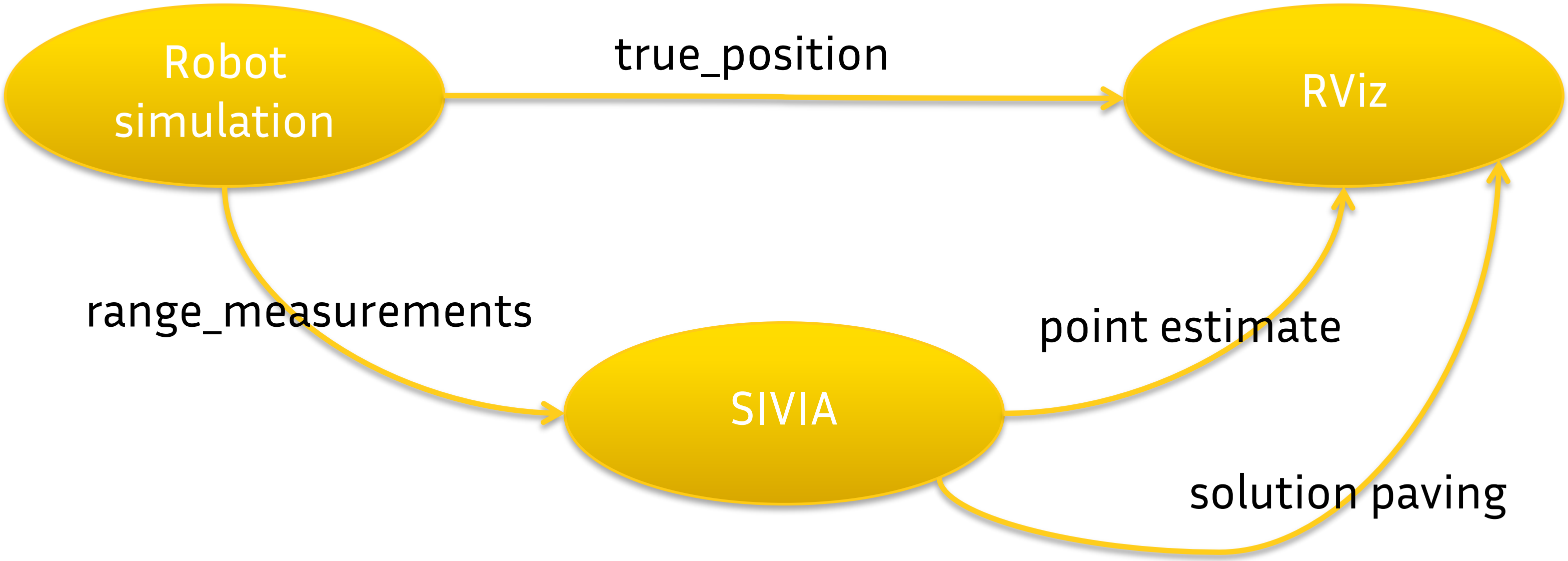
Configurable set-inversion solver (work in progress)

> Plug and play interval solver within a ROS graph

> Dynamic observation model setting (no compilation needed)

Demo

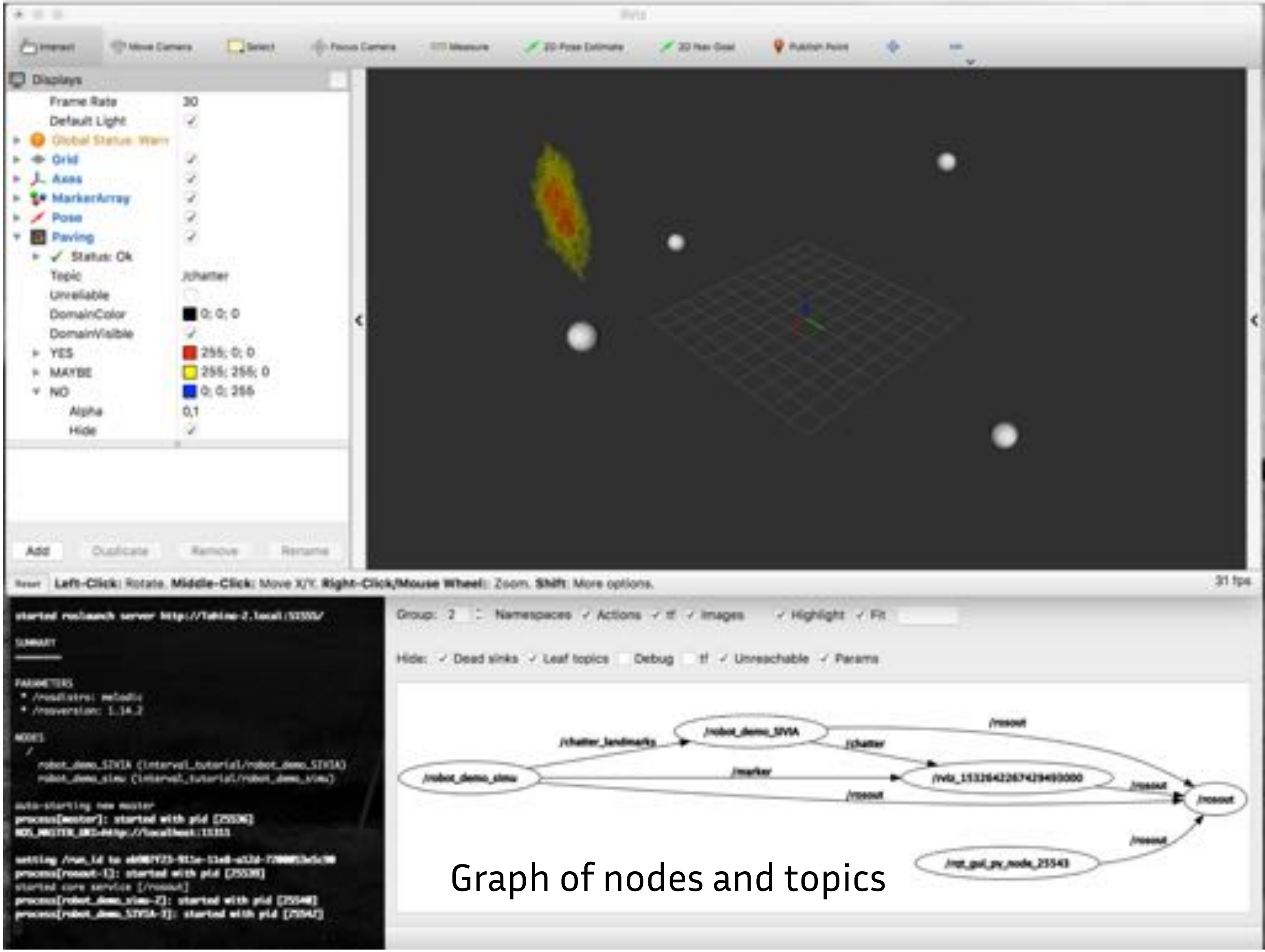
Robot positioning from ranging beacons, by using SIVIA



Demo

RViz

rosmaster and nodes



Frame Rate	30
Default Light	✓
Global Status: Warn	
Grid	✓
Axes	✓
MarkerArray	✓
Pose	✓
Paving	✓
✓ Status: Ok	
Topic	/chatter
Unreliable	□
DomainColor	■ 0; 0; 0
DomainVisible	✓
YES	🟥 255; 0; 0
MAYBE	🟨 255; 255; 0
NO	🟦 0; 0; 255
Alpha	0,1
Hide	✓

Left-Click: Rotate. **Middle-Click:** Move X/Y. **Right-Click/Mouse Wheel:** Zoom. **Shift:** More options.

```
started roslaunch server http://Tahine-2.local:53555/

SUMMARY
========

PARAMETERS
 * /rosdistro: melodic
 * /rosversion: 1.14.2

NODES
  /
    robot_demo_SIVIA (interval_tutorial/robot_demo_SIVIA)
    robot_demo_simu (interval_tutorial/robot_demo_simu)

auto-starting new master
process[master]: started with pid [25536]
ROS_MASTER_URI=http://localhost:11311

setting /run_id to [illegible]
process[rosout-1]: started with pid [25539]
started core service [/rosout]
process[robot_demo_simu-2]: started with pid [25540]
process[robot_demo_SIVIA-3]: started with pid [25542]
```

Group: 2 Namespaces ✓ Actions ✓ tf ✓ Images ✓ Highlight ✓ Fit

Hide: ✓ Dead sinks ✓ Leaf topics □ Debug □ tf ✓ Unreachable ✓ Params

Graph of nodes and topics

Outlook

Hosted at INRIA GitLab

- Unstable version, under development
- Open source (BSD license)
- https://gitlab.inria.fr/rainbow-intervals/ros_interval

Short term goal

- Finalize rqt 2D view, and simple Ibex paver
- First release by the end of September 2018

What’s next

Get indexed in the ROS package directory, for further visibility

Integration with other robotics related interval libraries (e.g Dynibex)