Platform(s) and State of Simulation

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Technical Aspects of Multimodal Systems

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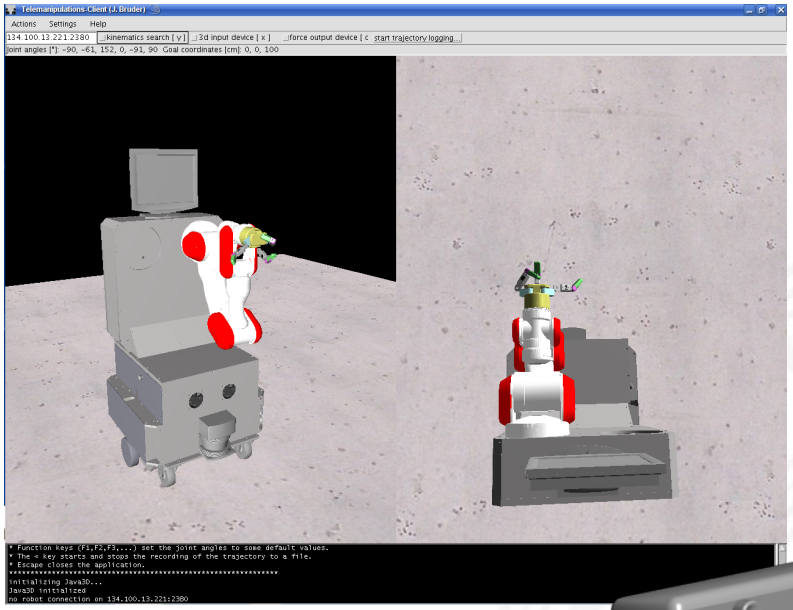
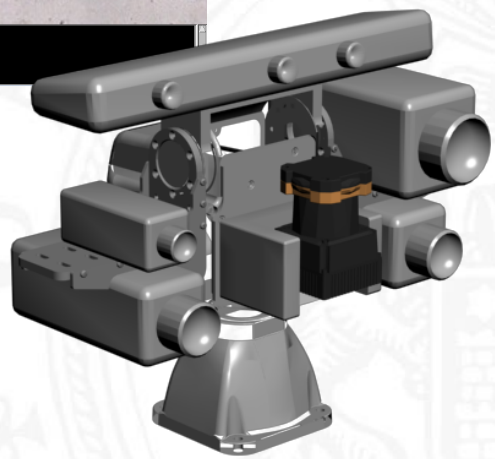
Outline

Outline

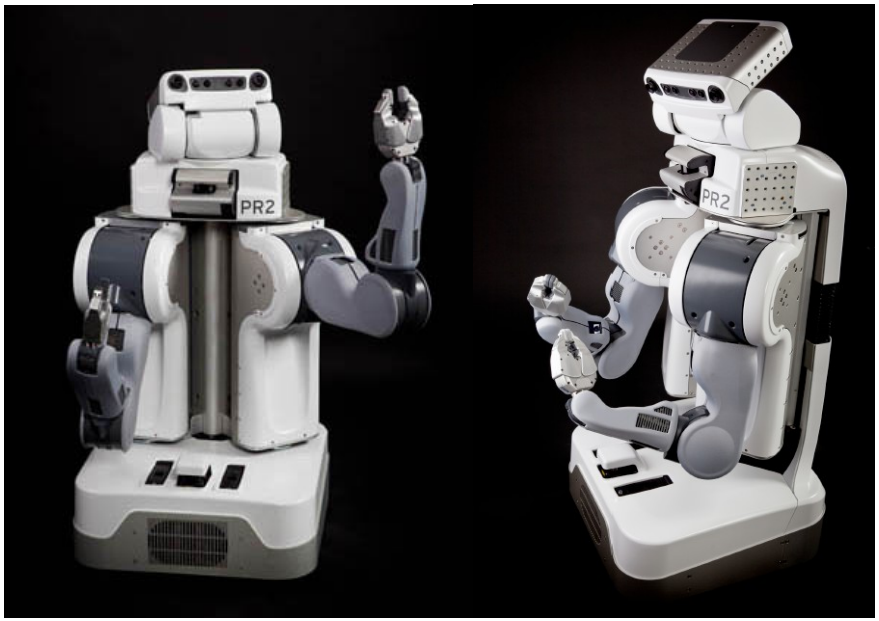
PR2 Introduction

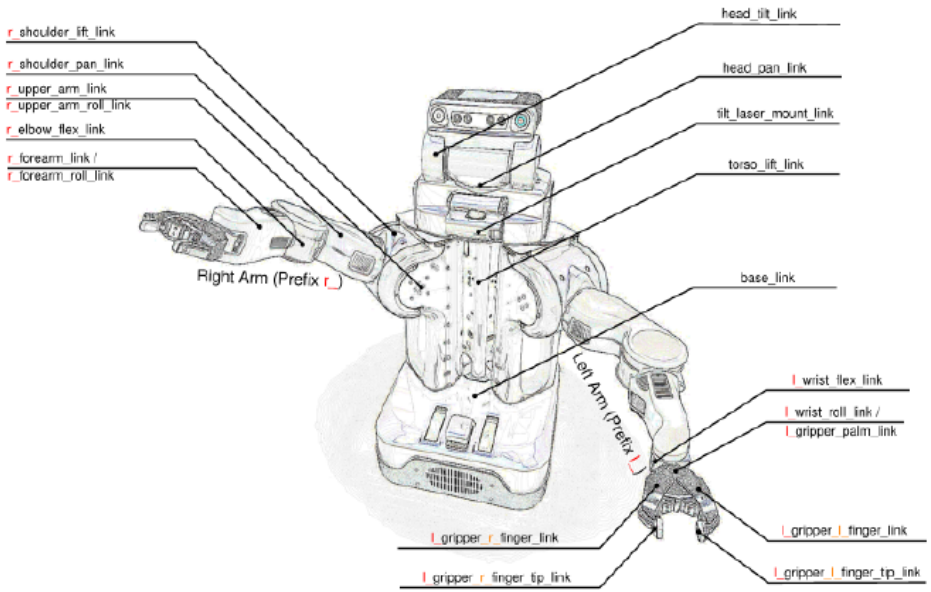




Outline

PR2


PR2
PR2


r_shoulder_lift_link
r_shoulder_pan_link
r_upper_arm_link
r_upper_arm_roll_link
r_elbow_flex_link
r_forearm_link /
r_forearm_roll_link
Right Arm (Prefix r_)
head_tilt_link
head_pan_link
tilt_laser_mount_link
torso_lift_link
base_link
l_wrist_flex_link
l_wrist_roll_link /
l_gripper_palm_link
Left Arm (Prefix l_)
l_gripper_r_finger_link
l_gripper_r_finger_tip_link
l_gripper_l_finger_link
l_gripper_l_finger_tip_link

PR2 - Users


LELAND STANFORD JUNIOR UNIVERSITY
DIE LUFT DER FREIHEIT WEHT
1891


UNI
FREIBURG


TECHNISCHE
UNIVERSITÄT
MÜNCHEN


THE UNIVERSITY OF CALIFORNIA
1868


USC
UNIVERSITY
OF SOUTHERN
CALIFORNIA


Massachusetts
Institute of
Technology


BOSCH


東京大学
THE UNIVERSITY OF TOKYO


Penn
UNIVERSITY of PENNSYLVANIA

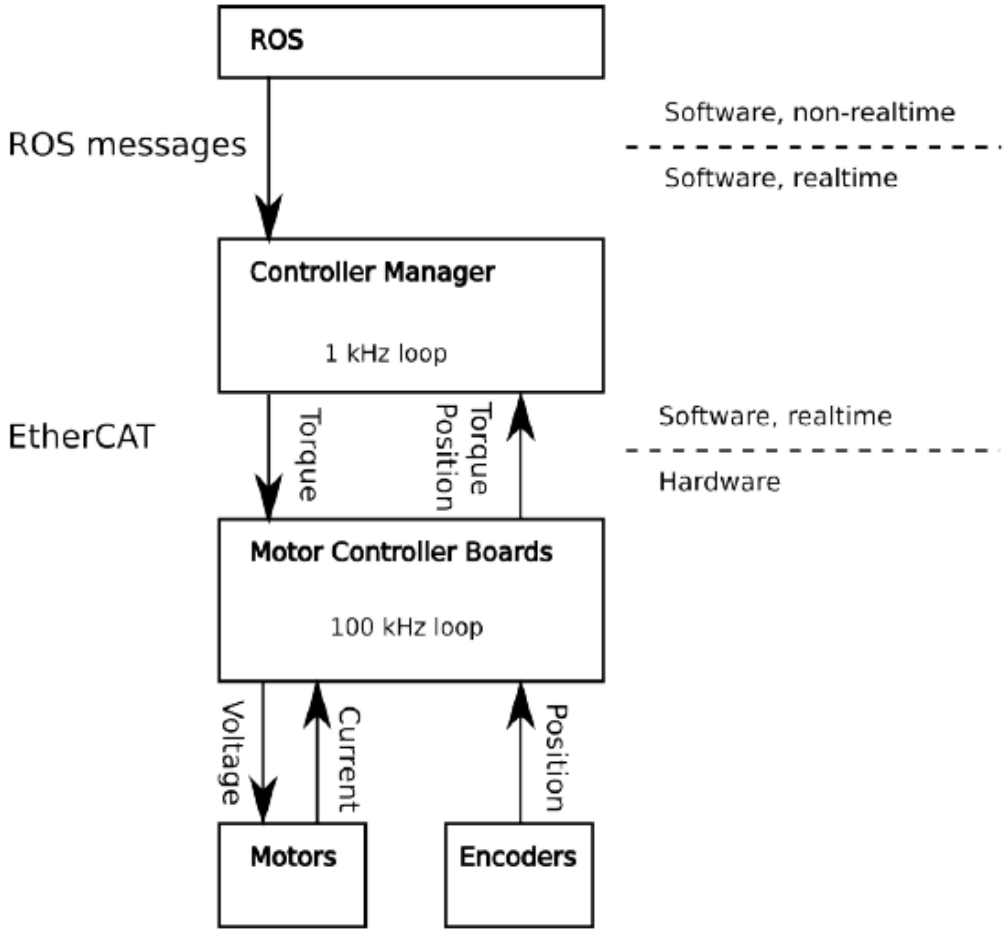

KATHOLIEKE UNIVERSITEIT
LEUVEN


Georgia Institute
of Technology

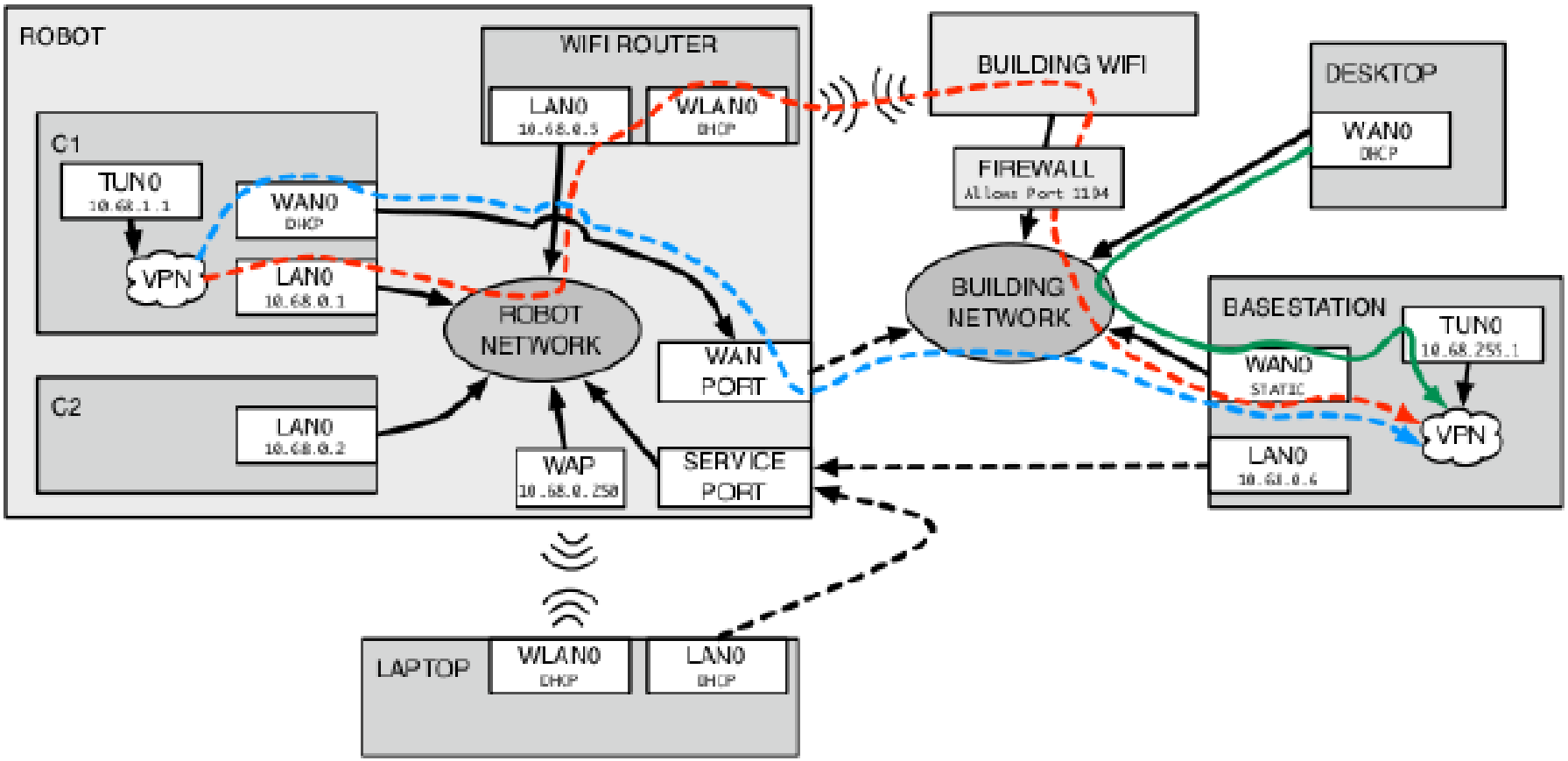
PR2 - Hardware Specification

- 2× computers with 24 Gb RAM and quad-core Nehalem processors
- 1.3 kWh Lion Battery Pack
- 2 hrs Approximate Runtime
- Coordinate system (for all links) positive z-axis up, positive x-axis forward, and positive y-axis robot-left when PR2 in the home pose

The PR2 Motion Control Layout

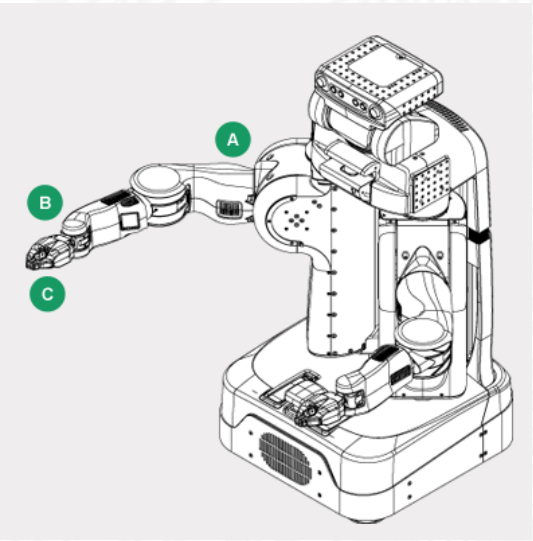


Network Explanation



PR2 - Hardware Specification

- Arm DOFs: arm 4 (A), wrist 3 (B), gripper 1 (C)
- Link Lengths: upper arm 400 mm, forearm 321 mm, wrist to gripper surface 120 - 200 mm
- Range of motion: shoulder pan/tilt $170^0/115^0$, upper arm roll 270^0, elbow flex 140^0, forearm roll continuous, wrist pitch/roll 130^0/continuous, gripper 90 mm max
- Force output: 4 DOF passive counterbalance, arm payload 1.8 Kg, wrist torque 4 Nm, grip force 80 N



PR2 - Intrinsic Sensors

- Microstrain 3DM-GX2 IMU (above the shoulders)
- Three-Axis Accelerometer (gripper)
- Calibration LED (gripper)

PR2 - Extrinsic Sensors - Head

- Microsoft Kinect (color/depth image/point cloud [640×480@30 *fps*])
- Global shutter color gigabit ethernet camera (Prosilica GC2450C, 5 MP, [2448×2050@15 *fps*])
- Wide stereo camera system (Aptina MT9V032C12STC, 100 Mb color ethernet, [752×480@15 *fps*])
- Narrow stereo system (Aptina MT9V032C12STM, 100 Mb monochrome ethernet, [752×480@15 *fps*])
- LED textured light projector (triggered with narrow-angle stereo camera)

PR2 - Extrinsic Sensors - II

- Tilting laserscanner (Hokuyo UTM-30LX, $135^0(+90^0 to -45^0)$,above the shoulders)
- Laserscanner (Hokuyo UTM-30LX, base)
- Global shutter gigabit ethernet camera ($2\times$, forearm)
- Fingertip pressure sensor arrays (gripper)
- Speaker

Outline

ROS Introduction

ROS

- Meta operating system for robotics
- Obtain, build, write and run code across multiple computers and robots
- Open source
- BSD licensed (very liberal[1])
- Willow Garage
- Community

[1] http://en.wikipedia.org/wiki/BSD_licenses

Introduction (cont.)

Robots Using ROS > 50

ROS Basics

- Supported Platforms
  - Linux, Mac OS, partial support for Windows
- Languages
  - C/C++, Python, Octave, Lisp, Java

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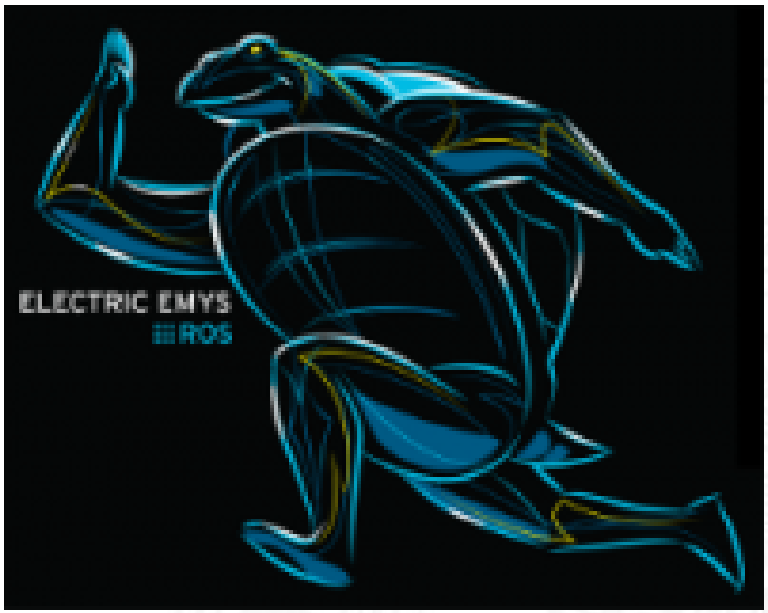
What does ROS cover?

ROS

- Simulation
- Task execution
- Mobile manipulation
- Navigation
- Visualization
- Client libraries
- Message passing



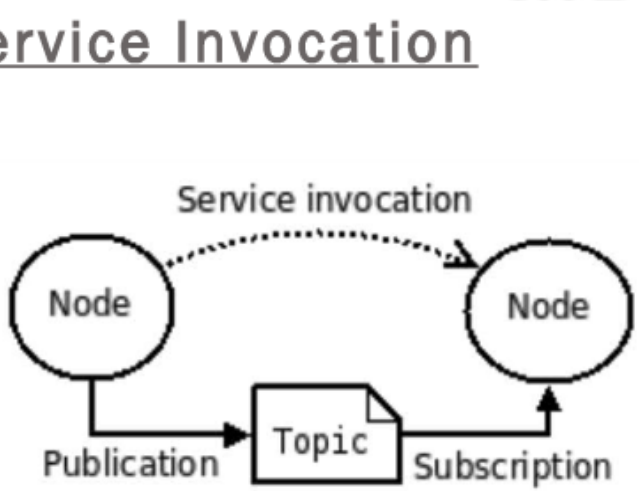
Outline

ROS Nodes

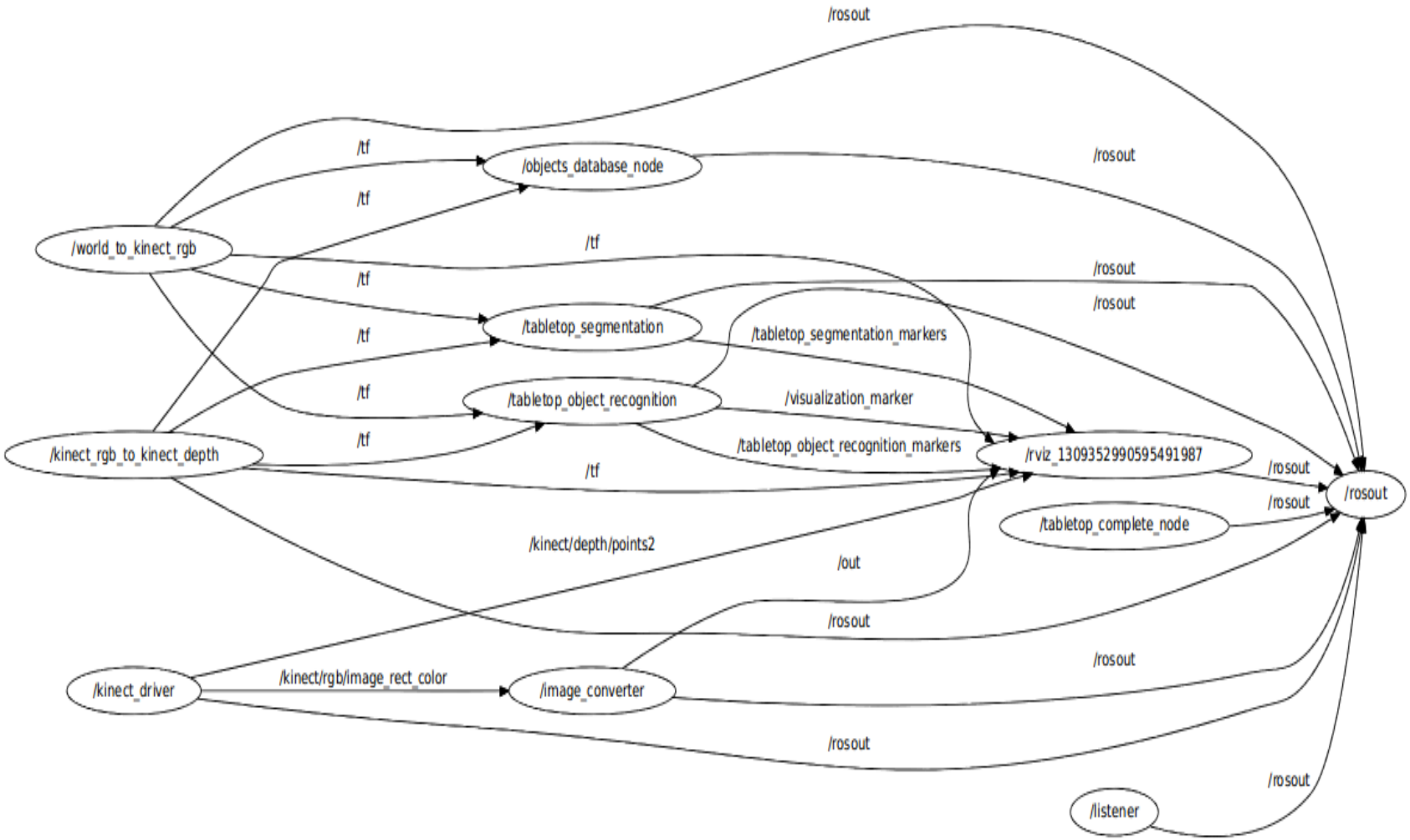
- Master (rosmaster)
  - provides naming and registration services
  - tracks topics and services
  - enables localization of nodes (they talk peer-to-peer)
  - XML-RPC-based API
- Generally: they are uniquely named

ROS Communication

- Publisher sends message to subscribers
  - Usually TCP/IP transport
  - XML-RPC is only used to negotiate transport (no messages via XML-RPC)



ROS Communication (cont.)

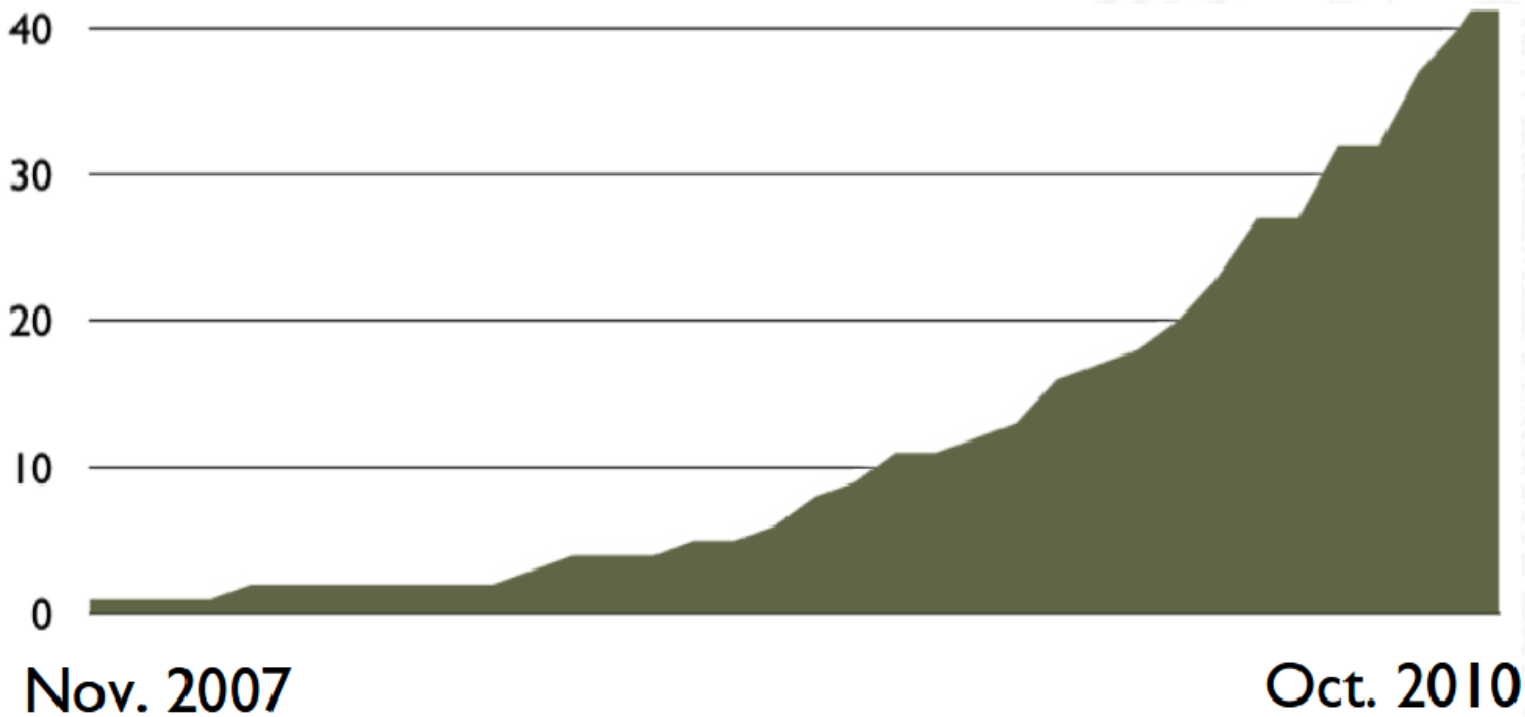


Outline

ROS Repositories

Repositories world-wide

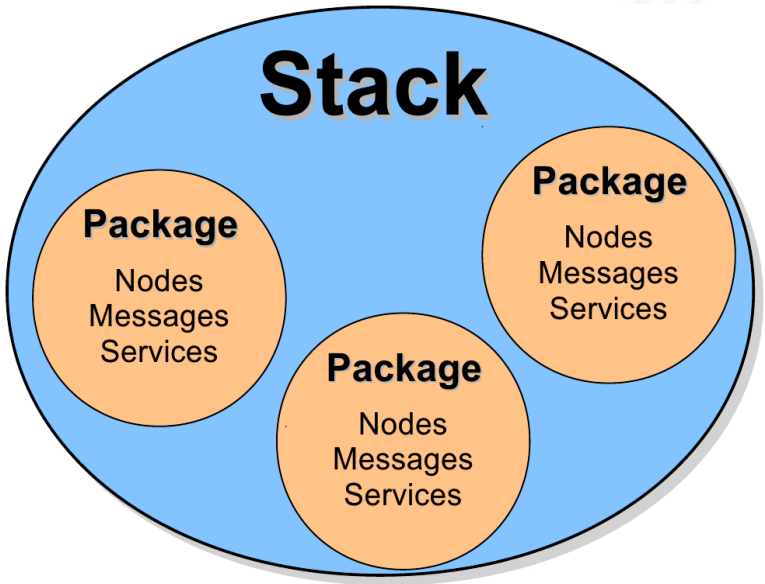
- Collection of packages and stacks, hosted online
- many repositories (>50): Stanford, CMU, TUM ..



ROS Repositories (cont.)

ROS Stacks

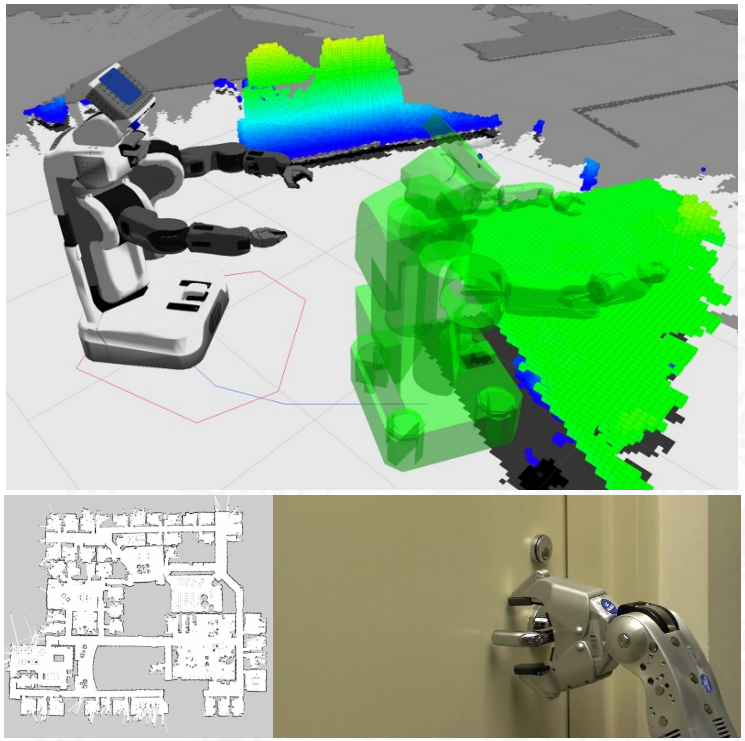
- Collect similar packages that work together to achieve e.g.:
  - 2D Navigation
  - Manipulation
  - SLAM



ROS Stacks Overview[2]

Currently > 400 Stacks available

- (2D/3D) Navigation
- PR2 arm navigation
- PR2 opening doors
- Exploration
- GUI for PR2 robot
- PR2 object manipulation
- PR2 simulator

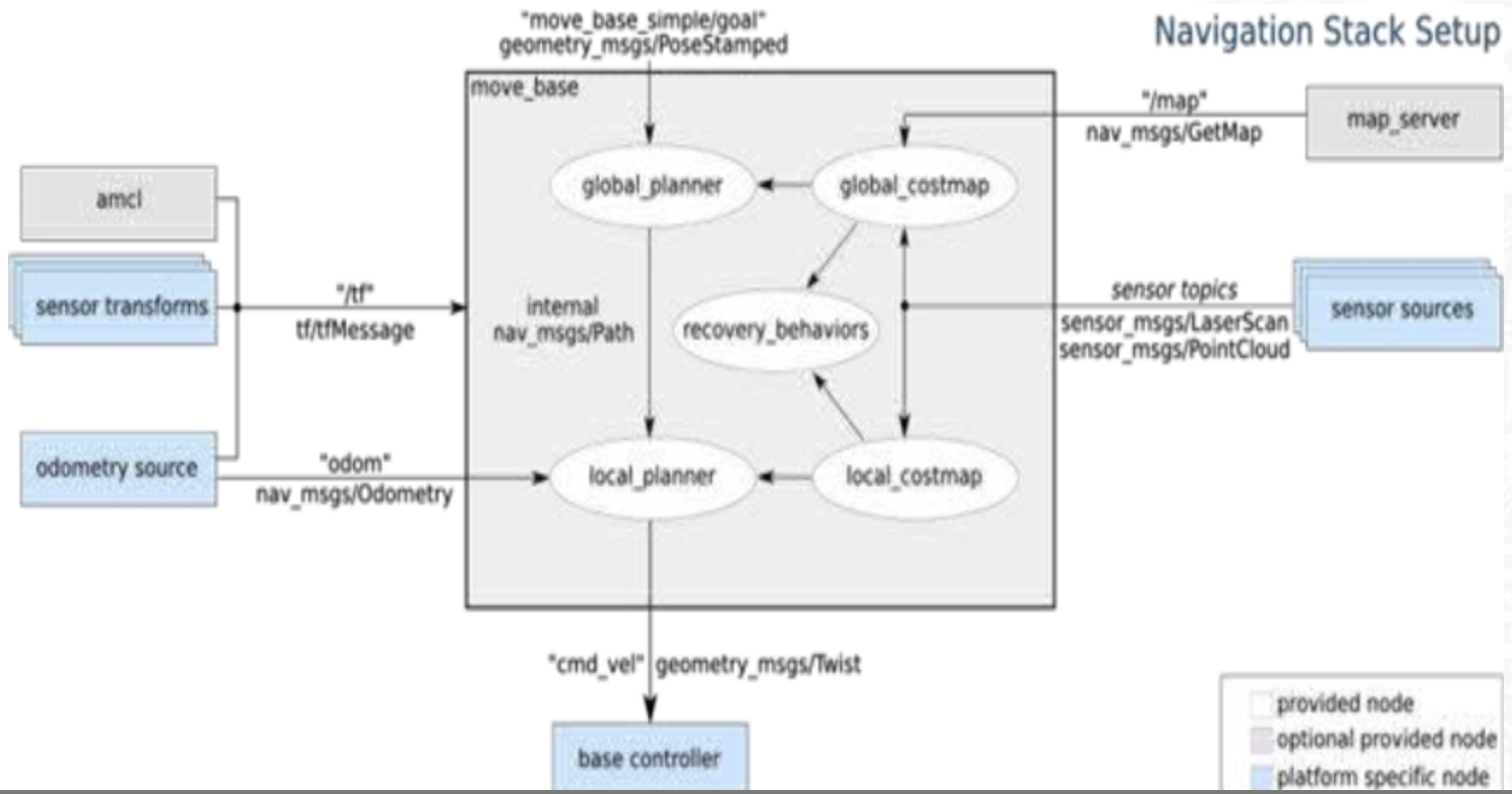


[2] http://www.ros.org/browse

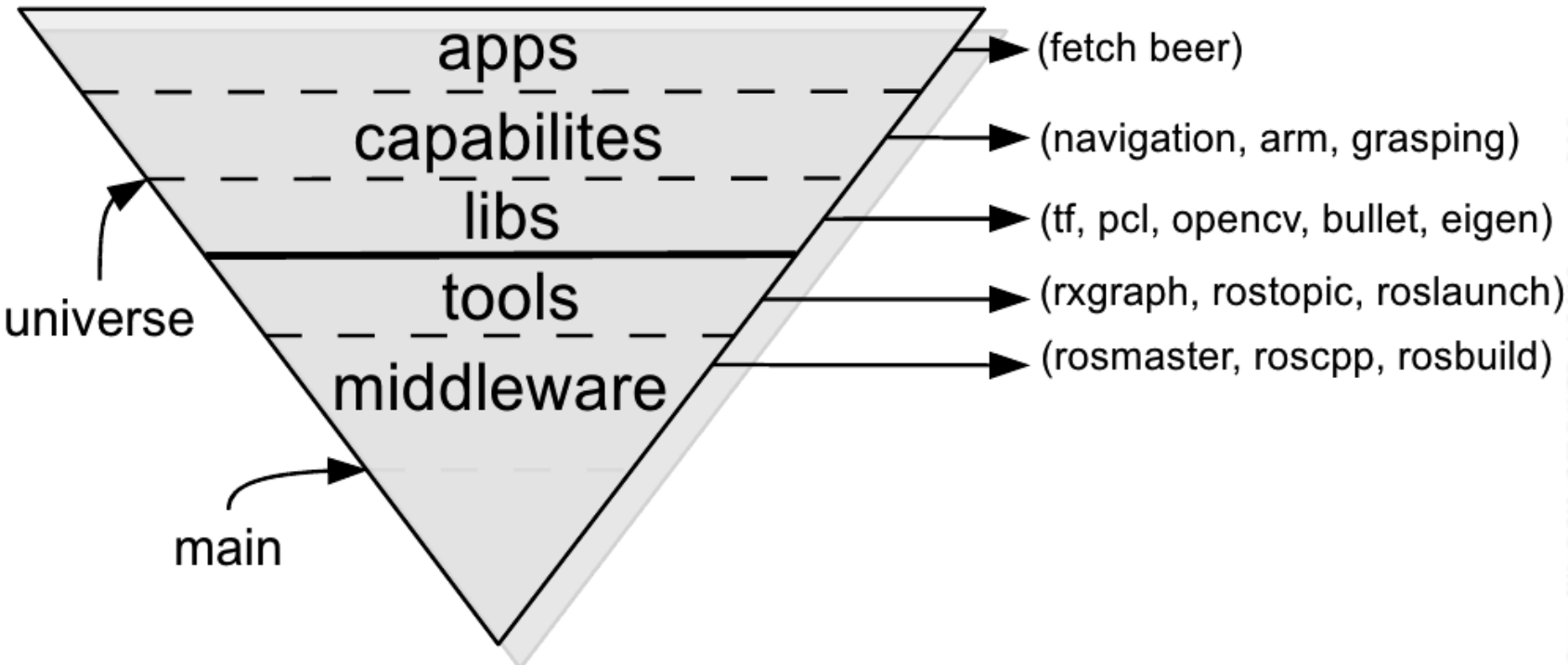
ROS-based Navigation

Includes

- Path planning, Obstacle avoidance, Automatic map making

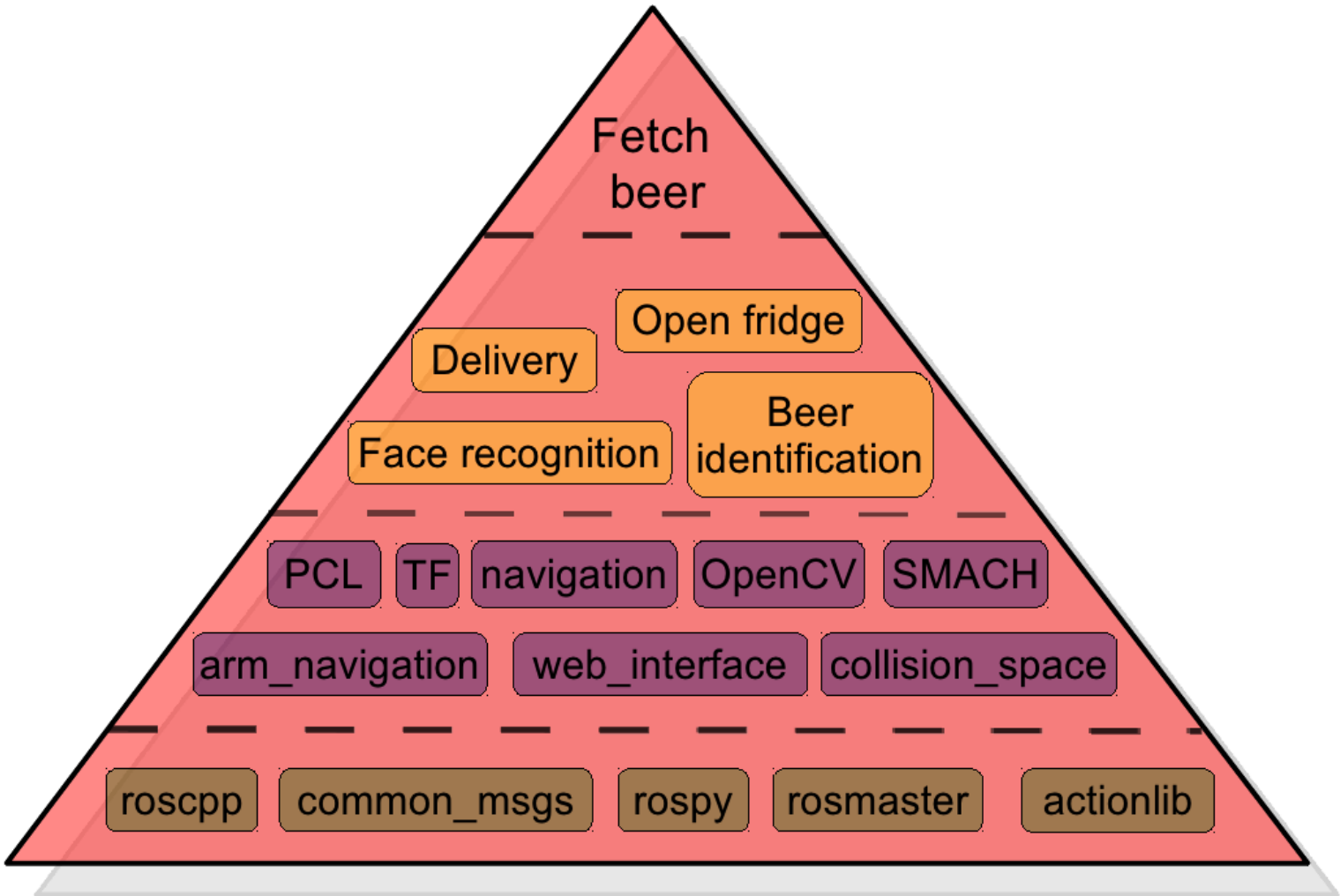


Example Application



- universe - robot centric, main - general

Example Application (cont.)



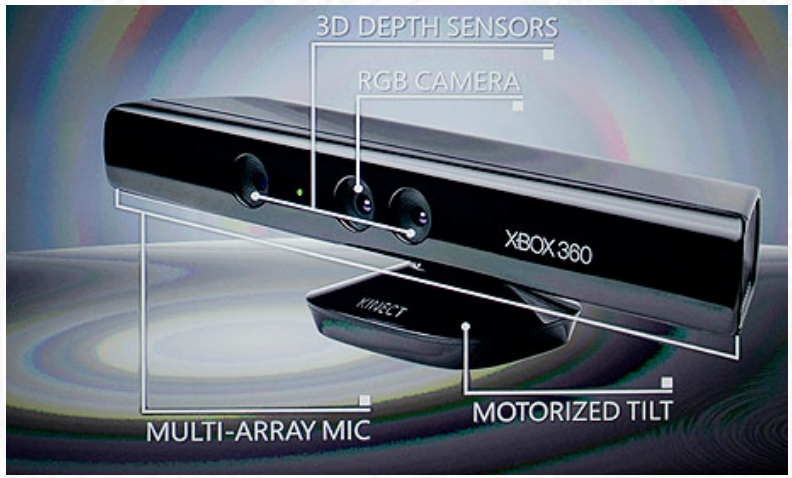
ROS Strengths for RACE

- Visualization
- Object recognition
- Navigation
- Manipulation/Grasping
- Plugging in Sensors
  - already integrated
  - RACE specific

Outline

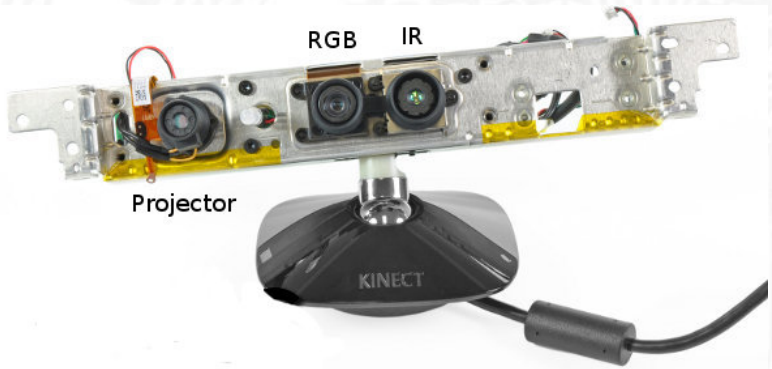
Kinect

- Motion sensing input device by Microsoft for the Xbox 360 video game console
- Range camera technology by Israeli developer PrimeSense
- 3D scene information from a continuously-projected infrared structured light



Kinect Operations - I

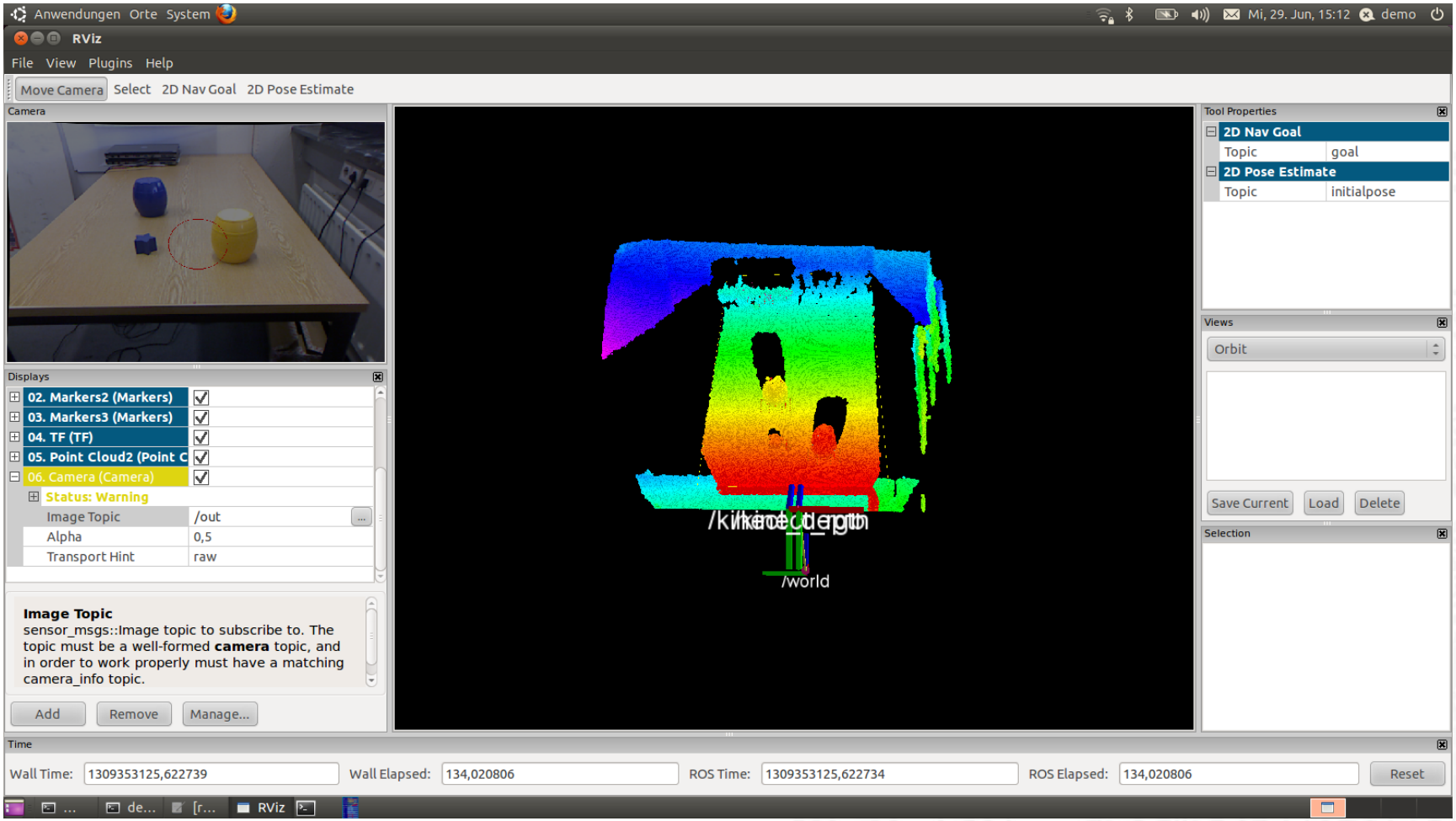
- The IR camera and the IR projector form a stereo pair with a baseline of approximately 7.5 cm
- The IR projector sends out a fixed pattern of light and dark speckles
- The pattern is generated from a set of diffraction gratings, with special care to lessening the effect of zero-order propagation of a center bright dot



Kinect - Technical Data

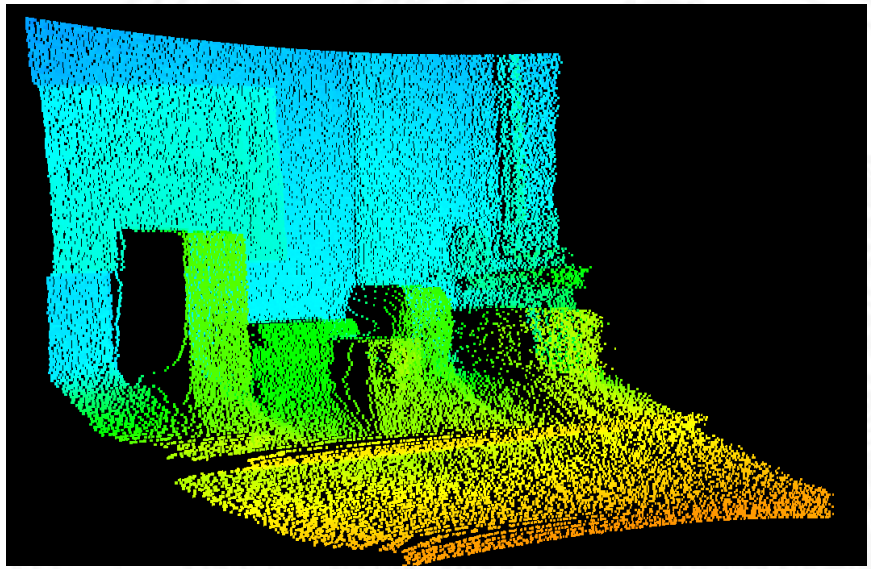
- Resolution of (640 $\times$ 480) @ 30 Hz (color) and (320 $\times$ 240) @ 30 Hz (depth)
- Angular field of view of 57^0 horizontally and 43^0 vertically
- Range of approximately 0.7 - 6 m (practical 0.7 - 3.5 m)
- Physical tilt range (-31^0 to $+31^0$)
- Voice microphone and array supporting single speaker voice recognition (16-bit audio @ 16 kHz)
- OpenNI and Freenect drivers

Kinect - First Results

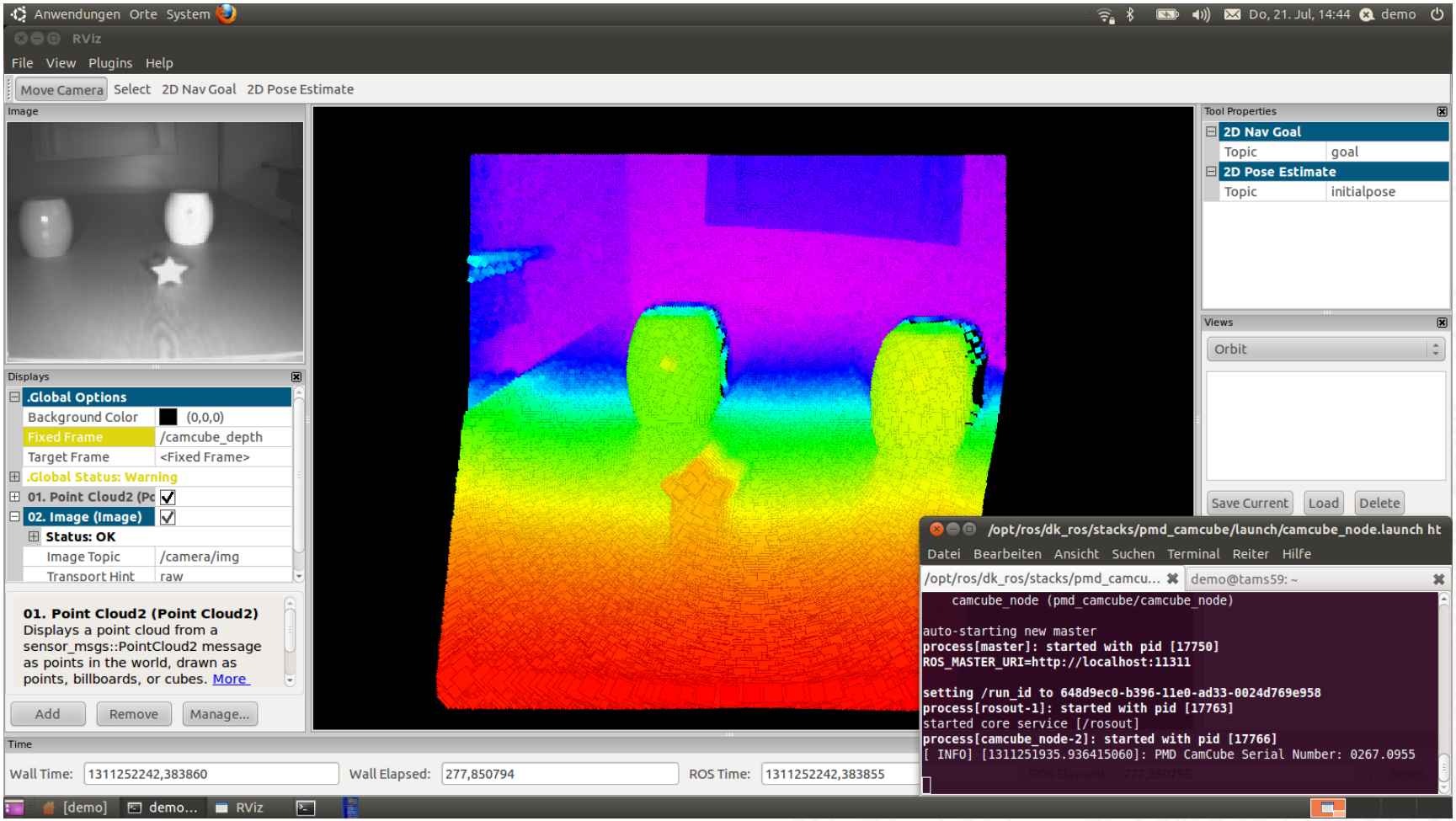


Kinect - Summary

- Fast sensor with large resolution
- Stable, repeatable results
- Ideal for surfaces, inaccuracy on edges (remedy through fusion with the tof-camera (200 $\times$ 200 @ 40 fps) or other sensors)



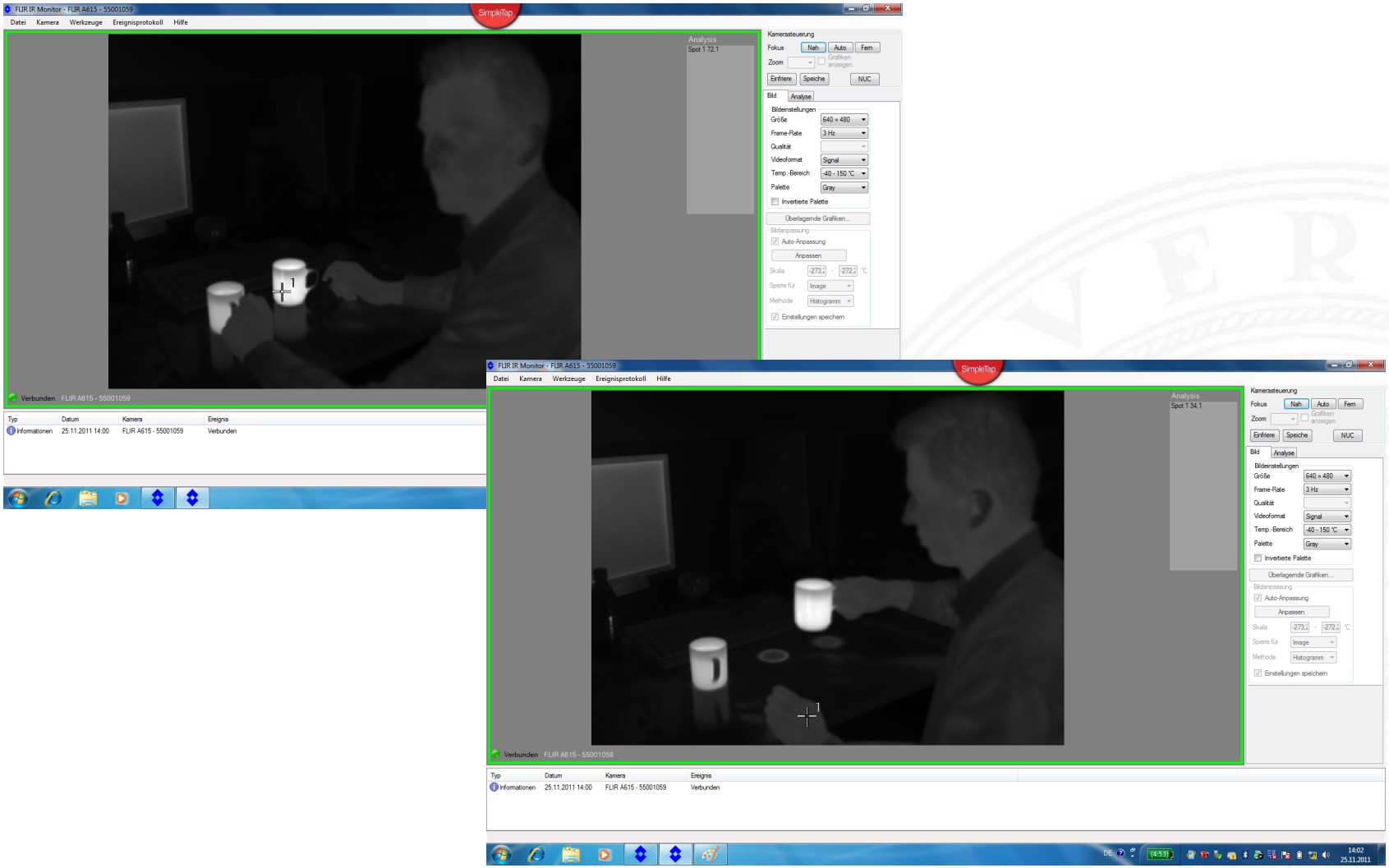
PMD Camcube in ROS



FLIR A615

- FOV $25^0 \times 19^0$
- IR resolution $[640 \times 480]$@50 Hz
- Accuracy $\pm 2^0$ C or $\pm 2\%$ of reading
- Image and control over Gigabit Ethernet

FLIR A615


FLIR IR Monitor - FLIR A615 - 55001059
Datei Kamera Werkzeuge Ereignisprotokoll Hilfe
SimpleTap
Kamerasteuerung
Fokus Nah Auto Fern
Zoom
Einfrieren Speicher NUC
Bild Analyse
Bildeinstellungen
Größe 640 x 480
Frame-Rate 3 Hz
Qualität
Videoformat Signal
Temp.-Bereich -40 - 150 °C
Palette Gray
Invertierte Palette
Überlagernde Grafiken...
Bildanpassung
Auto-Anpassung
Anpassen
Einstellungen speichern
Verbunden FLIR A615 - 55001059
Typ Datum Kamera Ereignis
Informationen 25.11.2011 14:00 FLIR A615 - 55001059 Verbunden

Outline

Gazebo

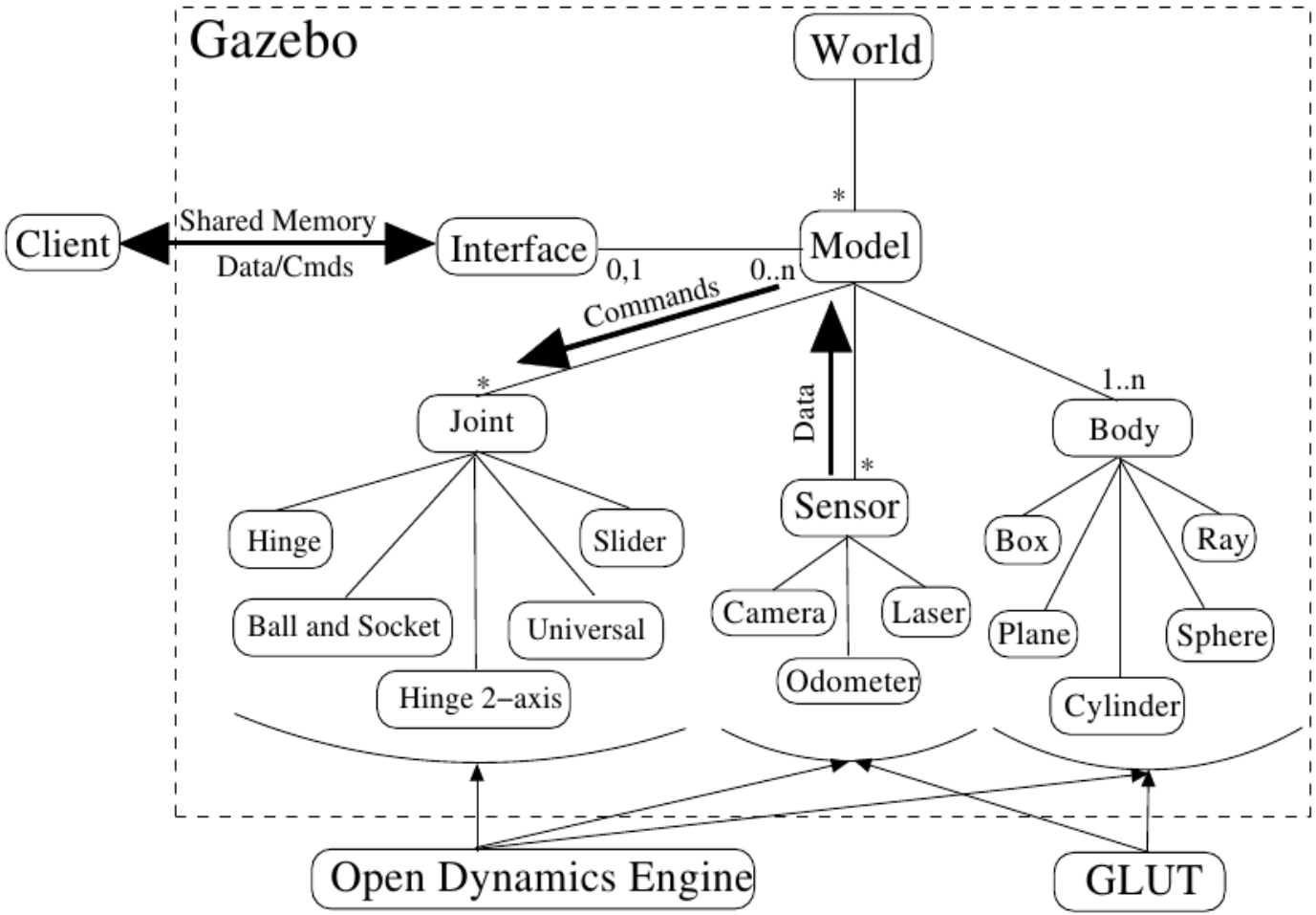
- Developed to be fully compatible with the Player[3] device server
- Full integrated in ROS (version 1.0)
- 3D dynamic multi-robot simulation
- Open source
- ODE - Open Dynamics Engine (Bullet)

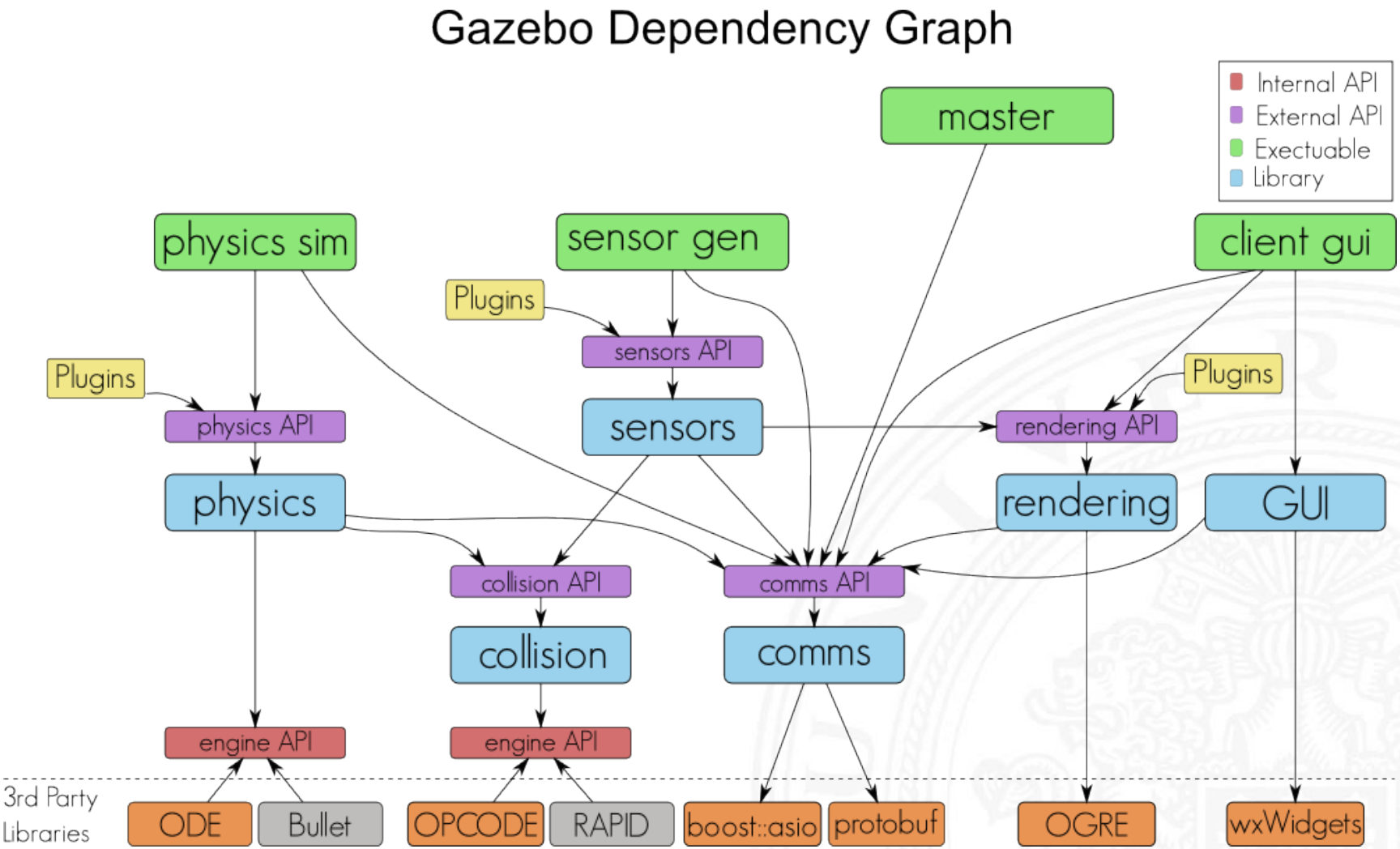
[3] The Player/Stage Projekt, http://playerstage.sourceforge.net/

Gazebo

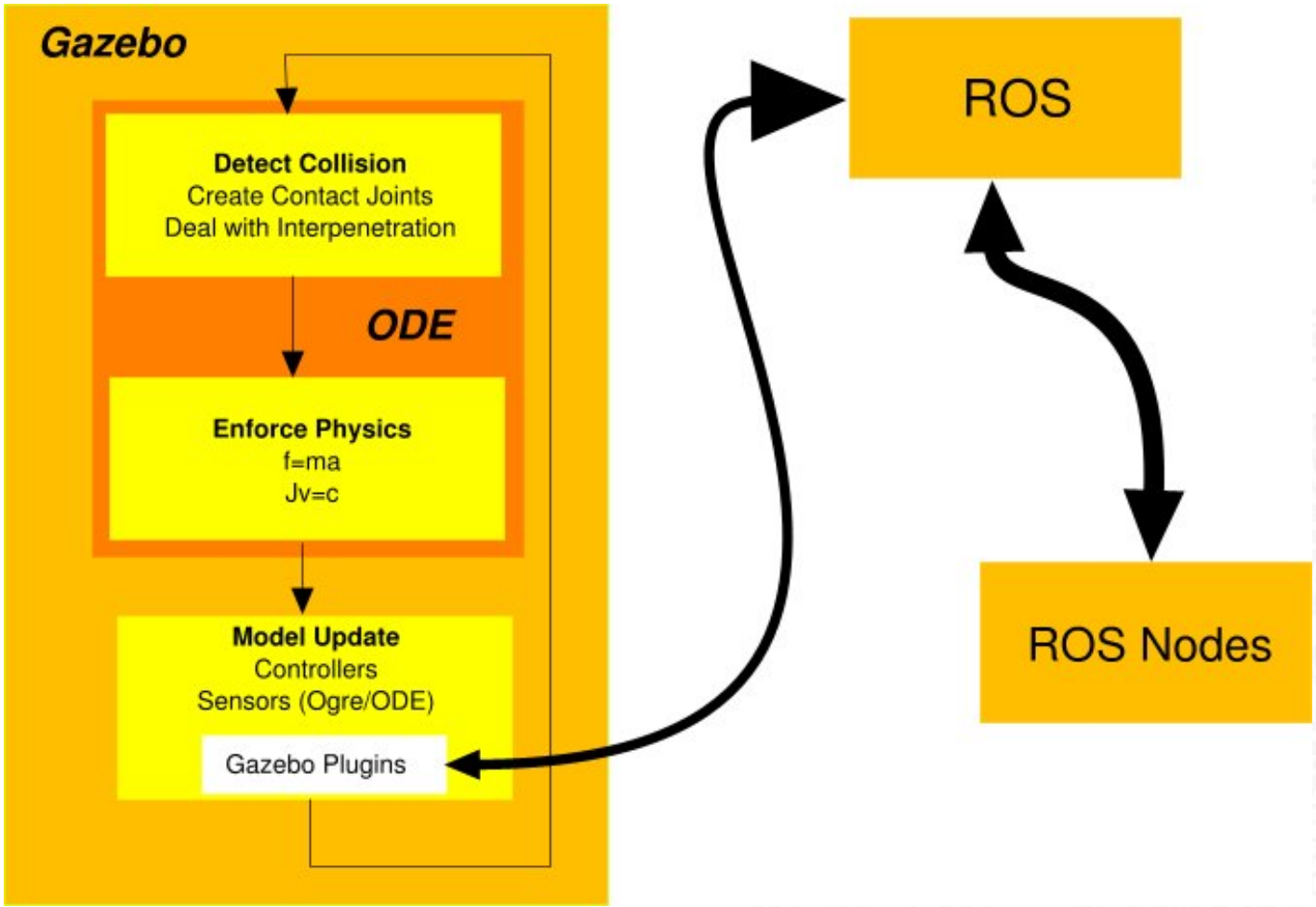
- The World represents the set of all models and environmental factors such as gravity and lighting
- Accuracy in terms of robot sensors and actuators
- API for easily create new robots, actuators, sensors, and arbitrary objects
- Possibilities to create complex worlds
- Simulation of remote environments
- GUI for data visualization
- Visualization with help of OpenGL and GLUT

General Structure of Gazebo components

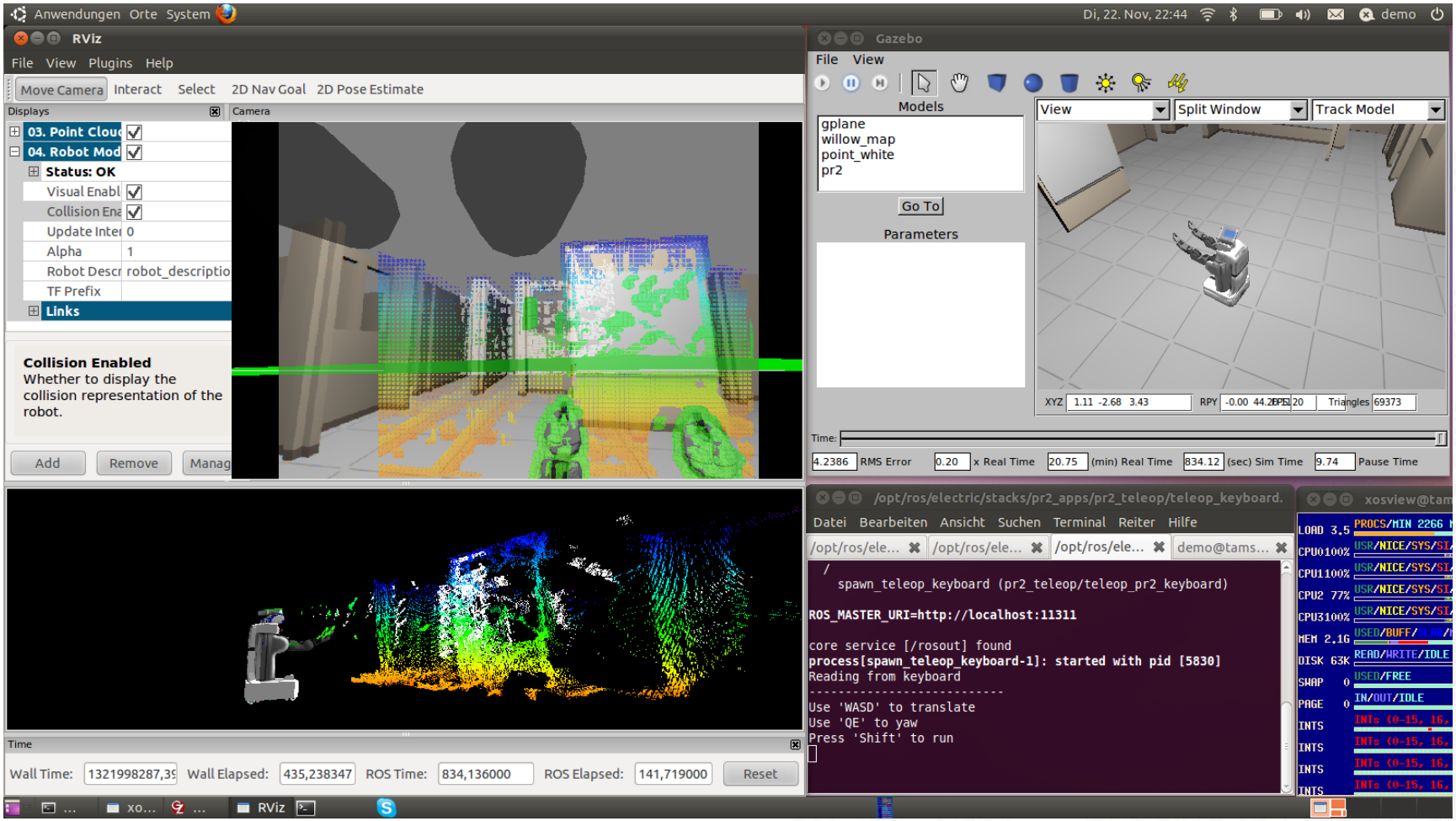



Gazebo Dependency Graph
Internal API
External API
Exectuable
Library
master
physics sim
sensor gen
client gui
Plugins
sensors API
Plugins
Plugins
physics API
sensors
rendering API
physics
rendering
GUI
collision API
comms API
collision
comms
engine API
engine API
3rd Party Libraries
ODE
Bullet
OPCODE
RAPID
boost::asio
protobuf
OGRE
wxWidgets

ROS Simulation Interface



ROS, Stage, PR2



Thank You!

Any questions?

Further Reading