ROS and PR2 Introduction

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Technical Aspects of Multimodal Systems

March 6, 2012

Outline

ROS

- Introduction
- ROS Repositories
- ROS - Universe

PR2 - Short Overview

- PR2 - Hardware Specification
- PR2 - Sensors

Extended Sensors

- Microsoft Kinect
- ASUS Xtion Pro Live

Available Sensor Information and Data Record

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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, Inc.
- Community

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

Introduction (cont.)

Robots Using ROS > 50

ROS Basics

- Supported Platforms
  - Linux (Ubuntu!), Mac OS, partial support for Windows
- Languages
  - C/C++, Python, Octave, Lisp, Java
- Hardware suggested
  - many cores, nVidia video card (for visualization and simulation)

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Prerequisites

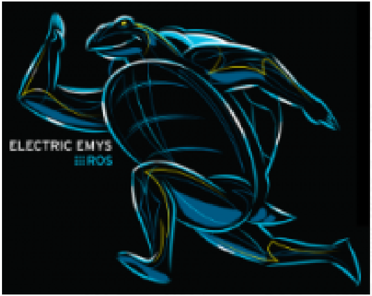
- Ubuntu (32bit), 10.10 (Maverick) or 11.10 (Oneiric)[2]
- ROS (Electric)[3]
- PR2 Electric PR2 Simulation Package[4]
- further questions: please ask

[2] http://www.ubuntu.com/download
[3] http://www.ros.org/wiki/electric/Installation/Ubuntu
[4] http://www.ros.org/wiki/Robots/PR2/electric

What does ROS cover?

ROS

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



ROS Core

- ROS Master (*rosmaster*)
  - provides naming and registration services
  - tracks topics and services
  - enables localization of nodes (they talk peer-to-peer)
  - centralized XML-RPC-server
- Parameter Server
  - stores persistent (run-time) configuration parameters
- rosout
  - network-based **stdout** for human-readable messages

ROS Core

- nodes
  A node is a source and sink for data sent over the ROS network

Generally: nodes shall be uniquely named!

- topics
  - asynchronous many-to-many communication streams
- services
  - synchronous one-to-many network-based functions

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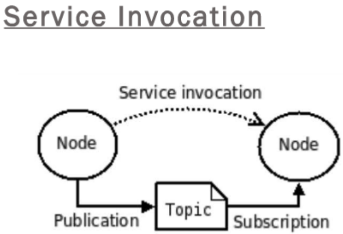
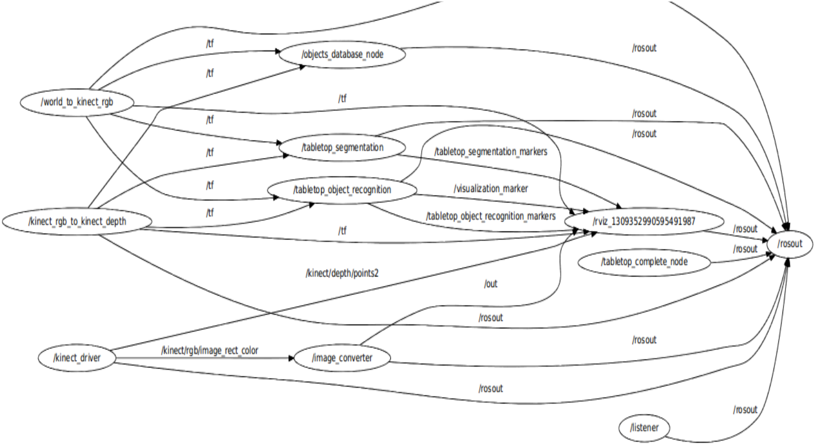
ROS Communication

- 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.)

rxgraph: communication network visualization



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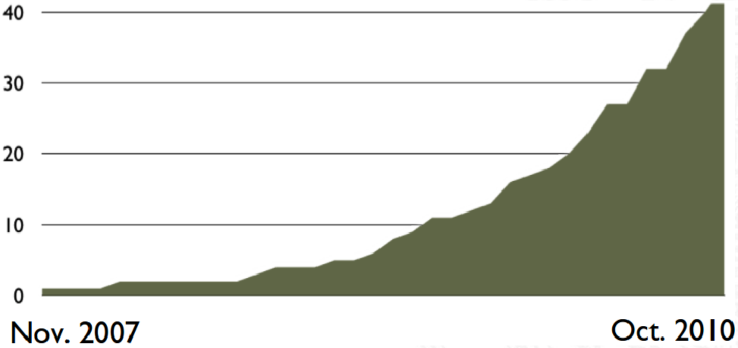
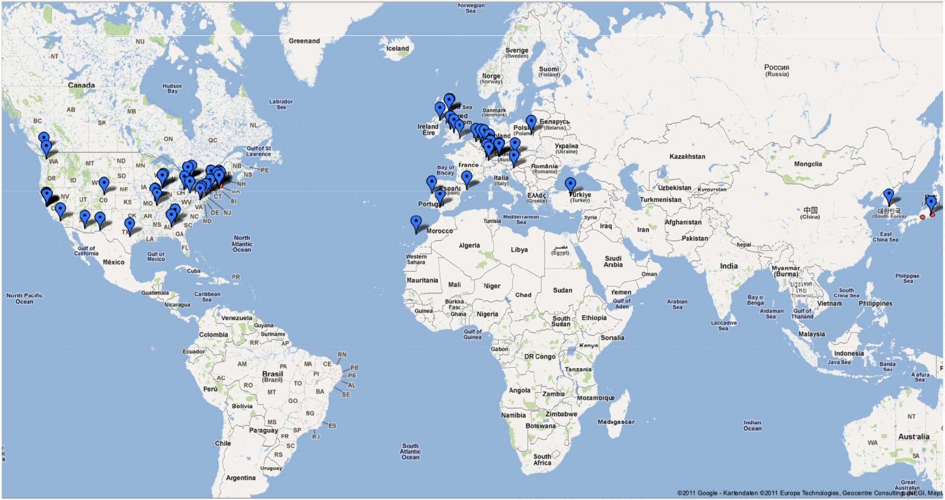
ROS Repositories

Repositories world-wide

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



ROS Repositories (cont.)



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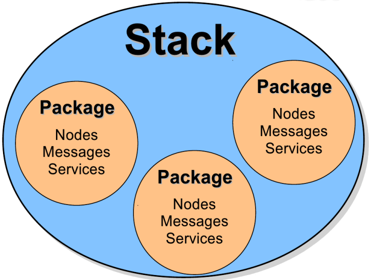
ROS Stacks

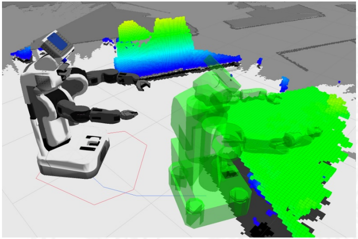
- Collect similar packages that work together to achieve e.g.:
  - 2D Navigation
  - Manipulation
  - SLAM

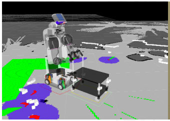


ROS Stacks Overview[5]

Currently > 400 Stacks available

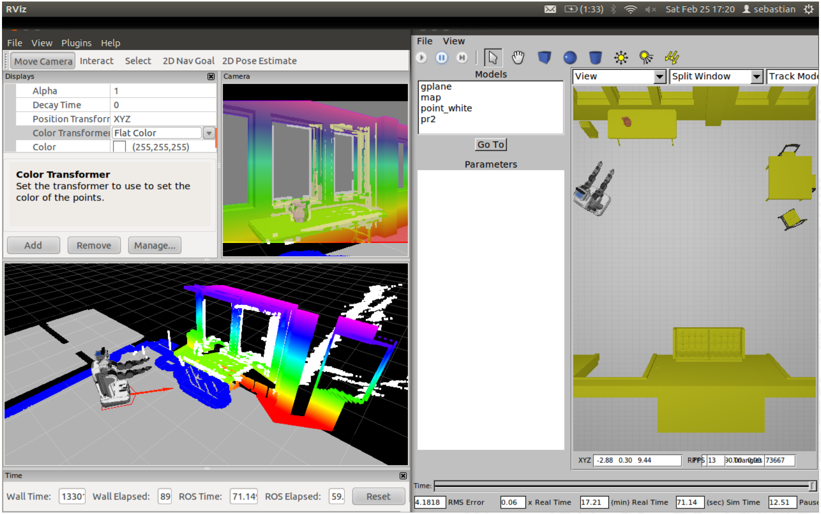
- (2D/3D) Navigation
- PR2 arm navigation
- PR2 opening doors
- Exploration
- GUI for PR2 robot
- PR2 object manipulation
- PR2 simulator





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

Visualization and Simulation



Alpha	1
Decay Time	0
Position Transforr	XYZ
Color Transforme	Flat Color
Color	(255,255,255)

Color Transformer
Set the transformer to use to set the color of the points.

Wall Time: 1330' Wall Elapsed: 89 ROS Time: 71.14! ROS Elapsed: 59.

Models:
gplane
map
point_white
pr2

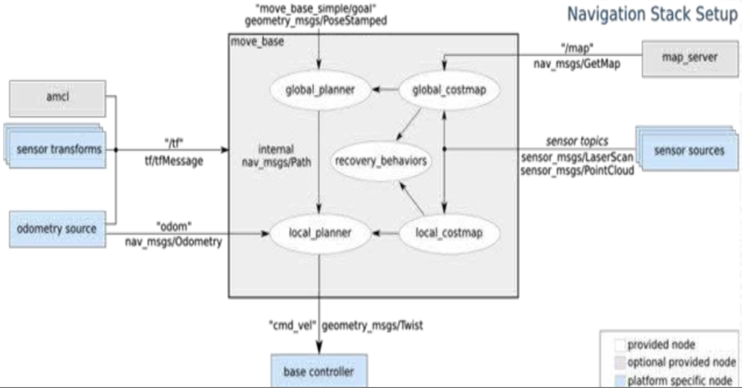
XYZ -2.88 0.30 9.44 RPY FPS 13 90.00 0.00 Triangles 73667

4.1818 RMS Error 0.06 x Real Time 17.21 (min) Real Time 71.14 (sec) Sim Time 12.51

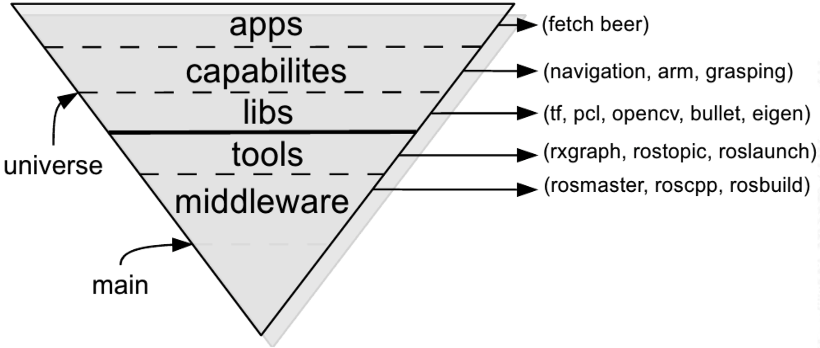
ROS-based Navigation

Includes

- Path planning, Obstacle avoidance, Automatic map making

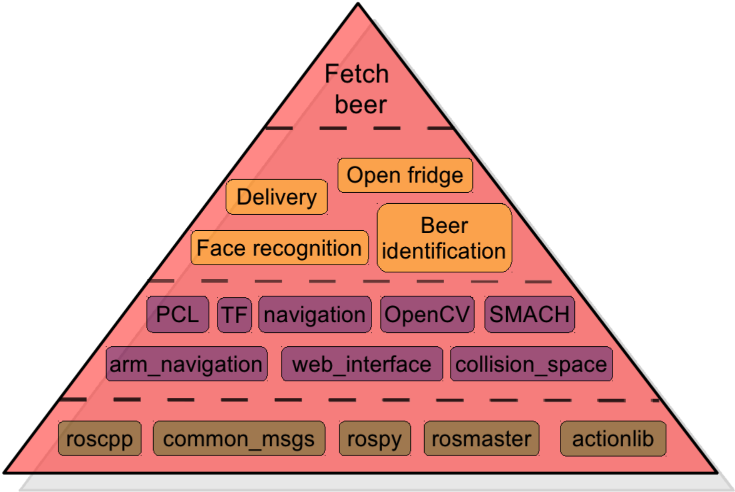


Example Application


apps
capabilites
libs
tools
middleware
universe
main
(fetch beer)
(navigation, arm, grasping)
(tf, pcl, opencv, bullet, eigen)
(rxgraph, rostopic, roslaunch)
(rosmaster, roscpp, rosbuild)

- universe - robot centric, main - general

Example Application (cont.)



ROS Strengths

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

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ROS - Universe

- Packages are the main unit for organizing software
- Manifests (manifest.xml) provide metadata about a package, including dependencies, language-specific information such as compiler flags
- Stacks are collections of packages that provide aggregate functionality
- Stack manifest (stack.xml) provide data about stack, including its dependencies on other stacks
- Message descriptions, define the data structures for messages sent in ROS
- Service descriptions, define the request and response data structures for services in ROS

ROS - Universe (cont'd)

- Nodes are combined together into a graph and communicate with one another
- ROS Master provides naming and registration services to the rest of the nodes in the ROS system
- Nodes communicate with each other by passing messages. A message is a simply a data structure, comprising typed fields
- Topics are named buses over wich nodes exchange messanges based on publish / subscribe policy
- Service request / reply is done via a Service, which is defined by a pair of messages

PR2 - Evaluation Platform

- PR2 as a main platform for evaluation
- Gazebo simulation
- ROS as a common framework
- Using/modification/improvement of existing stacks
- Integration of new algorithms and methods as a ROS-stacks

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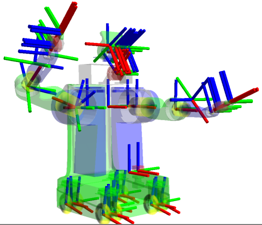
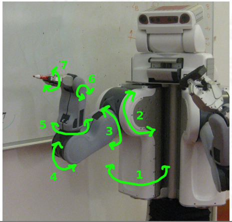
PR2 - Hardware Specification

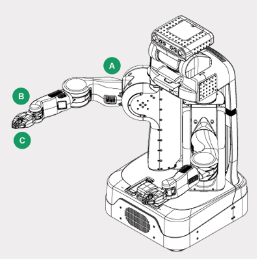
- 2× computers with 24 GB RAM and quad-core Nehalem processors
- 1.3 kWh Lion Battery Pack
- 2 hrs Approximate Runtime
- Coordinate system (for all links) positive z-axis up, positive x-axis forward, and positive y-axis robot-left when PR2 in the home pose





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



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PR2 - Intrinsic sensors

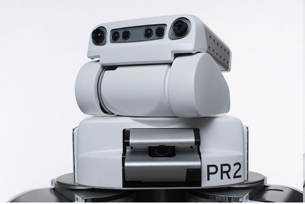
- Microstrain 3DM-GX2 IMU (above the shoulders)
- Three-Axis Accelerometer (gripper)
- Calibration LED (gripper)

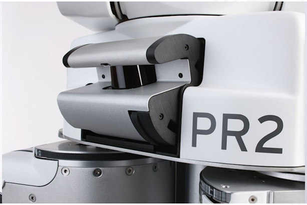
PR2 - Extrinsic sensors - Head

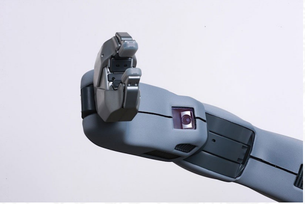
- Microsoft Kinect and/or ASUS Xtion Pro Live (color/depth image/point cloud [640 × 480@30 *fps*])
- Global shutter color gigabit ethernet camera (Prosilica GC2450C, 5 MP, [2448 × 2050@15 *fps*])
- Wide stereo camera system (Aptina MT9V032C12STC, 100 Mb color ethernet, [752 × 480@15 *fps*])
- Narrow 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 laser scanner (Hokuyo UTM-30LX, $135^0(+90^0 to - 45^0)$,above the shoulders)
- Laser scanner (Hokuyo UTM-30LX, base)
- Global shutter gigabit ethernet camera (2×, forearm)
- Fingertip pressure sensor arrays (gripper)
- Speaker

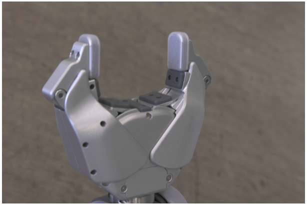


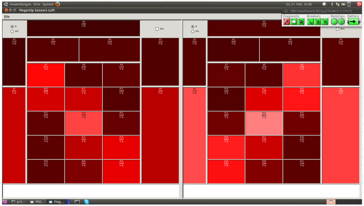




PR2 - Fingertip pressure sensor arrays (gripper)

- Each PR2 gripper is equipped with 2 pressure-sensitive fingertips
- Each pressure comprises 22 pressure sensing elements (1 on the back, 6 around the edges, and a 3 × 5 array on the front)





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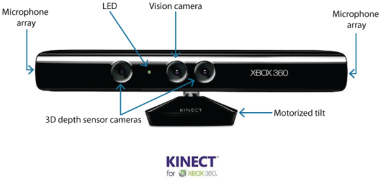
Kinect

- 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

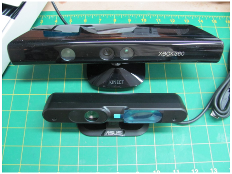


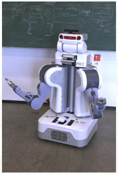
Kinect - technical details

- Resolution of (640×480) @ 30 Hz (color) and (320×240) @ 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

Microsoft Kinect vs. ASUS Xtion Pro Live

- The Xtion Pro Live is significantly smaller
- The placement of the lenses are more symmetric
(this give it a less lopsided appearance and makes it much more usable for humanoids)
- The Xtion Pro Live does not require an external power supply





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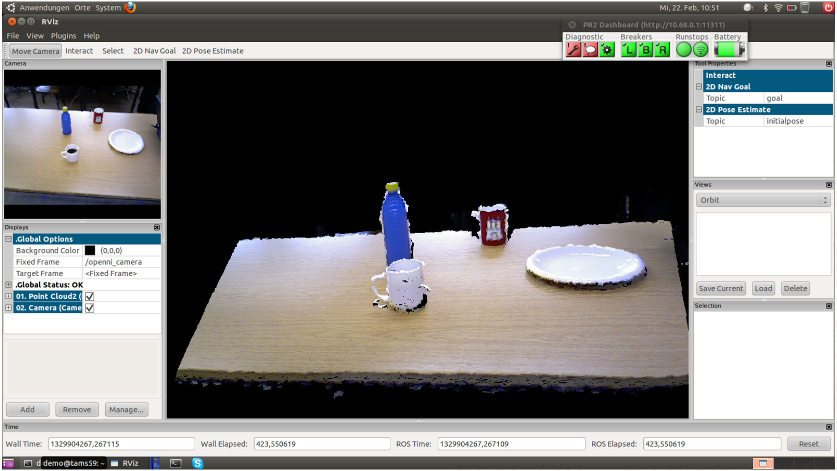
ASUS Xtion Pro Live - technical details

- Resolution of (640 × 480) @ 30 Hz (color) and (320 × 240) @ 30 Hz (depth)
- Angular field of view of 58^0 horizontally and 45^0 vertically
- Range of approximately 0.8 - 3.5 m (practical 0.7 - 3.5 m)
- Voice microphone and array supporting single speaker voice recognition (16-bit audio @ 16 kHz)
- OpenNI drivers

ASUS Xtion Pro Live - first results



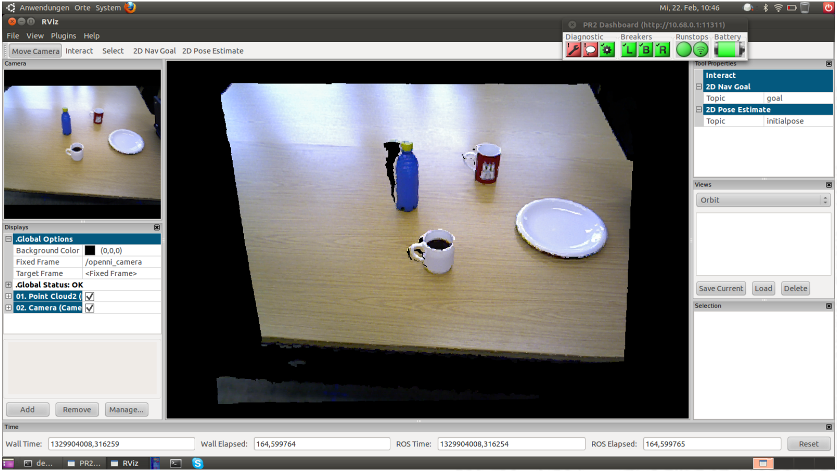
.Global Options	
Background Color	■ (0,0,0)
Fixed Frame	/openni_camera
Target Frame	<Fixed Frame>
.Global Status: OK	
01. Point Cloud2 (	☑
02. Camera (Came	☑

Interact	
2D Nav Goal	
Topic	goal
2D Pose Estimate	
Topic	initialpose

Orbit

Wall Time: 1329904267,267115 Wall Elapsed: 423,550619 ROS Time: 1329904267,267109 ROS Elapsed: 423,550619

ASUS Xtion Pro Live - first results



PR2 Dashboard (http://10.68.0.1:11311)

Mi, 22. Feb, 10:46

Tool Properties

Interact	
2D Nav Goal	
Topic	goal
2D Pose Estimate	
Topic	initialpose

Displays

.Global Options	
Background Color	■ (0,0,0)
Fixed Frame	/openni_camera
Target Frame	<Fixed Frame>
.Global Status: OK	
01. Point Cloud2 (	☑
02. Camera (Came	☑

Views: Orbit

Wall Time: 1329904008,316259 Wall Elapsed: 164,599764 ROS Time: 1329904008,316254 ROS Elapsed: 164,599765

Available sensor information

- Fingertip pressure sensor (4×22 values)
- Color information
- Wide stereo camera system (PointCloud)
- Narrow stereo camera system (LED textured light projector) (PointCloud)
- LRF in the Base (2D)
- Tilted LRF (PointCloud)
- Kinect or Asus Xtion Pro Live (Color and Depth) (PointCloud)

Data record and distribution

- ROSBAG
- Set of tools for recording from ROS topics as well as playing back
- Possibilities to record of all data or partial
- Data rate from 0.53 MB/s (tf/Odom/2D LRF) to 50 MB/s (+ data from the Kinect/Asus) (all data)
- 2× hard disks with 1,5 TB respectively (in the base of the PR2)
- Planing to buy: 3 further hard disks and 2 hard disk mobile racks

Thanks for your attention!

now see: http://www.ros.org/wiki/ROS/Tutorials

ROS Workshop at TAMS in April

23.04. – 27.04.12

- Hands-on ROS Tutorial
- ROS expert will guide you
- topics are to be proposed (by you:)
- of course about ROS and PR2

Be there or be square!

ROS Workshop Topics

Proposals

- understand stack and learn how to modify (e.g. tabletop)
- debugging + error detection + tracing
- installation of other stacks on PR2
- how to create own stack?
- how are singularities handled?
- combination (chaining of stacks?
- compiling/tool chain, how to use/how does it work?
- optimization of rosbag