Introduction to ROS

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Technical Aspects of Multimodal Systems

April 6, 2015

Motivation

- Heterogeneity vs. Homogeneity
  - sensor types, actuators, ...
  - sensor model, kinematic chain, ...
- Abstraction
- Algorithm re-usability
  - 2D laser data mapping
  - object recognition
- Debugging
  - simulation, data visualization, ...

Idea

- Robot Operating System
- Meta operating system
- Open source
- Hardware abstraction
  - portability
  - simplification of sensors and actuators
- Recurring tasks already solved
  - Navigation, data filtering, object recognition ...

Current State

- Multiple versions actively used
  - may not be compatible to each other
  - may not provide same libraries
- Linux (Ubuntu!)
- Supports C/C++, Python, Java, Lisp, Octave ...
  - Python for high level code/fast implementation
  - C/C++ for algorithms/computation
- Functions and algorithms already available
  - May be difficult to find
  - Better than reimplementing

ROS System

- ROS nodes
  - sensors
  - actuators
  - logic
- ROS core
- Communication

ROS Node

- Discrete part of the system
- Specialized software/algorithm
- Many ROS nodes per system
- Example:
  - node gets image
  - runs edge detection algorithm on it
  - provides found edges

ROS Core

- Central unit, also called ROS master
  - nodes
  - sensors
  - communication
- Coordination of nodes
- Communication Management
- Exactly one per system
- Transparent to the user

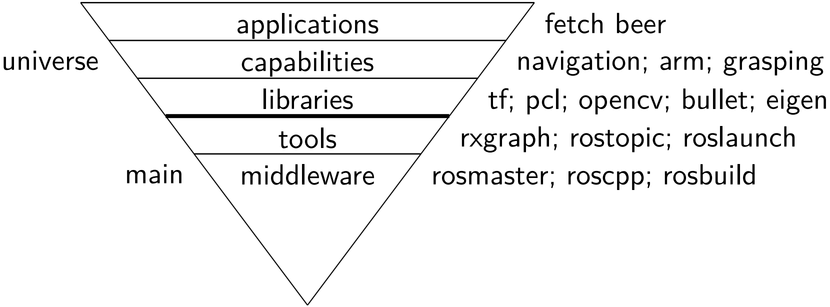
Communication

- Messages
  - standardized data types
- Topics
  - n:n communication
- Services and Actions
  - 1:1 communication

Sensors

- Exploration
- Localization
- Detection
- One node per sensor
  - provide data as topic
  - abstract from hardware

System structure



applications — fetch beer

universe: capabilities — navigation; arm; grasping

libraries — tf; pcl; opencv; bullet; eigen

tools — rxgraph; rostopic; roslaunch

main: middleware — rosmaster; roscpp; rosbuild

- universe → robot centric, developed by community
- main → general tools, maintained by Willow Garage

Messages

- Fundamental communication concept
- Description of data set
- Data types
  - ROS
  - general
- Header
  - time stamp
  - identifier

```
$ rosmsg show -r robot_msgs/Quaternion
# xyz - vector rotation axis, w - scalar term (cos(ang/2))
float64 x
float64 y
float64 z
float64 w
```

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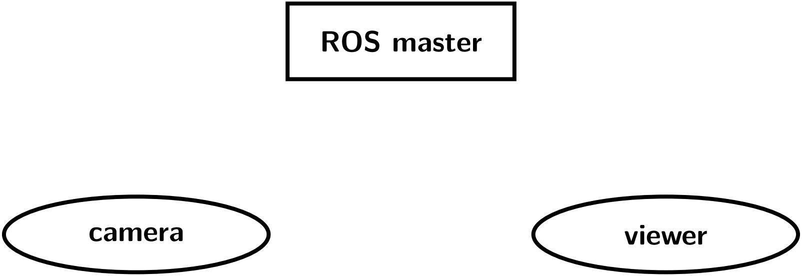
```

Topics

- Published by nodes
- Unique identifier
- Anonymity
- Open subscription
- Sensor data

Communication - Example



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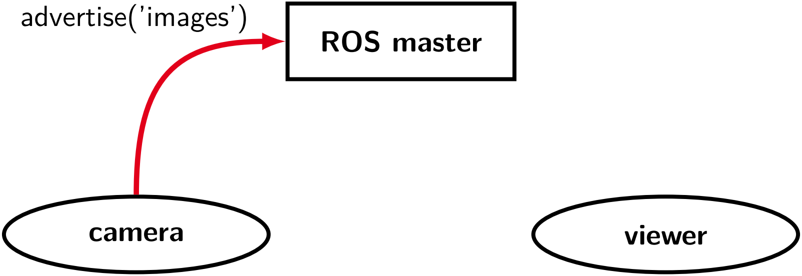

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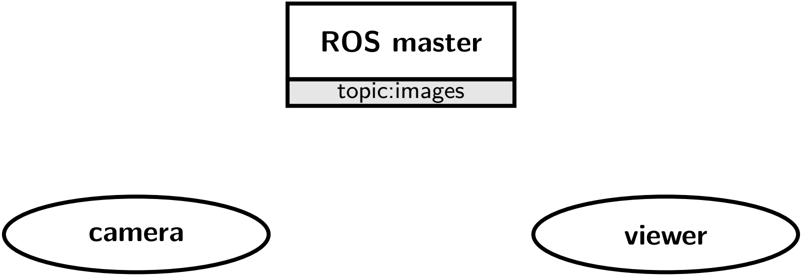

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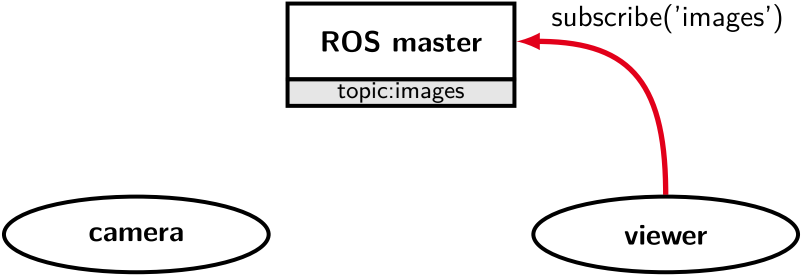

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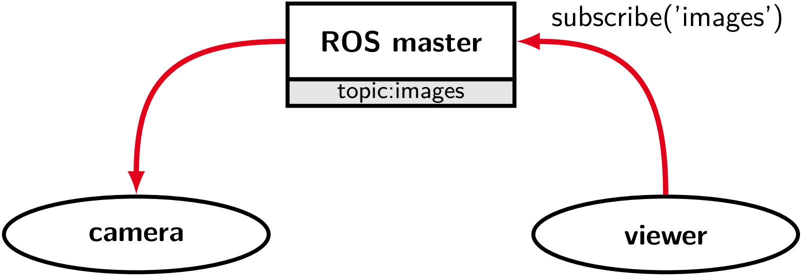

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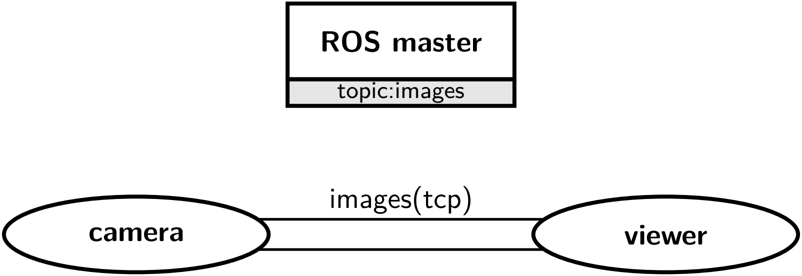

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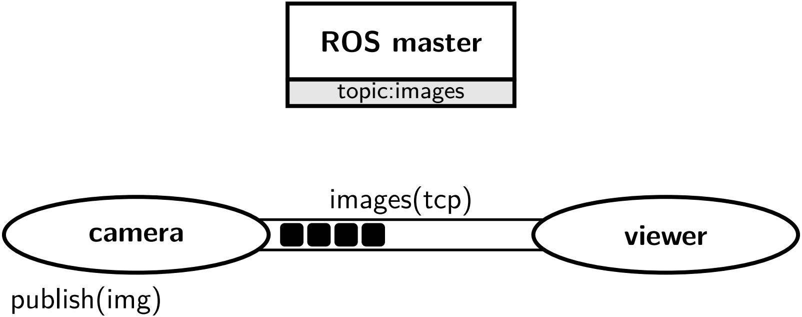

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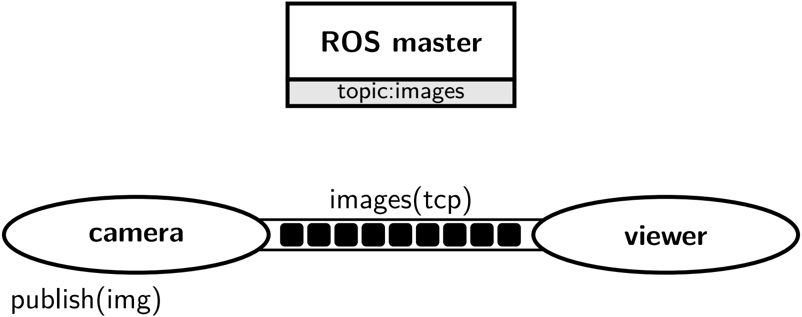

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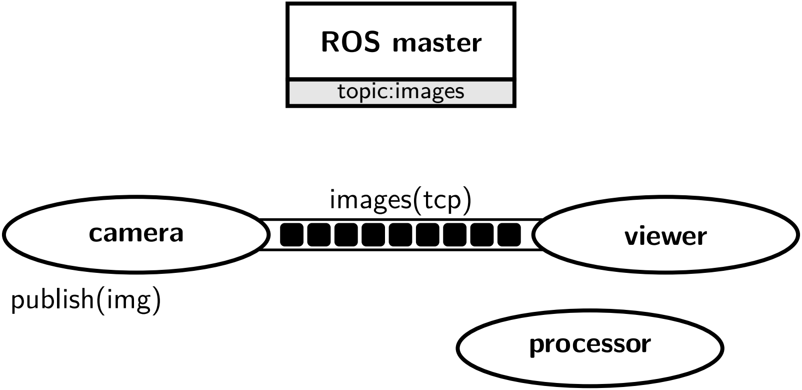


ROS master

topic:images

images(tcp)

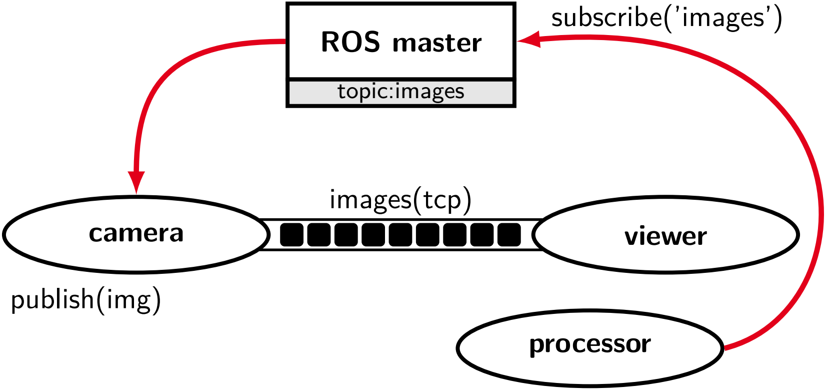
camera

viewer

publish(img)

processor

Communication - Example



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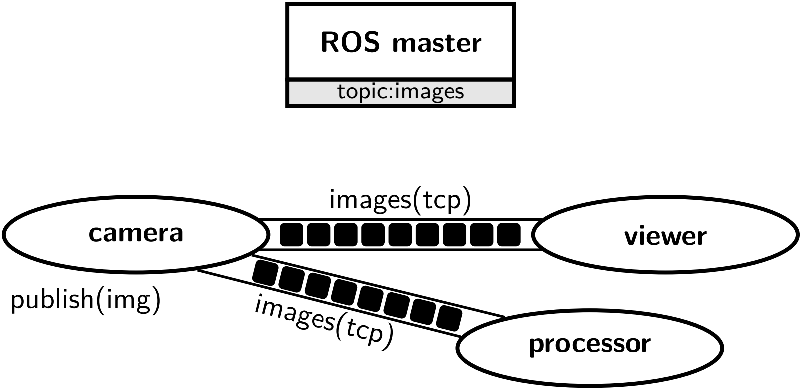

Services

- 2 message types
  - request and response
- Synchronous protocol
  - client sends request
  - client waits for server
  - server replies

```
$ rosservice type add_two_ints | rossrv show
int64 a
int64 b
- - -
int64 sum
```

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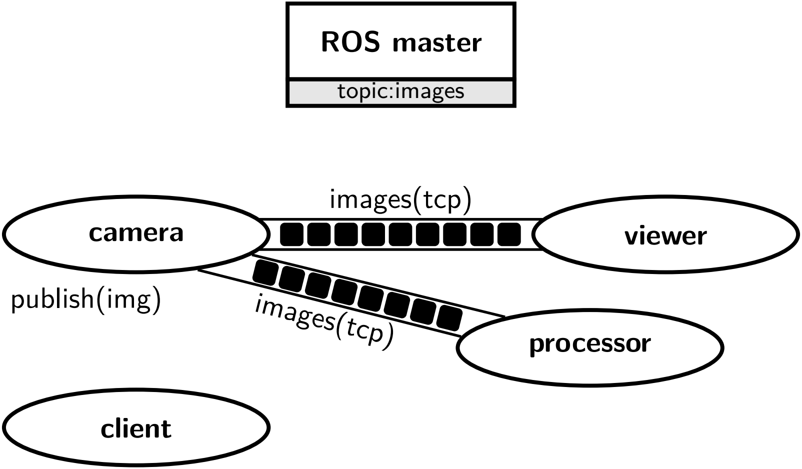

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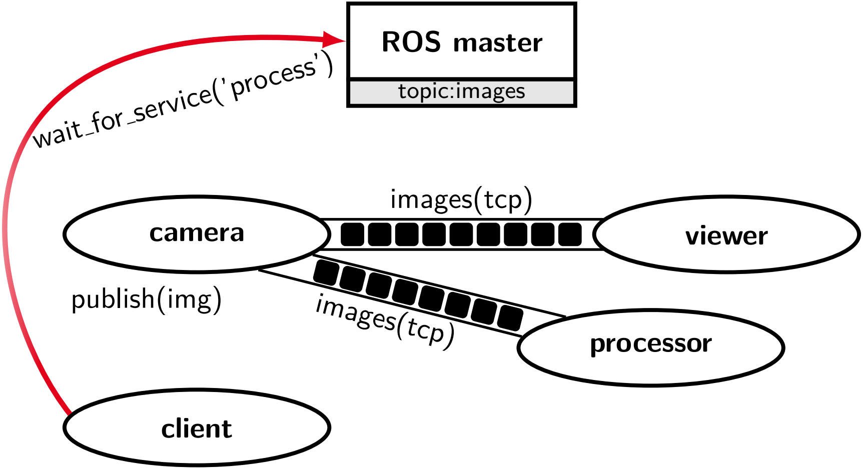

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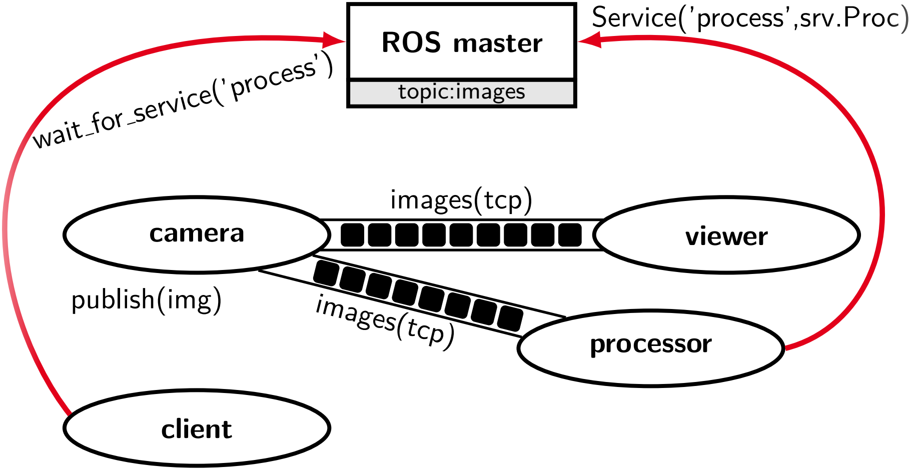

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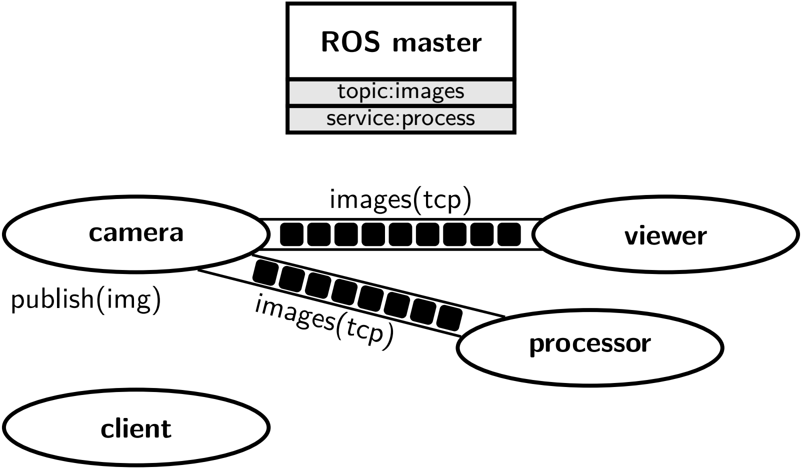

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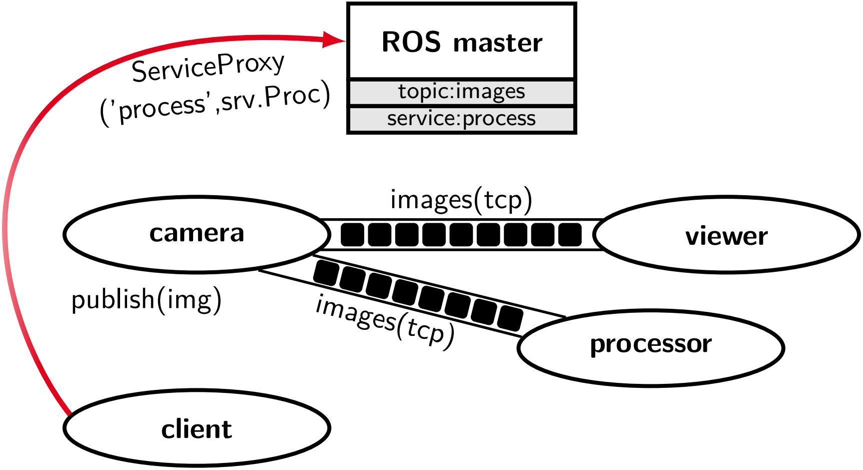

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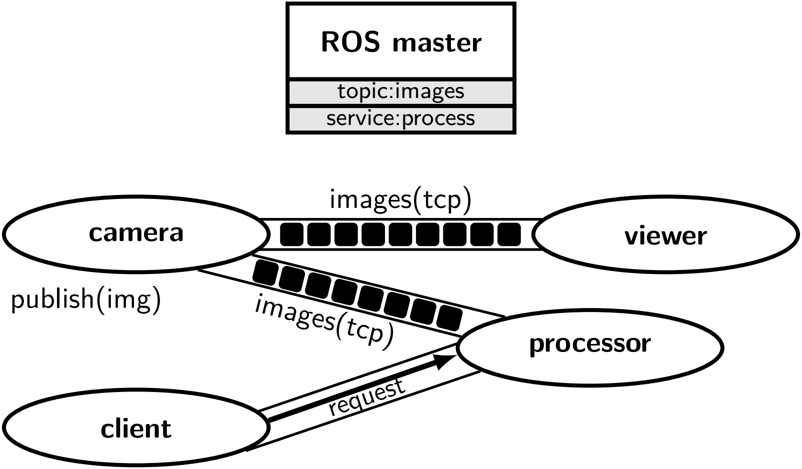

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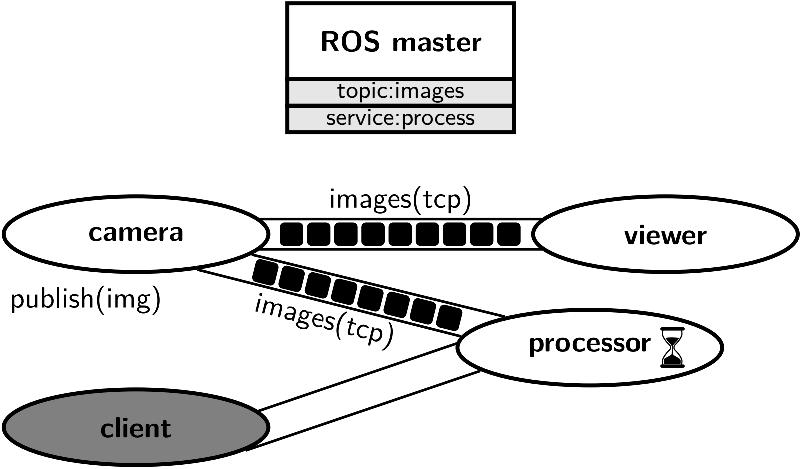

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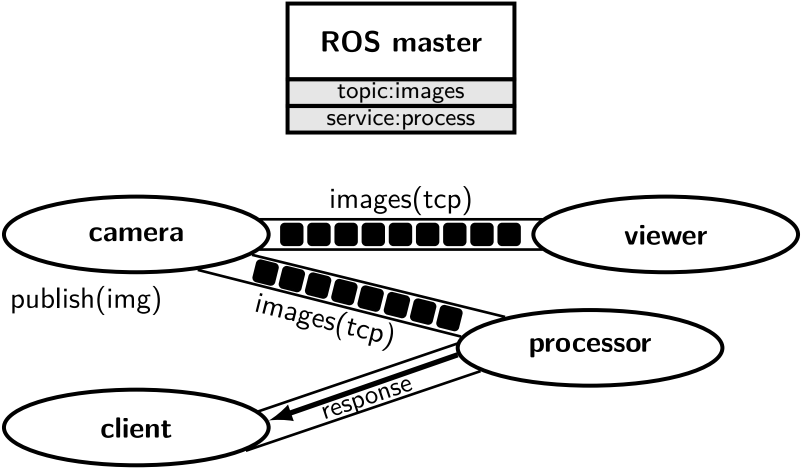

Actions

- 3 message types
  - goal and result
  - optional feedback
- Asynchronous protocol
  - client sends goal
  - server may respond with feedback
  - server delivers result
- Interruptible

```
# Define the goal
uint32 dishwasher_id    # Specify which dishwasher we want to use
---
# Define the result
uint32 total_dishes_cleaned
---
# Define a feedback message
float32 percent_complete
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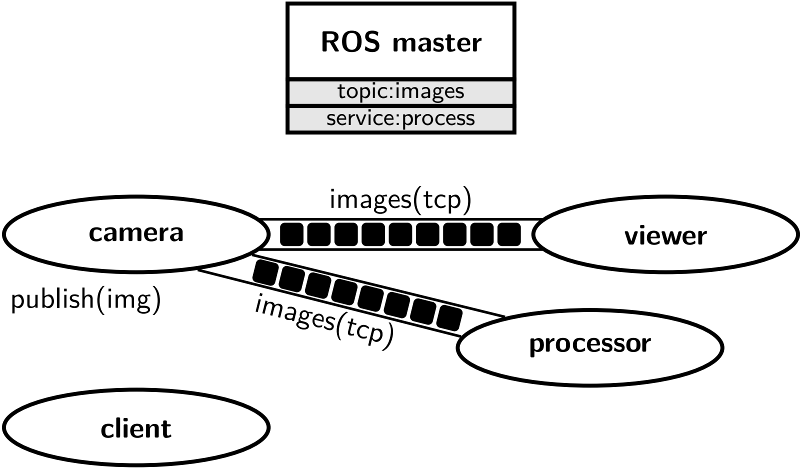

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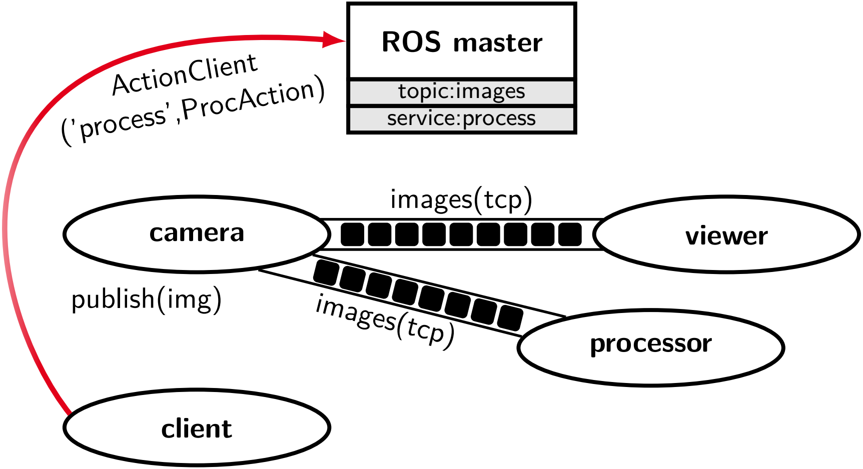

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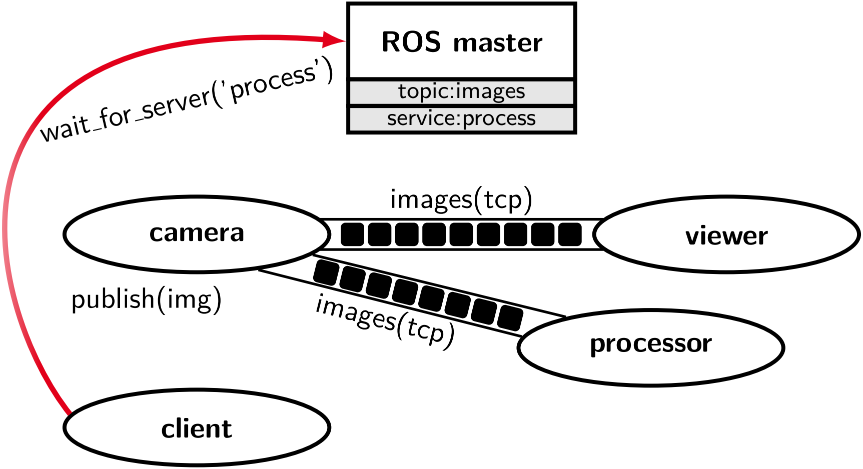

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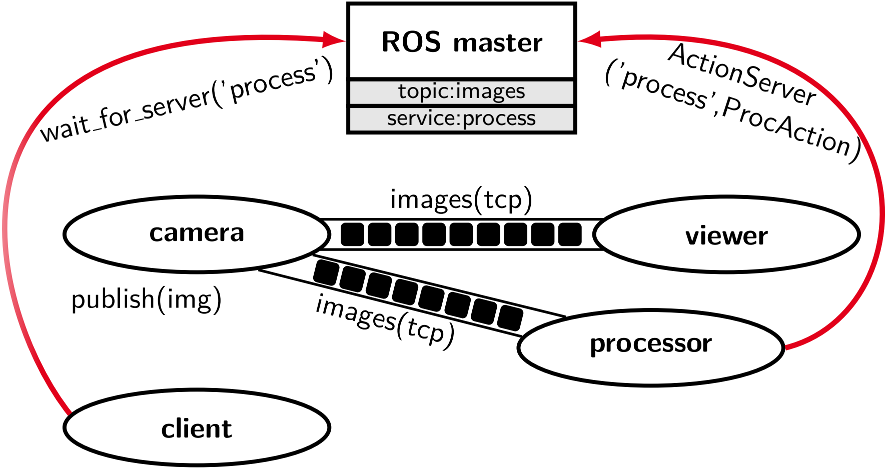

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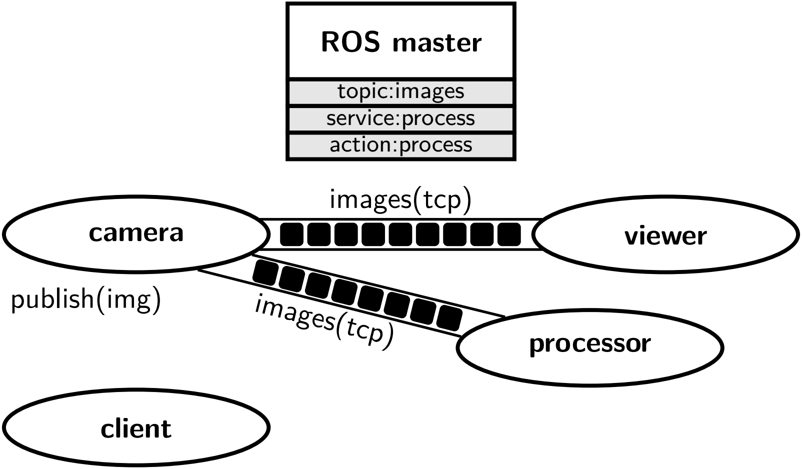

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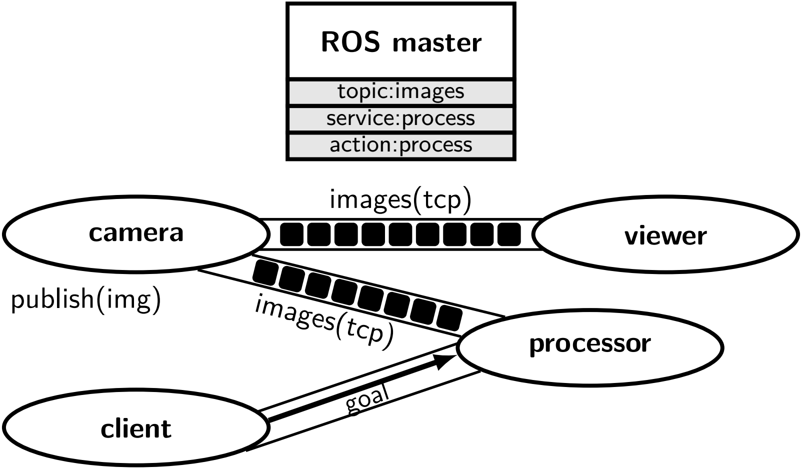

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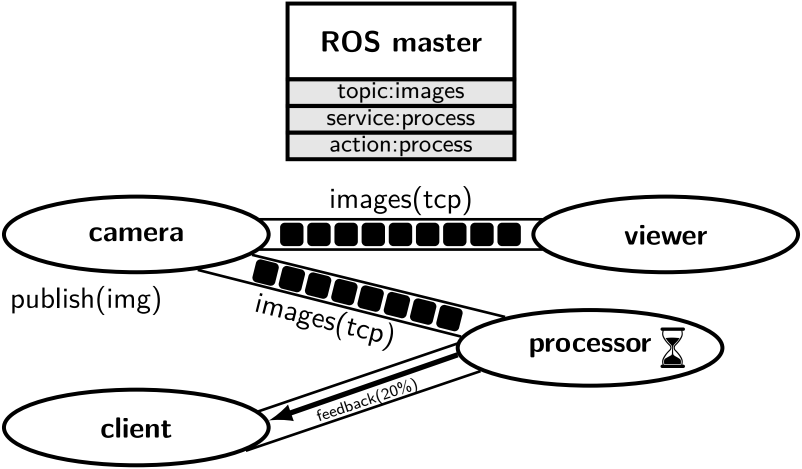

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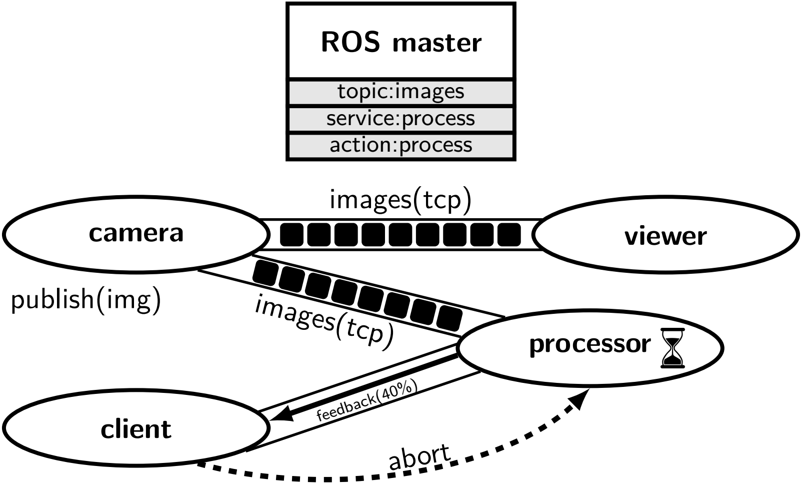

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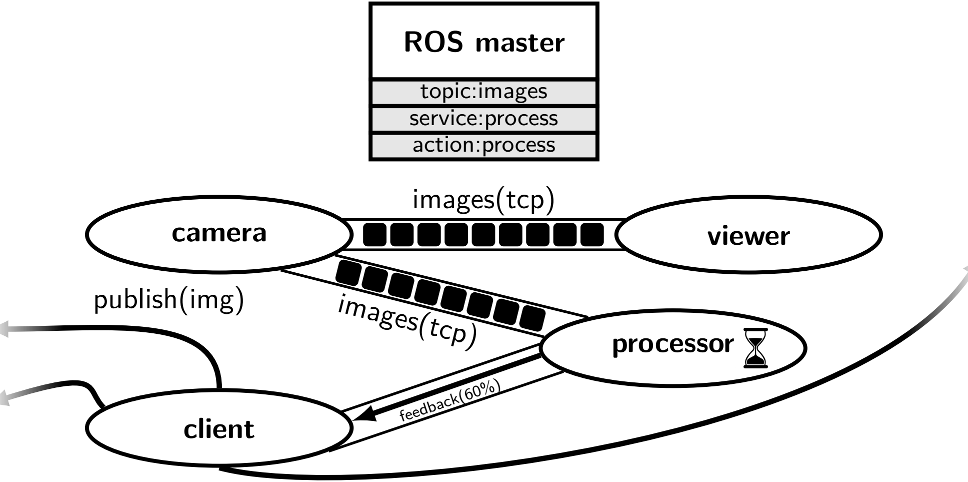


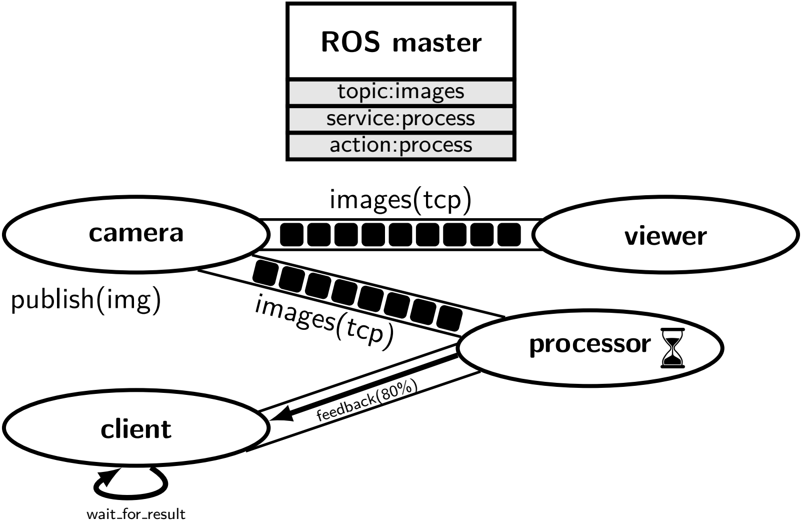
ROS master

topic:images

service:process

action:process

Communication - Example



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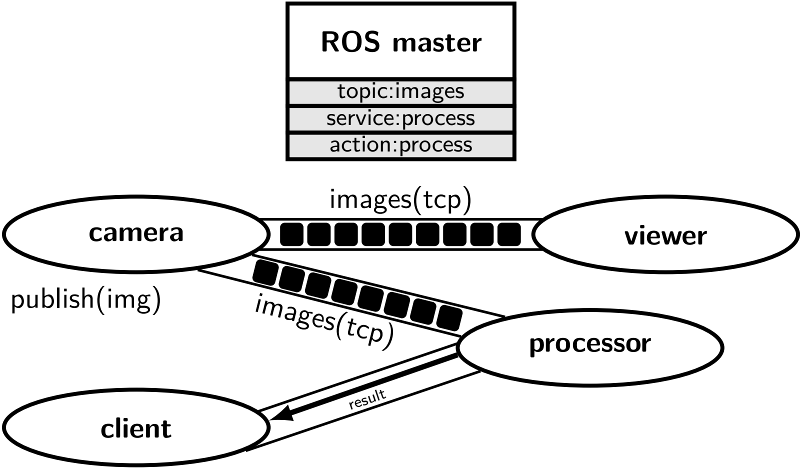
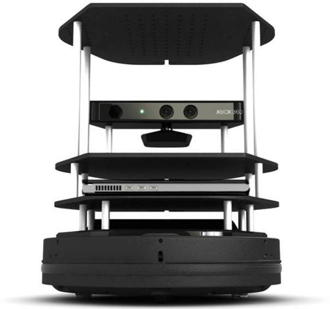


Turtle-Bot

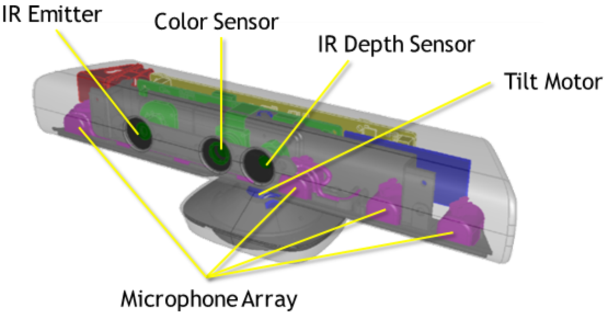
- Basic robot platform
- Capabilities
  - Kinect
  - navigation
  - transport
  - mapping
  - swarm tasks



Source: http://wiki.ros.org/Robots/TurtleBot

Microsoft Kinect

- Motion sensing device for the XBox 360 by Microsoft
- Range camera technology by PrimeSense
- 3D depth information from infrared structured light

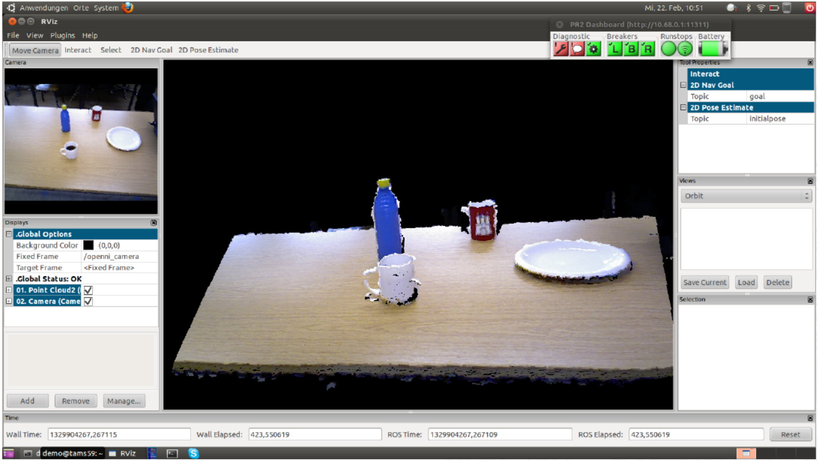


Source: https://msdn.microsoft.com

Kinect - technical details

- Resolution
  - 640 x 480 @ 30 Hz color
  - 320 x 240 @ 30 Hz depth
- FOV of 57° horizontally and 43° vertically
- Range ∼0.7 - 6 m
  - up to 3.5 m realistic
- Physical tilt range ±31°
- Microphone array with 16 bit @ 16 kHz
  - supports single speaker voice recognition
- OpenNI and Freenect drivers

Kinect - example



Interact

2D Nav Goal

Topic	goal

2D Pose Estimate

Topic	initialpose

Views: Orbit

Displays

.Global Options

Background Color	(0,0,0)
Fixed Frame	/openni_camera
Target Frame	<Fixed Frame>

.Global Status: OK

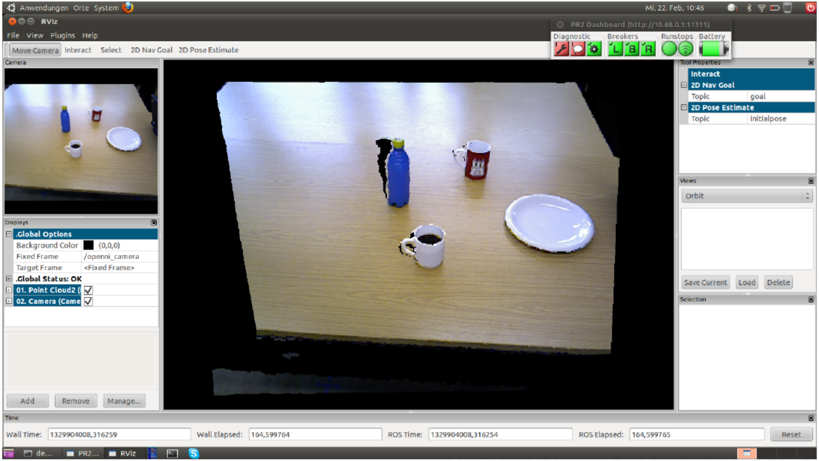
01. Point Cloud2 (☑

02. Camera (Came ☑

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

Source: TAMS, Uni Hamburg

Kinect - example



Displays:

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Background Color	■ (0,0,0)
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Tool Properties:

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

Views: Orbit

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

Source: TAMS, Uni Hamburg

Simulations

- Important development tool
  - protects expensive hardware
  - develop and test without robot
  - high-level test
- Simulates sensor data
  - clean data
- Turtlesim
  - ROS learning tool
- Gazebo
  - ROS simulator
- RViz
  - ROS data visualization

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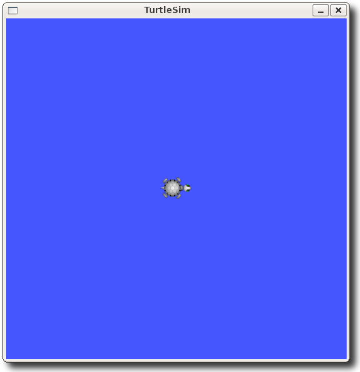
Turtle Sim

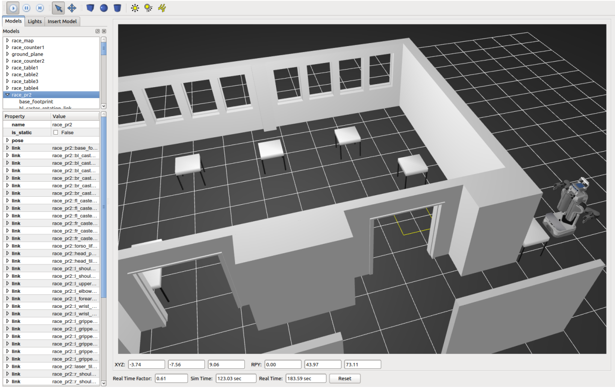
- Learning platform
- 2D turtle
  - move
  - turn
  - draw
- Communication
- ROS structure



Source: http://wiki.ros.org/turtlesim

Gazebo

- 3D rigid body simulator
- Simulates robots, environment and sensor data



Models

- race_map
- race_counter1
- ground_plane
- race_counter2
- race_table1
- race_table2
- race_table3
- race_table4
- race_pr2
  - base_footprint
  - bl_caster_rotation_link

Property	Value
name	race_pr2
is_static	□ False
pose	
link	race_pr2::base_fo...
link	race_pr2::bl_cast...
link	race_pr2::bl_cast...
link	race_pr2::bl_cast...
link	race_pr2::br_cast...
link	race_pr2::br_cast...
link	race_pr2::br_cast...
link	race_pr2::fl_caste...
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link	race_pr2::fr_caste...
link	race_pr2::fr_caste...
link	race_pr2::fr_caste...
link	race_pr2::torso_lif...
link	race_pr2::head_p...
link	race_pr2::head_til...
link	race_pr2::l_shoul...
link	race_pr2::l_shoul...
link	race_pr2::l_upper...
link	race_pr2::l_elbow...
link	race_pr2::l_forear...
link	race_pr2::l_wrist_...
link	race_pr2::l_wrist_...
link	race_pr2::l_gripper...
link	race_pr2::l_gripper...
link	race_pr2::l_gripper...
link	race_pr2::l_gripper...
link	race_pr2::l_gripper...
link	race_pr2::l_gripper...
link	race_pr2::laser_til...
link	race_pr2::r_shoul...
link	race_pr2::r_shoul...

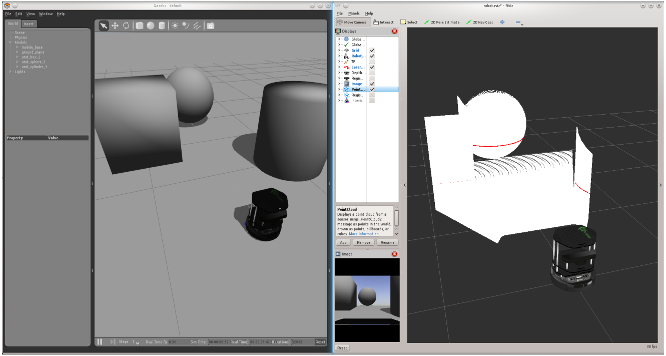
XYZ: -3.74 -7.56 9.06 RPY: 0.00 43.97 73.11

Real Time Factor: 0.61 Sim Time: 123.03 sec Real Time: 183.59 sec

Source: Lasse Einig

RViz

- 3D visualization environment
- Different data can be shown
  - Laser scan data, map, ...

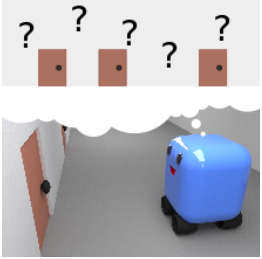


PointCloud
Displays a point cloud from a sensor_msgs::PointCloud2 message as points in the world, drawn as points, billboards, or cubes. More Information.

Source: http://wiki.ros.org/turtlebot_gazebo

Key questions

- Mapping
  - How to build a map?
- (Self-)Localization
  - How to find own position?
- Navigation
  - How to move from one position on the map to another?



Source: Wikipedia

Mapping

How to solve the
problem with the map

Mapping

Solution

- Gather 3D information
  - using available sensors
  - kinect, laser scanner
- Create a part of map
  - from observable area
- Fuse map parts
  - using additional information
  - e.g. odometry

Self-Localization

We already have a map

Self-Localization

Solution

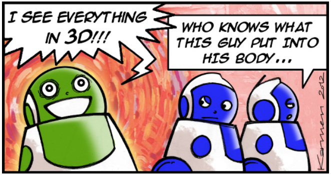
Estimate robot position from 3D information and odometry

Problems:

- odometry error
- occlusion
- sensor noise

Solutions:

- modeling the odometry error
- probabilistic algorithms
- preprocessing (e.g. smoothing)


I SEE EVERYTHING IN 3D!!!
WHO KNOWS WHAT THIS GUY PUT INTO HIS BODY...
Karmen 2012

Source: http://thecorpora.com/blog/wp-content/uploads/2012/03/Qbo-robot-Xtion-3D-sensor.jpg

Navigation

We know where we are

Navigation

Solution

Find path from current position to goal position

Prerequisites:

- precise map
- precise current position on the map
- appropriate way-points