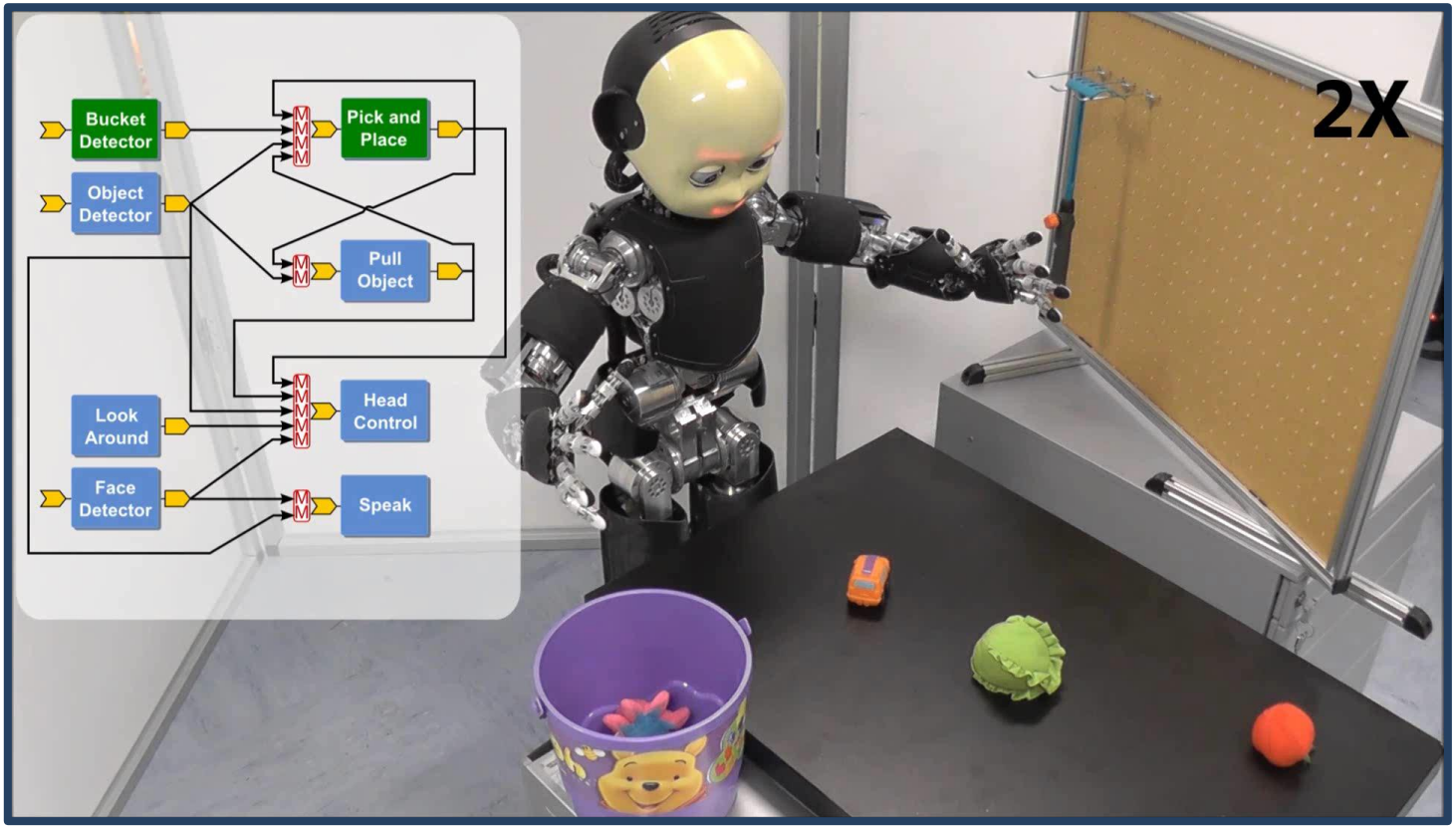
ISTITUTO ITALIANO
DI TECNOLOGIA

The YARP middleware

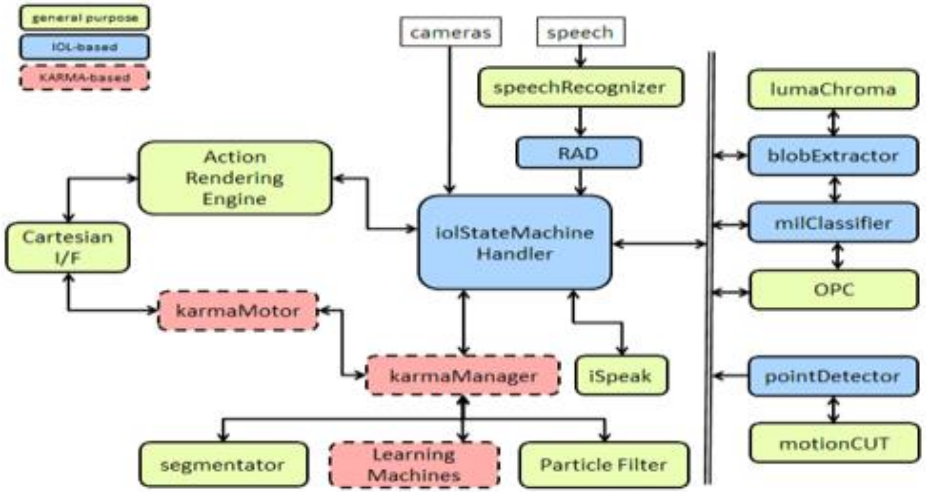
Lorenzo Natale
iCub Facility
Istituto Italiano di Tecnologia, Genova, Italy

Towards Humanoid Robots OS
Humanoids 2016 Workshop, Cancun, Mexico, 15th November, 2016



Paikan, A., et al., Enhancing software module reusability using port plug-ins: an experiment with the iCub robot, IROS 2014.

System Integration



Key issues

Complexity: distributed processing, heterogeneous systems, noise, real-time

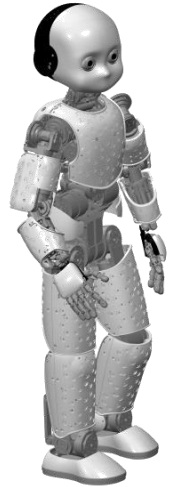
Asynchronous development

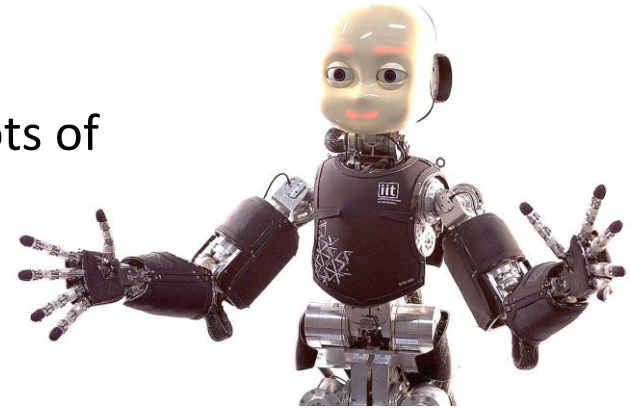
Variability: various scenarios and platforms

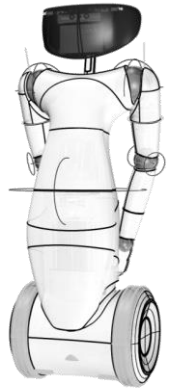
Fast prototyping

Lack of standards

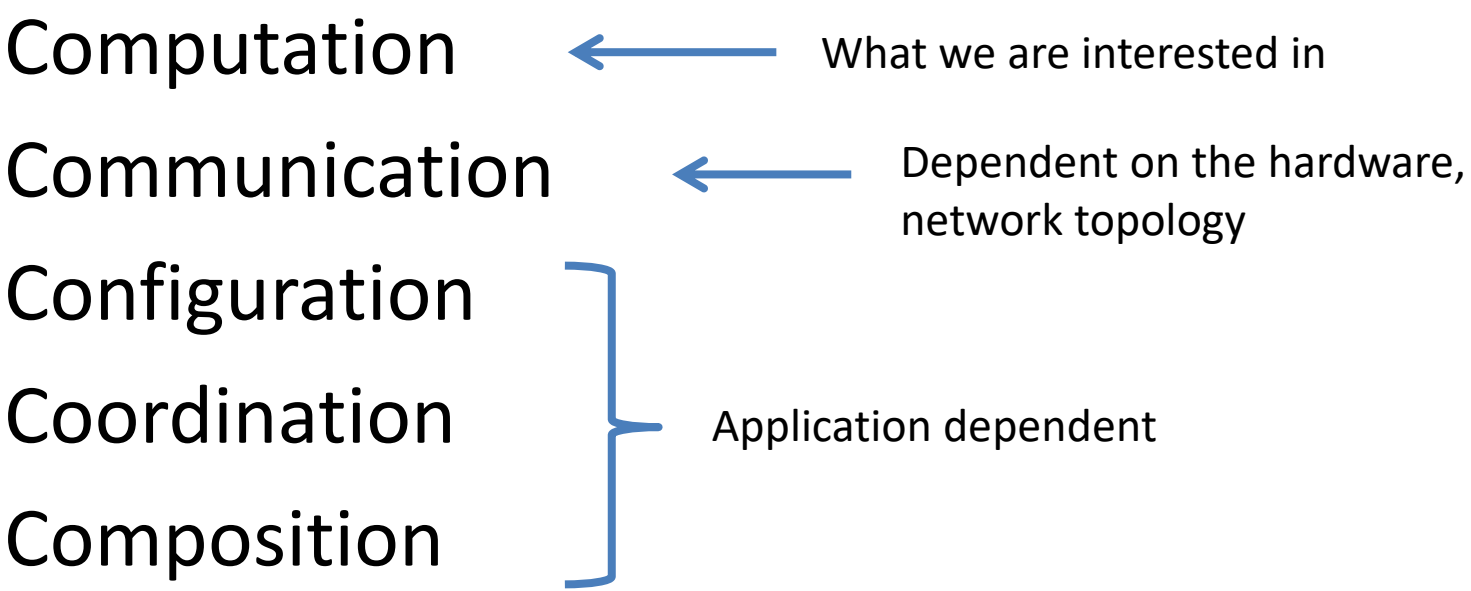
Fluctuation in hardware and algorithms, lots of open questions







Component driven software development

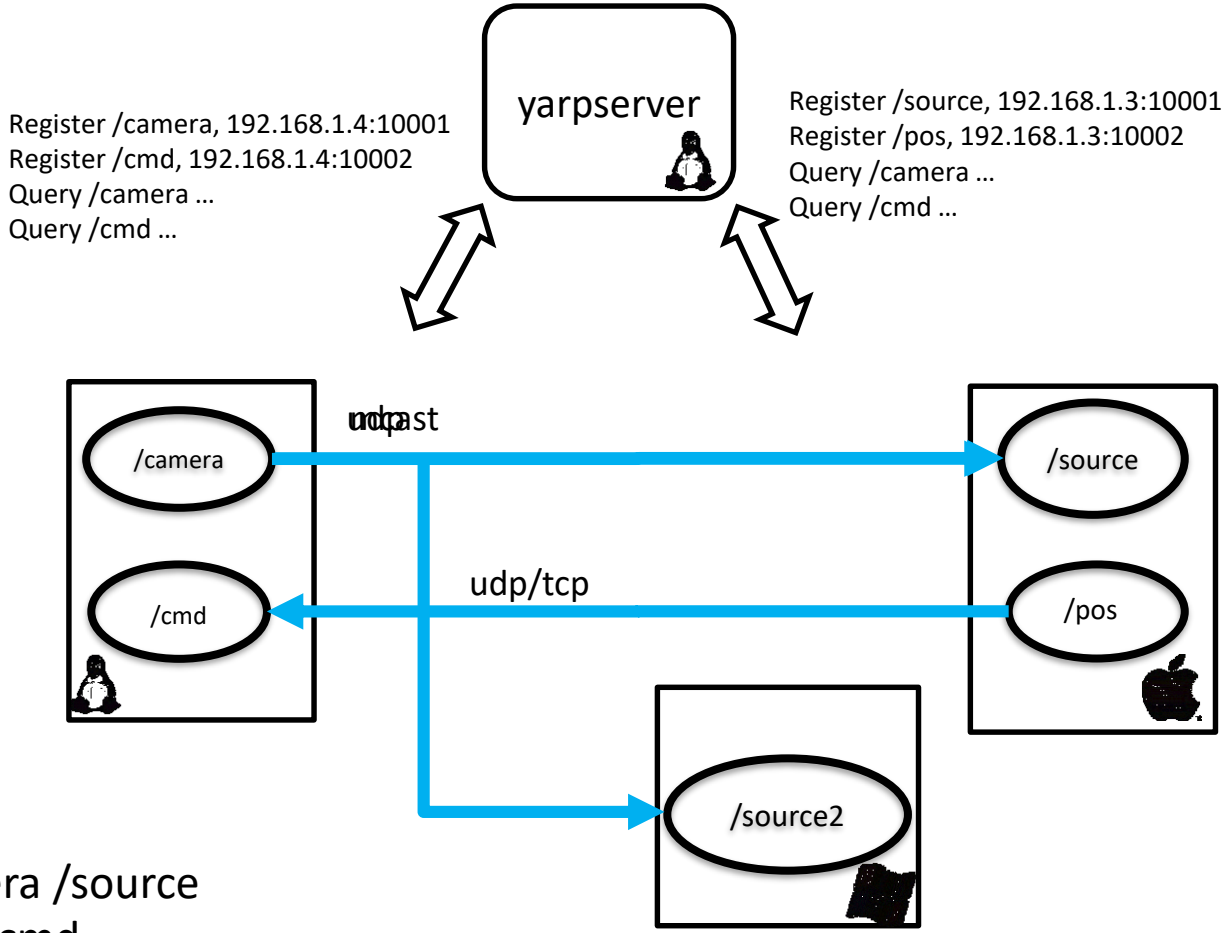


BRICS Component Model, 2013

YARP approach

- Simplified form of **publish-subscribe**
  - *Observer patter*: subscribers register their interest directly with publishers, which mange subscriptions and sends events
- Communication is **asynchronous** or synchronous
- Space decoupling
- Connections are **dynamic**
- Remote procedure calls for server-client type of communication

See also:
YARP: Yet Another Robot Platform, G. Metta, P. Fitzpatrick, L. Natale, 2006
Design of Dynamically Reconfigurable Real-time Software Using Port-Based Objects, Stewart et al., 1997



connect /camera /source
connect /pos /cmd
connect /camera /source2 mcast

Which Middleware

- Robot Operating System (ROS)
- YARP
- OROCOS
- SmartSoft
- CORBA
- ICE
- OMG DDS
- Many others: OpenRDK, Mira…

YARP/ROS comparison

YARP

Run-time reconfiguration of connections

Pluggable protocols and **devices**

Multicast for efficient one-to-many communication

Multi-platform

QoS, channel prioritization

LGPL/GPL

Smaller community

No packet management

ROS

Strongly **typed**

Rich set of **libraries** and **tools**

Eco-system, very active community

Packet management

BSD license

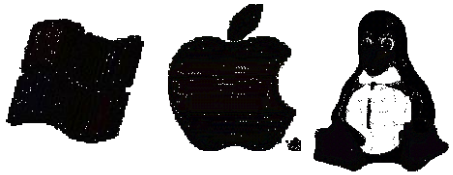
Ubuntu based

Restricted set of protocols

All connections from a topic use the same protocol

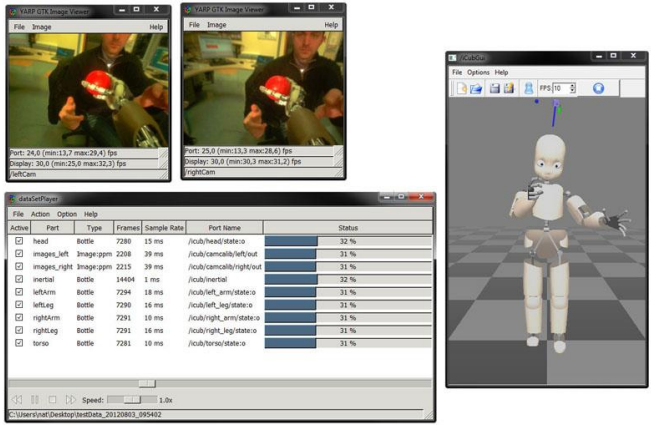
YARP main features

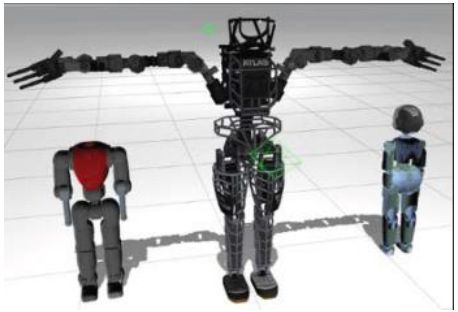
- Peer-to-peer, loosely coupled, communication
- Stable code base >10 years old
- Written in C++, bindings for python, Java, Matlab etc..
- Easy install with binaries on many OSes/distributions (Ubuntu, Debian, Windows, MacOs
- Recently added: channel prioritization (including QoS)
- Custom protocols:
  - Built-in: tcp/udp/mcast
  - Plug-ins: ROS tcp, xml rpc, mjpg etc..



Simulators and datasets

- Using YARP without hardware: dataset player, simulators
- Available in sources and binary releases for Linux and Windows
- URDF models for iCub, Coman, Armar III, Walkman
- Gazebo (https://github.com/robotology/gazebo-yarp-plugins)
- Robotran (symbolic engine)

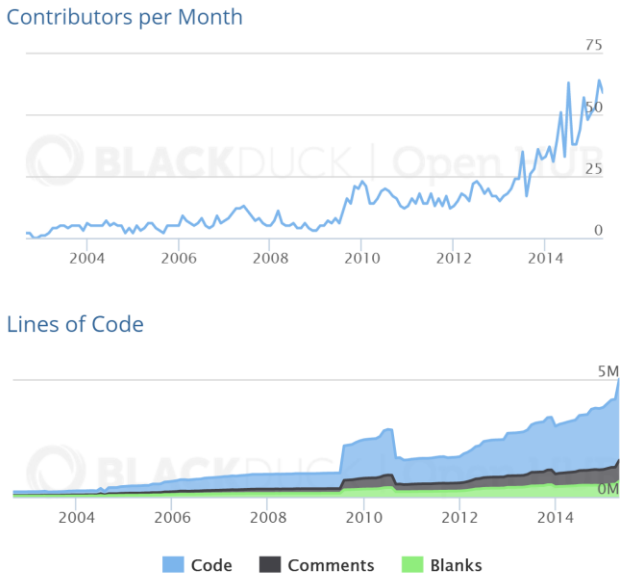


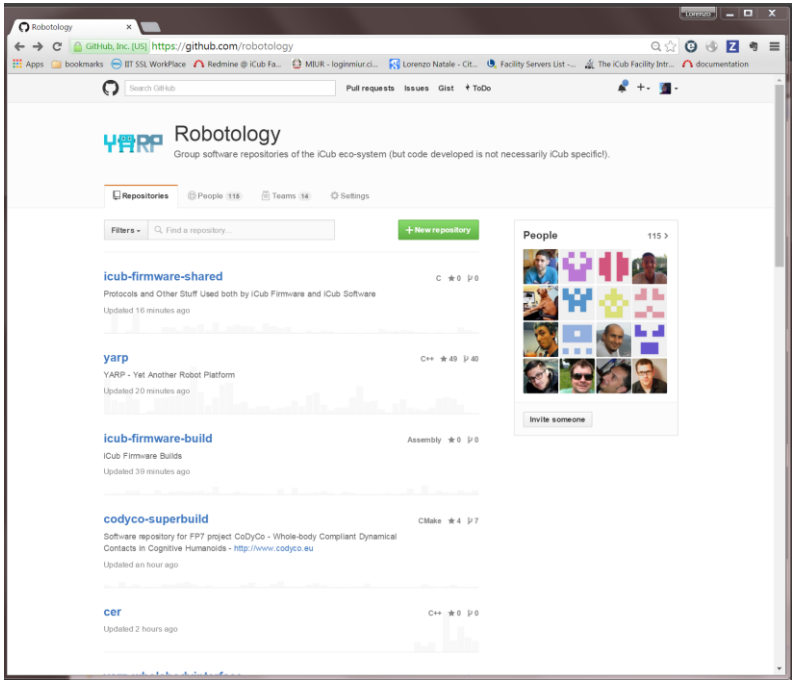


GAZEBO

Robotran
Multibody Models Online

Repositories





116 members
160 contributors/year
11115 commits/year
243 total contributors

Source: https://www.openhub.net/p/robotology

Managing repositories & build system

- Projects are managed at the level of **individual repositories** and **large builds** (i.e. project repositories)
- Repositories are hosted on Github and on our own GitLab installation
- Single build system (YCM):
  - Agglomerate several projects in larger builds
  - Favor sharing of code (as opposed to binaries)
  - Built on top of CMake (~20 patches contributed to CMake)

https://github.com/robotology/ycm

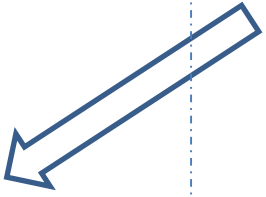
lib-ace
libxml2-dev
libeigen3-dev
….

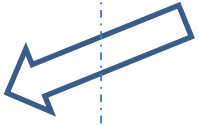
ros-indigo-desktop-full
ros-indigo-joy*
ros-indigo-openni2

Issue & Bug Tracking
Documentation
Continuous integration
Better visibility

GitLab.org
gitlab.icub.org

rrts_core
ComanSimulator
pilot_interface
planner
valve
….





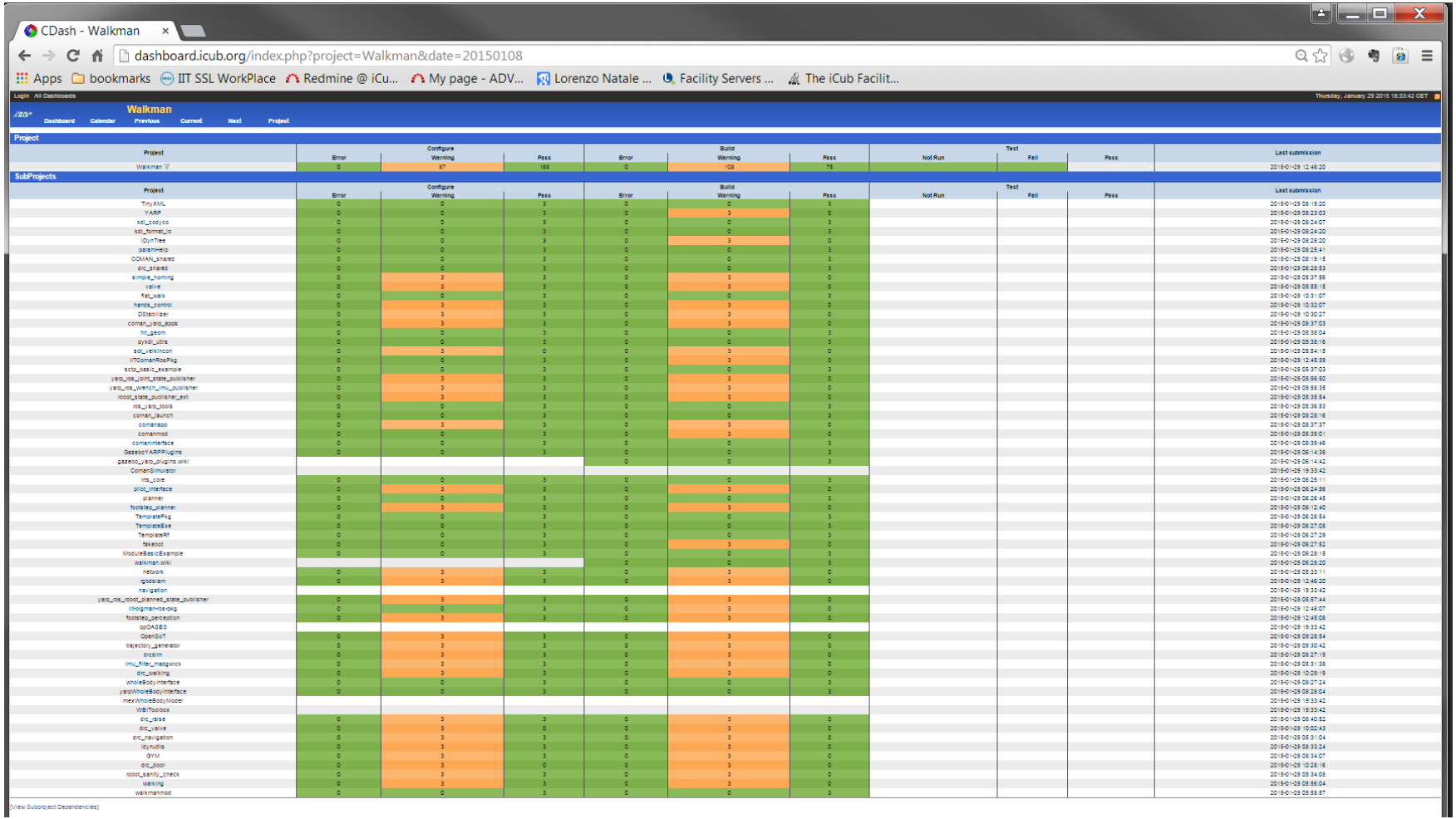
Walkman
download_and_compile(yarp)
download_and_compile(Gazebo)
download_and_compile(GazeboYARPPlugins)
download_and_compile(ComanSimulator)
download_and_compile(planner)
download_and_compile(valve)
….

Easier deployment
Documentation
Continuous Integration

github
SOCIAL CODING
github.com

GazeboYARPPlugins
Gazebo
YARP

https://github.com/robotology/ycm



CDash - Walkman

dashboard.icub.org/index.php?project=Walkman&date=20150108

Apps bookmarks IIT SSL WorkPlace Redmine @ iCu... My page - ADV... Lorenzo Natale ... Facility Servers ... The iCub Facilit...

Login All Dashboards

Thursday, January 29 2015 18:33:42 CET

Walkman

Dashboard Calendar Previous Current Next Project

Project

Project	Configure Error	Configure Warning	Configure Pass	Build Error	Build Warning	Build Pass	Test Not Run	Test Fail	Test Pass	Last submission
Walkman	0	87	168	0	108	75				2015-01-29 12:46:20

SubProjects

Project	Configure Error	Configure Warning	Configure Pass	Build Error	Build Warning	Build Pass	Test Not Run	Test Fail	Test Pass	Last submission
TinyXML	0	0	3	0	0	3				2015-01-29 08:19:20
YARP	0	0	3	0	3	0				2015-01-29 08:23:03
kdl_codyco	0	0	3	0	0	3				2015-01-29 08:24:07
kdl_format_io	0	0	3	0	0	3				2015-01-29 08:24:20
IDynTree	0	0	3	0	3	0				2015-01-29 08:25:20
paramHelp	0	0	3	0	0	3				2015-01-29 08:28:41
COMAN_shared	0	0	3	0	0	3				2015-01-29 08:19:15
dic_shared	0	0	3	0	0	3				2015-01-29 08:28:53
simple_homing	3	3	3	0	3	0				2015-01-29 08:37:56
valve	0	3	3	0	3	0				2015-01-29 08:55:15
flat_walk	0	0	3	0	0	3				2015-01-29 10:31:07
hands_control	0	3	3	0	3	0				2015-01-29 10:32:07
ODEoptimizer	0	3	3	0	3	0				2015-01-29 10:30:27
coman_yarp_apps	0	3	3	0	3	0				2015-01-29 09:37:03
ht_geom	0	0	3	0	0	3				2015-01-29 08:38:04
pykdl_utils	0	0	3	0	0	3				2015-01-29 08:38:16
sot_velkincon	0	3	0	0	3	0				2015-01-29 08:54:15
ITCompliancePkg	0	0	3	0	3	0				2015-01-29 12:45:39
scto_basic_example	0	0	3	0	0	3				2015-01-29 08:37:03
yarp_ros_joint_state_publisher	0	3	3	0	3	0				2015-01-29 08:56:50
yarp_ros_wrench_imu_publisher	0	3	3	0	3	0				2015-01-29 08:58:36
robot_state_publisher_ext	0	3	3	0	3	0				2015-01-29 08:38:54
ros_yarp_tools	0	0	3	0	0	3				2015-01-29 08:36:53
coman_launch	0	0	3	0	0	3				2015-01-29 08:28:16
comanapp	0	3	3	0	3	0				2015-01-29 08:37:37
comanmod	0	0	3	0	3	0				2015-01-29 08:39:01
comaninterface	0	0	3	0	0	3				2015-01-29 08:39:46
GazeboYARPPlugins	0	0	3	0	0	3				2015-01-29 06:14:38
gazebo_yarp_plugins.wiki				0	0	3				2015-01-29 06:14:42
ComanSimulator										2015-01-29 19:33:42
ihs_core	0	0	3	0	0	3				2015-01-29 06:25:11
pilot_interface	0	3	3	0	3	0				2015-01-29 06:24:56
planner	0	3	3	0	0	3				2015-01-29 06:26:46
footstep_planner	0	3	3	0	3	0				2015-01-29 06:12:40
TemplatePkg	0	0	3	0	0	3				2015-01-29 06:26:54
TemplateExe	0	0	3	0	0	3				2015-01-29 06:27:08
TemplateRt	0	0	3	0	0	3				2015-01-29 06:27:29
fakebot	0	0	3	0	3	0				2015-01-29 06:27:52
ModuleBasicExample	0	0	3	0	0	3				2015-01-29 06:28:15
walkman.wiki				0	0	3				2015-01-29 06:28:20
network	0	3	3	0	3	0				2015-01-29 05:33:11
iguidslam	0	3	3	0	3	0				2015-01-29 12:46:20
navigation										2015-01-29 19:33:42
yarp_ros_robot_planned_state_publisher	0	3	3	0	3	0				2015-01-29 05:57:44
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footstep_perception	0	3	3	0	3	0				2015-01-29 12:45:08
opOASES										2015-01-29 19:33:42
OpenSoT	0	3	3	0	3	0				2015-01-29 09:28:54
trajectory_generator	0	3	3	0	3	0				2015-01-29 09:30:42
dvcsim	0	3	3	0	3	0				2015-01-29 08:27:19
imu_filter_madgwick	0	3	3	0	3	0				2015-01-29 05:31:38
dic_walking	0	3	3	0	3	0				2015-01-29 08:29:19
wholeBodyInterface	0	0	3	0	0	3				2015-01-29 08:27:24
yarpWholeBodyInterface	0	0	3	0	0	3				2015-01-29 08:28:04
mexWholeBodyModel										2015-01-29 19:33:42
WBIToolbox										2015-01-29 19:33:42
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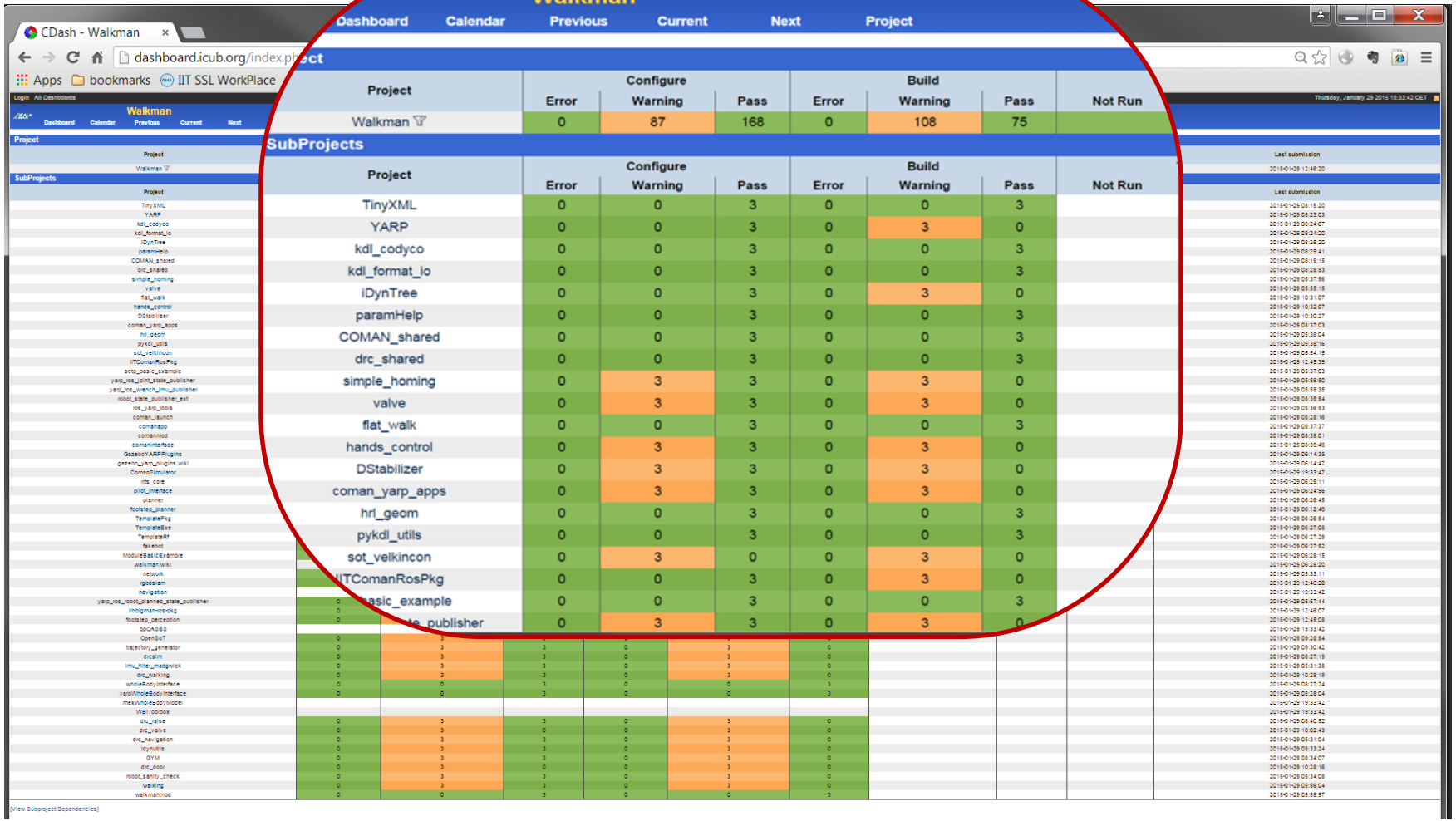
dic_valve	0	3	0	0	3	0				2015-01-29 10:02:43
dic_navigation	0	3	3	0	3	0				2015-01-29 05:31:04
idyntutils	0	3	3	0	3	0				2015-01-29 08:33:24
gyro	0	3	3	0	3	0				2015-01-29 08:34:07
dic_door	0	3	0	0	3	0				2015-01-29 10:28:16
robot_sanity_check	0	3	3	0	3	0				2015-01-29 08:34:08
walking	0	3	3	0	3	0				2015-01-29 05:56:04
walkmanmod	0	0	3	0	0	3				2015-01-29 05:58:57

[View Subproject Dependencies]



CDash - Walkman

dashboard.icub.org/index.php?project

Apps bookmarks IIT SSL WorkPlace

Walkman

Dashboard Calendar Previous Current Next Project

Project	Configure			Build			Not Run
	Error	Warning	Pass	Error	Warning	Pass	
Walkman	0	87	168	0	108	75	

SubProjects

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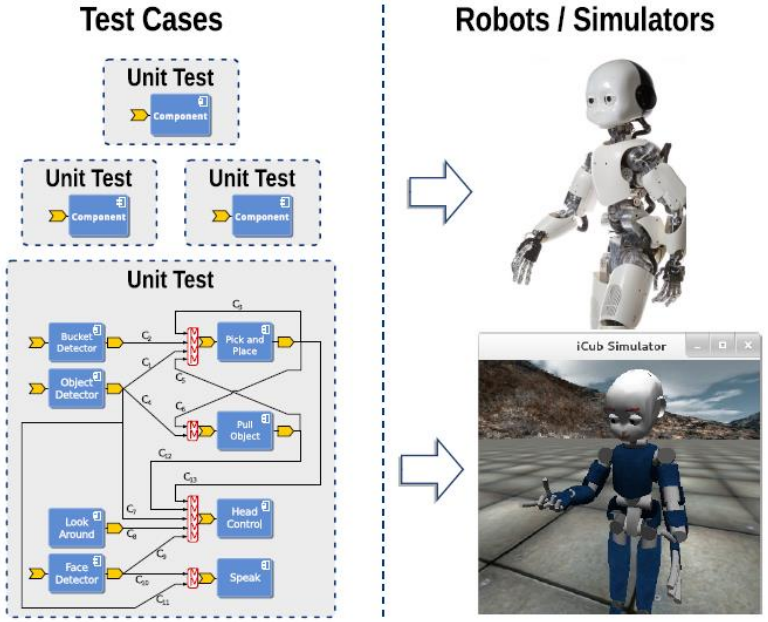
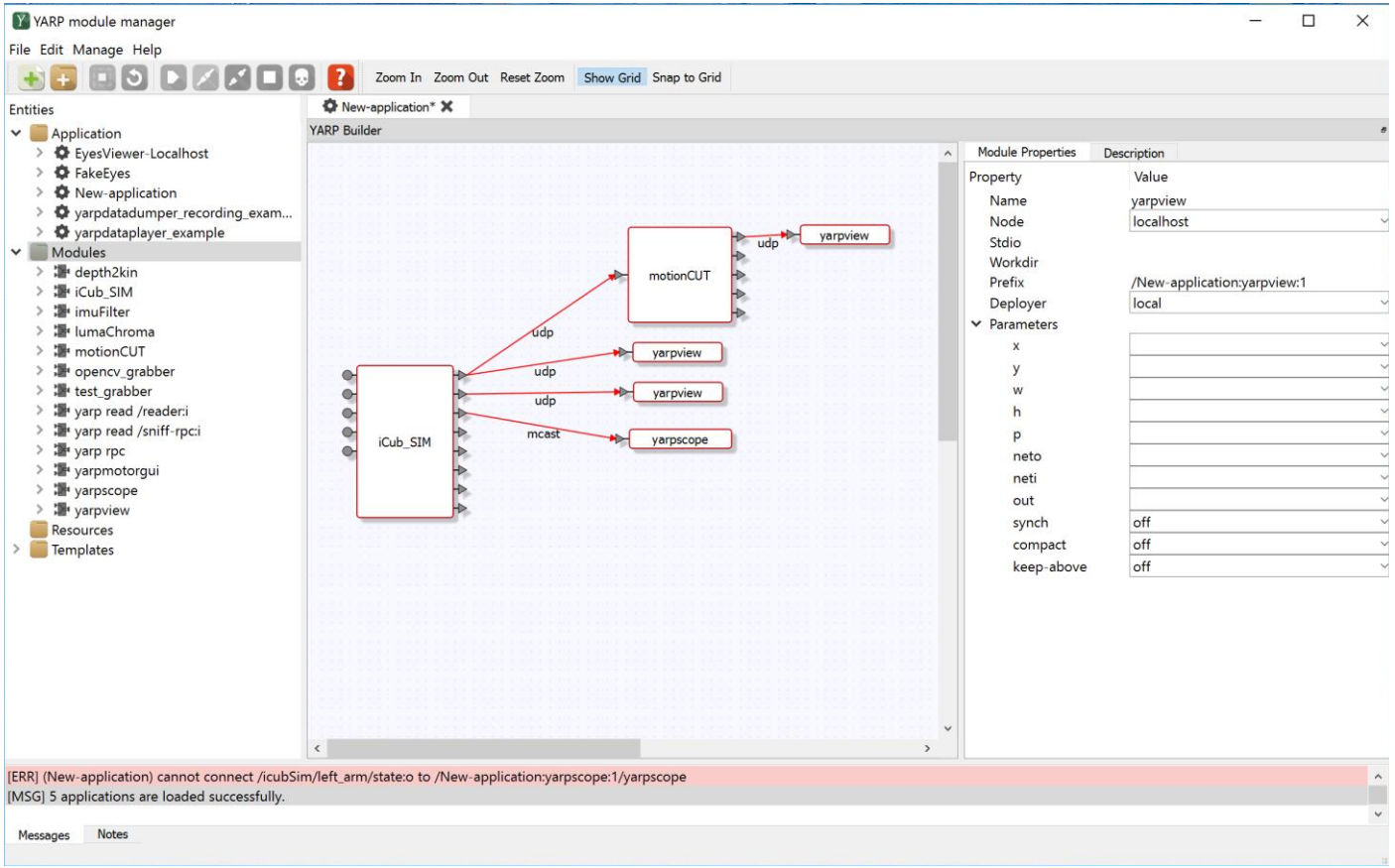
	Error	Warning	Pass	Error	Warning	Pass	
TinyXML	0	0	3	0	0	3	
YARP	0	0	3	0	3	0	
kdl_codyco	0	0	3	0	0	3	
kdl_format_io	0	0	3	0	0	3	
iDynTree	0	0	3	0	3	0	
paramHelp	0	0	3	0	0	3	
COMAN_shared	0	0	3	0	0	3	
drc_shared	0	0	3	0	0	3	
simple_homing	0	3	3	0	3	0	
valve	0	3	3	0	3	0	
flat_walk	0	0	3	0	0	3	
hands_control	0	3	3	0	3	0	
DStabilizer	0	3	3	0	3	0	
coman_yarp_apps	0	3	3	0	3	0	
hrl_geom	0	0	3	0	0	3	
pykdl_utils	0	0	3	0	0	3	
sot_velkincon	0	3	0	0	3	0	
IITComanRosPkg	0	0	3	0	3	0	
basic_example	0	0	3	0	0	3	
publisher	0	3	3	0	3	0	

Testing

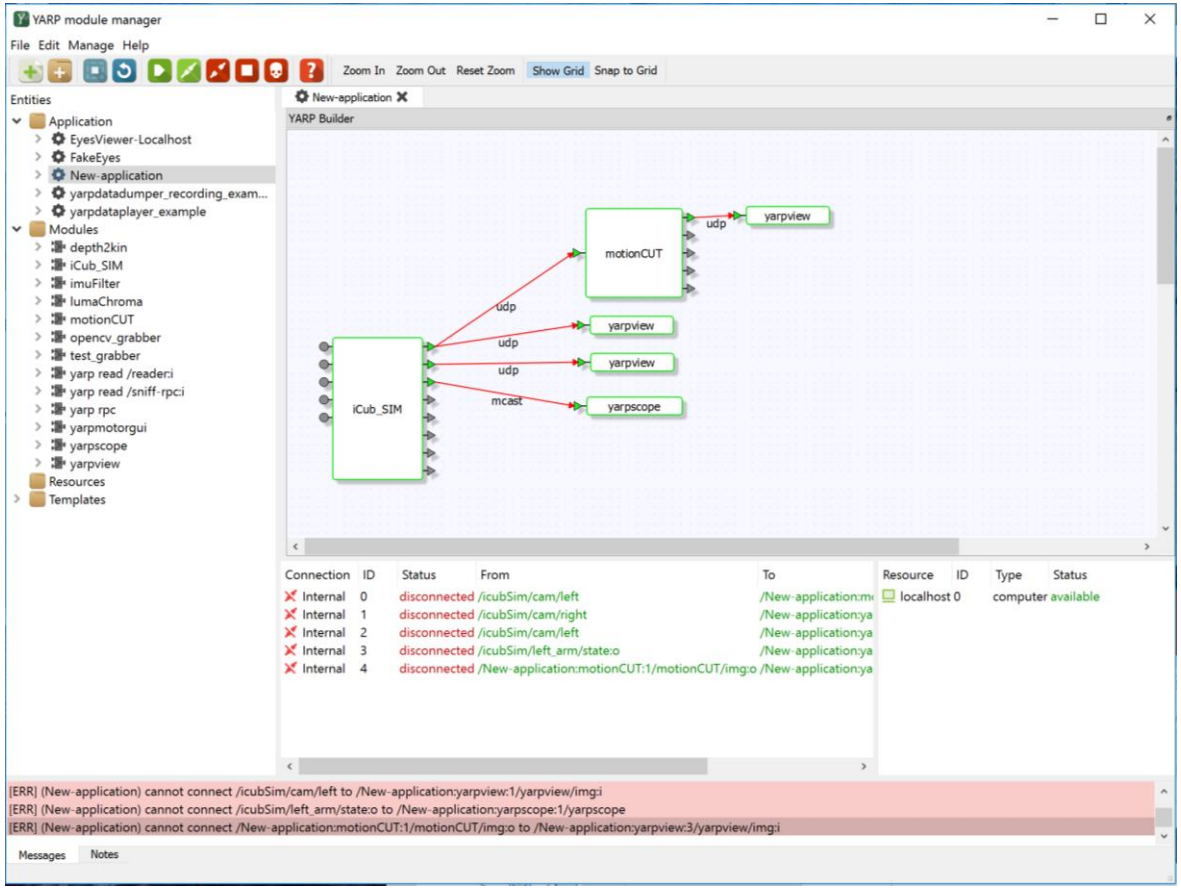
- Unit testing for the YARP middlware on compile farm and github (travis)
- Pull Requests are peer-reviewed using CodeReviewHub
- Robot software is tested using Robotic Testing Framework
  - Specifications
  - Individual components
  - Configuration
  - Bugs



Managing and building



Managing and building



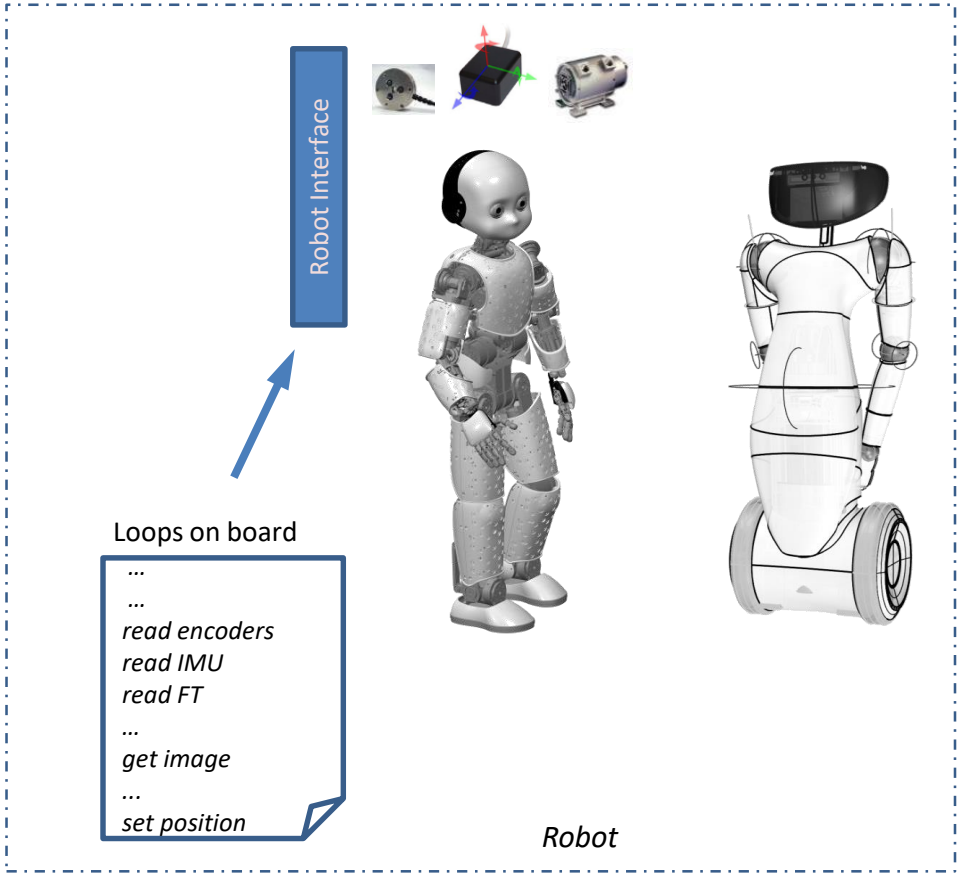
Interfaces

- Robot abstraction layer: interfaces to motors and sensors minimize the impact of changes in the hardware
- Custom interfaces and data types (Thrift IDL)

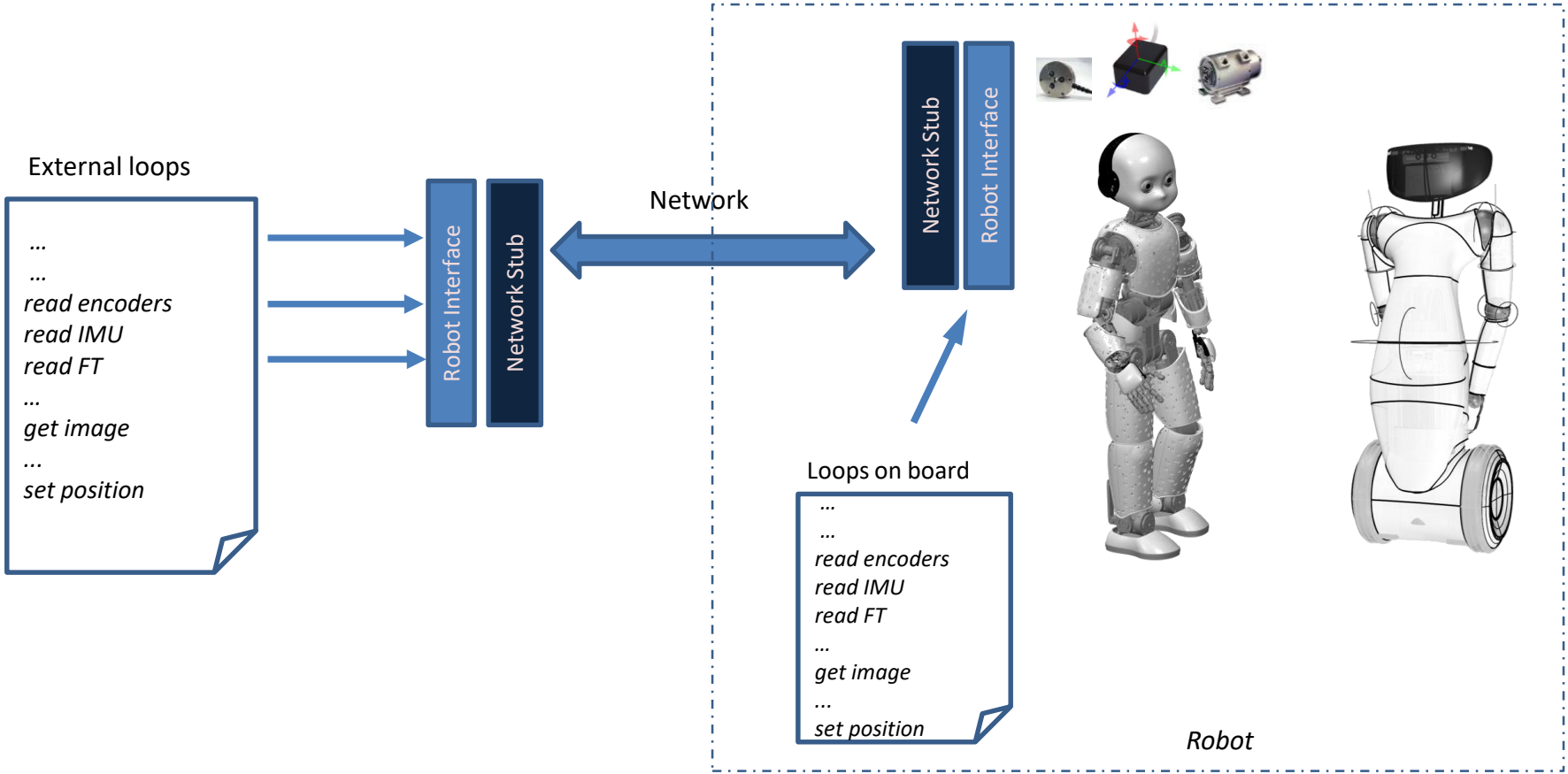
```
point3d.thirft
struct Point3D {
     1: i32 x;
     2: i32 y;
     3: i32 z;
}
```

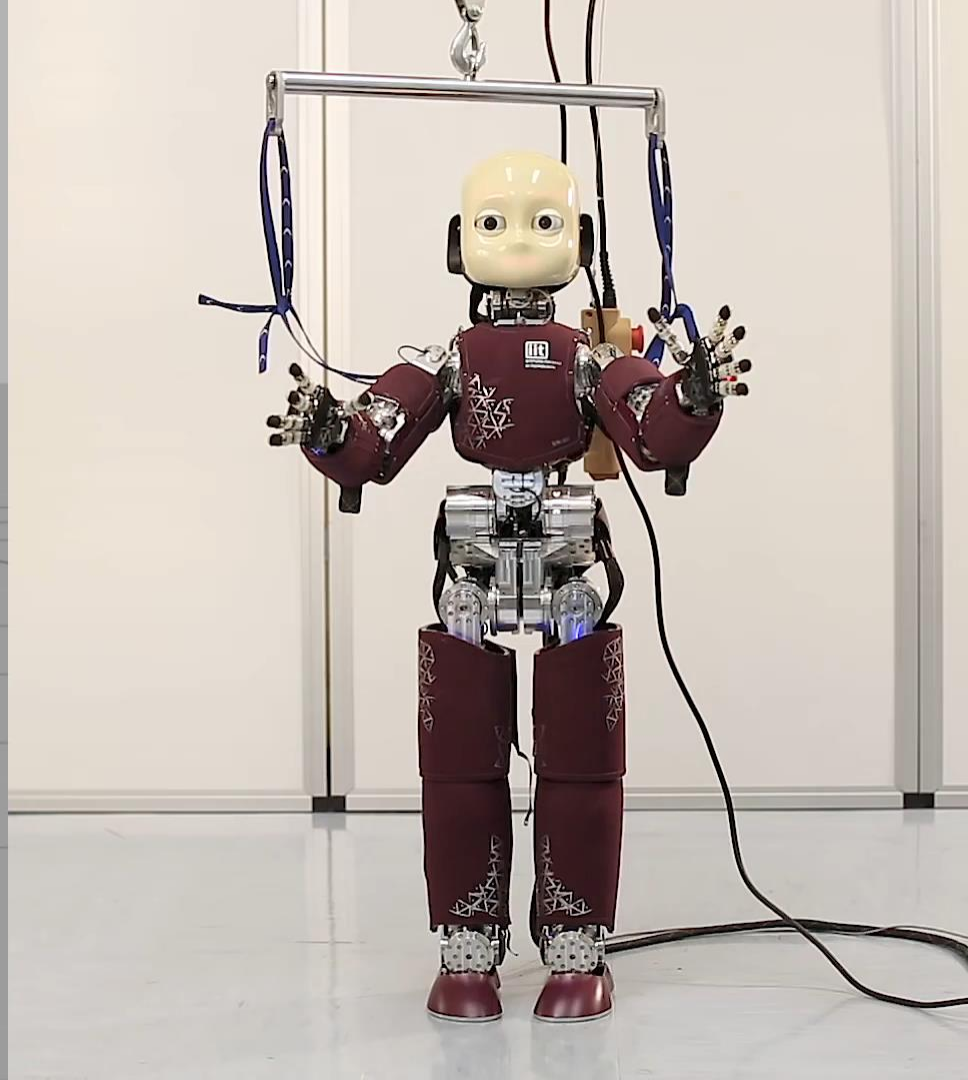
```
adder.thirft
service Adder {
      /** … */
      i32  get_answer();
      /** … */
      bool set_answer(1:i32 val)
      /** … */
      i32  add (1:i32 x);
}
```

Robot Interfaces



Robot Interfaces

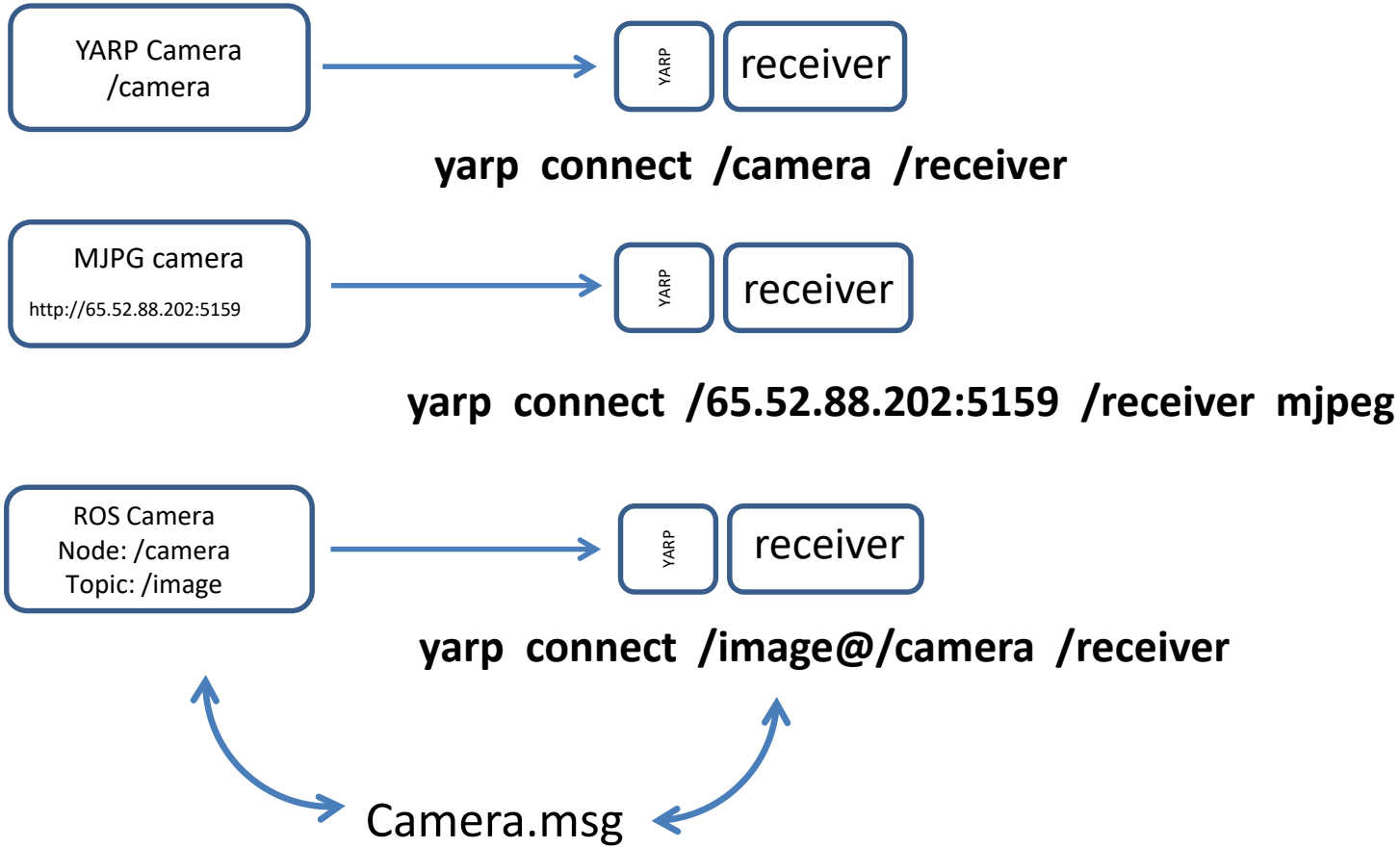




YARP plugins

- YARP includes a plugin system for drivers and protocols (carriers)
- Interchangeable carriers allow:
  - interfacing existing software with ports (without bridges)
  - change significantly port behavior
- Examples: ROS, mjpeg, xml rpc, …, port monitor

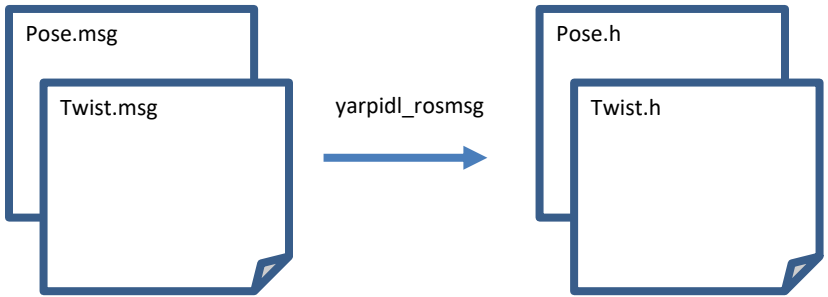
Carrier plugins



More on YARP-ROS (1)

- YARP protocols for rostcp and xmlrpc
- Compatibility with roscore
- YARP can interpret ROS messages, statically or dynamically
- Extended YARP's API (nodes, publishers, subscribers)

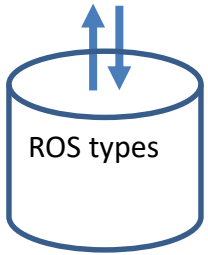
```
#include "Pose.h"
#include "Twist.h"
/* create ROS Node /controller */
yarp::os::Node node("/controller");
/* create a subsriber for Pose.msg */
yarp::os::Subscriber<Pose> pose;
/* subscribe to /turtle1/pose  */
pose.topic("/turtle1/pose");
/* create a publisher for Twist.msg */
yarp::os::Publisher<Twist> cmd;
/* publish to /turtle1/cmd_vel */
cmd.topic("/turtle1/cmd_vel");

/* read a new value from the topic */
pose.read(p);
/* publish the command */
cmd.write(t);
```



[type] BEGIN turtlesim/Pose
[type] float32 x
[type] float32 y
[type] float32 theta
[type] float32 linear_velocity
[type] float32 angular_velocity
[type] END turtlesim/Pose

ROS+YARP machine

yarpidl_rosmsg –name /typ@yarpidl



turtlesim/Pose?

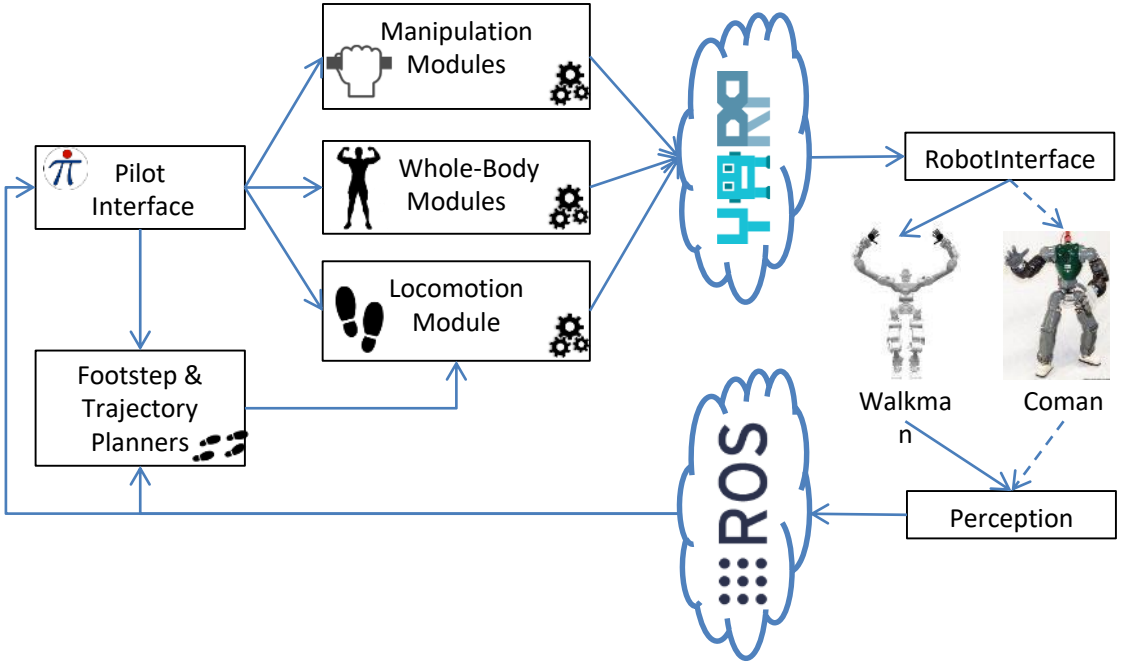
YARP machine

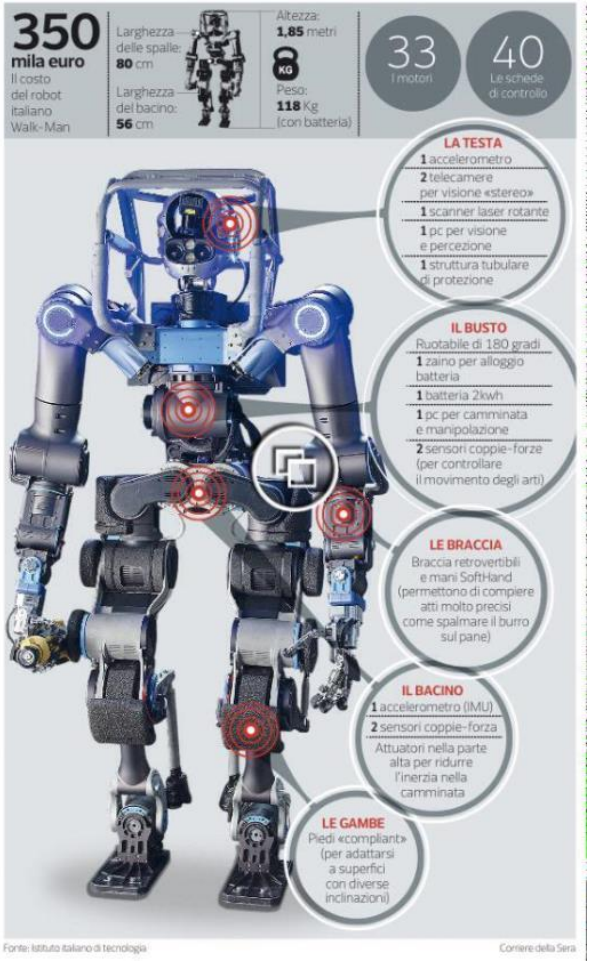
C:\yarp read /turtle1/pose@/reader
yarp: Receiving input from /turtlesim to /turtle1/pose-@/reader
5.544445 5.544445 0.0 0.0 0.0
5.544445 5.544445 0.0 0.0 0.0
...

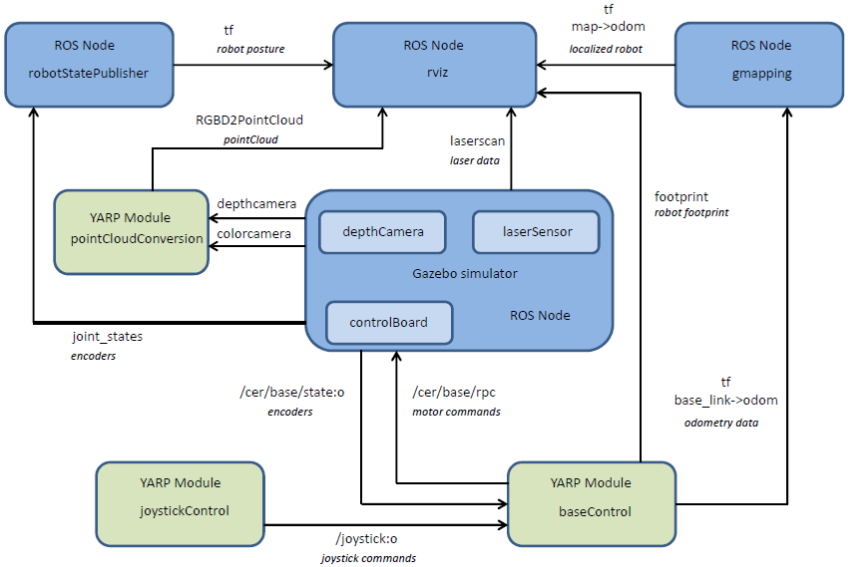
turtlesim/Pose [Data]

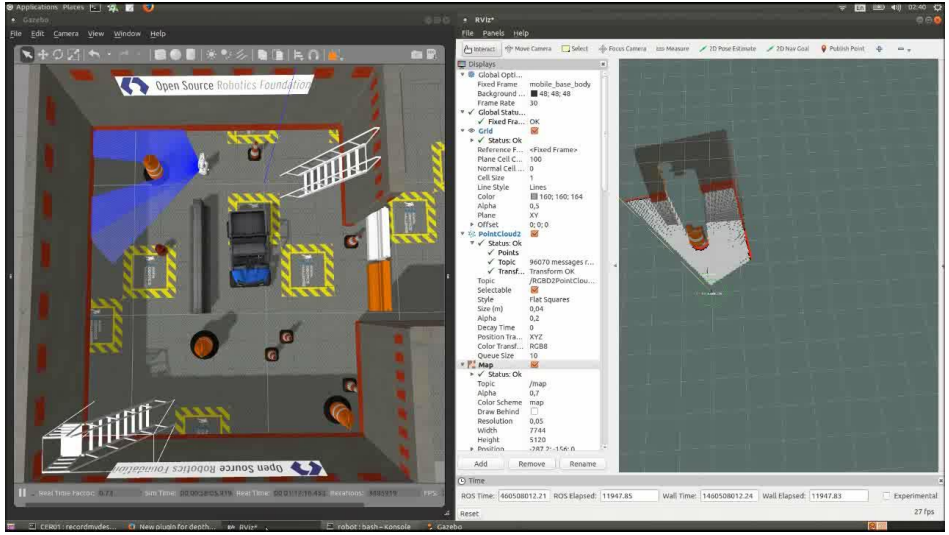
ROS machine

$ rosrun turtlesim turtlesim_node
[INFO] [1444722896.501281004]: Starting turtlesim with node name /turtlesim


Manipulation Modules
Whole-Body Modules
Locomotion Module
Pilot Interface
Footstep & Trajectory Planners
YARP
ROS
RobotInterface
Walkman
Coman
Perception

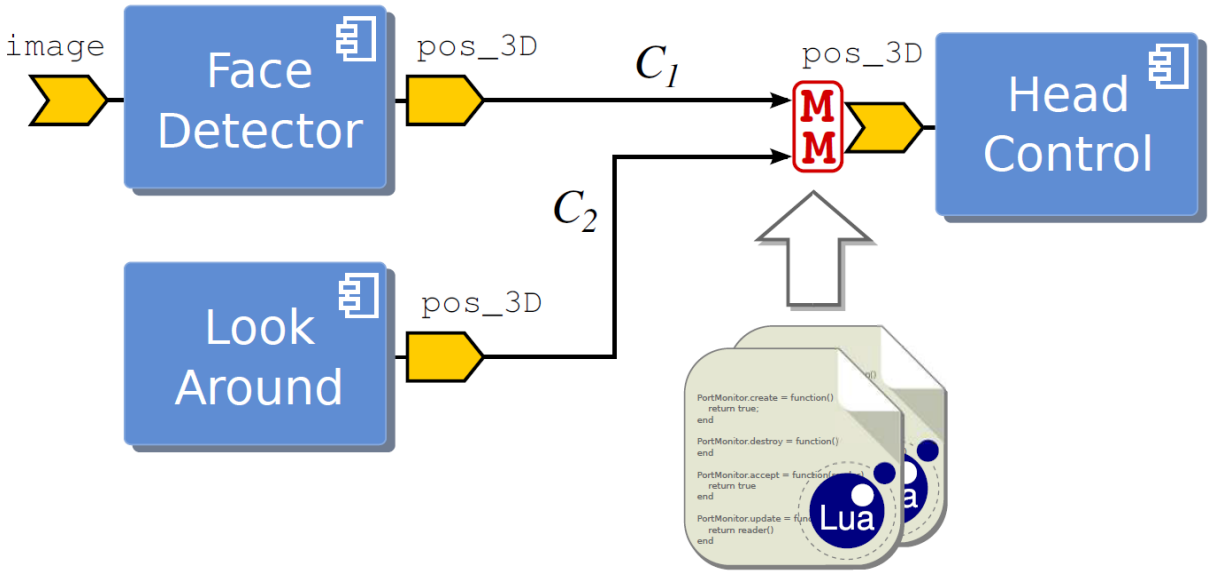

350
mila euro
Il costo del robot italiano Walk-Man
Larghezza delle spalle: 80 cm
Larghezza del bacino: 56 cm
Altezza: 1,85 metri
8 KG
Peso: 118 Kg (con batteria)
33
I motori
40
Le schede di controllo
LA TESTA
1 accelerometro
2 telecamere per visione «stereo»
1 scanner laser rotante
1 pc per visione e percezione
1 struttura tubulare di protezione
IL BUSTO
Ruotabile di 180 gradi
1 zaino per alloggio batteria
1 batteria 2kwh
1 pc per camminata e manipolazione
2 sensori coppie-forze (per controllare il movimento degli arti)
LE BRACCIA
Braccia retrovertibili e mani SoftHand (permettono di compiere atti molto precisi come spalmare il burro sul pane)
IL BACINO
1 accelerometro (IMU)
2 sensori coppie-forza
Attuatori nella parte alta per ridurre l'inerzia nella camminata
LE GAMBE
Piedi «compliant» (per adattarsi a superfici con diverse inclinazioni)
Fonte: Istituto italiano di tecnologia
Corriere della Sera



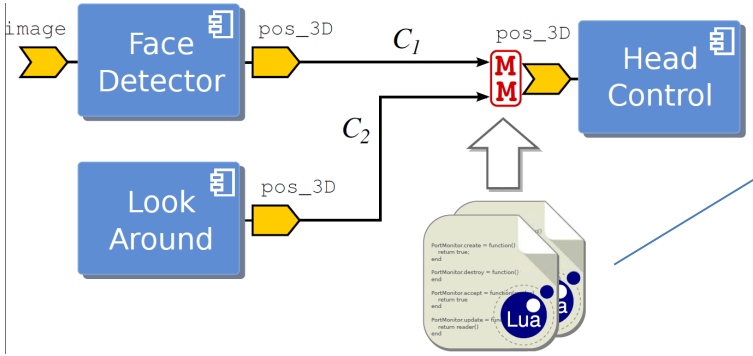


ROS gmapping, RVIZ, Gazebo

Port monitor



Paikan, A. et al, Data Flow Port's Monitoring and Arbitration, JOSER 2014




```
if (C1.certainty > 0.9)
   accept(C1)
else
   accept(C2)

if (check(C1)
    dispatch(event)

C1=filter(C1)

dispatch(C1)

If (C1)
    T1=getTime()
```

arbitration

coordination

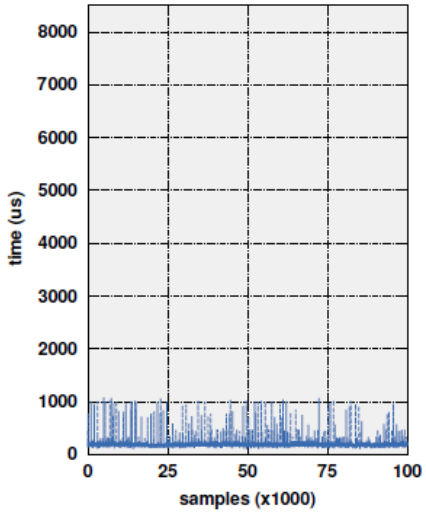
filtering

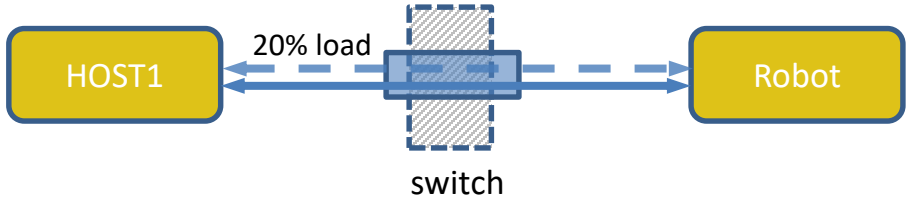
logging

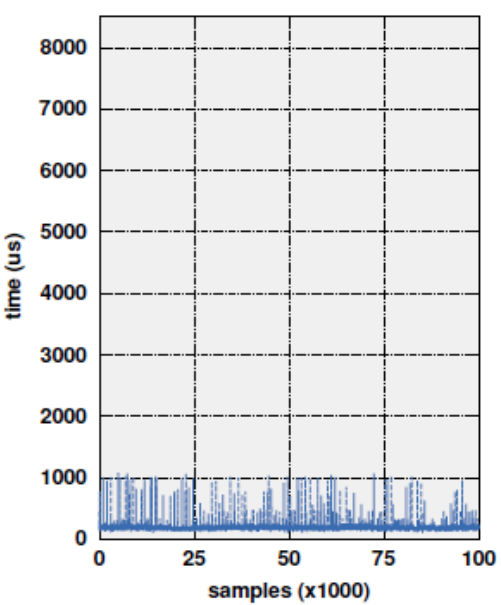
monitoring delays, QoS

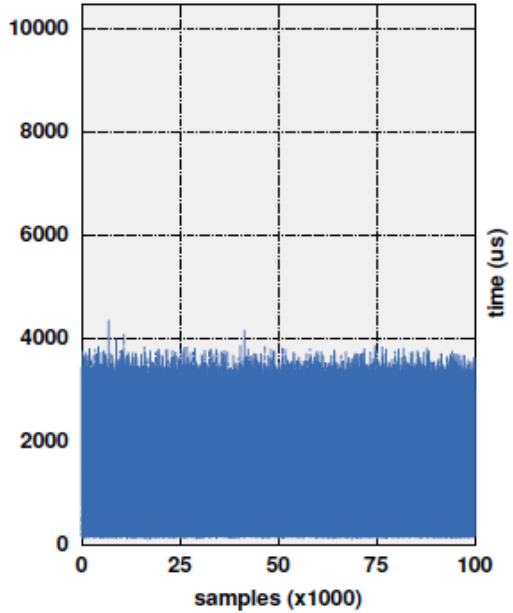
Paikan, A. et al, Data Flow Port's Monitoring and Arbitration, JOSER 2014

Why Channel Prioritization (QoS)

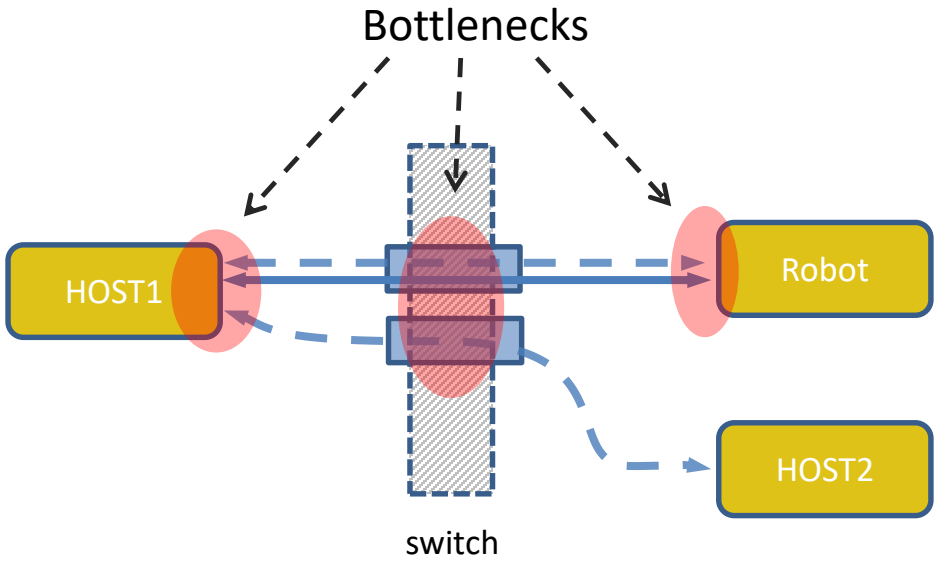



HOST1
20% load
Robot
switch


8000
7000
6000
5000
4000
3000
2000
1000
0
time (us)
0
25
50
75
100
samples (x1000)


10000
8000
6000
4000
2000
0
time (us)
0
25
50
75
100
samples (x1000)

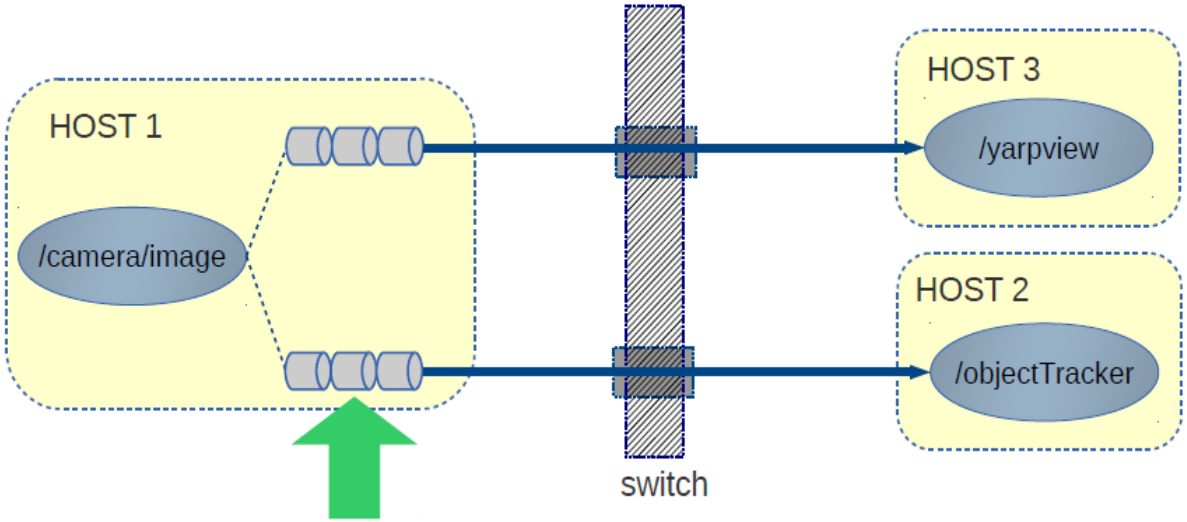
Channel prioritization



Determinism is affected by:

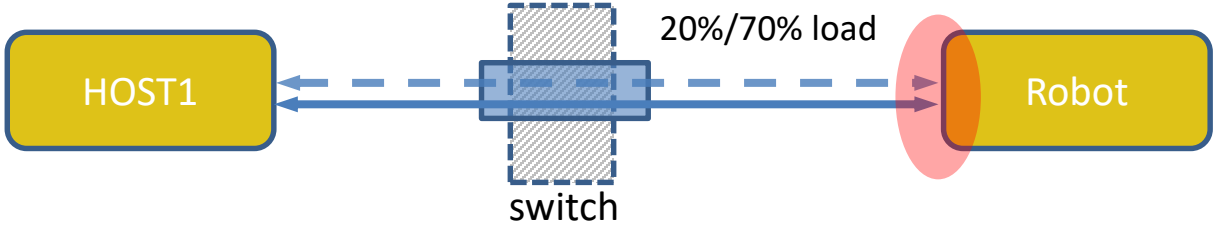
- Thead scheduling (CPU usage)
- Packet conflicts (network usage)

Approach: improve determinism by **increasing thread priorities** and reducing network bottlenecks using **QoS**

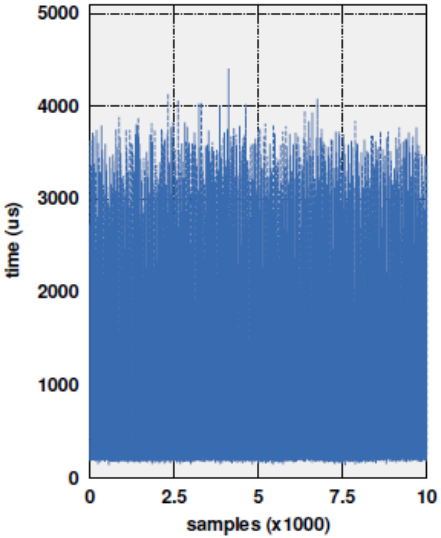



```
> prop sched policy 1 priority 30
> prop set qos priority HIGH
```

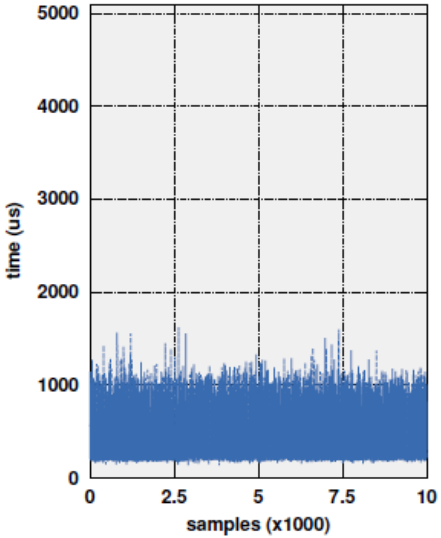
Paikan et al., A Best-Effort Approach for Run-Time Channel Prioritization in Real-Time Robotic Application IROS 2015



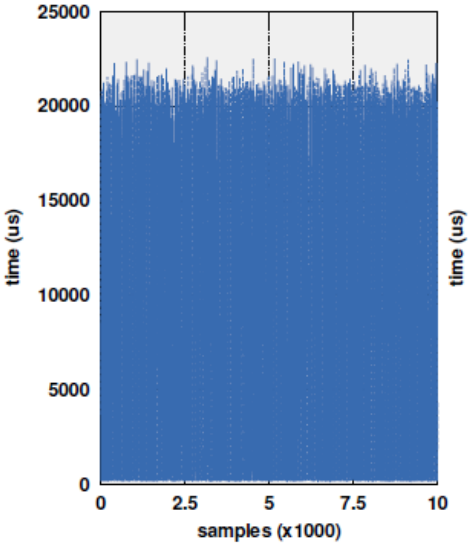
Standard YARP (20%)



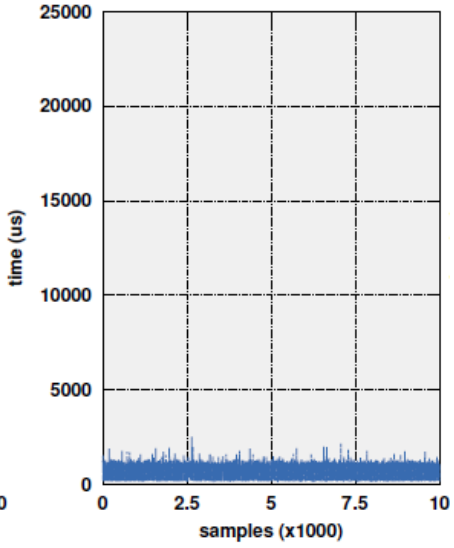
With priority (20%)

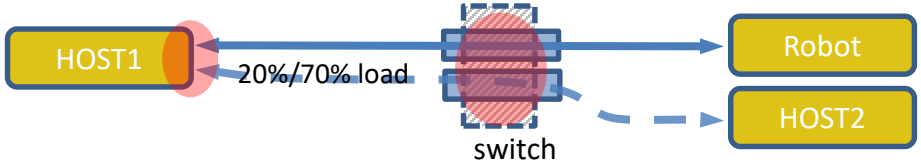


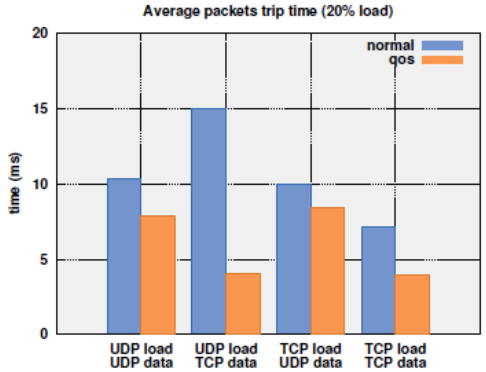
Standard YARP (70%)

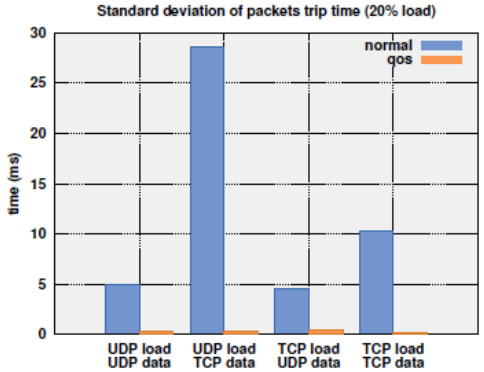


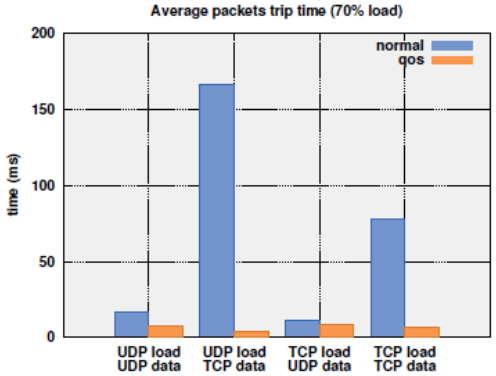
With priority (70%)

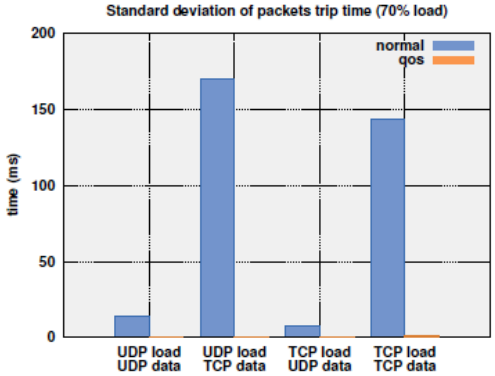



HOST1
20%/70% load
switch
Robot
HOST2

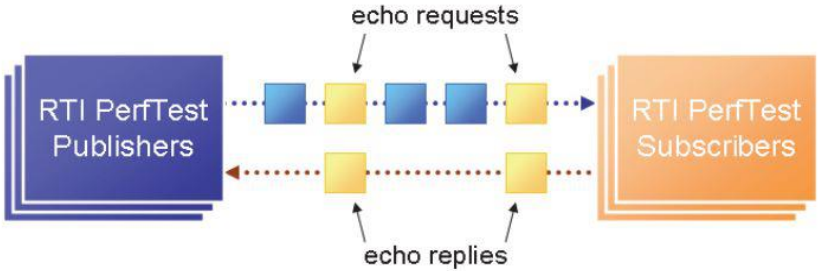

Average packets trip time (20% load)
time (ms)
normal
qos
UDP load UDP data
UDP load TCP data
TCP load UDP data
TCP load TCP data

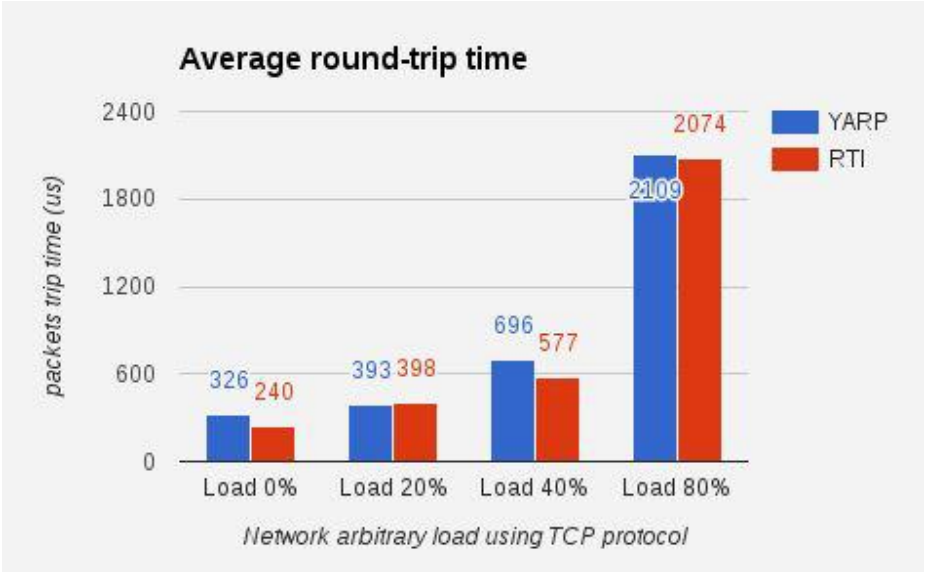

Standard deviation of packets trip time (20% load)
time (ms)
normal
qos
UDP load UDP data
UDP load TCP data
TCP load UDP data
TCP load TCP data

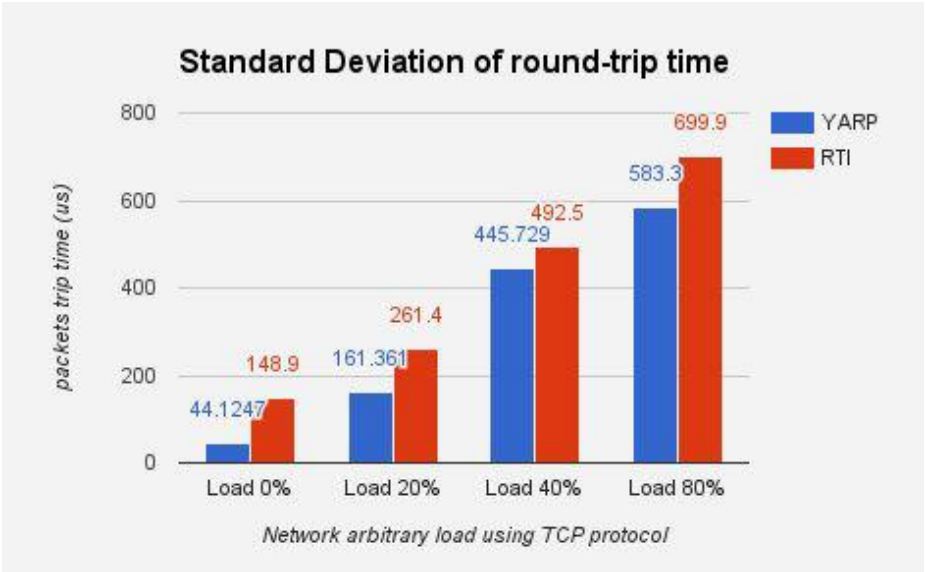

Average packets trip time (70% load)
time (ms)
normal
qos
UDP load UDP data
UDP load TCP data
TCP load UDP data
TCP load TCP data


Standard deviation of packets trip time (70% load)
time (ms)
normal
qos
UDP load UDP data
UDP load TCP data
TCP load UDP data
TCP load TCP data

Comparison with DDS

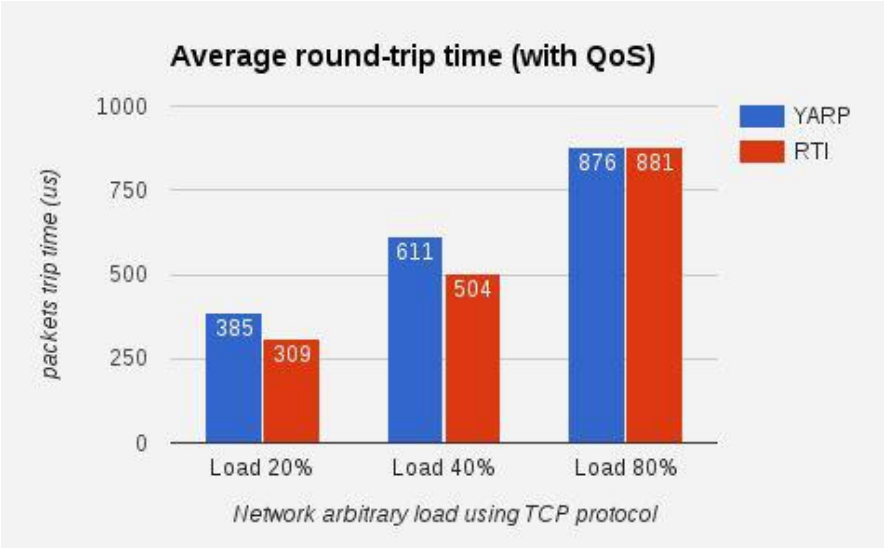


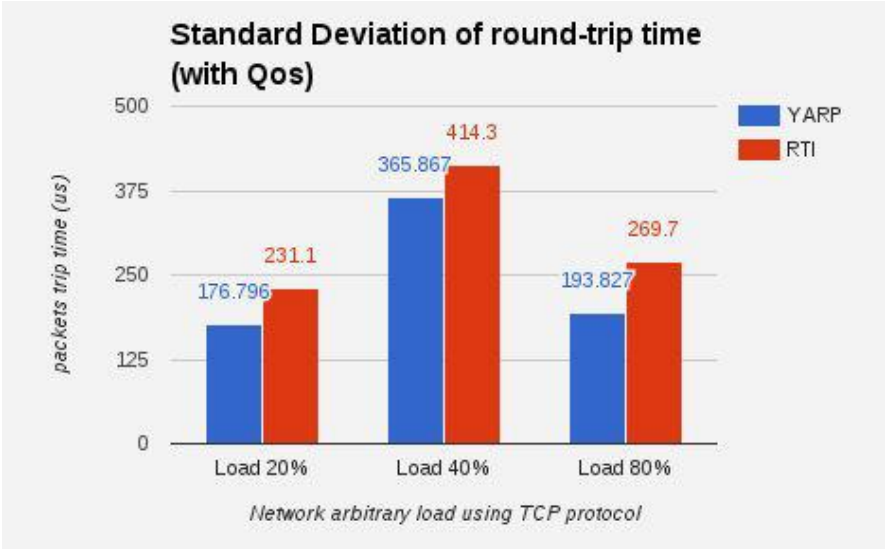




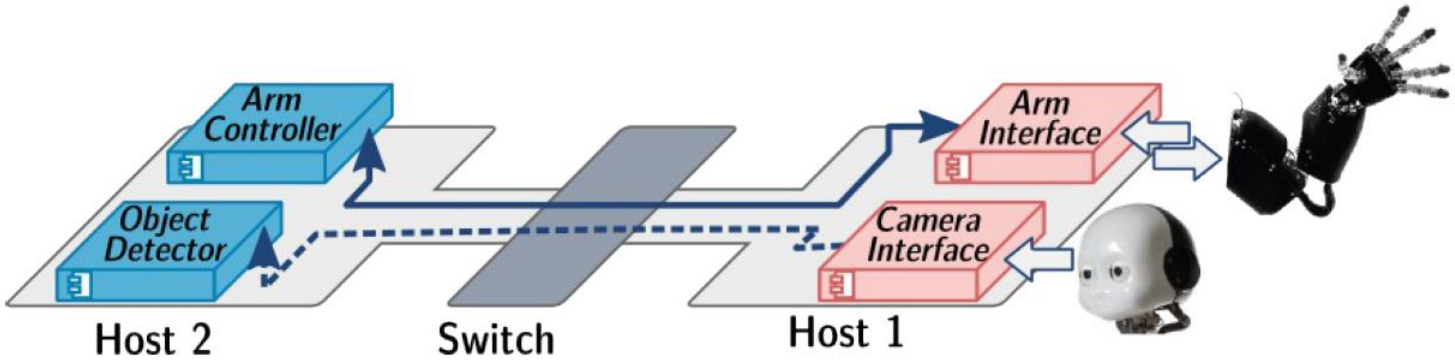
Comparison with DDS

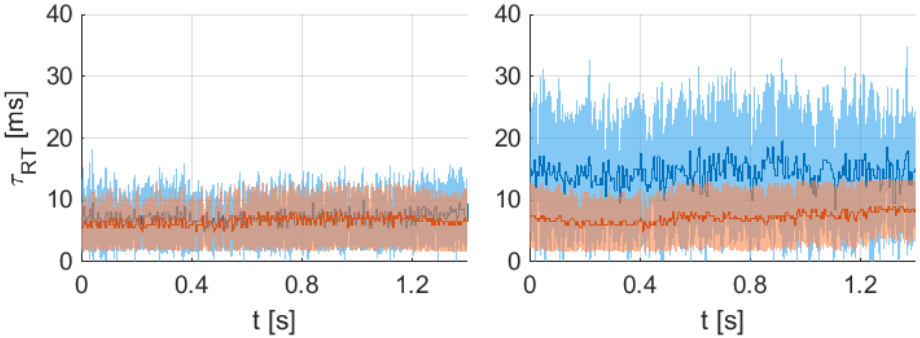
RTI QOS (DataWriter)	YARP QOS
history: KEEP_ALL_HISTORY_QOS Reliability: DURATION_INFINITE_SEC Transport_priority : 36 Thread.mask: DDS_THREAD_SETTINGS_REALTIME_PRIORITY; thread.priority = 30;	threadPriority: 30 packetPriority: HIGH (36) threadPolicy: SCHED_FIFO

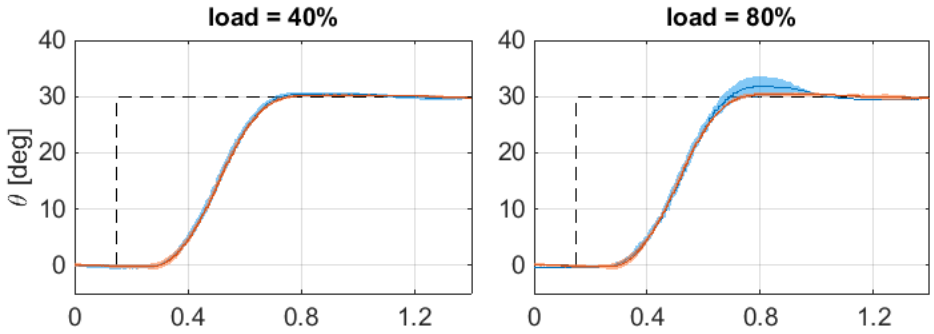




An application







Acknowledgements

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Valentina Gaggero (firmware)
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