ERLANG SCALES ROBOTS

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12 OCTOBER 2018

WHO AM I…

Bournemouth University

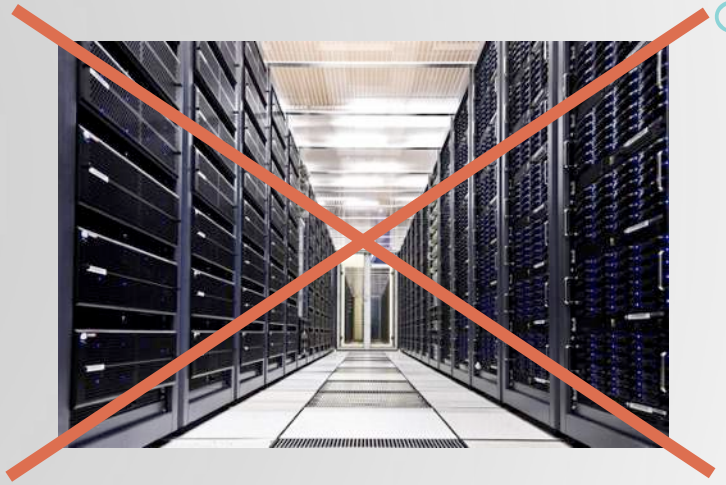
- Lecturer in Computing at Bournemouth University, UK
- Research interest – **Scaling distributed systems reliably**
- Students and colleagues from Glasgow University

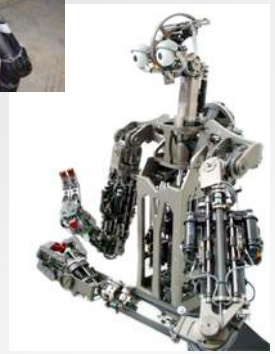
University of Glasgow




AUTONOMOUS DEVICES

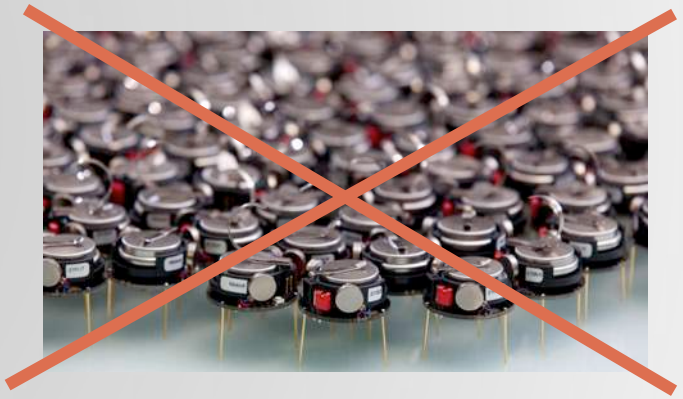
- Not “classical” distributed systems
- Lower and less stable communication
- Limited computation resources
- Limited power resources
- A single robot can be a network of devices

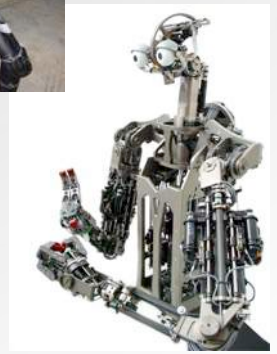




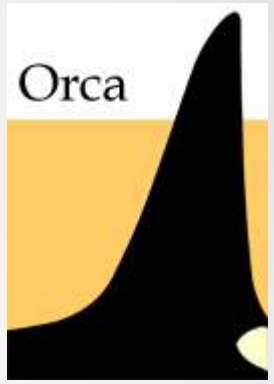
COOPERATIVE ROBOTICS

- Pack of autonomous devices
- Not swarm robotics
- Complex devices capable of various tasks
- Robots cooperate with other robots
  - similar architecture
  - different architectures
  - human operators
- Contribute to a common goal

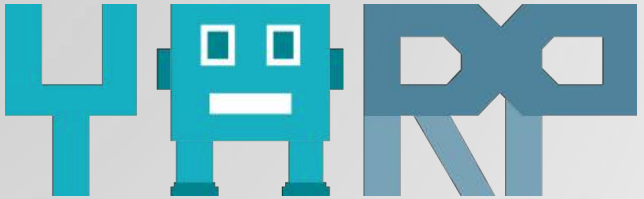




ROBOTICS MIDDLEWARE



OpenRDK



Microsoft

ROS

Carmen
Robot Navigation Toolkit

CORBA®

Player

ROBOTICS MIDDLEWARE

Microsoft

The MOOS

Cross Platform Software for Robotics Research

Carmen

Robot Navigation Toolkit

ROBOT OPERATING SYSTEM

- Since 2007 simplifies the creation of complex robot behaviour across a wide variety of robotic platforms
- A de facto standard collection of
  - Tools
  - Libraries
  - Conventions

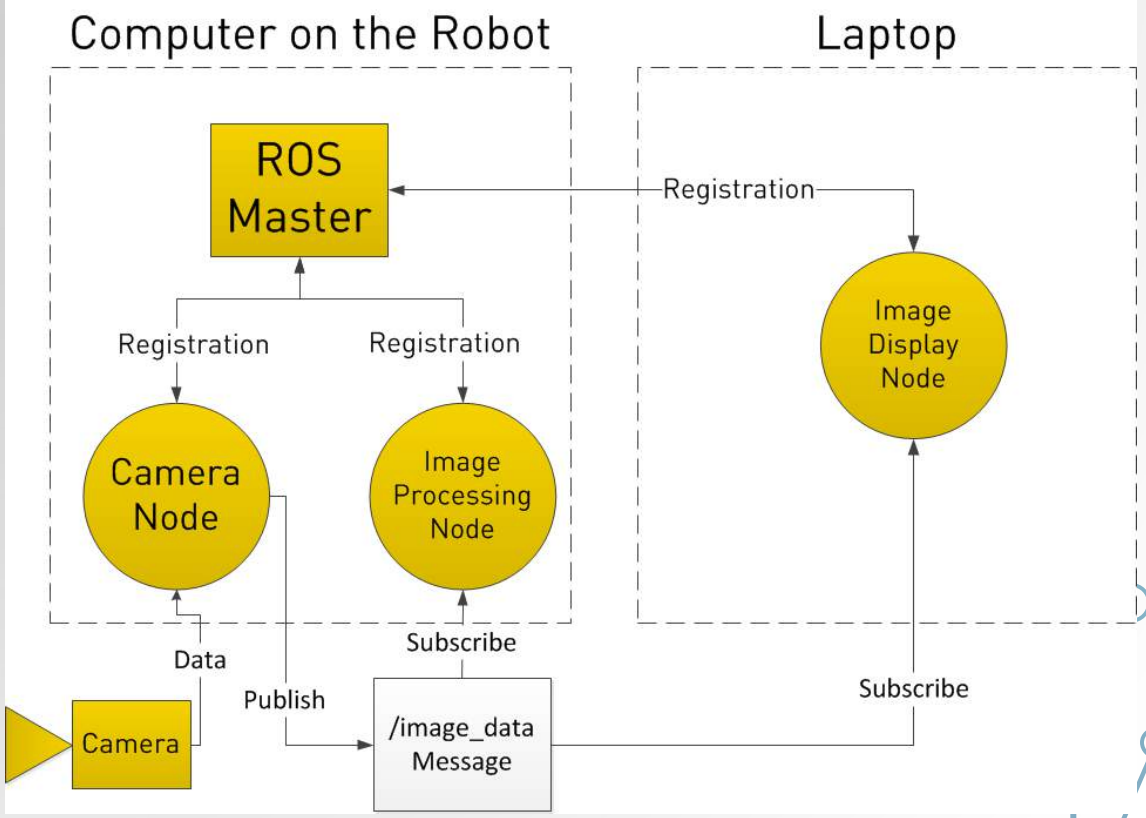
NO SINGLE INDIVIDUAL, LABORATORY, OR INSTITUTION CAN HOPE TO DO IT ON THEIR OWN

PURPOSE

- Access to
  - Hardware drivers
  - Generic robot capabilities
  - Development tools
  - External libraries
  - etc...
- Systems may use as much or as little of ROS
- Encourage collaborative development of robotics software

OVERVIEW

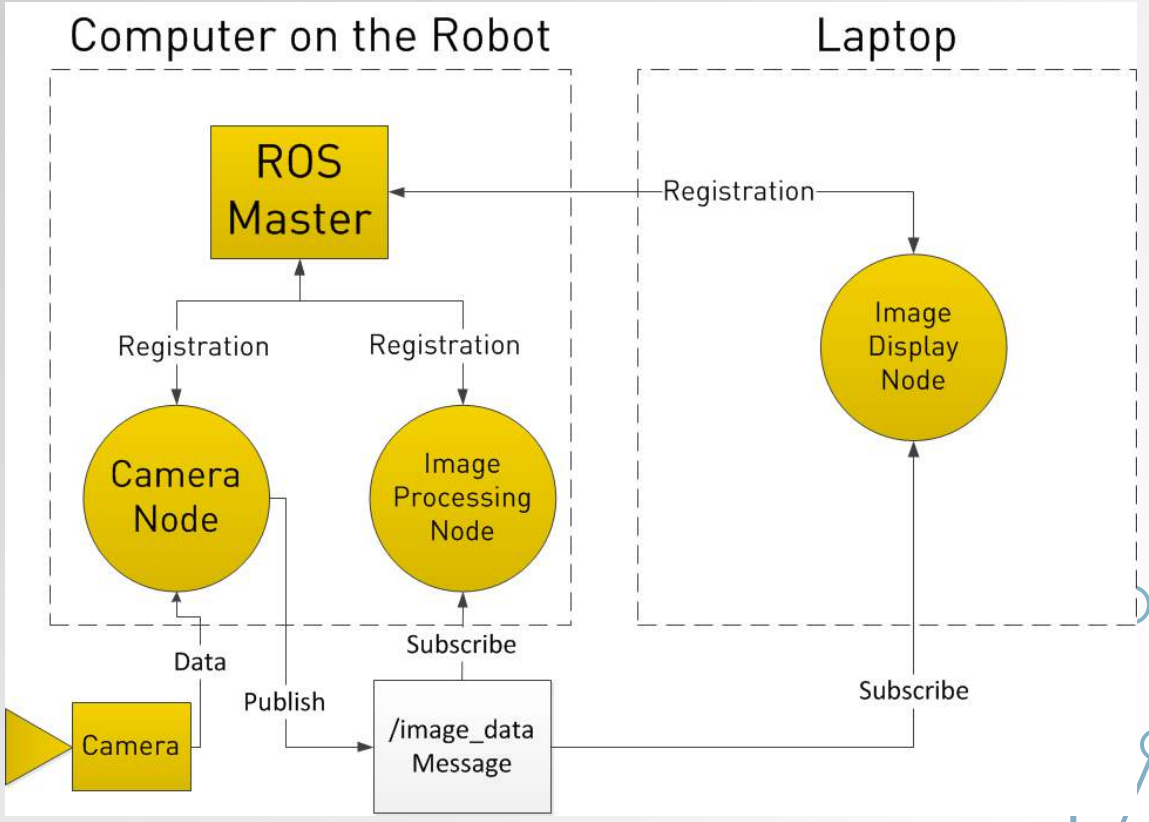
- Distributed Modular Design
- Open source
- Shared development of common components
- Publish/subscribe message passing
  - Any node can subscribe to any other node
- Master node
  - Registration of all nodes



ROS is not scalable and is not fault tolerant

REASONS

- Scalability
  - Master node
  - ROS was not designed for scalability
- Fault tolerance
  - ROS was not designed for reliability
  - **`roslaunch`**



How scalable is ROS?



SCALABILITY OF ROS

SINGLE HOST

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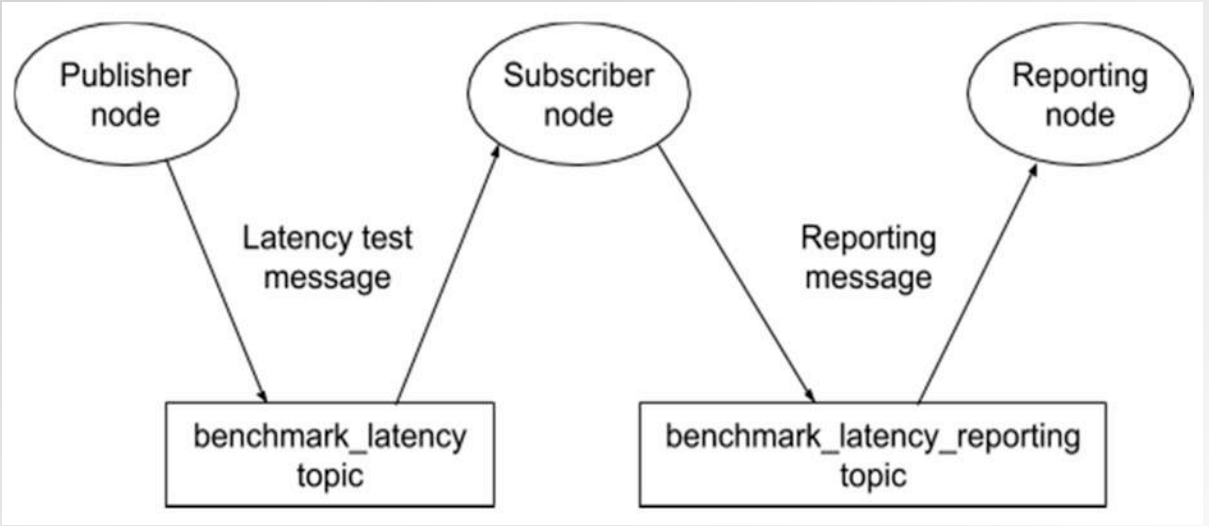
SINGLE HOST

- Latency
- Throughput



SINGLE HOSTS: LATENCY

- Message size
- Language: C++ vs. Python
- Message send frequency

- Processor: Intel(R) Core(TM) i7-2670QM CPU @ 2.20GHz × 4
- Memory: 15.6GB
- Operating System: Linux Mint 18 Cinnamon 64-bit.
- Linux Kernel: 4.4.0-43-generic.
- Python version: 2.7.12
- GCC version: 5.4.0
- ROS distribution: kinetic
- rospy and roscpp version: 1.12.5

SINGLE HOSTS: LATENCY

- Message **queue** size
- Language: C++ vs. Python
- ~~Message send frequency~~

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SINGLE HOSTS: LATENCY

- **Message queue size**
- Language: C++ vs. Python
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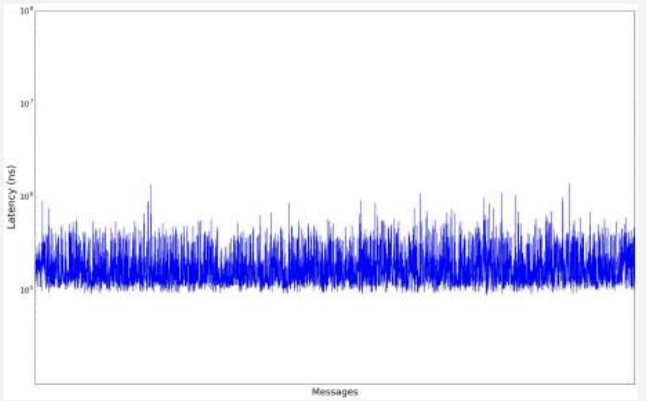


Figure 9a: message size of 2 bytes, frequency 1000Hz

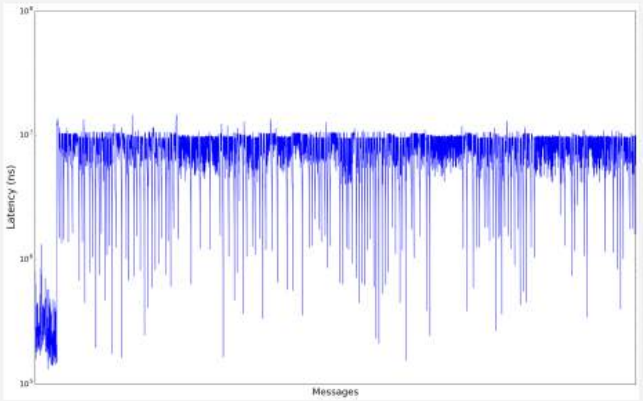


Figure 9b: message size of 512 bytes, frequency 1000Hz

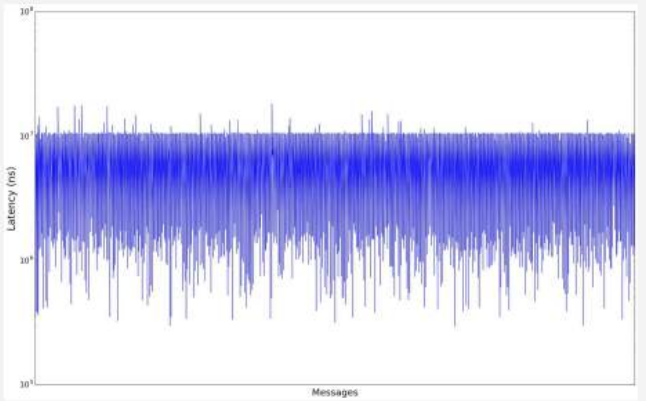


Figure 9c: message size 4096 bytes, frequency 1000Hz

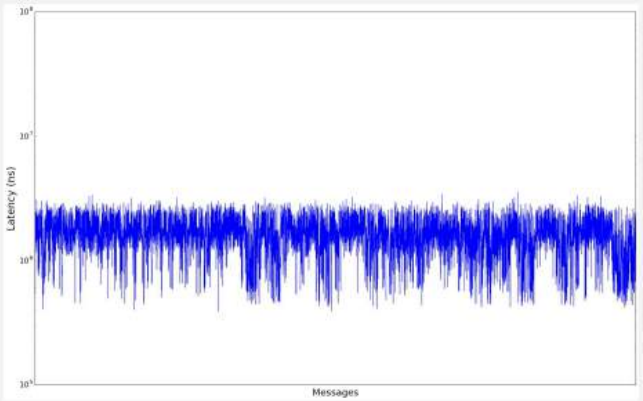
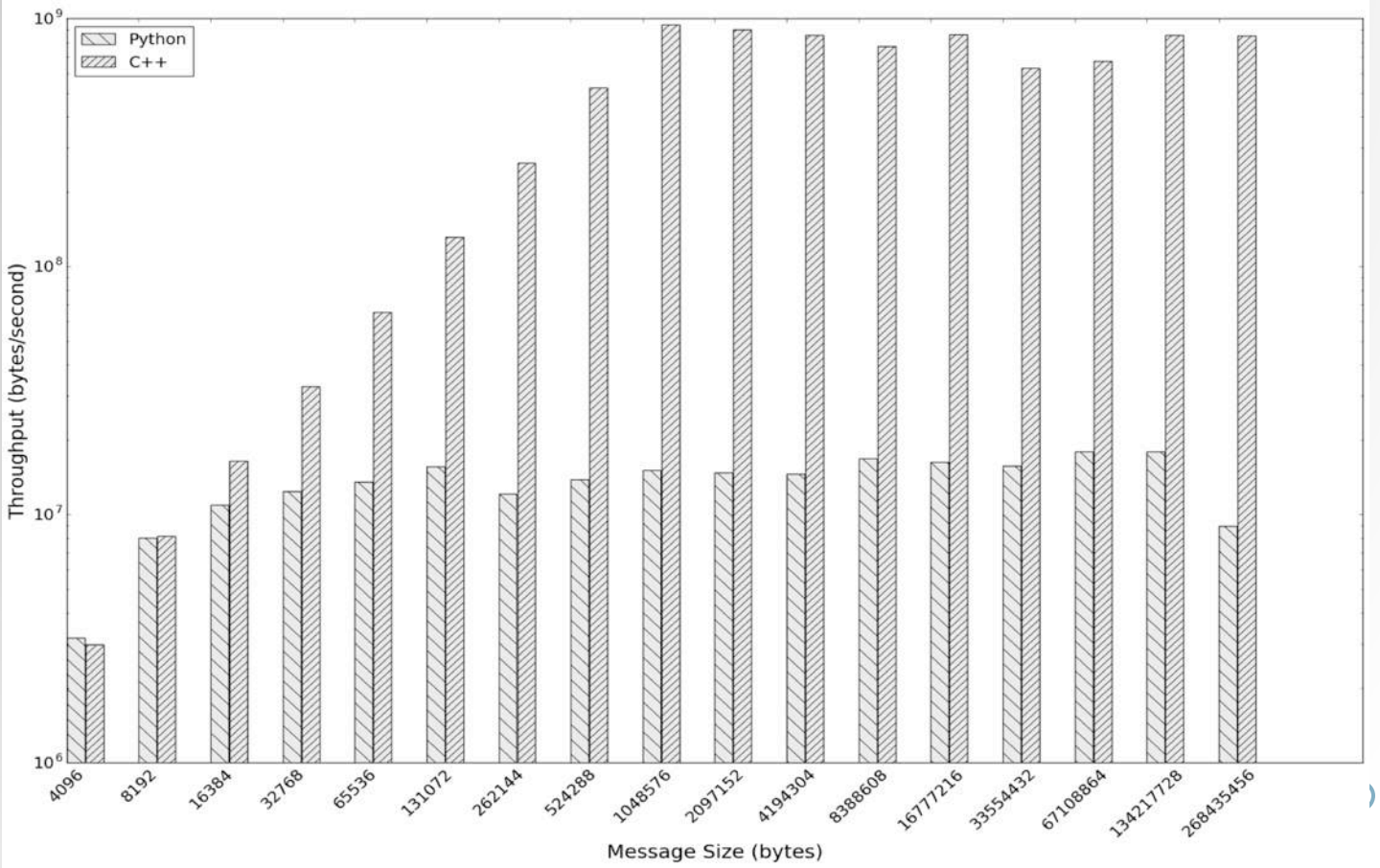


Figure 9d: message size 4096 bytes, frequency 10Hz

SINGLE HOSTS: LATENCY

- Message queue size
- **Language: C++ vs. Python**
- ~~Message send frequency~~






SCALABILITY OF ROS

MULTIPLE HOSTS

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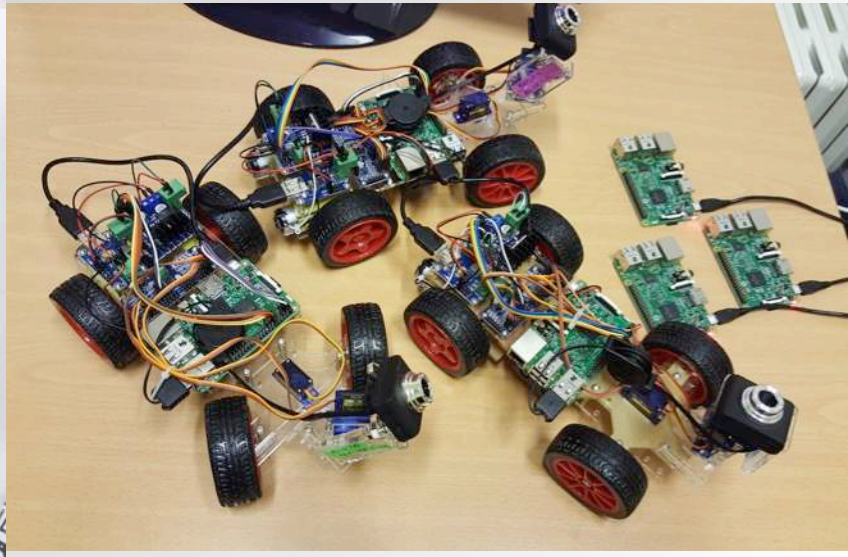
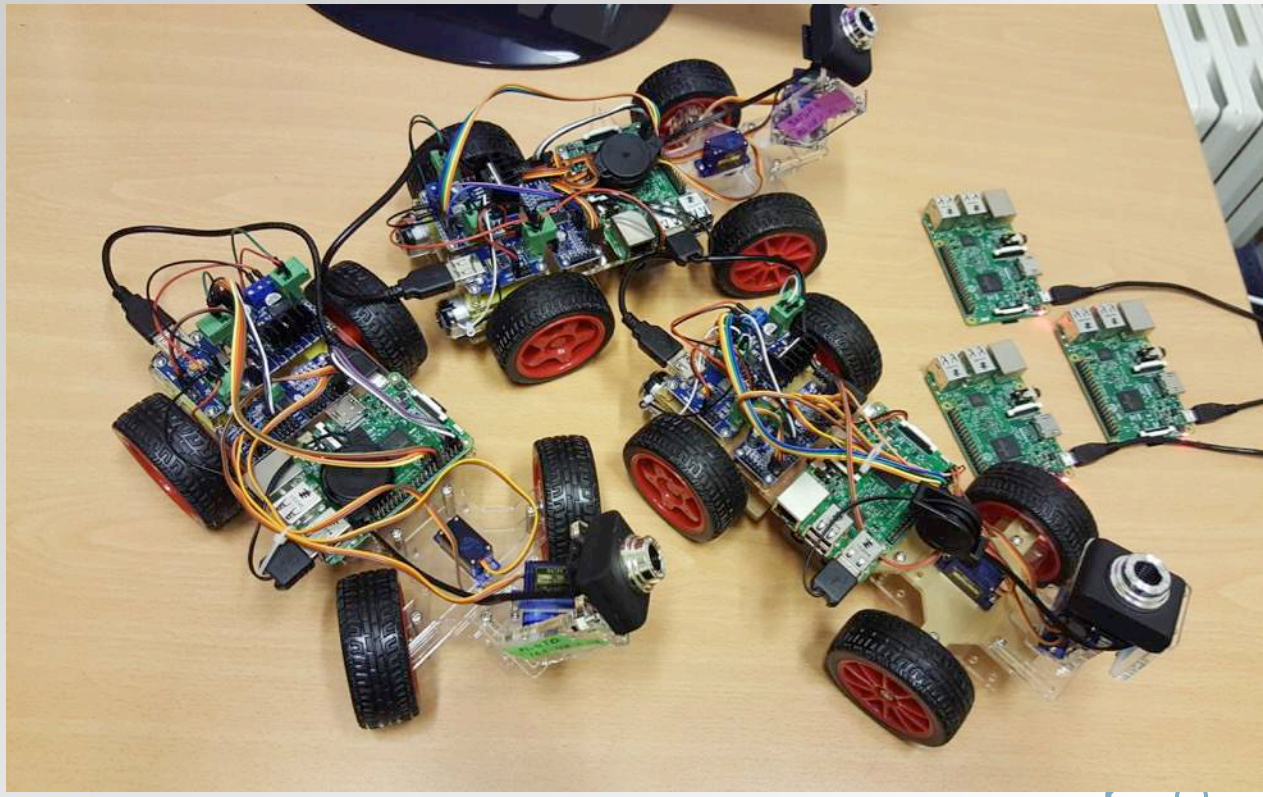
CAR KIT ROBOTS



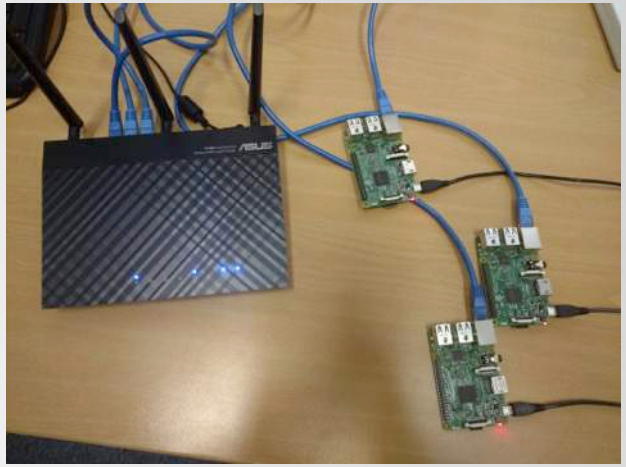
http://www.dcs.gla.ac.uk/research/rosie/blog.html

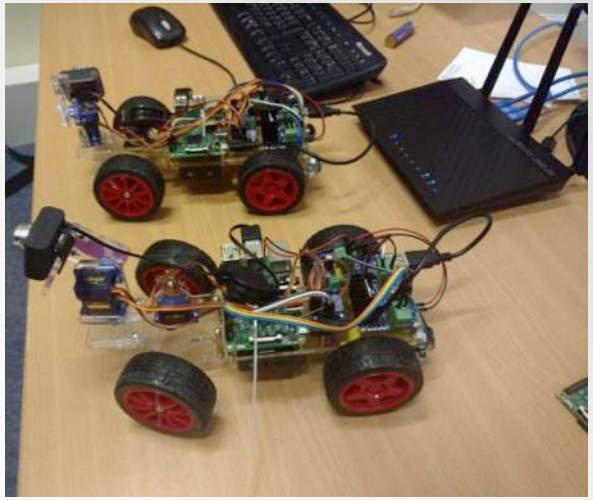
MULTIPLE HOSTS

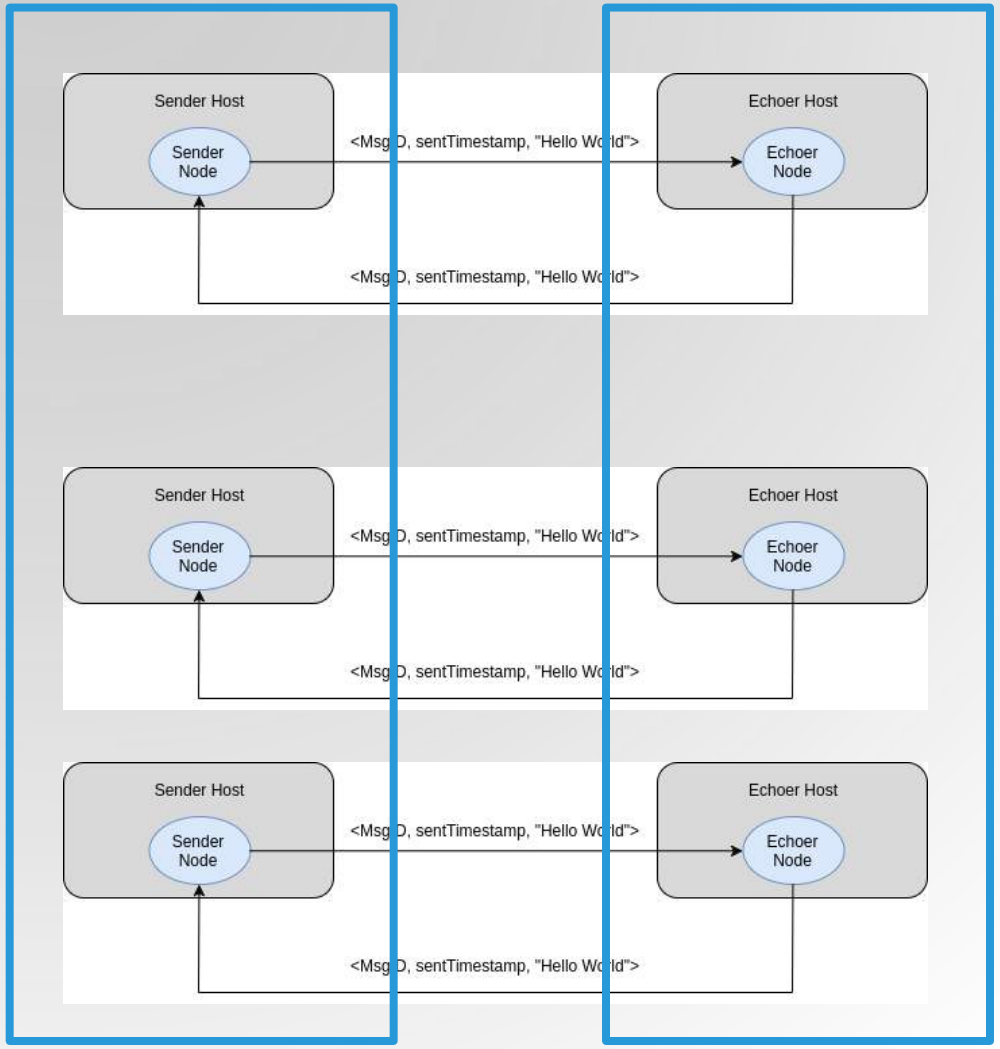
- Scope experiments
- Representative data experiments
- Vertical experiments



MULTIPLE HOSTS: VERTICAL SCALABILTY





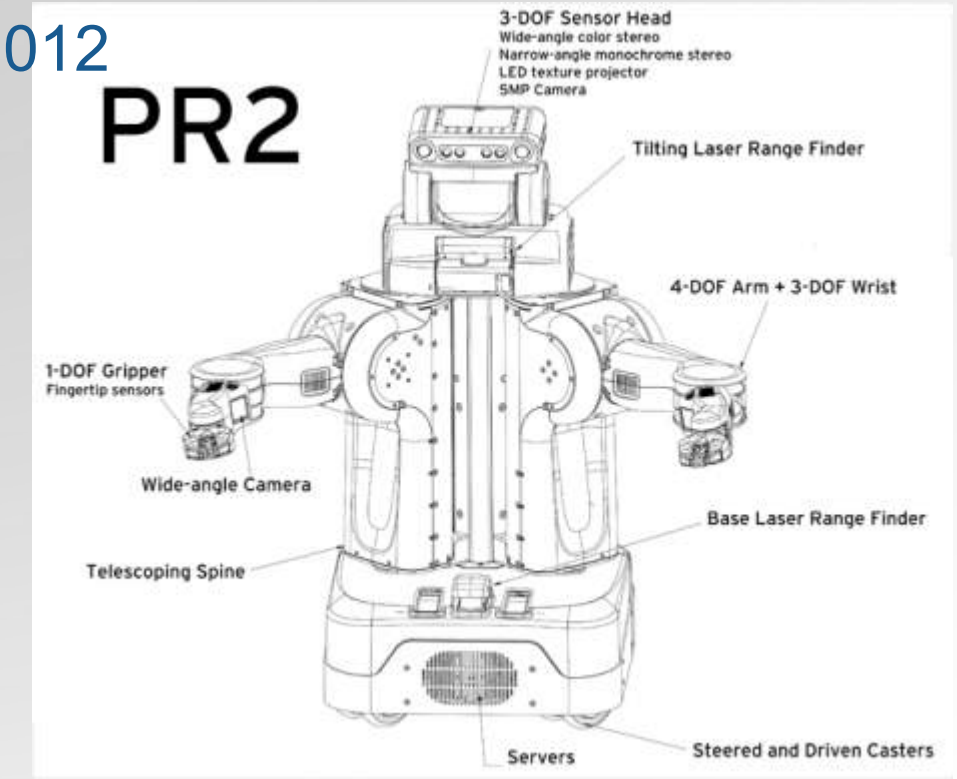


MULTIPLE HOSTS: VERTICAL SCALABILITY

- Hosts
  - Raspberry Pis
  - Car kit robots
- Representative data
- Wi-Fi connection

MULTIPLE HOSTS: REPRESENTATIVE DATA

- Collected January 2011 -- September 2012
- Comprises over 2.3TB
- Sensor data
- Video data

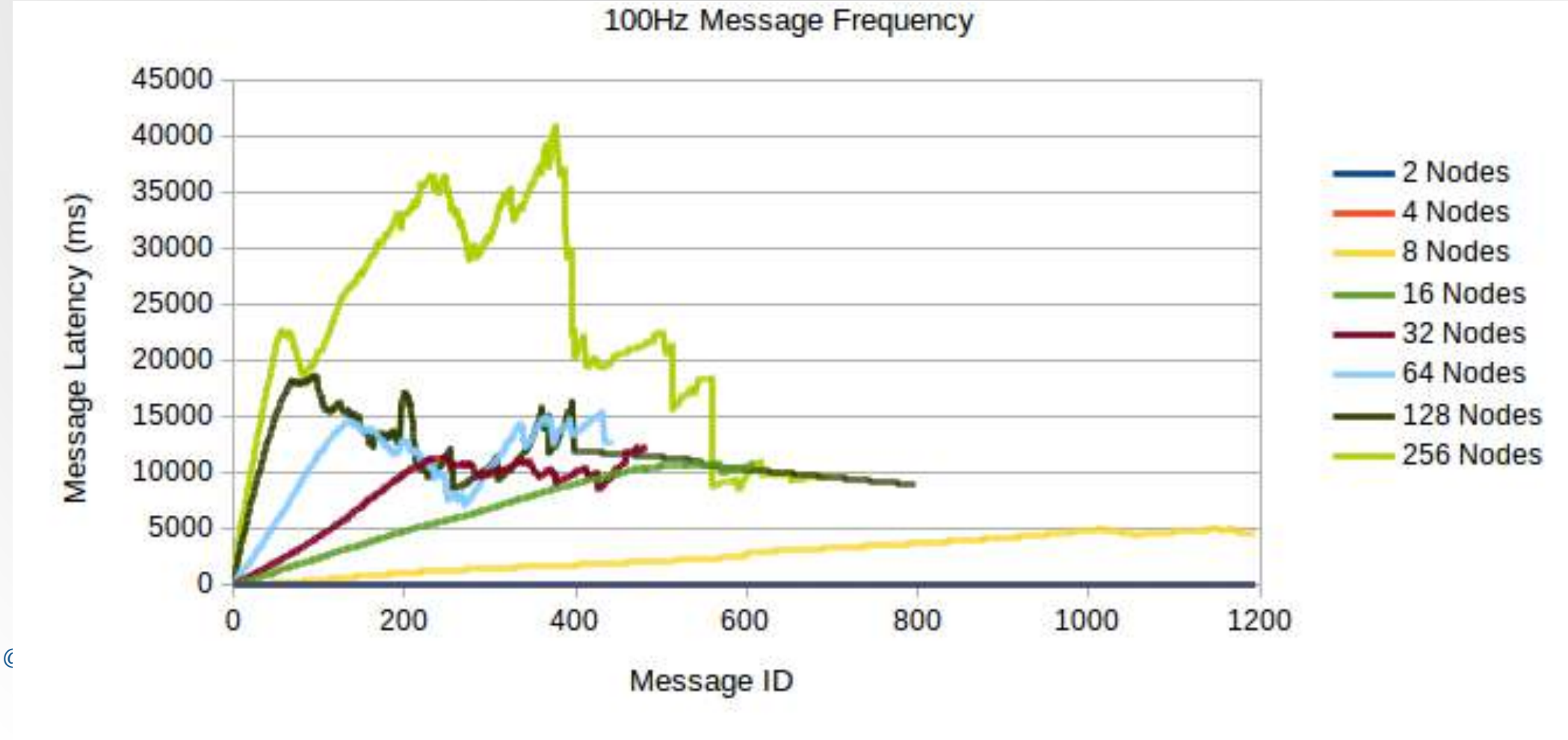


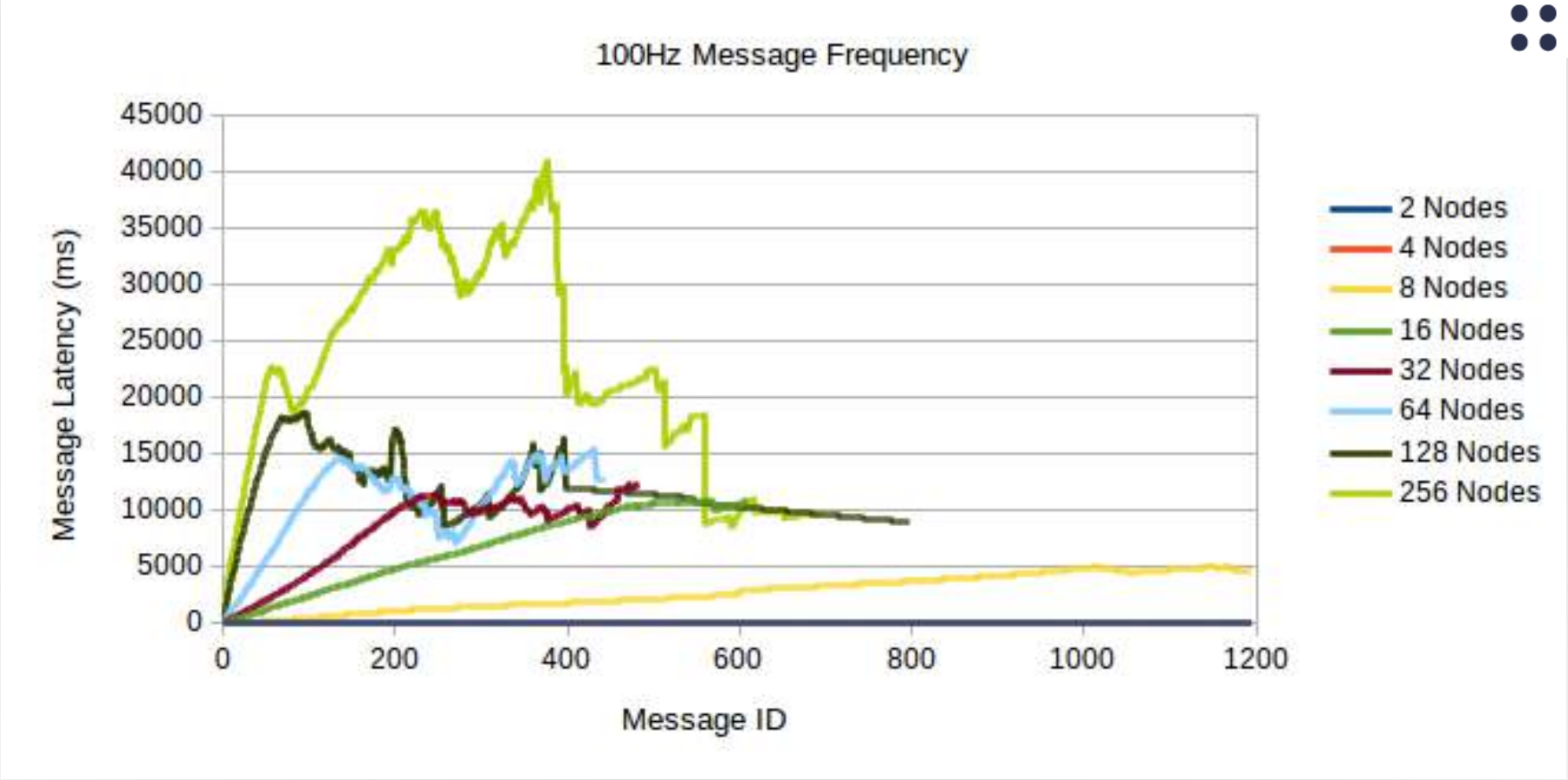
MULTIPLE HOSTS: REPRESENTATIVE DATA

- Sensor data
  - 20Hz message stream
  - 85kB/s of bandwidth
  - Individual message size = 4.25kB

- Video data
  - Kinect RGB + depth camera
  - 30Hz (30 frames-per-second)
  - RGB (colour) video stream
  - Resolution of 640480 pixels
  - 9.25MB/s of bandwidth
  - Message size = 308KB

MULTIPLE HOSTS: VERTICAL SCALABILITY





$$CSLV = N \cdot f_m \cdot S_m$$

- ***SCLV*** -- Communication Scaling Limit Volume
- ***N*** -- number of sending nodes on the host
- f_m -- message frequency
- S_m -- message size


FAULT TOLERANCE OF ROS

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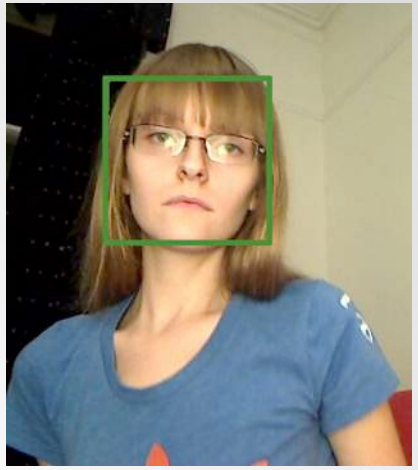
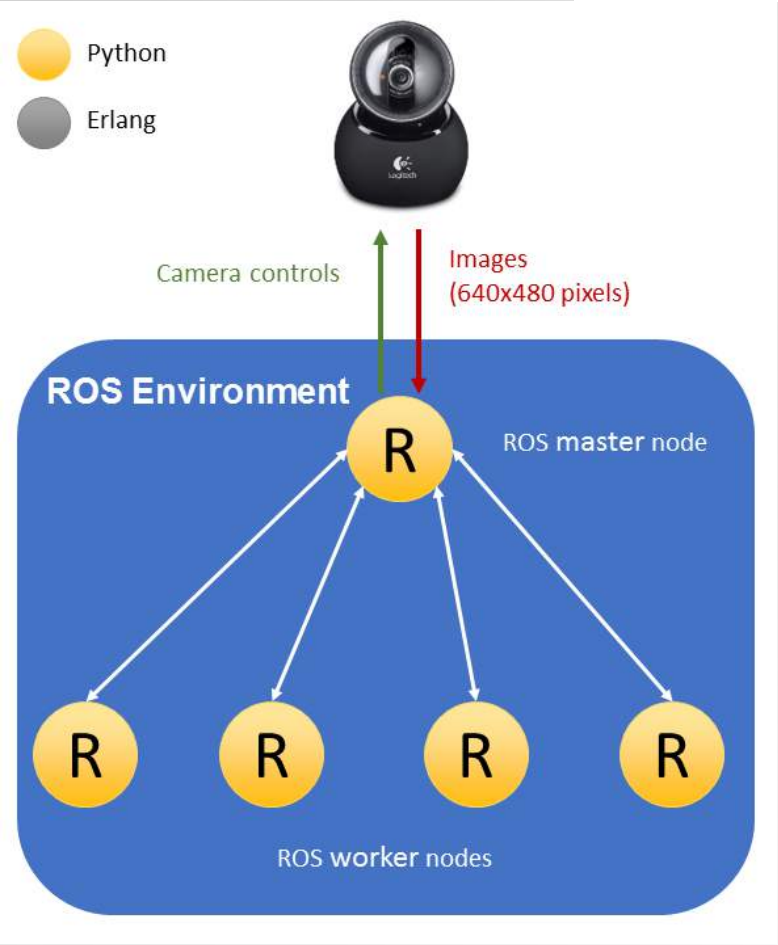
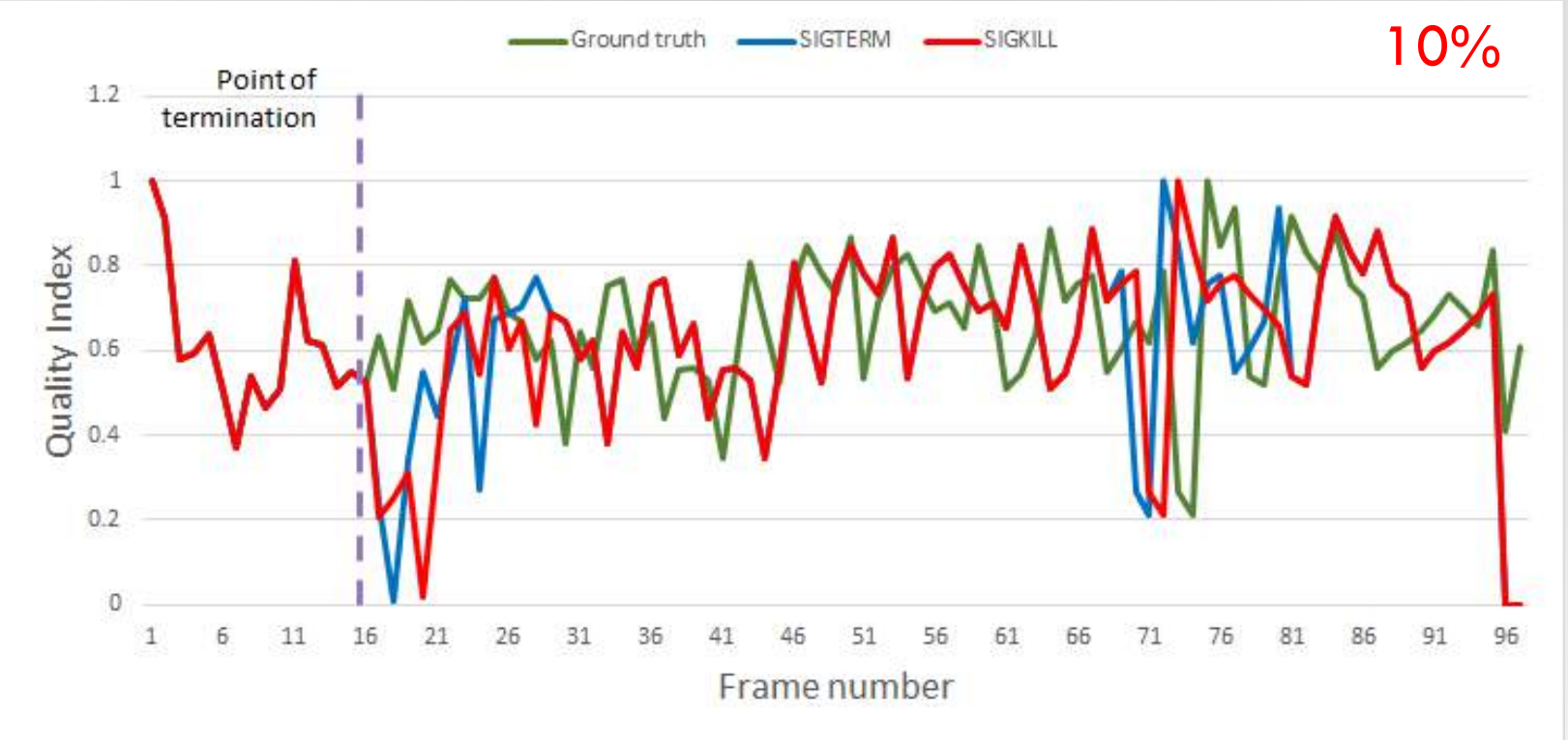
PRELIMINARY RESULTS



ROS



QUALITY VARIATIONS WITH WORKER FAILURES



ROS

SCALE ROS AND INTRODUCE FAULT TOLERANCE

SCALE ROS AND INTRODUCE FAULT TOLERANCE

ERLANG IN ROBOTICS

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KERL

University of Kent

- Kent Erlang Robotic Library for Player (open source robot middleware)
- Practical way of teaching Erlang
  - Programming a popular robot simulator in Erlang
  - Visual and attractive teaching of functional languages
  - Physical robots and simulation framework

ROSEN

- Research from 2005
- Aim: Complete robotic framework in Erlang
  - For a set of robots for Eurobot competition
  - From low-level (control layers)
  - To higher-level (interpretation layers)
- + Simulation engine

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degli STUDI
di CATANIA

OPENRTM-AIST PROJECT

National Institute of Advanced Industrial Science and Technology
AIST

- Open source robotic middleware
- Based on CORBA (Common Object Request Broker Architecture)
- Provides communication services to sensor and control programs
- Initial goal:
  - To develop Erlang tool for the monitoring and orchestration of a network of OpenRTM-aist components
- Supports Erlang (unofficially)

CRITERIA OF SUCCESS

- Adopted by roboticists
  - Easy to use – e.g. programming using Python, APIs
  - Enables to focus on a robotics issue rather than the code
  - Large community of contributors and user from both industry and academia
  - State-of-the-art libraries, techniques
- Modular approach
- In industry
  - Performance
  - Fault tolerance
  - Security
  - Developers

OUR IDEA

To replace communication layer

- Only replace the bit that does not work
- Intra-robot and inter-robot communication


ROS VS. ERLANG

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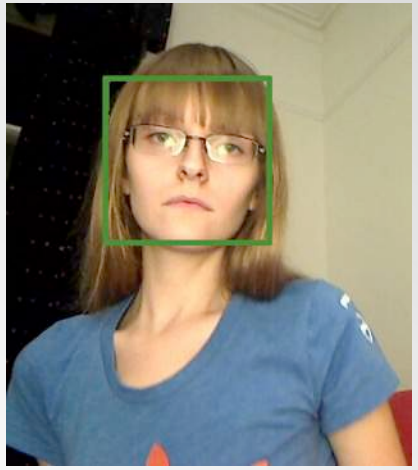
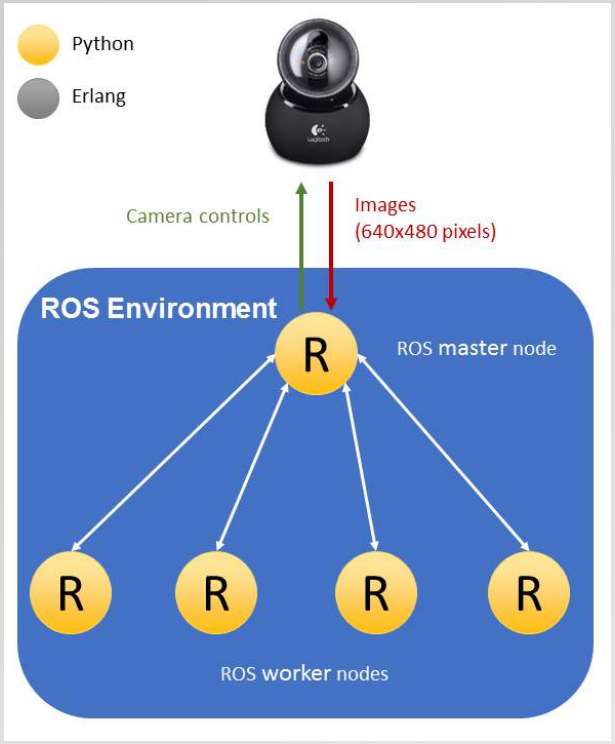
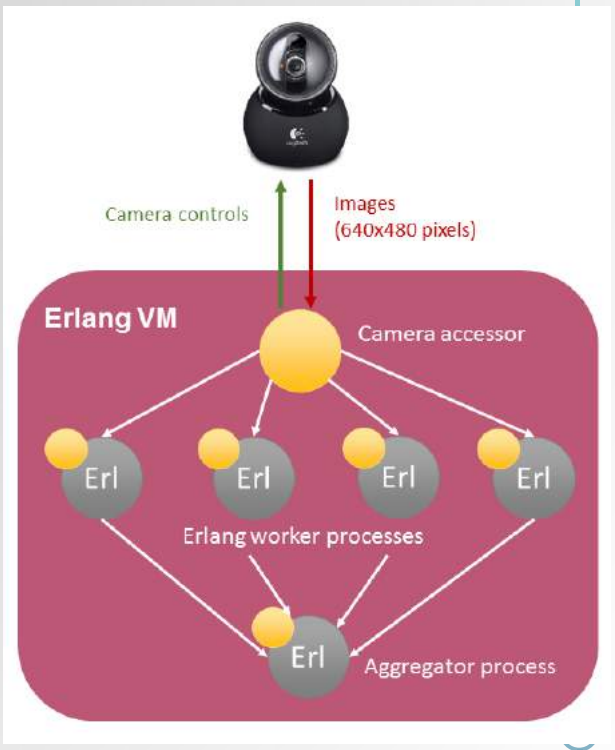
PRELIMINARY RESULTS





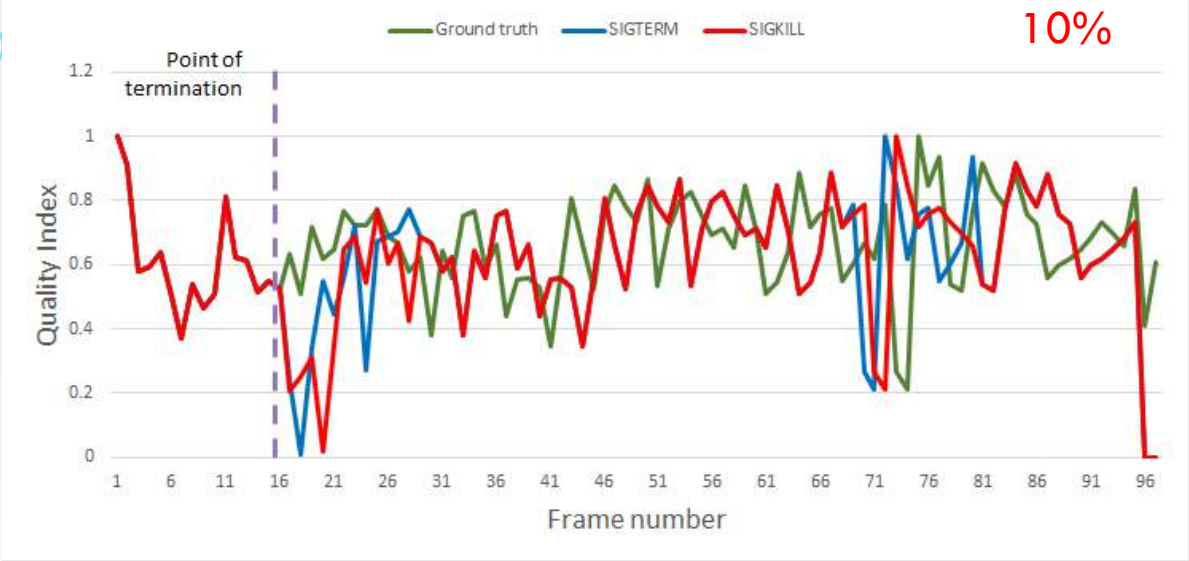


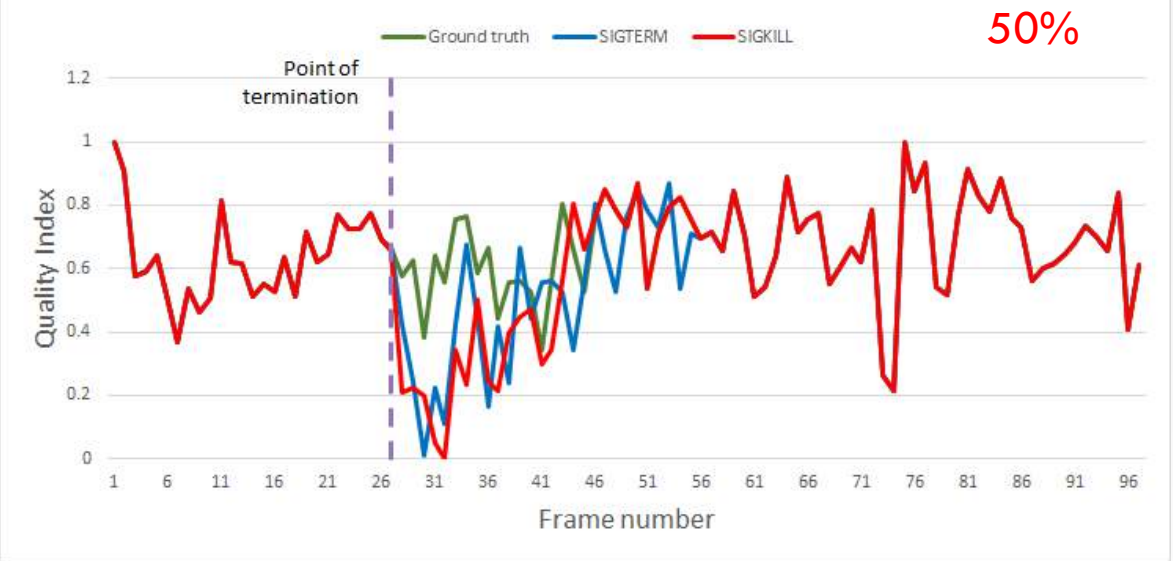
The most widely used Robot Operating System

vs.

"Let it crash" using Erlang programming language

QUALITY VARIATIONS WITH WORKER FAILURES





ROS

Erlang

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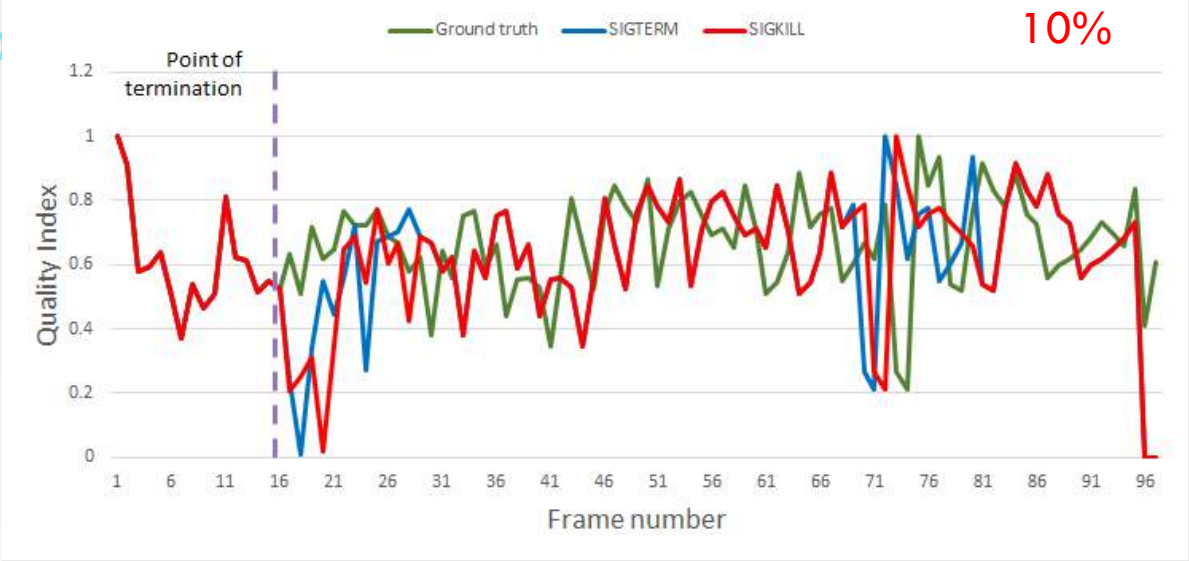

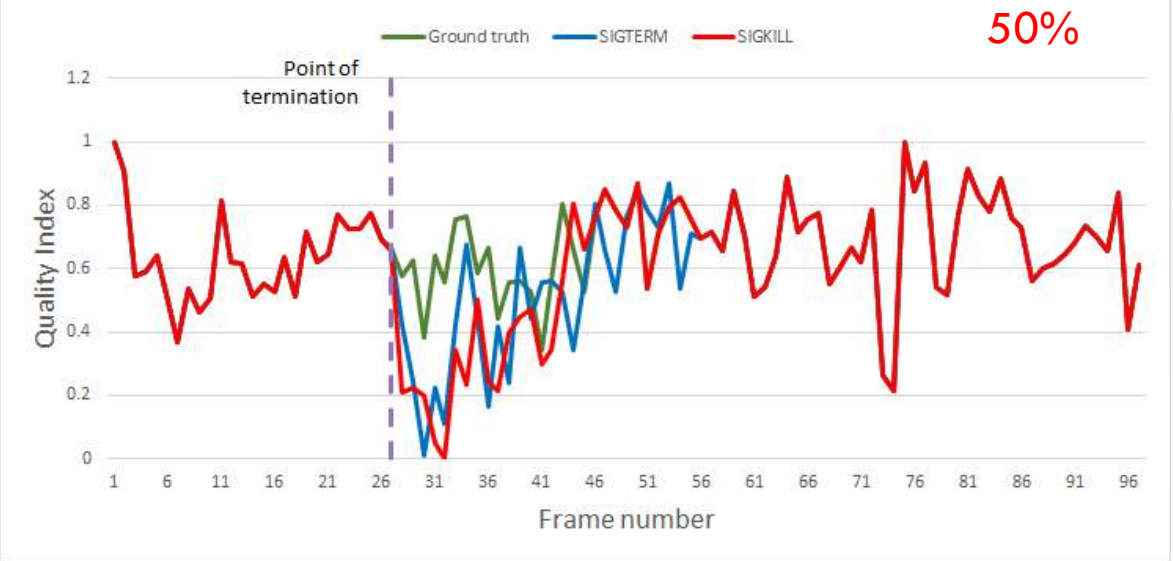

ROS

Erlang

- **Reduces** robot component downtime
- **Mitigates negative impact** of failures

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WHAT'S NEXT?

- H2020 proposal
- GRiSP boards
  - Robots and IoT devices
  - Erlang VM on bare metal
- Autonomous mobility and load distribution

DIPL. PHYS.
PEER STRITZINGER GMBH

EPSRC
Engineering and Physical Sciences Research Council

European Commission
HORIZON 2020

Bournemouth University

THANK YOU!

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https://staffprofiles.bournemouth.ac.uk/display/nchechina